Educational Multimedia Databases

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prof.dr.ir. P.M.G. Apers
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Preface

Five years ago, I embarked on a journey towards a new country. I did not know much about that country; where or how to find it? I only knew that this country would be able to provide a fertile soil for my academic ambitions.

The end of the journey is now in sight. Research questions have been posed, answers have been sought, and research results have been documented and reported upon. Doing these activities kept the train in motion. Without realising it, the destination of the journey came closer with each step. Now it is time to disembark and to explore the country.

I would like to thank my fellow Idylle researchers for joining me on (parts of) the journey. Some of you have chosen a different destination or direction to travel to, but nevertheless your company made the journey more pleasant.

I would also like to thank my supervisors Henk Blanken and Pløn Verhagen for helping me to find ways to reach the destination; roadmaps of this kind of journey are difficult or impossible to obtain, so their help was much appreciated.

Also, many thanks to my promotors Peter Apers and Jef Moonen for providing a critical look, and for checking if the train was indeed going towards the chosen destination in a certain and efficient way.

And last but not least, my gratitude to Joyce. Our roads crossed and then merged. Thanks for sharing this and many other destinations with me.

Enschede, October 2001

Contents

List of Tables

List of Figures

Chapter 1

Introduction

1.1 Computers in education

The use of computers to support learning and education already has a long history. During the sixties the first programs were written to facilitate many learning models that differed only slightly in the amount and nature of the computer's support. Examples of these learning models are: Computer Assisted Instruction, Computer Assisted Learning, Computer Based Learning, Computer Assisted Education, Computer Based Learning, Computer Managed Instruction, and Computer Mediated Communication (Moonen & Plomp, 1987; Mast & Rantanen, 1990; Harold F. O'Neil, 1981). Many programs were written from scratch, each implementing their own set of functionalities (Crowell, 1998). There was one system that set a trend however: the Hypercard system developed by Apple Computer Inc. (Crowell, 1998; Milheim, 1994). This system, and its derivatives, typically presented a screen-full of text and/or graphics (sometimes called "frames") which the learner could study in a predefined sequence. Some systems allowed the instructional designer to define certain decision points in which the system would decide which frame to present next, based on answers of the learner to multiple-choice questions. This concept evolved, amongst others, into so-called Intelligent Tutoring Systems that try to model the learner's knowledge level in order to detect misconceptions and knowledge gaps. The system then formulates a strategy to solve these gaps and misconceptions (Brusilovsky, Schwarz, & Weber, 1996). A different group of systems are the so-called *authoring systems* that allow an instructional designer to compose instruction by authoring materials (text or pictures) and creating decision points. Some systems could be operated by visually manipulating objects, others could be programmed using authoring languages (a programming language targeted at creating instruction, see for example Barker (1987)), and some systems could be programmed by creating menu structures (Moonen, in press).

In the early years a lot had yet to be learned about the design and use of (educational) software: not many generic software components were used; the programs were each written from scratch, and many used proprietary file formats so that exchanging data between programs was difficult or impossible. Presently, however, many course environments are implemented as *software modules* (using CGI technology, Active Server Pages, or Java servlets for example) of a World Wide Web server that stores data in a database. Examples of these systems are Blackboard[1], WebCT[2], and TeleTOP[3]. Using these course environments, learning materials can be offered on the Web. The materials themselves are authored using common word processors, presentation tools, HTML authoring tools and other user-friendly software. These materials are then "uploaded" to the web server, which then stores them into a database for later retrieval.

Already since the beginning of the nineties, ideas and concepts were generated concerning storing learning materials into a database (Persico, Sarti, & Viarengo, 1992). One of the major advantages that were explored, were the opportunities for reuse of learning materials (Olimpo, Chioccariello, Tavella, & Trentin, 1990; Rada, 1995; Sarti & Van Marcke, 1995, August). Although opportunities exist, it is very hard to achieve actual reuse. The Ariadne project[4], for example, has as motto "share and reuse"; it turned out, however, that many teachers wanted to reuse, but only few wanted to share (Ariadne, 1999). A project that achieved "reuse by design" was the Optical Database project (ODB) (Bestebreurtje & Verhagen, 1992). In this project, the curricula (using traditional media) on cheese-making were collected from vocational schools at various levels, and this material was re-engineered into components (learning objects) consisting of video-framents on a videodisc and computer-based instruction software so that each school could reuse those components that suited their needs (Verhagen & Bestebreurtje, 1995), in a form that was appropriate for the educational level of that school.

Due to the exponential growth of the World Wide Web since the mid nineties, the world-wide availability of easily accessible learning materials has sparked the re-emergence of these "old" concepts in the late nineties, and these concepts are presently being further developed to generate knowledge and insights into storing and retrieving learning materials.

This thesis tries to contribute to this development by refining the concept of a Unit of Learning Material (ULM), by exploring factors that inhibit the reuse

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[1] www.blackboard.com

[2] www.webct.com

[3] teletop.edte.utwente.nl

[4] Alliance of Remote Instructional Authoring and Distribution Networks for Europe; see also http://ariadne.unil.ch

of these materials, and by exploring novel ways of retrieving relevant learning materials from large databases of learning material.

1.2 Multimedia databases in education

As this thesis is about “multimedia databases in education”, this section will first discuss what these terms mean.

1.2.1 Multimedia

The term “multimedia” can have many different meanings, but this thesis will adapt the popular meaning of information that is represented in multiple ‘media’ simultaneously, for example text, motion video, and audio.

During the eighties, some Personal Computers (PC’s) were able to play multimedia data, however, they needed dedicated hardware such as videodisc players and graphics overlay cards. These discs contained analogue video fragments of various lengths Verhagen (1992) and still pictures, which were “overlayed” onto the computer screen by a special overlay card, without intervention of the computer itself.

During the nineties, however, several technological advancements have enabled PC’s to handle multimedia data *without* additional hardware:

- Advancements in video compression formats: The Motion Pictures Expert Group (MPEG) is doing continuous work on compressing audio- and video data, targeted at good quality but with fairly high bandwidth demands (ISO, 1996). The proprietary RealVideo[5] format is targeted at low bandwidth demands (e.g. modem connections); the quality is poor compared to MPEG, but still reasonable. A standard that is somewhat in between is the proprietary QuickTime format by Apple Computer.

- The average CPU speed has increased from about 16 MHz in the year 1990 to over one GHz (1000 MHz) in 2000, which is more than sufficient computing power to decode and display the MPEG, QuickTime and RealVideo streams in real-time without additional hardware (and so without extra costs). The term “real-time” indicates that the movements in the video will be perceived as being smooth, and that the audio will run without interruptions.

- Personal Computers are often used to play video games, and at least one positive aspect of this is that the video cards used in PC’s have also seen

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[5] See http://www.real.com

a tremendous advancement during the nineties. The first graphical cards (i.e. cards that can not only display text but also images) had 256 KB of memory, nowadays 8 MB (32 times as much) is not unusual. These cards are optimized to transfer data as quickly as possible from the computer's memory to the video memory that resides on the card.

- The operating systems have also seen some improvements towards displaying video: the Microsoft Windows series has incorporated Intel's DirectX technology, which effectively means that an application can gain (almost) direct access to the video card instead of having to do this via the operating system. The X11 windowing system for Unix and derivatives also allow an application to directly access the video card using shared memory techniques. This direct access to the video card means that applications can display images much faster.

- The 'invention' of the World Wide Web made the Internet much easier to use, in fact so easy that also non-technical people can use it. This caused a tremendous growth of the WWW, and also created a large demand for associated computer supplies: modems to connect to the Internet, scanners to digitize photographs and images, soundcards to digitize one's voice, webcams to transmit motion video, and colour printers to print images received via the Internet. This large demand lowered the costs for these auxiliaries, so that even more people could afford them.

Due to these advancements, PC's are even better able to display video frames at sufficient speeds onto the screen, and people are able to afford a computer and auxiliary hardware to create and process multimedia data.

The impact of the fact that PC's can play video "out of the box" (as it was bought in the shop) is large: information producers can rely on the fact that video can be played by the PC, so that they use more and more video fragments in their products (in the form of CD-ROMs or websites). But what about the application of multimedia in education? We will talk about this in the next section.

1.2.2 Educational Multimedia

Many computer software that was developed for educational purposes before the nineties used the videodisc to play video (Crowell, 1998; Bestebreurtje & Verhagen, 1992). But as the hardware equipment needed to overlay the anologue video on the digital screen was quite expensive, this technology never really became available on the consumer market. The production of a video disc was quite expensive for small series (Tan & Nguyen, 1993; Verhagen & Bestebreurtje, 1994).

As the typical number of discs for an educational institution ranged from one to ten or twenty pieces, this technology was too expensive for most institutions. Due to the technological advancements explained in the previous section, the equipment costs of multimedia equipment has become within economic reach of many more educational institutions. So, multimedia is becoming more common in educational applications, although its growth is limited due to the fact that video files are still quite large, causing download times over several minutes which is undesirable in many educational scenario's. The implementation of Asynchronous Digital Subscribe Line (ADSL) connections (via the telephone line) and Internet via the TV cable in residential areas has already begun, offering sufficient bandwidth to receive high-quality video streams. Therefore, it can be expected that multimedia information will become more and more common, in general as well as in educational applications.

The pedagogical issues of using multimedia in education are myriad. On the one hand, multimedia seem to motivate learners, increase learning effects, provide unique opportunities to show movements and provide insights that would otherwise have been difficult to transfer onto learners (Salomon, 1984; Kozma, 1991). Yet on the other hand, research results seem to indicate that if you formulate the same 'message' in traditional media (eg. text) and account for other confounding effects, then there is no difference in the learning effect (Clark, 1983, 1985). In practice however, one often creates different messages when using new media, so that different learning effects may be expected. These issues and the debate that surrounds them is called the "Media debate" and will be discussed in more detail in Section 2.3.3.

1.2.3 Databases in education

It was discussed above that producing multimedia learning material can be quite expensive, but that the computer equipment needed to show it has become less expensive. Therefor some researchers focused on *reusing* multimedia learning material (Rada, 1995; Sarti & Van Marcke, 1995, August; Olimpo et al., 1990) by storing learning material in a multimedia database (Persico et al., 1992) and providing search facilities so that learning material can be easily retrieved. Before, the multimedia files resided on the harddisk of the teacher who created them. Exchanging them by floppy disk often was not possible because the files (especially if they include video) could become too big for a floppy disk. Also, reusing materials between two institutions or even two faculties was difficult because faculties may be geographically distributed over a city or a campus.

A simple improvement would be to connect the computers together via a local area network (LAN). This eliminates the need to go to another computer and disturb other people. However, the problem of going through directories and files persists, even if the multimedia files would have been put on CD-ROM.

There are several projects that are further exploring and testing principles for storing and (re-)using multimedia learning material in *databases*, so that a Database Management System (DBMS) can provide controlled access to centrally stored materials. This control consists of providing high-level search capabilities (the teacher is able to compose structured queries, instead of having to examine filenames), access protection (a student is not allowed to retrieve the answers to exam questions) and ensuring data integrity. We will go deeper into this subject in Section 2.2.

Examples of these projects are the IMS project (Instructional Management System, see also Appendix A.2), which tries to develop methods and techniques of instructional management systems by building and testing a prototype. The European Ariadne project (see also Appendix A.9) is targeted at the development of tools and methodologies for producing, managing and reusing computer-based pedagogical elements and telematics supported training curricula. Finally, there are several smaller projects that try to achieve similar goals (Hiddink, 1998).

The fact that large corporations are participating in these projects, and the activities they are undertaking are indications that there is a need for construction- and implementation methodologies for educational multimedia databases. Especially the IMS project has attracted large investing software companies, such as Microsoft, Apple Computer, Oracle and Sun Microsystems; but also educational companies such as Pearson Education, Eduprise.com, Asymetrix and some universities are so-called *investment members* of the IMS project. The fact that the Learning Technology Standards Committee of the IEEE (Institute of Electrical and Electronics Engineers) has a working group on Learning Object Metadata standards[6] provides further evidence for the proposition that storing multimedia learning objects in a database and retrieving them using metadata are a key issue in the electronic learning environments that are presently being developed by the software industry.

1.2.4 Searching Multimedia Documents and Metadata

Currently, computers of educational designers are connected through a wide area network: the Internet. Teachers are able to exchange learning materials worldwide, and they can locate each others' work by using search engines. The learning materials are offered in digital form to the students, also via the WWW, so that students can easily access the materials online. Consequently, these learning materials con-

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[6] online at http://ltsc.ieee.org/wg12

sist of HTML files, presentation files (such as Powerpoint) or wordprocessor documents. A teacher that is looking for certain materials types in some keywords into a search engine, clicks “submit”, and then often a very long list of matching documents is presented. How does this mechanism work?

The World Wide Web

A WWW search engine indexes all documents that are available on the Web. It does this (crudely) in the following manner: it assigns each document a unique number, creates a very large list of all words present in all documents, and stores for each word a list of document numbers in which that word appears. It also stores the URL where that document came from. Words that are very common, such as ’a’ and ’is’ are not indexed. For example, if document 15363 at URL http://www.url.com/index.html that says “This page is empty” then it adds 15363 to the document list of the words ‘this’, ‘page’, and ‘empty’. If a user searches for the word ‘page’, then the search engine looks through the document list of the word ‘page’ and returns, amongst others, document 15363 and it presents the URL to the user.

This is the basic principle that is used by most search engines[7]. Many extensions to this mechanism exist that relate to the frequency of words throughout all documents: a word that is used very frequently, such as ’this’, does not say much about a document, while a word that is used infrequently such as ‘ULM’ does.

This principle works fine with text- or HTML documents, but what about other documents? The current search engines are not able to index Microsoft Word documents or Powerpoint documents, for example. A search engine also cannot ‘see’ what is inside a video clip or an audio clip. Yet, a teacher may be looking for a video clip that shows what manual gestures a person makes when giving a presentation. A search engine will then be less helpful; it can only find a HTML page that writes about it. The teacher may then have to follow a few links to finally arrive at the video.

So it can be observed that the more *multimedia* documents appear on the WWW, the more difficult it becomes to find these documents using current search engines. This problem of bad *retrievability* can be solved by adding *metadata* to multimedia learning objects, so that a search engine is able to ‘look inside’ objects for indexing purposes. We will elaborate on this in Chapter 5.

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[7] Unfortunately, the precise algorithms of the current WWW search engines are often not publicly disclosed, because these are intellectual property of the respective companies.

1.3 How to store multimedia learning material

Already as early as in the beginning of the nineties (Olimpo et al., 1990; Persico et al., 1992) it was proposed to model learning material in certain units: Units of Learning Material (ULMs) and to store them in a database. Many variations on this model have been developed throughout the years: learning objects, (interactive) multimedia units, etcetera.

Many prototypes that stored multimedia learning material in databases were built the past decade (Hiddink, 1998). The fact that the database would have to store multimedia data with variable, unknown length in its tables was not the largest problem; this problem is often solved by storing the actual multimedia data elsewhere, and inserting a reference (for example a URL or a filename) into the database tables. A problem that is more challenging, is how to find back learning material. The field of Information Retrieval (IR) has already provided a lot of insights into the generic problem of retrieving multimedia data, and several approaches have been devised to try to solve the problem (Grossman & Frieder, 1998; de Vries, 1999); we will discuss several approaches in Chapter 5.

1.3.1 Metadata

A database system can make use of so-called *metadata* to know more about the multimedia data. Metadata are information (data) about these multimedia data objects, such as: who created them, what are they about, how should they be interpreted, how should they be presented to the user when retrieved, and other properties of the data objects. If the multimedia data are stored outside the control of the DBMS as described above, then the metadata also contains a reference where the real multimedia object can be found (such as a URL or a filename). Finding multimedia data then consists of composing a database query on the metadata, retrieving the metadata, and referencing the pointer to the raw multimedia data.

Metadata for learning material has been a research focus for the past decade, although the term “metadata” was not used at that time. Instead, researchers discussed about “attributes for educational database objects” (Olimpo et al., 1990; Persico et al., 1992) or “labels” to be assigned to units of learning material. During the nineties, many groups that researched learning objects (such as NIST, IEEE, IMS and ARIADNE, see Appendix A) realized that standardizing metadata would mean that educational institutions could reuse each others’ learning material, increasing the options of choice for educational designers. See Hiddink (1998) for an elaborate overview of projects that researched educational learning objects. During 1998, several of these groups either merged, joined forces or disappeared, and currently almost all groups have united in the IEEE P1484.12 group called Learning

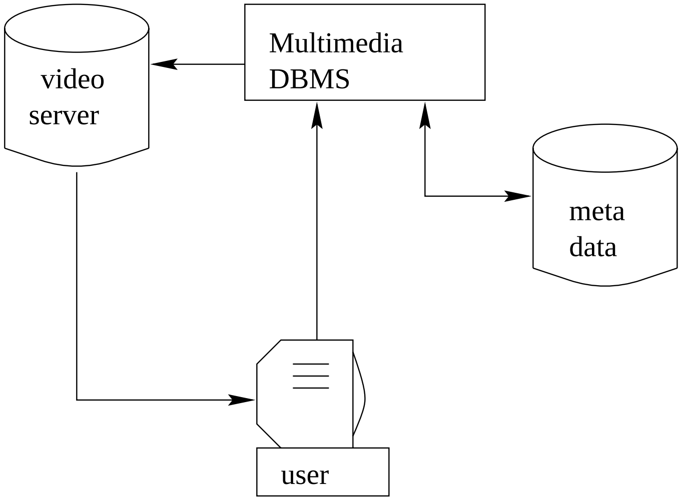

Figure 1.1: Architecture of a database system that uses a dedicated video server to deliver videostreams.

Objects Metadata Group. These groups are working together to standardize educational metadata, and seem to form a critical mass that may induce a world-wide exchange of learning materials based on a standard that is generally agreed upon by all parties.

1.3.2 Architecture

When storing multimedia data, the common practice is to store the "raw" data (the multimedia data streams) separate from their *metadata* (data about data, see Section 1.3.1), for example on a dedicated video server, or on a web server; see Figure 1.1. The incentive to do this is the proposition that a video server has been designed especially to deliver video streams. Sometimes, even the filesystem of the video server has been optimized to deliver a certain type of videostream, such as MPEG movies. A database management system has been designed for other purposes than delivering MPEG movies, so that it will not be able to perform this task optimally. Sometimes, it is even impossible to integrate the video delivery software into the database because this delivery software is proprietary, for example the RealVideo format. For these reasons, the architecture shown in Figure 1.1 is often the best (or the only) way to make multimedia materials accessible to the user.

1.4 Research Questions

The issues problems described above were addressed by a a specific research programme of the University of Twente called ‘Idylle’: “Innovative Distributed Learning Environments”. This multidisciplinary project focused on increasing the so-called “study-ability” of academic education by introducing various telematics tools (IDYLLE, 1996). Within this framework, the current research targeted on developing methodologies for building educational multimedia databases.

The research questions were stated rather broad in the subproject’s description (Verhagen, Blanken, Moonen, & Apers, 1996), and have been refined during the first two years of the project as the researchers’ knowledge richened through reading and reasoning. This section will try to give insight into the development of the research questions.

1.4.1 Evolution of the problem statement

The initial research question is formulated as follows:

> What is a sufficient set of generic building blocks to develop knowledge landscapes for educational use that show completeness in respect to domain knowledge to serve certain but multiple target groups on certain but multiple educational levels for multiple educational objectives?

The first issue that arises is: what are these “generic building blocks”? In earlier research, a method to structure knowledge was developed (Bestebreurtje, Verhagen, & Zwart, 1995; Bestebreurtje, 1989) so that certain reusable ‘knowledge elements’ could be identified. Using these elements new curricula were designed as well as multimedia learning materials that enabled the transfer of these knowledge elements onto the learner, and then these materials were stored on a laserdisc and tested in practice. From these tests it was concluded that the approach “is only valid for what is called ‘process technologies’ or vocational training” (Bestebreurtje et al., 1995). The current research, however, targets at academic education, so a new approach is required. It was decided to try to structure elements of *learning material* instead of knowledge, because for academic material the instructional design step from subject matter to actual learning material is much larger than for vocational training (Hiddink, 1997). This led to the development of the so-called “Unit of Learning Material” (ULM). This model will be presented in Chapter 4.

The second issue is the reuse of materials for “multiple target groups on certain but multiple educational levels for multiple educational objectives”. As explained earlier, many researchers agree that multimedia learning material can be expensive to produce, especially when video material is involved (Verhagen & Bestebreurtje, 1994; Tan & Nguyen, 1993) and that reusing these expensive materials may reduce the total costs (Rada, 1995; Sarti & Van Marcke, 1995, August; Olimpo et al., 1990). But what are the properties of material so that it becomes (re)usable for multiple target groups, on multiple educational levels, and for multiple educational objectives? What determines this ‘reusability’ of learning materials? To resolve these issues, four research questions were formulated:

RQ1 What is an appropriate model to store and retrieve multimedia learning material so that it can be used by multiple target groups with different information needs?

RQ2 What factors are of influence on the reusability of learning materials that are stored in a multimedia database?

Chapter 4 will identify, amongst others, that a factor that influences the reusability of learning material is the *search method*: what methods and techniques are used to search through the database? As the focus of this research is reusability of learning material, a third and fourth research question can be formulated:

RQ3 Is it possible to develop a search method based on predicting the usability of search results based on educational metadata, so that retrievability and thus reusability can be increased?

RQ4 What is an appropriate software architecture for a database application that allows learning material to be stored in, and retrieved from a multimedia database using, if possible, the new search method developed while answering RQ3?

The answers to these research questions will bring forward many insights into the storage and retrieval of multimedia learning material, and in software architectures that are suited to build an application necessary to deliver multimedia learning materials in a flexible manner.

1.5 About this thesis

Globally, this thesis will start with a broad discussion on various aspects of educational multimedia databases in theory and practice, and after that the theory is refined towards the research questions. The existing theory on learning objects and retrieval methods will be expanded, and then these new pieces of theory will be validated by doing experiments using a prototype database application.

Looking at the thesis in some more detail, Chapter 2 discusses aspects of multimedia database systems relevant to two different viewpoints: a technology viewpoint and an educational viewpoint.

Chapter 3 will then give the state of the art of existing educational database systems. The major conclusion of this chapter is that most systems do not build upon well-defined models. This thesis proposes that the functionality of these systems can be increased if better models are used, so a theoretical framework of the 'Unit of Learning Material' has been developed. Chapter 4 will discuss a model of learning material that provides many ways to facilitate learning and to enhance browsing and searching the database using educational metadata. Economically, one of the most important advantages of using a database system is the opportunities for *reuse* of learning material. So, to explore the theoretical context of this concept the chapter will also present a model of the factors influencing reuse of learning material, thus providing a clear view of how actual reuse can be increased.

After that, Chapter 5 will focus on making units of learning material accessible. The techniques that have been developed so far will be explored, and from these techniques one will be selected: annotating learning objects with educational metadata 'by hand' as opposed to doing this automatically, and using the metadata fields in database queries, search forms and advanced retrieval techniques. The chapter will discuss the development of educational metadata, and show how it can be used.

Then, Chapter 6 will describe a prototype of an educational database system that was developed as a 'proof of concept' of several concepts introduced in this thesis. It will be shown how reusability can be increased by decoupling the layout of learning material from their structure by using a markup language known as "XML", and how the model of a Unit of Learning Material can help the learner navigate through the database.

The prototype also served as a playground for research to increase the way search results are presented. Often, this is a long list ordered by characteristics such as word frequencies and document lengths. In the research described in Chapter 7, the use of a measure of relevance based on educational metadata is proposed. To be more specific, the measure of relevance is based on the teachers' preferences for certain characteristics (metadata fields) of learning material. The chapter describes the mathematical basis of a distance measure, and the nature of the "preference for characteristics of learning material": what factors influence this preference?

In Chapter 8 the distance measure is tested to see if it is able to predict, to some extent, the relevance of search results to teachers that are looking for learning material.

Chapter 9 will end this thesis by presenting issues that remain open for future research, and by providing some reflection upon the conducted research.

Chapter 2

Multimedia Databases in Education

2.1 Introduction

The term “database” can mean different things. In general, a “database” is a collection of related data (Elmasri & Navathe, 1989, p. 3) that can reside on any digital medium such as a computer disk, a computer’s main memory, or on a CD-ROM. The collection of data is often managed by a Database Management System (DBMS). Without a DBMS, the database itself may loose its meaning; it is no longer clear how to interpret the data and the “organized collection” is reduced to meaningless files with ‘unreadable’ binary data. So, often we will denote this duo of the database and its DBMS just as a “database system”.

A special kind of database is the so-called “relational database”, which is managed by a “Relational Database Management System” (RDBMS). This type of database finds its roots in a well-known article by Codd (1970) who developed a relational algebra that formed the basis for relational databases and the Structured Query Language (SQL). Data in this type of databases is represented in *tables* where the rows represent data records, and the cells represent record fields. Almost all current commercial database systems have adopted this model because it allows database applications to access the data through a formal definition, thus abstracting from the way the data are physically stored and accessed.

The DBMS provides the functionality of structured access to the data using a query language, such as SQL. However, additional software is then still needed to process the data, or present it in graphical or table form. The software is needed to do this is called the “database application”. For the communication between the database application and the DBMS special computer languages have been developed. The first few DBMS's each had their own computer language, so that a particular database application 'A' could only communicate with a DBMS of brand 'X'. If brand 'Y' would introduce a better, faster, and/or cheaper system, then it would not be possible for application 'A' to use it. To solve this problem, an Application Programming Interface (API) has been developed by Microsoft Corporation. The language is called “ODBC” which means Open Database Connectivity[1], and it has become the de-facto standard for communicating with databases. A Java version has been derived by Sun Microsystems for Java applications, called “JDBC” which stands for Java Database Connectivity[2]. If a database application uses one of these languages, then it is very easy to move from DBMS brand 'X' to DBMS brand 'Y'. Often, the only changes needed are configuration details and some SQL query syntaxes.

The total system of database, DBMS and database application will be called “database system” throughout this thesis. The architecture is pictured in Figure 2.1. If the database application has been designed to store, retrieve, and deliver learning materials then we will call the system an “educational database system”.

This thesis will take the currently available Database Management Systems as a starting point. This research project will experiment with innovative ways to implement search algorithms in an educational setting, so a working, stable DBMS is needed for experiments. On top of this DBMS, new methods will be explored. Therefore, this thesis will not concentrate on the *internals* of DBMS'es (such as query optimizers, or logical and physical storage methods). Instead, it will take a practical viewpoint with regard to databases and explore techniques that are needed to build the total system of database, DBMS, and database application as depicted in Figure 2.1.

When implementing an educational database many issues arise: how will the teachers and the students cope with the technological innovation (Russell & Bradley, 1997; Tobin & Dawson, 1992; Riel, 1994; Kromhout & Butzin, 1993; Becker, 1999)? What will the total “cost of ownership” be and what will be the (economical) benefits? What is needed to re-engineer traditional courses into computer-supported courses? What needs to be done to train the end-users (Collis, 1998b)? What methods exist to learn more about the degree of success of an implementation? Answers to many of these questions have been sought elsewhere and in spite of their relevance they are not within the scope of this thesis.

This chapter will discuss some issues that are very important to the current research: labeling learning material and how an educational database can be used by learners. But first some aspects of database technology will be discussed.

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[1] see http://www.microsoft.com/data/odbc/

[2] see http://www.sun.com

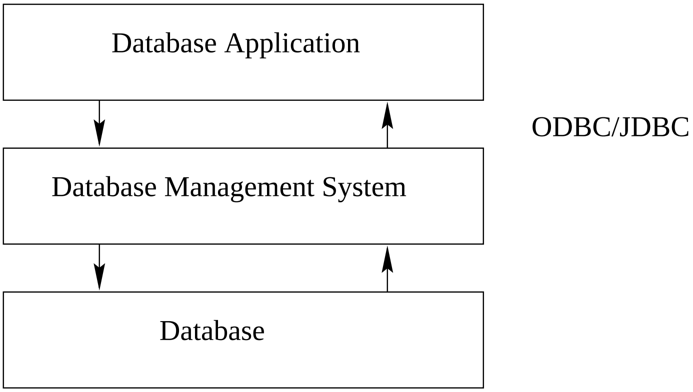

Figure 2.1: Generic architecture of an application using a database system.

2.2 The technology of databases

The purpose of a DBMS-managed database is to store structured information. This functionality could (in part) also be provided by operating systems in the form of a file system. Sometimes, a system designer has (technical) reasons to choose a non-DBMS driven database, for example when a different data storage medium is the only way to reach certain goals. The ODB project, for example, used an optical disc to store analogue video fragments and still pictures, because this was at that time the best way to use video fragments in educational software (Bestebreurtje & Verhagen, 1992). But what features does a Database Management System provide that makes it so interesting to use instead of a file system? Below, the functions that are most interesting will be discussed (Davis, 1995; de Vries, 1999; Adjeroh & Nwosu, 1997).

2.2.1 Features of Database Management Systems

Self-contained nature

A database not only contains the data, but also *data about data* (so-called metadata) such as the data definitions, the relationships between data, etcetera. All information that is needed to interpret, access, and manage the data are contained within the database. This centrality may prevent programming errors due to the otherwise distributed nature of the data.

Suppose, for example, that personnel data are not stored in a database but in a file on a file system. Let us say that the “address” field is 40 characters long, and that data typists have noticed that some addresses do not fit properly into this size.

The company decides that the address field size has to be increased to 50 characters, which has as a consequence that the birthdate field that started at position 60, now starts at position 70. This modification is reflected in the metadata of the database, so that access software immediately knows that the birthdata field now starts at position 70. So, the data the DBMS manages contains all information needed to manage the data, and no additional information is stored elsewhere: the DBMS is self-contained.

Isolation between Program and Data

The way data are physically stored is managed by the DBMS, and is not made visible to the application program. Therefore, the program does not depend on the data storage. Due to this independency it is possible to modify the structure of the data (for example to add a new attribute “mobile phone number” to a person’s record) without breaking existing access software. Also, no data are contained in the program code, so that there is no danger of corrupting the data while modifying or adding the program.

If, for example, the names and locations of the departments of a company are hard-coded into the program, then an expansion of the company would mean that the program would have to be modified, and probably even re-compiled if it is not written in an interpreted language. But in general, modification and recompilation of a tried-and-tested program should be minimized to avoid new programming errors. So the fact that the program and data are isolated, avoids the need for program modifications when the data are modified, thus reducing the risks of introducing programming errors.

Data Abstraction

A database management system (DBMS) provides users with a *conceptual representation* of the data. Then, the user is not bothered with technical details of how the data are stored; instead, data models are expressed in logical concepts such as objects, their properties, and their relationships with other objects. The user can use these logical concepts in queries that seem very logical, e.g. “`select name, income from persons where (income < 40 000) and (children > 3)`” which would retrieve the name and income of those persons that earn less than 40000 and have more than 3 children. The user is, fortunately, totally unaware of how the table ‘persons’ is stored on the file system.

This property enlightens the task of the programmer writing the educational database application. He does not have to worry about writing data to files, organizing the files, creating programming code for maintaining indexes to find data back, making sure the data stays consistent etcetera. Instead, the programmer just writes code to connect to a DBMS, issue a query, and read the result tables. This code, furthermore, is very common so software components are readily available that perform these tasks. Writing applications that access very large collections of data thus becomes very easy. The fact that pre-built, well-tested components are used reduces the amount of programming errors that have to be resolved before the application is ready for use.

Multiple Views

A DBMS is able to present multiple views to support different data needs of different users. The data needs to be entered only once, avoiding redundancy and inconsistency. This also means that a DBMS must take care that only one user at a time can modify data: if two teachers want to add one grade to a student’s record simultaneously, the results can be unpredictable.

To be able to define multiple views is a requirement for educational database systems: the teacher should be able to view the structure of the learning materials in all details, and modify them if needed. The student, however, should only be able to view as much structure as is didactically appropriate. Also, for different students there could be different views: some students may need to go through a fixed schedule of learning materials step by step; others, perhaps more advanced, may be allowed to browse the learning material by subject or search through the database by subject keyword. Thus, the same materials are accessed from multiple views.

Enforcing Constraints

A DBMS can have certain *constraints* that must hold on the data. For example, the value of a database object ‘grade’ must lie in the range of 1 to 10 (in the Netherlands), or that a course *must* belong to at least one department. A DBMS can enforce these constraints by warning the user if a data entry or modification would violate a constraint, and refusing the entry. Thus, the integrity of the data can be guaranteed.

Search Capabilities

The database of a relational DBMS can be searched using the Structured Query Language. As mentioned in Section 2.1, the introduction of a relational algebra allows the user to state queries in terms of conceptual entities such as “courses” and “persons” in SQL. Although this approach works fine for data that can be easily stored in tables, such as administrative data, it does not work well with multimedia objects (such as multimedia learning materials). The Information Retrieval discipline has developed many approaches to tackle this problem, and we will discuss the most important of these in Chapter 5. Most techniques require a DBMS to execute the complex tasks that are often required to retrieve multimedia information, tasks that cannot (and should not) be implemented by a file system.

2.2.2 Inside the database or outside?

Section 1.3.2 already briefly discussed the architecture of a multimedia database system, and the issue of where to store the multimedia data itself: as very large binary objects in the database tables, or as files on the filesystem with only the filename in the database tables? In spite of this being a practical issue, it can have a large impact on the performance of a database system. It is believed that a thesis on educational databases should not go without some thoughts on this issue.

The question cannot be answered with a simple answer; it depends on the software components that the DBMS has to interact with. The RealVideo server software, for example, takes its data streams from a file system instead of a database, so that it will not be possible to integrate the video delivery software with a database management system. If multimedia objects would have been stored *inside* the database tables, then the Database Management System would have to retrieve the multimedia stream, write it to a file, and then tell the (RealVideo) video server software to deliver it to the user. Writing the data to a file first would reduce the performance of the entire system when compared to a system in which the datastream itself would already be stored on the file system.

In general, it can be stated that the *amount of integration* between the DBMS and its auxiliary software components determines if it is possible to store the multimedia data inside the database tables. The example described above shows that there are architectures in which this is not possible due to the fact that the auxiliary software (the video server) is not very well integrated with the DBMS; it would have been better whether the video server would be able to access the database itself via the DBMS (for example using ODBC or JDBC) to retrieve the multimedia data.

If the integration between DBMS and its auxiliary servers does not depend on the multimedia data being stored using the file system, then storing the multimedia objects *inside* the database tables would be the best answer to the question mentioned above. The complexity of the software would be less: all data are treated equal, namely as rows in database tables, no objects are residing outside the control of the database management system, and no other access systems interfere with the DBMS's control. This is in concordance with the “self-contained nature” of DBMS's, see Section 2.2. In the situation where multimedia objects are stored in the file system, two access systems would interfere: the operating system's file access system, and the DBMS's access system. A user with sufficient write privileges would be able to erase or rename a multimedia file, causing the DBMS to be confused because it cannot find the file back. Also, it is tempting to make *assumptions* upon the location or the name of the multimedia file, for example to publish the directory or the file onto the Web. However, if the DBMS manufacturer decides to change the mapping of multimedia objects to the filesystem, then the application breaks. This defies the independencies that were introduced by Codd (1970) when he designed the relational model.

2.3 The Educational Database

The previous section has shown what functionality a Database Management System offers, and what advantages a DBMS has. But what makes a database 'educational'?

With "Educational Multimedia Database" is meant the database application and the logical contents of a database system that allows users to store and retrieve multimedia learning materials (for example in the form of certain *Units of Learning Material*). The database application can provide many different functionalities: it can provide Intelligent Tutoring capabilities, drill-and-practice training, an online encyclopedia of learning materials, a course-materials database, etcetera. Chapter 6 will go into further detail on the architecture of the database application.

As explained, an educational database is not an end-application. Instead, it is a component of a larger whole. This 'larger whole' can be denoted as a digital learning environment. It is believed that a thesis about educational multimedia databases should also cover the most important aspects of introducing digital learning environments that utilize multimedia materials into education.

This section will also discuss some educational issues that arise when implementing hypermedia systems in general in education. These are important issues because introducing an educational multimedia database does not simply mean digitizing the syllabi, or creating digital movies from recordings of classes. Instead, the courses must be "re-engineered", that is: redesigned from scratch with a new pedagogy in mind. Section 2.3.1 will show how an educational database can be used in education. Three pedagogical issues are important for this: learner control (Section 2.3.2), the purpose of multiple media in education (Section 2.3.3), and some issues on hypermedia (Section 2.3.4).

2.3.1 Use modes

In this section, three modes in which an educational database can be used by learners and teachers will be described: as an encyclopedia of learning materials, as a courseware database, and as a presentation tool.

Resource of Learning Materials

Learners can have a number of reasons to search a database of learning materials:

- They have to do an assignment for a course, involving gaining certain knowledge and expertise by searching the database.
- The learners are doing a (design) project for which they have to define information- or knowledge needs themselves, and then try to fulfill these needs. They access the database as a kind of digital encyclopedia, the difference with a true (digital) encyclopedia being that the material in it is specifically designed for educational purposes for a specific target group and a specific educational level (or specific educational leves). In other words, the encyclopedia is less general than a regular one.
- The learners are engaged in a course that requires certain learning materials to be studied. These materials can support drill and practice learning, but can also contain explorative materials like simulations.

Courseware Database

Some institutions, such as the University of Twente, provide online course materials for some courses[3]. Students can select a course to study and retrieve learning material that belongs to this course.

In this mode of use, as well as the previous one, auditing information can be generated such as: what learning material did which student examine? Which answers were given by the students to questions the material posed? Which simulations did the student study and did he or she reach certain objectives? This auditing information can be logged into the same (logical) database as the database of learning material, but in some cases it may be better to create a separate database for it. If the auditing information is managed by a different system, such as an instructional management system as specified by the IMS project (see Appendix A.2), then the auditing information needs to be transferred from the courseware database system to the instructional management system.

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[3] http://teletop.edte.utwente.nl

Presentation Tool

Sometimes, the teacher may want to present multimedia material in the classroom. Instead of trying to transfer the learning material from the database system to a presentation tool such as Powerpoint, it would be easier for the teacher if the database system would be able to enter a presentation mode. Teachers sometimes use a web browser as a presentation tool, so if the database system is able to present the learning material via the web (which is desirable from a telelearning point of view), then no extra design efforts are necessary.

2.3.2 Learner Control

One of the supposed advantages of hypermedia is the proposition that the control the learner has on his own study pace has a positive effect on the learning results. This, however, has not yet been empirically proven. Niemiec, Sikorski, and Walberg (1996) conclude after reviewing a large body of learner control literature: “Although learner control has theoretical appeal, its effects on learning seem neither powerful nor consistent”. But Hannafin and Sullivan (1995) conclude from experiments that “learner control may be more appropriate for high-ability learners than for low-ability ones” (p. 28), as high ability learners appeared to choose more instruction voluntarily, and thus performed better on post-tests. Similarly, Young (1996) found that learners with good “self-regulated learning strategies” performed better in learner-controlled situations.

There is, however, also a risk in precisely matching the learners’ needs: they are not challenged to adapt to the amount of materials that is offered, so they will not learn to filter if there is too much material. This effect is called “learned helplessness’.

Many experiments seem to show increased learning effects when learners select and choose their own materials, but at least one confounding variable is the Amount of Invested Mental Effort (AIME): the higher this amount of effort, the better the learning effects are (Salomon, 1984). The amount of effort learners invest in materials, appears to depend on how difficult the learners think the learning task is (“Perceived Demand Characteristics”) and how well they deem themselves fit to perform this task (“Perceived Self-Efficacy”).

A possibly negative aspect of learner control is the fact that learners have to focus on learning and on navigating simultaneously. If the navigation task is not easy (i.e. not intuitively), then the learning task is too much interfered by the navigation task. This type of interference is called *retroactive interference* (Bower, Thompson-Schill, & Tulving, 1994).

2.3.3 The Media Debate

As stated in Section 2.2.1, anyone using multimedia data may benefit from a multimedia Database Management System. But what are the consequences of using multimedia in education?

Clark (1983) wrote a paper that sparked a heated discussion among scientists whether or not using multiple media (perceptional channels) would increase learning. After reviewing the literature, he concluded that effects could not be shown, and that research results that did show effects were confounded by the newness of the medium, by methodological flaws, or had other errors. In essence, he states that if two *identical* messages are presented in different media, then there will be no noticable effect. As watching a movie may sometimes even cost less mental effort than reading a book, the learning effect may even be less when watching a movie due to the effects of AIME (Salomon, 1984).

His opponents, however, state that new media can bring new types of messages: a video of a moving piston in a combustion engine can be more insightful than a paragraph of text that describes this movement. Also, providing complementary information via multiple "channels" can have a positive effect (Park & Hannafin, 1993). There is, however, a risk of "cognitive overload": the learner is getting too much information via too many channels. The point at which this occurs depends, amongst others, on how familiar the learner already is with the presented materials (Park & Hannafin, 1993).

Another way to utilize multimedia materials is to exploit the *richness* of the media: in some situations, video sequences can show how things work better than words. For example, a video or animation can show how a piston engine works: when do the valves open, how is this moment determined, and at which moment is the gas ignited. Video fragments can also illustrate social cues and gestures during a conversation, which would have been hard to explain on paper with words or figures.

Simulations are also a good example of exploiting modern media in education. Using a simulation, learners can modify parameters themselves and see the results of their actions. Medical students, for example, can inject various amounts of medicine into a "virtual" patient, and see the effect on the heart beat rate, blood pressure, and various concentrations of chemical substances on their screen without harming human beings or animals.

This thesis will take notice of Clark's warning that just using multiple perceptional channels will not guarantee an increased learning effect. It is believed that using multimedia learning material in education is only useful if the educational message could not have been formulated as well *without* the extra medium.

2.3.4 The Hypermedia Myth

Some researchers propose to structure subject matter semantically by identifying concepts and relations between these and implementing this hyperlinked structure into a hypermedia system. They then claim that learning is enhanced, because the hyperlinked structure would resemble the way information is stored into the human brain (eg. in frames, see Rumelhart and Ortony (1977)). Learning using a frame-resembling structure such as a concept map is said to yield a better learning effect. However, this is very hard to prove, and in spite of many efforts it has not been done (Romiszowski, 1990).

One of the negative aspects of hypermedia is the risk that the learner becomes “lost in hyperspace”. Research results suggest that learners should have sufficient meta-cognitive capabilities to make proper decisions about their learning processes (Young, 1996; Freitag & Sullivan, 1995; Park & Hannafin, 1993), which seems logical as navigating through a hyperstructure is a form of learner control. So the decision when to use hypermedia should be made by the persons that know best what the meta-cognitive capabilities of the students are: the teachers. Therefor, this thesis will not make that decision for them, but instead try to facilitate their teaching with innovative tools.

2.3.5 Discussion

Although creating a hyperlinked structure of learning materials provides more learner control, this is not always a *positive* aspect. Learner control appears to be only useful for learners that have sufficient meta-cognitive capabilities to direct and guide themselves through the hyperlink structure and to select materials that are appropriate for them with respect to their advancements through the subject matter and their own learning abilities. Also, navigation should be given extra attention because it may distract the learner from the learning task.

Another risk of using hypermedia is that the structure may quickly become too complex for the learners to comprehend, so that they will become confused and frustrated. Modern media should be used only when there is a *need* for them, in situations where the richness of the media really adds something to the learning process.

The paradox is, however, that adapting the materials, the navigation, and the amount of control to the learners’ needs *for them* will never challenge them to adapt *themselves*, so that they will not develop the metacognitive capabilities of adapting their learning style to the situation. The perfect amount of adaptation can only be found through trial and error during many years of professional experience.

2.3.6 Conclusions

From the observations made in this chapter, some conclusions can be drawn:

- A DBMS is to be preferred above a file system.

  Database Management Systems can help in many ways to build an application for accessing, retrieving, and presenting learning materials. Not only do DBMS's enlighten the task of the programmer and the system designer, and reduce the risk of programming errors, it also allows one data set to be approached from different viewpoints and in a structured, high level manner.

- Multimedia objects should reside under control of a Database Management System. This does not necessarily mean that the objects are stored as binary large objects (BLOBs): due to performance considerations, a designer may choose to store the objects themselves as files, but he or she must make sure that the file access system will not interfere with the DBMS's access system. Also, the database designer should not be tempted to assume the location or the name of any particular multimedia file, unless this location and name are obtained from the DBMS.

- Multimedia learning material can be useful to the learner, but it should be used only when the richness of the "new media" can be exploited. Using multimedia learning material does not automatically mean that learning is increased.

- Learners should be ready for self-control. The literature suggests that multimedia learning systems that provide a lot of learner control should be used with learners that have sufficient meta-cognitive capabilities. An educational database can also be used in less hyperlinked modes: as a presentation tool or as a resource of learning materials. The precise amount of learner control is a matter of professional expertise.

So, the students may benefit from an educational database due to the independence of time and place, but there may also be disadvantages due to complex hyperstructures, reduced interaction with the teacher and inappropriate use of (hyper) media and learner control. It is up to the expertise of the teacher to find the right balance of these instruments. An educational database system should not interfere with this expertise, and support the teacher where ever possible.

Chapter 3

State of the art of educational database systems

In the past, many projects have investigated theoretical and practical issues of educational database systems. In order to build upon the results of these projects, they have been studied and design methodologies and principles have been extracted. For a complete overview of the projects, the reader is referred to Appendix A; for clarity, the abbreviated project names will be used here. This chapter will discuss the aspects that are of most interest to the current research: the labeling methods, the search interface, quality and validation techniques, the functionality of the systems, and the theoretical models of learning material that are used.

3.1 Labeling Methods

As has been explained in Section 1.2.4, current Internet search engines are not able to index multimedia documents very well. Moreover, as we will see in Chapter 5, the best technique available today for creating a retrieval system for multimedia documents, is to use metadata labeling. This section will therefor focus on the labeling methods that have been developed during other research activities.

First, a ‘metadata field’ will be defined:

Definition 3.1 *A* metadata field F *is a tuple* (V, t) *where* t *is the title of the label, and* V *is a set of values.*

Then, a ‘metadata value’ can be defined as follows:

Definition 3.2 *A* metadata value *is a set of values* $v \subset V$ *where* V *is the set of values of a metadata field* F*.*

For example, if V equals to $\{$‘primary school’, ‘secondary school’, ‘high school’, ‘university’$\}$, then a metadata value ‘primary school’ can be assigned to learning material to denote the school type for which it was developed.

Often V is a predefined set, also called a ‘vocabulary’. Some labels however, are so-called ‘free text’, which indicates that any text string is allowed. In these cases, V is the set of all text strings of finite length.

Throughout this thesis, the term ‘labeling system’ will be used to denote the set M of metadata fields (V, t) that is attached to a learning object to characterize it.

3.1.1 Subject Classifications

As Rada (1995) writes, a flexible and powerful description and classification schema is necessary for the purpose of efficient retrieval and reuse of Units of Learning Material. “Flexible” often means that the vocabulary of a metadata field is open or extensible; yet, “powerful” means that a certain structure is imposed upon the schema, which implies a restriction in vocabulary. It is clear that this is a difficult balance, and there have not been many projects that used a subject classification schema. The GEM project, for example, uses the ACM subject classification (a classification of main subject areas, such as archeology, education, computer science, statistics, mathematics, sport) and the Computer Science curriculum classification. Similarly, the ARIADNE system uses an extensible list of concepts from which the user can choose to denote the subject of the learning object (see Appendix A). This is not a standardized list, however.

Classifications that are not extensible are easy to use on one hand, as a user learns the elements after some time, and uncomfortable on the other hand if the user is not able to choose an element that fully fits the learning object (for example if it is about optical computing, while there only is an entry ‘computer science’). Although an extensible classification does offer the option to add new elements (such as ‘optical computing’ and ‘electrical computing’), this introduces the risk that objects that were entered earlier are now no longer optimally labeled, if they also match the newly added element better. So, introducing a new element would require the labels of all objects that were already entered to be reviewed.

3.1.2 Educational Metadata

Many different combinations of pedagogical metadata fields have been proposed. Most of the sets of metadata fields that were encountered were based on the Dublin Core (Hakala, Husby, & Koch, 1996), which is an extensible generic metadata set to describe online documents.

Table 3.1 presents an overview of what educational fields have been used by what projects (as the projects tend to update their metadata sets based on their experiences, this overview provides a snapshot taken in the summer of 2000), so that insight can be gained into metadata fields that the projects found important or usable. Only the metadata fields that could be relevant to teachers are shown, and fields that are too technical or not relevant considering the intended use mode of the database system are omitted. Table 3.2 shows the more generic metadata fields that were used by the projects.

Table 3.1: Overview of what educational fields were used by what projects.

Field	ESM	GEM	CSTC	ENC	ARIADNE	PEDAGO
pedagogical quality	x					
learning objectives		x				
subject	x			x	x	x
completeness	x					
educational function	x	x	x	x	x	
difficulty	x				x	
school level					x	x
audience				x	x	
duration		x			x	
semantic density					x	
grade		x		x	x	

3.1.3 Other Metadata

As can be seen in Table 3.2, many different fields have been tried in actual prototypes; unfortunately no results that can be compared are available to find out what fields are most useful to teachers.

3.2 Search interface

The search interface depends a bit upon the chosen metadata system: only those fields present in the metadata definition can be used by the search system. Many different ways exist to create a search interface, varying from simply browsing through lists of subjects (PedagoNET) or a simple keyword search to advanced customized search forms. This section will discuss the main three search interfaces

Table 3.2: Overview of what generic fields were used by what projects.

Field	ESM	GEM	CSTC	ENC	ARIADNE	PEDAGO
author		x	x	x	x	x
abstract			x	x		
description		x			x	x
resources needed				x	x	
keywords	x		x		x	
copyrights					x	
costs		x		x	x	x
geogr. region of origin						x

that were encountered during the study. Note that although a large body of literature exists on the theory and practice of human-machine interaction, screen design, and search methods, this literature will not be discussed here as the focus is on getting insight into what search methods educational technology designers found appropriate in past research projects, so that the results of the current research can be put into a perspective.

3.2.1 Keyword Search

Keyword search forms are usually very straight-forward: they just consist of a single field in which the user enters one or more keywords, comparable to most Internet search engines. The system then returns the learning objects that have one or more of the keywords in their content or in their metadata fields. Although very simple and intuitive to use, the largest disadvantage of this technique is that it is often not possible to *exclude* keywords. A user might find a lot of ‘hits’ (objects that match the search specification) that are about the wrong subject. The user might want to exclude these subjects by writing “and not these keywords”. So keyword search forms sometimes allow the user to build boolean expressions such as “combustion AND chamber AND NOT diesel”. Internet search engines often provide this functionality as an ‘advanced search query’.

3.2.2 Metadata Search

Metadata search forms allow the user to indicate a prefered value for certain values for certain metadata fields, one of which is ‘keywords’. This allows the user to indicate a preference for fields such as educational level, target group, or pedagogical function (GEM, ENC). The largest disadvantage of this method is that often the result list consists of only ‘perfect matches’: learning objects whose metadata fields match all of the specified field values. Small deviations are not tolerated, while this may be acceptable to the user: a learning object that was developed for first-year students may be well usable as introductory or refreshment material to third-year students.

3.2.3 Advanced Search

There are some search interface which are a little bit more complicated. For example, the Explorer advanced search[1] allows the user to first indicate what metadata fields he or she wants to incorporate into the search and how many values the user would like to enter, after which a custom search form is created. This search form can then be filled in and submitted, after which the system starts searching. Although the interface looks complicated, it is merely a metadata search with multiple values for a selected set of fields.

3.3 Quality and Validation

This section will discuss two aspects of quality and validation: applying the peer review principle in educational databases, and metadata validation.

3.3.1 Peer Reviewing

The NEEDS[2] database and the CSTC system[3] allow peer educators to provide comments on learning objects so that other educators have an indication of the quality of the learning objects. Although this can be very useful, it is believed that teachers will not easily return to the repository where they found a resource to enter comments after using it.

3.3.2 Metadata Validators

In the Ariadne project, metadata are not entered by subject matter experts, but by metadata typists. This is similar to the library world: authors write books, and library personnel enters the metadata into the library database. The metadata are then validated by yet another person, the ‘metadata validator’.

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[1] see http://unite.rtec.org

[2] see http://www.needs.org

[3] see http://www.cstc.org

The main disadvantage of this is that the metadata typists may have problems identifying representative keywords for the learning objects, or to find appropriate values for educational metadata fields. In the library world, authors sometimes write the keywords themselves in the cover pages of the book. Translated to the educational world, this would mean that teachers have to add keywords and educational metadata fields to the learning objects. The current research will therefore assume that teachers enter these metadata fields.

3.4 Functionalities

Most educational database systems are a *repository* of learning materials that educators can search (GEM, CSTC). Sometimes, the material itself is stored in the database, sometimes hyperlinks are provided using URLs, and sometimes the metadata refer to offline materials. Systems that provide hyperlinks as URLs run the risk of pointing to non-existant URLs, as pages are often published on personal homepages that disappear whenever the owner changes jobs. Also, reorganisations of directory structures and websites are a cause of malfunctioning links. It is preferable to copy the learning objects into the database itself above merely linking to them, as faulty links can be very frustrating to learners, discouraging their motivation to learn. Another disadvantage of mixing online and offline materials is that the user is often unable to indicate that he or she only desires online materials (online materials can often be immediately downloaded, while offline materials are much more difficult to obtain).

Some systems also include support for organizing course contents and include personal and group communication facilities (such as the TeleTOP course management system).

3.5 Models of Units of Learning Material

The examined projects have also been studied for finding models of learning material. This section presents four of the most important models of learning material that were developed in past projects. The section concludes with a summary of the models.

3.5.1 Delta project ESM-BASE

The ESM-BASE project proposed a four layer model for the physical aspects of a Unit of Learning Material (Persico et al., 1992)

- particles are (monomedia) pieces of text, audio or video in a particular language;
- elements are (monomedia) collections of particles in various languages;
- molecules are collections of particles, so that they are multimedia and in multiple languages;
- a Unit of Learning Material is a collection of molecules.

The ‘pedagogical aspects’ of the ULM are covered by the ULM labels and the relations of a ULM to other ULMs, contexts, topics, and keywords.

This elaborate structure can quickly become confusing to the user, as was discovered during the ESM-BASE project. In spite of the users’ problems while using the conceptual database schema, the researchers still considered the complexity of the schema necessary to enable the database to handle large amounts of learning objects (Persico et al., 1992).

3.5.2 Delta project DISCOURSE

The DISCOURSE project also used a multi-layered model (Chalon, 1994), see also Figure 3.1:

- the lowest layer contains the “raw” multimedia data, encapsulated by objects written in a multimedia description language ‘MHEG’ (Meyer-Boudnik & Effelsberg, 1995) to describe the spatial and temporal relations of the multimedia presentation, and the hyperlinks between the objects;
- the second layer encapsulates the MHEG objects and adds interactivity and sequencing, to compose Interactive and Multimedia Units (IMU’s);
- the third layer adds instructional features to compose Instructional Objects. These objects were retrieved and presented by a management system to provide instruction to the learner.

So, the lowest layer basically provides encapsulation of raw objects and provides presentation characteristics, the second layer adds interactivity and sequencing, and the third layer provides instructional characteristics.

3.5.3 The OSCAR system

The OSCAR project also used a three-layer model (Rada, 1995): a Unit of Learning Material is a collection of MultiMedia Units (MMU). A MMU is in turn a composition of several Monomedia Units (MU).

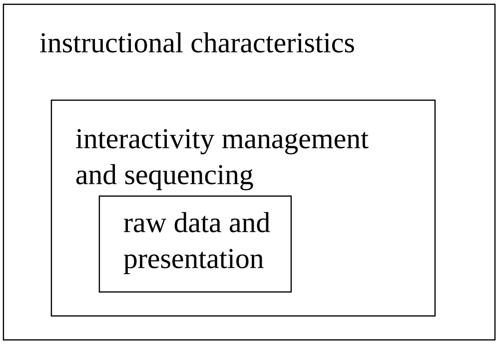

Figure 3.1: Architecture of learning objects in DISCOURSE

The model included a form of pedagogical metadata, that consisted of classification schema of the source, identification, quality level, and completeness. The project emphasized the importance of classification schema for achieving efficient retrieval and reuse.

3.5.4 IEEE Learning Object

The IEEE Learning Object Metadata group defines a learning object as any entity, digital or non-digital, that can be used, re-used or referenced during technology-supported learning (IEEE, 2000). This is a very broad definition, which is understandable as the metadata standard this group is preparing should be applicable to a wide range of learning environments.

3.5.5 Summary

The models resemble each other: a multi-media unit is composed of single-media units, sometimes accompanied by yet another decomposition in individual human languages. This decomposition allows for complex objects to be created, but they also make it difficult for the human user to work with these complex models.

Although the models provide very rich functionality, there is a discrepancy between the theory and the educational database systems that were examined earlier in this chapter: the retrieval capabilities of the systems are very limited compared to the theoretical promises of the models and their classification and metadata.

This thesis will try to fill this gap by using a simple ULM model and applying a retrieval mechanism that is based on metadata (see Chapter 7).

3.6 Conclusion

Many educational databases have been built the past decade. Also, many different ways to use these databases in practice have been explored:

- A database of learning materials that is labeled upon entry, and that is reviewed by peers (CSTC, NEEDS). These reviews are added to the metadata of the learning materials, and can be used as search criteria.
- The database can contain fragments of learning material that can be accessed and copied online at will (IMS, Ariadne, Explorer), but other databases may contain pre-packaged courses through which the user can search (OLA, PHOENIX Web). Other databases contain only references to offline materials and/or lesson plans (ENC).
- The database can be accompanied by a presentation and course tracking mechanism as well as other course management facilities, so that it forms an integreated learning environment (OLA, TeleTOP, Phoenix WEB).

The systems that have been discussed in this chapter share a more or less common way to search for materials: the user can choose from a simple, fast form that usually only consists of a single field, and an advanced method that can be as elaborate as choosing how many, and which fields to search (Explorer). The retrieval capabilities of the systems is rather simple: only “perfect matches” are shown, i.e. learning objects that match all of the search criteria. As educational metadata often consists of open vocabularies or vocabularies that can be interpreted in many ways, learning objects that would be “perfect” cannot be found back due to improper labeling. Therefore, it would be better to use a retrieval mechanism that is less strict, and that also returns results that are “nearly perfect”. This thesis will explore a method to also retrieve these almost-perfect objects (see Chapter 7).

The fact that large database companies (such as Oracle) are investing in online educational databases suggests that (at least from an industrial point of view) this type of database is considered useful, and has a certain future.

Many metadata or labeling systems have been discussed. Although it is important to ask: ‘which one is the best?’, it is evenly important to create a *standard* labeling system if the learning material is to be exchanged (reused) with other educational institutions. Also, the labeling system has to be easy to understand to the persons that have to enter the metadata, which are mostly the teachers. But as is the case with so many standards, a learning object metadata standard will be a compromise of the voices of all parties involved, and hence it will not be the ultimately best labeling system.

Chapter 4

Theoretical Framework

4.1 Introduction

Objects in a database represent particular aspects of objects in the "real-world", in database terminology also called *Universe of Discourse* (Elmasri & Navathe, 1989). The selection of these aspects ('attributes') greatly depends on the purpose of the database system, and the choice of aspects can have a great impact on the performance of the system, so one has to carefully choose how to *model* the real-world objects.

In this chapter, the theoretical background is presented for one of the goals of a multimedia educational database: to increase the amount of *reuse* of learning material by developing an appropriate model of learning material.

Some of the models presented in the previous chapter are very elaborate, and are very laborious to implement in an actual prototype. Also, the user may become confused by the complexity of the model. As the model should be comprehended by non-technical educational staff members, a model was developed that is less complex, yet provides the necessary functionality of enabling storage and efficient retrieval.

This thesis will try to fill this gap by using a simple ULM model and applying a sophisticated retrieval mechanism (Chapter 7) in a prototype which will be field-tested (Chapter 8).

4.2 The simple ULM Model

This section will present a simple model of Units of Learning Material which is based on the concept of "ULM" as defined in the DELTA projects. Only the most rich features of this definition will be selected, so that the new model will be much simpler and thus easier to understand for teachers. In fact, this is a main viewpoint in this thesis: the concept of Unit of Learning Material should be understandable for teachers, and they should be the judge of what they consider a “unit” of learning material. It is the teacher who will eventually have to use the concept to divide learning material into pieces, so the teacher should be the ultimate authority. This thesis believes that a technological system should assist the user, and not obstruct his or her natural, intuitive way of working with the system. Inherently, this means that the model is not very restrictive.

Some researchers believe that modeling learning material implies modeling *domain knowledge* (Reigeluth, Merrill, & Bunderson, 1978; Reigeluth, Merrill, Wilson, & Spiller, 1980; Hendley, Whittington, & Jurascheck, 1993; Horn, 1989; Broeke, Zwart, Verhagen, & Rhemrev, 1994; Merrill, Li, & Jones, 1990). However, the name “Unit of Learning Material” indicates that it is not so much a unit of *knowledge*, but more an object that has been specifically designed to achieve *learning*. It is the *message* that the teacher uses to transfer that knowledge that we want to capture in the ULM. Often, the knowledge contained in the message cannot be distinguished from the message itself, especially in technical subjects: the knowledge to be transferred is simply described (which is often hard enough as it is) in the message. However, especially in the affective domain, the knowledge that the teacher tries to transfer (e.g. insights concerning being tolerant to another human being) is very abstract, and difficult to describe. The knowledge is transferred using for example an anecdote, an exercise, or a case study. These types of knowledge cannot be modeled very easily, yet learning material that handles this kind of knowledge should also ‘fit’ into the model. So, the model should not try to model knowledge, but instead focus on the educational *message* that the teacher uses to transfer the knowledge. This thesis assumes that the teacher is not just looking for learning material about a certain subject, but instead that the teacher is looking for *educational* materials with certain desired *educational* properties.

So, the current research does not try to model knowledge, or “to obtain completeness with respect to domain knowledge” (as was stated in the original research problem, see Chapter 1) which is evenly difficult. Instead, this research will focus on labeling ULMs with educational characteristics based on the *contents* of the ULM in such a way that a teacher is able to retrieve them, re-purpose them, and re-use them in a different educational context than they were originally designed for.

4.2.1 Model

This thesis conceives a ULM is a multimedia building block that contains multimedia content, metadata, relations to other ULMs, a history file and presentation information (see Figure 4.1). These components will be discussed below.

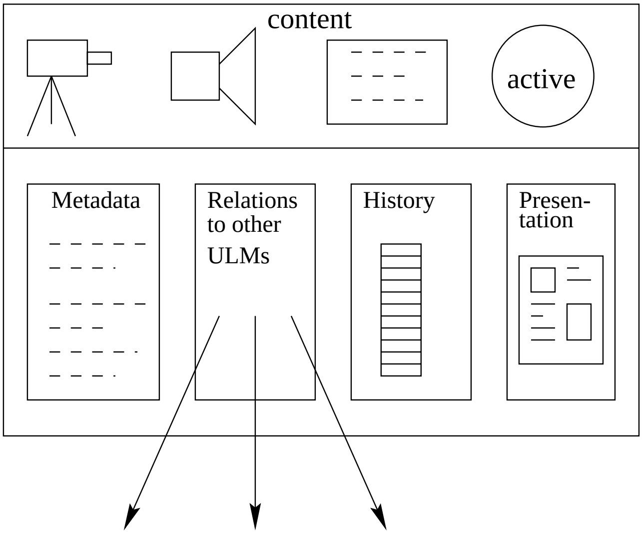

Figure 4.1: The structure of a Unit of Learning Material

Multimedia content

The multimedia content are the pieces of data that contain the actual content of the learning material (comparable to the "elements" of the ESM-BASE project, see Section 3.5.1):

- audio clips in various coding formats (eg. wave formats (.wav), MPEG audio, RealAudio[1]), which is denoted with the loudspeaker icon in Figure 4.1;
- video clips (eg. quicktime, MPEG video, animated GIF, RealVideo) and still pictures (eg. JPG, GIF, TIFF), denoted by the camera icon;
- text, eg. ASCII, Microsoft Word, Portable Document Format (PDF), marked-up text (SGML or XML), HTML documents, denoted by the icon with the three lines of dashes;
- "active" objects such as Java applets, Authorware applets, which are represented by the 'active' circle in the figure.

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[1] see http://www.realaudio.com

Metadata

A Unit of Learning Material not only carries educational content, but also meta-information, for example who created the ULM, for what subject area is it intended, or for what educational level was it created. A ULM can best be seen as a container: on the outside, there's a description of what is in it, while the interior is somewhat hidden but consists of a unit of some kind. We will call the meta information "labels", as they are intended to help retrieving the ULMs for specific educational purposes.

In the previous chapter, many different sets of metadata fields were presented. Examining the number of projects that utilized some form of metadata, it can be considered "common practice" to add metadata fields to learning objects.

Relations

Units of Learning Material often have some kind of educational relationship: ULM A can be an example of ULM B, or A can give a deeper understanding of the subject matter in B, etcetera. These relations have a specific educational purpose. In order to make ULMs better accessible, these relations can be stored in the ULM, so that when accessing ULM A it is also possible to easily access ULM B.

The relations can have more types than 'example-of'; semantical relations can also be used, especially if the ULMs represent concepts. For example, a ULM representing a piston can have a relation "moves inside" to a ULM representing a cilinder of a combustion engine. This idea was used by Elsom-Cook (1990) to build a concept map consisting of ULMs and relations. This allows the student to browse through the concept structure as if wandering through a "knowledge landscape". This application also touches the area of *Intelligent Tutoring*, enabling ULMs to be used in a system that can autonomously decide what learning material is to be presented to a particular student (Merrill, 1987; Li & Merrill, 1991; Brusilovsky et al., 1996). However, as the current research focuses on the storage of *learning* objects as opposed to *knowledge* objects, this topic will not be elaborated further upon.

History

A Unit of Learning Material carries a history file which describes in what courses the ULM has been used in the past. This file holds knowledge about for what courses the ULM has been considered to be useful by some educational designers.

Suppose, for example, that a teacher is preparing material for a course on recording information on magnetic surfaces for a Computer Science course, and he or she poses a question to the database application to retrieve some material.

The teacher likes the material he or she gets very much, and would like to find related information. The teacher then accesses the history information of the retrieved ULMs to see in what courses they have been used, and learns that the faculty of Electrical Engineering also has a course related to magnetic recordings. The teacher asks the database what other material was used in those courses, and finds a useful animation of the mechanics of a floppy drive. It will be clear that storing history information can increase the reuse of learning material.

Presentation information

In order to properly display all raw data components (i.e. layout aspects) in the proper sequence with the proper timings and on the proper screen locations, presentation information is needed in the form of positions on space- (screen) and time dimensions.

This component stores information that says, for example, "play the second audio clip two seconds after the first has ended". These kind of rules can be noted in for example MHEG (Meyer-Boudnik & Effelsberg, 1995), SMIL[2], or SGML[3]-derived languages such as XML or HyTime (ISO, 1992).

4.2.2 Nesting ULMs

In the simple ULM model, as opposed to the model of Persico et al. (1992) a ULM can consist of several sub-ULMS which in turn can consist again of sub-ULMS and so forth. In Figure 4.2 a ULM is depicted consisting of two sub-ULMs. The composed ULM carries its own history information, metadata and relations. As it contains the entire sub-ULMs, i.e. their content *and* their history, metadata and relations, the composed ULM can access this data as well.

4.2.3 The size of ULMs

One major question about ULMs is: What is the desired size of a ULM? This thesis proposes that this depends on two factors, which will be treated below.

Educational Purpose

The purpose of a particular collection of learning material may determine if the collection can be considered a unit, or should be considered to form several units. For example, a description of a chemical reaction can consist of many units (bits

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[2] see http://www.w3c.org/AudioVideo

[3] Standardized General Markup Language

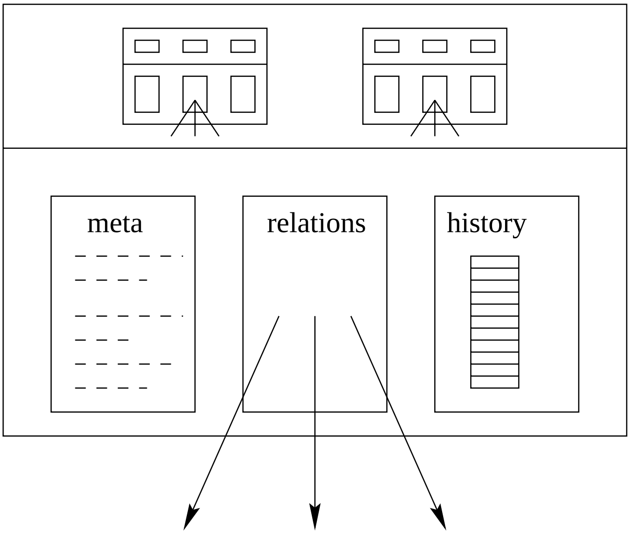

Figure 4.2: An example of a composed ULM

of theory, bits of examples, images) in a chemistry course, but it can also serve as one large example of how descriptions of chemical reactions look like in a course on scientific communication, and as such the description can considered to be one large unit. In the first case, the educational purposes of the respective units are ’theory’, ’example’ and ’visual representation’, while in the second case the educational purpose is ’example’.

Personal preferences

Personal preferences may influence what an educational designer considers a *unit* of learning material. Different designers may use different instructional design theories to design instruction, and designers each have their own unique experiences in designing instruction which may also influence their opinion about what can be considered an educational unit.

This flexible definition suggests that almost every ULM will have an unpredictable size, because each is created by different persons for different educational purposes. This would seem to reduce reuse, as the desired size would not seem to correspond easily with any ULM that is present in the database. There are two cases:

- the ULM the designer is looking for, should be larger than the ULMs he or she has retrieved from the database. In this case, the designer could easily create a new composed ULM consisting of (a selection of) the retrieved ULMs;

- The ULM the designer is looking for, should be smaller than the ULMs he or she has retrieved from the database. If one of these is a composed ULM, then perhaps a sub-ULM fits his or her goals. If not, then a multimedia editor may be needed to split the data in one of the ULMs into smaller parts and create new basis ULMs using this data.

So, to meet the personal preferences and the requirements in unforeseen characteristics, a very flexible unit-size has to be adopted. In the above two cases it was shown that although there seems to be a danger of reducing the opportunities for reuse, as long as editing facilities are available the educational designer can still select those parts of a ULM that he needs. Due to the recursive definition of a ULM, a designer can compose larger ULMs from smaller ones if he thinks this is appropriate. The freshly created ULM is then also inserted into the database. Note that the raw data (video fragments, audio clips) do not need to be *copied*; a simple reference to these objects suffices.

There is an interesting trade-off between size of a ULM and its usability: a large ULM is often more specific than a small ULM, so that the large ULM is less reusable than the small one. Consider for example a ULM consisting of a video fragment of 2 seconds showing a blue sky with some fluffy clouds, and a ULM containing a video fragment of 20 seconds showing the same sky crossed by a swarm of bees chasing the queen bee. The ULM of 2 seconds with the blue sky can be used in learning material about weather forecasting, cloud types, the filtering of specific colours by the atmosphere, or the lifecycle of water on this planet. The ULM with the bees is actually only suited for learning material about bees. So, the small ULM is more reusable, however it is difficult to put labels on the 2-second ULM so that it can be retrieved for all courses we mentioned.

The only upper limit that exists on the size of a ULM is the maximum attention span of the student. A ULM can be as large as one hour, and as small a picture plus one sentence, which could take about one minute to study.

4.2.4 Context Adapters

Units of Learning Material are in most cases designed with a specific educational situation in mind. When reusing a ULM in another situation, this may lead to practical problems (Marcke, 1995): the ULM may, for example, refer to preliminary knowledge that the learners do not have in the new situation, or the ULM may mention details that the current learners do not understand. To solve this problem, our ULM model includes the concept of ‘context adapters’: small elements that are presented before or after a certain ULM to “change” the context in which the ULM was originally designed. This can be done by briefly introducing the learner into the subject matter that is presented in the ULM, or to give instructions of how to interpret the subject matter, what details to ignore, or what details to pay special attention to.

Due to time constraints, this concept was not tested in a prototype implementation in the current research.

4.3 Summary on the ULM model

The concept of Units of Learning Material as it was presented here has many advantages:

- The relations between Units of Learning Material can facilitate explorative learning in a way that is easy to implement;
- the nested nature of ULMs can provide in-depth material as well as material that gives an overview of a certain topic, so that learners with different needs can be served; as these ULMs are linked to each other, the user and/or the computer software can easily move focus from one to another;
- using context-adapters, the reusability of a ULM can be greatly enhanced as it is no longer context-dependent but can be adapted to all kinds of new contexts;
- to allow users to easily grasp the concept, the model has been kept as simple as possible while keeping the richest features.

The model borrows parts and pieces of existing models, so it is not very innovative. It will be the working model of the current research, however, for building a prototype and testing methods to increase the reusability of learning materials. But first, the factors that affect this reusability of learning materials will be discussed in the next chapter.

4.4 Reusability

Already in the beginning of the nineties, it was expected by some researchers that reusability could be a key factor to solving high costs of multimedia learning materials. Persico et al. (1992) write, citing Olimpo:

> Courseware re-usability is one of the most promising approaches to the solution of key problems in courseware development such as high development costs, unsatisfactory quality, and the need for tools for fast prototyping.

Chalon (1994) agrees that due to reusability of media and multimedia components, efficiency of authoring and the global cost-effectiveness of courseware production is increased; see also Bloom (1995). The opportunities for reuse have greatly increased since the Internet, and especially the World Wide Web, became popular as a vehicle to deliver instruction during the second half of the nineties.

According to Persico et al. (1992), the following issues have to be addressed to make a piece of learning material re-usable:

accessibility: the development of a system which is endowed with powerful retrieving capabilities in a large pool of diverse material, by using explicit logical and pedagogical properties of the material;

modifying the material to adapt it to the context in which it is being re-used;

interoperability: the possibility of exchanging multimedia material between different hardware/software environments and the possibility of designing new applications by linking existing components which were not originally designed to be used together.

portability: the ability to handle with linguistic and cultural differences while reusing the learning material for another target audience

Duval (1999, June) identifies five further factors to achieve reuse: designing for reuse, self-containment, customizability, adaptability, and multilinguality. To achieve an increase in reusability, insight is needed into how these factors increase reuse. This thesis will organize the factors mentioned above into a *hypothetical* model, called Formula-M (see also Hiddink (2001a)), of factors and how these could influence reuse. This model serves to position the efforts of the current research into a theoretical framework, and to indicate where further work on increasing reusability can find a starting point. Although it would be possible to try to validate this model by undertaking an empirical study, this is outside the scope of the current research. Where possible, however, the model will be supported with references to existing literature.

4.4.1 Aspects of reuse

Three global factors that determine reusability will be defined here:

accessability The ease with which Units of Learning Material can be accessed; if access is very difficult, then it is unlikely that ULMs will be reused. As Verhagen and Bestebreurtje (1995) write, the applicability of a large multimedia database depends on the retrievability of the required information to cover specific needs that can differ from person to person.

genericity One can imagine that a ULM is very specific to a certain subject area, a certain educational setting or a certain teacher or class. These ULMs are less likely to be reused than very generic ULMs. Designing for reuse, as Duval (1999, June) calls it, will increase the genericity of ULMs.

opportunities This aspect refers to the amount of opportunities for reuse that exist in the educational institution (i.e. the organization complete with the people working in it and the culture that exists within the organization). One can imagine an institution in which people are very eager to create and present their *own* work, and just consider other people's learning material inferior. In such an organization not much reuse will occur.

These three aspects can be further refined; this refinement will be discussed in the sections below.

Accessability

The ease of finding ULMs back is believed to depend on several hypothetical factors.

- The labeling system (metadata fields) with which the ULMs are labeled needs to correspond to the way teachers think about searching learning material. If the teachers, for example, think in terms of pedagogical styles, learning objectives and didactic strategies, then the labeling system should allow teachers to use these terms in search criteria. If the labeling system only allows keyword searches, then the ULMs will not be well accessible to teachers, so that not much reuse occurs. As Rada (1995) states, a powerful yet flexible description and classification schema is needed for the purpose of efficient retrieval and reuse of ULMs.

- The search facility is also important: if it is not functioning well, then no matter how good the labels are, the teachers will still not be able to retrieve learning material, and reuse will hardly occur. If the search facility is, on the other hand, able to provide an intuitive interface that allows the teachers to quickly select appropriate learning material (for their individual goals), then reuse may have a better chance of occuring.

- If the search facility also uses usage history information to rate the appropriateness of learning material, then the amount of usage of ULMs also affects the amount of reuse: if no usage history information is present, there is a lower chance that appropriate ULMs are retrieved, decreasing opportunities for reuse.

Genericity

Several factors can increase the genericity of a Unit of Learning Material:

- During the development of the concept of a Unit of Learning Material, we also developed the concept of *Context Adapters*, as is described in Section 4.2.4. These context adapters allow a teacher to "adapt" the context of a ULM to a new context, making it more suitable to be reused in this new context. So the genericity of a ULM can be enhanced by the presence of context adapters suitable for it.

- *Designing for reuse* (Duval, 1999, June)) can be achieved in many different ways; one of the design principles that can be used, is to try to avoid references to local institutions, companies, persons etcetera. Doing so will make the material more generic and thus more reusable.

  Another design principle is to create the material in different human languages, in other words: to make it multi-lingual.

- The *layout* of a Unit of Learning Material can make it very specific to the educational institution where it was developed; for example by the presence of many logo's, color schemes, and other details specific to the graphical house-style of the institution (Hiddink, 2001a). Chapter 6 will present an architecture that allows for the separation of content and layout, so that a teacher that dislikes a ULM for its layout can still reuse the content, and add his or her own layout.

Opportunities

There are several opportunities "external" to the ULM or the database that can influence the amount of reuse.

- If at an educational institution one course is taught at several educational levels, then there are *subject matter commonalities* between the two levels; this approach was chosen by the Optical Database Project to achieve reuse (Bestebreurtje & Verhagen, 1992). These commonalities indicate the need for identical learning material that is applied in slightly differing contexts, so that learning material for one level can be reused at the other. These commonalities indicate opportunities for reuse.

- The social relationships in an educational organization can inhibit the reuse of learning material: if people do not wish to publicly show that they reuse learning material created by others, then less reuse will occur at that organization. This phenomenon is commonly known as the “not being made here” syndrome.
- Also, legal factors such as copyright policies of departements of an organization can inhibit reuse: if the department has decided to ask royalty fees for reusing materials, then other departments may be less eager to reuse their materials.

4.4.2 Graphical representation

The factors that have been discussed above have been organized graphically in Figure 4.3. We have called this model *Factors of Reuse of Multimedia Learning Material*, or Formula-M for short.

4.5 Conclusion

The model of Units of Learning Material presented in this chapter has been composed from key aspects of previous models. While not a very novel model, it should provide sufficient modeling power to allow the entry of a wide range of learning materials into an educational database. The chapter also presented a hypothetical model for organizing factors that affect the reusability of online learning materials. The model can be used to identify strong and weak points of models of learning material, considered from the viewpoint of increasing reusability of learning material.

This thesis hypothesizes that the model of Units of Learning Material facilitates the reusability of online materials in a number of ways through the Formula-M model:

- the history information enables search methods based on the past and current use of learning materials, making them better accessible;
- the context adapters increase the genericity of ULMs, which in turn makes a ULM more reusable;
- the relations between a ULM further help the user in finding related ULMs;

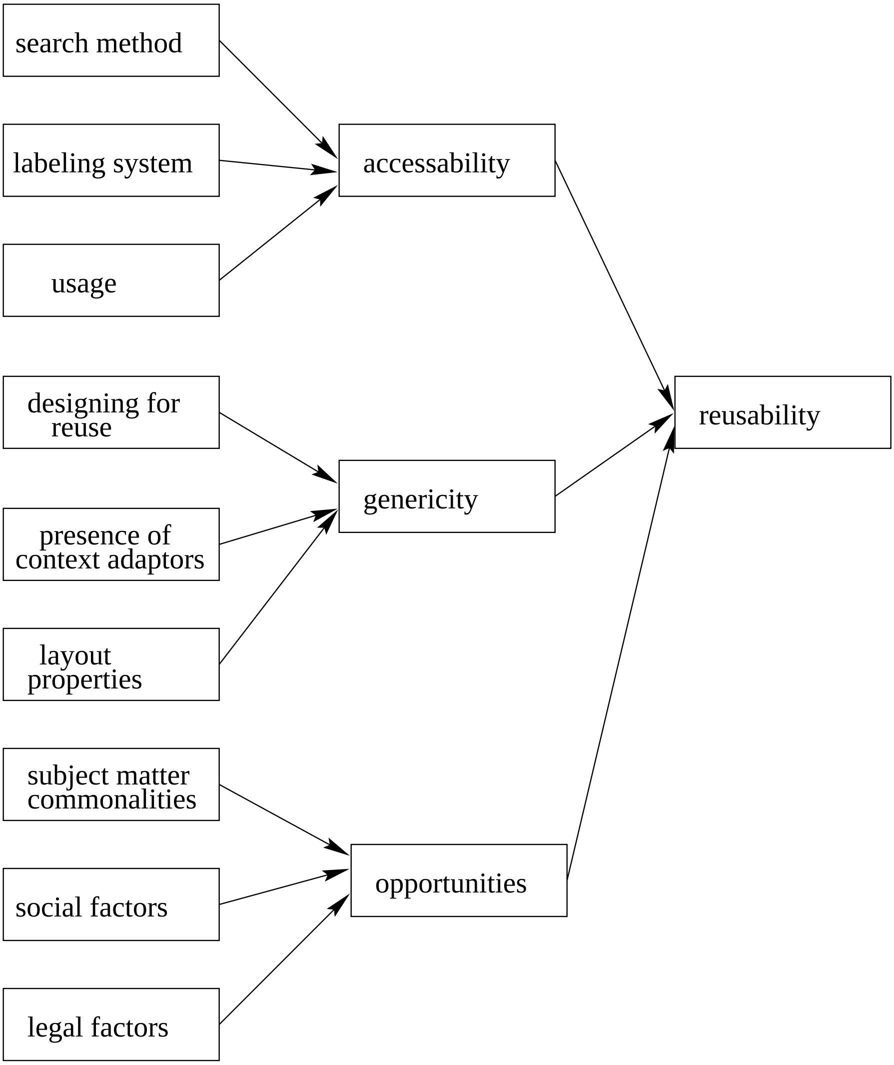

Figure 4.3: Factors Of Reuse of MUltimedia LeArning Material

- the metadata that is added to the ULM allows for advanced search methods to be used; see Chapter 7.

Using the Formula-M model, it is possible to find opportunities to increase the reusability of online learning materials. It would be possible to provide better search methods, provide a well-designed labeling system or create the right conditions for reuse within the educational institution. Although it would also be possible to try to find an optimal labeling system, these are currently being standardized, and tools are being written to use these standards. The standardized labeling system may not be the best, but in order to be able to use the tools, one has no choice but to accept this possibly sub-optimal labeling system.

A topic that can be dealt with by the Computer Science discipline is the problem of providing better search methods. This thesis will therefor focus on enhancing the reusability of learning materials by developing retrieval methods that utilize the opportunities provided by educational metadata.

Chapter 5

Access and Retrieval Methods

5.1 Introduction

Chapter 2 introduced the reader to various aspects of using educational multimedia databases: why are databases in general convenient to use, what are their properties, and what is the impact of an educational multimedia database and its applications on its users (students and teachers). After that, a model of learning objects was discussed in Chapter 4 to answer Research Question 1 (see Section 1.4.1), and identified factors that influence the reusability of these learning objects to answer Research Question 2. As answering Research Question 3 requires insights into search methods, this chapter will focus on search and retrieval methods that have been developed in the past. The objective is not to provide an in-depth discussion of all existing techniques, but rather to provide a broad overview that can be comprehended by technical as well as by non-technical readers. The purpose of this chapter is to provide a context of existing techniques so that the retrieval mechanism presented in Chapter 7 can be viewed in the proper perspective.

Figure 5.1 is proposed[1], depicting three sample data objects each with a metadata record. The figure serves as a framework along which various access methods will be discussed. The object on the left side shows a certain content structure, visualized by two rectangles. The object at the lower part of the picture shows three attributes. The arrows indicate where the various retrieval methods operate:

- the content-based retrieval methods operates on the contents of the data objects;

- metadata-based retrieval methods operate on the metadata of data objects;

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[1] This figure should not be interpreted as an Entity-Relationship (ER) diagram!

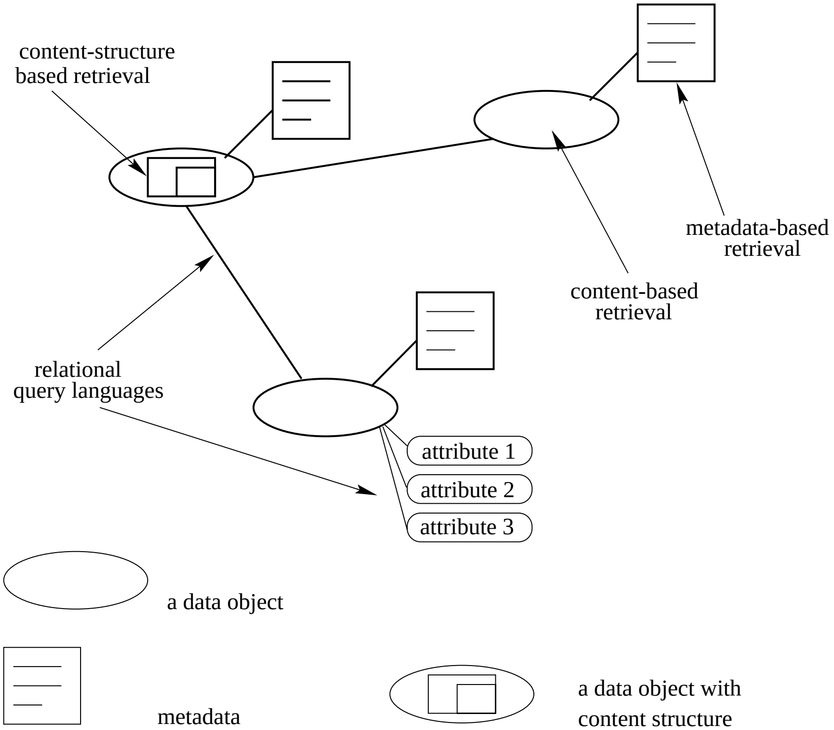

Figure 5.1: Different retrieval methods and where they operate.

- relational query languages (such as SQL) operate on the attributes and inter-object relationships;
- content-structure based retrieval methods operate on the (syntactical or conceptual) structure of the contents of the data objects.

Note that the figure presents an overly sharp distinction between the various methods. In practice, almost all methods present themselves to the user as an environment in which (relational) queries can be formulated. Furthermore, metadata are often stored as a data object so that there is almost no distinction between metadata approaches and a normal relational database. Also, the content-based method resembles the content-structure based methods, because both methods examine the contents of data objects. Still, for the purposes of organizing the different approaches into one framework, these similarities will be ignored.

5.1.1 Relational query languages

Many of the database systems currently in use are so-called ‘relational databases’: retrieval is based on the relationships between different types of data objects, or ‘entities’ (see Elmasri and Navathe (1989)). These relationships are encoded in so-called Entity-Relationships (ER) diagrams. For example, one entity type can be `teacher`, and another can be `course`. The relationship between the two is `taught_by`; see Figure 5.2. An entity can have several data fields, or ‘attributes’: the name of the teacher, his or her address, the name of the course, the trimester in which the course is taught. Each entity also has a ‘key’: an attribute (or set of attributes) that uniquely identifies the entity, such as Social Security Number (ssn) for `teacher`, or course number for `course`. Keys are very important to the database system, because they allow the DBMS to uniquely address entities. The keys are underlined in Figure 5.2.

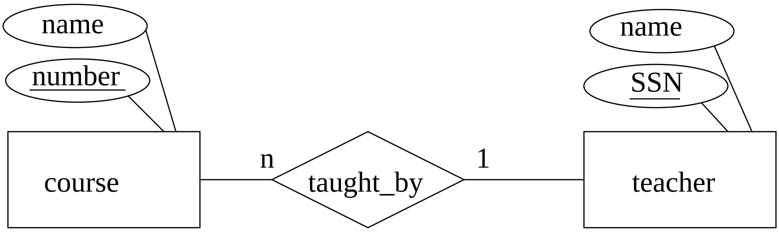

Figure 5.2: An entity-relationship diagram.

The numbers “1” and “n” next to the `taught_by` relationship diamond indicate that one teacher can give many courses; it is a so-called “1:n” relationship.

This diagram can be checked for certain desired properties in a number of 'normalization' phases; the resulting diagram can be in the Third Normal Form (3NF) (see Elmasri and Navathe (1989, p 376)) or the Boyce-Codd Normal Form (BCNF, see page 380 of the same book) which are forms that make it easy to translate the diagram to database tables. The database tables that can be derived from the diagram in Figure 5.2 look as follows (the keys are underlined):

teacher	
name	<u>SSN</u>

course			
<u>number</u>	name	trimester	taught_by

The fact that a teacher gives a course is denoted by the appearance of the so-called 'foreign' key `ssn` of the teacher as attribute `taught_by` in the `course` entity. Each "row" in the database table now stores the data of one entity.

Data can be retrieved from a relational database using the Structured Query Language (SQL), in which queries such as the following can be formulated: `select name from course where trimester=1`. This query would retrieve all courses that are taught in the first trimester. A query that would retrieve all courses given by a particular teacher would be:

```
select course.name
  from course, teacher
  where course.taught_by = teacher.ssn
```

This retrieval method deploys *exact matching*: the data that is retrieved matches the search specification exactly.

With the advent of databases that contain multimedia, however, retrieving data becomes more difficult. If a database consists of a large collection of video, audio, and text fragments, then there is no elaborate conceptual schema to refer to when searching for information. For example, one could imagine a database of learning material with only one entity type: 'Video Material', containing a large collection of assorted video fragments. How can one find a video fragment that shows the manual gestures a speaker makes to support a course on presentation techniques? Many retrieval techniques that try to solve this type of problem have been developed. The next sections will try to classify these methods and techniques. The discrimination that will be made, is to first differentiate between adding *new* data as metadata on the one hand (Section 5.2), and *deriving* data (or features) from existing data on the other hand. The derived data can be based on the data content of the document (Section 5.3), on the structure of the document (Section 5.4) or the conceptual structure of the information contained in the document (Section 5.5).

5.2 Adding Data

The technique that will be discussed here is providing data elements with *metadata*: data about data. The metadata tell something about the data objects; for example who created it, when, for what purpose, who updated the object at what time, what's in it, or how to use it. The metadata fields can be collected in an entity type, but sometimes the metadata fields are added to the entity as attributes; indeed, there is a thin line between what can be considered 'metadata' and 'data attribute'. The educational level of a Unit of Learning Material can both be modeled as a regular attribute, as well as a metadata field. Generally, a field that is only used for retrieval purposes but that is not made known to the user in an apparent way can be considered metadata. For example, the average pitch of a sound is a characteristic of the sound object that is generally not presented to the user, see also Section 5.3.3.

There is a wide variety of types of metadata that can be added to data objects, and about as many methods have been developed to utilize the metadata for retrieving data.

5.2.1 Annotating Metadata

With "annotation" is meant: the process of adding metadata to a data element. Plain text transcripts, for example, can be made of audio tracks that contain spoken language. The transcripts can be searched more easily than the audio tracks. Due to the development of speech recognition, this process can be done by computer programs.

Annotating video data is much more difficult: the temporal structure (time relations), the semantic representation of the video and the relations between visual and audible objects cannot be described well with words (Davis, 1995).

For example, imagine a video fragment showing a meadow in which cows are eating grass, while from the left a cloud of bees enters the scene, causing a cow to be startled and running away, tail upright. If this fragment is annotated from an agricultural point of view, then the accompanying text could indicate that a black-speckled cow is startled by a cloud of insects, possibly causing the cow to give less milk. A biological annotator, on the other hand, could write that a queen bee is chased by a large crowd of bees through a meadow where some cows are strolling about.

According to some researchers, icons or other symbols (Costagliola, Ferrucci, Tortora, & Tucci, 1995; Alberto Del Bimbo & Zingoni, 1995) may be a better way to annotate video or pictures; this is a less subjective manner because the scene is less interpreted. The query is then formulated in terms of the same set of icons.

Several types of annotations can be made:

- Annotations about what is happening in a particular video sequence (movements, objects and their relations, meaning of these movements, etcetera (Wiesman, 1999; Costagliola et al., 1995)). Figuring out "what is happening" requires human intelligence, as one has to interpret the video scenes and see relationships between objects and movements. Therefor, this process cannot currently be done by computers.

- Spatial annotations: what is the shape of the forms in the images: rectangles, circles, lines, etcetera. This process *can* be done automatically, as it only requires recognizing simple shapes.

- Unintended annotations: sometimes a side-effect of the way an information system was built is that parts of the data can be used as annotation. For example, the subtitles that are transmitted along with a videostream give a fairly good impression of what the video is about. Note that as the subtitles are not "new data", this type of annotation should not be considered a "metadata" technique according to the classification principle in Section 5.1.

5.2.2 Advantages of using metadata

According to Boll, Klas, and Sheth (1998), there are a number of reasons why metadata are especially useful in managing multimedia data which will be treated below.

Processing Power

Content-based retrieval (see Section 5.3) requires the database system to analyze the data, which can be very laborious, especially if the content-based retrieval algorithm involves recognizing geometrical shapes. If, on the other hand, the query processor only has to inspect metadata fields instead of processing very large raw data objects, then it can process the query much faster. A metadata record of 1 Kbyte can contain a wealth of metadata elements, while a raw data object can easily be several megabytes, three magnitudes larger.

Semantics of Multimedia Data

The metadata assigned to data objects contain the *semantics* of the data, something which a computer system cannot currently extract from the data itself. These semantics are of greater value for retrieval purposes than the raw data itself.

A disadvantage of manually annotating is that it is a highly subjective task, so that the annotation may be useless to another person: he or she may use very different keywords for identical phenomena (Wold, Blum, Keislar, & Wheaton, 1996). This problem is also known as the *vocabulary problem* (Furnas, T.K.Landauer, L.M.Gomez, & Dumais, 1987).

A special type of metadata has been developed by researchers in the field of Educational Technology: educational metadata. Section 5.8 will elaborate on this type of metadata.

5.3 Extracting Data

It is also possible to examine the *content* of the multimedia data and to try to derive metadata from these contents. Retrieval mechanisms based on extracting data from the content are often called "content-based retrieval" (CBR). There are several approaches, which will be discussed below.

5.3.1 Keyword Indexing

Keyword indexing is often used in the field of "Information Retrieval". Here, documents are indexed based on the words they contain. A query is then formulated in terms of a boolean expression: "present all documents that have this keyword AND this one but NOT this other keyword". Document rankings are often based on word frequencies, document size and word density (how often does the word occur in other documents). The probability that a keyword can be expected in a document can help in ranking the search results: the higher the chance that a keyword can be expected in a document, the less it 'adds' to the relevance of a document; keywords that have a high chance to appear in a document are 'common' words such as "this", "the", etcetera. This probability is the Inverse Document Frequency (IDF) of a specific term.

Of course, keyword indexing does only work well for text-based documents, and is not very suitable for multimedia libraries.

5.3.2 Form and Movement recognition

For pictures, algorithms have been developed that try to recognize geometrical shapes like circles, rectangles, and sometimes even larger constructed shapes such as houses, trees, cars, etcetera. Queries can then be formulated in terms of, for example, "shows house" or "contains cars".

For movies, algorithms have been devised to track movements within a video stream (Kobla & Doermann, 1997). Queries can then be stated in terms of "moves towards" or "appears", etcetera (Wiesman, 1999).

5.3.3 Formal Feature Extraction

Formal feature extraction is a relatively new technique. The idea is that multimedia data has many so-called ‘formal features’ such as colour and texture distribution and variances (Zaniolo et al., 1997; Faloutsos et al., 1994, p. 301), audio frequency and amplitude distributions and variances, so-called envelopes[2], etcetera. These characteristics, or *features*, can be easily measured. It has been proven that these formal features can sometimes be mapped onto human, fuzzy characteristics such as “scratchy noises”. These audio characteristics can help in discriminating video framents, for example to identify sports videos (a lot of rapid talking and cheering) from news reports (one voice that talks quite steadily).

These fuzzy characteristics can then be used in a query, which are translated into formal features for the database to select multimedia data (Wold et al., 1996). These features can also be modeled in a multi-dimensional space, where each feature is a dimension. Below, this will be elaborated upon.

Multi-dimensional Spaces

Documents can be mapped into a multidimensional space (sometimes also called the Vector Space Model, see Grossman and Frieder (1998)), so that mathematical techniques can be applied to aid the search process. Neural networks, for example, can be used to classify the space, i.e. find clusters of documents that resemble each other (Liu, Huang, Wang, & Chen, 1997).

Quite often, a user that requests multimedia documents from a database is looking for documents that *resemble* something, or that are *as near as possible* to an ideal document. To implement this notion of similarity, distances have been defined in multi-dimensional feature spaces. Many different methods exist to map a document into such a space: using concepts, terms, extracted features, etcetera. On these spaces, a distance function is defined so that a query is a point in this space, and a database management system can easily retrieve documents that are within a distance ϵ from the query point. The problem of finding the nearest documents within a certain vicinity of a query point is known as the *nearest neighbour problem* (Yianilos, 1998, 1992) or *similarity search* (Weber & Zezula, 1997; Seidl & Kriegel, 1997).

The notion of similarity can also be used in systems in which the user tells the system that he or she likes a particular document, a technique called ‘relevance feedback’ (Boll et al., 1998, p. 183). The system can then try to find documents that are similar by finding the nearest neighbors of that document.

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[2] the Attack, Decay, Sustain, and Release amplitudes and periods, which together describe the overall envelope of an audio signal

5.4 Document Structure

This section will examine retrieval techniques that are based on the structure of a document. This structure can be denoted using structure description languages such as MHEG (Meyer-Boudnik & Effelsberg, 1995; Chalon, 1994) or SGML (Goldfarb, 1990). SGML is in fact a meta-language: many markup languages can be specified in SGML using a so-called Document Type Definition (DTD). The Hypertext Markup Language (HTML) is one of the most well-known markup languages that is derived from SGML. The more recent XML language is also brought forth by SGML.

A Unit of Learning Material, for example, could be decomposed into an introduction, some theory, a few examples, and a test. An Educational Markup Language (EML) could be designed to capture this structure. The user can then refer to the structure to specifiy documents that he or she is seeking, for example to answer questions such as “give me all units of learning material that have at least two examples, a test, and a theory part about programming in Pascal”.

The Hypermedia/Time-based Structuring Language (HyTime) can be used to specify time- and space constraints (ISO, 1992), such as: “the second videoclip has to start 20 seconds after the first one has started, and it should appear to the left of the text”. These characteristics are very useful when presenting multimedia objects onto the screen, but are less useful when searching a database.

5.5 Conceptual Structure

The previous sections mostly discussed rather syntactical characteristics: keywords, movements, objects, textures, etcetera. There are, however, also many techniques that are based on more *semantical* characteristics of the data: concepts, meaning or interpretations. Some of these will be discussed below.

5.5.1 Knowledge Networks

Especially in the field of educational technology, knowledge networks are used as a structuring principle for multimedia data. These knowledge networks (also known as concept maps or semantic networks) can help in formulating queries or automatically retrieving (multimedia) learning material (Hendley et al., 1993). Elsom-Cook (1990), for example, built a system that allowed the user to relate learning material to concepts in a concept map. An Artificial Intelligence algorithm is then used to present proper learning material to teach certain concepts.

Merrill et al. (1990) use a similar algorithm: subject matter is decomposed into so-called *transactions*, and for each type of transaction learning material with specific characteristics is needed (Li & Merrill, 1991).

This approach saves development and maintenance costs, as the author of learning material can design courseware at a high conceptual level, and automatically generate actual multimedia material that matches the conceptual design (Hendley et al., 1993).

5.5.2 Naming Hierarchies

A slightly different technique is to map all data elements into a naming hierarchy. For example, the subject areas of a Computer Science curriculum could be organised as follows:

```
Computer Science
    State Machines and Languages
        ...
    Computer Networks
        Network Architectures
        Protocol Design
        Protocol Validation
    Database Systems
        Relational Database Systems
        Hierarchical Database Systems
        Network Database Systems
```

Such a hierarchical naming structure is often called a *taxonomy*. Educational taxonomies have been devised for a number of subject areas, such as the US-MARC[3] system (see also Appendix 3.1.1).

Duval (1990) describes a project in which medical multimedia data was indexed using the Medical Subject Headings (MeSH) and a standard textbook to obtain keywords. He notes that MeSH is usable because of the gradual refinement or broadening of the subject under consideration as the user goes up or down in the tree representation of the domain.

Similarly, the Ariadne project (see Appendix A.9) uses an extensible list of ‘known concepts’ from which the metadata typist can choose when describing a learning object. However, this list is not hierarchical.

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[3] see http://lcweb.loc.gov/marc/

5.6 Generic techniques

There are also some techniques which operate on all locations indicated by the arrows in Figure 5.1. These will be discussed below.

5.6.1 Inference Networks

Inference networks are probabilistic, for example by using a Bayesian network (Jensen, 1996), which means that nodes in the network provide ‘evidence’ for other nodes. Nodes are propositions, for example Node 1 may be the proposition “There is a tree in the picture”. If the user is looking for trees, then this proposition may be evidence to the proposition “The document is relevant to the user”. The observation (derived from analyzing the contents of the data object) that there is a brown object in the picture with a green sphere on top of it, may be evidence to Proposition 1. This way evidence can be collected for the proposition that the document is relevant, and search results can be ordered in sequence of decreasing relevance (see for example de Vries (1999)).

5.6.2 Document similarity

Some retrieval systems engage into a dialogue with the user. After presenting the search results of an initial query, the user is able to indicate that certain documents are relevant, and others are not. The system then tries to find documents that are ‘like’ the relevant documents, and ‘unlike’ the irrelevant documents. This notion of ‘document similarity’ can thus help in finding relevant documents (Korfhage, 1997, p. 125)

This technique is also helpful when using the “query by example” paradigm: the user provides a picture, drawing, or sound that is interpreted by the database system of an example of what is to be retrieved: data objects that are as similar as possible to the given example (Alberto Del Bimbo & Zingoni, 1995).

5.7 Discussion

Globally, there are two options for retrieval mechanisms in educational databases: adding new information, or extracting information from existing data. Techniques from the Content-Based Retrieval can be used, for example, to index multimedia objects based on their content. Teachers can then, for example, retrieve video objects that contain cows and meadows. However, in Section 4.2 it was stated that the Unit of Learning Material should not be considered to be a unit of subject matter, or a unit of knowledge. This thesis proposes a different approach: to treat a learning object as truely an object that has been created for learning purposes, and that the teacher should be able to search for *learning objects* instead of just subject matter about a certain subject or whose (moving) pictures contain certain objects. The Content-Based Retrieval techniques are inadequate to do this: there is no known algorithm that can determine, by looking at the content of a learning objects (text, video, images) what educational objectives the object tries to reach, or for what target group the material is designed, or how much interactivity the object provides.

Determining these properties can currently only be done by human beings, adding these labels manually. Of course this is a subjective task as there are many different views on learning (such as constructivism and behaviorism), and each view may have its own set of terms to describe learning objectives or target audiences. Yet, if an agreement between these different views is found, or constructed, then manually assigning educational metadata labels may be a useful tool for retrieval purposes. The next section will discuss educational metadata in some more detail.

5.8 Educational Metadata

As the previous overview showed, metadata can be used for retrieval purposes. This thesis proposes to use educational metadata that is added manually to the Units of Learning Material (see also Section 3.1.2), and to implement a retrieval mechanism using this metadata in Chapter 5. But first, this section will present an overview of the evolution of educational metadata.

5.8.1 Dublin Core

The Dublin Core[4] was one of the first metadata initiatives that attracted many researchers from various fields. It is a metadata scheme that initially did not focus on educational resources, but that was designed to provide a basic metadata set for online documents.

The first meeting in March 1995 was held in Dublin (hence the name of the Dublin Core) as an invitational workshop that was attended by researchers from the fields of computer science, digital libraries, and (geological) database experts (Weibel, Godby, & Miller, 1995). The workshop was organized by the Online Computer Library Center (OCLC, a nonprofit library computer service and research organization) and the U.S. National Centre for Supercomputing Applications (NCSA). The goal of the workshop was to get an idea of the requirements of

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[4] see http://purl.org/DC

a generic metadata scheme for networked resources, and to reach a consensus on a core set of metadata elements. The elements that were defined are:

Subject The topic addressed by the resource.

Title The name of the resource, or a descriptive phrase if the resource does not have a name.

Author The person(s) primarily responsible for the intellectual content of the resource.

Publisher The agent or agency responsible for making the resource available.

OtherAgent The person(s), such as editors and transcribers, who have made other significant intellectual contributions to the resource.

Date The data of publication.

ObjectType The genre of the resource, such as novel, poem or dictionary

Form The data representation of the resource, such as Postscript file or Windows executable file.

Identifier String or number used to uniquely identify the resource.

Relation Relationships to other resources,

Source Objects, either print or electronic, from which this resource is derived, if applicable

Language Language of the intellectual content

Coverage The spatial locations and temporal durations characteristic of the resource.

Values for each of these elements can be added to an online resource. There is not a fixed vocabulary from which the values should be taken. It is possible, however, to specify this vocabulary to avoid ambiguous interpretations of the element values.

The list of elements is extensible so that other fields (e.g. the educational field) can add specific elements while still maintaining compatibility with the Dublin Core. The Dublin Core workshop series are still being held each year, and on-going work includes amongst others the deployment of the Dublin Core for educational resources.

Some of the fields that are in the Dublin Core have also been explored by educational database-projects (see Section 3.1.2), and some projects discussed in Chapter 3 extended the Dublin Core with educational metadata fields. In Appendix A an overview of these projects is given, including a diagram of the relationships between the projects concerning the metadata fields (see Figure A.2). The figure shows that many projects were inspired by the Dublin Core, and that many projects eventually lead to the common standardization efforts undertaken by the IEEE Metadata group.

5.8.2 The IEEE Metadata set

Several initiatives were developed to explore the use of metadata for educational metadata. These initiatives have merged in the IEEE Learning Technology Standards Committee P1484.12: Learning Objects Metadata group[5].

The Instructional Management Systems project (IMS, see Appendix A.2) was among the first to extend the Dublin Core for educational purposes. This project was formed to initiate the development of a body of instructional software, an information infrastructure for managing access to learning materials and environments, and to facilitate collaborative learning activities. Many large and small companies are involved either as a development member or an investor, including Apple, Microsoft, and Sun. Also, a lot of universities are participating in the project. In the project, the Dublin Core was extended with educational elements such as interactivity level, keywords, learning level, learning objectives etcetera. At the same time, a European project called ARIADNE was also working on defining metadata standards.

These two projects, along with some smaller ones, joined forces in a group that belongs to the Learning Technology Standards Committee (LTSC) of the IEEE, called Learning Objects Metadata Group. A joint proposal was submitted in 1998, and both projects currently follow the standardized metadata definition. The most notable difference with the Dublin Core is that the range of values that can be used for the metadata fields is much more restricted: in the IEEE metadata standard, many fixed vocabularies are used. Note that for the distance measure that will be discussed in Chapter 7, fixed vocabularies are much more usable than ‘open’ vocabularies.

5.8.3 “Voluntary Labeling” problem

Chapter 3 showed that there is a practical basis for developing an educational database system; this chapter showed that the best way to implement this, is to use

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[5] http://ltsc.ieee.org/wg12/index.html

learning objects to which *labels*, or metadata, are attached.

The IEEE metadata standard is such a labeling system; it consists of many mandatory and additional voluntary labels (see Appendix C.3). It would take considerable time for a person to assign values to all these labels, doubting the feasability of such a scheme. In the Ariadne project, this task was assigned to *metadata typists* that were not necessarily an expert on the subject matter. However, the person entering the metadata *should* be a subject matter expert, because one of the most important metadata fields is the list of the main concepts that the learning material is about. Only a subject matter expert will be able to accurately describe these concepts, especially if the learning material concerns subject matter at an academic level. The consequence is that the *teacher* will have to enter the metadata, because in academic settings he or she is the subject matter expert of his courses.

However, one could propose that teachers will never voluntarily label learning material, and that therefore database systems based on labeled learning material will fail in practice. This proposition will be called the *Voluntary Labeling Problem*.

It is believed to be no problem for the following reasons:

- In the world of libraries, objects have been labeled for decades. People are hired to categorize objects and make sure they are stored in a logical manner which enables library users to find the books back. Similarly, personel can be hired to label educational materials and store them in an educational database, or teachers can be trained to do this.

- An educational institution could motivate personel to use the labeling system using, for example, a competition system in which the person whose material is actually reused most often receives a prize. Something as simple as a ranking list that is published on the WWW or on the department's announcements board could also help motivate people to use the labeling system and to encourage reuse.

- There are examples of projects that use a system in which the teachers have to label learning material themselves (such as the GEM[6] system), and that show that teachers are willing to do this.

5.9 Conclusion

In this chapter, an overview was given of existing retrieval techniques. Globally, two methods can be identified: adding new information to the data, and extracting

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[6] see http://www.thegateway.org

information from existing data. Educational metadata usually add new information to certain learning objects, and are in the process of being standardized. This enables the world-wide exchange of learning objects between large educational database systems. To generate methods and principles that support this process, and because educational metadata are a feasible way to implement search algorithms, the remaining part of this thesis will be based on educational metadata as is currently being standardized by the IEEE.

In the next chapter, a prototype of such an educational database system will be described. This prototype will be used to test (Chapter 7) and validate (Chapter 8) a method for improving the retrieval of learning objects using educational metadata.

Chapter 6

A Prototype Architecture

6.1 Introduction

The previous chapters have discussed various models of learning objects, and a novel model was proposed in Section 4.2. Also, various access methods were described in Chapter 5, and it was concluded that educational metadata are a suitable way to make learning materials retrievable.

This chapter will describe a prototype multimedia educational database system that was built as a "proof-of-concept" for the model of a Unit of Learning Material, and that provided an experimental environment for research on a distance measure that uses educational metadata fields; Chapter 7 will elaborate on this distance measure, and Chapter 8 will describe the experiments performed using the prototype. The prototype also served as a vehicle to test architectures of online multimedia delivery applications, so that answers to Research Question 3 can be found. This architecture allows for the separation of content and layout, which is hypothesized to increase the reusability of online learning materials (see also Section 4.4.1).

To make sure that the prototype implementation will meet certain goals, a requirements analysis will be made so that an explicit statement about these requirements exists; the final design can then be checked against these statements to ensure that all requirements are met by the design.

The requirements analysis is described in Section 6.2. Section 6.3 will review some existing architectures: of what functional components does it consist? How do these components interact with each other? After that, the prototype architecture will be presented in Section 6.4. The architecture was implemented in a prototype, which is discussed in Section 6.5. Section 6.6 will review the question whether large binary objects should be stored inside the database tables or outside, based on the experiences with the prototype. Finally, Section 6.7 concludes the chapter with some final remarks.

6.2 Requirements

This section will describe the requirements that the prototype has to meet. It is structured according to recommendations for software requirements specifications of the Institute of Electrical and Electronics Engineers (IEEE) as quoted by Behforooz and Hudson (1996, p. 114). First, the functional requirements are presented in Section 6.2.1: what is the prototype supposed to do? Then, Section 6.2.2 will discuss interface requirements. After that, Section 6.2.3 will discuss performance requirements. Finally, Section 6.2.4 will present some design constraints. Note that as this thesis does not intend to present the entire development process, only the most important requirements will be discussed.

6.2.1 Functional requirements

Functional requirements specify the functionality of the software, or: *what* is the program supposed to do. These requirements can be worked out in various levels of detail, but as the design process is not the focus of this research only a broad description will be given.

To show the usability of the ULM model, the prototype has to allow the teacher to search for ULMs, arrange and configure them into usable course components, and make these components available to students to use them. The students have to be able to access the course materials created by the teacher, to browse freely through the ULM collection, or to search for particular topics. Thus the following requirement can be formulated:

Requirement 6.1 *The prototype's basic functionality is to allow the entry, configuration, and retrieval of Units of Learning Material.*

6.2.2 External Interface Requirements

External Interface Requirements should specify the requirements concerning the user interface, the interface of the product towards the hardware, and the communication interfaces of the product. As the intended software should operate on various hardware and with various communications technologies (see Requirement 6.10), no specific requirements on these aspects will be formulated.

In an environment with many end users with many types of computer configurations (combinations of Operating Systems, applications, hardware, software) it is very difficult to guarantee that a particular new software component will work flawlessly with the other installed components. Therefore, it is desirable that the prototype requires as few extra software components as possible at the end-users' computers. If the prototype is to be accessed via the World Wide Web, then a standard web-browser should be the only component to be installed.

Requirement 6.2 *The prototype shall require as few software components as possible to be installed at the computers of the end-users.*

6.2.3 Performance Requirements

As there is a central database, and a distributed number of learners that access it simultaneously, the prototype will have to use networking facilities to make the database contents accessible to the learners. Thus the following requirement can be formulated:

Requirement 6.3 *The prototype shall be built as a network resource that can be accessed simultaneously by concurrent users.*

As a learning environment is typically accessed by a large number of students simultaneously, and as handling multimedia data can be very CPU- and IO-intensive, performance problems can be expected when deploying an educational database system in a large setting. So the system should be 'scalable': the ability of a system to adapt to a growing load. A scalable system is manually or automatically adaptable to large loads. So, the next requirement is formulated as follows:

Requirement 6.4 *The architecture as well as the implementation of the prototype shall be scalable.*

6.2.4 Design Constraints

This section will discuss several important design issues that have to be taken into account when designing the prototype.

Solving Statelessness

A very suitable network-based mechanism to disclose multimedia database contents to many users exists: the Hypertext Transfer Protocol (HTTP). This is the protocol used by the World Wide Web to transfer hypertext documents. However, if this protocol is to be used to implement the interaction between a learner and the application, then problems can be expected: the HTTP protocol was designed as a document retrieval protocol, not as a delivery platform for interactive network-based applications. For example, the HTTP protocol assumes that the server (the network host that offers documents for retrieval by clients) is *stateless*, which means that it does not store any information about the clients. This is not needed in the context the protocol was originally meant for: the client sends a request for a hypertext document to the server, and the server sends that document back to the client. The HTTP protocol is, however, currently used for much more advanced applications than just requesting hypertext documents; the HTTP protocol is also used for interactive applications such as online shopping systems. This type of applications are not stateless, and the server will need a method to remember the per-client state. For example, a webserver that wants to keep track of a *shopping cart* for a customer that visits an online shop, needs to store a list of items that the customer has in his cart. An online learning system has similar problems: when a learner starts a session, the learning system has to remember the username, the current position of the user in the course, the history of what the user has done to generate navigation, and so on. Often, this problem is solved by making use of so-called *HTTP cookies*. These are small messages that an HTTP (web) server sends to the client's web browser, containing a name, a value, an expiry date and the server's domain name (such as `utwente.nl`). The cookie is deleted from the client's computer after the expiry date. A web server that is in the cookie's domain can ask the value of the cookie. Using this mechanism, a web server can for example store a cookie with name "SessionId" and value "526447" on the computer of the user when the user logs in on an online shop system and is assigned shopping cart number 526447. When the user then clicks an item to be put in his or her shopping cart, the web server can request the value of the cookie with the name "SessionId", and it will receive the reply "526447" from the user's web browser. The web server then knows in what shopping cart the item is to be put. This way, the web server is able to track the actions of a user, in spite of HTTP being a stateless protocol.

Although these observations have already indicated how the issue of storing state information can be solved, a requirement on this issue will be formulated below:

Requirement 6.5 *The prototype will implement state information for each client to track the client's session.*

Search Facilities

One of the goals of the prototype is to explore new search facilities utilizing educational metadata. In one of these search facilities, the prototype will use the measure of relevance that will be developed in the next chapter to enhance the way the search results are presented.

Requirement 6.6 *The prototype shall be designed so that a distance measure can be incorporated into the search algorithms, and so that experiments can be done to validate the distance measure.*

Separating Content from Layout

As mentioned in Chapter 4, one of the problems when reusing learning material is the fact that “foreign” learning material does not have the look and feel used at a particular educational institution. A teacher may not agree with the position, color and style of buttons, menu options, general screen layout, etcetera. Even when the *content* of the learning material may be suitable, the *layout* of it may inhibit reuse. The prototype will try to separate layout from content, so that a teacher may select units of learning material based solely on content, and after that impose his or her own layout onto this content.

Requirement 6.7 *The prototype shall allow the separation between content and layout.*

Navigation

As mentioned in Section 2.3.2, learners may become distracted by the navigation task when using an interactive learning environment. To avoid this task to be too difficult causing the learners to become “lost in hyperspace”, this task has to be intuitive and clear. To achieve this, the following requirement is formulated:

Requirement 6.8 *The prototype shall provide sufficient navigational clues so that the user will always know where he is, where he has come from, and where he can go next.*

Modularity

Modularly designing a computer system prevents errors: if modules are as independent of each other as possible, then an error in one module does not as quickly lead to errors in other modules. Also, designing independent modules allows for easy replacement of modules, as long as it implements the same function calls with the same functionality. A design that is sufficiently modular will allow modules to be replaced without rewriting other modules. So, the next requirement is the following:

Requirement 6.9 *The prototype should be designed in a modular fashion, allowing for easy replacement of modules and easy error localisation.*

Portability

A prototype of a learning environment that is supposed to enable the reuse of learning materials between departments or even between universities, should be able to run on a diversity of Operating Systems. Also, within the Idylle project it was specified that all software should eventually be able to run on the Microsoft Windows platform, while the researcher preferred the Unix-like platforms as a development environment. So, the prototype should be able to run on a multitude of operating systems without major modifications, that is, it should be *portable*. This leads to Requirement 6.10:

Requirement 6.10 *It should be possible to run the components of the prototype under various Operating Systems.*

6.3 Common Architectures

This section will review some architectures for accessing databases via the World Wide Web.

6.3.1 Web-enabled databases

Many database vendors developed software components to make the contents of their databases available through the web. Popular systems include IBM's Lotus LearningSpace[1] which is based on Lotus Domino. Another example of a learning environment based on Lotus Domino is the TeleTOP system developed at the University of Twente (Collis & de Boer, 1999).

6.3.2 Accessing databases via the World Wide Web

The traditional method to achieve access a database via the WWW is to write script commands in the HTML files; see Figure 6.1. These commands are interpreted by the Web server when the HTML page is requested; this technique is therefore known as "server-side scripting" (SSI). Popular script languages to do this are PHP (Hypertext Preprocessor), and Microsoft's ASP (Active Server Pages). Documents that include these scripts are often called "dynamic documents", as their content depends on what was retrieved from the database.

The following example was taken from a PHP/MySQL tutorial[2]:

---

[1] Note that IBM has decleared that Lotus LearningSpace will be IMS standards-conformant as soon as these standards are finalized and released.

[2] http://hotwired.lycos.com/webmonkey/99/21/index3a.html

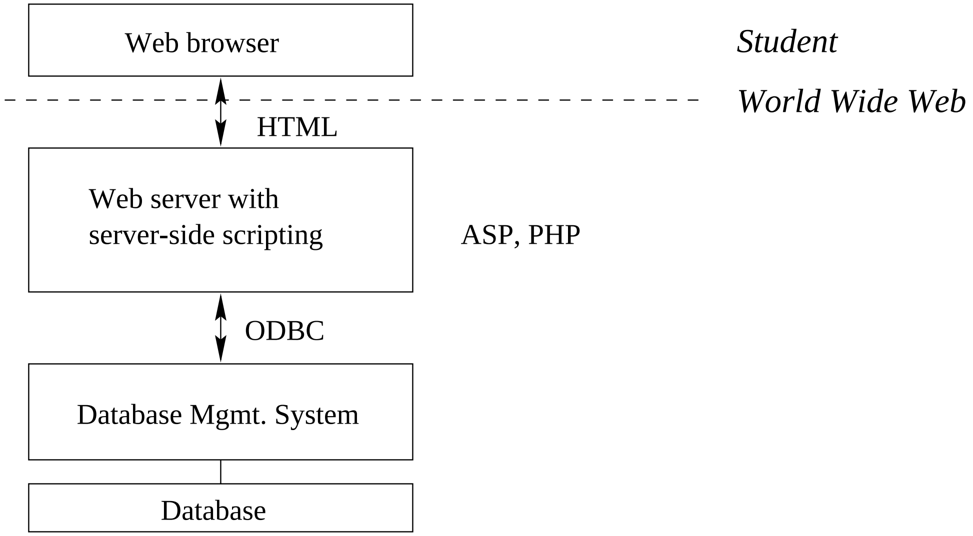

Figure 6.1: Architecture of common WWW-enabled database applications.

```
<html>
   <body>
      <?php
         $db = mysql_connect("localhost", "root");
         mysql_select_db("mydb",$db);
         $result = mysql_query("SELECT * FROM employees",$db);
         echo "<table border=1>\n";
         echo "<tr><td>Name</td><td>Position</tr>\n";
         while ($myrow = mysql_fetch_row($result)) {
            printf("<tr><td>%s %s</td><td>%s</td></tr>\n",
                 $myrow[1], $myrow[2], $myrow[3])
         }
         echo "</table>\n";
      ?>
   </body>
</html>
```

As can be seen, the HTML tags are interleaved with SQL queries and result processing code. It is very common to mix SQL queries and programming code; see for example Elmasri and Navathe (1989, p. 204). The advent of HTML as a layout language (although intended as a markup language) has made things worse:

now SQL queries are mixed with programming code *and* layout code. ASP works similarly; see the following example[3]:

```
<%
  DO WHILE NOT sessionRecords.EOF
%>
<tr>
  <td><p><% =sessionRecords("Name") %> </td>
  <td><p><% =sessionRecords("Position") %> </td>
</tr>
<% sessionRecords.MoveNext
LOOP
sessionRecords.Close
%>
```

The commonly accepted layout of indenting the code for each loop, tag or procedure fails so that the programmer cannot see the loops and tags clearly anymore. In the PHP example, it cannot be seen anymore by looking at the indentation where the `<table>` elements start which table elements belong in it, and where the `<table>` element ends. This increases the chance of mistakes and errors, such as forgotten element ending tags (such as `</table>`), unmodular PHP code (everything has to be written in a particular HTML file, although files can be included) and so on. Similarly, in the ASP example it is impossible to correctly indent the `DO WHILE ... LOOP` and the HTML table tags simultaneously. Properly indenting is one of the virtues of the art of programming.

Observe, for example, that the PHP script uses a `mysql_fetch_row` call. This indicates that apparently the MySQL database is used. When the company decides to use another database, then a programmer would have to edit the script-file, and modify the queries and the database call *without touching the HTML code*. This is extremely error-prone.

Another method that is popular on Unix-like operating systems is to use the Common Gateway Interface definition (CGI) to execute a program (written in a scripting language such as Perl, or an executable program) to process the request. The CGI script would connect to the database, retrieve the data, format the returned results, and give the resulting HTML page back to the Web server. It is totally up to the CGI file how to generate the HTML file. The main disadvantage of this technique is that to execute the CGI program (or script) a process is created each

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[3] taken from http://www.bann.co.uk/asp/global/connections.asp, an online ASP tutorial; some irrelevant code was omitted and the column names were modified to match the PHP example.

time a request to the CGI program is made. In most operating systems, a process creation is a relatively slow operation.

Finally, many Database Management Systems allow web integration via extra modules (sometimes also called plug-ins or datablades). These software modules enable the DBMS to return query results as HTML code by using a (mostly proprietary) script language. These techniques resemble Server-Side Scripting techniques, but the languages used are less common.

These technologies are used in many application domains, amongst others the delivery of online learning materials. The Blackboard system version 5, for example, uses the MySQL database, the Apache webserver and Perl scripting for Unix platforms. On Windows platforms, the Microsoft SQL server and the Microsoft Information Server are supported.

6.4 Prototype Architecture

The architecture of the prototype is pictured in Figure 6.2 (Hiddink, 2001b). As presenting multimedia learning material to the learner is not trivial, a Presentation Layer has been created for this purpose. This layer consists of two parts: client software that is able to present multimedia streams to the learner, and server software that is able to create these streams and transmit them across a computer network.

It should be fairly easy to replace the Presentation Layer for another one. The development of multimedia presentation tools is proceeding rapidly, and during a four-year project a lot can change. New, better multimedia presentation tools may become available (such as the Java Media Framework), other network technologies may emerge etcetera. To make it easier to replace the Presentation Layer and to satisfy Requirement 6.9, an abstract interface was defined between this layer and the Interaction Processor. This interface consists of an Application Programming Interface (API) and a specification of the data exchanged between the Presentation Layer and the Interaction Processor. This specification is written in SGML, which stands for Standardized General Markup Language. Creating a new Presentation Layer then simply involves implementing the API and parsing and creating SGML documents, avoiding the need to rewrite the other components of the prototype.

The API simply consists of the following two function calls:

```
void process (Document inputDoc);

Document generateOutput ();
```

The interaction events from the user (menu selections, filled in forms, navigation events) are encoded in an XML document by the presentation layer, and

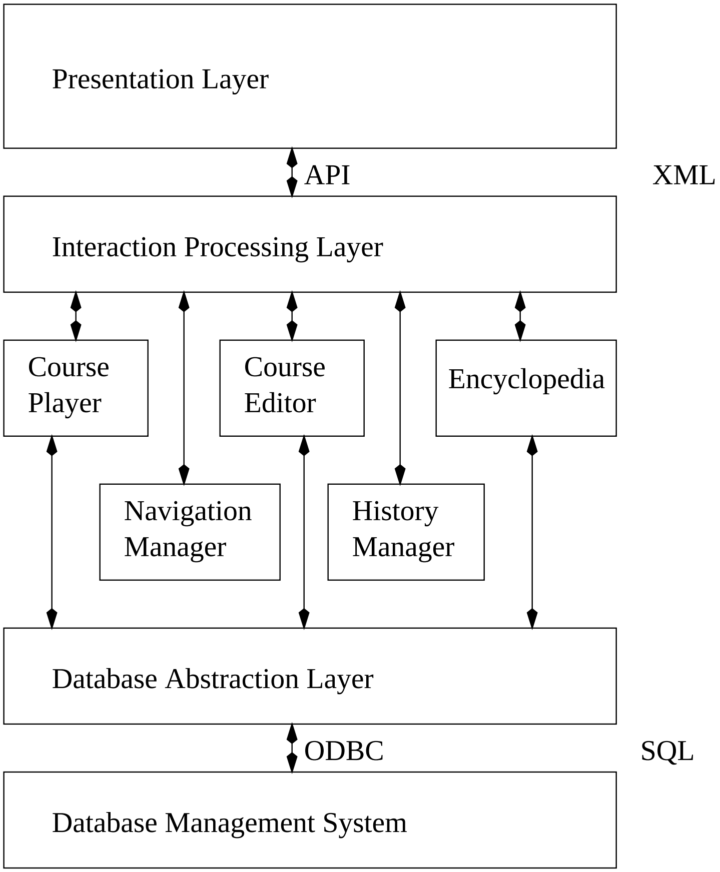

Figure 6.2: Architecture of the learning environment

then passed on to the Interaction Processor using the `process` API call. The Interaction Processor communicates with functional components that implement the basic functionality of the prototype (as described in Requirement 6.1): editing and "playing" courses, and making learning material accessible to the user via an encyclopedia. These components are the Course Editor, the Course Player, and the Encyclopedia. Other components are the History Manager (which traces the usage history so that the user can go back one or more events), and the Navigation Manager which generates and manages the navigation events (satisfying Requirement 6.8).

These components create output in so-called *Interaction Elements*: tables, fill-in forms, menus, warnings, errors, and ULMs themselves. These components are capable of creating an XML representation of themselves (for an example of a menu, see below). These XML parts are gathered by the Interaction Processor, and are stored temporarily until the `generateOutput` call is made; the Interaction Processor will then return the XML document containing the outputs of the components. The presentation layer will use the XML document to create a screen which the user can view and interact with. By encoding all interaction into XML documents, these components are as independent of the presentation layer as possible (satisfying Requirement 6.9). This means that any presentation technology can be used to create the user interface itself.

The forementioned components interact with a Database Abstraction Layer that was provided to create minimal dependencies on a particular database system, making it easier to switch to another database system in the future (see Requirement 6.9). It should be noted in this context that although JDBC provides a uniform interface to the database management system, but it does *not* hide specific details: each DBMS has its own dialect of SQL, which is almost never completely compatible with other SQL dialects. The purpose of the Database Abstraction Layer is to hide these dialect differences as well.

As an example, the CoursePlayer uses the Database Abstraction Layer to retrieve a list of courses that a particular student can do, and generates the following SGML code:

```
<menu title="Select a course:" identifier="main-menu">
  <menu-option ref="14065" name="Distributed Databases">
  <menu-option ref="16023" name="Discrete Mathematics">
  <menu-option ref="12036" name="Telematics Systems">
</menu>
```

This code is then given to the Interaction Processing Layer that will transform it for example into HTML (for the Web), Xwindows API calls (for the Xwindows environment), or AWT calls (for the Java Abstract Window Toolkit) to create a presentation for the user.

6.5 Implementation

In the course of the project, a prototype implementation was continuously revised and improved to test various ideas. The technical problems and their solutions that were encountered during these efforts will not be discussed here, as the purpose of this Section is to show that the architecture presented above can be successfully implemented. So only the final implementation will be discussed here. Section 6.5.1 will present the software components that were used while constructing the implementation, Section 6.5.2 will discuss how HTML code was generated by the presentation layer, and Section 6.5.3 will explain how the interaction with the user was handled. Finally, Section 6.5.4 will present some thoughts on scalability issues.

6.5.1 Software components

It was decided that the Java programming language would be used for software components that had to be written, because Java programs are portable without modifications across many platforms (see Requirement 6.10). The Java Database Connectivity (JDBC) API was consequently chosen to communicate with the Database Management System. The MySQL database[4] was chosen for its free availability, scalability, and its compatibility with JDBC. Although other database management systems such as PostgreSQL[5] also offered these characteristics, the MySQL database was the only one supported by the only free JDBC driver that could be found (called ‘`twz1`’). Furthermore, MySQL was known to run under SunOS, the Operating System used by the faculty’s servers. MySQL can also be compiled under the Windows Operating System, providing even greater portability of the software to other Operating Systems so that Requirement 6.10 is satisfied.

The prototype uses the Java Database Connectivity (JDBC) API to connect to the Database Management System so that it is truely independent of the DBMS, satisfying Requirement 6.9.

The architectural concepts of the prototype incorporated SGML documents. It was found, however, that XML is rapidly gaining momentum in the software industry, causing more and better tools to be available for XML than for SGML, so that it was decided to use XML instead of SGML. As XML is derived from SGML,

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[4] available at http://www.mysql.org

[5] see http://www.postgresql.org

and uses almost the same syntax, this decision has no impact on the architecture itself.

To disclose the database contents via a computer network (to satisfy Requirement 6.3), the webserver “Apache”[6] was chosen for reasons of stability, free availability, extensibility, and the fact that it supports Java and XML. Apache is one of the most popular webservers at the time of writing. The webserver was extended with a Java Servlet Engine, which is a software component that enables Java Servlets to process certain types of requests. The Cocoon servlet (also being developed by the Apache community) was used to format XML documents; see also Figure 6.4. Cocoon was chosen for its free availability and its compatibility with the Apache webserver. It was the only XML publishing framework written in Java that could be found.

The application-specific components, such as the Interaction Processing Layer, the Course Player and so on, were implemented as a Java Servlet, called “DILE” which stands for “DIstributed Learning Environment”.

These components were configured to operate together; see Figure 6.3. The figure shows the WWW client interacting with the Apache server using the HTML language. The Apache server also communicates with the Servlet Engine using the HTML language. The Java implementation in the lowest box implements the architecture shown in Figure 6.2. Note that the WWW client, the Apache web server and the Cocoon formatting engine are part of the ‘Presentation Layer’, as they are responsible for getting data across the network onto the screen of the user.

The advantage of implementing the application as a Java servlet is that the Servlet Engine is capable of tracking HTTP sessions, satisfying the Statelessness Requirement 6.5 (see Section 6.2.4). Also, the Servlet Engine runs as one process for all users interacting with the prototype, so that no process needs to be created for each request as is the case with CGI technology (see Section 6.3.2).

In the next sections, some more details on the inner working of the prototype will be presented.

6.5.2 Generating HTML

The communication language between the client and the prototype was chosen to be HTML, so that the client would need no special software but a standard Web browser, in concordance with Requirement 6.2.

Section 6.3 has shown that WWW pages are often generated using server-side scripting techniques, such as PHP or ASP. There are three reasons why this approach is not suited for our architecture.

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[6] available at http://www.apache.org

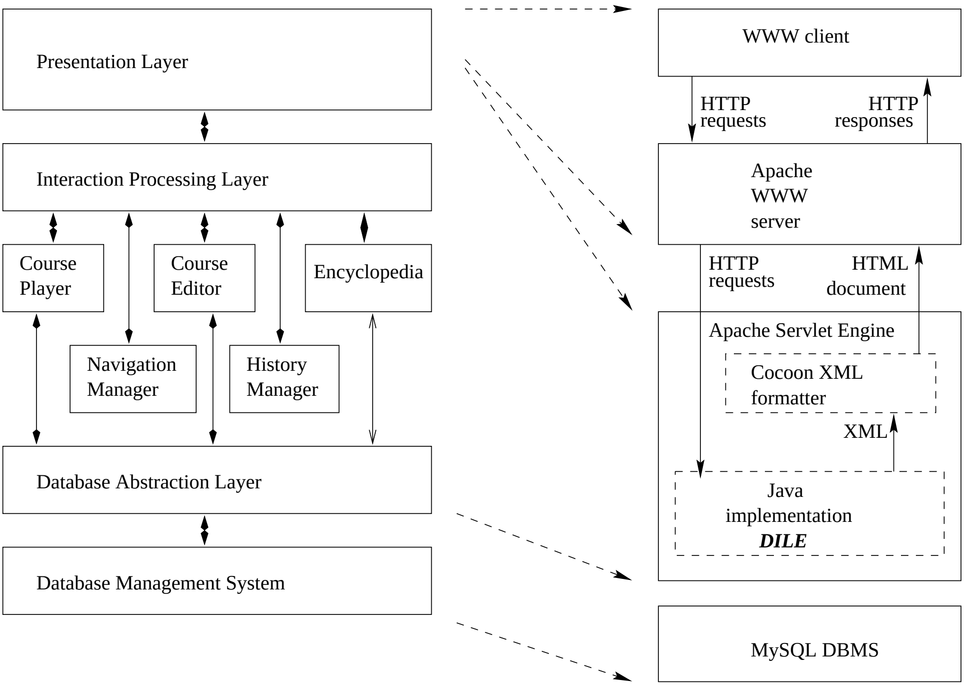

Figure 6.3: From architecture to implementation.

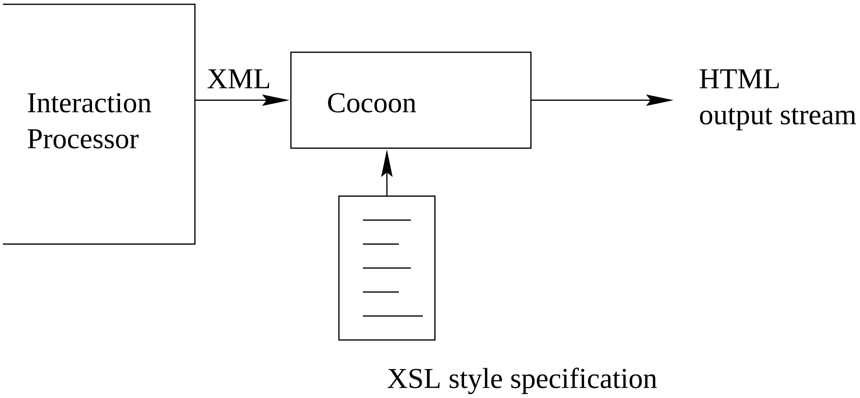

Figure 6.4: Creating HTML output by applying style (XSL) to content (XML).

As discussed in Section 6.3, the HTML document becomes ‘polluted’ with database-specific details and with implementation details. Also discussed in that Section was the problem with indenting two ‘flows’ of code: HTML and script. The third reason is that mixing HTML code and script code would violate Requirement 6.9, because the database module depends on the presentation layer: its queries are stored there. As can be seen from the architecture in Figure 6.2, the database layer is not located near the presentation layer, so they should also be as independent as possible. If the database queries would be encoded in the HTML files, then it would not be very easy to remove the ‘web-based’ presentation layer and put another one on top (for example, one that implements presentation facilities using the Windows desktop environment): this presentation layer would not offer facilities to encode database queries inside the layout language. The Windows desktop environment does not even use a layout language.

So, another way to generate HTML documents containing dynamic content had to be found. A possible solution is to fully seperate the content of the learning material from the layout (in concordance with Requirement 6.7) and to specify the content using the eXtensible Markup Language (XML) and the layout using the eXtensible Style Language (XSL), see Figure 6.4. Software components are readily available to generate HTML by applying an XSL stylesheet to an XML document, such as the Cocoon XML publishing framework[7].

As shown, the output of the Interaction Processor is specified using the XML language. This output is fed to “cocoon”, as well as a style document written in XSL. The output is fed back to the web server, which in turn transmits it across the Internet to the client’s web browser.

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[7] http://www.apache.org

The fact that the output of the Interaction Processor is partly generated by sending queries to a DBMS is fully hidden from this scheme, so that the presentation layer does not rely on particular features of a particular DBMS, further increasing the independence between software modules.

6.5.3 Encoding Interaction

If one abstracts away from specific presentation mechanisms and assumes a generic and abstract presentation layer, then an “interaction specification language” is needed. We have developed such a language in XML by specifying the “tags” (elements) in a Document Type Definition. For example, it is possible to specify that an element “menu” consists of several menu options. It could also be specified that the menu element has a “title” and an “identifier” attribute, and that the menu option elements have a “name” attribute and an internal reference identifier. This is specified as follows:

```
<!ELEMENT menu          - O          (menu-option)*>
<!ATTLIST menu          title        CDATA    #REQUIRED
                        identifier   CDATA    #REQUIRED>
<!ELEMENT menu-option   - O          (#PCDATA)>
<!ATTLIST menu-option   name         CDATA    #REQUIRED
                        ref          CDATA    #REQUIRED>
```

The ‘`- O`’ sequence indicates that the “opening” tag `<menu>` may not be omitted and that the “closing” tag `</menu>` of the menu may be omitted. The ‘CDATA’ indicates that no further sub-elements are specified and that the element can contain any (textual) data.

We have created a DTD containing elements for menus, forms, navigation, history, and other interaction elements. Documents that conform to this DTD should be able to represent all possible output data of the prototype. Similarly, a DTD was created for all possible *input* data of the prototype. Each SGML document specifies in a “DOCTYPE” element to what DTD it conforms. For example, the following SGML document describes the main menu of the prototype using the “output.dtd” DTD:

```
<manager id = "1"/>
<menu title="Main menu" identifier="main-menu">
    <menu-option ref="do-course"
                 name="Do a course"/>
        Do a course
```

```
    <menu-option ref="encyclopedia"
                 name="Go to encyclopedia"/>
        Go to encyclopedia
    <menu-option ref="edit-course"
                 name="Edit a course"/>
        Edit a course
    <menu-option ref="view-results"
                 name="View student’s results"/>
        View student’s results
    <menu-option ref="logout"
                 name="Logout"/>
        Logout
</menu>
```

The “manager” element is used as a reference to the per-user session data, so that Requirement 6.5 can be satisfied.

The presentation layer uses this document to generate an image on the user’s screen which should allow the user to examine the menu options and select one. The HTML presentation layer that the prototype uses, generates the following HTML code (only a part is shown):

```
<TABLE BORDER="0" WIDTH="100%">
   <TR>
      <TD WIDTH="20%">
      </TD>
      <TD WIDTH="40%">
        <FORM method="POST" action="menu">
           <H1>Main menu</H1>
           <INPUT TYPE="HIDDEN" name="managerid"
                  value="1">
           </INPUT>
           <INPUT TYPE="HIDDEN" name="identifier"
                  value="main-menu">
           </INPUT>
           <INPUT TYPE="HIDDEN" name="type"
                  value="menu">
           </INPUT>
           <INPUT TYPE="submit" value="Do a course"
                  name="do-course">
```

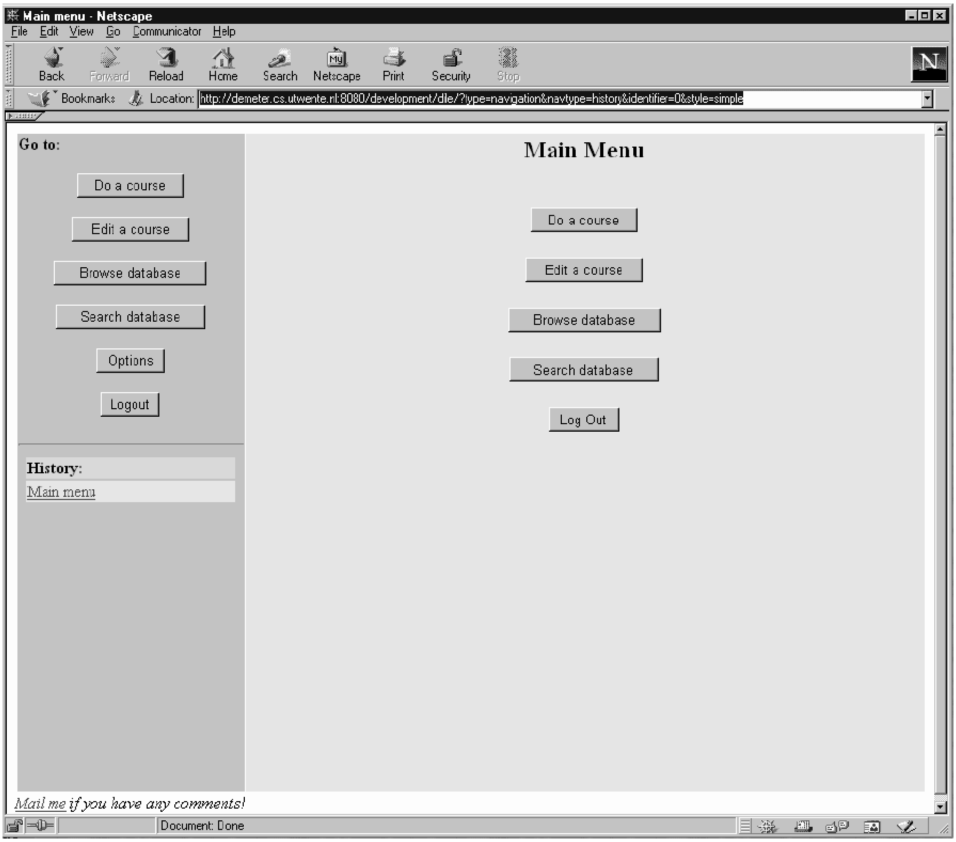

Figure 6.5: Appearance of the HTML code in a Netscape browser window

As can be seen, this HTML code is not “polluted” with database queries. The menu shown does not include any information retrieved from the database. However a menu that consists, for example, of the names of some courses retrieved from the database is similarly specified in XML, and similarly translated to HTML by Cocoon. The HTML code appears as shown in Picture 6.5 on the computer screen.

The user will then click a menu-option, which is translated to a URL by the user’s web browser and that looks something like this: “`?managerid=1&identifier=main-menu&type=menu&do-course=Do+a+course`”. This URL will be sent by the web client to web server (located in the presentation layer) which translates it to an abstract representation in XML that again conforms to the “input.dtd” DTD. The XML document then looks as follows:

```
<submission type="menu-option" name="main-menu">
```

```
   do-course
</submission>
```

The interaction processor, that receives SGML documents from the presentation layer, now knows that the user has selected menu option “do-course” from the menu that is identified with “main-menu”.

6.5.4 Scalability

What about Requirement 6.4 on scalability? The prototype implementation can be scaled upwards in several phases. Some scalability is already included in the Apache webserver: it will create more clones of itself as the load (number of URL requests) increases; each clone is capable of handling one request at a time. If the load decreases, then the clones are disposed of by Apache. The maximum number of clones can be speficied in a configuration file. If the machine that the webserver runs on has multiple CPU’s, then the clones will each use a different CPU concurrently so that multiple requests can be handled at the same time.

All clones use the same Apache Servlet Engine and the same Java Virtual Machine. If this part of the system becomes overloaded, then several instances of Apache can be started, each with its own Servlet Engine (Apache is not designed to run multiple Servlet Engines). Each Apache instance will have to run at its own *network port* i.e. one at port 8080, the next at port 8081, and so on, because almost all known operating systems do not allow multiple applications to listen to the same port. Note that clients that connect to the system must specify in the URL (using the `protocol://host:port/path` notation) to what port they want to connect, which is undesirable because learners do not want to be bothered with network port numbers. This problem can be solved by setting up Apache servers at different machines, and assigning these machines the same Internet hostname[8]. It would also be possible to run one Apache server for each department. Note that the Apache instances will still all connect to the same MySQL database, thus sharing one large collection of learning materials.

Another bottleneck that can occur is the Database Management System (DBMS), because it has to transmit the multimedia data to the database application, a task that is very IO intensive. The current version of the MySQL database cannot be replicated, although a “master” DBMS can be setup to which all updates are sent; one or more “slave” DBMS’s are updated from the master, and non-updating queries (“read only” queries) are sent to the slave(s). The Ariadne Knowledge Pool system (see Appendix A.9) also uses this technique. Commercial databases

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[8] This can be achieved by implementing a round-robin IP number assignment scheme in the Domain Name Server (DNS).

sometimes do implement replication, but this option is often *very* expensive. A disadvantage of the master/slave configuration is that changes in the database are not immediately visible to the user; true replication does not have this disadvantage, although a slight delay (several minutes) may occur. Another disadvantage when using the MySQL database was that the version used did not support transactions[9]. This means that when a ‘mirror’ (an exact copy of the database contents) has to be made, the entire DBMS has to be shut down (or all tables locked) to avoid update queries that could make the mirror inconsistent. As the prototype implementation uses JDBC, it is not very difficult to use a DBMS that *does* implement replication or transactions.

If all three stages are implemented, multiple complete “stacks” (database, DBMS, Dile, and Apache) can be setup on different computers to spread the load. If a DNS round-robin IP assignment mechanism is used, then all machines appear to be the same Internet host; a technique that is also used often for websites of large corporations (e.g. www.microsoft.com). Another technique is to use HTTP-level redirection using the `META REFRESH` tag, which redirects a web client to another (random or least-loaded) web server, so that in the learners’ perceptions there is only one website.

6.6 Review: Inside or Outside?

Section 2.2.2 discussed the question: “should the multimedia objects be stored inside the database (as BLOBs), or outside (as files)?” This question will be reviewed given the experiences while designing and implementing the prototype.

In the current implementation, the multimedia data are stored *inside* database tables to maintain the self-contained nature of the DBMS. This means that the multimedia objects (such as the actual pictures, audio- and video fragments that are part of the learning materials) have to be written to a file before being transmitted across the network by the Apache webserver. We encountered some problems with this approach. Let’s say, for example, that a teacher has prepared an assignment in which the students have to study some MPEG movies that are stored in the database first, then write an essay, and turn in the essay at the end of the month. It is very likely that many students will concurrently access the prepared materials simultaneously, so that one multimedia object may be written to multiple files (say `file1.mpg` and `file2.mpg`: one for each access. Not only does this consume more disk space than needed, it also prevents *WWW caches* from operating properly: the caches will not notice that `file1.mpg` and `file2.mpg` are identical

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[9] The latest versions do support transactions, but this feature was not tested in the prototype.

files, and download both. This defies the purpose of the cache. Similarly if a student accesses the materials twice, the MPEG object may again be stored in two files, which will each be downloaded because the web browser's internal cache will not be able to notice that the two files are identical. Another, although smaller, problem is that it is difficult to determine when these temporary files are no longer needed. The database application has to have a policy for deciding when these files can be safely removed, e.g. when they have not been accessed for one week, or when the original multimedia object that is in the database has been modified (to avoid inconsistencies).

Although these problems illustrate that consistency problems may arise when the self-contained nature of a DBMS is abandoned, it may still be better to store multimedia objects *outside* the database when accessing the database contents through the web. Storing objects in files prevents object-to-file mapping problems, so that WWW cache mechanisms operate as intended, and also avoids the need to copy the database objects into files before they can be transmitted across the WWW.

The aforementioned problems can be solved by making sure that the database application has a 1:1 mapping of multimedia objects onto temporary files, and that there is an appropriate policy to remove unused files.

A better solution, however, is to maintain the self-contained nature of a DBMS, and to require that the DBMS is able to send its multimedia objects *directly* to the web browser without storing it in a file, *and* using a unique and permanent URL for each object. This URL can have the form of http://dbms.host.name/?id= identifier with `identifier` being the unique object identifier of the object within the DBMS. The DBMS has to make sure, however, that only users that have read access to the object are allowed to retrieve the object (for example by using HTTP cookies).

6.7 Conclusions

In this chapter, nine requirements were identified which together, when fulfilled, should yield an architecture of a modular, scalable, extensible, flexible digital learning environment that will allow a teacher to efficiently retrieve learning materials, add his own layout to the content, and make these available to students via the network.

Three implementations allowed us to test and revise the architecture, eventually yielding an architecture that fulfills all of our requirements. While writing the implementations, it became clear that the database-web integration solutions that are currently commonly accepted (such as PHP and ASP) are not consistent with proper system design. Therefore, this thesis has adopted an approach using XML and Java servlets that enables to separate database issues from content layout issues. This leads to a modular software product that is easier to maintain and extend.

The architecture allows for the separation between content and layout of online learning materials. This thesis proposes that this helps to increase the reusability of learning materials: a teacher that dislikes a ULM for its layout, may still be able to reuse it by replacing the layout with his or her own layout.

The question whether to store the objects inside or outside the database was reviewed based on experiences with implementing the architecture. This lead to a requirement for "web-enabled" Database Management Systems: they have be able to disclose their objects via the WWW (i.e. using the HTTP protocol) while retaining the privilege system.

Chapter 7

A Distance Measure for Units of Learning Material

7.1 Introduction

In Section 4.4 a model for the reusability of online learning materials was presented. Reuse is a desirable phenomenon, because it saves the costs of producing (potentially expensive) learning materials. One of the factors that was hypothesized to affect the reusability was the search method: the better the search method, the better a teacher is able to find relevant Units of Learning Materials (ULMs), and the more reuse will occur. For the purpose of organizing the research, Research Question 3 has been formulated: it concerns the possibility to develop a search method based on educational metadata. To address this question, this chapter will propose a *distance measure* that tries to predict the usability of search results to a teacher. Using such a prediction, the teacher should be able to search a database of learning materials effectively, so that the reusability of the learning materials that are stored in the database is increased.

This chapter is structured as follows: first, Section 7.2 will explain how the concept of 'distance' can be seen in relation to educational metadata. The section will explain that the relative importance that teachers assign to characteristics of learning material should be taken into account, so Section 7.3 will present a research effort to investigate this relative importance. This knowledge will be incorporated into a mathematical distance measure in Section 7.4. Section 7.5 will summarize the results of this chapter.

The knowledge obtained in this chapter will be used by the next chapter to construct and validate the distance measure.

7.2 Proximity in Metadata Spaces

Section 5.9 concluded that educational metadata provided a feasible way to implement a search algorithm. However, a problem that may arise is the following: suppose that a teacher is looking for a Unit of Learning Material on a certain subject with moderate interactivity, and approximately 20 minutes to work through. If a search algorithm would try to find a ‘perfect match’, that is a ULM whose metadata fields have exactly the same values as specified by the teacher, then only ULMs whose metadata field indicate that the ULM takes 20 minutes would be returned to the teacher. But ULMs that take 18 minutes, or 24, could also be of use to the teacher. Similarly, if the ULM has more interactivity than ‘moderate’, as specified, then it could again still be a useful ULM. In general, the ‘closer’ the values of the metadata fields of a ULM are to what the teacher has specified, the more useful the ULM is.

There is, however, another reason why it is difficult to implement a search method based on a perfect match: ULMs are entered by different people, who each have their own implicit definitions of ‘interactivity’, ‘difficulty’, and who make their own estimations of the duration of a ULM. Thus, if two persons would fill in the metadata values of a ULM, then it may very well be possible that different results are obtained. So some differences in the values of the metadata fields should be tolerated, because the values are only estimates. This tolerance is translated into the need for a search method that finds imperfect matches, i.e. ULMs that do not precisely match the search specification, but that come *close*. The remainder of this thesis will call the (possibly non existent) ULM that precisely matches the search specification the “ideal ULM”, because this is what the teacher is ultimately looking for.

The following sections present the concept of ‘distance’ in so-called “metadata spaces” to obtain a measure of closeness of a ULM as compared to what a teacher has specified. Using this distance measure, a search method can be developed that is able to find learning objects that ‘match’ or ‘almost match’ the search specification entered by the teacher. The search algorithm that will be developed in this thesis will calculate the closeness (distance) of each ULM to the ideal ULM (the one that would exactly match the search specification). This distance can be used, for example, to return the ten ULMs that are closest to the ideal ULM, sorted in order of increasing distance; or it can present the search results graphically as a cloud of dots centered around the ideal ULM. The teacher can then start examining these ULMs to find out whether ULMs at some distance from the ideal ULM will still fit his goals

7.2.1 Defining distances

Many metadata fields can be seen as some sort of sequence with a certain ordering from ‘none’ to ‘many’, or ‘easy’ to ‘difficuly’, etcetera. This observation can be exploited in building a distance measure. To be able to do this, a mathematical construct is needed to capture the property of values being orderable. This section and Section 7.2.2 will present the mathematical definitions for this concept.

The *metric space* is a suitable, well-known construct from the discipline of discrete mathematics. It is defined as follows:

Definition 7.1 *A metric space*[1] *is a tuple* (X, ρ) *with* X *a set and* ρ *a mapping* $\rho : X \times X \to R$ *so that for all* $x, y, z \in X$*:*

1. $\rho(x, y) \geq 0$ *where* $\rho(x, y) = 0$ *iff* $x = y$
2. $\rho(x, y) = \rho(y, x)$
3. $\rho(x, z) \leq \rho(x, y) + \rho(y, z)$ *(triangle inequality)*

Here, ρ imposes an ordering upon X.

This concept will be used to model a metadata field. Recall Definition 3.1: a metadata field is a tuple (V, t) where V is the set of allowed values and t is the title of the metadata field. So, finding a mapping ρ for the metadata values in V such that conditions 1, 2 and 3 are met implies that the metadata field can be modeled as a metric space, allowing for further mathematical operations to be applied on the metadata field.

Note that only metadata fields on which a ‘semantic’ ordering exists can be incorporated into the distance measure. ‘Semantic ordering’ means that for any two different values a and b from the possible range of values V for the metadata field, it should make sense to write ‘$a > b$’ or ‘$a < b$’. For example, consider the range of values for the difficulty of a ULM. If this range consists of, amongst others, the values `very_difficult` and `a_bit_difficult`, then it would make sense to write that `very_difficult > a_bit_difficult`: a ULM that has a label `very_difficult` is *more* difficult than a ULM that has a label `a_bit_difficult`. Consider the range of values for first names, then it would not make sense to write, for example, that `Peter > Mark` in a semantical sense, although lexicographically this is true. So the range of difficulty-values is considered ‘semantically orderable’ in this thesis, while the range of surnames is not. From this it can be derived that if a metadata field is semantically orderable,

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[1] Introduced by Hausdorff (1869-1942)

then it can be modeled using a metric space; and if a metadata field is not orderable, then it cannot be modeled using a metric space.

One metadata field (e.g. "difficulty") is modeled using metric space. But how to model a metadata-set of a ULM with n fields? This can be done by combining n metadata fields in a *vector*, so that u_i for $i = 1..n$ gives the value of metadata field i of ULM u.

But what is ρ? It is an operator that models the ordering upon the n-dimensional metadata space X. There are a number of definitions of ρ on spaces with n dimensions which fulfill the three demands mentioned in Definition 7.1 (Rudin, 1953):

Definition 7.2 *The Euclidean distance (or L_2) between two points x, y is defined as*

$$\rho(x, y) = \sqrt{(x_1 - y_1)^2 + (x_2 - y_2)^2 + \ldots + (x_n - y_n)^2}$$

Definition 7.3 *The Taxicab distance (or L_1) between two points x, y is defined as*

$$\rho(x, y) = |(x_1 - y_1) + (x_2 - y_2) + \ldots + (x_n - y_n)|$$

Definition 7.4 *The L_∞ distance between two points x, y is defined as*

$$\rho(p, q) = max[(x_1 - y_1), (x_2 - y_2), \ldots, (x_n - y_n)]$$

The Euclidean distance requires a minus operator on the set of metadata values X, which we will define next (for examples, see the next section). The minus operator $x - y$, with $x, y \in X$ can be defined by sorting the elements x of X in increasing order, based on ρ. If the sorted list of elements is numbered so that each element x is given a rank number $r(x)$, then the minus operator on a, b can then be defined as the number difference $r(a) - r(b)$ between the position numbers of a and b:

Definition 7.5 *The* rank number $r(x)$ *of a metadata value x from metadata set X is the position of value x in a certain fixed ordering imposed on metadata set X.*

Definition 7.6 *The* minus *operator (notation: $-$) is a function $X \times X \rightarrow R$ that is defined as follows: $a - b = r(a) - r(b)$ with $a, b \in X$.*

Using this definition of the minus, the terms $x_i - y_i$ that are used in the three distance definitions given above can now properly be calculated, so that in principle the three distance functions are well defined.

However, there is still a problem that needs to be solved: a difference of one rank position does not necessarily have the same impact on all dimensions. This problem is solved in the next section.

7.2.2 Normalization

It should be noted that the metadata fields can count a different number of values. The range of possible distances in a metric space (recall from Section 7.2.1 that there is one metric 'space' for each metadata field) therefor also varies between metadata fields: a field A with 5 values has distances ranging from 0 to 4, while a metadata field B with 10 values has distances ranging from 0 to 9. These distances on the individual dimensions are combined into one distance measure in a multidimensional space using formulas such as the Euclidean distance (see Definition 7.2). But then, the distances in metadata field B would have a greater impact on the total distance than the distances in field A. So, to give each metadata field the same weight they should be *normalized*: the distances in each individual dimension should range from 0 to 1. This can be accomplished as follows. Let V be a set of metadata values that can be ordered, and let ρ_V be the distance function that belongs to this set. Let $|V|$ be the cardinality[2] of V. Then the normalized metric distance between two values $x, y \in V$ is defined as:

$$\rho_V(x, y) = \frac{|r(x) - r(y)|}{|V|}$$

with r(x) the rank number of x (see Definition 7.5).

For proof that ρ_V is a *distance* and as such exhibits the three properties given in Definition 7.1 the reader is referred to Appendix E.

7.2.3 Selection

In Section 7.2.1, three distances were defined: the Euclidean, Taxicab, and L_∞ (pronounced "el infinity") distance. But not all three of these are suitable as a distance for the intended goal of comparing educational materials: the L_∞ distance only takes into account the dimension with the highest difference, ignoring the other dimensions. However, a distance measure that ignores dimensions also ignores certain choices that teachers have indicated for learning material. This is not desirable, because the teacher did not make these choices for nothing; these choices have to make some difference. For this reason, the L_∞ distance will not be considered further.

7.2.4 Example

Consider the following metadata field called 'difficulty' as defined in Table 7.1.

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[2] Recall from set theory that the cardinality of a set is the number of elements in that set.

Table 7.1: An example metadata field and the use of the rank r(x) function.

code	label	rank r(x)
D_a	very easy	0
D_b	easy	1
D_c	average	2
D_d	a bit difficult	3
D_e	difficult	4
D_f	very difficult	5
D_g	extremely difficult	6

The ‘code’ is a short way of writing the label; so instead of writing ‘a bit difficult’ each time in mathematical formulas, this thesis will just write ’D_d’. This metadata field has seven values, so the normalized metric distance between two values x and y in the ‘difficulty’ dimension is $(r(x) - r(y))/7$.

Another metadata field called “educational level” can be introduced; see Table 7.2, describing the educational level a unit of learning material was designed for. This metadata field has 6 values, so that the normalized metric distance between two values x and y in this dimension is $(r(x) - r(y))/6$.

Table 7.2: Another example metadata field and its rank r(x) function.

code	label	rank r(x)
L_a	elementary school	0
L_b	high school	1
L_c	university first year	2
L_d	university second and third year	3
L_e	university graduate level	4
L_f	postgraduate level	5

The distance between two Units of Learning Material can be calculated as follows: assume that ULM u has been designed for university first year students (L_c), and that it is fairly difficult (D_e). The rank numbers for ‘difficulty’ and ‘educational level’ are 4 and 2 respectively. ULM v has been designed for graduate students (L_e), and is just a bit difficult (D_d). Its rank numbers are 3 for difficulty and 4 for educational level. The L_2 distance can then be calculated as follows:

$$\rho_2(y, v) = \sqrt{(u_1 - v_1)^2 + (u_2 - v_2)^2} =$$

$$= \sqrt{\left(\frac{D_e - D_d}{|D|}\right)^2 + \left(\frac{L_c - L_e}{|L|}\right)^2} =$$

$$= \sqrt{\left(\frac{r(D_e) - r(D_d)}{7}\right)^2 + \left(\frac{r(L_c) - r(L_e)}{6}\right)^2} =$$

$$= \sqrt{\left(\frac{3-4}{7}\right)^2 + \left(\frac{2-4}{6}\right)^2} \approx \sqrt{0.1429^2 + 0.3333^2} \approx 0.132$$

Similarly, the L_1 distance can be calculated.

7.2.5 Graphical represenation

To get a better feeling for how the remaining two distances work, they will be examined graphically. The Taxicab distance looks as depicted in Figure 7.1: two ULMs, u and v are represented as vectors in a two-dimensional space. The taxicab distance is the length of difference between u and v projected on the x-axis (distance d1) plus the distance between u and v projected on the Y axis (distance d2). So the Taxicab distance equals to the sum of the length of d1 and d2, indicated by the dotted line. The 'corner' of 90 degrees explains the name of the Taxicab distance, that is, if the reader is familiar with the blocked pattern of American cities. This explains why the Taxicab distance is sometimes called 'Cityblock distance'.

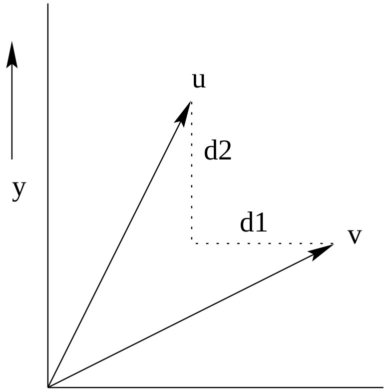

Figure 7.1: The Taxicab distance between ULM u and ULM v

In Figure 7.2, the Euclidean distance is depicted. This is the definition of ‘distance’ that is used in everyday life, for example to calculate the distance between two locations on a map. The distance ’d’ is found graphically by drawing a straight line from u to v and measuring its length.

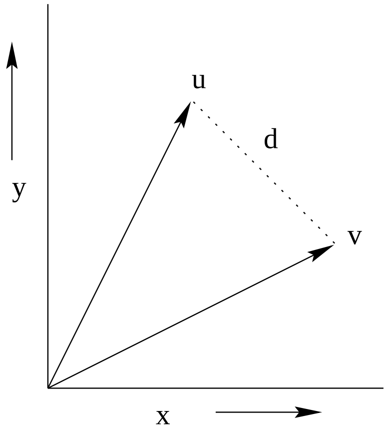

Figure 7.2: The Euclidean distance between ULM u and ULM v

Of these two distance definitions, the Taxicab distance intuitively seems to be the best choice, because it represents the sum of the differences on each characteristic (see Definition 7.3). The Euclidean distance, on the other hand, seems to be more consistent with the concept of ‘distance in a space’, because it allows one to follow a straight line through the space, which is shorter than taking a ‘corner’ as the Taxicab distance does (see Figure 7.1). For the remainder of this thesis, we will therefor consider both definitions to be a candidate for building a distance measure in a metadata space upon.

To provide some more insight into how a multi-dimensional metadata space looks like, Figure 7.3 depicts a three-dimensional space whose dimensions consist of characteristics of learning material: educational level, interactivity, and duration. The arrow represents a vector in this space, pointing to a metadata record with value “little” for interactivity, “15” for duration, and “university graduate” for educational level. Along with the dimensions, the rank numbers for the metadata values are shown. Note that the “duration” dimension does not need a rank number, as the number of minutes that the ULM lasts can serve itself as a rank number.

There are, however, three problems with the theory explained above:

Problem 1 Teachers may find certain characteristics (dimensions) more important than others. These dimensions should be “weighted” more than others;

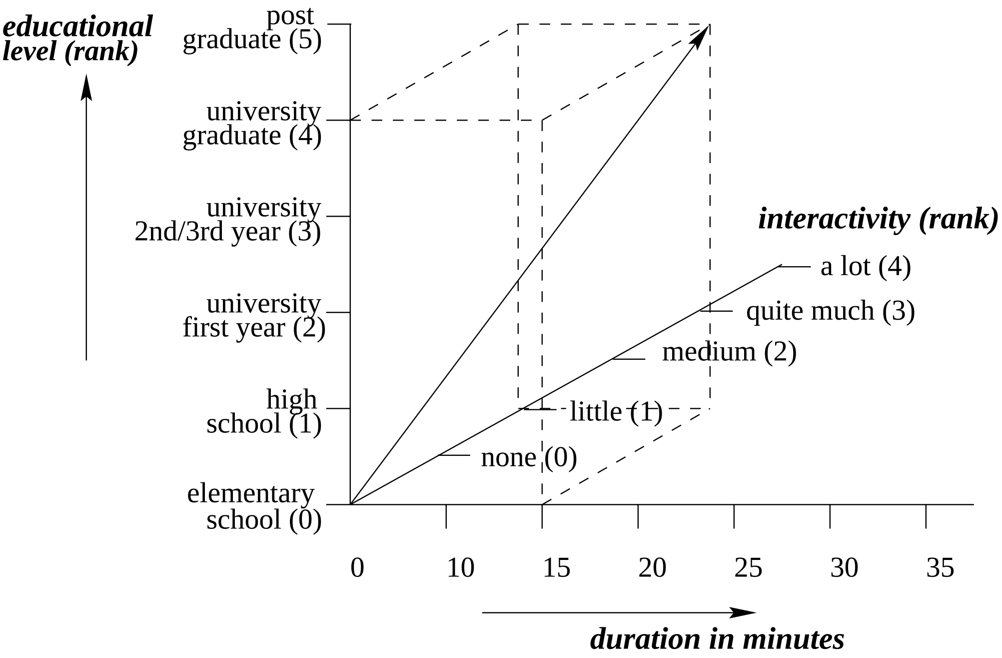

Figure 7.3: A multidimensional space of metrics, based on metadata fields

Problem 2 Some dimensions have an infinite number of values, such as “duration” and “size”: theoretically, any duration or size is possible. This thesis will avoid this problem by assuming that there are practical bounds to these fields, so that the dimension counts a limited number of values so that it can also be normalized.

Problem 3 Some metadata fields allow more than one value to be assigned; for example, the “educational level” dimension can have the values “fourth grade” and “sixth grade”; however, the range-index function ρ is only defined on one value. To solve this problem, a new ρ' could be defined that calculates the average of the individual rank indices of all values. In the remainder of this thesis, metadata fields with more than one value are avoided so that this problem can be safely ignored.

Problem 2 and 3 can be avoided; so the remainder of this chapter is about solving problem 1: how to deal with the relative importance (weight) that teachers assign to characteristics (metadata fields) of learning material? The next section will clarify the problem, while Section 7.3 will describe a research effort to learn more about how teachers deal with characteristics of metadata fields.

7.2.6 The teacher and the distance measure

A search interface could make use of the distance measure by providing a fill-in form to the teacher in which he or she can enter desired values for metadata fields; such as: ‘a lot of interactivity’, ‘designed for second-year university students’, ‘a bit difficult’. To indicate the subject, keywords would be used. The search algorithm would then try to find those ULMs that best match this search specification. There may be ULMs that have only a bit interactivity, or that are too difficult. The distance measure as has been presented in the previous sections, however, has no way of knowing what is more important: the interactivity, or the difficulty. If the teacher finds interactivity very important, then the distance measure could try to put some more ‘weight’ on that characteristic. Characteristics that are less important, for example the size in kilobytes of the ULM, can tolerate more deviations than characteristics[3] that are very important. So trying to predict how ‘close’ a search result is to the teacher’s ideal ULM depends on *how important the teacher thinks interactivity is*. However, the previous section implicitly assumed that all metadata fields are equally important. The Taxicab and the Euclidean distance measure do

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[3] Note that the term ‘characteristic’ is used to denote common characteristics of learning material; the term ‘metadata field’ is only used if specific properties of the concept of a ‘metadata field’ are needed. Here, a ‘metadata field’ is a *mechanism* to store ‘characteristics’ into a database.

not take the relative importance into account, so that each dimension (characteristic) is weighted equally. This thesis proposes that the distance measure can be improved (i.e. is able to predict the usability of a ULM better) if it would take the relative importance that teachers assign to characteristics into account. But what is the nature of this importance? Is it a constant, or does it depend on 'environmental' factors such as the educational context? A context that demands practical material, could cause a teacher to find interactivity more important. Another factor could be the teacher him- or herself, or better, the teacher's own 'belief system': some teachers like to include a lot of hands-on experience in their classes, while other teachers find that less important. These preferences may lead to certain preferences for characeristics of online learning materials (i.e. for certain metadata fields). If it would be possible to discover the teacher's belief system, then perhaps it is also possible to predict what characteristics the teacher prefers. And as the teacher's belief system changes only very slowly, this would only have to be measured once, or at least not very often.

So, two factors are proposed that could have an impact on the teachers' preferences for characteristics of learning material: (1) the educational context, and (2) the teachers' belief system. The next section will present results of an investigation targeted at finding the influence that these factors have on the teachers' preferences. Insight in the nature of these influences provide answers to the question whether the teachers' preferences are dynamic or static; this will have a great impact on the way the 'weights' of the various dimensions of the distance measure will be implemented.

7.3 The relative importance of metadata fields

This section will describe a research to factors that influence the teachers' preference for characteristics of learning material. The previous section hypothesized that this preference depends on two factors: (1) the educational context, and (2) the teacher's belief system. Section 7.3.1 will first discuss a literature review on teacher's conceptions on teaching to find a suitable model. Using this model, two research questions are formulated in Section 7.3.2. Then, Section 7.3.3 will verify these hypotheses by developing an instrument to measure the teacher's belief system and the teacher's preferences for characteristics of learning materials in various educational situations. Section 7.3.4 will discuss how the sample population was chosen, after which Section 7.3.5 will present the results of the survey. Finally, Section 7.3.6 will discuss the findings and draw conclusions upon the research results.

7.3.1 Teachers' Conceptions of teaching

Theoretically, a teacher's conceptions of teaching would reflect the teacher education he (or she) has enjoyed, both in theory and in practice. However, in reality it seems that teachers base their belief system upon their daily experiences, both during their own training and their classes. Kagan (1992) reviewed a large body of research literature and found that the personal beliefs of preservice teachers changed during their professional formation.

There have been several research efforts to determine aspects of teacher belief and to measure them, many utilizing different research methodologies. According to Kagan (1990), the concept of "teachers' conceptions" itself is too ambiguous to provide a coherent set of research results. Furthermore, conceptions are often held unconsciously by the teachers, making it difficult to measure them: time consuming methods have to be used to elicit and assess thoughts. These time constraints force many researchers to limit the size of the subject population, so that the results may not be very generalizable, and so that statistical methods are hard to use due to a limited data set.

Yet, Samuelowicz and Bain (1992) succeeded in analyzing academic teachers' conceptions of teaching. They synthesized a framework consisting of five dimensions, which are relatively consistent with other research results on teacher belief (Proser, Trigwell, & Tayler, 1994; Gow & Kember, 1993). To describe a conception of teaching, one value is chosen on each of the five dimensions. On each dimension, three 'values' are possible: two extremes A and B, and a value AB 'in the middle' which means "both A and B". The dimensions and their values are:[4]

Learning Outcome (LO) The expected outcome of the learning process. This dimension ranges from (A) "after the learning process, students know *more* than before the learning process" to (B) "after the learning process, students' knowledge has *changed* rather than increased".

Nature of Knowledge (NK) the nature of the knowledge to be learned, which ranges from (A) *knowing just the subject matter* without links to reality, to (B) being able to *relate* the subject matter to reality.

Students' Conceptions (SC) The degree to which the teacher takes the conceptions the students have on the subject matter into account. "Not taken into account" is coded as A, while "taken into account" is coded as B.

Bidirectionality (BI) The degree of bidirectionality that the teacher finds is most appropriate: none (teaching is unidirectional, i.e. transmitting knowledge,

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[4] The dimensions have been renamed to make it easier to define a continuous scale; refer to the original paper for the original names.

which is coded as A) or a lot (teaching is bidirectional, e.g. engaging in a conversation with the students, which is coded as B).

Content Control (CC) The amount of control students have over the content of teaching. This variable is given the code A when students have no control over the content, while value B is assigned to the variable when students to have control over the content.

Samuelowicz and Bain (1992) use these five dimensions as “building blocks” for five conceptions of teaching. As an example, they explain how the conception “teaching is transmitting knowledge” can be built up using the five dimensions as shown in Table 7.3:

Table 7.3: Example of how a teaching conception can be built up using the five dimensions of Samuelowicz and Bain.

dimension	value	meaning
Learning Outcome	AB	both to know more, or differently
Nature of Knowledge	A	bound by the curriculum
Students’ Conceptions	A	not taken into account
Bidirectionality	AB	education is sometimes bidirectional
Content Control	A	teacher is in control of the content

This way, many conceptions can be analyzed and described by five values; one for each of these five dimensions. Theoretically, the five dimensions (with each three values) can describe $3^5 = 243$ possible conceptions. Of course, not all conceptions make sense in the real world, but still the dimensions are more powerful than other methods that describe *individual* conceptions of teaching found by other researchers (Proser et al., 1994; Gow & Kember, 1993). These methods describe a fixed number of conceptions, usually less than 10. The behavior of a teacher can then only be described using one of this limited number of conceptions, yielding a very coarse categorization. The model of Bain and Samuelowicz, however, allows a much finer categorization, as there are theoretically 243 conceptions; so there are more conceptions with enables a more accurate description of the teacherss conceptions of teaching. This model was therefor chosen as the basis of the current research.

7.3.2 The research questions

Having decided how the teacher’s conceptions can be modeled in the previous section, this section first recalls why such a model is needed. After having presented the concept of a metadata space in Section 7.2, Section 7.2.6 noted that the *importance* that teachers assign to characteristics of learning material (i.e. metadata fields) could improve the distance measure. Two factors were hypothesized to influence this importance: (1) the teacher's conceptions on teaching, and (2) the educational context. The model of Samuelowicz and Bain makes it possible to develop an instrument that measures the teacher's conceptions by assigning values A, B or AB on each of five "dimensions" that can be formulated into questions. The "Content Control" dimension, for example, can be formulated as: *who is most often in control of the content of teaching, the teacher or the student?* Depending on the answer, one of the three values can be assigned. Doing this for all five dimensions yields a 'pattern' of A, B and AB values that described the teacher's conceptions of teaching. This thesis will call such a value for one dimension the 'position' of a teacher on that dimension.

Having obtaind values for the five dimensions, correlations can be calculated between the position of a teacher on a dimension and the preference for certain characteristics of learning material.

The following research question can then be formulated:

> **RQ 7.1** Does the importance teachers assign to characteristics of learning material depend on their position on one or more of the dimensions of conceptions of teaching as modeled by Samuelowicz and Bain?

The second factor is the educational context in which the teacher is performing. For example, if the target group of learners does not have sufficient self-management capabilities such that they can work through large assignments unattended, then they may need other pedagogical material. The teacher will then find the *pedagogical* aspects of learning material of particular interest. Or, if the teacher wants to find extra assignments for fast students, then the subject matter may be considered less important, while the difficulty of the learning material must be relatively high to make sure the fast students will not become bored. If the educational context is *not* of influence to *any* of the contexts, then one distance measure is appropriate for all contexts. If, on the other hand, the educational context *is* of influence to the importance that teachers assign to one or more characteristics of learning material, then the distance measure will depend on the educational context. This means that the educational context has to be taken into account by the distance measure, so it is important to know the effect of the educational context on how important teachers find characteristics of learning material. This leads to the second research question:

> **RQ 7.2** Does the importance a teacher assigns to one or more charac-

teristics of learning material depend on one or more educational contexts?

The next section will develop an instrument that will be used to find answers to these two questions.

7.3.3 Instrument

This section will develop an instrument to measure two properties: (1) the teacher's conception, and (2) the teacher's preferences for characteristics of learning material in a certain educational context. First, both the dimensions of Samuelowicz and Bain as well as the characteristics of learning material that will be measured, will be defined properly. Then, the instrument to do these measurements will be discussed, including the pilot test and formative evaluation.

Types of research efforts

A suitable research method to answer the two research questions mentioned in the previous section has to be found. Charles (1988)[p. 7 to p. 14] identifies six types of educational research:

1. *Historical research*, which describes and attempts to explain conditions, situations, and events in the past. Sources of data are people, documents, and objects as they were in the past, and traces of these three sources if nothing more than just traces can be found.

2. *Descriptive research*, which describes conditions, situations, and events of the present using data obtained from people, documents, and objects as they are in the present.

3. *Correlational research*, which attempts to find relationships between certain conditions or events ("variables"). Often the objective of this type of research is to predict behavior or processes, based on these relationships. The data are obtained by measuring the variables to be correlated on each subject, and then calculating the *correlation coefficient* which is an indication of how much the variables are related to each other.

4. *Causal-comparitive research*, which tries to find causes for phenomena by comparing possible causes, and selecting those that seem to "cause" certain effects. It is especially used in situations where the person, object, or event that is the subject of the study cannot be changed.

5. *Experimental research*, which also tries to find cause-effect relationships by manipulating the subject of the study and examining the results of that change.

6. *Research and Development*, which focusses on the development and evaluation of a new product (physical or conceptual)

The research questions talk about concepts such as “importance that teachers assign to characteristics”, and “conceptions of teaching”. These are properties of human beings that can be measured. Furthermore, the research questions concern the supposed existence of *dependencies* between these concepts. As the “correlational research” method attempts to find relationships (dependencies) between certain conditions (properties of human beings), this research method is the most suitable one for the current research.

The following three paragraphs will operationalize the three properties that are to be measured in the current research: the dimensions of teaching, the importance that teachers assign to characteristics of learning material, and the educational contexts.

Redefining the five dimensions

As explained in Section 7.3.1, in the model of Samuelowicz and Bain three ‘values’ are possible on each dimension: A, B, and AB. Here, the code AB means “both A and B” which corresponds to a teacher saying, for example, “Sometimes I do take the students’ conceptions into account, and sometimes I don’t”. However, this defies the concept of a ‘dimension’: a certain position on a dimension can only be described by *one* value; compare this to a position on a ruler: only *one* value (e.g. 5.4 cm) belongs to that position. It is not possible to find a location on the ruler to which *two* values belong. Similarly, only *one* value, either A or B, should be allowed for each dimension. The combination AB of Samuelowicz and Bain will be interpreted by this thesis as a position somewhere *between* A and B, see Figure 7.4. So instead of interpreting AB as “both A and B”, this thesis will interpret it as “neither A nor B” which corresponds to saying “I don’t ignore the students’ conceptions, but I also don’t take them *always* into account”. So, the different interpretation that this thesis assigns to the ‘value’ AB does not significantly change the meaning of the values on the dimensions.

The dimensions are therefor interpreted in this thesis as having a *continuous* scale[5]. The range of this scale was chosen to be from 0 to 10 which corresponds to the Dutch grading system. This would make it easier for the researchers to verify the scores of the test subjects on the dimensions.

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[5] This means that variables on this scale can take any value from the set of real numbers R.

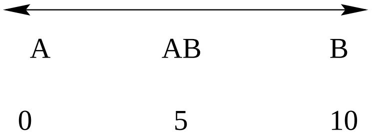

Figure 7.4: A dimension with two extreme values: A and B

Below, we will give a new formal definition of the dimensions. This section will describe later how these dimensions can be measured.

SC Students' Conceptions type: a variable on this dimension takes the value '0' if the teacher, when taking educational decisions, does not take into account what the students' conceptions are. A variable takes the value '10' if the teacher *does* take these conceptions fully into account.

CC Content Control: a variable on this dimension is '0' if the students have no control whatsoever on the content of the courses. The variable is '10' if the students really have much freedom in determining their own course content.

NK Nature of Knowledge: a variable on this dimension is '0' if the nature of the knowledge to be taught is very theoretical and no relation with practice are shown by the teacher. The variable is '10' if the knowledge as it is taught by the teacher has a very strong relationship with practice.

LO Learning Outcome: a variable on this dimension takes the value '0' if the teacher has the opinion that the goal of learning is to know *more* (i.e. to learn new knowledge), and '10' if the teacher finds that the goal is to know *differently* (i.e. to obtain a deeper and richer understanding of existing knowledge).

BI Bidirectionality: the extend to which a teacher thinks that education is a two-way process (value '10'); a teacher that thinks that education means primarily a one-way transfer of knowledge is assigned value '0' on this dimension.

Characteristics of learning material

Research Question 7.1 is about the importance that teachers assign to characteristics of learning material. What characteristics are these? For finding suitable characteristics of learning material, the IEEE Metadata set (see Appendix C.3) was analyzed. In this metadata set, learning objects are characterized by many metadata fields. However, only those characteristics that were expected to be the most important ones to a teacher when making decisions about choosing online learning material, and that would be easy to understand by the teachers were selected. As the teachers have to indicate which characteristic is more important to them than others, only a small number of characteristics was used; otherwise, the task would become too difficult to the teachers. The five characteristics that were selected are listed in Table 7.4.

Table 7.4: The five characteristics of learning material that have been selected for the experiment.

characteristic	description
subject	the subject of the Unit of Learning Material
pedagogical function	the pedagogical function of the material, such as exercise, theory, test, example
educational level	the educational level for which the learning material was originally designed, such as primary or secondary education, freshmen, or graduate student level
duration	the time a typical learner needs to work through the Unit of Learning Material (ULM)
amount of interactivity	of the ULM (i.e. is it “lean back and watch” material with no interactivity, or does the learner have to interact with the ULM such as a simulation?)

The educational contexts

Research Question RQ 7.2 is about finding out whether the preference of teachers for characteristics of learning material depends on the *educational context*, that is: *educational aspects of the situation that the teacher is in when he or she will want to consult a database of learning materials*. As the purpose of the research question is to test whether the preferences of teachers for certain characteristics is rather constant or not, the contexts should be chosen from several *extremes*. If the preferences of the teachers are found not to vary in ‘extreme’ contexts, then they can be expected to also not vary in milder contexts. So the first requirement to the contexts is that they should reflect very different situations.

As the purpose of the contexts is to describe a situation in which a teacher would feel the need to consults a database of learning materials, the second requirement was stated: the contexts should describe a *need* for specific learning material. The teacher should be able to translate the need for this specific learning material into characteristics of learning material. So the contexts should ‘drive’ the teachers into a specific direction on one or more of the five chosen characteristics (see Table 7.4), so that it can be tested whether the teacher’s preference for characteristics really varies between contexts.

So the contexts were varied by describing a *need* for learning materials from different angles: a need for extra material, very practical or theoretical material, or material for a specific target group. Of course many more combinations are possible, and it is difficult to say which ones are better than others. In fact, as long as the requirement of “describing a need for specific material with respect to one or more of the five characteristics” is met, the context is suited for this research.

Six contexts were created which described a need for the following material:

1. additional highly practical material for senior students;

2. introductory material for laboratory exercises;

3. all materials that could be suitable to put online for a specific course (i.e. a very broad need);

4. additional material to keep clever students working;

5. additional theoretical material for junior students;

6. interactive material for senior students.

It was expected that the teachers’ preferences for, for example, the characteristic ‘educational level’ will vary between these contexts: in context 5, material for *junior* is explicitly needed, so the teachers were expected to find the characteristic ‘educational level’ important in this context. In context 2, however, the educational level is of less importance; here, the characteristic ‘interactivity’ was expected to be found more important by the teachers. Similarly, the other contexts also drive the teachers into a specific ‘direction’ with respect to one or more characteristics of learning material. The full text of the context descriptions that were used can be found back in part C of the questionnaire that is printed in full in Appendix B (Dutch). An english translation is provided at the end of the appendix.

Questionnaire

The previous paragraphs explained three concepts that are to be measured: the teachers’ conceptions of teaching, the characteristics of learning material, and the educational contexts. This paragraph will discuss the questionnaire that was designed to measure these concepts. The questionnaire consists of three parts. Below, we will discuss how these three parts served to measure the two variables: teachers' conceptions on teaching and the teachers' preference for characteristics of learning material in different educational contexts.

The first part (A) contains general (demographical) questions such as age, years of experience in education, years of experience with computers. These data were obtained to get an impression of the target group, and to be able to discover differences between subgroups if necessary.

The second part (B) was designed to measure the teachers' position relative to the five dimensions of Samuelowicz and Bain. This is done in two ways: first, six multiple-choice questions were posed to measure the position of a teacher on a dimension *indirectly* (these questions were numbered "B1" to "B6" in the final version, see Appendix B). The teachers were presented with a case description, such as: *Suppose that your students are able to reproduce and apply all aspects contained in the subject matter. Does this mean that your goals as a teacher are reached?*. Then, the teachers were given several possible answers, such as *No, the knowledge and insights of the students can perhaps be broadened or deepend*. For each answer, a score on the dimension that the question tried to measure, was assigned on a scale from 0 to 10 by two researchers independently to avoid subjectivity, and then the averages of these two sets of scores was calculated. If there was a difference of more than three points, then the researchers discussed their opinions on the matter, and after having exchanged interpretations a score that both researchers agreed upon was determined.

Next, proposition-based attitude questions are used to measure the position of a teacher on one of the five dimensions *directly* by posing attitude questions. Each question measured the position of a teacher on one dimension. The subjects were asked to indicate inhowfar they agreed with the proposition described in the question using a 5-point Likert scale. These questions are numbered "B7.1" to "B7.24" in the final version (see Appendix B). To avoid bias, some questions were formulated so that the more subjects agreed, the higher their score on the question's dimension would be, while the other questions were formulated in a negative form so that the more subjects agreed, the *lower* their score on the dimension would be.

The results on both types of questions will be used to cross-validate the results of this part of the survey.

Finally, the third part (C) of the questionnaire contains six educational contexts in which a need for learning material is described. For each educational context, the teacher is asked to rank five characteristics of learning material from most important to least important. The characteristic ranked most important receives score '5', the next important one score '4', and so on so that the least important characteristic receives score ’1’.

Validity

According to Tuckman (1994), the validity of an instrument is the extent to which the instrument measures what it purports to measure. Four types of validity can be identified (p. 182 and 183):

1. *Predictive validity*: the extent to which the outcomes of a test are able to predict a certain related behavior; for example, students that are slow learners can be expected to pass less courses per year. The validity of a test that measures the ‘slowness’ of a student can be established by relating the slowness of a student to the number of courses he or she passed this year.

2. *Concurrent validity*: the extent to which the outcomes of a test are comparable to other (known valid) tests; for example, many versions of IQ tests are already available. The concurrent validity of a new test could be established by trying to relate its outcomes with the outcomes of an IQ test that is known to be valid.

3. *Construct validity*: the extent to which the outcomes of a test that measure a construct (or concept) can be related to *known* effects of that construct; for example, teachers that find that the outcome of the learning process is “to know differently” (see variable LO above) can be expected to often engage students into a discussion about the subject matter. A relation between LO and the number of times a teacher engages students into a discussion will then prove construct validity of the test.

4. *Content validity*: the extent to which the sample situations in which the test is performed represent all situations in which the behavior could be observed. For example, a test for a certain course should be representative for all topics covered in the course.

Establishing predictive validity would mean that a new test would have to be developed to measure a related behavior. For example, to prove predictive validity of the dimension ‘bidirectionality’, the number of times a teacher interacts with a student during a lecture could be counted and related to the score of the teacher on this dimension. The precise definition of what type of events count as ‘interaction with the student’ would have to be defined, and then a number of lectures would have to be observed. This kind of time-consuming research, however, is out of scope of the current research.

To prove concurrent validity, a known valid test for measuring the scores of the teachers on the five dimensions would have to be used. The research of Samuelowicz and Bain (1992) does not provide such a test, because their goal was to explore the teachers' conceptions and after that *synthesize* (as opposed to measuring) a framework of dimensions. Therefor, the current research tried to prove concurrent validity by using two different test types concurrently: one using case-based questions, and one using attitude questions.

There is a second way in which concurrent validity was established: during the pilot test, the results of the questionnaire were compared to the researchers' own interpretation of the teachers' conceptions of teaching, measured on the five dimensions of Samuelowicz and Bain (see the next paragraph). The researchers' interpretation of the teachers' conceptions can be seen as a 'known valid test' to which the instrument's results were compared, so that concurrent validity could be tested (and improved).

The case-based questions in part B tried to measure the score of a teacher on a dimension *indirectly*, by measuring the behavior of a teacher in a hypothetical situation. A list of possible behaviors was provided from which the teacher could choose. This thesis assumed that a teacher that scored high on a dimension D would expose a certain behavior and choose for a certain answer. This answer would thus be assigned a high score on dimension D. It can be stated that the answers were based on certain assumed *relationships* between the score of a teacher on a dimension and certain behavior exposed by the teacher, which conforms to the definition of construct validity.

Content validity could not be established because it is difficult if not impossible to assess the behavior of the teachers in 'all situations possible'.

So, to summarize: two types of validity could be established: concurrent validity and construct validity. The other two types of validity could neither be proven nor disproven.

Pilot test

The first version of the questionnaire was tested for comprehensiveness and interpretation problems in two rounds.

The first round took place during January 1999, with three fellow researchers as test subjects. It was found that the variable about Students' Conceptions ('SC') covered too many different notions, causing the pilot persons to have difficulties in answering questions about it. Therefor, this variable was split up into three subvariables: conceptions on the subject matter, conceptions on the teaching process, and conceptions on society and the world; these variables also have a *continuous* scale, which means that any value between 0 and 10 is possible. The three subvariables are then defined as follows:

SCa Students' Conceptions type 'a': a variable on this dimension takes the value '0' if the teacher, when taking educational decisions, does not take into account what the students' conceptions are regarding the subject matter. A variable takes the value '10' if the teacher *does* take these conceptions fully into account.

SCb Students' Conceptions type 'b': a variable on this dimension is '0' if the teacher does not take into account what the students' conceptions are regarding the educational processes they see happening at their institution; the variable will take the value '10' if the teacher does take these conceptions fully into account.

SCc Students' Conceptions type 'c': a variable on this dimension is '0' if the teacher does not take into account what the students' conceptions are regarding the society around them. The variable will be '10' if the teacher does take these conceptions into account.

These three variables (SCa, SCb, SCc) and the other four variables described previously (CC, NK, LO and BI) will together be called the "seven variables" in the remainder of this thesis.

After the questionnaire was revised, it was tested in a second round during February 1999 using five test subjects (colleagues with a lot of teaching experience). Their teaching behavior was determined beforehand in terms of their position on each of the seven dimensions by the two researchers (Van der Peet[6] and Hiddink) and written down; for example, a test subject could score "high" on the dimension "bidirectionality of the education". The test subject was then asked to think aloud while filling in the questionnaire, and one of the researchers (who was present in the room) annotated the scores of the test subject. These annotated scores were immediately compared with the scores that were determined beforehand. If there was a conflict, for example if the subject scored "2" on the dimension "bidirectionality of the education" while the teacher was expected to score "high" on this dimension, then the researcher tried to find the cause of the conflict by engaging in a conversation with the test subject to find out why the test subject choose his answers. Using this method, some questions were found to have interpretation problems, which were solved in the next revision of the questionnaire. The concurrent validity of the instrument was also ensured using this method.

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[6] George van der Peet assisted in creating the questionnaire as a part of a course on doing educational research.

In the initial versions of the questionnaire, it was attempted to have one case-based question for each dimension, and about four attitude questions per dimension. However, the questionnaire evolved through many informal discussion rounds and the two pilot test rounds. Some questions had been dropped, some turned out to be better suited to measure another of the seven variables than they were originally designed for, and some questions were added. The criteria on which these decisions were based, are a combination of a lot of different considerations based on questionnaire design principles, and creativity involved in such a design process. It would be too laborious to document all of these (mostly implicitly made) considerations here. Instead, table 7.5 illustrates how many questions for each variable remained in the final version of the questionnaire after the pilot test; the final version is given in Appendix B.

Table 7.5: The seven variables and the number and type of questions that measure them.

Variable	case-based	attitude
SCa	1	3
SCb	1	2
SCc	1	2
CC	2	2
NK	2	3
BI	0	5
LO	1	7
total	8	24

After these preparations and revisions, an instrument was obtained that was believed to have sufficient validity to use for gathering data. Further validity tests will be done on the basis of the empirical data.

7.3.4 Experiment

In the previous section, an instrument was developed and tested to measure the teachers' conceptions on teaching using seven variables as well as the teachers' preferences for characteristics of learning material in six different educational contexts. Also, ways to ensure the validity of the instrument were described. This section will describe how this instrument was deployed.

A sample of the teachers of the University of Twente was selected randomly from the university's Course Guide by selecting the teacher of the first course that was mentioned on each page. If that person was a teacher that had been involved in the formative testing of the questionnaire, then the next teacher on the same page was selected. This process yielded 196 subjects.

All subjects were contacted by phone during March and April 1999 to ask whether they were willing to participate in the research. A paper copy of the final version of the questionnaire was sent to those who agreed. Several teachers asked whether they could fill in the questionnaire through the World Wide Web. This option has been made available; the paper copy of the questionnaire that is sent to each participant mentions this possibility but leaves the choice to the subject.

7.3.5 Results

This section will describe the results of the experiment. First, the number and nature of the respondents is analyzed. Then, after standardizing the scores on the seven variables, the concurrent validity and the reliability of the data are assessed to get an impression of the quality of the data. After that, an analysis of the educational contexts is conducted to answer RQ 7.2: are there significant differences between the contexts? An answer to this question is needed for properly analysing the data to answer RQ 7.1: are the teachers' preferences for characteristics of learning material related to the teachers' conceptions of teaching? This analysis will be done by correlating the teachers' scores on the seven variables (dimensions of conceptions of teaching) with the teachers' ranking of characteristics of learning materials.

Respondents

Of the 196 selected teachers, only 86 could be reached by phone (44%) within about three tries. Of these 86 teachers, 71 (83%) were willing to participate in the research. These 71 teachers were sent a paper copy, of which 53 were returned (75%). Only three were returned via the World Wide Web, the others were returned by mail.

Table 7.6 illustrates the distribution of the respondents across faculties, which is fairly equal (we didn't perform an analysis of per-faculty means because of the large number of variables involved and the small number of respondents per faculty).

Of two questionnaires the faculty could not be traced: a unique number was written on the self-addressed envelope that accompanied the copy; this number corresponded to a translation table, however, the respondents returned the copy in a different envelope.

Table 7.6: Distribution (both in numbers and percentage of returned questionnaires) of respondents across the faculties.

Faculty	Number	Percentage
Mechanical Engineering	3	75
Electrical Engineering	6	86
Chemical Technology	3	75
Applied Physics	5	100
Mathematical Sciences	5	63
Philosophy and Social Sciences	2	67
Applied Communication Sciences	3	75
Public Administration adn Public Policy	7	100
Industrial Technology & Management	4	57
Civil Technology & Management	1	50
Educational Technology	5	45
Computer Science	5	83
Business Information Technology	2	67
unknown	2	

Standardizing

The questions in part B of the questionnaire are targeted at measuring the position of a teacher on one of the seven variables (SCa, SCb, SCc, CC, NK, LO, BI). To be able to calculate averages of answers for a particular dimension, the values have been standardized to so-called *Z scores*: a mean of 0 and standard deviation of 1 (Ferguson, 1981, p. 449). The averages of the teachers' standardized answers on each of the seven dimensions are presented in Appendix D, Figure D.1.

Concurrent Validity

As described in Section 7.3.3, part B of the questionnaire contained two types of questions for measuring the score of a teacher on one of the five dimensions: case-based questions and attitude question, for the purpose of testing on concurrent validity. This section will investigate whether concurrent validity can indeed be established using this approach. Table 7.7 presents the correlations between the averages of the case-based questions and the attitude questions[7]. Pearson's correlation coefficient was used as the values are numerical. The bold printed correlation

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[7] The data from which these correlations were calculated can be found in Appendix D, Figure D.1.

coefficients are significant at the 0.01 level. For variable ’BI’ no correlation could be calculated because the only case-based question that was present for this variable was removed during the pilot test because it was confounding.

Table 7.7: Pearson’s correlation between case-based questions and attitude questions.

Variable	Correlation	N
SCa	0.28	28
SCb	-0.09	27
SCc	-0.12	24
CC	**0.54**	50
NK	0.12	51
LO	**0.37**	49

As Table 7.7 shows, not all case-based questions and the attitude questions correlate significantly; only CC and LO do. This can be explained by the fact that the case-based questions elicit a certain behavior in a hypothetical situation, while the attitude questions require the subject to be the judge of their own attitude. As Kagan (1990) states, the teachers’ conceptions are often held unconsciously, and appear to be highly contextualized, i.e. their conceptions depend on many aspects of the situation the teachers are in. This is consistent with the discrepancies that were found between the behavioral questions and the attitude questions: in different situations, the teachers’ conceptions appear to be very different. To summarize, for only two out of the seven variables, moderate concurrent validity can be proven using the approach of using attitude questions and case-based questions.

This means that the two methods, using attitude questions and using case-based questions, of measuring the position of teachers on the seven dimensions are not in agreement with each other. There are two possibilities to proceed: (1) merge the data sets of the case-based questions and the attitude questions and use this data set for further data analysis, or (2) choose one of the two data sets to use for the data analysis. Option (2) can be chosen if there are indications that one of the two methods yields more reliable results than the other. Three observations can be made with respect to these two possibilities:

- Merging two data sets that do not agree with each other will result in a data set with a high standard deviation, so it will be more difficult to find significant relationships.

- From Table 7.5 it can be calculated that data set of the attitude questions contains more ‘datapoints’ (answers to questions; on average 3.4 datapoints per dimension (24 questions for 7 variables) while the case-based questions contains on average 1.1 datapoints per question (8 questions for 7 variables). Therefor it can be expected that the attitude dataset is more reliable.

- The case-based data set does not contain any data for variable BI (see Table 7.5). So choosing for the case-based data set would mean that variable BI cannot be analyzed.

For these three reasons it was decided to choose the attitude dataset for the remainder of the data analysis.

Reliability

To determine the reliability of the data obtained, the results of the attitude questions (questions B7.1 to B7.25, see Appendix B) were tested for reliability using Cronbach s α (Tuckman, 1994, p. 181). This number indicates whether or not a set of datapoints are in agreement with eachother, on a scale from 0 to 1.

The reliability indications turned out to be quite low for some questions; some were even less than 0.10. To improve the reliability, questions that were confounding were removed from the data set. The decision which question to remove was based on the item-total correlation, so items that correlate least with the total score were removed. Only questions whose removal would provide a reasonable improvement of the reliability (an increase of α of more than 0.10) were actually removed.

The variables and their Cronbach α coefficient are shown in Table 7.8. Per variable, the number of questions and the reliability index α is given on the left side of the table. The right side of the table shows, if applicable, what question was removed, and the α after removal. As five questionnaires were not complete, the data of 48 subjects could be extracted.

As can be observed, SCb and SCc have a very poor reliability. These variables will therefor no longer be considered in the remainder of this data analysis.

Due to the straight-forward nature of the questions in the third part of the questionnaire, in which the respondents were asked to rank five characteristics of learning material in order of importance for a certain educational context, no reliability and validity checks were built into part C of the questionnaire.

Mean differences between contexts

The previous paragraphs have investigated the validity and reliability of the data. The reliability was improved by selectively removing answers from the data set.

Table 7.8: Reliability of the answers, 48 subjects

Variabele	nr. of questions	α	removed question	α’
SCa	3	0.13	B7.13	0.47
SCb	2	0.09		0.09
SCc	2	0.10		0.10
CC	2	0.48		0.48
NK	3	0.42	B7.3	0.70
LO	7	0.45		0.45
BI	5	0.43	B7.5	0.52

The remaining data (i.e. what remains after removing the answers to the questions as described in Table 7.8) will now be analyzed to answer Research Questions 7.1 and 7.2.

RQ 7.1 is about a dependency between the importance that teachers assign to characteristics of learning material, and their position on the dimensions of teaching (as operationalized by the seven variables SCa, SCb, SCc, CC, NK, LO and BI). However, the importance that teachers assign to characteristics of learning material has been measured by part C of the questionnaire in several educational contexts. The question that now arises is: should this importance be examined on a per-context basis, or for all contexts at the same time? To answer this question, it is necessary to investigate Research Question 7.2 first: does the importance that teachers assign to characteristics of learning material depend on the educational context? If it does not, then RQ 7.1 can be answered for all contexts at the same time. But if it does, then RQ 7.1 can only be answered for individual contexts.

The data obtained from part C of the survey consist, per teacher, of a rank number (1 to 5) for each characteristic (duration, level, function, interaction, subject) for each of the six contexts (see Appendix D, Figure D.2). To test whether the teachers’ preferences varied between contexts, the means of the rank numbers of each characteristic will be compared between contexts as described in part C of the questionnaire to see whether they differ significantly. If so, then apparently the teachers’ preferences for characteristics differs between contexts.

So a paired samples t-tests was performed for each characteristic; for example, for characteristic “duration” a paired t-tests was performed for the means in context 1 and 2, context 1 and 3, and so forth. Per characteristic, this yields $5 + 4 + 3 + 2 + 1 = 15$ t-tests (on the same data set). To obtain an approximate familywise error of $\alpha = 0.05$ a per-comparison test of $\alpha_{PC} = 0.05/15 \approx 0.0034$ was used. These results are summarized in Table 7.9 in bold face. To get some insight into possible other relations, also characteristics that have a familywise error of $\alpha_{PC} = 0.10/15 \approx 0.0067$ are printed in normal face. The results of these tests are summarized in Table 7.9.

Table 7.9: Characteristics that have a significant mean difference between two contexts.

characteristic	contexts	t	df	sig
level	**2 and 4**	**-3.2**	**45**	**0.003**
level	4 and 6	3.0	44	0.004
function	**1 and 3**	**3.5**	**44**	**0.001**
function	**1 and 4**	**4.1**	**44**	**0.000**
function	4 and 6	-3.1	44	0.004

The table shows that for the characteristics “level” and “function”, there are contexts with significantly different means for these characteristics. This means that in these contexts, the teachers’ preference for these characteristics significantly differed. So although no significant difference for *all* characteristics in *all* contexts was found, Research Question 7.2 should still be answered with “yes”: the teachers’ preferences for one or more characteristics of learning material (metadata fields) *is* related to one or more educational contexts.

Correlations between dimensions and preferences

Part B of the questionnaire was developed to measure seven variables, using two methods: case-based questions and attitude questions. In Section 7.3.5 it was decided to only use the data set of the attitude questions. After a reliability analysis in Section 7.3.5, it was decided to drop variables SCb and SCc because they were insufficiently reliable. The reliability of variables SCa, NK, and BI was improved by removing a question from the data set. So, the final data set consists of the columns “at.cc.avg”, “at.lo.avg”, “sca-7.13”, “nk-7.3” and “bi-7.5” from Figure D.1 in Appendix D.

The data from part C consist of rank numbers for five characteristics in six educational contexts (see Figure D.2). In the previous paragraph, it was concluded that the teachers’ preferences sometimes varies between contexts, so the contexts have to be examined individually. To answer Research Question 7.1, the following analysis will try to find correlations for each characteristic between the scores of a teacher on the five dimensions of teacher conceptions, and the rank number of that characteristic in each of the five contexts.

This yields six tables (one for each educational context), in which the five dimensions of teaching conceptions are compared with the rank numbers of the five characteristics of learning material. Note that for each context-characteristic pair, unique data are present from the results of part C of the questionnaire. However, the data for each dimension of teaching conception is re-used five times in each table, so using the data for each dimension, throughout the six tables 30 comparisons are made. To maintain a familywise error of 0.5, the per-comparison error rate would have to be $\alpha_{PC} = 0.5/30 \approx 0.0017$.

As a rank variable is involved, Spearman's ρ will be used as correlation coefficient (Charles, 1988, p. 101). Not all six tables will be presented here, instead Table 7.10 only presents the relations with an error rate of less than 0.05, with printed in bold face those relations with an error rate of less than 0.0017; the boldly printed relations will therefor have a familywise error rate of 0.05.

Table 7.10: Correlations between characteristics of learning material and dimensions of teaching conceptions.

Context	dimension	characteristic	Spearman's ρ	N	sign.
1	LO	level	-0.30	45	0.048
2	LO	level	-0.30	46	0.043
3	BI	duration	-0.39	45	0.007
4	SCa	function	-0.37	46	0.011
5	CC	duration	-0.37	46	0.011
5	BI	duration	-0.39	46	0.007
6	CC	duration	-0.47	45	**0.001**
6	BI	duration	-0.59	45	**0.000**

As can be seen, two significant relations are found in context 6: dimensions Content Control (CC) and Bidirectionality (BI) correlate significantly with a preference for the characteristic “duration”. From this it follows that the answer to RQ 7.1 is “yes”: the importance teachers assign to characteristics of learning material *does* depend on one or more of their conceptions of teaching in certain situations.

Note that one of the reasons that only two relations are significant, is the fact that to get a familywise error rate of 0.05, a per-comparison error rate of 0.0017 (significance) is required. Usually, researchers agree to accept a result if there is an error rate of 0.05 or 0.10 (to find trends in explorative research), or sometimes 0.01 if a high degree of reliability is required. If the questionnaire would be readministered to a new sample, and if only a selected number of comparisons would be planned, then a larger error rate than 0.0017 would be sufficient to obtain a familywise error rate of 0.05. As a basis for these planned comparisons, the relations from Table 7.10 could be chosen. These 8 comparisons would then require a per-comparison error rate of $0.05/8 \approx .0062$.

7.3.6 Discussion

The data show that for two characteristics ("level" and "function") there are significant differences in means between contexts (see Table 7.9), which means that in some situations, the teacher has a significantly different preference for characteristics of learning material. So it should be concluded that the educational context *is* of influence on the teachers' preferences for characteristics of learning material (answering RQ 7.2 affirmatively). Three characteristics, however, are not sensitive to the contexts: "subject", "duration", and "interaction". Apparently, teachers have a fixed preference for these characteristics, which is not subject to context changes.

For the development of the distance measure, it would have been convenient if the teachers' preference for characteristics of learning material was independent of *all* contexts, so that one measure would be appropriate in all situations.

There are some small to medium interactions between dimensions of teachers' conceptions of teaching and their preference for characteristics of learning material. Table 7.10 shows that two relations have been found in context 6: one between duration and Content Control, and the other between duration and Bidirectionality. In the other contexts however, no significant relations were found. Although the data suggests that Research Question 7.1 should be answered affirmatively, the number of significant relations that were found is quite limited.

7.4 Relative importance and the Distance Measure

The results from the previous section indicate that the teachers' preference for characteristics of learning material is related to the educational context and to the teachers' conceptions of teaching. The goal of the research effort described in the previous section was to try to find an easy way to predict the teachers' preferences for characteristics of learning material, because the distance measure depends on the "weights" that teachers assign to these characteristics (encoded in metadata fields). If these weights can be predicted, then it would not be necessary to ask them from the teacher each time, thus simplifying the search process. Unfortunately, it is very difficult to predict the teacher's preferences for the characteristics of learning material on the results from the previous section for the following reasons:

- Only in context 6 significant relations were found (see Table 7.10). This means that in the other five contexts, no data to base a prediction on are present, and therefor prediction is impossible.

- Relations were found only for one characteristic of learning material (‘duration’, see Table 7.10), so that no prediction can be made for the other four characteristics.
- The relations that were found only have small effect sizes: the effect size is equal to the square of the correlation coëfficient, so that the dimension CC only explains $.47^2 \approx 22.1\%$ of the variance of the preference for the ‘duration’ characteristic, while dimension BI explains $.59^2 \approx 34.8\%$ of the variance of the preference for the ‘duration’ characteristic (see Table 7.10).

Due to these three reasons, it is not possible to predict the weights of the metadata fields (see end of Section 7.2.6) by measuring the teachers’ conceptions on teaching. The distance measure will therefor be based on relative “weights” that the teacher enters for each search question. This gives the teacher the opportunity to indicate how important he thinks the characteristics of learning material are in his current educational context. The search results can then be sorted on distance to the ideal ULM (the ULM that exactly matches the search specification), or visualized graphically to give insight into the relevance of the search results.

The next section explains how the relative importance that teachers assign to characteristics of learning material is translated into a weight factor and how this factor fits into the distance measure.

7.4.1 Adding Weights

The next step in the construction of the distance measure is to incorporate the weights that the teacher assigns to characteristics of learning material (metadata fields). We will assume that the teacher has created a ranking order of the metadata fields so that the most important field gets the highest value. If a teacher finds two fields equally important, then each field will get the weight of the average that the two fields would get if one would be more important than another; for example, if the teacher wants to have two fields at the second-heighest position out of five, then these two fields would get weights four and three. However, as they are considered equally important, they will each get weight $(3 + 4)/2 = 3.5$. This way, equal fields get equal weights, without affecting the weights of the other three fields.

For each metadata field i a weight w_i is thus obtained. The normalized metric distance on field i is multiplied by this factor, and these products are summed over all values i. Assume that x and y are vectors in a multidimensional metadata space, and that x_i is a value from a metadata set V_i. Then the following distance can be calculated:

$$\rho_{WTD} = \sum_i w_i \frac{|r(x_i) - r(y_i)|}{|V_i|}$$

In the remainder of this thesis, this distance measure will be called the *Weighted Taxicab Distance* or WTD.

Similarly, dividing the terms in Definition 7.2 by the cardinality of the metadata sets, and multiplying these with a weight factor w_i yields the following formula for the Weighted Euclidean Distance (WED):

$$\rho_{WED}(x, y) = \sqrt{\sum_i w_i \left(\frac{r(x_i) - r(y_i)}{|V_i|} \right)^2}$$

These formulas constitute a ‘distance measure’ in the mathematical sense of the word. For a proof the reader is referred to Section E.1 and Section E.2, respectively.

Note that this formula alone is not sufficient to predict the usability of a Unit of Learning Material; the “ideal ULM” is needed, as well as the weights w_i for each characteristic. So, to use this formula an “ideal ULM” should be known (from the search specification a user has entered), and the relative importance of characteristics of learning material. As the questionnaire results (see Table 7.9) showed that this relative importance changes from situation to situation, the actual distance measure (with all weight factors filled in) will also vary from person to person, and from situation to situation.

7.5 Conclusion

In this chapter, the concept of “distance in metadata spaces” has been explored. Such a distance can be measured, but one first needs to know how important the teachers each characteristic (metadata field) find. A research effort has been described that tries to learn more about this importance, and in particular, if it can be related to how a teacher thinks about teaching. An instrument was developed to measure this, and an experiment was executed. The results suggest that this importance sometimes depend on the educational context in which the teacher is looking for materials. Also, the results suggest that this importance relates, in some situations, to one or more conceptions of teaching as measured using seven variables. A distance measure based on this importance therefor may also (in some situations) vary with the educational context and the teacher’s conceptinos on teaching. Although the results showed that only in a few situations the teachers’ preferences for characteristics of learning materials varied with these two concepts, still these effects *may* occur so that it is necessary to take them into account when developing a distance measure.

The results have been used to incorporate the importance that teachers assign to characteristics of learning material into a measure of distance. Two distance measures were defined: the Weighted Euclidean Distance (WED) and the Weighed Taxicab Distance (WTD). These measures depend on the teacher's search specification, which is translated into a so-called 'ideal ULM', a hypothetical ULM in a metadata space. The distance measure is then able to calculate inhowfar a certain search result differs from what the teacher ideally wants. These distances could then, for example, be used to sort the search results in order of increasing distance.

The next chapter will describe a research effort that tries to investigate if these distance measures are indeed able to give an indication of the "distance" as perceived by a teacher between the ULM he or she is ultimately looking for (the 'ideal ULM'), and certain search results.

Chapter 8

Validation of the Distance Measure

8.1 Introduction

This thesis proposes that the use of a measure of distance in a metadata space can help the teacher in finding learning materials that fit his or her purposes. The previous chapter proposed two distance measures: the Weighted Taxicab Distance (WTD) and the Weighted Euclidean Distance (WED). The weight factor in these formulas is derived from the relative importance that teachers assign to characteristics of learning materials (see Section 7.4.1). The distance measures calculate the distance between the search profile that the teacher has entered (the ‘ideal’ ULM) and the ULMs in the database; a list of search results can then be sorted on their distance to the ideal ULM.

This chapter will try to validate whether one or both of the distance measures really succeed in predicting the ‘usability’ of ULMs to a teacher; this attempt can be called the *validation* of the distance measures. More specifically, this chapter will attempt to compare a teacher’s judgement of the usability of a ULM (given a certain educational situation) with the prediction of the usability according to the two distance measures. This can be worded in the following research question:

> **RQ 8.1** How does the prediction of the usability of a ULM according to the distance measures compare to the judgement of usability of that ULM according to a teacher?

The two distance measures are based upon the assumption that the preference of teachers for certain characteristics (that are modelled by the metadata) of a Unit of Learning Material is related to their opinion on the usability of that ULM (see

Section 7.4). There may be, however, many other factors that also influence the teacher's judgement. The greater the influence of these factors, the less the distance measures are able to predict the usability of the learning materials (because these other factors are not taken into account). So, the distance measures can be made more effective by basing it on the most important factors, i.e. those that are the most relevant to the teacher when judging the usability of ULMs. For this purpose the following research question is formulated:

> **RQ 8.2** What characteristics of learning material, other than those represented in the metadata fields that are incorporated into the distance measure, are relevant to the teacher when making a judgement about the usability of learning materials?

The previous chapter introduced *weights* into the distance measure, because it was shown that the teachers' preference for characteristics of a ULM is related to their opinion on the usability of that ULM (see Section 7.4.1). However, this section did not specify how the teachers' 'preference' for characteristics is translated into a number. This is a difficult question. In the current research it was decided to start with a simple approach and evaluate how effective it is: assign the value '1' to the least important characteristic, '2' to the second least important one, and so forth. With four characteristics, the most important characteristic gets weight '4', four times as much as the least important characteristic. To get an impression of the effects of these weights, two different versions will be tested in this chapter: a Euclidean distance measure with weights that increase by 1, and a Euclidean distance measure that has *equal weights*, i.e. $w_i = 1$ for all i. If the results of the Equal Weights Distance (EWD) measure are better than the results of the Weighted Euclidean Distance (WED), then weights with small increases are probably better. To be able to compare the Weighted Taxicab Distance with the Weighted Euclidean Distance, both will be used with a weight vector that increases by 1 for each field (this increase will be called the *weight step* in this thesis). So in total, three distance measures will be tested in this chapter: the Weighted Euclidean Distance (WED), the Weighted Taxicab Distance (WTD), and the Equal Weights Distance (EWD) to be able to assess the impact of the weight vector.

This chapter is structured as follows: first, Section 8.2 will discuss the design of the research effort undertaken to answer Research Question 8.1 and 8.2. Then, Section 8.3 will discuss what instrument has been used to collect data. After that, Section 8.4 will present how the instrument was used to gather data. Section 8.5 will present the results of the experiment, and finally Section 8.6 will discuss the results and close the chapter.

8.2 Research Design

Recall the list of six types of educational research methods presented in Section 7.3.3: (1) historical, (2) descriptive, (3) correlational, (4) causal-comparative, (5) experimental, and (6) research and development. In Research Question 8.1, two variables can be identified: “the prediction of the usability of a ULM” according to either one of the distance measures, and “the judgement of usability” according to a teacher. These two measures should be compared to each other, so in this case the correlational research method again seems most appropriate.

Research Question 8.2 is not about correlations, but it attempts to describe on the basis of what characteristics a teacher selects learning material. So to answer this question, a descriptive research method is the most suited.

The next section will explain how variables that can be measured are derived from both Research Questions. After that, Section 8.2.2 will explain what procedure is needed to collect data of these variables, and Section 8.2.3 will explain how this approach relates to the existing research methodology in the field of Information Retrieval.

8.2.1 Operational definitions

Research Question 8.1 is about comparing the ‘judgement of usability according to a teacher’ and the ‘prediction of the usability of a ULM according to the distance measures’. The latter concept can be well measured, because the input to the distance measure is the teacher’s search profile (representing the ‘ideal ULM’) and a weight vector, and the output of the distance measure is a number. However, for the concept ‘judgement of usability according to a teacher’ a so-called *operational definition* must be found (Tuckman, 1994, p. 102). This definition should allow the human judgement of usability to be compared to the output of the distance measure. The output of the distance measure is a number, so to be able to compare these two concepts, the ‘judgement of usability according to a teacher’ should also be a number. A simple way to do this, is to ask the test subject to rate the ULM with a grade (in the Netherlands ranging from 1 to 10). This number can then easily be correlated to the judgement obtained by applying the distance measures. As the distance measure indicates the “distance” between a certain ULM and the teacher’s search profile, it can be expected that as the distance goes to zero, the grade goes to 10: the teacher will tend to like ULMs that resemble his search specification more than ULMs that do not resemble his search specification. This means that it can be expected that the two variables would be negatively correlated.

In the previous chapter it was discussed how a search specification could be obtained from a teacher. But how to get the “weight vector” from the teacher as discussed in Section 8.1? As the judgement of the usability of a ULM depends on the educational context, an educational context has to be described to the teacher first. The teacher can then determine his (or her) preferences for certain characteristics, and make these known to the computer. To do this, an operational definition for these preferences should be determined. In part C of the questionnaire (see Section 7.3.3) the test subjects were asked to number five characteristics in order of relevance. From comments that were written on the copies of the questionnaire, it became clear that the subjects found it very difficult to assign a number that indicates an 'importance'. So, for the current study a different approach was taken. On the computer, the (four) characteristics were summed up, and for each characteristic so-called 'radio buttons'[1] were present. Using these buttons, teachers could indicate which characteristic would be "checked first". In reality, the buttons were not used to indicate an order in which characteristics were to be checked, but instead weights were assigned: the characteristic that the subject said "should be checked first", received weight 4; the characteristic that should be checked second received weight 3, and so on.

Research Question 8.2 is about finding factors other than those represented by the metadata fields that are relevant to the teacher when judging the usability of a Unit of Learning Material. To get an overview of these factors, the test subject could be asked for each search result what his or her motives (or factors) were to assign the grade that he or she assigned. To help the test subject in analyzing what factors played a role, a list of possible factors is presented to the subject, and then the subject is asked to indicate per factor if it played a role in the decision or not. Of course, the test subject will also have the opportunity to write down his or her own factors if it is not present in the list. This list will be written down on a form called the "ULM Evaluation Form", which the test subjects are required to fill out for each search result.

The initial list of factors that was created is depicted in Table 8.1. The factors in this list were gathered through many informal discussions with teachers about educational databases and the usability of Units of Learning Material.

8.2.2 Procedure

Using the operational definitions described above, the procedure for collecting data will be described. For answering RQ 8.1, a correlation needs to be calculated between two variables: a teacher's judgement on the usability of a ULM in a given situation, and the distance between this ULM and the search specification that the

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[1] A series of buttons on the screen of which at most one at a time can be in the 'selected' state (compare listening to one radio station at a time). This mechanism has been incorporated into most Graphical User Interfaces.

Table 8.1: Initial list of factors that are expected to play a role in determining whether a ULM is useful or not.

Factor	description
F_{layout}	layout characteristics such as font size and use of colours
$F_{references}$	amount of references to other learning materials
$F_{textstyle}$	style of the textual content
$F_{correctness}$	correctness of the content
$F_{pedagogy}$	the used pedagogy of the material
$F_{exercises}$	the way exercises conform to the teacher's own insights
$F_{interactivity}$	the amount of interactivity of the material
F_{time}	the duration of the material
$F_{difficulty}$	the difficulty of the material
F_{size}	the size (in kilobytes) of the material

teacher would enter to find learning material. To collect data points, the following procedure will be used:

1. A test subject is given an educational context in which a need for learning material is described. The educational context will take the form of a case description.

2. The test subject examines the case description, and will fill out a computer-form that specifies what characteristics the ULMs should have in the case and how important they find each characteristic. The search specification will specify the 'ideal ULM', because it describes what the ULMs would ideally look like.

3. The computer will return a list of ULMs which the test subject is asked to examine. For each ULM, the subject is asked to evaluate the usability of the ULM for the educational context by assigning a grade number.

4. For each ULM in the search result list, the computer will calculate the distance between the ULM and the 'ideal ULM' according to the three distance measures (WTD, WED and EWD).

This procedure yields four numbers for each ULM: the test subject's grade number, and the distances according to the three distance measures. For each distance measure, a correlation coëfficient between the test subject's grade and the distance according to the measure will be calculated. Thus, for three distance measures, a correlation coëfficient is obtained that indicates how well the distance measure relates to the test subjects’ judgement on usability of ULMs in certain educational contexts.

To ensure the external validity (generalisability) of the results, the educational contexts, the test subjects, and the ULMs should consist of a representative sample of the respective populations.

8.2.3 Other approaches

This section will discuss two alternative approaches that may at first seem also suitable for the current research, but upon a closer look problems arise.

An approach to evaluate the effectiveness of a retrieval method that is well known in the Information Retrieval discipline is the TREC method. In this method, a large collection of documents is composed, and a number of queries are formulated by an independent party (the TREC organisation). Research groups that want to test the performance of a novel search method can obtain a copy of the document set and feed the queries to their search algorithm, which will then search the documents and return a list of search results. The results of each query are then judged by members of the TREC organisation, to see if the search results are relevant considering the query. These results are then publicized and discussed on the TREC conference. But as the TREC document set does not consist of educational multimedia documents this approach is not suited for the current research.

An alternative approach would be to sort the list of search results according to the distance measure, and also to ask the test subject to sort the search results according to his judgement. These two lists of the same search results can be seen as permutations of a set of ULMs, so that methods from discrete algebra (Kececioglu & Sankoff, 1993; Foata, 1976) can be used to see how much the two lists differ (i.e. how much agreement there is between the order generated by the distance measure and the order determined by the test subject). The main disadvantage of this approach is, however, that small differences in the order of the lists can result in a relatively large amount of ‘disagreement’. However, the most important issue in the current research is if the distance measure is able to discriminate between usable and useless ULMs, and not if the distance measure is able to precisely predict the order that the test subject would choose. So this research method is too sensitive to small errors in the order of the result list, and not sufficiently sensitive to large relevance errors.

8.3 Research instrument

In this section, the “instruments” needed to execute the procedure described in Section 8.2.2 are discussed. First, the dimensions of the distance measure are determined in Section 8.3.1. Then, a set of suitable ULMs that will be used during the experiment are derived in Section 8.3.2. Then, the design of the case descriptions will be presented in Section 8.3.3. For each case, a predefined list of search results will be presented to the test subjects. Section 8.3.4 will explain how an expert was consulted to develop this list. Section 8.3.5 will then present the software that was used to conduct the experiment. Then, the evaluation form that the test subjects used to evaluate the search results is presented in Section 8.3.6. Finally, Section 8.3.7 will describe a pilot test that was conducted to assess the effectiveness of the instrument, and how this was improved.

8.3.1 The dimensions of the distance measures

The goal of the experiment is to validate three distance measures that are based on metadata fields. More specifically, the intention of the current research is to show that the *method* of using metadata fields in a distance measure indeed works, in that it is able to predict (to some extent) the teacher’s judgement on the usability of a ULM. As explained before, the distance measure will be validated by comparing the judgement of the usability of ULMs according to a teacher with the “judgement” of three distance measures (see also Research Question 8.1). To make sure that the outcome of the experiment represents the validity of the distance measures as a whole, different values on all of the dimensions (metadata fields) must be used. This would yield an exponentially large number of ULMs as the number of dimensions increases. So, to limit the complexity of the experiment, a relatively small number of dimensions will be used. This section will derive the dimensions by examining metadata fields.

To ensure that the metadata fields have a relationship with the real world and produce valid results, the experiment will make use of the IEEE LTSC Learning Object Metadata (IEEE, 2000). A short explanation of these fields is given in Appendix C.3. Two criteria will be used to select metadata fields: (a) the possibility to impose a semantical ordering upon the values, which is a requirement for using the metadata field in the distance measure (see Section 7.2.1) and (b) the usefullness of the metadata field for the teacher when he or she is searching for learning material. Of course, making decisions what metadata fields would be useful to a teacher is highly subjective without first studying the preferences of the teachers. These decisions on usefulness are subjective, but the purpose of this research is to show that the *method* of basing a distance measure on metadata fields works, and not to find the best set of metadata fields.

Below, the metadata fields of the IEEE metadata set are examined for these two desired properties; an elaborate description of the choices made can be found in Appendix C.3. Fields that have both properties, are printed in a bold typeface.

It follows from Table 8.2 that there are six suitable metadata fields seem to be both orderable and useful. Let's examine them for the two desired properties "orderability" and "usefulness":

Size As the size of a ULM is measured in bytes[2], it is trivial that the "size" field is orderable: it is possible to unambiguously state that a certain ULM is larger in size than another. The field can be useful to a teacher to determine whether a ULM will not cause unnecessary download delays due to large sizes.

Interactivity Level The amount of interactivity in a ULM is also orderable: Although the type of interactivity may be different (e.g. passive or proactive interactivity), some ULMs may have no interactivity (e.g. plain texts), while other ULMs may have "lots of" interactivity and so it can be considered to be orderable. As the amount of interactivity determines to a large amount the pedagogy of a Unit of Learning Material, teachers can also be expected to find it *useful* to know the amount of interactivity of a ULM.

Educational Level The orderability of educational levels is obvious; also, teachers will find such a field very useful because ULMs that are designed for a much higher educational level might be too difficult for the teacher's own target group.

Difficulty Again, the orderability of the difficulty field is obvious: a ULM can be *more* difficult to a student (within the intended educational context as described in element 5.6) than another ULM. Also, it can be very useful to a teacher to know how difficult a ULM is.

Typical Learning Time The orderability of the typical learning time is trivial. It is important to a teacher because teachers often want to know the learning material's "time load" onto the learners.

TaxonPath The subject as it is "encoded" in the Taxonomy Path of a ULM is not easily orderable; however, using a hierarchical list of topics or concepts (such as used in the Ariadne project) an ordering can be created so that a certain ULM is on a "deeper" level in the hierarchy than another. It is trivial that it is useful to a teacher to know the subject of a ULM.

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[2] A unit of computer memory storage.

Table 8.2: Fitness of metadata fields to serve as metric space

nr	metadata field	ordering?	useful?
1	GENERAL		
1.1	Identifier	no	no
1.2	Title	no	yes
1.3	Catalog Entry	no	no
1.4	Language	no	yes
1.5	Description	no	yes
1.6	Keywords	no	yes
1.7	Coverage	no	no
1.8	Structure	no	no
1.9	Aggregation level	no	no
2	LIFECYCLE		
2.1	Version	yes	no
2.2	Status	yes	no
2.3	Contribute	no	no
3	METAMETADATA		
3.1	Identifier	no	no
3,2	Catalog Entry	no	no
3.3	Contribute	no	no
3.4	Metadata Scheme	no	no
3.5	Language	no	no
4	TECHNICAL		
4.1	Format	no	no
4.2	**Size**	**yes**	**yes**
4.3	Location	no	no
4.4	Requirements	no	yes
4.5	Installation Remarks	no	no
4.6	Other Platform Requirements	no	no
4.7	Duration	yes	no

nr	metadata veld	ordering?	useful?
5	EDUCATIONAL		
5.1	Interactivity Type	yes	no
5.2	Learning Resource Type	no	yes
5.3	**Interactivity Level**	**yes**	**yes**
5.4	Semantic Density	yes	perhaps
5.5	Intended End Role	no	no
5.6	**Context *(educational level)***	**yes**	**yes**
5.7	Typical Age Range	yes	perhaps
5.8	**Difficulty**	**yes**	**yes**
5.9	**Typical Learning Time**	**yes**	**yes**
5.10	Description	no	perhaps
5.11	Language	no	yes
6	RIGHTS		
6.1	Cost (y/n)	yes	no
6.2	Copyright (y/n)	yes	no
6.3	Description	no	no
7	RELATION		
7.1	Kind	no	no
7.2	Resource	no	no
8	ANNOTATION		
8.1	Person	no	no
8.2	Date	yes	no
8.3	Description	no	no
9	CLASSIFICATION		
9.1	Purpose	no	no
9.2	**TaxonPath**	**yes**	**yes**
9.3	Description	no	yes
9.4	Keywords	no	no

Note: A TaxonPath is a path in a taxonomy structure, such as: “computer science / networks / ethernet / collision avoidance”.

So, these six metadata fields comply with the two requirements, and hence are sufficiently usable to base the distance measure upon and to conduct the experiment with.

The consequence of the fact that only a small subset of the metadata fields are used in the distance measure is that the distance measure will be less able to predict for sure if a certain ULM is relevant to the teacher, compared to methods that include all metadata fields. Therefor, small effect sizes should be anticipated, and consequently the predictive power of the distance measure will be relatively small. For practical applications of the distance measure, for example to sort database search results in order of decreasing predicted usability, this means that the order will be less accurate than when more metadata fields would have been used.

Note, however, that the goal of the current research is to try to demonstrate that the mechanism of using a distance measure in a metadata space can predict to *some* effect the relevance of ULMs to a teacher. If it can be proven that a prediction is possible, then the mechanism could be refined and improved to allow for greater effect sizes and more accurately sorted lists of search results.

As said before, the experiment will use Units of Learning Material with varying values for certain metadata fields. These fields form the dimensions of the distance measure. Now that the metadata fields are known, the next section will determine what the ULMs that will be used in the experiment should look like.

8.3.2 The contents of the database

To ensure that the different versions of the distance measure (EWD, WTD, and WED) are fully tested, the values on *all* dimensions (metadata fields) that are used in the distance measure will be varied. In this study, the values on the various dimensions will assume a ‘high’ and a ‘low’ value; for example, for the metadata field “length” a short (‘low’) and a long (‘high’) value will be used. This means that both a short, and a long ULM will be put into the database. The other metadata fields, however, should also be varied simultaneously. The number of needed metadata “profiles” then increases exponentially: for six fields that will be varied using two values, $2^6 = 64$ profiles are needed. For each profile, at least one ULM should be used in the distance measure, so a minimum of 64 ULMs would then be necessary. Fortunately, a reduction of the number of metadata fields can be made: as the experiment will involve academic teachers and academic subject matter, the field ‘educational level’ will always have the value “university”. Also, problems were anticipated if teachers would be allowed to search the database freely; chances would be that they would not be able to find the prepared materials if they would use unanticipated keywords.

So, it was decided to use a fixed subject, and to deliver a fixed set of search results; we will discuss this decision in Section 8.3.4. This also eliminated the need to vary the “subject” field. Thus, four fields remained: Size, Interactivity Level, Difficulty, and Typical Learning Time. To vary these four fields on two values would require $2 \times 2 \times 2 \times 2 = 16$ ULMs. As it was expected that the teachers would find the “Interactivity” field the most important, it was decided to vary the ‘Interactivity’ field on three values. Thus, a total of $2 \times 2 \times 2 \times 3 = 24$ ULMs are needed. Their specification (“profile”) is listed in Table 8.3.

Table 8.3: Specification of the ULM profiles for the validation experiment.

Nr	size	interaction	difficulty	time
1	low	low	low	low
2	low	low	low	high
3	low	low	high	low
4	low	low	high	high
5	low	medium	low	low
6	low	medium	low	high
7	low	medium	high	low
8	low	medium	high	high
9	low	high	low	low
10	low	high	low	high
11	low	high	high	low
12	low	high	high	high
13	high	low	low	low
14	high	low	low	high
15	high	low	high	low
16	high	low	high	high
17	high	medium	low	low
18	high	medium	low	high
19	high	medium	high	low
20	high	medium	high	high
21	high	high	low	low
22	high	high	low	high
23	high	high	high	low
24	high	high	high	high

Now that the profiles of the ULMs are determined, *content* for the ULMs that suit each specification is needed. The subject of computer networks was chosen for the following reasons: teachers of the Telematics Systems and Support group of the University of Twente had shown a great interest in the concept of “Units of Learning Material”. Secondly, as the group teaches courses to many different target groups, much reuse of materials occurs. Finally, the teachers already had put a lot of their course materials online, including some simulations. The subject area was narrowed down to the “Internet Control Message Protocol” (ICMP), because many different materials on this subject were available on the Internet from many universities.

To ensure that the decisions that the test subjects will make about the learning material are valid and represent real life situations, it was decided to use existing learning material that is actually being used in education. The Internet was searched[3] on keywords such as ‘icmp’, ‘course’, ‘traceroute’, ‘ping’, ‘exercise’, ‘simulation’ ‘computer networks’ and various combinations of these words. The course materials that were found were examined and in a creative process, parts of courses were combined and edited to comply with one of the profiles listed in Table 8.3. For large ULMs, the table gives video fragments as example; but as no video fragments related to the subject matter could be found, ULMs with many pictures were created. Also, simulations on ICMP could not be found (for highly interactive ULMs), so instead ULMs with many assignments or exercises were created.

Interpreting the specification listed in Table 8.3 is a subjective process: at what size should a ULM be considered “small”, and when is a ULM to be considered “large”? The size of the collected ULMs varied from a few kilobytes to tens of kilobytes, so it was determined that ULMs that are smaller than 5 kilobytes (about 730 words) were considered “small”, while ULMs that were larger than 15 kilobytes (about 2200 words) were considered to be “large”. Similarly, ULMs that take less than 10 minutes to work through (the ‘duration’ property) were considered to be “short”, while ULMs that take longer than 20 minutes were considered to be “long”. The list of ULMs that were created is presented in Table 8.4. The profile numbers correspond to the profile numbers in Table 8.3. Note that the ranges that were chosen to distinguish between “short” and “long”, and “small” and “large” are subjective. This is unavoidable, as no objective definition exists for how big a “small” ULM typically is. ULMs were considered to be “difficult” if they were written in a difficult to read style, or if difficult words were used that weren’t explicitly explained first. ULMs that were written in clear, easy to understand language, were considered to be “easy”.

Note that the 24 profiles in Table 8.3 are only a guideline to make sure that all “quadrants” of the metadata space are represented by at least one ULM. Sometimes, the ULM does not exactly match a profile; ULM 20, for example, has a

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[3] using the search engines www.hotbot.com and www.google.com

Table 8.4: The actual ULMs and their metadata values that were used in the experiment.

ULM	size (k)	size	interact.	difficulty	time (min)	time	profile
1	3.9	small	medium	easy	20	long	6
2	2.1	small	none	easy	10	short	1
3	0.6	small	a lot	very easy	10	short	9
4	2.9	small	none	difficult	10	short	15
5	29.2	large	none	very diff.	60	long	16
6	36.2	large	none	very easy	20	long	14
7	0.9	small	some	very easy	7	short	5
8	18	large	some	easy	13	short	17
9	18	large	a lot	easy	12	short	21
10	2.3	small	none	difficult	10	short	3
11	10.6	medium	none	very easy	10	short	13
12	1.7	small	medium	difficult	8	short	7
13	4.5	small	medium	very diff.	30	long	8
14	3.0	small	a lot	difficult	45	long	12
15	1.6	small	a lot	difficult	10	short	11
16	12.5	medium	a lot	difficult	50	long	24
17	13.8	large	a lot	difficult	10	short	23
18	4.6	small	none	easy	18	medium	2
19	5.0	small	none	difficult	18	medium	4
20	2.5	small	a lot	very easy	15	medium	10
21	15.2	large	some	very easy	25	long	18
22	20.8	large	some	very diff.	35	long	20
23	22.4	large	some	difficult	15	short	19
24	18.3	large	a lot	very easy	30	long	22

"medium" duration, while it should be "long" according to its profile (10). It was decided to leave these ULMs as intact as possible, to preserve their representativeness for real-life learning material. The fact that they do not fully comply with the specification has no influence on the outcomes of the current experiment; the only objective of the 24 profiles is to ensure that all metadata fields get a chance to play a role in the distance measure.

8.3.3 The design of the case descriptions

In step 1 of the procedure described in Section 8.2.2, it was stated that the subject would receive a case description. This case description should be designed to elicit a search specification from the test subject, as well as an indication in what order the characeristics of learning material are supposed to be checked by the computer (see step 2 of the procedure). The case descriptions need to be developed so that they represent a natural, realistic situation. To make sure that the test subject is able to form an idea about the material he is looking for, the case description should direct the test subject towards a preference for at least one characteristic. To evenly distribute cases over characteristics, it was decided to design two cases per characteristic: one that directs the test subject towards the "maximum" value of a characteristic, and one that directs the test subject towards the "minimum" value of a certain intended characteristic (interactivity, difficulty, duration, size). An advantage of this approach is that this 'need' for learning material nicely matches the extreme values for metadata fields that have been developed in the previous section.

To ensure that ULMs from the entire metadata space have a chance to play a role, the case descriptions should, where possible, direct the test subject to one of the extremes of one of the four metadata fields (characteristics). As this study is concerned with four metadata fields, being Size, Interactivity Level, Difficulty and Duration, the case descriptions will each try to describe a need for material that is on the extremes of one of these four fields; see Table 8.5.

Table 8.5: The framework for the design of the case descriptions

	max: a lot, large	min: little, few
Interactivity Level	1	5
Difficulty	2	6
Duration	3	7
Size	4	8

Below, the eight cells in the framework are worked out into a case description:

1. **A lot of interactivity** is needed for practical trainings. Therefor, the following case description was created: *Suppose that you have to give one class per week on computer networks to senior students this trimester, and that you have experienced in previous years that the students have insufficient practical skills in working with network analysis software such as 'ping' and 'traceroute'. You want to enhance their skills by supplying online learning materials.*

2. **Very difficult** material is needed in a situation in which 'fast' students should get additional material to prevent them from becoming bored. A case that describes this need is: *Suppose that during your course it turns out that many students grasp the subject matter very quickly. To make it a bit more difficult to these students, you want to put additional materials onto the Internet on the Internet Control Message Protocol.*

3. **Long duration** material is needed if a certain amount of time has to be filled. A case description that suggests that a particular long period of time should be filled, will accomplish this: *For the lab assignments of your course you have scheduled four hours on the subject "TCP/IP in the OSI model", and you want to use one hour of this for the network layer and signaling. The students should get a theory part during this hour, as well as a practical part.*

4. **Large size** material: it is rather difficult to imply a need for large material. If the same material exists with a smaller size, then it is not logical to choose the large materials. For this reason, this combination was found to be insufficiently realistic and no case description was created.

5. **No interactivity:** as exercises are almost always welcome in an online course, it is also difficult to create a need for material that is not interactive. It was felt that teachers would consider a situation that called for online, non-interactive material would not be realistic. Therefor, this combination was also dropped.

6. **Low difficulty:** as the material is about a technical subject, it was decided to describe a situation in which non-technical students would have to learn it. This can only be achieved if the material is sufficiently easy: *A non-technical faculty has decided to give her students a course on Information Technologies. The students do not have any prior technical knowledge. As the programs 'ping' and 'traceroute' can be found on any PC and as these programs illustrate how the Internet works, the Internet Control Message Protocol and these two programs are also part of the course.*

7. **Short duration:** the need for material with a short duration can be suggested by describing a situation in which there is only very little time, such as: *The course that you give already demands too much time from the students. Still, a subject is missing: the Internet Control Message Protocol. The existing material cannot be made smaller, but still you want to give some material on ICMP.*

8. **Small sized** material is needed when the Internet connections are very slow, for example when the target audience is at a large distance. This observation formed the inspiration to the following case description: *Due to a European project, your course has gained an extra target audience: students of a university in the eastern part of Europe want to study parts of your course on computer networks. Their level is comparable to that of your own students, but of course their network connection is much slower. The standard books such as "Computer Networks" by Tanenbaum are not available, so the students have to rely on your online materials. The subject that you are looking material for, is again ICMP.*

So, there are six cases with each six ULMs to judge. However, during the pilot test (see Section 8.3.7) it was noted that one case takes about 15 minutes, so the experiment would take $6 \times 15 = 90$ minutes. This was found to be too long, and also there would be a risk that filling in the ULM evaluation form (that will be described in Section 8.3.6) might become an automatism to the subjects. Therefor it was decided that each subject would do three cases. Two versions of the experiment were created: the first version uses the first three cases, and the second version uses the second three cases. The test subjects were assigned randomly to one of these two versions. Subjects of the first group were numbered 1, 2, 3 etcetera, while subjects of the second group were numbered 101, 102, and so on.

8.3.4 The search results

In the previous sections, it was discussed how the distance measure will be validated, and what kind of learning material is needed to do this: departing from three metadata fields that are varied on using two values and one that will be varied on 3 values, 24 profiles were obtained (defined in Table 8.3). For each of these profiles, one Unit of Learning Material was composed from actual learning materials found on the Internet, yielding 24 test ULMs (described in Table 8.4). As described in Step 3 in Section 8.2.2, the test subject will examine a case description, fill in his or her search specification, and be presented a list of search results. This list of search results should contain a *small* subset of the 24 test ULMs, because the test subject will be asked to fill out a ULM evaluation form for each of the ULMs. A search result list should be determined for each of the case descriptions that was determined in Section 8.3.3. How to determine these lists? The current section will find an answer to this question.

The purpose of the experiment is to try to relate the judgement of usability of a ULM to a teacher with the distance between that ULM and the ‘perfect ULM’ of that teacher. To properly calculate correlations, the entire range from “useless” to “very useful” should be covered. So there should be some search results that are very useful to a teacher, as well as search results that are useless. This means that somebody or something will have to determine what ULMs are useful in a certain case, and what ULMs are useless. Obviously, the computer by itself is not able to determine the usability of a ULM; this is a decision that ultimately has to be taken by human experts. Also, the distance measure itself cannot be used to check for usability, because it is the subject of this study. The only option that remains is to ask a human expert to select three useful and three useless Units of Learning Material for each case, and to present these six ULMs as “search results” to the test subject. Although the test subject may disagree with the expert on the usability of the search results, it still can be expected that there is a certain agreement between their opinion so that the test subject will find both useless and useful ULMs in the search results.

The following procedure was used: hardcopies of the 24 ULMs were created (insofar as this was possible), as well as a list with a very short objective description of each ULM. A teacher from the Telematics Systems and Services group was asked to review the list of the 24 ULMs online and if needed on hardcopy, and to review the cases. The expert was then asked to take the list of ULMs and to write down for each ULM some cases that the ULM was very useful in, and some cases that the ULM was not useful in (see Table 8.6). The expert chose to denote the usability of a ULM using the signs “+”, “–” and “o” for “useful”, “useless”, and “undecided” respectively.

For example, the expert judged that ULM 4 was particularly suited in case 2 (+), and that ULM 2 was useless in all cases (–) except in case 5 (undecided).

After that, the expert was asked to take the list of cases and to select three usable ULMs, and three useless ULMs per case using Table 8.6. The results are shown in Table 8.7. The table shows, for example, that the expert chose ULM 4 as a ‘useful’ ULM in case 2, and ULM 2 as a ‘useless’ ULM in case 1, 2, 3 and 6.

Two problems arose, however: not all ULMs are used in Table 8.7. For example, ULM 5 and 7 are not in Table 8.7. Recall that per case, the three ‘useful’ ULMs and the three ‘useless’ ULMs together form the result list that will be returned to the user. So a ULM that is not in Table 8.7 would not be present in any result list, and hence would not participate in the experiment. This conflicts

Table 8.6: The ULMs (vertically) and their fitness for particular cases (horizontally)

	case							case					
ULM	1	2	3	4	5	6	ULM	1	2	3	4	5	6
1	0	0				+	13		0				
2	–	–	–	–	0	–	14	0	0	+	0	–	0
3	0	0		0	+		15	0	0	+	0	–	0
4		+					16	0	0	0	–	–	0
5		0					17	0	0	0	–	–	–
6	–	–	–	–	0	0	18	–	–	–	–	–	0
7		0					19	–	–	–	–	–	–
8	0	–	–	0	0	0	20	–	–	–	0	0	0
9	0	–	0	+	0	+	21	0	0	0	–	–	–
10	–	–	–	–	–		22	0	–	0	0	–	–
11	–	0	–	0	0	–	23	0,+	–	+	0	–	–
12	–	–	–	–	0	–	24	0	0	0	0	–	–

Table 8.7: The list of search results: six ULMs varying from ‘useful’ to ‘useless’ for each of the six cases.

case	useful (rated ‘+’)	undecided (rated ‘0’)	useless (rated ‘-’)
1	ULM 23	ULM 24, 16	ULM 2, 6, 11
2	ULM 4	ULM 11, 16	ULM 2, 22, 6
3	ULM 14, 23	ULM 22	ULM 2, 6, 11
4	ULM 9, 20	ULM 24	ULM 4, 6, 21
5	ULM 3	ULM 20	ULM 14, 18, 23
6	ULM 1, 9	ULM 20	ULM 2, 11, 12

with the design of the 24 experiment-ULMs: they have been designed especially to cover the ‘metadata space’.

The second problem is that some ULMs are used quite often; ULM 2, for example, is assigned to case 1, 2, 3, 5, and 6. Similarly, ULM 6 is used in case 1, 2, 3, and 4, so that these ULMs would be present in four of a total of six search result lists. By counting the number of cases a ULM is used in Table 8.7, one can find that there are eight unused ULMs, four ULMs that are used once, six ULMs that are used two times, two ULMs that are used three times, two ULMs that are used four times, and one ULM that is used five times (ULM 2). As the test subject has to examine each ULM in all search results, he or she would have to judge ULM 2 five times. This could become a bit boring to the test subject, which might endanger the results of the experiment.

To solve both problems, the table of search results (Table 8.7) that was developed by the expert should be modified. This could compromise the subjectivity of the table, but this thesis assumes that as long as the expert’s judgement concerning the (un)usability of a ULM for a case is respected, the subjectivity of the search results list remains intact. So a ULM should only be assigned as a ‘useless’ ULM to a case if the expert indicated that the particular ULM is ‘useless’ for that particular case. Note that the purpose of the search result list is to return a list of six ULMs varying from useful to useless as judged by an expert; this requirement remains fulfilled.

So, it was decided to select ULMs that were used often (such as ULM 2) and to replace them in some cases with ULMs that were unused (such as ULM 5). As the judgement of the expert concerning what ULMs are useful in a case and what ULMs aren’t should not be violated, Table 8.6 should be respected. For example, the table says that the expert found ULM 5 “neither useful nor useless” (rated ‘0’) for case 2. In case 2 (see Table 8.7), ULMs 4, 11, 16, 2, 22 and 6 are returned; it was already shown that ULM 2 is used relatively often (four times). So by replacing ULM 2 with ULM 5 in case 2, the number of times ULM 2 is used as a search result is reduced, while ULM 5 is now incorporated into the experiment. Note that ULM 2 was judged to be ‘useless’ for case 2, while it is now replaced with ULM 5 of which the expert judged it was ‘neither useful nor useless’ for case 2. The search results for case 2 are now “$+, 0, 0, 0, -, -$” which still fulfills the requirement of returning both useful as well as useless ULMs.

There were eight unused ULMs in Table 8.7: 5, 7, 8, 10, 13, 15, 17, and 19, so eight replacements had to be made. The resulting table and the changes made to Table 8.7 to arrive at this result is shown in Table 8.8. In this revised table, there are 16 ULMs that are used one time, four ULMs that are used twice, and four ULMs that are used three times. So a test subject will have to evaluate a ULM at most three times, instead of up to five times according to Table 8.7.

Table 8.8: The modified cases (vertical) with six ULMs, both useful and useless (horizontal).

case	useful (‘+’)	undecided (‘0’)	useless (‘–’)	replaced:	replaced:
1	ULM 23	ULM 17, 16	ULM 5, 6, 11	2 by 5	24 by 17
2	ULM 4	ULM 7, 13	ULM 2, 22, 6	11 by 7	16 by 13
3	ULM 14, 23	ULM 15	ULM 2, 19, 11	22 by 15	6 by 19
4	ULM 9, 8	ULM 24	ULM 4, 6, 21	20 by 8	
5	ULM 2, 3	ULM 20	ULM 14, 18, 23		
6	ULM 1, 9	ULM 20	ULM 10, 11, 12	2 by 10	

This table shows per case the search results that will be presented to the test subjects. Case 3, for example, has as search results ULMs 14, 15, 23, 2, 19 and 11; for an example of the search result list, see Figure 8.2. The experimental environment was programmed so that the results were presented in a random order.

8.3.5 The experimental environment

The prototype as described in Chapter 6 was extended with an ExperimentProcessor that manages the interaction with the test subject according to the steps given in Section 8.2. Database tables were created to store the test subject’s search specification and weights for later analysis. The online environment allowed a subject to enter a search specification belonging to each of the case descriptions. After clicking the “submit” button, the user was presented the search result list for that case. These two steps will be elaborated below.

The search form

The search form that was designed to be used during the experiments is shown in Figure 8.1. It allows the test subject to select desired values for the four metadata fields that were selected in Section 8.3.1 to be used in the distance measure. To make the form more naturally-looking, some extra metadata fields were added, and the ‘keywords’ field was filled in in advance with two relevant keywords: “icmp” and “internet”. The teacher is still able to modify the keywords, but this has no impact on the search results: these are pre-determined, as described in Section 8.3.4.

The search results

Figure 8.2 shows an example of how the search results are presented to the test subject. The table shows the ID of the Unit of Learning Material, a short description, and two links on which the test subject can click: ‘view’ to view the contents of a ULM, and ‘metadata’ to get the ‘metadata overview’. Figure 8.3 shows what the metadata overview looks like. The metadata fields were the same ones as used in the search specification form.

After having examined the contents and the metadata of the search results, the user could click a button “to next case” after which a new search form was presented. When the last case was finished, the subject was thanked for his or her cooperation, and was logged out.

Manual

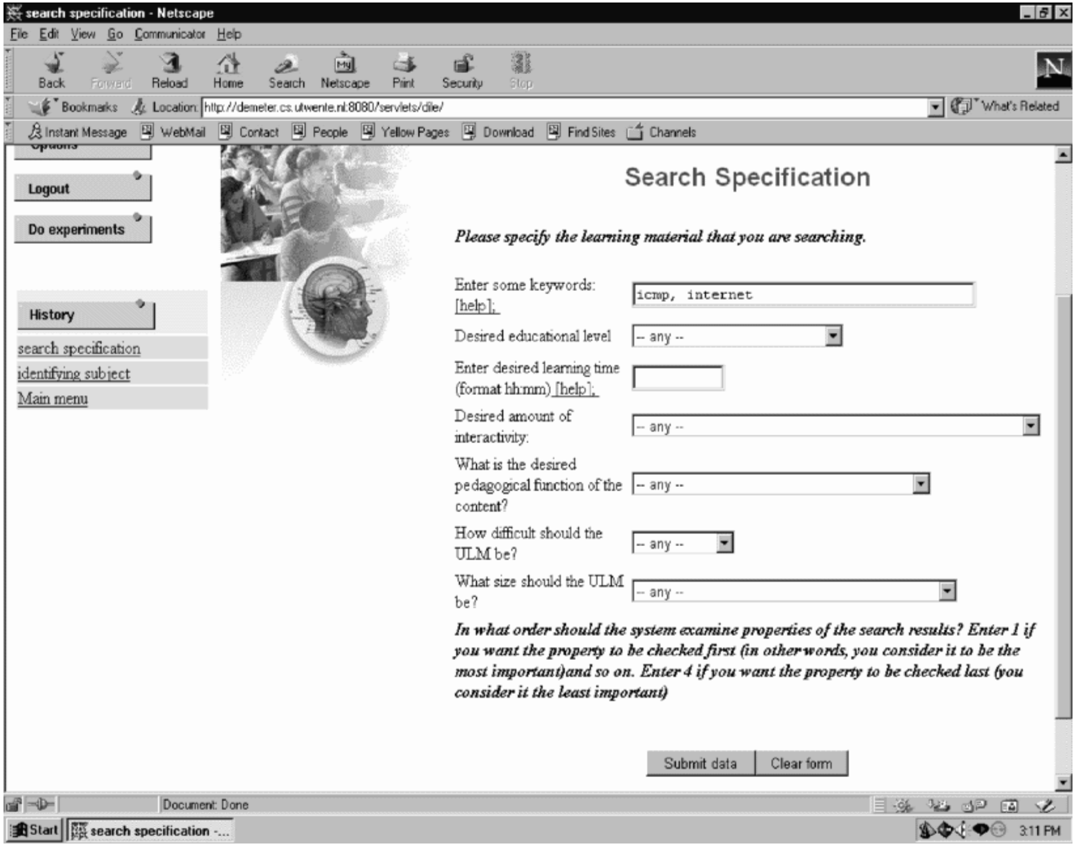
A manual was written to introduce the test subject to the experimental environment to instruct the test subject how to carry out the experiment. The figures 8.1, 8.2, and 8.3 were incorporated to prepare the test subject to using the experiment environment. The final version of the manual, after the revisions induced by the pilot test (see below), is printed in Appendix C.2 (Dutch).

8.3.6 The ULM evaluation form

As specified in Step 3 of the experiment procedure (see Section 8.2), the test subject is asked to evaluate each search result. To this end, a ULM evaluation form was designed: the form first asked the overall score for the usability of the ULM for the case.

The form also serves to answer RQ 8.2: it attempts to measure for a range of factors if these factors played a role when the test subject determined the overall grade of the ULM. As the goal of the current research is to gain insight into the criteria that teachers use to decide upon the usability of a Unit of Learning Material, many factors were included (see Table 8.1). Among these factors are also the four characteristics that form the basis of the distance measures: the amount of interactivity, the duration, the difficulty, and the size of the ULM. These were included to allow a comparison to be made between these four factors (for which the subject provides “weights” in the search specification form, see Section 8.2.1) with the other factors: if two (or more) variables are to be compared, they should be measured using identical instruments.

The final evaluation form is given in Appendix C.4 (Dutch).



Search Specification

Please specify the learning material that you are searching.

Enter some keywords: [help]; icmp, internet

Desired educational level: -- any --

Enter desired learning time (format hh:mm) [help];

Desired amount of interactivity: -- any --

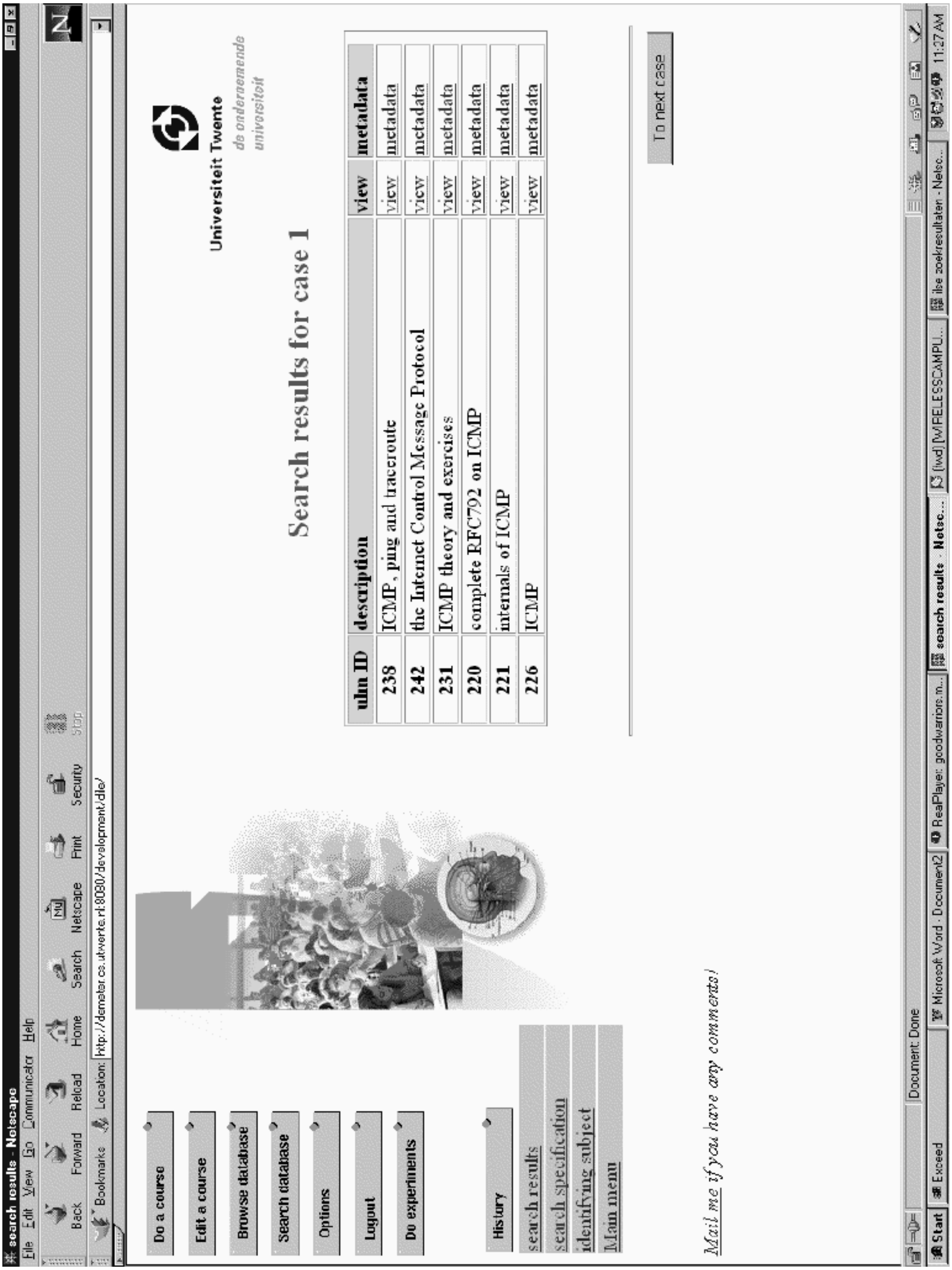
What is the desired pedagogical function of the content? -- any --

How difficult should the ULM be? -- any --

What size should the ULM be? -- any --

In what order should the system examine properties of the search results? Enter 1 if you want the property to be checked first (in other words, you consider it to be the most important)and so on. Enter 4 if you want the property to be checked last (you consider it the least important)

Figure 8.1: Search form that was designed to be used during the experiments.

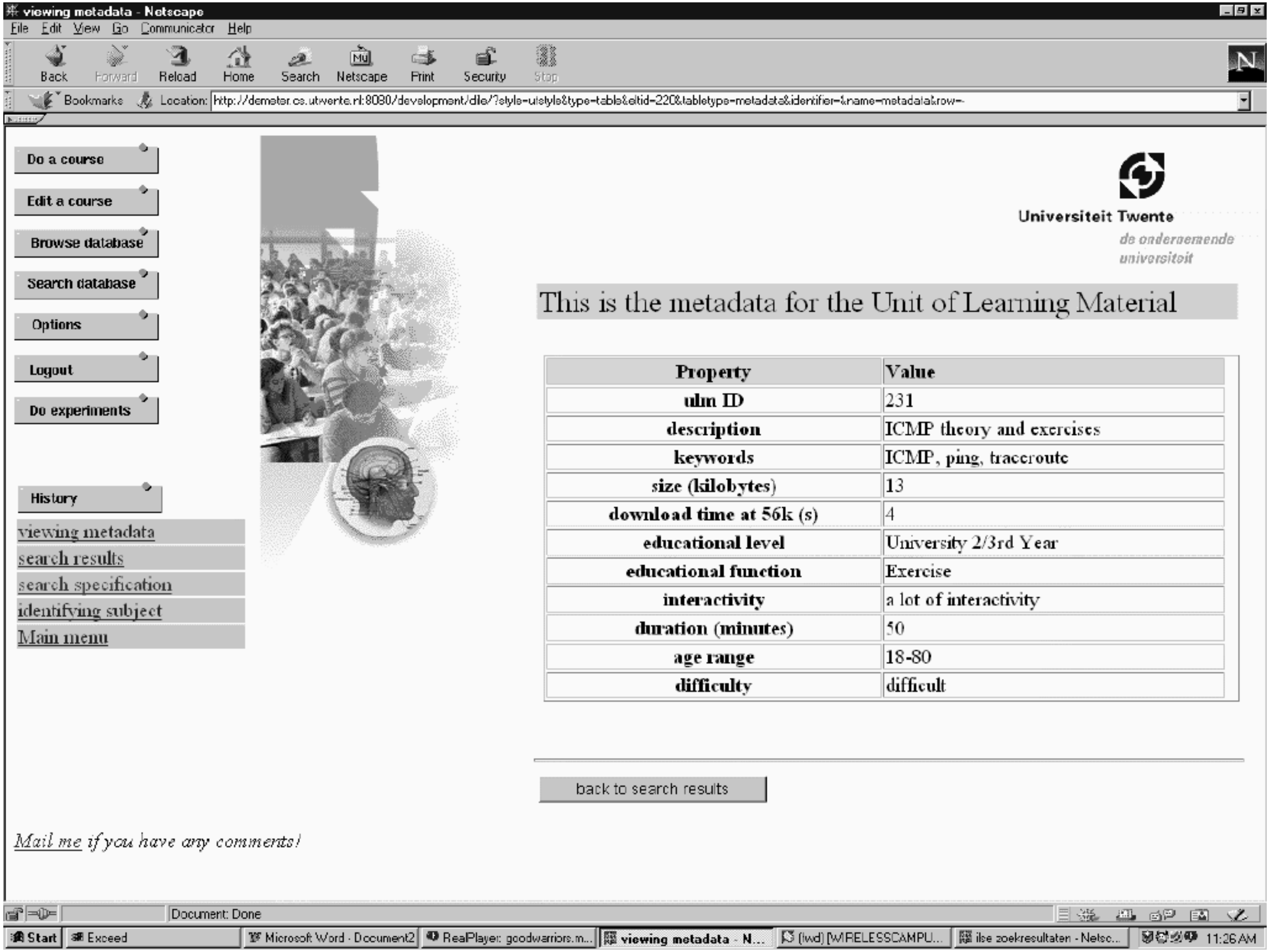


Search results for case 1

ulm ID	description	view	metadata
238	ICMP, ping and traceroute	view	metadata
242	the Internet Control Message Protocol	view	metadata
231	ICMP theory and exercises	view	metadata
220	complete RFC792 on ICMP	view	metadata
221	internals of ICMP	view	metadata
226	ICMP	view	metadata

Mail me if you have any comments!

Figure 8.2: An example of the ‘search results’ screen.



This is the metadata for the Unit of Learning Material

Property	Value
ulm ID	231
description	ICMP theory and exercises
keywords	ICMP, ping, traceroute
size (kilobytes)	13
download time at 56k (s)	4
educational level	University 2/3rd Year
educational function	Exercise
interactivity	a lot of interactivity
duration (minutes)	50
age range	18-80
difficulty	difficult

Mail me if you have any comments!

Figure 8.3: An example of a ‘metadata overview’ screen.

8.3.7 Pilot test

In the previous section, the various parts of the research instrument were described: the dimensions of the distance measure, the contents of the database, the case descriptions, how the search result list is composed, the experimental environment, the manual, and the ULM evaluation form. To verify if these components together interoperated as intended, a pilot test was performed on August 29th, 2000 with a test subject (a researcher in the area of computer networks). The subject first read the manual, and was asked whether anything was unclear. The subject indicated that everything was clear to him. Then, the subject was asked to carry out the experiment, and to mention any difficulties. The researcher kept a time log to see how much time every step took to get an impression of the time a test subject would need to complete the experiment.

The following issues arose:

- The subject found it difficult to indicate whether or not he agreed with the propositions on the evaluation form.
- The evaluation form said ”number” while the prototype said ”ID” when indicating ULMs.
- The subject wondered whether he had to fill in factors on the evaluation form that were irrelevant to the case. The instructions should mention that this is not needed.
- The evaluation form should have “I agree” on the right hand, and “I disagree” on the left hand instead of the other way around.
- The subject wondered whether ULMs could be combined into larger constructs. This is not allowed, so the manual should explain this clearly.
- The button “back to search results” in the online environment did not always work as expected if the subject had also used the “back” button of the web browser.
- The subject needed about 15 minutes to do one case; this was slightly more than anticipated so that it was decided to let each subject do only three cases.

During this pilot test, as well as during informal discussions with other teachers, two more factors were determined that might be of importance when judging the usability of a ULM: the level of completeness (denoted as $F_{completeness}$) and the measure to which the abstractness level of the ULM was appropriate for the educational situation (denoted as $F_{abstraction}$). These two factors were added to the list presented in Table 8.1 and to the ULM evaluation form.

These issues were resolved in the next version of the evaluation form, which is depicted in Appendix C.4. The prototype was also updated to address these issues, as well as the manual (see Appendix C.2).

8.4 Subjects

To ensure the validity of the experiment, the subjects have to be familiar with the subject matter so that they can make a founded decision upon the usability of a ULM in the hypothetical situations. As the subject matter, the Internet Control Message Protocol, is often part of courses on computer networks, the websites of Dutch technical universities were browsed to search for teachers that give these courses. During the search for online learning material (see Section 8.3.2) a non-technical university was discovered that also gave a course on computer networks. In total, 11 teachers were found. The teachers were approached by email to inquire whether they were willing to participate in the experiment; the letter used can be found in Appendix C.1 (Dutch). The teachers of the University of Twente, where the researcher had his office, were approached in person. Nine teachers agreed to participate: four from Delft University (TUD), two from Eindhoven University (TUE), two from Leiden University (LU) and three from Twente University (UT).

8.5 Experiment

This section will first present the results of the experiment concerning the validation of the distance measures (to answer Research Question 8.1), and then it will discuss the factors that are relevant to the teachers when selecting online learning materials (to answer Research Question 8.2).

8.5.1 Data collection

The experiment was conducted by the subjects during September and October 2000. After a gentle reminder in person or by e-mail, a total of five subjects (out of 9 invited subjects) had completed the experiment.

The data were encoded in the following manner. The search specification form provided two types of data: four weights and four values for the metadata fields Interactivity, Size, Duration, and Difficulty. The weights together form the weight vector **w**, and the four metadata values together form the ‘ideal ULM’. These values are then used to calculate the three distance measures as explained in Section 8.3.1.

The second source of data is the ULM evaluation form. The variable S records the score that the subject assigns to the ULM. The ULM evaluation form also provides data on the factor variables as listed in Table 8.1. These variables take the value “1” if the subject indicated that the factor did play a role when judging the usability of a ULM, and “0” in all other cases.

The third source of data are the distances as calculated using the three formulas for the Weighted Euclidean Distance (WED), the Weighted Taxicab Distance (WTD), and the Equal Weights Distance (EWD), yielding the variables WED, WTD, and EWD.

8.5.2 Validity of the distance measure

Recall Research Question 8.1:

> How does the prediction of the usability of a ULM according to the distance measures compare to the judgement of usability of that ULM according to a teacher?

In the current experiment, the phrase “prediction of the usability of a ULM” is operationalized using the distance between the ULM and the ‘ideal ULM’ of a teacher, measured by three distance measures: WTD, WED and EWD. The phrase “judgement of usability of that ULM according to a teacher” is operationalized by the score that a teacher assigns to a ULM, and is measured by variable S.

Table 8.9 shows the correlations between the scores of the subjects and each of the three distance measures: the Equal Weights Distance (EWD), the Weighted Euclidean Distance (WED) and the Weighted Taxicab Distance (WTD). The table shows large differences in correlation coefficients: all three distance measures performed very well with subject 3 (-0.67, -0.51 and -0.56). A correlation coefficient of -0.67 means that $-0.67^2 = 44\%$ of the variance of the score S can be explained by the variance of the distance measure (EWD). The fact that the coefficient is negative means that as the distance between a search result and the ‘ideal ULM’ becomes smaller, the usability score the subject assigns to the result gets larger.

On the other hand, the distance measures failed to predict the scores of subject 2: no significant correlation exists between any of the distance measures and the scores of subject 2. There were no indications that these scores could considered to be “outliers”, so they could not be removed from the dataset. The first conclusion that can be drawn from these results is therefor that apparently the distance measures (as used in the experiments) are not able to predict the scores of *all* teachers. However, the second conclusion is that apparently the distance measures work reasonable well for *some* teachers: almost all distance measures correlate with the scores of the teachers.

Table 8.9: Spearman's correlation coefficient for the relationship between the subject's score S and the three distance measures EWD, WED, and WTD

	EWD		WED		WTD		
Subject	corr	sig	corr	sig	corr	sig	N
1 (UT)	-0.18	0.47	-0.45	0.06	-0.34	0.16	18
2 (UT)	-0.07	0.79	-0.05	0.85	-0.09	0.71	18
3 (TUD)	-0.67	0.00	-0.51	0.03	-0.56	0.02	18
102 (TUE)	-0.53	0.02	-0.46	0.05	-0.25	0.32	18
103 (TUE)	-0.56	0.02	-0.44	0.07	-0.44	0.07	18
All subjects	**-0.21**	**0.04**	**-0.26**	**0.01**	**-0.20**	**0.06**	**90**

UT: University of Twente
TUE: University of Eindhoven
TUD: University of Delft

The line "all subjects" in Table 8.9 shows the overall performance of the three distance measures. It shows that in general, the Weighted Euclidean Distance performs best (correlation coefficient -0.26, predicting 6.7% of the variance). The performance of the Equal Weights Distance, however, is not very much worse: a correlation coefficient of -0.21. Recall that in the Equal Weights Distance, all metadata fields are assigned an equal weight. So a third conclusion that can be drawn from the current research is that the "relative importance" (the weight vector **w**) that teachers assign to the metadata fields has not much effect on the performance of the distance measure. To get more insight into the effects of the weight vector, the next paragraph will analyze the experimental data some more.

8.5.3 The effect of the weight vector

To analyze the predictiveness of the distance measure with different weight schemes, the correlations were re-calculated using different "weight steps": a weight step of zero yields the equal weights distance. A weight step of 0.1 yields the weights 1.0, 1.1, 1.2, and 1.3 (so that weight 1.3 is assigned to the characteristic which the teacher finds most important, weight 1.2 is assigned to the characteristic which the teacher finds second-most important, and so on). Table 8.10 presents the results of this analysis. From these results it follows that a weight step of about 0.8 gives the best correlation between the subjects' scores and the Weighted Euclidean Distance, although there is not much improvement compared to a weight step of 1.0. Figure 8.4 presents these results in a diagram.

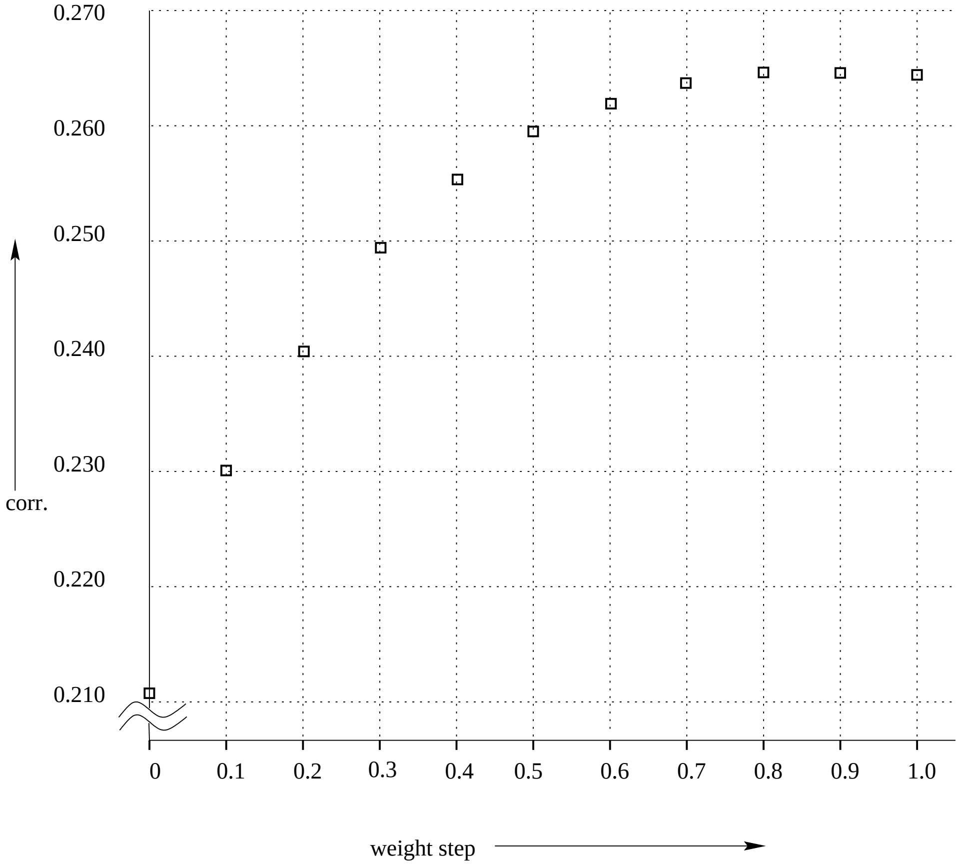


Figure 8.4: The correlations between the weighted Euclidean distance and the test subjects' scores with different weight steps (N=90).

Table 8.10: Correlations between the weighted Euclidean distance and the test subjects' scores with different weight steps (N=90).

weight step	correlation	significance
0.0	-0.213	0.044
0.1	-0.230	0.029
0.2	-0.241	0.022
0.3	-0.249	0.018
0.4	-0.255	0.015
0.5	-0.259	0.014
0.6	-0.262	0.013
0.7	-0.264	0.012
0.8	-0.265	0.012
0.9	-0.265	0.012
1.0	-0.264	0.012

8.5.4 Usability of the distance measures

From the experiment and the analysis of the results it can be concluded that for some teachers, the distance measure works remarkably well, while for others, it does not seem to work at all. Apparently, teachers think and act quite differently while working with an online database of learning materials. Further research should be done to discover in what aspect teachers are so different.

In the experiment, three distance measures were tested: an Equal Weights distance where all metadata fields are weighted equally, and two weighted distance measures that are defined differently (one using the Taxicab distance, and one using the Euclidean distance). From the analysis, it can be concluded that the distance measures work best when a weight step of about 1 is chosen. The fact that the weighted distance measures work better than the equal weights distance support the hypothesis made in this thesis that a distance measure can be based on weights that teachers assign themselves when submitting their search specification to the educational database.

8.5.5 Factors

Recall that on the ULM evaluation form, 12 factors were mentioned for each of which the subjects had to indicate whether or not this factor played a role when judging the usability of a search result (see Section 8.2.1). These factors were included to find answers to Research Question 8.2: what factors are relevant to teachers when making a judgement about the usability of learning materials? Having an understanding of these factors is important to create a search method (i.e. a distance measure) that can help the teachers in finding relevant learning material.

As each subject has judged six ULMs in three cases, there are 18 ULM evaluation forms per subject; so five subjects yield a total of 90 evaluation forms. For each factor, the times a subject had indicated that the factor did play a role when judging the usability of a ULM. The resulting histogram is pictured in Figure 8.5.

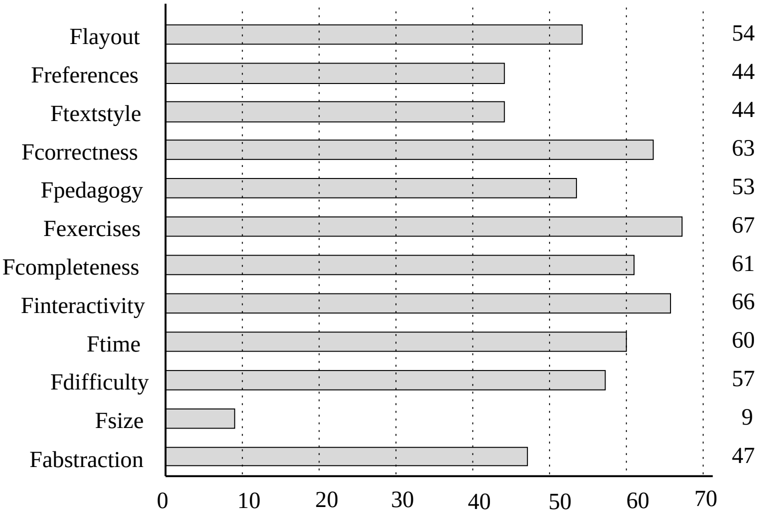


Figure 8.5: Histogram of the times a factor was relevant to a subject (N=90).

The figure shows that almost all factors are taken into account when judging the usability of a ULM (44 to 66 times out of 90). The only factor that is not often considered is F_{size}, which represents the size of a ULM. Note that the factors on which the dimensions of the distance measure are based in the current experiment (interactivity, difficulty, size and time) were also measured. The figure shows that there are other factors that are more often considered when judging the usability of a ULM. This data suggests that the distance measure as used in the current research can be improved by removing the “size” dimension (which is not considered often by the subjects), and including other factors that the teachers do consider often according to Figure 8.5, *and* that are semantically orderable as explained in Section 7.2.1, such as the completeness and the abstraction level of a ULM. Further research can use this input to refine the distance measure, and to try to increase the “predictability” of it (i.e. the correlation between the distance measure and the teacher’s scores for the usability of a ULM).

8.6 Conclusion

This chapter has explored a novel search method based on educational metadata to answer Research Question 3. The method uses a distance measure that calculates how much a search result differs from the search specification (i.e. how relevant it is to a teacher). Based on results from a survey research described in Chapter 7, it was decided to base the distance measure ('how different is a search result from the search specification') on weights that had to be indicated by the teacher explicitly each time he or she submits a search query to the database.

In this chapter, an experiment was devised to validate three distance measures: a weighted Taxicab distance, a weighted Euclidean distance (in which the weights increase by 1) and a Euclidean distance with equal weights. The data suggest that a weight step of about 1 yielded optimal results, while the performance decreased rapidly with a smaller weight step. Therefor, a Weighted Euclidean Distance with a weight step of 1 should give the best results (i.e. it correlates best with the teachers' judgement on the usability of the search results).

It should be noted that for some test subjects, the distance measure worked particularly well (up to a correlation of -0.67), while for other subjects no significant correlation was found. Apparently, for some persons it works better than for others. Further research is needed to study why it works well for some subjects, and why it doesn't for others.

Finally, this chapter investigated what characteristics (factors) of learning material were relevant to the test subjects when judging the usability of the search results. The research results suggested that only one of the presented factors was almost never found relevant: the size of learning materials. The other factors were found relevant many times. This thesis proposes that the more of these factors are incorporated into the distance measure, the better it will be able to predict the teachers' scores on the usability of search results.

Chapter 9

Conclusions and recommendations

9.1 Introduction

This section will discuss the results of this thesis. Section 9.2 will recall the research questions, and discuss what answers were found. Then, Section 9.3 will state some recommendations for other research efforts based on the results of this thesis. Section 9.4 will conclude the chapter.

9.2 The Research Problem

In the past ten years, many new technologies emerged. The World Wide Web has become popular; personal computers that can play audio and video have become affordable for students; educators are using computers more and more as an educational tool. These developments enable the concept of a "database of learning materials" that, amongst others, teachers can use to store, search, and retrieve learning objects. To save development costs, learning objects could be reused for several different target groups, in different situations, and even at different educational institutions distributed all over the globe, using the World Wide Web as an information delivery infrastructure. However, to build a database of learning materials more insight is needed into storing and retrieving learning materials, and how the reusability of these materials can be improved. To find these insights, this thesis tried to answer the following research questions:

RQ1 What is an appropriate model to store and retrieve multimedia learning material so that it can be used by multiple target groups with different information needs?

RQ2 What factors are of influence on the reusability of learning materials that are stored in a multimedia database?

RQ3 Is it possible to develop a search method based on predicting the usability of search results based on educational metadata, so that retrievability and thus reusability can be increased?

RQ4 What is an appropriate software architecture for a database application that allows learning material to be stored in, and retrieved from a multimedia database using, if possible, the new search method developed while answering RQ3?

The sections below will describe how answers were found for each of these research questions.

9.2.1 Units of Learning Material

The answer to RQ1 consists of a model for Units of Learning Material (ULM) described in Chapter 4. The model is based on other models for various purposes and target groups that were described in the literature. A prototype implementation that uses this model has been built (see Chapter 6, and experiments with teachers have indicated that teachers are able to work with the model to create and manage online learning materials.

Key characteristics of the model include:

- it includes the concept of 'educational metadata': information *about* the ULM, such as: who created it, for what purpose, and for what target audience. This information can be used by teachers as well as students to search ULMs in databases of learning materials.
- The model includes conceptual relationships (ULM A describes something that 'moves-inside' the object ULM B describes) and educational relationships (ULM A 'is-example-of' ULM B). These relationships can be used to build conceptual structures that students can browse through as if it were a knowledge landscape (see Section 4.2.1).
- The model includes the concept of 'context adapters': small (textual) elements that are presented before or after a certain ULM to change the context for which the ULM was originally designed. This makes the ULM more generic, and thus more reusable.

Only the opportunities that the educational metadata provides are explored in this thesis. Although the relationships and the context adaptors also provide many opportunities that can be used to enhance electronic learning systems, due to time constraints these characteristics were not further studied. More research is needed to explore these concepts and to develop methods and design principles to use them effectively in educational learning systems.

9.2.2 Factors of Reuse

Regarding RQ2, a model has been developed that tries to capture various factors that influence the amount of reusability of a Unit of Learning Material. The model is called “Formula-M” (Factors Of Reuse of MULtimedia learning Materials), and is described in Chapter 4. Three global factors were identified: accessability, genericity, and opportunities for reuse. From these, nine subfactors were derived. The model functions as an organizer that locates these factors in a framework. Also, it can serve as a checklist to find opportunities to increase reuse of learning materials in an educational database.

For two of the factors, methods have been developed to gain control of them with the goal of increasing reuse:

1. the *search method* that is used to find appropriate Units of Learning Material that reside in an educational multimedia database system. In this thesis, a search method was developed based on educational metadata (see RQ3 and Chapter 7).

2. the *genericity* of learning materials can be increased by detaching the (institution-specific) layout from the content. An architecture that enables this decoupling has been developed (see Chapter 6).

Future research should be directed towards developing methods to gain control over the remaining factors, so that more options are available to educational system designers to increase the amount of reuse of learning materials.

9.2.3 Distance Measure

To provide an answer to RQ3, Chapter 7 describes the development of a so-called “distance measure” that tries to predict the usability of search results to a teacher. This is achieved by comparing the educational metadata fields of the search results and the search specification of the teacher (also expressed using educational metadata fields): how different are they? Using such a prediction, a database system is better able to return only the most usable Units of Learning Material. Chapter 8 describes an experiment to test if the proposed distance measure is indeed able to predict the usability of ULMs. The results suggest that for some teachers the distance measure is very well able to predict the usability of search results, while for some teachers it is not at all able to predict the usability (see Section 8.5.2).

What is the cause of this? The fact that the distance measure is unable to predict the usability of learning materials, means that apparently some teachers base their judgement upon other characteristics than ‘encoded’ in the metadata used in the experiment. A possible explanation could be that these other characteristics are related to pedagogical principles that are difficult to explicitly describe. From conversations with teachers about this subject, it appeared that sometimes teachers choose a ULM just because it contains a picture that perfectly explains the relationships between concepts of the subject matter, or because a ULM contains a very good exercise. Even if other characteristics of the material are less optimal (such as amount of interaction, or size) then the teacher will still choose the ULM. It could be that teachers for whom the distance measure works better base their opinion more upon the explicit characteristics of the ULMs.

This leads to the proposition that the distance measure is perhaps better suited for application areas where a user will base his or her judgement more on the characteristics encoded in the metadata fields. For example, on the Internet hundreds of building plans for model airplanes can be found. Now, imagine an online database of building plans for model airplanes that uses metadata fields based on semantically orderable properties of these plans, such as the airplane’s wing span, engine power, weight, and scale factor of the plane. A distance measure could be based upon these metadata fields, and a search interface could be built that allows the user to search building plans. The user would then be able to find building plans that suit his basic requirements, after which he would be able to customize the airplane during the actual building process (using balsa wood, a knife, glue, and paint).

Stated in more general terms, the distance measure may be well suited for those application areas where a certain degree of ‘re-purposing’ or manufacturing is already part of the natural process. In the educational setting, most teachers want to reuse a ULM unmodified; changing it may sometimes even cost more time than creating it from scratch.

The distance measure as it was used in Chapter 8 uses the following metadata fields: size, educational level, difficulty, and typical learning time. Using these fields, it is able to predict the usability of Units of Learning Material to some extent. If more metadata fields are taken into account by the distance measure, then it may be better able to predict the usability of ULMs. Further research is needed to investigate what combination of metadata fields yield the best results (i.e. allow the distance measure to best predict the usability of ULMs).

9.2.4 Software Architecture

Chapter 6 describes a software architecture to answer RQ4. To make sure that the architecture is able to function properly in practice, a list of ten requirements was developed (see Section 6.2). These requirements express the need for the basic functionality, the user interface, performance requirements, and design constraints. Table 9.1 presents the ten requirements, and the sections in which it is described how these requirements are met.

Table 9.1: Requirements that the software architecture has to meet

req.	description	Section
functional requirement		
6.1	functions: entry and retrieval of learning materials	6.5.1
interface requirements		
6.2	user shall not need to install many components	6.5.2
6.3	system shall be built as a network resource	6.5.1
performance requirement		
6.4	the architecture shall provide scalability	6.5.4
design constraints		
6.5	the statelessness of WWW must be solved	6.5.1
6.6	use a search method based on a distance measure	8.3.5
6.7	allow for separation between layout and content	6.5.3
6.8	provide navigational clues to the user	6.3.2
6.9	provide a modular design	6.4
6.10	shall run under various Operating Systems	6.5.1

The architecture has proven to allow implementations that can have many different “faces”. The face of an application can be changed without running the risk of altering the programming instructions by accident; no HTML, SQL and script languages need to be interleaved, thus preventing many errors. Encoding the database results, and in fact the entire interaction between the user and the application in XML has proven to be a suitable way to implement the separation of content, layout, and programming instructions.

XML was also used to encode the internal structure of ULMs. This concept was not explored fully, as many good alternatives exist (such as SMIL, HyTime, MHEG). Still, an Educational Markup Language that is based on XML provides many advantages such as enabling search methods based on the internal structure of ULMs, and adding layout to ULMs using XSL. For example, assignments and questions can be automatically made accessible by clicking a button, or a search method could automatically show only the introduction of a ULM so that the user can quickly get an impression of what the ULM is about. The disadvantage is that dedicated XML-authoring tools are needed, that are able to communicate properly with the educational database application itself. As XML gains more momentum in industry, these tools will probably become available during the current decade.

This thesis has shown that using the XML/XSL duo, content and layout can be separated. Due to this property, XML is very useful as a vehicle to transport certain content to various types of end-user "terminals": mobile devices, desktop computers, text-only devices, or as input for automated information processing devices. XML is better suited for these tasks than HTML; it is, for example, very difficult to display HTML pages with a rich layout on text-only devices. This thesis therefor recommends that XML be used in the next generation of the World Wide Web.

9.3 Recommendations

Based on the results from the current research, a number of recommendations can be stated. These will be discussed below.

9.3.1 Educational Metadata

Educational metadata standards are currently emerging. In order for a distance measure to be based on educational metadata, an important requirement has to be met: the metadata values should be *semantically orderable* (see Section 7.2.1). This means that at least a fixed vocabulary is needed for such values, and second, that the values for the metadata fields should be chosen so that an ordering upon these values can be imposed.

9.3.2 Database Management Systems

Database Management Systems should focus on efficiently delivering multimedia content via the World Wide Web. A DBMS should provide direct access using the HTTP protocol to the multimedia objects, which effectively means that they should be tightly integrated with a web server. It should not be necessary to first *copy* the multimedia object to a file, which is then made accessible via a separate webserver. Some commercial database systems already provide mechanisms to efficiently deliver multimedia content via the web, such as the Informix Universal server.

9.3.3 Information Retrieval

In Chapter 8 a novel research method was used to test the effectiveness of a search mechanism (the distance measures). The method involves developing various case descriptions, and asking an expert to create a ‘fake’ search result list. Test subjects then examine the result list, and assign scores for the relevance of each search result. This list is then correlated with the ‘prediction’ of the search method that is to be tested (see Section 8.2.2).

The Information Retrieval discipline should examine this research method to determine if it can be used to test the effectiveness of other search methods and algorithms.

9.3.4 Distance Measure

The distance measure has been developed specifically for educational database systems. However, it can be applied to many more areas, such as a database of building plans for model airplanes. There are many more possible application areas. To develop a distance measure for another application area, the following steps should be taken:

1. define a model of the objects that are to be stored in the database
2. perform research to find the characteristics that the users of the database system find most important;
3. define metadata incorporating these characteristics, in such a manner that the characteristics are *semantically orderable* as much as possible;
4. construct a distance measure based upon these orderable characteristics;
5. perform research (much the same way as done in Chapter 8 to study if the distance measure is sufficiently able to predict the usability of the search results;
6. adjust the metadata definition if needed, and re-test if necessary.

These are globally the steps taken in the current research, and this approach could also work well in other application areas.

9.4 Concluding remarks

This thesis forms a bridge between two disciplines: Educational Technology and Computer Science. Collecting knowledge from these two disciplines has been found fruitful: educational metadata can be used to develop a novel search method that is not only relevant to the educational world, but that may also prove useful to many other disciplines. In this respect, this thesis is truly *multidisciplinary*.

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Summary

Research into methods to use computers in education started already in the sixties. This research is a continuous process, because information technology is also in continuous motion: new technologies become available every year, and with it also new possibilities to use these technologies in education.

A technology that has seen a tremendous growth during the nineties is the World Wide Web (WWW): millions of computers distributed over the entire globe that together make available a huge amount of information in the form of web pages. These pages can contain text, but also pictures, movies, and interactive elements, or in other words, multimedia data. A standard consumer PC as it is for sale currently is very well able to handle these kinds of data.

Another development that is important for the research described in this thesis, is the development of relational databases. These were primarily used for administrative data in the eighties, but a number of new developments has made them suitable to also store multimedia data (see also Chapter 2).

The combination of these two developments led to the concept of a *multimedia database of learning materials* that can be used by students and teachers via the WWW. During the nineties, a lot of research efforts were put into developing this concept. However, a problem that remained was that the costs of developing multimedia learning materials can be quite high. To reduce these costs, researchers have focused on *reusing* the same materials for different target groups on different educational levels. Many factors can affect the reusability of learning materials; these have been organized in the Formula-M model in Section 4.4 of this thesis.

A teacher that is looking for learning materials for a particular course can access the database to check if another teacher has entered suited material previously, and if so, reuse it in his or her course. The pieces of learning material that are stored in the database are called “Units of Learning Material”, or ULMs for short.

The question that arises is, however: what Units of Learning Material are ‘suited’ given a certain educational setting[1]? The database must be able to de-

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[1] An educational setting are all educational aspects of the given situation, such as the target group,

termine this ‘suitability’, but at the moment a computer is not capable to determine this itself. This knowledge must be added to a Unit of Learning Material by human beings in the form of so-called “educational metadata”. This is information that describes the object at hand: who made it, with what pedagogy, for what target group, how large is it, about what subject matter is it, how difficult is it, and so on (see Section 5.8). A standard that specifies these metadata is in preparation; using this standard, it is precisely known what characteristics need to be described, and what ‘values’ are allowed for these characteristics. If a teacher specifies his search criteria in terms of these metadata values, then the database can use these values to check if a certain ULM present in the database fits the teacher’s search criteria.

But there’s one problem: most database systems can currently only compare whether the values for metadata fields are exactly identical, which is called “perfect matching”. For example, a value “very difficult” for a characteristic “difficulty” of a certain is not exactly identical to a search criterium “a bit difficult”, so that the database decides not to return this ULM as a search result. However, the other fields of this ULM might match all other search criteria perfectly, so that the ULM might be a very usable to the teacher. This thesis tries to solve this problem by proposing a measure of conformity between the search criteria and the ULM, based on the metadata values. The database will then be able to find those ULMs that best conform to the search criteria.

If the metadata characteristics are modeled using dimensions of a mathematical space, then mathematical formulae can be used to calculate the distance between two ULMs (see Section 7.2). The search criteria then also need to be modeled as a (possibly non-existent) ULM: the “ideal ULM” that exactly matches all search criteria. The measure of conformity between a particular ULM and the search criteria is then equal to the distance between that ULM and the ideal ULM, and therefor it is called a *distance measure*.

It should be noted, however, that not all characteristics are equally important to a teacher. For example, a characteristic “duration”, indicating how much time a typical student needs to work with the ULM, can be very important to a teacher whose course already poses a high time demand upon the students. Similarly, a characteristic “interactivity” can be very important to a teacher that is convinced that education is more than just absorbing information, and that there should be an interaction during the educational processes. This observation leads to the proposition that there might be a relation between the importance (“weight”) a teacher assigns to a characteristic, and his or her attitude towards giving education. If this importance would be known then the computer would not have to ask them to the teacher with each search query, which would simplify the search process.

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the pedagogy that is being used, the educational level, and so on.

To attempt to find this relation, an experiment was conducted (see Section 7.3). The teachers' attitude towards giving education was described using a variant of the model proposed by Samuelowicz and Bain (1992) who used five dimensions. In the variant, one of the dimensions was split into three dimensions, resulting in seven dimensions. The 'position' of the test subjects on each of these seven dimensions was determined using a questionnaire. The questionnaire also presented six hypothetical educational situations, and asked the test subjects to indicate how important they found five characteristics of learning material using the numbers 1 to 5. An analysis of the data only revealed a few very weak relations. The purpose of the experiment was to *predict* the weights of the characteristics to a teacher, but for this there were too fewrelations, and those that were found were too weak.

The implication of this is that the weights a teacher assigns to characteristics of learning material have to be asked with each search query. To investigate how effective the distance measure is using this method, a second experiment was developed. In this experiment, the test subjects had to work with a prototype of an educational database. The effectiveness of the distance measure (which indicates how well a search result conforms to the search criteria) was measured by comparing the computed distance with a human judgement on the usability of the search results: it can be expected that the smaller the distance is, the better the judgement will be. In the experiment, the test subjects were given a hypothetical educational situation, and they were asked to give search criteria that ULMs should conform to in that situation. The search criteria consisted of five characteristics of learning material as specified in the metadata standard. Then, the test subject was asked in what order the system should check each characteristic; it was assumed that the characteristic that the subject would like to have checked first was the most important one; the characteristic that should be checked second was the second-most important one, and so on. Then, the prototype would present a predetermined list of search results, and the test subject was asked to evaluate each search result and indicate a score ranging from 1 to 10. The prototype calculated the distance between each search result and the 'ideal ULM', making use of the weights that the test subject indicated. These distances were compared with the scores of the test subjects after the experiment. An analysis showed a strong relation between the computed distance and the scores of some test subjects, while it did not show a relation at all with some other test subjects (see Section 8.5).

In the experiment described above, only a small number of characteristics of learning material was used, described in metadata fields (the selection of these fields can be found in Section 8.3.1). The experiment assumes that using these characteristics it can be predicted whether the teacher finds the search result usable in the given situation. As such, these characteristics are *factors* that relate to the judgement of the teacher. The more factors are known, the better the prediction will be. So the experiment also tried to provide insight into what other factors play a role during the judgement of the teacher. The test subjects were asked for each search result that they evaluated to also indicate for twelve factors whether this factor played a role during the evaluation process or not. The results showed that almost all of these factors play about equally often a role; except the factor "size" (F_{size}) that did not very often play a role. As these twelve factors also included the five characteristics of learning amterial that were used in the distance measure, it can be concluded that there are still $12 - 5 - 1 = 6$ factors that do play a role when judging learning materials, but that have not been included into the distance measure.

From the results of this experiment it can be concluded that the distance measure does have potential, but that there is insufficient insight into what factors play what role when a teacher is judging online learning materials. At least six factors that do play a role have not been considered in the distance measure, which could explain why the distance measure appeared to be able to well predict the scores for some teachers, while it was not able to do so for other teachers. This provides many opportunities to improve the distance measure.

Applying a distance measure based on metadata does not need to be restricted to the educational domain. In every domain where metadata is used that fulfills certain requirements (see Section 7.2) a distance measure can be defined; also, the research method of comparing a computer judgement (the distance measure) with a human judgement to validate the computer judgement, could prove to be very useful in other application areas as well.

Samenvatting

Al sinds de jaren 60 wordt onderzoek gedaan naar methoden om computers toe te passen in het onderwijs. Dit is een continu-proces, omdat de informatie-technologie evolueert: wanneer nieuwe technologiën worden ontwikkeld, ontstaan ook nieuwe mogelijkheden om deze technologie toe te passen in het onderwijs.

Een technologie die vooral in de jaren 90 een zeer grote groei heeft doorgemaakt, is het World Wide Web (WWW): miljoenen computers verspreid over de hele wereld ontsluiten een zeer grote hoeveelheid informatie in de vorm van web-pagina's. Deze pagina's kunnen multimediaal zijn, waaronder verstaan wordt dat ze behalve tekst ook foto's, filmpjes, en interactieve elementen kunnen bevatten. De PC zoals die voor consumenten te koop is, is ook steeds beter in staat om deze soorten gegevens op te slaan en af te spelen.

Een andere ontwikkeling die belangrijk is voor het onderzoek dat beschre-ven is in dit proefschrift, is de ontwikkeling van relationele databanken. Deze werden in de jaren '80 en daarvoor voornamelijk gebruikt voor administratieve gegevens, maar daarna was er een aantal ontwikkelingen die ertoe geleid heeft dat databanken steeds meer geschikt werden om er ook multimediale data in op te slaan (zie ook hoofdstuk 2).

De combinatie van deze twee ontwikkelingen geeft aanleiding tot het concept van een *databank met multimediaal leermateriaal*, welke door studenten en docenten via het WWW geraadpleegd kan worden. In de jaren '90 is er al veel onderzoek gedaan om dit concept verder uit te werken. Een terugkerend probleem was echter dat het maken van multimediaal leermateriaal erg prijzig is. Om deze kosten te delen, hebben onderzoekers zich gericht op het *hergebruiken* van leermateriaal voor verschillende doeleinden. Verschillende factoren kunnen van invloed zijn op de herbruikbaarheid van leermateriaal; deze zijn samengevat in het Formula-M model in paragraaf 4.4 van dit proefschrift.

Een docent die op zoek is naar leermateriaal voor een bepaald vak, kan de databank raadplegen om te zien of andere docenten al eerder een geschikt stukje leermateriaal hebben gemaakt en ingevoerd, en zo ja, deze (eventueel met wijzigingen) opnemen in zijn of haar cursusmateriaal. Deze stukjes leermateriaal die in de databank worden opgeslagen, worden “leerobjecten” genoemd of ook “eenheden van leermateriaal” (Units of Learning Material, of ULMs).

De vraag die hierbij echter rijst is: welke leerobjecten zijn ‘geschikt’ gegeven een bepaalde onderwijscontext[2]? De databank moet dit kunnen beoordelen, maar het is vooralsnog onmogelijk dat computers zelf kunnen beoordelen welk leermateriaal het meest geschikt is voor een gegeven situatie. Deze kennis wordt daarom door mensen toegevoegd aan een leerobject middels wat men noemt “onderwijskundige metadata”. Dit is beschrijvende informatie over onderwijskundige kenmerken van het materiaal, zoals: wie het gemaakt heeft, met welke pedagogiek, voor welke doelgroep, hoe groot het leerobject is, over welk onderwerp het materiaal gaat, hoe moeilijk het is, enzovoorts (zie paragraaf 5.8). Er is een standaard in voorbereiding die deze metadata specificieert; wanneer gebruik gemaakt wordt van deze standaard is precies bekend is welke kenmerken beschreven moeten worden, en welke ‘waarden’ daarvoor toegestaan zijn. Wanneer een docent dan aan de databank opgeeft voor welke doelgroep en welk onderwerp materiaal nodig is (de zoek-criteria) dan kan de databank door middel van de metadata nagaan welke aanwezige leerobjecten aan deze criteria voldoen.

Een probleem dat zich hierbij echter voor kan doen, is dat een databank slechts in staat is om te vergelijken of de door de docent opgegeven gewenste waarde voor een kenmerk, bijvoorbeeld de waarde “zeer moeilijk” voor het kenmerk “moeilijkheid”, precies gelijk is aan de waarde die de leerobjecten in de databank hebben voor dit kenmerk; men noemt dit een “perfect match”. Een leerobject met de waarde “moeilijk” komt dan al niet meer in aanmerking, terwijl dit leerobject voor wat betreft de overige kenmerken misschien wel zeer toepasselijk is. In dit proefschrift wordt getracht dit probleem op te lossen door een maat op te stellen voor de *gelijkenis* tussen de opgegeven zoekcriteria en een leerobject. De databank zal dan in staat zijn om de leerobjecten te vinden die het meest lijken op wat de docent opgegeven heeft.

Wanneer de metadata-kenmerken opgevat worden als dimensies van een wiskundige ruimte, dan kunnen wiskundige formules gebruikt worden om de afstand te berekenen tussen twee leerobjecten (zie paragraaf 7.2). De zoekcriteria die de docent opgegeven heeft, moeten dan ook worden opgevat als een fictief leerobject: het ‘ideale leerobject’ dat precies voldoet aan alle opgegeven zoekcriteria. De mate van gelijkenis tussen een leerobject in de databank en de zoekcriteria is dan gelijk aan de afstand tussen het leerobject zelf en het ideale leerobject, en wordt daarom ‘afstandsmaat’ genoemd.

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[2] Onder ‘onderwijscontext’ wordt verstaan: alle onderwijskundige aspecten van de gegeven situatie, zoals samenstelling van de doelgroep, de gebruikte pedagogiek, het onderwijsniveau, enzovoorts.

Hierbij dient een kanttekening geplaatst te worden: niet elk kenmerk zal voor elke docent even zwaar wegen. Zo kan een kenmerk “tijdsduur”, dat aangeeft hoe lang een gemiddelde student bezig is met het leerobject, heel zwaar wegen voor een docent wiens vak eigenlijk al teveel tijd vraagt van de studenten. Ook zou een kenmerk “interactiviteit” zwaar kunnen wegen voor docenten die het belangrijk vinden dat onderwijs meer is dan alleen maar het opnemen van informatie, en dat er dus een vorm van interactie moet zijn tijdens het leren. Dit geeft aanleiding tot het vermoeden dat er een zekere samenhang bestaat tussen het gewicht dat een docent toekent aan een kenmerk, en de houding van de docent ten opzichte van het geven van onderwijs. Deze samenhang is interessant, omdat daarmee wellicht voorspeld kan worden hoe zwaar bepaalde kenmerken wegen voor een bepaalde docent. En als deze gewichten van een docent bekend zouden zijn dan hoefde de computer deze niet telkens aan de docent te vragen, en zou het zoekproces eenvoudiger worden.

Om te trachten de hierboven beschreven vermoede samenhang te vinden, is een onderzoek opgezet (zie paragraaf 7.3). De houding van de docent ten opzichte van het geven van onderwijs werd beschreven door middel van een variant op het model van de vijf dimensies zoals beschreven door Samuelowicz en Bain (1992). In de variant werd één dimensie opgesplitst in drie dimensies, waardoor het model zeven dimensies telde. De ‘positie’ van de proefpersonen op elk van de zeven dimensies werd bepaald door middel van een vragenlijst. In deze vragenlijst werden daarna zes hypothetische onderwijskundige situaties gepresenteerd, en werd de proefpersonen gevraagd hoe zwaar elk van een vijftal kenmerken van leermateriaal woog (door middel van getalletjes 1 tot en met 5). Een analyse van de onderzoeksgegevens bracht slechts enkele zwakke verbanden aan het licht. Het doel van het onderzoek was te pogen de gewichten die een docent toekent aan kenmerken van leermateriaal te voorspellen aan de hand van de houding van de docent; maar hiervoor zijn er te weinig, en te zwakke verbanden gevonden.

Dit betekent dat de gewichten die een docent toekent aan kenmerken van leermateriaal bij elke zoekactie opnieuw aan de docent gevraagd moeten worden. Om te onderzoeken hoe effectief de afstandsmaat is op die manier, is een tweede onderzoek opgezet waarin de proefpersonen met een prototype van een onderwijskundige databank moesten werken. De effectiviteit van de afstandsmaat (die aangeeft in hoeverre een zoekresultaat overeenstemt met de zoekcriteria) werd gemeten door de berekende afstand te vergelijken met het oordeel van een proefpersoon met betrekking tot de bruikbaarheid van het zoekresultaat: hoe kleiner de afstand, hoe beter het oordeel naar verwachting. In het experiment werd de proefpersonen een aantal hypothetische onderwijskundige situaties voorgelegd, waarna gevraagd werd om zoekcriteria op te stellen waaraan leerobjecten moeten voldoen in zo’n situatie. Deze zoekcriteria bestonden uit een vijftal kenmerken van leermateriaal zoals is vastgelegd in de metadata-standaard. Daarna werd gevraagd in welke volgorde het zoeksysteem de kenmerken moest controleren; hierbij werd aangenomen dat het kenmerk dat de proefpersoon het eerst gecontroleerd wilde hebben, het zwaarst weegt. Het tweede kenmerk weegt dan het op één na zwaarst, enzovoorts. De proefpersoon kreeg daarna een fictieve lijst met zoekresultaten te zien, en moest op een evaluatie-formulier invullen hoe bruikbaar elk zoekresultaat was in de gegeven onderwijssituatie door middel van een score van 1 tot 10. Het prototype berekende telkens de afstand tussen het zoekresultaat en de opgegeven zoekcriteria, gebruik makend van de gewichten die de proefpersoon had opgegeven. Deze werden naderhand vergeleken met de scores van de proefpersonen. Uit de analyse bleek dat er een sterke samenhang bestond tussen de gemeten afstand en de score van de proefpersoon voor enkele proefpersonen, terwijl er voor andere proefpersonen geen enkele samenhang aangetoond kon worden (zie paragraaf 8.5).

In het experiment dat in de bovenstaande alinea is geschetst werd een klein aantal kenmerken van leermateriaal gebruikt, beschreven in metadata velden (de keuze van deze kenmerken is te vinden in paragraaf 8.3.1). Het experiment gaat ervan uit dat aan de hand van deze kenmerken gedeeltelijk voorspeld kan worden of een docent een zoekresultaat bruikbaar vind of niet. Als zodanig zijn deze kenmerken *factoren* die samenhangen met het oordeel van de docent. Des te meer van deze factoren bekend zijn, des te beter is het mogelijk het oordeel van de docent te voorspellen. Daarom is tijdens het experiment getracht om inzicht te krijgen in andere factoren die mogelijk ook een rol spelen wanneer een docent leermateriaal beoordeelt. Hiertoe moesten de proefpersonen bij het beoordelen van zoekresultaten van een twaalftal factoren aangeven of deze factor een rol speelde of niet. Uit de resultaten blijkt dat vrijwel alle factoren ongeveer even vaak een rol spelen, en dat alleen de factor “afmeting” (F_{size}) opvallend weinig een rol speelt. Aangezien deze twaalf factoren ook de vijf kenmerken omvat die in de afstandsmaat verwerkt zijn, kan geconcludeerd worden dat er nog minstens $12-5-1 = 6$ factoren zijn die een rol spelen bij het beoordelen van leermateriaal, en die *niet* in de afstandsmaat verwerkt zijn.

Uit de resultaten van het experiment kan geconcludeerd worden dat de afstandsmaat weliswaar potentie heeft, maar dat er nog te weinig inzicht is in welke factoren welke rol spelen wanneer een docent digitaal leermateriaal beoordeelt op bruikbaarheid. Er zijn nog minstens zes factoren buiten beschouwing gelaten, hetgeen kan verklaren waarom de afstandsmaat voor sommige docenten een goede voorspelling kan doen van de bruikbaarheid van leermateriaal, terwijl dat voor andere docenten niet het geval is. Dit biedt duidelijke aanknopingspunten voor verdere verbetering van de afstandsmaat.

Het toepassen van een afstandsmaat gebaseerd op metadata hoeft overigens niet beperkt te blijven tot het onderwijskundige domein. Overal waar metadata gebruikt wordt die aan bepaalde eisen voldoet (zie paragraaf 7.2) kan een afstandsmaat gedefinieerd worden. Ook de gebruikte onderzoeksmethodiek, waarbij het door de computer berekende oordeel (de afstandsmaat) wordt vergeleken met een door proefpersonen toegekende score om het computeroordeel op correctheid te verifiëren, kan ook in andere toepassingsgebieden zeer nuttig blijken.

Appendix A

Overview of Database Systems

In the past, many projects have investigated theoretical and practical issues of educational database systems. In order to build upon the results of these projects, we will examine them in this appendix. Emphasis is put on the labeling systems and the search facilities. The projects were found by searching the World Wide Web, searching the library, and following literature references. Only projects that actually use a database of learning materials are incorporated; a more elaborate overview has been give elsewhere (Hiddink, 1998). Also, common commercial packages whose internals are mostly unknown (such as Blackboard, WebCT, Oracle Learning Architecture) are not discussed.

Note that many of the references to online materials (URLs) may have become invalid since the time of writing. The reader is advised to use a WWW search engine to find online documents back if the URLs have become invalid.

A.1 The DBML of the Delta ESM-BASE Project

One of the first database systems that stored units of learning material was the DBML (Database of Learning Material) that was developed in the ESM-BASE project (Educational Systems based on Multimedia Databases), as described by Yazdani (1990).

The ESM-BASE project was executed during 1990 and 1991, and laid the basis for databases of learning material. It was funded by the European Commission under the Delta projects series as D1012. The goal of the project was to address the problem of courseware reusability by developing a database structure suitable for organising multimedia learning material in a given domain (Persico et al., 1992). This project was the first to use the concept of a *Unit of Learning Material* (Olimpo et al., 1990), see also Chapter 4.

The database itself is based on a filesystem (i.e. the multimedia data are stored outside the reach of the DBMS, see Section 2.2.2) and files are “registered” to the system. Users have to describe the contents of the file with a few keywords and/or write a small abstract. Users can then search for a file by providing keywords.

A.1.1 Labeling system

The ULMs were labeled using the following fields (Persico et al., 1992): learning-obj-type, pedag-qual-level (pedagogical quality level), completeness, educational-function, difficulty-level, knowledge-type, ulm-source (describing the creator of the ULM), ulm-id, ulm-quality-level, comments, ulm-approach, approach-type, school-level, context-id, and context-source (describing the context in which the ULM is used). Most of these fields can be found back in the current proposed IEEE Educational Metadata standard (IEEE, 2000).

In a preliminary study of the prototype, it was found that the users questionned the significance of some fields, such as pedagogical quality, approach type and completeness. After a training of the users, their problems were mainly solved (Persico et al., 1992).

A.1.2 Search capabilities

The ULM model provided semantical relations between ULMs, so that the user could explore the knowledge contained in the ULMs using these relations. The relations existed within a certain context; if, for example the context is “geodynamics” then the topics of *volcanoes* and *earthquakes* would be related. If the context is “photography”, then *volcanoes* would be related to *colours*. The user could also browse content descriptions (Persico et al., 1992).

A.2 The Instructional Management Systems project

The IMS project (Resmer, 1999, June) is an initiative of EDUCOM, a company that conducts educational research and consultancy. The IMS project is funded by a wide range of companies and academic institutions, for example: Apple Computer, AT&T Learning Network, IBM Education, University of Michigan, University of California and Microsoft.

In the initial project description, the goal was, amongst others, to develop a prototype for the storage, management and retrieval of online learning materials. This goal was soon found to be too ambiguous, so the focus shifted to creating a specification of the information infrastructure for building instructional management systems. One of the results is the specification of an educational metadata standard, which is based on the Dublin Core. The IMS project cooperated with the Ariadne project (see Section A.9 to create the first draft of the IEEE Learning Object Metadata specification.

A.3 Oracle Learning Architecture

The Oracle Learning Architecture (OLA) is an online educational system for delivering and managing interactive, multimedia education over networks[1] from either one of three websites (USA, Europe and Asia). This is primarily a commercial course delivery system; some 300 courses can be ordered online, which mostly are business training courses on various topics of Information Technology. The search interface features the following fields: subject (mostly computer related subjects), role (of the user in his/her work situation), vendor (of the course), language, solution type (certification, course, subject library, training path[2]), delivery format (download, web playable), training method (knowledge tutorial, performance support, simulation or skill tutorial). The results can be sorted on title, subject, vendor or language. Finally, options can be flagged if the course is allowed to have video, audio or plug-ins or helper applications.

The learning materials are stored as so-called “Reusable Content Objects”. A press release suggests that input was used from the IEEE Working Group, but as this is a proprietary system no further details are available about the system’s architecture, labeling system, search algorithms and how the courses are composed from smaller objects.

A.4 Gateway to Educational Materials (GEM)

The Gateway to Educational Materials (GEM) project[3] is a special project of the ERIC Clearinghouse on Information and Technology that started in 1996. It is sponsored by the U.S. Department of Education’s National Library of Education, and has formed a consortium throughout the years. The consortium consists of organizations and individuals that have collections of educational materials that are or will be cataloged and entered into the GEM database, or organizations and individuals who use materials from the GEM database.

The GEM project is a development member of the IMS consortium.

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[1] see http://ola.oracle.com

[2] A training path is a series of courses that prepare employees for specific roles, such as a database administrator or application developer

[3] see http://thegateway.org

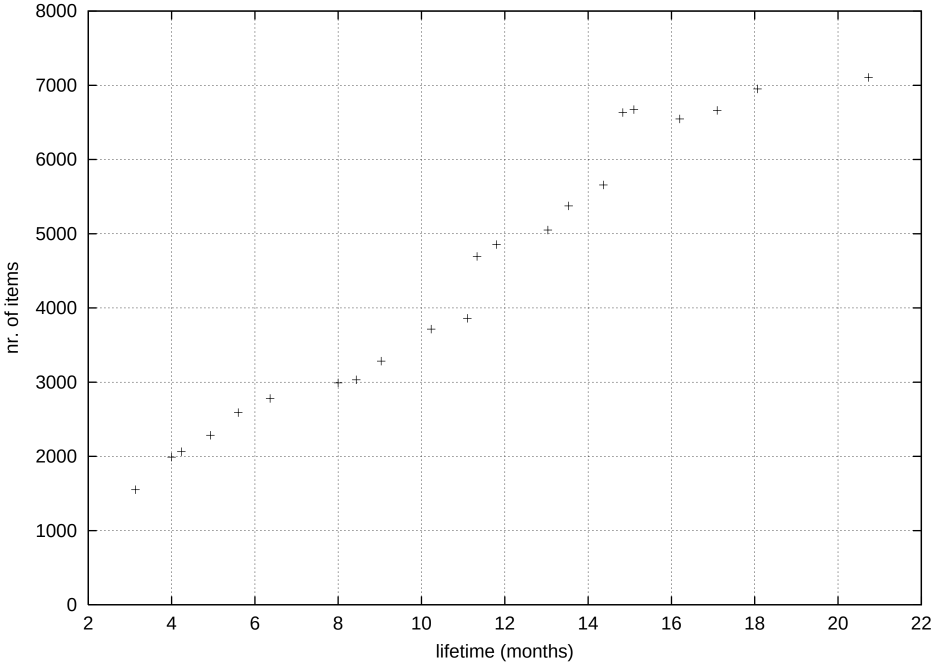

Figure A.1: Growth of the GEM database

A.4.1 Entering Material

The material and its metadata is entered using a Java program called "GEMCat". An extensive manual for this program is online[4].

A.4.2 Search Interface

The search interface of GEM allows the user to search on keywords, combined with values for the grades (pre-K, K, 1-12) and educational level (vocational, higher education and adult/continuing education). The user can also browse through the list of available keywords, and browse through a subject tree. A usability study was performed with the emphasis on navigation and cosmetic aspects of the search interface.

The number of available resources grows steadily, as is depicted in Figure A.1. At the time of writing (september 1999) there are about 7000 learning resources available.

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[4] See http://gem.syr.edu/Workbench/training/index.htm

The labeling system is an extension of the Dublin Core (see also Section 5.8.1, and consists of 23 elements. The extension consists of the following fields[5]:

Audience Information from a controlled vocabulary that most closely identifies the specific audience of the resource being described.

Cataloging The cataloging agency provides basic information about the agency that created the GEM catalog record

Duration The duration of the activity or lesson

EssentialResources Resources essential to the effective use of the entity by the teacher

Grade Grade, grade span, educational leve, or age of the entity's audience.

Pedagogy Denotes the student instructional groupings, teaching methods, assessment methods, and learning prerequisites of a resource.

Quality The Quality Indicators element is a means for assessing the quality of instructional materials.

Standards State and/or national academic standards mapped to the entity being described.

During the project, controlled vocabularies for Audience, Format, Grade, Language, Pedagogy, Relation, ResourceType and Subject were determined. During 1999, the GEM project was in the process of harmonizing their metadata with those of the IMS project, which in turn has been one of the largest sources of input for the IEEE Learning Object Metadata standard.

A.5 Computer Science Teaching Center

The CSTC is a digital library of peer reviewed resources for teaching computer science, targeted at reuse. The library maintains an online database[6] to which teachers can submit resources.

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[5] See http://www.geminfo.org/Workbench/Metadata/GEM_Element_L ist.html

[6] located at http://www.cstc.org

A.5.1 Labeling system

The resources are labeled with the following fields: author, type of resource (multimedia, laboratories, visualizations), ACM subject classification, Computer Science curriculum classification, keywords, and abstract. Also, some optional fields can be added: language, programming language or markup language, operating system, platform, tools (necessary to view the resource), publisher, acknowledgements, source (of the resource), copyrights and multimedia content. It is not clear what this last field is precisely meant for.

A.5.2 Search facilities

The search facilities consist of a simple keyword search, or by metadata fields. The fields that can be searched are first- and last name, date of submission, type of resource (multimedia, laboratories or visualizations), and ACM subject classification.

A.6 Optical Database Project

The Optical Database Project (ODB) was a project that intended to achieve reuse of video materials by collecting the curricula of a course on three educational levels, analyzing these curricula, and synthesizing a new curriculum that consisted of a framework of common learning objects that were shared by each curriculum, and a wealth of optional learning objects that each educational level could choose from as they saw fit (Verhagen & Bestebreurtje, 1995).

A.6.1 Labeling technique

The labeling technique consisted of a semantical labeling of knowledge objects, combined with a conceptual network (Bestebreurtje et al., 1995). Note that we are mainly interrested in labeling techniques for *learning* objects as opposed to *knowledge* objects.

A.7 Eisenhower National Clearinghouse

The Eisenhower National Clearinghouse (ENC) is an online database[7] located at the Ohio State University in Columbus, Ohio. It is targeted at mathematics and science educators. Regional consortia were created to provide technical assistance

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[7] see http://www.enc.org

and professional development opportunities on topics important to the regions and the United States as a whole. The database mostly contains metadata of books, CD-ROMs and lesson plans, but also metadata of online learning materials.

A.7.1 Labeling system

The metadata consists of descriptive fields (author, title, abstract, ordering information etc). The only pedagogical metadata that is present is the school-grade for which it is targeted, and the subjects covered by the resource.

A.7.2 Search Interface

The database can be searched using a simple search and an advanced search mechanism. The simple search consists of a form in which the user can enter search words and the target grade(s) for which the learning material was developed. Also, a maximum cost parameter can be entered. The advanced search facility allows the user to choose from an alphabetic list of subjects, a list of grades for which the material was developed, a list of maximum cost options, an extensive list of resource types, and a list of national standards.

A.8 The NEEDS database

The National Engineering Education Delivery System (NEEDS) is an online database[8] that contains learning resources for engineering education. The resources can be commented on by teachers that use it in their courses. It uses a standard library format for indexing and storing documents, called USMARC[9]. A future version of the NEEDS database will use the IMS metadata scheme.

A.8.1 Search Interface

The homepage of the database provides a simple search facility, in which only keywords can be entered. The advanced search facility provides free-text fields for the title, authoer, publisher, subject heading, and keywords. Also, some multimedia aspects can be requested: the specific MIME type(s) one is looking for, and keywords present in the text contents.

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[8] see www.needs.org

[9] see http://lcweb.loc.gov/marc/

A.9 ARIADNE Knowledge Pool

The Ariadne project (Duval, 1999, June) has collected a large amount of learning material into their Knowledge Pool. The Ariadne metadata laid the basis for the IEEE Learning Object Metadata standard (IEEE, 2000).

A.9.1 Search Interface

The search interface consists of a very elaborate form in which values for *all* (about 50) metadata fields can be specified. The search interface is implemented in a *search tool* written in Java, although a web-based version is expected to be released during 2000.

A.10 ELECTRA

The universities of Aachen, Liége, Maastricht and Diepenbeek-Hasselt (the “ALMA” universities) have joined together in a project called “Electronic Learning Environment for Continual Training and Research in the ALMA Universities”, or ELECTRA for short. The goal of the project is to realize a sophisticated electronic learning environment. Part of this project was the Interactive Multimedia Database (IMM-DB), developed by the Expertise Centre for Digital Media of LUC (Limburgs Universitair Centrum). These projects have ended, but the technology that was developed lead to the TUTORAID learning environment (Teaching Utility Through Online RDBMS And Interactive Discussions)[10]

A.10.1 Search Interface

The Tutoraid learning environment features a search interface based on a HTML form in which the user can choose from fixed vocabularies for language, target group, course, type and author. The learning environment currently is no longer available online.

A.11 Explorer

The Explorer database[11] is being developed by the Great Lakes Collaborative and the University of Kansas UNITE group. It stores K-12 mathematics and science

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[10] see http://www.edm.luc.ac.be/edm2/act_4.html

[11] see http://unite.rtec.org

education resources (learning plans, lab exercises etcetera). The database contains about 1000 resources, most of which are downloadable.

A.12 Search Interface

The database can be accessed in a variety of ways:

- The Mathematics Curriculum and the Natural Sciences Curriculum can both be browsed. These curricula are presented as a large hierarchical list of up to 7 levels. When the user selects a topic, a list of resources concerning this topic is shown.

- There is also a Quick Search, which consists of a single search field in which keywords can be typed. The search facility then searches the title, author and description for these keywords, and then presents a list of resources that contain the keyword(s).

- The Advanced Search facility allows the user to select text fields (resource title, author, publisher, resource description, cost description, ISBN, availability, series, email address, publication date, cost in US dollars, GeoFocus code and comments) the user wishes to use as a search parameter. These fields contain free text. The user can also select zero or more of the list fields (resource type, grades, process skills, physical media, curriculum, GeoFocus location) the user wishes to use as a search parameter; these fields contain a fixed vocabulary. A custom search form is then created.

A.13 TeLeTOP

The TeleTOP system was developed at the University of Twente (Collis, 1998a), and is primarily a course management system in which a teacher is guided through a decision process to generate a custom course environment. This course environment consists among others of a course schedule, with task descriptions and learning resources for each week. The teacher can add learning materials and references (URLs) to this schedule.

Although the system is built on a database (it is implemented using the Lotus Domino Server and the Lotus database management system), it focusses on course management capabilities instead of the storage and retrieval of learning objects. The system stores (references to) learning material without metadata, except a textual description.

A.14 Online databases

There are some more organizations that host a database of learning materials. Below follows a list of the largest ones at the time of writing (September 1999).

A.14.1 Pathlore PHOENIX Web

Pathlore[12] offers comprehensive training solutions to companies; one of their solutions is a web-based course delivery and management system called *PHOENIX Web*. The system uses so-called Learning Objects, although no further information about the this model is disclosed on the website. It should be noted, however, that Pathlore is a development member of the IMS consortium.

A.14.2 PedagoNet

PedagoNet[13] is a learning material and resources center where users can post requests for learning materials, or browse the database to find suitable learning materials. Some of these are free and online, others have to be paid for and are not directly accessible. The labels that can be assigned to a resource are the following: region of origin (states in the USA, provinces of Canada, or elsewhere); subject (fixed vocabulary), educational level (fixed vocabulary), price, a description, and a URL if the resource is online. The database can be searched by selecting a subject, and then the entire list of resources within this subject is displayed. As the database is not very large (less than ten resources per subject), this is a suitable search method.

A.15 Conclusion

Figure A.2 shows many projects about educational databases and metadata. Not all projects shown in the figure have been discussed in this appendix; for a complete overview, see Hiddink (1998).

The figure shows, from left to right, the evolution from theory through research and development projects to industry. The projects are (roughly) situated at this scale. A straight line from one project A to project B means that project B is explicitly based on (results of) project A. A dotted line from A to B means that persons from project A are participating in project B, so that knowledge is implicitly transferred form project A to project B.

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[12] see http://www.pathlore.com

[13] see http://www.pedagonet.com

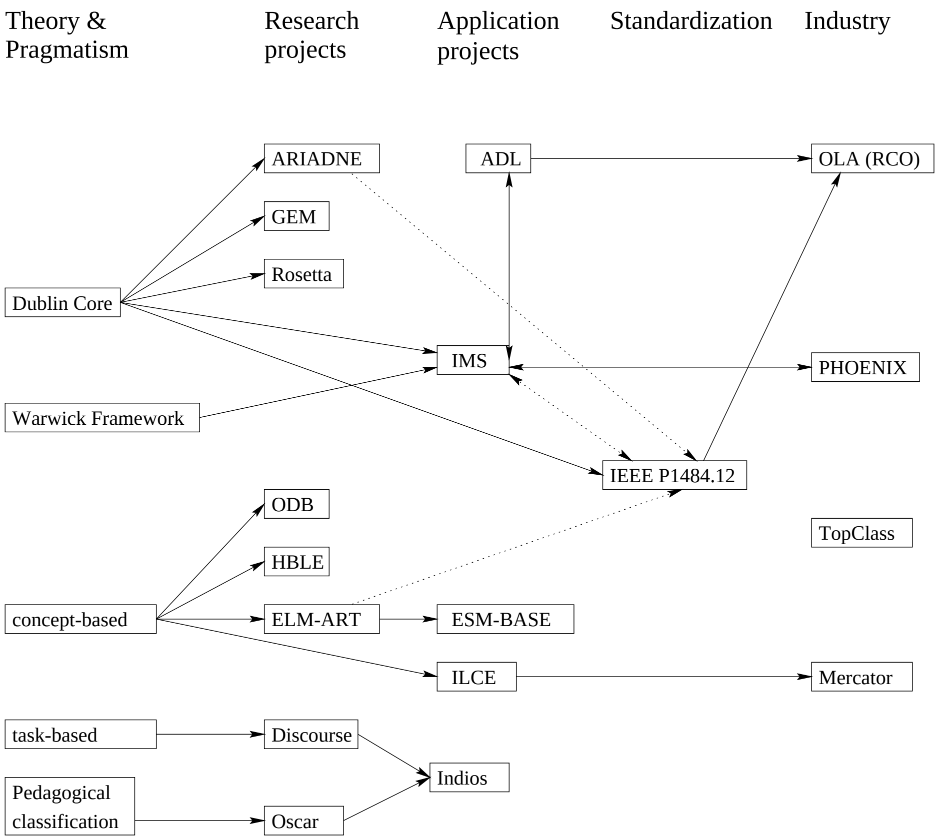

Figure A.2: Overview of all projects and their interrelationships

It becomes clear that already many projects have been working on educational databases, and that standardization efforts come together in the IEEE Metadata group.

Appendix B

Questionnaire

Enquête

“Onderzoek naar het verband tussen onderwijs-houding en voorkeur voor kenmerken van digitaal leermateriaal”

Gerrit Hiddink
George van der Peet
Mei 1999

Centrum voor Telematica en Informatie Technologie
Toegepaste Onderwijskunde - afdeling ISM

Inleiding

Het Centrum voor Telematica en Informatie-Technologie doet in samenwerking met de vakgroep Instrumentatie van de faculteit Toegepaste Onderwijskunde onderzoek naar toepassingsmogelijkheden van moderne Informatie- en Communicatie Technologie (ICT). Het Idylle project[1] bestudeert de mogelijke toepassing van technologie als tools voor teleleren. Eén van de aandachtsgebieden binnen het Idylle project is het toepassen van een digitale databank voor de opslag van leermateriaal, zoals video's, simulatie's, teksten, COO programmatuur etcetera. Een dergelijke databank maakt het naar verwachting mogelijk voor docenten om snel en effectief kwalitatief hoogwaardig leermateriaal te vinden, aan te passen en te integreren in hun bestaande vakken.

Dit onderzoek wordt uitgevoerd door Gerrit Hiddink (AIO), en een onderdeel van het onderzoek is deze enquête. Deze is mede opgesteld door George van der Peet (student Toegepaste Onderwijskunde) in het kader van het vak “Onderzoeks-opdracht”.

Deze enquête heeft de volgende doelen:

- inzicht krijgen in de belangrijkheid die docenten toekennen aan bepaalde kenmerken van leermateriaal bij het zoeken in de databank
- onderzoeken of er een verband bestaat tussen deze belangrijkheid met de houding die docenten hebben ten opzichte van het geven van onderwijs.

De enquête bestaat uit drie delen:
Deel A: algemene vragen
Deel B: vragenlijst met betrekking tot de houding van docenten ten opzichte van het geven van onderwijs;
Deel C: vragenlijst met betrekking tot de behoefte van docenten aan leermateriaal.

Het invullen van de enquête kost circa 30 minuten. De door u gegeven antwoorden zullen enkel voor het onderzoek gebruikt worden. Indien u er prijs op stelt zullen we u op de hoogte houden van de uitkomsten van het onderzoek; vul hiertoe bij vraag A9 uw naam en adres in.

U kunt de enquête na het invullen in de bijgevoegde antwoordenvelop doen en deze per interne post opsturen, liefst voor 21 mei. Als u het echter prettiger vindt om de enquête op het WWW in te vullen, dan kan dat ook. U kunt de enquête vinden op:

http://www.wwcn.org:1080

Nadat u deze heeft ingevuld kunt u met een druk op de knop uw antwoorden electronisch verzenden.

Alvast bedankt voor uw tijd en moeite,

Gerrit Hiddink en George van der Peet.

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[1] http://www.ctit.utwente.nl/Docs/projects/idylle/IDYLLE.htm

Deel A

A1. Aan welke jaargroepen geeft of gaf u onderwijs? (Meer antwoorden mogelijk)

[ ] a. eerstejaars
[ ] b. tweede- en derdejaars
[ ] c. vierdejaars
[ ] d. mijn vakken zijn niet specifiek bestemd voor één jaargroep

A2. Hoeveel procent van de tijd die u beschikbaar heeft voor onderwijsactiviteiten besteed u aan:

[ ] a. voorbereiden en geven van hoorcollege	..... %
[ ] b. voorbereiden en geven van werkcollege	..... %
[ ] c. voorbereiden en geven van kolstructie	..... %
[ ] d. voorbereiden en begeleiden van practica	..... %
[ ] e. begeleiden van projectgroepen	..... %
[ ] f. begeleiden van afstudeerders	..... %
[ ] g. Anders, nl:	..... %

....
....

A3. Hoeveel jaren geeft u reeds onderwijs?

[ ] a. minder dan 1 jaar
[ ] b. tussen 1 jaar en 3 jaar
[ ] c. tussen 3 jaar en 10 jaar
[ ] d. tussen 10 jaar en 20 jaar
[ ] e. meer dan 20 jaar

A4. Welke soort(en) cursus(sen) en/of opleidingen heeft u gevolgd om te leren hoe onderwijs te geven:

[ ] a. lerarenopleiding
[ ] b. didaktisch inwerktraject UT
[ ] c. pedagogische of didaktische opleiding
[ ] d. cursus mondelinge- en presentatie vaardigheden
[ ] e. cursus begeleiden van werkcolleges
[ ] Anders, nl:
....
....

A5. Wat is uw leeftijd?

[ ] a. 20 - 29 jaar
[ ] b. 30 - 39 jaar
[ ] c. 40 - 49 jaar
[ ] d. ouder dan 50 jaar

A6. Welk soort vak(ken) geeft u? (meerdere antwoorden mogelijk)

[ ] a. vakken in de sociale- en gedragswetenschappen (*gamma*)
[ ] b. (toegepaste) technische of technologische vakken (*beta, toegepast*)
[ ] c. wiskunde (*beta, theoretisch*)

A7. Hoeveel jaren heeft u ervaring met het gebruik van computers? (voor onderwijs, onderzoek of hobby)

[ ] a. 0 t/m 5 jaar
[ ] b. 6 t/m 10 jaar
[ ] c. 11 t/m 15 jaar
[ ] d. 16 t/m 20 jaar
[ ] e. meer dan 20 jaar

A8. Wilt u meewerken aan een vervolgonderzoek?

[ ] ja [ ] nee [ ] weet (nog) niet

A9. Indien u prijs stelt op de resultaten van het onderzoek of mee wilt werken aan een vervolgonderzoek, vul dan hieronder uw naam en adres in:

Naam: ....
Gebouw: ....
Afdeling: ....

Deel B

Dit deel van de enquête heeft tot doel na te gaan wat uw houding ten opzichte van het geven van onderwijs is. Kruis het hokje aan dat het meest met uw mening overeenstemt. Probeert u zich bij het beantwoorden van de vragen af te vragen hoe u zèlf zou reageren, waarbij u geen rekening hoeft te houden met tijdsdruk, organisatorische randvoorwaarden, faculteitsbeleid en dergelijke. We willen graag weten hoe u zèlf zou handelen.
Lees eerst alle alternatieven voordat u de (volgens u) beste aankruist. Als u zich in geen van de alternatieven kunt vinden dan hoeft u niets aan te kruisen, maar vul wel op de commentaar-regel in wat uw mening is. Als u zich bedenkt, maak dan het foute hokje helemaal zwart en kruis uw nieuwe keuze aan.

B1a. Stel dat u een vak geeft bestaande uit een hoorcollege en een praktikum aan eerstejaars studenten. Het vak is afgestemd op deze doelgroep. Stel dat een andere afdeling of faculteit u zou vragen dit vak ook bij hun te geven, maar dan voor *ouderejaars* studenten. Deze studenten bezitten de voorkennis die voor uw vak nodig is. Zou u veranderingen aanbrengen in de stof van het vak?

[ ] a. Ja
[ ] b. Nee (ga naar vraag B2)

B1b. Hoeveel veranderingen zouden noodzakelijk zijn om de stof af te stemmen op de ouderejaars?

[ ] a. kleine veranderingen
[ ] b. matige veranderingen
[ ] c. redelijk veel veranderingen
[ ] d. veel veranderingen
[ ] e. compleet herontwerp
[ ] f. Anders, nl:
....
....

B1c. Welke reden(en) heeft u om deze veranderingen aan te brengen (meerdere antwoorden mogelijk)

[ ] a. ouderejaars zijn inhoudelijk verder dan eerstejaars
[ ] b. ouderejaars kijken anders tegen het krijgen van onderwijs aan, waardoor de opzet gewijzigd moet worden
[ ] c. ouderejaars ouderejaars staan anders in het leven (zijn bijvoorbeeld kritischer, mondiger of academischer)
[ ] d. Anders, nl:
....
....

B2. Stel dat u een vak geeft aan ouderejaars studenten met een praktikum waarbij de studenten een opdracht moeten kiezen uit een vooraf opgestelde lijst. Wat is uw houding ten opzichte van studenten die zelf een opdracht verzinnen (zowel vorm als inhoud)?

[ ] a. u zult hun dit niet toestaan vanwege de volgende reden:
....
....
[ ] b. slechts bij hoge uitzondering staat u studenten toe zelf een opdracht te formuleren
[ ] c. op voorwaarde dat studenten een inhoudelijk goede opdracht hebben die aansluit bij de doelen van het vak, bestaan hier goede mogelijkheden voor
[ ] d. in de praktijk staat u vaak toe dat studenten een zelfgeformuleerde opdracht doen
[ ] e. u moedigt studenten aan om zelf een opdracht te formuleren
[ ] f. u vindt dat studenten eigenlijk nooit vastgelegde opdrachten moeten doen, en dat ze zoveel mogelijk hun eigen onderwijs plannen
[ ] g. anders, namelijk:
....
....

B3. Stel dat u gevraagd wordt een curriculum voor een nieuwe afdeling samen te stellen. Wat wordt, als het aan u lag, ongeveer het percentage vakken waarin studenten zelf de inhoud van het vak samen kunnen stellen, zoals probleemgestuurd onderwijs of projectonderwijs? Doctoraalopdrachten hoeft u niet mee te tellen.

[ ] a. 0% tot 20%
[ ] b. 21% tot 40%
[ ] c. 41% tot 60%
[ ] d. 61% tot 80%
[ ] e. 81% tot 100%

B4. Stel dat u een nieuw vak aan het inrichten bent, en dat u één studiepunt (40 uren) over hebt nadat u verder alle verplichte stof hebt verwerkt. Wat doet u met het resterende studiepunt? U mag aannemen dat uw afdeling middelen voor bijvoorbeeld excursies beschikbaar stelt. Kruis aan welke (meerdere antwoorden mogelijk) van de volgende alternatieven u zou uitvoeren, en vermeld ook welk percentage van de studiepunt u hieraan zou besteden.

[ ] a. u besteedt dit voor ..... % aan het door studenten laten voorbereiden en uitvoeren van een excursie naar een bedrijf of organisatie die iets doet met de in de stof behandelde theorie
[ ] b. u besteedt dit voor ..... % aan een extra college om de stof te oefenen
[ ] c. u besteedt dit voor ..... % aan een extra college om de stof verder uit te diepen
[ ] d. u besteedt dit voor ..... % aan een praktikum over technieken en methoden om de behandelde stof praktisch toe te passen

[ ] e. Anders, nl voor .... % aan:
....
....

B5. Stel dat een student bij een werkcollege reeds alle vereiste aspecten van de stof blijkt te beheersen en toe te kunnen passen. Is dan uw doel bereikt?

[ ] a. Ja, de student heeft alle nodige kennis en inzichten verworven die nodig zijn om het vak succesvol af te kunnen ronden. De student kan zijn/haar tijd dan beter besteden aan een ander vak.
[ ] b. Nee, de kennis en inzichten van de student kunnen misschien nog genuanceerder of dieper worden
[ ] c. Anders, nl:
....
....

B6a. Gebruikt u naast de theorie in het boek en/of het diktaat nog aanvullend materiaal voor uw collegestof?

[ ] a. Ja (*ga naar vraag B6b*)
[ ] b. Nee (*ga naar vraag B6c*)

B6b. Welke eisen heeft u ten aanzien van het aanvullende materiaal? (meer antwoorden mogelijk)

[ ] a. het materiaal moet de stof in het boek of diktaat ondersteunen
[ ] b. het materiaal moet laten zien hoe de stof in het boek of diktaat gerelateerd is aan de praktijk
[ ] c. het materiaal moet de stof in het boek of diktaat illustreren
[ ] d. Anders, nl:
....
....

Ga nu verder met vraag B7.

B6c. Om welke reden heeft u geen aanvullend materiaal nodig? (meer antwoorden mogelijk)

[ ] a. het boek en/of het diktaat dekken de stof voldoende
[ ] b. het boek en/of het diktaat geven voldoende relaties tussen de stof en de praktijk
[ ] c. het boek en/of het diktaat geven voldoende illustraties bij de behandelde stof
[ ] d. Anders, nl:
....
....

B7. In hoeverre bent U het met onderstaande uitspraken eens?

	zeer mee oneens	enigzins oneens	neutraal	enigzins mee eens	zeer mee eens
1. Studenten weten al veel over de onderwerpen waarin ik onderwijs geef, maar ik probeer hun inzichten te *veranderen.*	[ ]	[ ]	[ ]	[ ]	[ ]
2. Onderwijs geven betekent eigenlijk alleen maar dat aan studenten feiten worden *toegevoegd.*	[ ]	[ ]	[ ]	[ ]	[ ]
3. Het is niet zo belangrijk dat studenten de stof in het boek niet helemaal beheersen, als ze maar inzicht hebben in het onderwerp in het algemeen.	[ ]	[ ]	[ ]	[ ]	[ ]
4. Hoe studenten tegen de stof aankijken bepaalt in grote mate mijn wijze van lesgeven.	[ ]	[ ]	[ ]	[ ]	[ ]
5. Onderwijs geven betekent dat mijn kennis naar de student overgebracht wordt.	[ ]	[ ]	[ ]	[ ]	[ ]
6. Onderwijs geven is voor mij het prettigst wanneer er een dialoog ontstaat tussen mij en de studenten.	[ ]	[ ]	[ ]	[ ]	[ ]
7.Wat mij betreft mogen studenten dikwijls zelf de inhoud van een vak bepalen.	[ ]	[ ]	[ ]	[ ]	[ ]

	zeer mee oneens	enigzins oneens	neutraal	enigzins mee eens	zeer mee eens
8. Op het eerste college neem ik een afwachtende houding aan om eerst de sfeer in de groep aan te voelen.	[ ]	[ ]	[ ]	[ ]	[ ]
9. Ik relativeer in mijn vakken het theo- retische karakter van de stof om de relatie met de praktijk beter uit te lichten.	[ ]	[ ]	[ ]	[ ]	[ ]
10. Als studenten vragen hebben, dan vind ik het het prettigst als ze die in de pauze of nà het hoorcollege stellen.	[ ]	[ ]	[ ]	[ ]	[ ]
11. Als studenten zich niet naar mij toe kunnen uiten, dan kan er geen goed onderwijs plaatsvinden.	[ ]	[ ]	[ ]	[ ]	[ ]
12. Ik stimuleer de studenten voortdurend om vragen te stellen of te reageren op de stof.	[ ]	[ ]	[ ]	[ ]	[ ]
13. Bij een praktikumbeoordeling geldt: “fout is fout”, studenten hoeven niet te proberen punten erbij te praten.	[ ]	[ ]	[ ]	[ ]	[ ]
14. Mijn stijl van onderwijs geven verandert, omdat ik merk dat jongeren tegenwoordig anders tegen onderwijs aankijken.	[ ]	[ ]	[ ]	[ ]	[ ]
15. Ik probeer door mijn onderwijs de studenten een beter beeld van de beroepspraktijk te geven.	[ ]	[ ]	[ ]	[ ]	[ ]

	zeer mee oneens	enigzins oneens	neutraal	enigzins mee eens	zeer mee eens
16. Studenten kunnen, mits deskundig begeleid, hun eigen onderwijs *inhoudelijk* plannen.	[ ]	[ ]	[ ]	[ ]	[ ]
17. In het ideale geval zou een mondelinge toets te prefereren zijn boven een schriftelijke omdat kennis heel persoonlijk kan zijn.	[ ]	[ ]	[ ]	[ ]	[ ]
18. Hoorcolleges, ook massale, zijn een uitstekend middel om kennis over te dragen.	[ ]	[ ]	[ ]	[ ]	[ ]
19. Ik houd bij het inrichten van mijn colleges rekening met vakinhoudelijke inzichten die studenten reeds hebben.	[ ]	[ ]	[ ]	[ ]	[ ]
20. Ik houd bij het inrichten van mijn colleges rekening met de houding die studenten hebben ten opzichte van onderwijs in het algemeen.	[ ]	[ ]	[ ]	[ ]	[ ]
21. Ik houd bij het inrichten van mijn colleges rekening met de houding die studenten hebben ten opzichte van hun eigen leven in de huidige maatschappij.	[ ]	[ ]	[ ]	[ ]	[ ]
22. Ik beschouw de kennis in mijn vakgebied als een absuluut gegeven dat studenten moeten leren reproduceren en/of toepassen.	[ ]	[ ]	[ ]	[ ]	[ ]
23. Bij het beoordelen van leerresultaten houd ik er rekening mee dat kennis van persoon tot persoon kan verschillen.	[ ]	[ ]	[ ]	[ ]	[ ]
24. In mijn vakken is theorie ondergeschikt aan praktijk.	[ ]	[ ]	[ ]	[ ]	[ ]
25. Je kunt een student eigenlijk zien als een blanco vel dat op de universiteit beschreven wordt.	[ ]	[ ]	[ ]	[ ]	[ ]

Deel C

De volgende vragen bevatten een situatie-beschrijving. U moet zich voorstellen dat u een computer tot uw beschikking heeft waarmee u leermateriaal kunt opzoeken in een databank. Het leermateriaal kan bestaan uit videofragmenten, al dan niet met geluidssporen, maar ook uit teksten, animatie's, simulaties waarbij de student bijvoorbeeld parameters van processen kan instellen en het effect hiervan kan bestuderen, maar ook meer traditionele COO (computer-ondersteund onderwijs) is mogelijk. Het leermateriaal dat u vindt kunt u nadien via de computer op het WWW klaarzetten voor de studenten, of u kunt het op een floppydisk of CD-ROM (laten) zetten.

De computer is in staat om niet alleen op sleutelwoorden te zoeken, maar ook op andere kenmerken van leermateriaal:

- *onderwijsniveau* (middelbare school, eerstejaars, ouderejaars, wetenschappelijk niveau)
- *tijd* die een student nodig heeft het materiaal door te werken (hieronder verder steeds "doorwerk-tijd" genoemd)
- mate van *interactiviteit*, oftewel (in toenemende mate van interactiviteit) hoeft de student alleen maar pagina's "om te slaan", moet de student vragen beantwoorden, moet de student parameters van een simulatie instellen, of zelfs adequaat reageren op situaties die zich op het scherm voordoen
- *onderwijskundige functie*: is het een theoretische uitleg, een praktische oefening, een simulatie, een voorbeeld, een eindopdracht, etcetera
- *onderwerp*: het onderwerp waar het *leermateriaal* over gaat.

Dit deel van de enquête heeft tot doel na te gaan hoe belangrijk u bovenstaande kenmerken van leermateriaal vindt in de gegeven situaties, door deze telkens te rangschikken op belangrijkheid. Dit is van belang voor het ontwerpen van een database voor leermateriaal, omdat de computer moet weten welke kenmerken hij zwaarder moet laten wegen dan andere.
U rangschikt de bovenstaande vijf kenmerken met getallen van 1 tot 5, waarbij u het kenmerk dat u het belangrijkst vindt met een 5 waardeert, en de minst belangrijke met een 1. Als u twee kenmerken van eenzelfde belang vindt dan mag u deze ook hetzelfde getal geven. U nummert dan van 1 tot 4. Als u het antwoordt niet zo snel kunt verzinnen, kunt u zich afvragen: *welk kenmerk zou ik als eerste laten vallen als zoek-criterium als de database niets vindt? en welke als tweede?* enzovoorts.

U heeft bij elke vraag ook ruimte voor opmerkingen.

C1. Stel u geeft een trimester lang elke week een hoorcollege voor ouderejaars studenten. U heeft vanuit voorgaande jaren de ervaring dat studenten te weinig praktische vaardigheid bezitten, en u wilt dit verbeteren door “digitaal leermateriaal” beschikbaar te stellen (bijvoorbeeld via het WWW) welke u zoekt via de databank. Geef voor deze situatie een rangorde voor onderstaande kenmerken, waarbij 5 het belangrijkste aangeeft en 1 het minst belangrijk:

onderwijsniveau .....
doorwerk-tijd .....
interactiviteit .....
onderwijskundige functie .....
onderwerp .....

Opm:
....
....

C2. Stel u moet een practicum samenstellen voor een bepaald vak, en tijdens de eerste sessie wilt u dat de studenten wat voorbereidende opdrachtjes doen om een basis te hebben voor de grotere opdracht(en), en u raadpleegt de databank op zoek naar leermateriaal. Geef hieronder uw rangorde aan voor de belangrijkheid van onderstaande kenmerken (5 is het belangrijkst):

onderwijsniveau .....
doorwerk-tijd .....
interactiviteit .....
onderwijskundige functie .....
onderwerp .....

Opm:
....
....

C3. Stel dat u een groot deel van uw vak via de computer (op het WWW, op CD-ROM of anderszins) geeft, en u raadpleegt de databank op zoek naar leermateriaal hiervoor. Wat is in deze situatie uw rangorde wat betreft belangrijkheid?

onderwijsniveau .....
doorwerk-tijd .....
interactiviteit .....
onderwijskundige functie .....
onderwerp .....

Opm:
....
....

C4. Stel dat u voor leergierige of "snelle" studenten extra leermateriaal beschikbaar wilt stellen, welke u wederom in de databank zoekt. Hoe rangschikt u in deze situatie de kenmerken van het leermateriaal?

onderwijsniveau .....
doorwerk-tijd .....
interactiviteit .....
onderwijskundige functie .....
onderwerp .....

Opm:
....
....

C5. Stel dat u merkt dat eerstejaars een bepaald onderwerp niet uitvoerig genoeg onderwezen hebben gekregen toen ze nog op het VWO zaten, en dat u met name hun theoretische ondergrond bij wilt spijkeren. Hoe ziet nu uw rangschikking eruit?

onderwijsniveau .....
doorwerk-tijd .....
interactiviteit .....
onderwijskundige functie .....
onderwerp .....

Opm:
....
....

C6. Stel dat u een nieuw keuzevak voor ouderejaars aan het ontwikkelen bent, en dat u hiervoor een practicum wilt inrichten. Wat is dan uw rangschikking? (5 is het belangrijkst)

onderwijsniveau .....
doorwerk-tijd .....
interactiviteit .....
onderwijskundige functie .....
onderwerp .....

Opm:
....
....

Bedankt voor het invullen. U kunt deze enquête in de bijgevoegde retourenveloppe per interne post verzenden, liefst voor 21 mei, naar:

G. W. Hiddink, CTIT/INF

Appendix C

Instruments

C.1 Invitation letter

Geachte heer xxxx,

ik ben promovendus bij het Centrum voor Telematica en Informatie Technologie bij de Universiteit Twente. Ik doe onderzoek naar het toepassen van onderwijskundige databanken, dat zijn databanken die gevuld zijn met digitaal, multimedia leermateriaal. Dit kunnen filmpjes zijn, audio fragmenten, animaties, Java applets, teksten, HTML documenten, etcetera. Mijn onderzoek richt zich met name op de zoekmethoden die een docent ter beschikking kunnen worden gesteld. Hiertoe heb ik een prototype gemaakt, en deze gevuld met leermateriaal over een specifiek onderwerp: inleiding in computernetwerken.

Op het World Wide Web zag ik dat u een soortgelijk vak geeft, en ik zou het dan ook een zeer waardevolle aanvulling van mijn onderzoeksgegevens vinden als u uw medewerking zou willen verlenen aan het onderzoek. Het betreft het doen van een klein aantal zoekopdrachten, en het invullen van korte vragenlijstjes per zoekopdracht. Alles bij elkaar zal het onderzoek ongeveer een uur in beslag nemen. Het onderzoek loopt van 14 augustus t/m 1 september.

Zou u willen of kunnen deelnemen aan dit onderzoek? Kent u docenten die ook een dergelijk vak geven die misschien ook mee zouden willen werken?

In afwachting van uw reactie,

Gerrit Hiddink

C.2 Onderzoek naar selectie-criteria bij het zoeken in onderwijskundige databanken.

Gerrit Hiddink
Centrum voor Telematica en Informatie Technologie

Inleiding

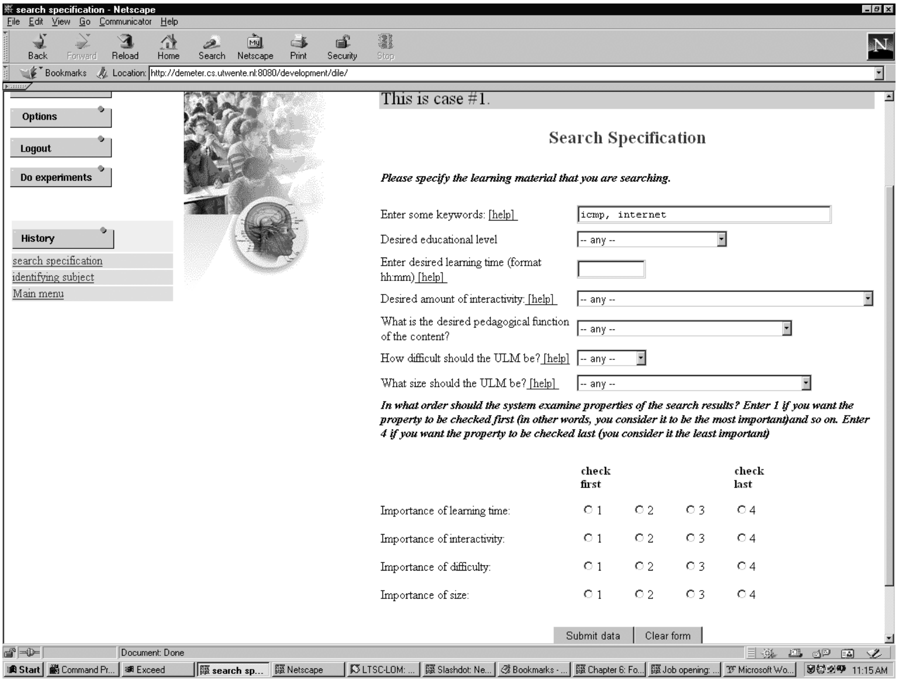
Het Centrum voor Telematica en Informatie-Technologie doet samen met de faculteit Toegepaste Onderwijskunde onderzoek naar het toepassen van onderwijskundige databanken in het onderwijs. Docenten kunnen een dergelijke databank doorzoeken naar online leermateriaal. Eén van de aandachtspunten is op welke manier docenten kunnen worden ondersteund in het zoekproces. Om de tot nu toe ontwikkelde methodiek te toetsen en om meer inzicht te krijgen in het zoekproces, neemt u deel aan een experiment.. Het experiment bestaat uit een drietal hypothetische onderwijs-situaties (casussen). Uw opdracht is om met behulp van een onderwijskundige database leermateriaal (zogenaamde Units of Learning Material, ofwel ULMs) te zoeken dat geschikt is om in de beschreven onderwijs-situatie aan de studenten aan te bieden via het Internet. De databank zal telkens een beperkt lijstje zoekresultaten presenteren (4 tot 6) waarna u gevraagd zal worden de bruikbaarheid van de resultaten voor de gegeven situatie te beoordelen op een beoordelingsformulier. Deze indicatie van `bruikbaarheid' zal vergeleken worden met een indicatie die de het prototype zelf vaststeld op basis van de door u opgegeven zoekspecificatie.

Instructie

Start op uw computer een internet-verkenner zoals Internet Explorer of Netscape Navigator. Ga naar de volgende URL: `http://demeter.cs.utwente.nl:8080/development/dile/`. Vergeet niet de laatste 'slash'! U kunt nu inloggen met de naam "experiments". Een wachtwoord is niet nodig. Klik daarna op "Do experiments" links in beeld. Als u deze optie niet kunt vinden, dan heeft u waarschijnlijk een typefout gemaakt bij het inloggen. Klik "Logout", daarna "Login", en probeer opnieuw.
Nadat u op "Do experiments" heeft gelikt moet u het "Subject ID" intoetsen, dit is voor u: ...... Klik na het invullen van het nummer op `submit'. Dit nummer wordt gebruikt om de door u ingevulde zoekgegevens te koppelen aan de door u ingevulde beoordelingsformulieren. Als u dit nummer heeft ingevuld, verschijnt het zoekformulier voor de eerste casus. Na de instructie volgen zes casus-beschrijvingen, en per casus zult u een formulier invullen. De cyclus die doorlopen wordt ziet er als volgt uit:

Voor 3 casussen:
1.u leest de casusbeschrijving;
2.u vult het zoekformulier in in de experimenteer-omgeving;
3.u krijgt een lijstje met zoekresultaten;
4.u bekijkt elk zoekresultaat en vult een beoordelingsformulier in;
5.u klikt "to next case", waarna u weer bij 1 begint.

Hieronder volgt een korte beschrijving van het formulier.



This is case #1.

Search Specification

Please specify the learning material that you are searching.

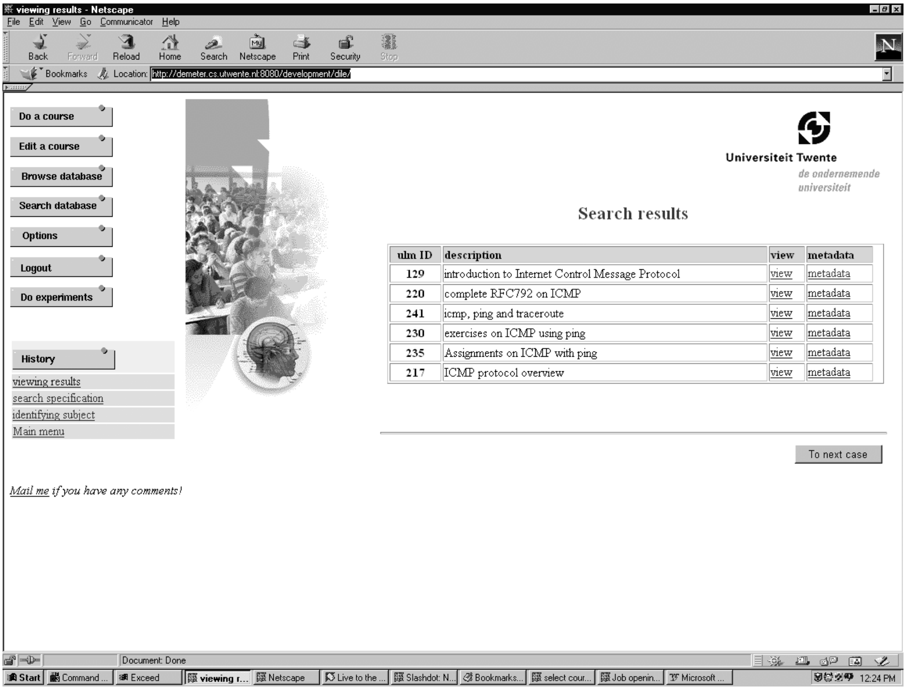
Enter some keywords: [help]	`icmp, internet`
Desired educational level	-- any --
Enter desired learning time (format hh:mm) [help]	
Desired amount of interactivity: [help]	-- any --
What is the desired pedagogical function of the content?	-- any --
How difficult should the ULM be? [help]	-- any --
What size should the ULM be? [help]	-- any --

In what order should the system examine properties of the search results? Enter 1 if you want the property to be checked first (in other words, you consider it to be the most important)and so on. Enter 4 if you want the property to be checked last (you consider it the least important)

	check first			**check last**
Importance of learning time:	○ 1	○ 2	○ 3	○ 4
Importance of interactivity:	○ 1	○ 2	○ 3	○ 4
Importance of difficulty:	○ 1	○ 2	○ 3	○ 4
Importance of size:	○ 1	○ 2	○ 3	○ 4

Figuur 1: zoekformulier van de eerste casus.

In de eerste 7 velden kunt u aangeven welk leermateriaal u zoekt door de gewenste kenmerken van het leermateriaal op te geven. Het eerste veld, de keywords, is alvast ingevuld met ‘icmp, internet’ maar u kunt dit zelf veranderen als u dat wilt. U kunt op het woordje “help” klikken om meer informatie te krijgen over de betekenis van het invoerveld. Tenslotte moet u in de laatste 4 velden aangeven in welke volgorde u vindt dat het systeem uw voorkeuren voor de kenmerken moet controleren: “1” betekent dat het kenmerk als eerste gecontroleerd moet worden, “2” als het kenmerk als tweede gecontroleerd moet worden, enzovoorts. Een “4” betekent dat het kenmerk als laatste gecontroleerd moet worden. U kunt elk cijfer maar éénmaal gebruiken, u kunt dus niet aangeven dat twee kenmerken als eerste (“1”) gecontroleerd moeten worden. Het systeem zal proberen om zoveel mogelijk aan uw wensen tegemoet te komen, maar zal hierbij een bepaalde volgorde hanteren. Het kenmerk dat het eerst wordt gecontroleerd, zal het best aan uw wensen voldoen. Het kenmerk dat als tweede wordt gecontroleerd, zal dus mogelijk iets minder aan uw wensen voldoen, etcetera.



Search results

ulm ID	description	view	metadata
129	introduction to Internet Control Message Protocol	view	metadata
220	complete RFC792 on ICMP	view	metadata
241	icmp, ping and traceroute	view	metadata
230	exercises on ICMP using ping	view	metadata
235	Assignments on ICMP with ping	view	metadata
217	ICMP protocol overview	view	metadata

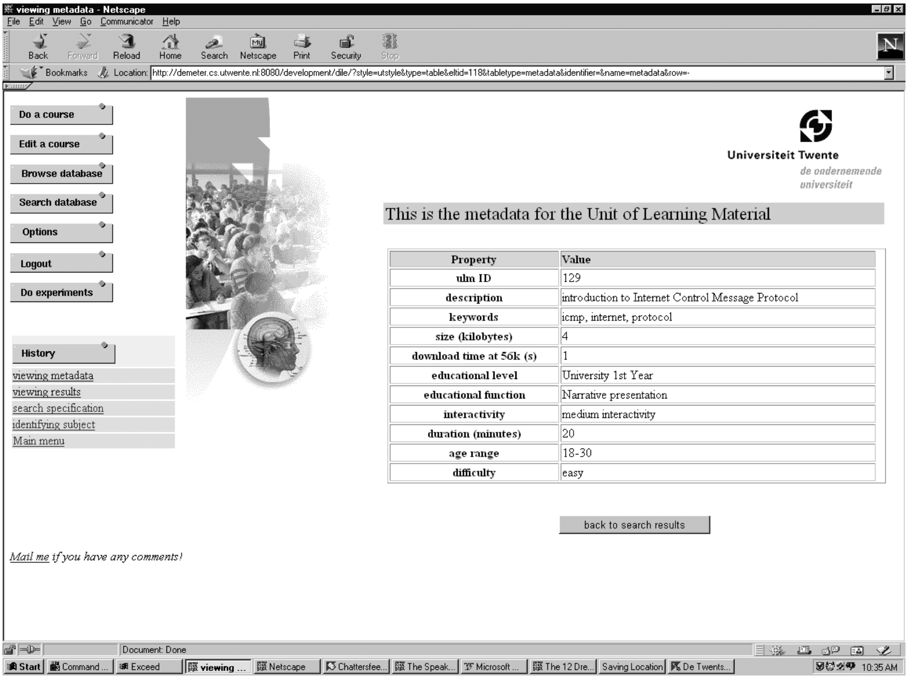
Mail me if you have any comments!

Figuur 2: voorbeeld van de zoekresultaten-lijst

Nadat u “submit data” hebt geklikt, krijgt u een lijst met zoekresultaten, zie Figuur 2. Door op “view” te klikken, kunt u het leermateriaal bestuderen. De knop “back to search results” onderaan de pagina brengt u terug in het overzicht; mogelijk moet u eerst naar onder ‘scrollen’ voordat u deze knop ziet. U kunt ook de “back” knop van uw browser gebruiken. De bedoeling van het experiment is nu dat u per zoekresultaat (“Unit of Learning Material”, of ULM) een beoordelings-formulier invult. Op het formulier vult u het nummer van de casus in, en het nummer van de ULM. Dit nummer kunt u vinden in het zoekresultaten-scherm onder de kolom “ULM id”. Als u eerst een overzicht wilt van alle zoekresultaten in een casus, dan mag u deze natuurlijk ook eerst alle bekijken, en daarna pas de beoordelings-formulieren invullen. Zorg wel dat u per zoekresultaat (ULM) één beoordelingsformulier invult.

Units of Learning Material kunnen in deze proef niet gecombineerd worden. Dus ook als u twee ULMs vind die tezamen een goede combinatie zouden vormen, dan moet u deze toch afzonderlijk beoordelen (en dus concluderen dat ze elk afzonderlijk minder bruikbaar zijn).

In de lijst met zoekresultaten vind u ook een hyperlink “metadata” bij elke Unit of Learning Material. Als u hierop klikt, dan krijgt u een opsomming van de belangrijkste kenmerken van de ULM, zoals: hoeveelheid interactiviteit, keywords, onderwijskundige functie, afmeting, doorwerktijd, download-tijd enzovoorts (zie Figuur 3). Deze kunt u ook raadplegen om de ULM te beoordelen op bruikbaarheid.



This is the metadata for the Unit of Learning Material

Property	Value
ulm ID	129
description	introduction to Internet Control Message Protocol
keywords	icmp, internet, protocol
size (kilobytes)	4
download time at 56k (s)	1
educational level	University 1st Year
educational function	Narrative presentation
interactivity	medium interactivity
duration (minutes)	20
age range	18-30
difficulty	easy

Mail me if you have any comments!

Figuur 3: voorbeeld van de "metadata" van een ULM.

De casussen

Hieronder volgen drie casussen. Elk van deze casussen beschrijft een behoefte aan leermateriaal. Deze behoefte kan worden vertaald in een bepaalde voorkeur voor kenmerken van het leermateriaal Probeer u in te leven in de situatie, en probeer van daaruit zinvolle keuzes te maken voor de invoervelden in het zoekformulier (bovenste helft) en de volgorde waarin het systeem deze moet beoordelen (onderste helft).

Het systeem zal u de zoekresultaten tonen, welke u kunt bekijken. Vul per zoekresultaat (“ULM”) een beoordelingsformulier in, waarop u het nummer van de casus en het nummer van de ULM noteert.

Casus 1.
Stel u geeft een trimester lang elke week een hoorcollege over computernetwerken voor ouderejaars studenten. U heeft vanuit voorgaande jaren de ervaring dat studenten te weinig praktische vaardigheden hebben in het werken met netwerkanalyse-programma’s zoals ‘ping’ en ‘traceroute’. U wilt dit verbeteren door “online leermateriaal” beschikbaar te stellen.

Vul uw zoekspecificatie in op het scherm, en beoordeel de zoekresultaten op geschiktheid binnen deze casus. Vul per zoekresultaat (“Unit of Learning Material”) een beoordelingsformulier in.

Casus 2.
Stel dat tijdens het college blijkt dat veel studenten de stof erg snel oppakken. Om het deze studenten wat moeilijker te maken, wilt u extra materiaal op het Internet beschikbaar stellen over het Internet Control Message Protocol.

Vul uw zoekspecificatie in op het scherm, en beoordeel de zoekresultaten op geschiktheid binnen deze casus. Vul per zoekresultaat (“Unit of Learning Material”) een beoordelingsformulier in.

Casus 3.
Voor het praktikum-gedeelte van uw vak heeft u 4 uur ingeroosterd voor het onderwerp “TCP/IP in het OSI model”, en u wilt nu 1 uur hiervan besteden aan de netwerk-laag en signalering. De bedoeling is dat de studenten een theorie-gedeelte krijgen tijdens dit uur, en aansluitend een praktijk-gedeelte.

Vul uw zoekspecificatie in op het scherm, en beoordeel de zoekresultaten op geschiktheid binnen deze casus. Vul per zoekresultaat (“Unit of Learning Material”) een beoordelingsformulier in.

Z.O.Z.

De casussen

Hieronder volgen drie casussen. Elk van deze casussen beschrijft een behoefte aan leermateriaal. Deze behoefte kan worden vertaald in een bepaalde voorkeur voor kenmerken van het leermateriaal. Probeer u in te leven in de situatie, en probeer van daaruit zinvolle keuzes te maken voor de invoervelden in het zoekformulier (bovenste helft) en de volgorde waarin het systeem deze moet beoordelen (onderste helft).

Het systeem zal u de zoekresultaten tonen, welke u kunt bekijken. Vul per zoekresultaat ("ULM") een beoordelingsformulier in, waarop u het nummer van de casus en het nummer van de ULM noteert.

Casus 1.
Een niet-technische faculteit heeft besloten haar studenten een vak Informatie-Technologie aan te bieden. De studenten hebben geen technische voorkennis. Omdat de programma's 'ping' en 'traceroute' op elke PC te vinden zijn, en omdat deze de werking van het Internet zichtbaar kunnen maken, behoort ook het ICMP protocol en deze twee programma's tot de stof.

Vul uw zoekspecificatie in op het scherm, en beoordeel de zoekresultaten op geschiktheid binnen deze casus. Vul per zoekresultaat ("Unit of Learning Material") een beoordelingsformulier in.

Casus 2.
Het vak dat u geeft vergt eigenlijk al teveel tijd van de studenten. Toch blijkt een hiaat in de stof te bestaan: het Internet Control Message Protocol mist. De bestaande stof kan eigenlijk niet ingekort worden. Toch wilt u materiaal aanbieden over ICMP.

Vul uw zoekspecificatie in op het scherm, en beoordeel de zoekresultaten op geschiktheid binnen deze casus. Vul per zoekresultaat ("Unit of Learning Material") een beoordelingsformulier in.

Casus 3
Via een europees project heeft u bij uw college een doelgroep erbij gekregen: studenten van universiteiten in oost-Europa gaan delen van uw vak "computernetwerken" volgen. Hun niveau is vergelijkbaar met dat van uw eigen studenten, maar hun netwerkverbinding is natuurlijk veel trager. De standaard-boeken zoals Tanenbaum zijn niet verkrijgbaar, dus de studenten zijn aangewezen op het online materiaal. Het onderwerp waar u materiaal over zoekt is wederom ICMP.

Vul uw zoekspecificatie in op het scherm, en beoordeel de zoekresultaten op geschiktheid binnen deze casus. Vul per zoekresultaat ("Unit of Learning Material") een beoordelingsformulier in.

Z.O.Z.

U kunt nu uitloggen door op “Logout” te klikken.

We zijn er ook in geïnteresseerd hoe moeilijk u deze proef vond. Daarom volgen hieronder enkele vragen over handelingen tijdens de proef. Kunt u hierbij aangeven hoe gemakkelijk u de handelingen vond?

	gemak-kelijk				moeilijk
1. Hoe gemakkelijk vond u het om te bepalen of een Unit of Learning Material bruikbaar was voor een casus?	[ ]	[ ]	[ ]	[ ]	[ ]
2. Hoe gemakkelijk vond u het om u in te leven in de casus-beschrijvingen?	[ ]	[ ]	[ ]	[ ]	[ ]
3. Hoe gemakkelijk vond u het om de situatie in de casus te vertalen naar keuzes voor kenmerken van het leermateriaal in het zoekformulier?	[ ]	[ ]	[ ]	[ ]	[ ]
4. Hoe gemakkelijk vond u het om de volgorde aan te geven waarin het systeem de kenmerken moet controleren?	[ ]	[ ]	[ ]	[ ]	[ ]
5. Waren er factoren in het beoordelingsformulier waarvan u het doorgaans moeilijk vond om te bepalen of deze meetelden bij het bepalen van de bruikbaarheid? Zo ja, geef dan hieronder de nummers op (zie het beoordelingsformulier):					

Tenslotte volgen hieronder nog enkele uitspraken. Kunt u aangeven in hoeverre u het ermee eens bent?

	mee oneens		neu-traal		mee eens
6. Het viel mij op dat de waarden in het “metadata” overzicht niet altijd correct of accuraat waren.	[ ]	[ ]	[ ]	[ ]	[ ]
7. Ik vond het “metadata” overzicht (bv. Figuur 3) handig bij het bepalen van de bruikbaarheid van het materiaal.	[ ]	[ ]	[ ]	[ ]	[ ]
8. De situaties die beschreven werden in de casussen zijn realistisch.	[ ]	[ ]	[ ]	[ ]	[ ]
9. Er waren casussen waar eigenlijk àlle ULMs wel bruikbaar waren.	[ ]	[ ]	[ ]	[ ]	[ ]

U kunt de beoordelingsformulieren en deze vragenlijst opsturen naar:

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Heel erg bedankt voor uw medewerking!
Gerrit Hiddink

C.3 The IEEE Metadata Standard

The IEEE metadata standard [1] consists of nine major categories: ‘General’; ‘Lifecycle’ (all about how the learning object was created, who contributed to it, etcentera); ‘Metametadata’ (what is known about the metadata record itself); ‘Technical’: technical details about using the learning object; ‘Educational’: educational characteristics; ‘Rights’: what is known about the intellectual property rights and the costs of using the learning object; ‘Relation’: relations that this learning object may have with other learning objects; ‘Annotation’: additional comments or notes added to the metadata record by users; and ‘Classification’: where does this learning object fall within a particular classification system.

These nine categories contain various elements or subcategories. The categories and their elements are described below. Note that this overview does not pretend to be able to explain the precise meaning of these elements in detail; it only serves as a global overview of what constitutes the IEEE metadata standard.

Table C.1: The IEEE metadata fields

nr	metadata field	description
1	GENERAL	This category describes general information.
1.1	Identifier	A globally unique identifier that identifies this learning object, such as a number.
1.2	Title	The name that was given to this learning object.
1.3	Catalog Entry	Describes an entry that this learning object may have into a catalog.
1.3.1	Catalog	the name of the catalog
1.3.2	Entry	an identifier describing the entry in the catalog mentioned in 1.3.1
1.4	Language	The primary human language(s) used in the learning object.
1.5	Description	A textual description of the content of this learning object.
1.6	Keywords	Keywords or phrases describing this learning object.
1.7	Coverage	The span or extent of things as time, culture, or geographical region that applies to this learning object.

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[1] http://ltsc.ieee.org/doc/wg12/LOM_WD6-1_without_tracking.htm

1.8	Structure	The internal structure of this learning object (eg. linear, or branched).
1.9	Aggregation level	The functional granularity of this learning object.
2	LIFECYCLE	The category describing the lifecycle of the learning object.
2.1	Version	The current version of the learning object.
2.2	Status	The state or condition (eg. draft, final) of the object.
2.3	Contribute	A data element describing the people that contributed to the object.
2.3.1	Role	the kind of contribution that a person made.
2.3.2	Entity	the person or organisation that made this contribution.
2.3.3	Date	the data on which the contribution took place.
3	METAMETADATA	This category describes what is known about the metadata record itself.
3.1	Identifier	A globally unique label that identifies this metadata record.
3.2	Catalog Entry	This describes a catalog entry in which this metadata record resides.
3.2.1	Catalog	The name of the catalog.
3.2.2	Entry	The string value of the entry in the catalog.
3.3	Contribute	This subcategory describes the contributions that have been made to this record.
3.3.1	Role	The kind of contribution that a person made.
3.3.2	Entity	The person or organisation that made this contribution.
3.3.3	Date	The date on which the contribution took place.
3.4	Metadata Scheme	The name and version of the specification used to create the metadata instance.
3	Language	The default human language of the texts in the metadata record.
4	TECHNICAL	The technical requirements and characteristics of the learning object.
4.1	Format	The data type(s) of this learning object (eg. MIME types).

4.2	Size	size of the digital learning object in bytes.
4.3	Location	A string that is used to access this learning object, such as a URL.
4.4	Requirements	A sub-category describing the technical requirements needed to use the learning object.
4.4.1	Type	The technology type required to use this learning object, such as hardware, network, or software.
4.4.2	Name	The name of the required technology.
4.4.3	Minimum Version	Minimum required version of the technology needed.
4.4.4	Maximum Version	Maximum version known to support the use of this learning object.
4.5	Installation Remarks	Description of how to install the learning object.
4.6	Other Platform Requirements	Information about other software and hardware requirements.
4.7	Duration	Time a continuous learning object takes to play.
5	EDUCATIONAL	The educational characteristics of this learning object.
5.1	Interactivity Type	The flow of interaction between this learning object and the user (eg. active, or expositive).
5.2	Learning resource type	The specific kind of the learning object (eg. graph, exam, or simulation).
5.3	Interactivity Level	The degree of interactivity between the end user and the object (very low . . . very high).
5.4	Semantic Density	The amount of information conveyed by this learning object as compared to its size or duration.
5.5	Intended End User Role	The intended role of the end user (eg. teacher, author, or learner).
5.6	Context	The principal environment within which this learning object was intended to be used.
5.7	Typical Age Range	The age range of the typical end user.
5.8	Difficulty	This defines how difficult it is for the intended end user to use this learning object.

5.9	Typical Learning Time	The typical time it takes to work with this learning object.
5.10	Description	How this learning object is to be used.
5.11	Language	The human language used by the typical intended user of this learning object.
6	RIGHTS	The intellectual property rights and conditions for using this object.
6.1	Cost	Whether or not using this learning object requires payment.
6.2	Copyright and other restrictions	Whether copyright or other restrictions apply to the use of this object.
6.3	Description	Comments on the conditions of use of this learning object.
7	RELATION	This category defines the relationshop between this learning object and others.
7.1	kind	Nature of the relationship (eg. IsPartOf, or IsBasedOn).
7.2	Resource	The learning object that this relation references.
7.2.1	Identifier	The unique identifier of the target learning object.
7.2.2	Description	Description of the target learning object.
7.2.3	Catalog Entry	See 1.3: Catalog Entry.
8	ANNOTATION	A category that describes comments added to the metadata record.
8.1	Person	The person who created this annotation.
8.2	Date	The date that this annotation was created.
8.3	Description	The content of this annotation.
9	CLASSIFICATION	This category describes where this learning object falls within a particular classification system.
9.1	Purpose	The purpose of classifying this learning object.
9.2	TaxonPath	A sub-category that describes a taxonomic path in the classification system.
9.2.1	Source	The name of the classification system.
9.2.2	Taxon	A sub-category that describes a particular term within the taxonomy.
9.2.2.1	ID	The identifier of the term.
9.2.2.2	Entry	The textual label of the taxon.
9.3	Description	The description of the learning objective with respect to the classification purpose.
9.4	Keywords	The keywords and phrases

C.4 Beoordelings-formulier

Casus nummer .....
ULM ID .....
Subject ID .....

Geef een algehele score voor de *bruikbaarheid* van dit leermateriaal (1 - 10) ....

Hieronder volgen 12 factoren die mee kunnen hebben gespeeld bij het bepalen van de bruikbaarheid van het leermateriaal. Kruis per factor aan of deze mee heeft geteld bij het bepalen van de bruikbaarheid van *deze* Unit of Learning Material voor *deze casus*, of niet. Als u het niet weet, kunt u dit ook aankruisen.

	telde niet mee	weet niet	telde wel mee
1. De mate waarin de uiterlijke kenmerken van het leermateriaal (opmaak, presentatie, kleurgebruik) acceptabel zijn	[ ]	[ ]	[ ]
2. De mate waarin het leermateriaal verwijst naar andere, mogelijk afwezige stof-onderdelen	[ ]	[ ]	[ ]
3. De stijl waarin de tekstuele inhoud van het leermateriaal is geschreven.	[ ]	[ ]	[ ]
4. De inhoudelijke correctheid van het leermateriaal	[ ]	[ ]	[ ]
5. De onderwijskundige aanpak die in de ULM is gebruikt	[ ]	[ ]	[ ]
6. De mate waarin de oefeningen in het leermateriaal aansluiten bij uw eigen inzichten over oefeningen.	[ ]	[ ]	[ ]
7. De compleetheid van de Unit of Learning material, d.w.z.: komen alle aspecten die behandeld moeten worden aan bod?.	[ ]	[ ]	[ ]
8. De hoeveelheid van interactiviteit van deze Unit of Learning Material	[ ]	[ ]	[ ]
9. De tijd die een student nodig heeft om deze Unit of Learning Material door te werken	[ ]	[ ]	[ ]
10. De moeilijkheid van deze Unit of Learning Material voor de doelgroep	[ ]	[ ]	[ ]
11. De afmeting in kilobytes van deze Unit of Learning Material	[ ]	[ ]	[ ]
12. De mate waarin het abstractie-niveau van de Unit of Learning Material overeenkomst met wat gewenst is in deze casus	[ ]	[ ]	[ ]
Wat voor mij ook belangrijk was voor het bepalen van de bruikbaarheid was:			

Opm: ....
....

Figure D.1: Answers of the test subjects on part B of the questionnaire (see Section 7.3.3)

ID	sca.avg	scb.avg	scc.avg	cc.avg	nn.avg	lo.avg	bi.avg	cb.scb (B1c.	at.scb.avg	cb.scc(B1c.c	at.scc.avg	cb.cc.avg	at.cc.avg	cb.nk.avg	at.nk.avg	cb.lo (B5)	at.lo.avg	sca-7.13	nk-7.3	bi-7.5
2	-0,0345	-0,0916	-0,1128	0,34897	-0,4675	-0,2714	-0,4439		-0,0916		-0,1128	-0,719	1,41689	-0,7035	0,13672	-0,4695	-0,2714	0,33804	-0,7027	-0,4439
3	1,34592	0,67036	0,01376	-0,7641	0,89434	0,25766	0,73975	-0,9309	1,47102	-0,6515	0,34641	-0,719	-0,8092	1,33169	0,59401		0,25766	1,19144	0,66685	0,73975
4	0,12726	-0,0916	0,34641	1,3524	0,46607	0,11804	0,31653		-0,0916		0,34641	1,2879	1,41689	0,26101	0,59401	-0,4695	0,11804	0,17498	0,66685	0,31653
17	0,8049	0,23184	0,34334	0,45742	-0,2812	0,5409	0,47273	0	0,34775		0,34334	0,28447	0,63036	-0,6939	0,13672	-0,4695	0,5409	1,19144	-0,2466	0,47273
144	0,24992	0,65721	1,25559	-0,6707	0,56691	-0,017	0,53284		0,65721		1,25559	-0,139	-1,2025	0,05698	0,59401	-0,4695	-0,017	0,76474	1,12298	0,53284
10	0,3834	-0,0916	0,59013	-0,5841	-0,0303	-0,3887	0,22044		-0,0916	0,17145	0,79947	-0,719	-0,4493	0,14972	-0,5357	-0,4695	-0,3887	-0,0887	0,20956	0,22044
32	0,40434	-0,9704	-0,018	0,45742	-1,0875	-0,3658	-0,1413		-0,9704	0,17145	-0,1128	0,28447	0,63036	-0,6664	-1,4503	-0,4695	-0,3658	0,76474	-1,6173	-0,1413
11	0,10946	0,68775	0,59013	1,64239	0,08413	0,33471	0,27713	0	1,03163	0,17145	0,79947	1,86789	1,41689	-0,6939	0,59401	-0,4695	0,33471	0,17498	0,66685	0,27713
14	-0,6176	-0,0916	0,79947	-0,0808	1,04758	-0,1533	-0,1357		-0,0916		0,79947	-0,139	-0,0227	1,25749	1,0513	-0,4695	-0,1533	-0,0887	1,12414	-0,1357
26	-0,0485	-0,0267	0,80254	-0,9607	0,93246	-0,3175	-0,4742		-0,0267		0,80254	-0,719	-1,2025	1,42814	0,13672	-0,4695	-0,3175	-0,0887	0,66569	-0,4742
18	0,11618	-0,596	-1,472	0,73429	-1,1884	-0,5219	-1,2328		-0,596		-1,472	1,13136	0,33722	-0,7035	-1,6654	-0,4695	-0,5219	0,17498	-1,16	-1,2328
x1	0,20818	-0,4147	0,79947	1,15576	0,27317	0,31278	0,74573	-0,9309	-0,1566		0,79947	1,2879	1,02362	-0,2212	0,59401	-0,4695	0,31278	0,76474	0,66685	0,74573
7	0,60049	0,29254	0,25834	0,87575	-0,2506	-0,7374	0,68904	0,93095	-0,0267	0,99444	-0,1097	1,021	0,73049	-1,0745	0,59401	-0,4695	-0,7374	0,76474	0,21073	0,68904
28	0,09934	-0,4661	0,34948	-0,9909	0,02344	-0,5361	0,16306		-0,4661		0,34948	-1,5658	-0,4159	-0,6293	-0,0784	-0,4695	-0,5361	-0,6784	1,12298	0,16306
30	0,1133	0,43814	1,25559	0,56907	-0,0704	0,65837	0,35956	0	0,65721		1,25559	0,44102	0,69711	-0,4067	-0,5357	2,08656	0,65837	-0,2517	0,66569	0,35956
29	0,66828	1,47102	0,01172	0,52257	0,23911	0,0242	0,37664		1,47102	-0,6515	0,34334	0,70792	0,33722	0,14972	0,59401	-0,4695	0,0242	0,17498	0,21073	0,37664
34	-0,2896	0,37744	0,62193	0,7657	0,78646	0,81871	0,6066	-0,9309	1,03163	-0,6515	1,25866	0,44102	1,09038	0,14972	0,59401	-0,4695	0,81871	0,17498	1,5791	0,6066
x2	0,16706	0,55954	-0,1128	0,34263	-0,1075	0,21564	0,52942	1,8619	-0,0916		-0,1128	0,70792	-0,0227	0,14972	0,47464	-0,4695	0,21564	-0,0887	-1,2042	0,52942
5	-0,0353	-0,2216	-1,0189	-1,3842	0,05666	0,24879	-0,4277		-0,2216		-1,0189	-1,5658	-1,2025	0,14972	0,59401	-0,4695	0,24879	-0,1024	-0,2454	-0,4277
33	0,51522	-0,3107	-0,6221	0,62506	-0,2656	-0,605	0,16921	0	-0,4661	0,17145	-1,0189	0,12793	1,61933	0,71588	-0,7779	-0,4695	-0,605	0,17498	-1,6173	0,16921
25	-0,1432	-0,458	-0,5597	-0,7792	0,74002	0,09286	-0,0731	-0,9309	-0,2216		-0,5597	-1,1424	-0,4159	0,94588	0,59401	-0,4695	0,09286	0,17498	0,66685	-0,0731
38	-0,1144	-0,1477	-0,318	0,1309	-0,1496	0,31265	-0,7041	0	-0,2216	0,17145	-0,5628	0,28447	-0,0227	0,09266	-0,3206	2,08656	0,31265	-0,6784	-0,7039	-0,7041
51	0,42153	-0,621	0,01376	-0,459	0,20986	0,06096	-0,2374	-0,9309	-0,4661	-0,6515	0,34641	0,28447	-1,2025	-0,3795	0,59401	2,08656	0,06096	1,19144	0,66685	-0,2374
55	-0,1432	-0,3714	-0,5628	-0,0808	0,52304	0,42308	-0,0812	-0,9309	-0,0916		-0,5628	-0,139	-0,0227	1,31685	0,13672	-0,4695	0,42308	0,17498	-0,2466	-0,0812
59	-0,6886	-0,6817	-0,2606	-0,341	-0,3439	0,2411	0,09212	-1,8619	-0,0916	-1,4745	0,34641	-0,9859	0,30385	-0,4191	-0,7508	2,08656	0,2411	0,17498	0,66685	0,09212
44	0,49251	0,65721	-0,1128	-0,6707	-0,0007	0,50644	-0,8234		0,65721		-0,1128	-0,139	-1,2025	0,46363	0,13672	-0,4695	0,50644	-0,0887	-0,7027	-0,8234

Figure D.1 (continued): Answers of the test subjects on part B of the questionnaire (see Section 7.3.3)

ID	sca.avg	scb.avg	scc.avg	cc.avg	nn.avg	lo.avg	bi.avg	cb.scb (B1c.	at.scb.avg	cb.scc(B1c.c	at.scc.avg	cb.cc.avg	at.cc.avg	cb.nk.avg	at.nk.avg	cb.lo (B5)	at.lo.avg	sca-7.13	nk-7.3	bi-7.5
43	0,16706	0,65721	0,83879	1,12559	0,43732	1,03313	0,22044		0,65721	1,81742	0,34948	0,44102	1,81016	-0,267	0,59401	2,08656	1,03313	-0,0887	1,12298	0,22044
42	0,1133	-1,3448	-0,316	-0,3875	0,46607	-0,0307	0,6066		-1,3448	0,17145	-0,5597	-0,719	-0,056	0,26101	0,59401	2,08656	-0,0307	-0,2517	0,66685	0,6066
37	0,99953	0,60285	0,22858	-0,2941	-0,4675	0,34148	-0,2606	1,8619	-0,0267	1,81742	-0,5658	-0,139	-0,4493	-0,7035	0,13672	2,08656	0,34148	0,76474	-0,7027	-0,2606
54	-1,5022	-0,9704	-0,8667	0,1758	-0,4335	-0,2791	0,02859		-0,9704	-1,4745	-0,5628	0,44102	-0,0894	-1,0745	0,13672	-0,4695	-0,2791	-1,8579	-0,2466	0,02859
41	-0,0014	0,73107	0,59013	0,31085	0,40375	-0,143	0,49595	0	1,0966	0,17145	0,79947	0,28447	0,33722	0,10521	0,59401	-0,4695	-0,143	0,76474	0,66685	0,49595
57	0,52043	-0,0611	-0,5658	-0,0673	-0,0619	-0,0588	-0,8092	0	-0,0916		-0,5658	0,70792	-0,8426	0,98298	-0,5357	-0,4695	-0,0588	0,76474	-0,7027	-0,8092
6	0,5085	-0,0437	0,26038	0,28585	0,46607	-0,2632	-0,6099	0,93095	-0,531	0,99444	-0,1066	1,021	-0,4493	0,26101	0,59401	-0,4695	-0,2632	0,17498	0,66685	-0,6099
13	0,16332	-0,8792	-1,0158	-0,5841	-0,3156	-0,188	0,10022	0,93095	-1,7842		-1,0158	-0,719	-0,4493	0,13489	-0,7779	-0,4695	-0,188	-0,5154	-1,1611	0,10022
39	0,22201	0,65721	-0,5646	-0,0824	-0,468	-0,1433	-0,3855		0,65721	-1,4745	-0,1097	0,28447	-0,4493	-0,7035	-0,3206	-0,4695	-0,1433	-0,0887	-0,7039	-0,3855
36	0,18724	-0,751	0,34027	0,81256	-0,433	0,30263	-0,9134	-0,9309	-0,661		0,34027	1,2879	0,33722	-1,0745	0,59401	2,08656	0,30263	-0,0887	-0,2454	-0,9134
9	0,0053	0,12782	-0,5658	-0,5841	-0,0817	0,50945	0,04989	-0,9309	0,65721		-0,5658	-0,719	-0,4493	0,26101	0,13672	-0,4695	0,50945	0,76474	-0,7027	0,04989
35	-0,8488	-0,9704	-0,5944	-0,7641	-0,8334	0,0896	-0,1691		-0,9704	-0,6515	-0,5658	-0,719	-0,8092	-0,7035	-0,7779	-0,4695	0,0896	-1,6949	-1,6173	-0,1691
16	0,19473	0,24922	1,25559	-0,0808	0,11433	-0,1006	0,51576	0,93095	-0,0916		1,25559	-0,139	-0,0227	-1,0745	0,59401	-0,4695	-0,1006	0,76474	1,12298	0,51576
24	-0,0345	0,12782	-0,1097	-1,1875	0,62691	-0,5127	-0,8126	-0,9309	0,65721		-0,1097	-1,5658	-0,8092	1,57652	0,13672	-0,4695	-0,5127	0,33804	-0,2466	-0,8126
15	-0,1572	0,28278	-0,318	-0,0975	0,34298	0,17683	0,85889		0,28278	0,17145	-0,5628	-0,139	-0,056	0,4094	0,59401		0,17683	-0,2517	0,21073	0,85889
50	-1,9057	-2,2056	-1,472	-1,2025	-0,9818	0,00845	0,11372		-2,2056		-1,472	0	-1,2025	-1,0745	-0,7779	-0,4695	0,00845	-2,8744	-1,6173	0,11372
40	0,31234	0,43814	0,28809	1,27412	-0,0681	0,21839	1,0752	0	0,65721	0,17145	0,34641	1,13136	1,41689	-1,0745	0,59401	-0,4695	0,21839	0,17498	0,66685	1,0752
21	-0,5895	-0,531	-1,0158	-0,0109	-0,0564	-1,3071	-0,3452		-0,531		-1,0158	-0,719	0,69711	1,42814	-1,4232	-0,4695	-1,3071	-0,0887	0,21073	-0,3452
61	-0,9124	0,65721	0,03943	-0,5841	-0,1672	-0,3701	0,53284		0,65721	-1,4745	0,7964	-0,719	-0,4493	0,72083	-0,993	-0,4695	-0,3701	-0,6784	-0,7039	0,53284
65	-0,1001	0,74845	-0,1097	0,31085	0,25693	0,21074	-0,1413	0,93095	0,65721		-0,1097	0,28447	0,33722	0,4094	0,37889	-0,4695	0,21074	0,17498	0,66802	-0,1413
56	-1,0216	0,21782	-0,5658	-0,0808	-0,2647	0,22412	-0,7983		0,21782		-0,5658	-0,139	-0,0227	0,26101	-0,3206	2,08656	0,22412	-1,6949	-1,16	-0,7983
66	0,10946	-0,6036	-0,016	0,27907	-0,5912	-0,5693	-0,2777	0	-0,9055	0,17145	-0,1097	-0,139	0,69711	-0,7962	-0,5357	-0,4695	-0,5693	0,17498	-0,2466	-0,2777
68	-1,2672	-0,9055	-1,0158	-0,9607	-1,4578	-1,0809	-0,2408		-0,9055		-1,0158	-0,719	-1,2025	-0,7035	-2,7951	-0,4695	-1,0809	-1,1051	-1,1611	-0,2408
63	-0,5364	-0,2216	1,44287	-0,7641	0,64852	0,42858	-0,316		-0,2216	1,81742	1,25559	-0,719	-0,8092	0,26101	0,59401	-0,4695	0,42858	-0,4148	1,12298	-0,316
47	0,54136	1,3517		0,6652	0,37187	0,27299	0,04716	1,8619	1,0966		0	1,32114	0,33722	0,14972	0,59401	-0,4695	0,27299	0,77848	0,71338	0,04716

Figure D.2: Answers of the test subjects on part C of the questionnaire (see Section 7.3.3)

context 1					context 2					context 3					context 4					context 5					context 6			average over all contexts							
subject ID	level	time	interactivity	function	subject	level	time	interactivity	function	subject	level	time	interactivity	function	subject	level	time	interactivity	function	subject	level	time	interactivity	function	subject	level	time	interactivity	function	subject	level	time	interactivity	function	subject
2	4	2	3	5	5	4	2	1	5	4	4	1	2	3	5	4	3	1	2	5	4	1	2	4	5	5	2	1	5	4	4.17	1.83	1.67	4	4.67
3	3	1	2	4	5	3	2	1	4	5	4	1	3	2	5	5	1	3	2	4	1	2	3	4	5	3	1	2	5	4	3.17	1.33	2.33	3.5	4.67
4	3	2	1	4	5	3	2	1	4	5	4	2	1	3	5	4	1	2	3	5	4	2	1	3	5	4	2	1	3	5	3.67	1.83	1.17	3.33	5
17	1	3	2	4	5	2	1	3	4	5	3	2	1	4	5	3	2	4	1	5	5	2	1	3	4	1	2	3	4	5	2.5	2	2.33	3.33	4.83
144	1	4	5	3	2	1	4	3	3	2	1	4	3	2	2	1	3	3	2	2	1	4	5	3	2	1	3	3	4	2	1	3.67	3.67	2.83	2
10	4	1	2	3	5	4	3	2	1	5	4	1	2	3	5	3	2	1	4	5	4	3	1	2	5	4	3	1	2	5	3.83	2.17	1.5	2.5	5
32	5	4	2	1	3	3	4	5	1	2	5	4	3	1	2	2	3	4	1	5	2	4	5	3	1	3	4	5	2	1	3.33	3.83	4	1.5	2.33
11	1	2	4	5	3	5	3	2	1	4	4	2	1	3	5	4	1	2	3	5	5	2	1	3	4	4	1	2	3	5	3.83	1.83	2	3	4.33
14	5	3	2	2	4	4	3	5	2	3	5	3	5	4	3	5	4	5	2	2	3	2	4	4	1	5	2	5	2	1	4.5	2.83	4.33	2.67	2.33
26	3	2	1	4	5	3	2	1	4	5	3	2	1	4	5	3	2	1	4	5	3	2	1	4	5	3	2	1	4	5	3	2	1	4	5
18	1	2	3	5	4	3	1	2	4	5	1	2	5	4	3	1	3	5	4	2	1	2	4	3	5	2	4	5	3	1	1.5	2.33	4	3.83	3.33
x1	4	1	3	5	2	3	4	2	5	1	4	1	2	5	3	4	1	3	2	5	2	1	3	5	4	2	1	3	5	4	3.17	1.5	2.67	4.5	3.17
7	2	1	3	3	3	1	4	2	3	5	1	1	1	1	1	5	1	3	2	4	3	1	2	3	3	2	1	2	2	2	2.33	1.5	2.17	2.33	3
28	4	1	5	2	3	2	1	5	4	3	4	1	5	2	3	5	1	4	2	3	3	1	4	2	5	2	1	3	4	5	3.33	1	4.33	2.67	3.67
30	2	1	5	3	4	2	1	4	5	3	1	2	4	5	3	4	3	5	2	1	4	3	2	1	5	2	1	5	3	4	2.5	1.83	4.17	3.17	3.33
29																																			
34	2	1	5	4	3	1	2	4	5	3	2	1	4	3	5	4	1	3	2	5	4	1	5	3	2	3	1	5	4	2	2.67	1.17	4.33	3.5	3.33
x2	3	1	2	4	5	1	3	2	4	5	4	1	2	3	5	4	1	3	2	5	3	1	2	4	5	2	1	3	4	5	2.83	1.33	2.33	3.5	5
5	1	2	3	4	5	4	2	3	1	5	4	2	3	1	5	4	1	3	2	5	4	3	1	2	5	4	3	1	2	5	3.5	2.17	2.33	2	5
33																																			
25	3	1	2	4	5	5	1	2	4	3	5	1	2	3	4	2	1	4	3	5	4	1	3	5	2	3	1	2	5	4	3.67	1	2.5	4	3.83
38	2	1	5	4	3	2	3	4	1	5	2	1	4	3	5	2	1	5	3	4	2	1	5	4	3	2	1	5	4	3	2	1.33	4.67	3.17	3.83
51	4	3	5	1	2	3	4	5	2	1	3	4	5	2	1	3	4	5	2	1	3	4	5	2	1	3	4	5	2	1	3.17	3.83	5	1.83	1.17
55	4	2	1	3	5	3	2	1	4	5	4	2	1	3	5	4	2	1	3	5	1	3	2	4	5	4	2	1	3	5	3.33	2.17	1.17	3.33	5
59	2	4	1	3	5	3	2	1	4	5	4	1	2	3	5	3	2	1	4	5	3	1	2	4	5	2	1	3	4	5	2.83	1.83	1.67	3.67	5
44	4	3	2	1	5	1	2	3	4	5	2	4	5	1	3	1	5	3	4	2	2	5	4	1	3	4	3	2	1	5	2.33	3.67	3.17	2	3.83
43	2	3	4	5	1	1	3	4	2	5	3	1	2	3	5	5	1	3	4	2	5	1	3	4	2	3	1	2	4	5	3.17	1.67	3	3.67	3.33
42	3	2	1	4	5	3	2	1	4	5	3	1	2	4	5	4	2	1	3	5	4	1	2	3	5	4	1	2	3	5	3.5	1.5	1.5	3.5	5
37	4	3	2	1	5	4	3	2	1	5	4	3	2	1	5	5	3	2	1	4	5	3	2	1	4	4	3	2	1	5	4.33	3	2	1	4.67
54	1	2	4	5	3	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5	1	2	3.17	4.17	4.67
41	3	1	2	2	3	3	1	2	2	3	3	1	2	2	3	3	1	2	2	3	3	1	2	2	3	3	1	2	3	3	3	1	2	2.17	3
57	2	1	5	4	3	5	4	3	1	2	5	1	2	4	3	5	2	1	3	4	5	2	1	3	4	1	2	5	3	4	3.83	2	2.83	3	3.33
6	3	3	2	4	5	3	3	2	4	5	3	3	2	4	5	3	3	2	4	5	3	3	2	4	5	3	3	2	4	5	3	3	2	4	5
13	4	1	2	3	5	3	1	2	4	5	4	2	1	3	5	5	1	3	2	4	4	1	2	3	5	4	1	2	3	5	4	1.17	2	3	4.83
39	5	3	4	5	5	5	3	4	5	5	5	3	4	5	5	5	3	4	5	5	5	3	4	5	5	5	3	4	5	5	5	3	4	5	5
36	5	1	2	4	3	2	4	3	5	1	3	5	4	2	1	4	1	2	3	5	1	4	2	3	5						3	3	2.6	3.4	3
9	2	1	3	5	4	2	1	4	5	3	4	1	2	3	5	4	1	3	1	5	4	1	3	2	5	4	1	2	3	5	3.33	1	2.83	3.17	4.5
35						3	4	1	2	5						3	4	1	2	5	3	4	1	2	5	3	4	1	2	5					
16																																			
24	5	1	2	3	4	5	1	3	4	2	4	2	1	3	5	4	1	3	2	5	5	1	2	3	4	3	4	1	2	5	4.33	1.67	2	2.83	4.17
15	5	1	2	4	3	4	3	2	5	1	5	1	3	2	4	3	1	4	5	2	5	1	3	4	2	3	1	2	5	4	4.17	1.33	2.67	4.17	2.67
50																																			
40																																			
21	4	1	2	3	5	4	2	1	3	5	4	2	1	3	5	4	2	1	3	5	3	2	1	4	5	4	1	2	3	5	3.83	1.67	1.33	3.17	5
61	5	1	3	4	2	5	1	3	4	2	5	1	3	4	2	5	3	4	1	2	4	1	2	3	5	5	1	4	2	3	4.83	1.33	3.17	3	2.67
65	4	2	1	3	5	3	1	2	5	4	4	2	3	1	5	4	2	3	1	5	4	3	2	1	5	3	2	1	5	4	3.67	2	2	2.67	4.67
56	4	1	2	5	3	4	3	1	2	4	4	1	2	4	3	5	2	1	4	3	3	2	1	4	4	3	2	1	4	3	3.83	1.83	1.33	3.83	3.33
66	4	1	3	2	5	4	1	3	2	5	4	1	3	2	5	4	1	3	2	5	4	1	3	2	5	4	1	3	2	5	4	1	3	2	5
68	3	2	1	5	4	2	3	1	4	5	3	2	1	5	4	5	2	1	3	4	5	2	1	3	4	3	2	1	4	5	3.5	2.17	1	4	4.33
63	3	1	5	2	4	1	3	4	2	5	3	1	5	2	4	5	1	4	3	2	5	4	1	3	2	1	3	5	2	4	3	2.17	4	2.33	3.5
47	2	5	4	3	5	4	3	1	2	5	4	1	2	3	5	4	1	2	3	5	5	1	2	3	4	4	1	2	3	5	3.83	2	2.17	2.83	4.83

Figure D.3: Data of the validation experiment (see Section 8.5)

persoon	casus	size	diff	int	time	sizeW	diffW	intW	timeW	ulm	size	diff	int	time	taxi	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	score	factor1	factor2	factor3	factor4	factor5	factor6	factor7	factor8	factor9	factor10	factor11	factor12
1	1		2	4	2:00:00	1	1	4	3	238	3	3	2	15	3,78	0,84	1,02	1,19	1,37	1,55	1,73	1,91	2,09	2,26	2,44	2,62	4	3	1	2	3	3	3	3	3	3	1	1	3
1	1		2	4	2:00:00	1	1	4	3	242	3	3	4	10	2,7	0,86	1,02	1,18	1,35	1,51	1,68	1,84	2,01	2,18	2,34	2,51	1				3		3	3	3				
1	1		2	4	2:00:00	1	1	4	3	231	3	3	4	50	0,7	0,26	0,28	0,31	0,33	0,36	0,39	0,42	0,45	0,48	0,51	0,54	5	2	2		3	2	3	2	3	2	2	2	2
1	1		2	4	2:00:00	1	1	4	3	220	3	4	0	60	3,07	0,78	0,95	1,14	1,33	1,52	1,71	1,91	2,11	2,3	2,5	2,7	1	2	1	1	3	1	3	3	3	1	1	1	1
1	1		2	4	2:00:00	1	1	4	3	221	3	0	0	20	5,07	1,02	1,25	1,47	1,7	1,94	2,17	2,41	2,64	2,88	3,12	3,36	5	3	1	1	3	3	3	1	3	1	1	1	1
1	1		2	4	2:00:00	1	1	4	3	226	3	0	0	10	5,57	1,14	1,38	1,63	1,88	2,14	2,39	2,65	2,9	3,16	3,42	3,68	1	3	1	3	3	1	1	3	3	1	1	1	1
1	2		4	4	2:00:00	1	4	1	1	219	2	3	0	10	2,3	1,09	1,1	1,11	1,13	1,15	1,18	1,21	1,23	1,27	1,3	1,33	8	1	1	1	3	1	3	3	1	1	1	1	1
1	2		4	4	2:00:00	1	4	1	1	222	2	0	2	7	4,42	1,24	1,4	1,59	1,79	2	2,21	2,43	2,65	2,88	3,11	3,34	1	1	1	1	3	1	3	3	1	1	3	1	1
1	2		4	4	2:00:00	1	4	1	1	228	2	4	2	30	0,83	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	0,6	1	1	1	1	2	3	3	3	1	1	3	1	1
1	2		4	4	2:00:00	1	4	1	1	217	2	1	0	10	3,9	1,22	1,32	1,44	1,56	1,7	1,84	1,99	2,14	2,3	2,46	2,63	6	1	3	1	3	3	3	3	1	1	1	1	1
1	2		4	4	2:00:00	1	4	1	1	237	3	4	2	35	0,75	0,53	0,53	0,53	0,53	0,53	0,53	0,53	0,53	0,53	0,53	0,53	6	1	3	1	3	1	3	3	1	1	1	1	1
1	2		4	4	2:00:00	1	4	1	1	221	3	0	0	20	4,53	1,24	1,4	1,59	1,79	2	2,21	2,43	2,65	2,88	3,11	3,34	1	1	3	1	3	1	1	3	1	1	1	1	1
1	3		2	4	1:00:00	1	4	4	1	229	2	3	4	45	1,05	0,32	0,36	0,41	0,45	0,51	0,56	0,61	0,67	0,72	0,78	0,84	3	1	3	1	3	3	2	3	3	1	1	1	1
1	3		2	4	1:00:00	1	4	4	1	230	2	3	4	10	1,63	0,86	0,87	0,89	0,92	0,94	0,97	1	1,04	1,08	1,11	1,16	3	1	3	1	3	2	3	3	3	1	1	1	1
1	3		2	4	1:00:00	1	4	4	1	238	3	3	2	15	2,88	0,84	0,9	0,97	1,05	1,14	1,23	1,32	1,42	1,52	1,62	1,73	4	3	3	1	3	2	3	3	3	1	1	1	1
1	3		2	4	1:00:00	1	4	4	1	217	2	1	0	10	4,3	1,09	1,23	1,39	1,56	1,74	1,93	2,12	2,31	2,51	2,71	2,91	2	1	3	1	3	2	3	3	3	1	1	1	1
1	3		2	4	1:00:00	1	4	4	1	234	2	3	0	18	4,17	0,99	1,14	1,32	1,5	1,68	1,88	2,07	2,27	2,47	2,67	2,87	1							3					
1	3		2	4	1:00:00	1	4	4	1	226	3	0	0	10	5,1	1,14	1,31	1,5	1,7	1,9	2,11	2,33	2,55	2,77	2,99	3,22	1		3					3					
2	1	2	2	0	0:20:00	1	3	2	4	226	3	0	0	10	2,12	0,5	0,59	0,68	0,77	0,87	0,98	1,08	1,2	1,31	1,44	1,56	6	3	1	3	3	2	3	3	1	3	1	1	2
2	1	2	2	0	0:20:00	1	3	2	4	221	3	0	0	20	1,45	0,47	0,54	0,62	0,7	0,79	0,88	0,98	1,08	1,19	1,3	1,42	7	3	1	3	3	3	1	2	1	3	3	1	3
2	1	2	2	0	0:20:00	1	3	2	4	220	3	4	0	60	4,12	0,82	1,02	1,23	1,45	1,67	1,89	2,11	2,33	2,56	2,79	3,02	5	3	2	3	1	3		1		1	2	1	2
2	1	2	2	0	0:20:00	1	3	2	4	231	3	3	4	50	4,18	0,89	1,04	1,2	1,36	1,52	1,69	1,86	2,04	2,22	2,4	2,59	7	3	3	3	3	3	2	3	1	3	3	1	2
2	1	2	2	0	0:20:00	1	3	2	4	242	3	3	4	10	2,85	0,76	0,84	0,93	1,02	1,12	1,21	1,32	1,42	1,54	1,65	1,77	7	3	1	3	3	3	1	2	1	3	3	1	3
2	1	2	2	0	0:20:00	1	3	2	4	238	3	3	2	15	1,85	0,47	0,52	0,57	0,63	0,7	0,77	0,85	0,93	1,02	1,11	1,22	7	3	1	3	3	2	3	3	1	3	1	1	2
2	2	2	3	2	0:30:00	1	4	3	2	221	3	0	0	20	3,98	0,75	0,93	1,12	1,32	1,51	1,72	1,92	2,14	2,35	2,58	2,81	4	3	1	3	3	3	1	2	1	3	3	1	3
2	2	2	3	2	0:30:00	1	4	3	2	237	3	4	2	35	1,22	0,33	0,38	0,44	0,51	0,59	0,68	0,78	0,89	1,01	1,14	1,29	7	3		3	3	3	2	2	1	1	1	1	1
2	2	2	3	2	0:30:00	1	4	3	2	217	2	1	0	10	3,27	0,62	0,75	0,89	1,02	1,16	1,3	1,44	1,58	1,72	1,86	2	3	3	3	3	2	3	2	2	3	2	2	1	3
2	2	2	3	2	0:30:00	1	4	3	2	228	2	4	2	30	0,8	0,2	0,26	0,32	0,38	0,44	0,5	0,56	0,62	0,68	0,74	0,8	1	3	3	3	2	3	2	3	2	1	1	1	3
2	2	2	3	2	0:30:00	1	4	3	2	222	2	0	2	7	3,17	0,71	0,89	1,06	1,24	1,42	1,61	1,79	1,97	2,15	2,34	2,52	1	3	1	3	2	3	3	3	2	3	1	1	3
2	2	2	3	2	0:30:00	1	4	3	2	219	2	3	0	10	1,67	0,47	0,54	0,61	0,69	0,76	0,83	0,91	0,98	1,05	1,13	1,2	6	3	2	3		1		3	3	1	3	1	2
2	3	2	2	3	1:00:00	1	4	3	2	226	3	0	0	10	5,02	1,08	1,24	1,41	1,58	1,76	1,94	2,12	2,32	2,51	2,72	2,93	5	3	3	3	2	2	3	3	3	1	1	1	2
2	3	2	2	3	1:00:00	1	4	3	2	234	2	3	0	18	3,7	0,88	1,01	1,14	1,27	1,4	1,53	1,67	1,8	1,93	2,07	2,2	2	3	3	3	2	3		3	1	1	1	1	3

Figure D.3: Data of the validation experiment (see Section 8.5)

2	3	2	2	3	1:00:00	1	4	3	2	217	2	1	0	10	3,97	0,99	1,13	1,26	1,4	1,54	1,68	1,82	1,96	2,1	2,24	2,38	2	3	2	3	2	3		3	1	1	1	1	3
2	3	2	2	3	1:00:00	1	4	3	2	238	3	3	2	15	3,05	0,83	0,92	1,02	1,13	1,23	1,35	1,47	1,6	1,73	1,88	2,03	5	3	2	3	2	3	3	3	2	1	1	1	2
2	3	2	2	3	1:00:00	1	4	3	2	230	2	3	4	10	2,97	0,87	0,97	1,08	1,18	1,28	1,39	1,49	1,6	1,7	1,81	1,92	1	1	3	1	2	3	2	3	1	1	2	1	3
2	3	2	2	3	1:00:00	1	4	3	2	229	2	3	4	45	1,8	0,36	0,43	0,5	0,57	0,64	0,71	0,78	0,85	0,92	1	1,07	1	1	1	1	2	3	3	3	1	1	1	1	3
3	1	3	2	2	0:30:00	2	3	4	1	238	3	3	2	15	0,85	0,32	0,35	0,38	0,41	0,44	0,47	0,51	0,54	0,58	0,61	0,65	6	1	2	2	3	2	3	3	3	3	3	1	2
3	1	3	2	2	0:30:00	2	3	4	1	242	3	3	4	10	2,27	0,51	0,6	0,69	0,78	0,88	0,98	1,08	1,19	1,29	1,39	1,5	7	1	2	2	3	2	3	3	3	3	3	1	2
3	1	3	2	2	0:30:00	2	3	4	1	231	3	3	4	50	2,27	0,51	0,6	0,69	0,78	0,88	0,98	1,08	1,19	1,29	1,39	1,5	8	1	2	2	3	2	3	3	3	3	3	1	2
3	1	3	2	2	0:30:00	2	3	4	1	220	3	4	0	60	3,03	0,72	0,82	0,92	1,03	1,14	1,26	1,38	1,5	1,62	1,74	1,86	6	1	2	2	3	2	3	3	3	3	3	1	2
3	1	3	2	2	0:30:00	2	3	4	1	221	3	0	0	20	2,7	0,55	0,67	0,79	0,92	1,04	1,17	1,29	1,42	1,55	1,67	1,8	6	1	2	2	3	2	3	3	3	3	3	1	2
3	1	3	2	2	0:30:00	2	3	4	1	226	3	0	0	10	2,87	0,62	0,73	0,84	0,96	1,08	1,2	1,33	1,45	1,57	1,7	1,82	6	1	2	2	3	2	3	3	3	3	3	1	2
3	2		3	3	0:30:00	1	4	3	2	219	2	3	0	10	2,17	0,6	0,7	0,81	0,91	1,01	1,12	1,22	1,33	1,43	1,54	1,64	7	1	3	2	3	2	3	2	3	3	3	1	2
3	2		3	3	0:30:00	1	4	3	2	222	2	0	2	7	3,67	0,73	0,91	1,09	1,27	1,46	1,64	1,83	2,01	2,2	2,38	2,57	6	1	3	2	3	2	2	2	3	3	3	1	2
3	2		3	3	0:30:00	1	4	3	2	228	2	4	2	30	1,3	0,26	0,33	0,4	0,46	0,53	0,6	0,67	0,74	0,81	0,87	0,94	6	1	3	2	3	2	2	2	3	3	3	1	2
3	2		3	3	0:30:00	1	4	3	2	217	2	1	0	10	3,77	0,72	0,87	1,03	1,19	1,34	1,5	1,66	1,82	1,97	2,13	2,29	7	1	3	2	3	2	2	2	3	3	3	1	2
3	2		3	3	0:30:00	1	4	3	2	237	3	4	2	35	1,47	0,27	0,34	0,41	0,48	0,55	0,61	0,68	0,75	0,82	0,89	0,96	7	1	3	2	3	2	2	2	3	3	3	1	2
3	2		3	3	0:30:00	1	4	3	2	221	3	0	0	20	4,23	0,8	1	1,2	1,41	1,61	1,82	2,03	2,23	2,44	2,64	2,85	6	1	3	2	3	2	2	2	3	3	3	1	3
3	3		2	3	3:00:00	1	3	4	2	229	2	3	4	45	1,77	0,36	0,42	0,49	0,56	0,62	0,69	0,76	0,82	0,89	0,96	1,03	6	1	3	2	3	2	3	2	3	3	3	1	2
3	3		2	3	3:00:00	1	3	4	2	230	2	3	4	10	2,93	0,87	0,97	1,07	1,17	1,27	1,38	1,48	1,58	1,69	1,79	1,89	5	1	3	2	3	2	3	2	3	3	3	1	2
3	3		2	3	3:00:00	1	3	4	2	238	3	3	2	15	2,77	0,79	0,89	0,98	1,07	1,17	1,26	1,36	1,46	1,55	1,65	1,75	5	1	3	2	3	2	3	2	3	3	3	1	2
3	3		2	3	3:00:00	1	3	4	2	217	2	1	0	10	4,27	0,99	1,15	1,31	1,48	1,64	1,81	1,98	2,15	2,33	2,5	2,67	4	1	3	2	3	2	3	2	3	3	3	1	2
3	3		2	3	3:00:00	1	3	4	2	234	2	3	0	18	4	0,88	1,04	1,19	1,35	1,52	1,68	1,85	2,01	2,18	2,35	2,51	4	1	3	2	3	2	3	2	3	3	3	1	2
3	3		2	3	3:00:00	1	3	4	2	226	3	0	0	10	4,87	1,05	1,22	1,4	1,58	1,76	1,94	2,12	2,31	2,49	2,68	2,87	4	1	3	2	3	2	3	2	3	3	3	1	2
102	4	4	2	4	null	1	4	2	3	241	3	1	4	13	1,05	0,32	0,37	0,43	0,5	0,57	0,66	0,76	0,88	1	1,13	1,28	7	3	2	3	3	3	3	3	3	1	3	1	3
102	4	4	2	4	null	1	4	2	3	240	3	0	2	12	2,52	0,58	0,69	0,8	0,93	1,06	1,2	1,35	1,5	1,66	1,82	2	5	3	2	3	3	3	3	3	3	3	3	1	3
102	4	4	2	4	null	1	4	2	3	239	3	0	4	30	1,85	0,47	0,58	0,7	0,82	0,95	1,09	1,23	1,39	1,54	1,71	1,89	9	3	1	3	3	3	3	3	3	3	3	1	3
102	4	4	2	4	null	1	4	2	3	219	2	3	0	10	2,63	0,86	0,93	1,03	1,14	1,27	1,42	1,59	1,79	2,01	2,26	2,53	5	3	1	3	3	3	3	2	3	3	3	1	3
102	4	4	2	4	null	1	4	2	3	221	3	0	0	20	3,18	0,82	0,94	1,06	1,2	1,34	1,48	1,63	1,79	1,96	2,13	2,31	5	3	1	3	1	3	3	2	3	3	3	1	3
102	4	4	2	4	null	1	4	2	3	236	3	0	2	25	2,52	0,58	0,69	0,8	0,93	1,06	1,2	1,35	1,5	1,66	1,82	2	6	3	2	3	1	3	3	1	3	3	3	1	3
102	5	4	2	3	0:30:00	1	3	2	4	217	2	1	0	10	3,43	0,81	0,9	1,01	1,13	1,26	1,41	1,56	1,73	1,91	2,11	2,32	3	3	1	3	1	3	3	3	3	3	3	1	3
102	5	4	2	3	0:30:00	1	3	2	4	218	2	0	4	10	3,37	0,74	0,84	0,96	1,1	1,24	1,4	1,57	1,75	1,94	2,14	2,36	2	1	1	1	1	3	3	3	3	3	1	1	3
102	5	4	2	3	0:30:00	1	3	2	4	235	2	0	4	15	3,03	0,71	0,79	0,9	1,02	1,14	1,29	1,44	1,61	1,79	1,98	2,19	4	3	1	1	1	3	3	3	3	3	3	1	3
102	5	4	2	3	0:30:00	1	3	2	4	229	2	3	4	45	2,43	0,62	0,68	0,75	0,85	0,96	1,08	1,22	1,38	1,54	1,73	1,93	5	3	1	3	1	3	3	3	3	3	3	1	3
102	5	4	2	3	0:30:00	1	3	2	4	233	2	1	0	18	2,9	0,76	0,83	0,91	1,01	1,12	1,24	1,37	1,52	1,69	1,87	2,06	3	3	1	1	3		3	1	3	3	3	1	3
102	5	4	2	3	0:30:00	1	3	2	4	238	3	3	2	15	2,18	0,44	0,51	0,59	0,68	0,77	0,87	0,97	1,08	1,19	1,3	1,43	9	3	1	3	1	3	3	2	3	3	3	1	3
102	6	2	2	2	0:50:00	4	1	2	3	129	2	1	3	20	2,03	0,56	0,66	0,75	0,85	0,95	1,05	1,15	1,25	1,35	1,45	1,55	3	3	1	1	1	3	3	1	3	3	3	1	3

Figure D.3 (continued): Data of the validation experiment (see Section 8.5)

persoon	casus	size	diff	int	time	sizeW	diffW	intW	timeW	ulm	size	diff	int	time	taxi	0	0,1	0,2	0,3	0,4	0,5	0,6	0,7	0,8	0,9	1	score	factor1	factor2	factor3	factor4	factor5	factor6	factor7	factor8	factor9	factor10	factor11	factor12
102	6	2	2	2	0:50:00	4	1	2	3	241	3	1	4	13	3,72	0,77	0,89	1	1,12	1,25	1,37	1,49	1,62	1,74	1,87	1,99	8	3	1	1	1	3	3	1	3	3	3	1	3
102	6	2	2	2	0:50:00	4	1	2	3	235	2	0	4	15	2,82	0,78	0,89	0,99	1,1	1,22	1,33	1,45	1,56	1,68	1,8	1,91	3	3	1	1	1	3	3	3	3	3	3	1	3
102	6	2	2	2	0:50:00	4	1	2	3	225	2	3	-1	10	3,2	0,86	0,99	1,13	1,27	1,4	1,54	1,68	1,82	1,96	2,1	2,24	2	3	1	1	1	3	3	1	3	3	1	3	3
102	6	2	2	2	0:50:00	4	1	2	3	226	3	0	0	10	4,07	0,88	1	1,12	1,24	1,37	1,5	1,63	1,76	1,89	2,03	2,16	6	3	1	1	1	3	3	3	3	3	3	3	3
102	6	2	2	2	0:50:00	4	1	2	3	227	2	3	2	8	2,3	0,73	0,86	1	1,14	1,28	1,41	1,55	1,69	1,83	1,97	2,11	1												
103	4		1	0	2:00:00	1	4	2	3	241	3	1	4	13	4,02	1,14	1,31	1,48	1,66	1,83	2	2,18	2,35	2,53	2,71	2,88	5	3	3	3	3	3	3	3	3	3	3	1	3
103	4		1	0	2:00:00	1	4	2	3	240	3	0	2	12	4,2	0,96	1,14	1,31	1,49	1,66	1,84	2,01	2,19	2,37	2,54	2,72	6	3	3	3	3	3	3	3	3	3	3	1	3
103	4		1	0	2:00:00	1	4	2	3	239	3	0	4	30	3,97	0,99	1,13	1,26	1,4	1,54	1,68	1,82	1,96	2,1	2,24	2,38	7	3	3	3	3	3	3	3	3	3	3	1	3
103	4		1	0	2:00:00	1	4	2	3	219	2	3	0	10	4,43	0,94	1,14	1,35	1,55	1,75	1,96	2,16	2,37	2,58	2,78	2,99	4	3	3	3	3	3	3	3	3	3	3	1	3
103	4		1	0	2:00:00	1	4	2	3	221	3	0	0	20	3,13	0,72	0,86	1,01	1,15	1,3	1,45	1,59	1,74	1,89	2,03	2,18	7	3	3	3	3	3	3	3	3	3	3	1	3
103	4		1	0	2:00:00	1	4	2	3	236	3	0	2	25	3,55	0,79	0,93	1,06	1,2	1,34	1,47	1,61	1,75	1,89	2,03	2,17	8	3	3	3	3	3	3	3	3	3	3	1	3
103	5		3	0	2:00:00	1	4	2	3	217	2	1	0	10	4,43	0,94	1,14	1,35	1,55	1,75	1,96	2,16	2,37	2,58	2,78	2,99	8	3	3	3	3	3	3	3	3	3	3	1	3
103	5		3	0	2:00:00	1	4	2	3	218	2	0	4	10	6,57	1,32	1,56	1,81	2,06	2,31	2,57	2,82	3,08	3,33	3,59	3,85	4	3	3	3	3	3	3	3	3	3	1	3	3
103	5		3	0	2:00:00	1	4	2	3	235	2	0	4	15	6,32	1,27	1,5	1,74	1,98	2,22	2,46	2,71	2,95	3,2	3,44	3,69	4	3	3	3	3	3	3	3	3	3	3	1	3
103	5		3	0	2:00:00	1	4	2	3	229	2	3	4	45	2,42	0,87	0,96	1,06	1,15	1,25	1,35	1,44	1,54	1,63	1,73	1,83	4	3	3	3	3	3	3	3	3	3	3	1	3
103	5		3	0	2:00:00	1	4	2	3	233	2	1	0	18	4,03	0,82	1	1,19	1,37	1,55	1,74	1,92	2,11	2,29	2,48	2,66	8	3	3	3	3	3	3	3	3	3	3	1	3
103	5		3	0	2:00:00	1	4	2	3	238	3	3	2	15	3,25	0,9	1,05	1,21	1,36	1,52	1,68	1,83	1,99	2,15	2,3	2,46	8	3	3	3	3	3	3	3	3	3	3	1	3
103	6	2		0	2:00:00	3	4	1	2	129	2	1	3	20	2	0,94	0,99	1,04	1,09	1,15	1,2	1,26	1,31	1,37	1,43	1,49	7	3	3	3	3	3	3	3	3	3	3	3	3
103	6	2		0	2:00:00	3	4	1	2	241	3	1	4	13	3,15	1,17	1,22	1,27	1,33	1,39	1,45	1,51	1,57	1,64	1,71	1,77	7	3	3	3	3	3	3	3	3	3	3	3	3
103	6	2		0	2:00:00	3	4	1	2	235	2	0	4	15	2,33	1,12	1,17	1,23	1,28	1,34	1,4	1,46	1,52	1,59	1,65	1,72	5	3	3	3	3	3	3	3	3	3	3	3	3
103	6	2		0	2:00:00	3	4	1	2	225	2	3	-1	10	1,67	0,83	0,92	1	1,08	1,17	1,25	1,33	1,42	1,5	1,58	1,67	7	3	3	3	3	3	3	3	3	3	3	3	3
103	6	2		0	2:00:00	3	4	1	2	226	3	0	0	10	2,58	0,89	0,96	1,03	1,11	1,19	1,27	1,35	1,43	1,51	1,59	1,67	7	3	3	3	3	3	3	3	3	3	3	3	3
103	6	2		0	2:00:00	3	4	1	2	227	2	3	2	8	2,23	1	1,08	1,15	1,23	1,31	1,39	1,47	1,56	1,64	1,72	1,8	8	3	3	3	3	3	3	3	3	3	3	3	3

Appendix E

Proofs

E.1 The WTD measure is a distance

Given

Given is a metric space of elements from V. It is known that the Taxicab distance, given by the formula:

$$\rho_T(x,y) = \sum_i |r_i(x_i) - r_i(y_i)|$$

with $x_i, y_i \in V$ is a distance and as such complies with the following three conditions:

1. $\rho_T(x,y) \geq 0$ where $\rho_T(x,y) = 0$ iff $x = y$
2. $\rho_T(x,y) = \rho_T(y,x)$
3. $\rho_T(x,z) \leq \rho_T(x,y) + \rho_T(y,z)$ (triangle inequality)

To be proven

To prove: the Weighted Taxicab Distance (WTD), given by the formula:

$$\rho_{WTD}(x,y) = \sum_i w_i \frac{|r_i(x_i) - r_i(y_i)|}{|V_i|}$$

is a *distance*, i.e. it fulfills the three conditions given above.

Proof

Each of the three conditions will be proven separately below.

1. The proof of the first condition is split into two parts: first, it is proven that the WTD distance is a value greater than or equal to zero; then, it is proven that $\rho_{WTD}(x, y) = 0$ iff $x = y$.

   (a)
   $$\rho_{WTD}(x, y) = \sum_i w_i \frac{|r_i(x_i) - r_i(y_i)|}{|V_i|}$$

   Observe that $w_i \geq 0$, and that the other terms are absolute values. Thus, ρ_{WTD} is a sum of terms that are all greater or equal to zero QED.

   (b)
   $$\rho_{WTD}(x, y) = \sum_i w_i \frac{|r_i(x_i) - r_i(y_i)|}{|V_i|} = 0$$

   A sum of all positive terms is zero if and only if all terms are zero, that is: $w_i = 0 \forall i$ or $|r_i(x_i) - r_i(y_i)| = 0 \; \forall i$. As $w_i > 0 \; \forall i$ it follows that $r_i(x_i) = r_i(y_i) \; \forall i$ which is true if and only if $x = y$ QED.

2. To prove: $\rho_{WTD}(x, y) = \rho_{WTD}(y, x)$

$$\rho_{WTD}(x, y) = \sum_i w_i \frac{|r_i(x_i) - r_i(y_i)|}{|V_i|} = \sum_i w_i \frac{|-(r_i(x_i) - r_i(y_i))|}{|V_i|} =$$

$$\sum_i w_i \frac{|r_i(y_i) - r_i(x_i)|}{|V_i|} = \rho_{WTD}(y, x)$$

   QED

3. To prove: $\rho_{WTD}(x, z) \leq \rho_{WTD}(x, y) + \rho_{WTD}(y, z)$

$$\rho_{WTD}(x, y) + \rho_{WTD}(y, z) =$$

$$\sum_i w_i \frac{|r_i(x_i) - r_i(y_i)|}{|V_i|} + \sum_i w_i \frac{|r_i(y_i) - r_i(z_i)|}{|V_i|} =$$

$$\sum_i w_i(\frac{|r_i(x_i) - r_i(y_i)|}{|V_i|} + \frac{|r_i(y_i) - r_i(z_i)|}{|V_i|})$$

given that $|r_i(x_i) - r_i(y_i)| + |r_i(y_i) - r_i(z_i)| \leq |r_i(x_i) + r_i(z_i)|$, because $\rho(x, y)$ is a distance measure and fulfills condition 3:

$$\rho_{WTD}(x, y) + \rho_{WTD}(y, z) \leq \sum_i w_i \frac{|r_i(x_i) - r_i(z_i)|}{|V_i|} = \rho_{WTD}(x, z)$$

QED

From the proof of these three conditions it follows that $\rho_{WTD}(x, y)$ is a distance measure.
QED

E.2 The WED measure is a distance

Given

Given is a metric space of elements from V. It is known that the Euclidean distance, given by the formula:

$$\rho_E(x, y) = \sum_i \sqrt{(r_i(x_i) - r_i(y_i))^2}$$

with $x_i, y_i \in V$ is a distance and as such complies with the following three conditions:

1. $\rho_E(x, y) \geq 0$ where $\rho_E(x, y) = 0$ iff $x = y$
2. $\rho_E(x, y) = \rho_E(y, x)$
3. $\rho_E(x, z) \leq \rho_E(x, y) + \rho_E(y, z)$ (triangle inequality)

To be proven

To prove: the Weighted Euclidean Distance (WED), given by the formula:

$$\rho_{WED}(x, y) = \sqrt{\sum_i w_i \left(\frac{r(x_i) - r(y_i)}{|V_i|}\right)^2}$$

is a *distance*, i.e. it fulfills the three conditions given above.

Proof

Each of the three conditions will be proven separately below.

1. The proof of the first condition is split into two parts: first, it is proven that the WED distance is a value greater than or equal to zero; then, it is proven that $\rho_{WED}(x, y) = 0$ iff $x = y$.

   (a) Recall the definition of $\rho_{WED}(x, y)$:

   $$\rho_{WED}(x, y) = \sqrt{\sum_i \left(w_i \frac{r_i(x_i) - r_i(y_i)}{|V_i|} \right)^2}$$

   Observe that $w_i \geq 0$, and that the other terms under the square root are squared, i.e. always greater or equal to zero. Thus, ρ_{WED} is a sum of terms that are all greater or equal to zero and hence the sum is also greater or equal to zero.
   QED

   (b) A sum of all positive terms is zero if and only if all terms are zero, that is: $(w_i(r_i(x_i) - r_i(y_i)))^2 = 0$ or $w_i = 0 \Leftrightarrow x = y$
   QED

2. To prove: $\rho_{WED}(x, y) = \rho_{WED}(y, x)$

   $$\rho_{WED} = \sqrt{\sum_i \left(w_i \frac{r_i(x_i) - r_i(y_i)}{|V_i|} \right)^2} =$$

   $$\sqrt{\sum_i \left(-w_i \frac{r_i(x_i) - r_i(y_i)}{|V_i|} \right)^2} = \sqrt{\sum_i \left(w_i \frac{-r_i(x_i) + r_i(y_i)}{|V_i|} \right)^2} =$$

   $$\sqrt{\sum_i \left(w_i \frac{r_i(y_i) - r_i(x_i)}{|V_i|} \right)^2} = \rho_{WED}(y, x)$$

   QED

3. To prove: $\rho_{WED}(x, z) \leq \rho_{WED}(x, y) + \rho_{WED}(y, z) \Leftrightarrow$

   $$\sqrt{\sum_i \left(w_i \frac{r_i(x_i) - r_i(y_i)}{|V_i|} \right)^2} + \sqrt{\sum_i \left(w_i \frac{r_i(y_i) - r_i(z_i)}{|V_i|} \right)^2} \geq$$

$$\sqrt{\sum_i \left(w_i \frac{r_i(x_i) - r_i(z_i)}{|V_i|} \right)^2}$$

Define $r'_i(x) = \frac{w_i}{|v_i|}$, then the equation is equivalent to:

$$\sqrt{\sum_i (r'_i(x_i) - r'_i(y_i))^2} + \sqrt{\sum_i (r'_i(y_i) - r'_i(z_i))^2} \geq \sqrt{\sum_i (r'_i(x_i) - r'_i(z_i))^2}$$

This is equivalent to proving the triangle inequality in a (metric) space that is defined using $r'_i(x)$. Usually, the triangle inequality is proven using the Schwarz inequality (see for example Lang (1989, p. 101)) that is defined on *vectors in* $\Re^n$. So the proof would require defining vectors in N^n, defining inner products, proving the Schwarz inequality, and then proving the triangle inequality. It was felt that this is inappropriate in this thesis, so here only the triangle inequality on a uni-dimensional metric space defined using $r'_i(x)$ will be proven, as this proof does not depend on the Schwarz inequality and thus does not require defining a vector space. Note that due to the uni-dimensional nature of the space, the index 'i' will be omitted.

To prove: $\rho(x,y) + \rho(y,z) \geq \rho(x,z)$

Proof:

$$\rho(x,y) + \rho(y,z) = r'(x) - r'(y) + r'(y) - r'(z) = \frac{w}{|V|} r(x) - \frac{w}{|V|} r(z) =$$

$$\frac{w}{|V|} r(x) - \frac{w}{|V|} r(z) = r'(x) - r'(z) = \rho(x,z)$$

QED

From the proof of these three conditions it follows that $\rho_{WED}(x,y)$ is a distance measure.

QED

Appendix F

Glossary

Introduction

This appendix will present a glossary of terms that have not been discussed elaborately in the thesis. The keyword index of this thesis can be used to find passages relevant to a certain keyword. Note that the purpose of this glossary is to *clarify* terms as opposed to *defining* them. This means that in some cases, accuracy has been sacrificed for better readability.

A

Abstract Windows Toolkit An Application Programming Interface for Java that allows Java programs to manipulate objects in a graphical windowing environment.

Active Server Pages A script language developed by Microsoft that allows a HTML page to contain active code that is executed by the web server whenever the page is requested. This is a form of Server-Side Scripting.

ADSR Attack, Decay, Sustain, Release: four phases of the amplitude of an audio signal that together describe the "envelope". Of these four phases, the duration and the "steepness" is specified.

API Application Programming Interface: the computer language interface of a software component to other software components; so an API specifies how a software component should interact with another on the level of a programming language.

applet a small program (often written in Java) that is part of a WWW page. When the user visits the page, the applet is downloaded from the WWW server to the user's computer, where it is executed.

ASP see Active Server Pages

Authoring System A system in which a person can create and/or compose learning materials by writing texts, and including (or creating) pictures, video fragments, and audio fragments.

B

bandwidth the capacity of a network to transmit data.

Bayesian network An abstract structure that allows one to calculate the likeliness of a certain outcome based on various 'evidences' that are input into the network.

BLOB Binary Large Object: a data type which allows large binary data (such as pictures, video and audio fragments) to be stored in database tables.

C

cardinality The cardinality of a set is the number of elements in that set.

CBI see Computer Based Instruction

Computer Based Instruction instruction that is primarily carried out by computer

CGI see Common Gateway Interface

CGI script a program written in a scripting language (often Perl) that is called using the CGI set of rules.

CD-ROM a storage unit for digital information, such as movies, pictures, audio, computer data, computer software, etcetera. The name "CD-ROM" can denote both the disc itself (resembling an audio CD) as well as the drive that reads the disc.

courseware computer software that is used as learning material in a course

Cocoon An XML publishing engine that executes as a Java servlet in the Apache webserver.

classification The process of defining groups (types) of elements, and assigning each element to a certain group.

Common Gateway Interface An set of rules that describe how information is described from a web server to an auxiliary program. The program will generate a web page based on this information, and hand the resulting page back to the web server for propagation to the user that requested the page.

concept map A 'network' in which the nodes are concepts, and the edges between the nodes are relationships between these concepts.

cookie A small message that a web server can store on the harddisk of a web client. Cookies are often used to overcome the statelessness of the HTTP protocol.

courseware database A database that contains course materials (reading directions, exercises, powerpoint slides, test exams, etcetera).

CPU Central Processing Unit: the main processor that is the core of the modern computer, which are almost all built according to the von Neumann[1] architecture: a central processing unit that executes instructions stored in a computer memory.

CPU-intensive A property of a computer program that indicates that the program requires a large amount of processing instructions (by the CPU) to complete.

D

DNS Domain Name System: the system (and the protocol) that allows any computer on the Internet to find the 'IP address' (in numbers) that belongs to an Internet host name. Below the surface, the Internet only works with numbers, but these are difficult to remember for human beings. Therefor, a translation service is provided.

download To retrieve information from a remote computer onto the user's local computer.

drill and practice A pedagogical strategy which is targeted at rote learning.

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[1] John Louis von Neumann, a Hungarian scientist who lived from 1903 until 1957; he studied chemistry but obtained a doctorate degree in mathematics.

Dublin Core A 'core' set of generic metadata fields for online resources.

dynamic documents Documents that are generated 'on the fly', that is, at the moment they are requested by the user. Generally, techniques such as Server-Side Scripting or CGI-scripts are used for generating the document.

E

educational database A database that stores learning material and/or course management information.

Entity-Relationship diagram a conceptual view on a part of the world, consisting of entities and relationships between them. An ER diagram is often used as a tool to develop database schemas.

ER diagram see Entity-Relationship diagram

F

file system a subsystem of an Operating System that is responsible for storing, organizing, and retrieving files.

File Transfer Protocol An Internet protocol that prescribes how files can be transferred from one computer to another.

formative evaluation An evaluation effort that is directed at finding ways to improve the object that is being evaluated.

front-end a special component of a software system that interfaces with the user.

FTP see File Transfer Protocol.

G

GHz Gigahertz, a measure of frequency (cycles per second). A Gigahertz is 1×10^9 cycles per second; see also 'MHz'.

GIF The name of a picture compression standard that is often used on the Internet.

GUI Graphical User Interface, a user interface that operates using graphical metaphors such as a desktop, trashcan, movable icons, etcetera.

H

harddisc a storage unit for digital information that consists of a number of magnetic discs that are sealed airtight in a housing. A harddisc is used to permanently store information, such as computer software, documents, and other data. The data are not lost when the power to the computer is switched off.

hardware the components of a computer system that are physical, such as the keyboard, the monitor, but also every component inside the computer cabinet. Popularly spoken, hardware are those parts of a computer that can be kicked.

Hypercard A hypermedia system developed by Apple that used a stack of cards as a metaphore.

hypermedia Multimedia material through which the user can navigate using hyperlinks.

hyperspace Popular term for a (worldwide) collection of hypermedia documents.

HyTime A multimedia presentation markup language that is a member of the SGML family.

I

IEEE Institute of Electrical and Electronics Engineers, a large organization of professionals.

Idylle Innovative Distributed Learning Environments; the project in which this research project was executed.

implementation A computer program that is built according to a certain architecture. Also: deploying a method or product in practice.

Information Retrieval The discipline that studies and develops methods to store and retrieve information from databases.

Intelligent Tutoring System An electronic learning environment that tries to model the learner’s knowledge level, and that uses learning strategies to increase or correct the learner’s knowledge.

Internet A world-wide network that interconnects many different types of computernetworks. The Internet makes it transparent that many subnetworks exist, so that the user perceives one large computer network.

Internet domain A part of the Internet ‘namespace’; see also ‘DNS’.

Internet host a computer that has a connection to the Internet.

Internet Protocol Suite The set of protocols that are used to operate the Internet and applications on it, such as: the Internet Control Message Protocol (ICMP), the User Datagram Protocol (UDP), the Transport Control Protocol (TCP), and the Hypertext Transfer Protocol (HTTP).

IO-intensive A property of a computer program that indicates that the program requires a large amount of data to be transmitted between the various parts of a computer system (CPU, harddisk, network).

IP number A unique ‘number’ (in fact it is an identifier of four numbers separated by a dot) that a computer needs to communicate through the Internet.

IR see Information Retrieval.

ISO International Standards Organisation.

ITS see Intelligent Tutoring System.

J

Java A platform-independent programming language developed by Sun Microsystems, based on the paradigm “write once, run anywhere”.

JDBC Java Database Connectivity: a standard method for Java programs to access a database; the functionality resembles ODBC.

JPEG Joint Photographic Experts Group: a group that works on standards for image coding and compression. Their best known standard is the JPG format (formally IS 10918-1).

L

LAN Local Area Network: a computer network that usually spans one building, or one complex of buildings.

learner control The amount and type of control the learner has over the (computer-supported) learning process.

LOMG Learning Objects Metadata Group; a working group of the IEEE Learning Technology Standards Committee (LTSC) that focuses on developing metadata standards for learning objects.

LTSC Learning Technologies Standards Committee, a committee of the IEEE that focusses on developing standards for learning technologies.

M

metadata data about a data item, such as: who created the data item, at what time, for what purposes, what natural language is used by the item.

MHz Megahertz: a measure of frequency, named after the German scientist Heinrich Hertz (1857-1894) who demonstrated the existence of radio waves. A MHz denotes a million cycles per second, and is often used to indicate the speed of computers (it then denotes the number of instruction cycles a CPU makes per second).

MHEG Multimedia and Hypermedia information coding Experts Group: a group of ISO that develops several standards which deal with the coded representation of multimedia and hypermedia information.

MPEG literally Motion Pictures Experts Group, but often the audio and video compression algorithms developed by this group is meant.

multimedia often used to denote the use of text, graphics, (digital) video and (digital) audio data in one application. Used by marketing drones to denote a PC with a CD-ROM drive and a soundcard.

multimedia database A database that stores multimedia data, such as video fragments, audio clips, images, text, or combinations of these.

N

network port On the Internet, computers (so-called “hosts”) can run many different services, such as mail, ftp, and www. To allow another computer to identify which service is to be accessed, network port numbers are used. For example, the port that the www server often uses is 80.

O

OCR see Optical Character Recognition

ODBC Open Database Connectivity; an standardized API that specifies how a software component should communicate with a database.

Operating System The software layer that encapsulates the specific hardware of a computer system, and that makes these resources available to application programs in a structured manner.

OS See Operating System

Optical Character Recognition the recognition by computer software of print or handwritten characters from previously digitized pages.

P

PC see Personal Computer

PDF Portable Document Format: a proprietary document format developed by Adobe to enable the world wide distribution of documents.

Personal Computer A computer that is destined to be used by only one person. Before the era of PC's, multi-user *mainframes* were used as computing power resources. Although many types of PC's existed, during the eighties the IBM PC became the "standard" PC.

peer reviewing A process in which "fellow" people (researchers, educational designers, teachers) evaluate certain products to objectively assess its value.

PHP Hypertext Preprocessor: a script language that allows a HTML page to contain active code that is executed by the web server whenever the page is requested. This is a form of Server-Side Scripting.

ping A program that sends a certain packet to an Internet host that should return the packet if it is up and running.

Powerpoint A widely used presentation tool that runs on the Microsoft Windows platform. The tool generates slides that can be projected on a screen, much like an overhead projector.

program the whole of software components that

prototype A program (or device) that is not fully operable, but that serves to demonstrate that certain ideas can work in practice, or that serves to develop new methods or techniques.

Q

Quicktime A proprietary video format, developed by Apple Computer. It deploys a lossy compression method with a high compression factor, so that the format is suited to transmit video fragments across the Internet.

R

radio button A series of buttons (analogue or digital) of which at most one at a time can be in the 'pressed' or 'selected' state (i.e. listen to one radio station at a time). This mechanism has been incorporated into most Graphical User Interfaces.

RAM See Random Access Memory

Random Access Memory Computer memory that has the physical form of Integrated Circuits, and that acts as "scratch" memory, as it can be written and read from very fast. This type of memory cannot be used for long-term storage, as its contents will disappear when the power to the computer is switched off.

RDBMS Relational Database Management System: a DBMS that manages a so-called "relational" database, which is a database that is modelled using entities and relationships between them.

S

scalability The ability of a system to adapt to a growing load.

search engine A program that builds a keyword index of a certain (sometimes worldwide) set of WWW pages, and that allows a user to search this index to find WWW pages.

Server-Side Scripting A technique in which the web server executes scripts when a HTTP request for a certain document (type) is received. The script generates, or helps to generate, the HTML output belonging to the request.

servlet A Java program that helps the web server to deal with certain types of requests, for example to access a database or to process information the user has sent. This technique is similar to so-called CGI scripts.

SGML Standard Generalized Markup Language (Goldfarb, 1990): a language in which markup languages can be specified. One of the most well-known languages which is derived from SGML is the Hypertext Markup Language (HTML).

software series of computer instructions that tell a computer how to do a certain task, for example how to behave like a typewriter or how to read a document from a disc. Software is contained on a carrier, such as a harddisc, a floppy disc, a CD-ROM, or a tape.

SMIL Synchronized Multimedia Integration Language: a multimedia presentation language that allows for time-based multimedia delivery over the web. It is based on XML.

speech recognition The process of recognizing spoken words by a computer.

stateless A property of a system that indicates that the system does not store 'state information' (this should be seen with respect to the model of Finite State Machines).

Structured Query Language A language that allows the user to specify a query to a relational database in a structured way.

SQL see Structured Query Language.

SSI see Server-Side Scripting

summative evaluation An evaluation effort that is directed at obtaining a final evaluation of the object at hand (see also 'formative evaluation').

SunOS The Operating System that runs on most computers manufactured by Sun Microsystems Inc.

T

t-test A statistical test on the t statistic (a stochastic variable that has a 'student' distribution). Such a variable often represents the mean of a population.

temporal structure The time-related relationships between certain objects, such as: A starts 10 seconds after B has started.

traceroute A program that tracks the route that Internet packets follow to a certain Internet host.

transcript A written representation of a spoken text.

U

ULM see Unit of Learning Material

Unit of Learning Material

upload To send information from the user's computer to a remote computer system.

URL Uniform Resource Locator: an "address" that points to a resource (WWW page, FTP file, telnet address, etcetera) on the Internet.

V

videodisc A disc that contains analogue video sequences and analogue still pictures; a dedicated videodisc-player is needed to play the discs. It is also known as "laserdisc".

W

WAN Wide Area Network: a computer network that spans a number of cities, or a number of countries.

web browser A program that runs on a computer which enables the user to retrieve documents from a webserver through an Internet connection.

web server A process (program that is being executed) on a computer that allows documents to be retrieved through an Internet connection. The pages are addressed using a Universal Resource Locator (URL), and are often written in HTML.

World Wide Web An information resource, implemented on the Internet, that consists of billions of HTML documents that have hyperlinks between them. The documents are located on web servers and can be retrieved using a web browser.

WWW see World Wide Web

WWW cache A temporary storage facility of WWW documents that have been fetched in the past; the facility is often built into web browers. If a page is requested again, then first the cache is examined to see if the page is still present, and if so, the cached page is presented. The page does not have to be re-fetched from the network, thus saving bandwidth and WWW server capacity.

X

XML eXtensible Markup Language: a markup language that can be used to markup many different types of documents. It is a member of the family of SGML languages.

XSL eXtensible Style Language: a language that assigns 'layout' properties to XML markup elements. These layout properties can then be translated into an output language such as PDF, RTF, or HTML.

XWindows A graphical user interface on Unix-like Operating Systems.

Index