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Master Thesis

Text-based indicators for architectural inventions derived from patent documents: the case of Apple's iPad

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Abstract

Nowadays companies are endangered not only from radical breakthrough innovations that disrupt the market and company knowledge, but also from architectural innovations, which recombine different existing technologies in a new way. There are already studies exploring the power of patent documents in finding indicators for potential architectural innovations. However, additional research on these indicators is needed. This thesis aims to further develop indicators for the architectural nature of technical inventions. It aims at building new theory, using a longitudinal embedded single case study as a research design. It focuses on Apple's iPad as an object of analysis due to its extreme impact on the mobile computers industry. This thesis proposes a new method for identification of the architectural nature of a patent using text-based indicators in form of keywords. The method is validated through an expert opinion, but it also shows low congruence. Nevertheless, results show potential despite the discrepancy between the keywords and the expert opinion approaches and further development seems plausible.

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1. Introduction: problem description, existing knowledge, research goal and research questions

Problem description, industry and product choice

Nowadays companies face difficulties in identifying potential market disruption caused by the development of new technologies when they are not involved in the actual technological research and development. Hence, they are challenged to react on time to the emerging novelty, which can often endanger the future of the company. However, looking deeper into the emerging novelties, it is visible that a big part of the disruption is related to recombination of existing technologies, identified as *architectural innovation* by Henderson and Clark (1990) and further elaborated by Baldwin and Clark (2000, 2006). In the event of architectural innovations, the knowledge about technologies exists in the form of patents, scientific publications and/or established products. Though, it still remains difficult to identify possible disruptions caused by the recombination of existing technologies, designs and artifacts (Baldwin & Clark, 2000; Henderson & Clark, 1990; Henderson, 1992).

An interesting example in this field is the case of Nokia. It was a world market leader in the mobile phone industry with an outstanding market position back in the 2000 (Nokia, 2013). However, the situation changed with the introduction of an innovative product in 2007 – the Apple's iPhone followed by the iPad in 2010. The iPhone redefined the word "smartphone" and endangered the future of Nokia leading to severe damages and loses for Nokia. On the other hand, the case of Apple's iPad and how it changed the mobile computers industry is considered remarkable with its growing sales in comparison to the declining mobile computer sales reported by world leading computer manufacturing companies like Dell and HP (Apple Inc., 2010a, 2013; Dell Inc., 2012; Hewlet-Packard, 2012). Even more, with their iPad, Apple did not invent the tablet. One of the first concepts of tablet computers already existed back in the 70's with the name "DynaBook". However, Apple dramatically changed the computer industry by recombining different existing technologies and disrupting the market with their device (Henderson & Clark, 1990; Kay, 1972). What is happening within ICT[1] industry and how technologies are

[1]ICT stands for Information and Communications Technology.

developing there are involving questions since our daily life seems impossible without Internet and online communication. That is why the ICT industry is chosen as a focal field of this research and to narrow down the research, the case of Apple’s iPad is further elaborated.

Existing knowledge and research gap

A possible way to identify potential disruption could be achieved using patent documents. They provide huge amounts of knowledge in a structured and searchable way, which can be utilized in finding indicators of potential disruptions. There are already studies investigating the possibilities, which patent documents provide in this regard. In their state of the art study, Arts, Appio and Looy (2012) compare and validate a number of patent indicators existing in the literature, reflecting the technological impact and the nature of the patented inventions (radically new or recombination/improvement of existing) (Arts et al., 2012). Their results show that the indicators for technological impact and value – so called *“ex post”* indicators – clearly outperform the indicators of technological nature and novelty – *“ex-ante”* indicators – in terms of precision and recall (Arts et al., 2012). Therefore, further development of the latter *“ex-ante”* indicators is needed (Arts et al., 2012, p. 13). Hence, the main goal of this thesis is to fill this gap and to derive indicators for the nature of the technology obtained from patent documents.

Research goal and research question

Isolating particular indicators for the recombination of technologies in the ICT industry is the center of this research. Furthermore, the core of this study is to identify patents, which describe architectural inventions and further analyze their contents in order to identify indicators for architectural inventions within the case of Apple’s iPad. More precisely, the main goal of this research is to identify text-based indicators for architectural type of inventions obtained from patent documents in order to help innovation and technology managers to identify possible disruptions caused by technology recombination and help companies adapt relatively easier to the upcoming technological trends.

Therefore, the identified research gap and the described field of interest lead to the following research question:

How can the architectural nature of patented inventions behind Apple's iPad be identified using patent documents?

Furthermore, this question can be divided into the following sub-questions:

1) *What are the characteristics of an architectural invention?*
2) *Which are the core components of the Apple's iPad?*
3) *Which keywords that can characterize the core components of Apple's iPad can be obtained from patents' title and abstract?*
4) *How can a patent be rated as an architectural invention through the help of keywords obtained from patents' title and abstract?*

By applying these questions in the specific case of Apple's iPad, this embedded single case study aims at building new theory in recognizing architectural inventions using the information provided in patent documents. By fulfilling this objective, help to innovation and technology managers at identifying potential disruption caused by recombination of existing technologies will be provided.

Research time frame

To set borders of analysis suitable for a Master's thesis time frame, this study focuses on Apple's iPad product, more specifically generation 1, released in April 2010 and generation 2, released in March 2011 (Apple Inc., 2010c, 2011b). Comparing the technical specifications of both devices, one can see that they use the same display and their processor chip operates at the same frequency of 1GHz (assuming that these two components highly influence the size and performance of the device). On the other hand, iPad 2 is considerably thinner, lighter and its performance is noticeably improved (iFixit.com, 2010, 2011). These improvements illustrate actual architectural inventions behind the iPad product – recombining already existing technologies in a new way - which is the field of interest in this project.

Thesis structure

This thesis contains 5 chapters. The first one introduces the problem to the audience, describing the main research question followed by four sub-questions. Chapter 2 discusses the relevant theory on the topic taking into account the patent system and existing innovation frameworks. It also discusses the differences between innovation and invention, as well as theory on complex systems and finally providing definitions, which are further used in this research. Chapter 3 describes the research methodology elaborating on the research design and defining the steps of the research. Next, the results from the analysis are provided and visualized in chapter 4, followed by their limitations and conclusion in chapter 5.

2. Theoretical framework: overview of relevant theory

In this chapter, an overview of the patent system is provided, including the structure of patent documents and further clarification of the essential terms in this thesis is given, namely *innovation* vs. *invention*. Furthermore, different concepts of innovations and innovativeness are reviewed and the choice of the framework proposed by Henderson and Clark (1990) is elaborated. In section 2 of this chapter, theory about complex systems and their structure is provided. Moreover, since the framework of Henderson and Clark (1990) deals with innovations instead of inventions (respectively patents), the framework is specifically adapted for the analysis of technical inventions, present in patent documents.

2.1 Patent system: general idea and structure of patent documents

Patent system overview

Although the terms innovation and invention sound very similar and are often used as equal, they are not the same. *Invention* is the creation of something new and usable that was previously unknown, whereas the *innovation* is its market realization (Chesbrough, 2006, 2012; Khilji, 2006; Roberts, 2007). To protect an invention that is usually a result of a time, research and development efforts and cost intensive processes, companies are allowed to patent their inventions according to the patent law. According to the World Intellectual Property Organization (WIPO[2]), the patent law is *"a legal framework that establishes a patent system which supports and encourages technological innovation and promotes economic development"* (WIPO, 2013a). Therefore, a patent is a document granting *"an exclusive right granted for an* ***invention****, which is a* ***product*** *or a* ***process*** *that provides, in general, a new way of doing something, or offers a new technical solution to a problem"* (WIPO, 2013b). In order an invention to be patentable, certain conditions must be fulfilled. For instance the invention must have a practical use; must show element of novelty, coming outside of the existing body of technical knowledge known to the moment (WIPO, 2013a). To obtain a patent, a patent application has to be submitted at the National patent office, European Patent Office (EPO) or at the Patent Cooperation Treaty (PCT), following a predetermined procedure, where each institution

[2] WIPO stands for World Intellectual Property Organization.

provides different level of geographical protection. In its essence, a granted patent provides a protection to the owner of the invention for certain period (maximum 20 years) in case the inventor pays the required patent fees. By doing so, the patent guarantees the inventor a temporary monopoly situation for the invention by allowing the inventor to make, use, sell, license or do nothing with its invention (WIPO, 2013a). After expiration of a patent due to end of the protection period or not paying the required annual fees, the invention's information described in the patent becomes freely usable by anybody and can be used as an unique source of knowledge providing free access to technical solutions available only in patent documents (European Patent Office & European Commission, 2007).

Structure of patent documents

A patent has three main sections: 1) *title page* containing bibliographic data; 2) *description* of the invention containing invention drawings and 3) *claims*, which describes what is claimed to be protected from the inventor (Al-Azzeh, 2009; Cambia, n.d.-a; Veer, 2011).

The *bibliographic* information on the title page contains patent *title* as well as providing information about the *inventor* (the person who made the technological invention), the *applicant* or *assignee* (the person who applies for the patent at the chosen patent office), the *date of filing* (mostly called *priority date*)[3], the *application number*, as well *as technology class(es)*, cited *prior art*, basic invention *drawing(s)* (if present), an *abstract* (containing short description of the invention) and others (Al-Azzeh, 2009; Cambia, n.d.-a; Veer, 2011).

The *description* part contains the invention title, a summary of the prior art or background of the invention, a description of the problem to be solved explaining at least one possibility of carrying out the invention, description of the drawings and others (Al-Azzeh, 2009; Cambia, n.d.-a; Veer, 2011).

[3] Priority date is *"sometimes called the 'effective filing date', is the date used to establish the novelty and/or obviousness of a particular invention relative to other art."* (Cambia, n.d.-b).

The third part – the *claims* – is the most important part of the patent. The claims define the scope of the invention, in other words what is protected by the patent law. They have to be written in a way that potential infringers have to be able to understand what exactly is protected with the patent and what is not (Al-Azzeh, 2009; Cambia, n.d.-a; Veer, 2011).

2.2. Innovation and Innovativeness: different concepts and frameworks

Different innovation frameworks exist representing innovation and innovativeness. Each takes different viewpoint and highlights different aspects. Some of them are overlapping, others complement each other, some take economic perspective, others technological (Arts et al., 2012). Within each of these, other definitions and concepts may exist. For instance Booz, Allen and Hamilton (1982) define the new product topology in two dimensions: 1) newness to the market and 2) newness to the company. Based on the high-low combination of these two dimensions, the authors define different degrees of innovativeness. Another example is the distinction between *product* and *process* innovation (OECD Eurostat & European Commission, 2005). According to the measurement of scientific and technological activities – Oslo Manual by OECD[4], product and process innovation are defined as follows: *"A technological product innovation is the implementation/commercialization of a product with improved performance characteristics such as to deliver objectively new or improved services to the consumer. A technological process innovation is the implementation/adoption of new or significantly improved production or delivery methods. It may involve changes in equipment, human resources, working methods or a combination of these"* (OECD Eurostat & European Commission, 2005, p. 10). Different classifications within the product-process dimension also exist. For example Veryzer (1998) classifies product innovation based same-enhanced/advanced scale of product and technology capability to: 1) continuous; 2) commercially discontinuous; 3) technologically discontinuous and 4) technologically and commercially discontinuous. In terms of component and system knowledge, Henderson and Clark (1990) rate the incremental/radical innovation framework incomplete. They expand this idea adding next to the core concepts a second dimension – linkages between core concepts and components (Figure 1). Based on the combination of different levels

[4] OECD – Organisation for Economic Co-operation and Development

of core concepts and linkages between components in a system, Henderson and Clark (1990) take the more technological perspective and distinguish between:

- incremental innovation;
- modular innovation;
- architectural innovation and
- radical innovation

		Core concepts/Components	
		Reinforced /Improved	*Overturned*
System/Linkages between concepts and components	*Unchanged*	Incremental	Modular
	Changed	Architectural	Radical

Figure 1 - Innovation types – Adapted from Henderson and Clark (1990)

However, no framework exists that encompasses all perspectives. For the purpose of this research project, the concept from Henderson and Clark (1990) is seen the most suitable as it refers to system and component knowledge and the interconnections between components in the system. The concept is considered highly applicable to this case due to the modular design of Apple products (Baldwin & Clark, 2000; Schilling, 2000). However, a drawback of the chosen framework in this particular application is that the authors take more socioeconomic perspective and talk about *innovation.* Important refinement here is that the term innovation represents the market realization of an idea either in product, process or service field (Chesbrough, 2006, 2012; Khilji, 2006; Roberts, 2007). In this thesis, taking more technological perspective, patent documents (or patents for short) are analyzed, where a patent represents technical *invention(s)*. Therefore, Henderson and Clark’s innovation framework is used as a foundation in this thesis but adapted and further elaborated for the specific case in section 2.4.

2.3. Systems’ operationalization: definitions and contents

To analyze inventions behind a complex product such as Apple’s iPad and its components, their characteristics and interfaces, a summary of definitions of complex systems and architectures is provided.

In his seminal paper on product architecture, Ulrich (1995) defines product architecture as: *“... the scheme by which the function of the product is allocated to physical components [...] (1) the arrangement of functional elements; (2) the mapping from functional elements to physical components; (3) the specification of the interfaces among interacting physical components”* (Gulati & Eppinger, 1996, p. 5; Ulrich, 1995, p. 420). According to Fixson (2005), *“product architecture can be nominally defined as a comprehensive description of a bundle of product characteristics, including number and type of components, and number and type of interfaces between those components, and, as such, represents the fundamental structure of the product”* (Fixson, 2005, p. 347). This is similar to the definition of a system offered by Carlsson, Jacobsson, Holmén and Rickne (2002). They define a system as *“a set of interrelated components working toward a common objective”* (Carlsson et al., 2002, p. 234). However, the first definitions come from the product perspective, whereas the latter from socioeconomic. Combining these definitions for the purpose of complex product analysis, including aspects like product architecture, characteristics and components, and furthermore consistent with the definitions of hierarchy offered by Simon (1962), the definition of complex (nested) system offered by Sanchez and Mahoney (2002) and Schiling (2000), for this particular case a **system** can be defined as:

> *A system is a nested architecture, consisting of components and their interconnections, where each component is performing certain functions and has distinct properties.*

The **function** represents an action or activity of a component. In other words:

> *Functions are what components “do”* (Ulrich, 1995).

Since functions represent activities and actions, it is assumed that functions can be found in the form of verbs in patents' titles, abstracts and claims (Dewulf, 2011).

Continuing with the definition of **property**, it is an attribute or characteristic or a quality of an object. In other words:

> *The properties are systems' or components' characteristics.*

They can be described by adjectives and adverbs in patent documents or in different construct via nouns describing possession (Dewulf, 2011).

The components are the "ingredients" of the system or according to Carlsson et al. (2002) its *"operating parts"* (Carlsson et al., 2002, p. 234). However, the authors take a socioeconomic perspective in their definition of systems and components. In comparison, Baldwin and Clark propose similar definition in more technical environment. They call a "*module [...] a unit whose structural elements are powerfully connected among themselves and relatively weakly connected to elements in other units"* (Baldwin & Clark, 2000, p. 63). Additionally, according to Sanchez and Mahoney (2002) *"A component in a product design performs a function within a system of interrelated components whose collective functioning make up the product"* (Sanchez & Mahoney, 2002, p. 65). In this particular case for the purpose of this research a **component** is defined as:

> *A component of a system is a separate unit of the system that has distinct borders, functions and properties, which is connected to other components through interface(s),*

which is also consistent with the definition proposed by Ulrich (1995). At a different level of abstraction, the component represents a system itself, which is further consistent with the nested hierarchy proposed by Simon (1962), Gulati and Eppinger (1996) and Schiling (2000).

An interface is defined in the management literature as: *"interacting components are connected by some physical interface"* (Ulrich, 1995, p. 421); "*how the components are linked together (the interfaces between components)"* (Baldwin & Clark, 2006, p. 5); *"The components are able to connect, interact, or exchange resources (such as energy or data) in some way, by adhering to a standardized interface"* (Schilling, 2000, p. 318). Therefore, consistent with the above mentioned definitions, an **interface** is:

An interface is the linkage or interconnection between components in a system.

Taking into account all the definitions above and going a step further, each component represents a system with its own functions, properties and components, until a certain level is reached where no more subdivision is possible from a specific perspective. However, components where no further subdivision is possible are referred as simple components or integral systems (Ulrich, 1995) but as stated above that highly depends on the perspective. Thus, for the purpose of this analysis, it is assumed that simple components exist and there will be no change in the perspective, for instance looking into the chemical or physical structure of the materials and their contents.

Since the framework proposed by Henderson and Clark (1990) deals with *innovations* and the object of analysis of this thesis is patent documents, describing technical *inventions*, the provided definitions in this section are used as a tool for adapting Henderson and Clark's innovation framework for analysis of technical inventions (Henderson & Clark, 1990). The actual adaptation is provided in the following section.

2.4. Inventions framework: Adapting the innovation framework from Henderson and Clark (1990) to the case of technical inventions in Apple's iPad

On a structural level, a system representing a combination of components (*C_1* and *C_2*) and

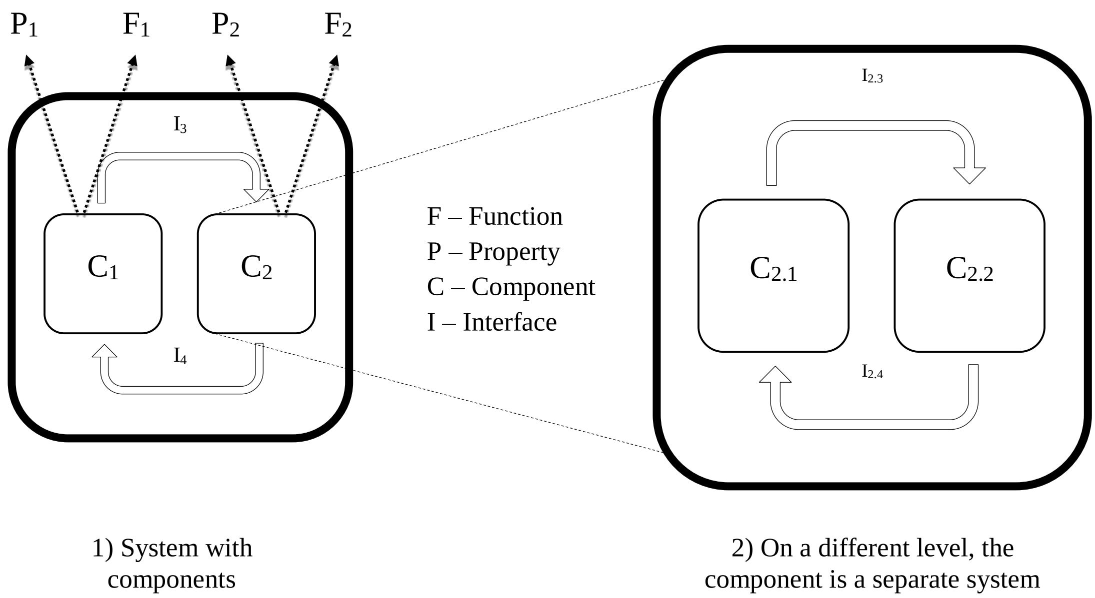

Figure 2 - Representation of a system (own creation)

interfaces (*I_3* and *I_4*) is presented on Figure 2. As stated in the previous section, the interfaces are the linkages between components, and for this thesis both terms *interface* and *linkage* between components are used as equal. At different level of aggregation, a component itself represents a system (case 2 from the same figure). Consistent with the previously defined component-function-property framework, each component has its own *sub-components (C)*, *functions (F)* and *properties (P)*. Taking as an example a mobile room fan, similarly to the one described in Henderson and Clark's paper (1990), its *function* is to generate airflow in order to create comfort. Its *properties* are color, weight, size etc. The mobile room fan's core *components* are the blades, the motor and the housing.

In order to make selection of relevant patents that need to be analyzed, building on the above-mentioned definitions and adapting the Henderson and Clark's innovation framework (1990) for this particular case, the following types of *inventions* (not innovations) are explained in the following section:

- *Incremental*
- *Modular*
- *Architectural*
- *Radical*

According to the proposed operationalization

> ***An incremental <u>invention</u>*** *illustrates an improvement on component level, where a single component in a system is enhanced in order to advance the system's overall functionality.*

Continuing with the example of the mobile room fan, an incremental invention would be an improvement of component's functions and/or properties taking a single component

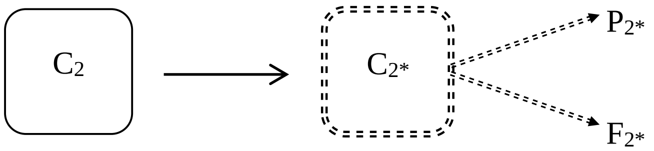

Figure 3 - Incremental invention

as a level of analysis. Analyzing the fan motor itself, an incremental invention would be an improvement in the motor such as it could produce higher rotating speed (function improvement) and/or decreasing its weight (property improvement) as illustrated on figure 3.

In the original paper of Henderson and Clark (1990), the term modular innovation is not clearly elaborated and one can argue if the distinction between incremental and modular innovation is clear enough (Henderson & Clark, 1990). In a more recent work by Smith (2011) in his book *Exploring Innovation*, the author provides an overview of the four types of innovations according to the framework proposed by Henderson and Clark (1990). The author proposes that the modular innovation consists of new components but the system architecture remains the same (Smith, 2011, p. 52;57).

Table 1 - Types of innovation and associated changes (Smith, 2011)

Innovation	Components	System
Incremental	Improved	No change
Modular	New	No change
Architectural	Improved	New configuration/architecture
Radical	New	New configuration/architecture

Therefore, consistent with Smith (2011) and making it more precise for the purpose of this thesis, the term *modular invention* is defined as follows:

> ***Modular** **invention*** *reflects not only the component, but the system level. Interchanging a module in a system with a new or improved one (substituting component C_2 from figure 2 with C_{2**} from figure 3) and leaving the remaining system and the interfaces between components intact represents a modular invention – see figure 4.*

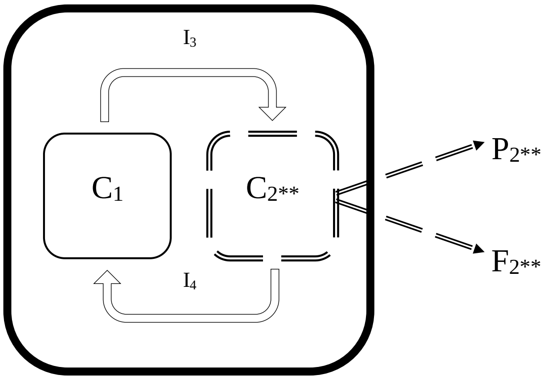

Figure 4 - Modular invention

In other words, taking the complete fan as a system and changing one of its components, for example the motor with one that provides higher rotating speed (function improvement) and/or reduces weight (property improvement), is modular invention. These component change(s) bring benefits to the whole system. Therefore, the overall system functions and properties are improved by the substitution of a single or multiple components, without changing the overall system architecture and components' interfaces.

Architectural innovation, as defined by Henderson and Clark (1990), represents a new combination of already existing or reinforced/improved components, but combined or interconnected in a new unseen to the moment way, in other words, it concerns both the component and the system level (Henderson & Clark, 1990). Baldwin and Clark (2000) describe all possible architectural changes in a modular system through six simple operations: *1) splitting* – creating two separate designs out of one module; *2) substituting* – substituting one module with another; *3) augmenting* – adding new module(s) to the system; *4) excluding* – removing a module from the system; *5) inverting* – makes previously "hidden" and not visible information visible to the system and available to other modules; and *6) porting* – when a module is *"unleashed"* from the system and is able to function in more than one system, but remains invisible to the system architecture (Baldwin & Clark, 2000, pp. 123–146). Taking into account the definition provided by Henderson and Clark (1990) plus the operators for architectural changes, provided by Baldwin and Clark (2000) and further refining and combining them in a single and synthesized for the purpose of this research definition, the *architectural invention* can be defined as follows:

> ***Architectural <u>invention</u>*** *comprises the integration of new (component C_4 on the figure 5) and/or improved components (component C_{2**} on the figure 5) into a system, using old components (components C_1 and C_3 on the figure 5) and rearranging the components by implementing new interfaces between components in the system (I* on figure 5). These result in systems overall function and/or properties improvement and/or functionality adding.*

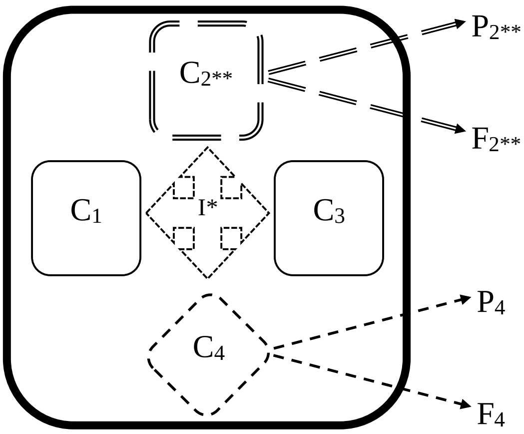

Figure 5 - Architectural invention

In the example of the room fan, an architectural invention is the reconfiguration of the system in such a way that the fan is mounted on the room ceiling and for instance an illuminating body is integrated into the fan's body. Such a configuration provides the main function of the room fan – to generate air flow in order to create comfort plus additional one – the light generation. The main components in the room fan system remain the same, namely blades, motor and housing. However, an additional component is also included – the illumination module, which provides opportunities light bulbs to be mounted on the room fan to generate light. Hence, the core components are arranged in a new way and are linked together through new interfaces forming an architectural invention.

Main difference between the modular and the architectural invention is the rearrangement of components in the system and their linkages as well as the possibility to include or exclude additional components in order to add or remove functions to/from the system. In case of architectural invention, the currently known and available components from different technology fields are implemented in the system. On the other hand, this is also the main difference, which further distinguishes the architectural and the radical invention, which is described in the following paragraph.

Radical invention represents a new technology, implementing both new components and new interconnections in the system (Henderson & Clark, 1990; Smith, 2011). Usually radical invention occurs when a new technology is developed and no dominant design is established (Murmann & Frenken, 2006). Once a dominant design is accepted, then for the same system/technology only incremental, modular and architectural inventions appear (Murmann & Frenken, 2006). Therefore, for the purpose of this research, *radical invention* is defined as follows:

> ***Radical <u>invention</u>*** *represents a high degree of novelty on both component and system level, in other words entire new system (Smith, 2011). It occurs when a system is fully changed in such a way that the core components are entirely new, not used in different technology fields before and new system interfaces are involved.*

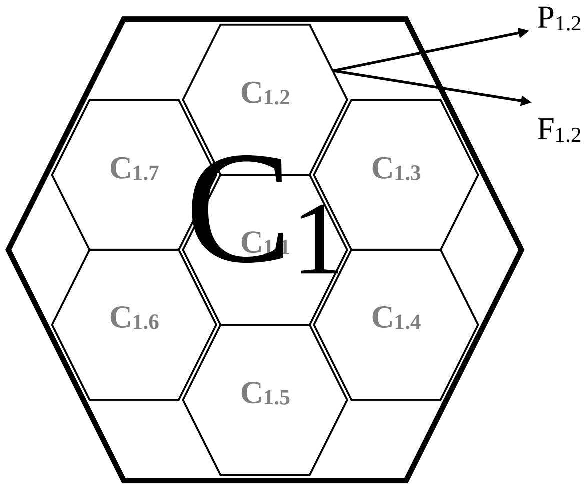

Figure 6 - Radical invention

Going back to the room fan example, a radical invention fulfilling the need of air circulation for better comfort is the central air conditioning system (Henderson & Clark, 1990). The central air conditioner is therefore a completely new system with a new set of components, and their interfaces, leading to new functions and properties. Schematic representation for radical inventions provided on figure 6.

Certainly, this classification highly depends on the level of aggregation. At different level of abstraction, one invention can be classified differently (Murmann & Frenken, 2006). The purpose of the provided definitions is not to divide all existing inventions and classify them to these particular types. Instead, it is intended to make clarification that the innovation framework proposed by Henderson and Clark (1990) is not applicable in its exact form for the particular patent analysis. Moreover, it intends to point the difference between architectural and non-architectural type of inventions. Since the incremental and modular inventions differ only from the hierarchy perspective, they will be regarded equal for the purpose of this thesis and will be referred from now on as ***non-architectural inventions.*** Furthermore, for the purpose of this research the radical inventions will be disregarded.

The next chapter sheds some light on the methodology applied in this research project and the performed steps of the analysis.

3. Methodology: research design, data sources and steps of the analysis

This chapter describes the methodology of the research. In the first section, the choice of the research design is elaborated. Next, a combination of different data sources required for the separate parts of the analysis is explained, followed by the single steps of the analysis and their explanation.

3.1. Research design: embedded single case study

As the aim of this thesis is building new theory using data from written documents, a qualitative method is seen highly suitable (Cavaye, 1996; Yin, 2003, Chapters 1–2). The qualitative methods provide a deeper understanding in the exploration of a complex phenomenon occurring under certain conditions (Blaxter, Hughes, & Tight, 2010, Chapter 3; Cavaye, 1996; L. Cohen, Manion, & Morrison, 2007, Chapter 11; Yin, 2003, Chapters 1–2). Hence, a case study is considered to be an appropriate research design as it aims at building new theory in a specific field, studying a contemporary event in its natural context (Blaxter et al., 2010, Chapter 3; Boeije, 2010; Cavaye, 1996; L. Cohen et al., 2007, Chapter 11; Eisenhardt, 1989; Yin, 2003, Chapters 1–2). Moreover, case study design addresses “how” and “why” research questions, which leads to in-depth understanding of the covered topic (Boeije, 2010; Cavaye, 1996; L. Cohen et al., 2007, Chapter 11; Yin, 2003, Chapters 1–2). An important advantage of the chosen method is its testability and further verification, providing foundations for future research (Eisenhardt, 1989; Yin, 2003, Chapter 2). A weakness of the chosen method is its low generalizability (Cavaye, 1996). To test the validity of the newly built theory a quantitative study is considered more suitable, because it can provide statistical significance and generalizability of the results (Cavaye, 1996; L. Cohen et al., 2007; Krefting, 1991; Yin, 2003, Chapter 2).

The focus of the research is on the ICT industry and more precisely in the case of Apple’s iPad. The case of Apple’s iPad is considered an extreme case (Yin, 2003, Chapter 2) as it changes the computer’s industry. Striking facts are its over 300 000 units sold in the first day after release, reaching 3 million units in only 80 days (Apple Inc., 2010a), totaling more than 32 million units sold in 2011 and more than 58 million units in 2012 (Apple Inc., 2013). In the same time laptop and personal computer (PC) sales decline as reported by world leading companies like HP and Dell (Dell Inc., 2012; Hewlet-Packard, 2012). Another interesting aspect of this success is that Apple did not invent the tablet (Kay, 1972). They used already existing technologies and recombined them in a new way providing great user experience resulting in huge sales volumes (Apple Inc., 2010a, 2013; Kay, 1972).

The chosen unit of analysis, namely the iPad device, represents a complex product, consisting of many components and their functions and properties, which are designed by different companies. In order to set boundaries feasible for a Master's thesis research by taking into account only Apple's patented inventions, the chosen research design is therefore an embedded single case study (Boeije, 2010; Yin, 2003, Chapters 1–2). Additionally, the fact that the unit of analysis embraces at least two generations of the Apple's product further specifies the research design as longitudinal embedded case study (Yin, 2003, Chapters 1–2).

3.2. Combination of different data sources: the origin of analysis

One of the main challenges for this thesis is finding the actual linkage between the invention (described in patents) and the end-user product – in this situation Apple's iPad. To overcome this challenge, the Thomson Innovation database providing access to DWPI – Derwent World Patent Index (Thomson Reuters, 2013a, 2013b, 2013c) is used with the exclusive support of Dr.-Ing. Peter Walde, CEO of Mapegy UG Berlin, Germany. In this case, Derwent information is very valuable because the level of the language used in patents is very specific and in most cases not easy to understand (Porter & Cunningham, 2005, Chapter 12). In this sense, Derwent fields provides simplified and more "reader-friendly" information delivered by field experts, which help the reader to enhance its understanding of the described invention (Intellogist, 2009c; Porter & Cunningham, 2005, Chapter 12; Thomson Reuters, 2013c). Such information is provided in the *DWPI Title, DWPI Abstract, DWPI Use, DWPI Advantage, DWPI Assignee Codes* and other DWPI fields, not present in freely accessible patent databases. *DWPI Title* is a field that contains new re-written title of a patent due to the *"often vague and difficult to understand"* original patent title, which is written in English, no matter the language of the original patent document (Intellogist, 2009c). Similarly, the *DWPI Abstract* is a field created in English, no matter the original patent language, and provides synthesized and *“concise, easily understood abstracts”* on the patented invention (Intellogist, 2009a). *DWPI Use* and *DWPI Advantage* are two fields providing information for the potential usage as well as its advantage over the inventions existing in prior art as described by the author (Thomson Reuters, 2013c). *DWPI Assignee Codes* is a field combining all registered company name variations coming from *“misspellings, transliterations from other languages, and abbreviations for common words (for instance "Co." for "Company" or "Ltd" for "Limited)”*, which can create obstacles in successful identification of all patents belonging to one single company (Intellogist, 2009b). Thus, the Derwent information is very beneficial in identifying architectural inventions and further limit the analyzed patents to iPad relevant only.

In order to set borders of analysis suitable for a Master’s thesis time frame, the choice of analysis is put on Apple’s iPad product generation 1 and 2. At first look on both devices, one can see that they use the same display (taking significant part of the device and its battery life) and their processor chip operates at the same frequency of 1GHz (assuming that the processor’s operating frequency has high influence on device’s performance) but the iPad 2 is considerably thinner, lighter and its performance is improved (iFixit.com, 2010, 2011). Such properties improvements illustrate actual architectural inventions behind the iPad product, which is the field of interest in this research project. Taking a look inside the two devices with the help of specialized expert web resources like iFixit.com and the official technical specifications provided by Apple, the core components of the two devices are identified and compared. As iPad is a complex device, build on a modular principle (Baldwin & Clark, 2000), some of its components are designed and manufactured by external companies. To limit the amount of patents to analyze, only the components designed by Apple and the inventions behind these components, which are protected by patents granted to Apple by the USPTO[5], are taken into consideration and further analyzed in this research project.

[5] USPTO stands for United States Patent and Trademark Office.

3.3. Steps of the study: breakdown of analysis in major steps

3.3.1 Identification of iPad's core components

In this section, two generations of the iPad device are operationalized and compared according to the proposed *function-property-component* framework based on the official technical specifications provided by Apple and a complete full pictured teardown guide provided by iFixit.com. The website iFixit.com was chosen among others because of its comprehensive expert materials and analysis supported by high resolution pictures. Additionally the site owners provide an open source model to its contents – using the community opinion and improvement suggestions moderated by the site owners and licensed under the creative commons license (iFixit.com, 2013).

iPad 1

According to the definitions provided in section 2.3 of this thesis, the first generation of iPad is a *system* that represents a tablet computer device (a portable computer that uses touchscreen as its input source) (Oxford University, 2013; TechTerms.com, 2013) with rectangular shape and curved edges with the following size and weight (Apple Inc., 2010b):

- Size:
  - Height: 242,8 mm (9,56 inches);
  - Width: 189,7 mm (7,47 inches);
  - Depth: 13,4 mm (0,5 inch);
- Weight:
  - 0,68 kg (1,5 pounds) Wi-Fi[6] model;
  - 0,73 kg (1,6 pounds) Wi-Fi + 3G[7] model;

According to the manufacturer's specifications (Apple Inc., 2010b) and the teardown guide provided by iFixit.com (iFixit.com, 2010), it consists of the following core components with their corresponding properties:

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[6] Wi-Fi stands for Wireless Fidelity (Wi-Fi Alliance, 2000).

[7] 3G stands for Third Generation of Mobile Telecommunications Technology (International Telecommunication Union, 2000).

1. **Display**

   A 9,7-inch (diagonal) LCD[8] display *(a component, for short (C))* with IPS[9] technology *(property from the proposed operationalization, for short (P))* with 1024x768 pixel resolution at 132 pixels per inch (ppi) *(P)*; LED[10] driver *(C)* and LED backlit *(P)*. Furthermore, a digitizer *(C)* is embodied in the display assembly, converting the touch gestures performed by the user to computer processed digital format *(function, for short (F))*. On top of the display glass, a fingerprint—resistant oleophobic *(P)* coating *(C)* is laid. A Broadcom chip – BCM5973, which is situated on the logic board, is responsible for the multi-touch control functions.

2. **Back casing**

   The back casing consists of an aluminum back shell equipped with headphone jack, external On/Off, sleep/wake buttons and volume controls, built-in two mono speakers, dock connector, microphone + additional micro SIM card tray (only for the 3G model) – all of which are components of the back casing core component. Additional liquids sensor *(C)* is added to the headphone jack in order to check if the devise had been wet in order to void warranty (iFixit.com, 2010).

3. **Logic board**

   A core of the device is the logic board where the processor chip *(C)*, the operating and the storage memory are located *(C)*. The processor chip is designed by Apple engineers described as: *"1GHz Apple A4 custom—designed, high—performance, low—power system—on—a—chip"* (Apple Inc., 2010b). The SoC[11] contains Cortex-A8 CPU core with a power VR SGX graphics processor (Mudugal, n.d.). According to the technical specifications, the operating memory *(C)* is 256MB and the storage memory *(C)* varies between 16, 32 and 64GB flash memory.

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[8] LCD stands for Liquid Cristal Display.

[9] IPS stands for In-Plane Switching.

[10] LED stands for Led Emitting Diode.

[11] SoC stands for System-on-a-Chip.

4. **Wireless Communication module**

   Wi-Fi and Bluetooth connectivity *(F)* are provided in all iPad devices. In the first generation of iPad, the wireless communication module is realized through components that are integrated into the dock connector cable *(C)*. The Wi-Fi provides connectivity *(F)* according to the IEEE[12] standard 802.11 a/b/g/n (Apple Inc., 2010b; IEEE, 2012). The Wi-Fi and the Bluetooth 2.1 are realized through a controller chip from Broadcom – BCM4329 *(C)* (iFixit.com, 2010). The 3G connectivity *(F)* is provided through the 3G control board *(C)* in the "extended" version of the device called iPad Wi-Fi + 3G model. The 3G model has also additional 3G antenna assembly and GPS antenna *(C)* for the Assisted GPS function.

5. **Battery & power supply**

   The power supply consists of a specially enhanced 10W USB power supply (for charging the device) *(C)* and two Li-Pol[13] 3,75V 25Wh (6,75Ah) *(P)* batteries *(C)* connected in parallel ensuring about 10 hours of use *(F)* (Apple Inc., 2010b; iFixit.com, 2010).

6. **Additional sensors**

   The device is equipped also with ambient light sensor *(C)* providing the possibility to automatically regulate display brightness *(F)* and accelerometer *(C)*.

The so identified components seem to be of the highest importance for the iPad device. As stated in the theory section, each of these components can be viewed as a complex system and further decomposed to its components and interconnections. However, since there is no easy method for such decomposition, this thesis is not going to deal with further component decomposition on their structural level. Instead, an attempt to analyze

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[12] IEEE stands for Institute of Electrical and Electronics Engineers (IEEE, 2013).

[13] Li-Pol stands for Lithium Polymer battery (full term is Lithium-Ion Polymer) (Battery University, 2010).

the functional level is made through looking into the US[14] granted patent documents of Apple.

iPad 2

The second generation of iPad was released in March 2011, which is a bit more than a year after the first iPad was out on the market (Apple Inc., 2011b). In the following section, first the components and their properties (where present in the used sources) are listed and a comparison with the previous generation is provided.

In order to improve the reader experience, the abbreviation for components, functions and properties respectively *(C)*, *(F)* and *(P)* will be omitted from the iPad 2 operationalization section as most of the core components remain the same as with the iPad 1 device.

The following information can be obtained from the official technical specification:

- Size:
    - Height: 241,2 mm (9,5 inches);
    - Width: 185,7 mm (7,31 inches);
    - Depth: 8,8 mm (0,34 inch);
- Weight:
    - 0,601 kg (1,33 pounds) Wi-Fi model;
    - 0,613 kg (1,35 pounds) Wi-Fi + 3G model;
    - 0,607 kg (1,34 pounds) Wi-Fi + 3G for Verizon model. This model is specially designed for the Verizon telecom in the USA and therefore will not be analyzed separately.

Taking a look inside the device the following components can be found:

1. **Display**

   In terms of display there is no difference comparing with the older generation device. It is the same 9,7-inch (diagonal) LCD display with IPS technology with 1024x768 pixel resolution at 132 ppi; LED driver and LED backlit plus a digitizer are embodied in the display assembly. On top of the display glass again, a fingerprint—resistant oleophobic coating is laid. The same Broadcom

[14] US stands for United States.

microcontroller, which is responsible for the touch screen control is also present in this device.

2. **Back casing**

   The back casing and its contents are considerably improved as it can be seen from the size changes mainly on the thickness of the device. The previously present buttons and connectors, speakers, microphone and SIM card tray (only for the 3G model) are also present in the device's second generation. Interestingly, the device has smaller size and weight. It is powered by a processor chip operating at the same frequency as the first iPad (both at 1GHz) but at the same time the second generation device is faster and provides additional functionalities through the added components like front and back cameras, gyroscope etc. As iFixit.com cites Apple, the new device is *"Thinner. Lighter. Faster. FaceTime. Smart Covers. 10-hour battery."* (iFixit.com, 2011).

3. **Logic board**

   The new logic board is shaped differently but the main components that were present on the older device are found here as well. However, in the second generation device there is a new processor chip described as *"1GHz dual—core Apple A5 custom—designed, high—performance, low—power system—on—a—chip"* (Apple Inc., 2011a). The new iPad is equipped also with twice as much operating memory amounting at 512MB compared to the previous device. The storage capacity is not changed and varies between 16, 32 and 64GB. Here as on the previous device, the multi touch control is assured by the same Broadcom chip – BCM5973.

4. **Wireless Communication module**

   Similarly to the previous device, the Wi-Fi and Bluetooth 2.1 connectivity are provided through the Broadcom – BCM4329 chip (iFixit.com, 2011). However, the Wi-Fi and Bluetooth connectivity circuitry are situated directly on the logic board, in contrast to previously situated on the dock connector cable.

5. **Battery & power supply**

   In comparison to the two Li-Pol batteries present in the first generation, here the Li-Pol battery cells are three 3,8V 25Wh assuring 10-hours battery life (Apple Inc., 2011a; iFixit.com, 2011).

6. **Additional sensors**

   Alike the first generation, the device is equipped with ambient light sensor and accelerometer. In addition however, a gyroscope is present in the second generation device.

Summarizing, the iPad 2 is an improved version of iPad 1, providing more functionality and additional components, keeping the 10 hours of working time. Since most of the core components of the device remain the same and the central processor operates at the same frequency as the old iPad one can argue that the improvements observed in the second generation are done through apparent architectural improvements. This is obvious through the big size reduction – depth decreased from 13,4mm to 8,8mm (>30%), which reflects in further weight reduction (both properties improvements). In order to summarize the described similarities and dissimilarities, table 2 provides an overview of the two generations of the device.

Table 2 - iPad 1 vs. iPad 2 comparison table[15]

iPads' properties and components comparison	iPad 1 Wi-Fi model	iPad 2 Wi-Fi model
Processor	***1GHz Apple A4***	***1GHz Apple A5***
RAM	***256MB***	***512MB***
Screen size and resolution	9,7-inch/1024x768 pixels	9,7-inch/1024x768 pixels
Display technology and ppi	IPS/132ppi	IPS/132ppi
Back camera	***NO***	***YES HD (720p), 30 fps***
Front camera	***NO***	***YES***
Bluetooth	YES (v2.1)	YES (v2.1)
Height (mm)	***242,8***	***241,2***
Width (mm)	***189,7***	***185,7***
Depth (mm)	***13,4***	***8,8***
Storage	16/32/64 GB	16/32/64 GB
Wi-Fi	YES (802.11a/b/g/n)	YES (802.11a/b/g/n)
Gyroscope	***NO***	***YES***
Accelerometer	YES	YES
Battery life	10 hours	10 hours
Weight	***680g***	***601g***

The structural improvements are relatively easier to detect in comparison to the technological changes that lie behind. In order to find out how Apple improved the iPad device, this thesis is going to analyze the technical inventions related to iPad described in Apple's patents from USPTO. As there is no database that provides the link between the end-user products with all the patents that are behind these products, an attempt to

[15] The differences in the core components between the two iPad generations are visualized in ***Bold/Italics.***

establish such a link and the further analysis is made based on the understanding and the experience of the researcher for the particular case of iPad generation 1 and 2.

3.3.2. Initial data filtration

The period of patent analysis is set between years 2002 until 2012. The reason for this is the information provided to the audience that iPad developments started before iPhone developments (Isaacson, 2011), where the iPad was introduced in 2010 and the iPhone in 2007. Therefore, considering the highly competitive and R&D[16] intense ICT industry, where technologies are rated obsolete very fast, the period of 5 years before the introduction of iPhone (7 years before iPad introduction) is assumed to reflect the inventions included in the iPad device. The object of analysis is only patents granted by the USPTO assuming that Apple designs and develops in the USA, therefore first patent there, thereafter elsewhere. In order to obtain all Apple patents, a DWPI Assignee Code field was utilized and *APPY-C* and *APPL-N* assignee codes were used for the search. These two assignee codes combine all registrations of Apple Company such as *Apple Co Ltd, Apple Computer Inc A California, Apple Inc., Apple Corporation, Apple Computer US, Apple Computer France Sarl* and others. Using these assignee codes and applying the filter for the Apple inventions between years 2002 and 2012 in Thomson Innovation Database resulted in 5666 patents granted to Apple by the USPTO by 14th May 2013.

The process continued with sorting of the data by date (putting the oldest first) and scanning the first 1000 (numbers 1-1000), the middle 1000 (numbers 2500-3500) and the last 1000 entries (numbers 4500-5500) by reading each patent's title and abstract. It was assumed that some interesting patents will be found in each of these samples. Covering three different sections of the 10-year sample (beginning, middle and end) is assumed to provide a more relevant picture of the patented inventions, avoiding information distortion from looking only into single part of the patent sample. However, according to the researcher, more interesting patents were found in the latter two sections, which required an extension of the researcher's attention leading to the scanning of all patents between numbers 2500 and 5666. This resulted in total sample size of 4166 patents, representing 74% of all Apple patents for the chosen time period, which were further

[16] R&D stands for Research and Development.

analyzed. No matter that large portion of Apple inventions were covered for the chosen time period, there is still a possibility that potential important for iPad patents with valuable keywords could be accidently omitted by this research.

3.3.3. Classification of architectural vs. non-architectural and iPad vs. non-iPad inventions based on definitions

Identification of architectural and non-architectural patents was performed by the researcher through intellectually applying the aforementioned invention definitions to the filtered set of 4166 Apple patents. For this purpose, patents' titles, abstracts, drawings and available Derwent information were used to select initial sample of architectural inventions patents and classify each patent as *potentially architectural* or *non-architectural*. All patents that do not comply with the architectural invention definition provided in section 2.3 were categorized as *non-architectural*. Furthermore, each of the analyzed patents was classified as iPad relevant or not, based on researcher's experience and his understanding of the invention. Since Apple has diverse products in various industries, their patent portfolio spreads over many different products and technology fields. All architectural patents related to other Apple products that are considered not relevant for iPad, for instance describing functions or components not present in the iPad device, for instance mouse or hardware keyboard, were discarded from further analysis. Furthermore, the sample contained many patents dealing with client-server methods and techniques, as well as authentication methods, video encoding, fingerprint sensing technologies, thermal cooling with active moving parts (fans), calendar synchronization and cloud backup technologies and many other software inventions. As these do not contribute to the architectural inventions analysis in the iPad device they were discarded from the sample. The process resulted in 97 potentially relevant architectural invention patents that were found interesting for the research based on the provided definition of architectural invention.

3.3.4. Patent clustering and keywords extraction

The analysis continued with manual assigning of each of the filtered potential iPad relevant architectural inventions to the iPad core components performed by the researcher. This process was done through scanning each patent's title, abstract, invention description, drawings, claims and DWPI data. After the scanning, each patent was rated as *“purely component”* if addressing only a single component or *“relatively more architectural”* if it describes overall product architecture or multiple components. This resulted in the creation of six patent clusters according to the six iPad core components that were previously identified in section 3.3.1 – see table 3.

Table 3 - Patent clusters for iPad

Patent clusters	**Cluster 1**	**Cluster 2**	**Cluster 3**	**Cluster 4**	**Cluster 5**	**Cluster 6**
Cluster names	Display	Casing	Logic board	Battery	Wireless Communication	Additional Sensors

In case a patent was relevant to only one core component, the same was assigned to the cluster that represents the corresponding core component. For instance, if a patent is describing invention related to display only, it was assigned to the *Display* cluster. In case one patent was relevant to more than one core component, it was assigned to all the core components’ clusters that were covered in the invention. For example, if a patent is describing inventions related to battery and logic board, the same patent was assigned to both clusters *Battery* and *Logic board*. The result of this process was that at the end all patents belonged to one or more core component clusters.

Next, patents from each cluster were used to extract its relevant keywords. To fulfill this step, the online tool for terminology extraction, which can be found at *www.labs.translated.net/terminology-extraction,* was used for the keyword extraction process. The web source provides automatic terminology extraction from a given text based on the frequency of a word present in the examined text but weighted for its presence in the common language. The source defines terminology as *“the sum of the terms which identify a specific topic”*, which is similar to the definition of keywords provided by Rose, Engel, Cramer and Cowley – namely *“…a sequence of one or more words, provide a compact representation of a document’s content. Ideally, keywords represent in condensed form the essential content of a document […] they are easy to define, revise, remember, and share”* (Rose, Engel, Cramer, & Cowley, 2010, p. 1; Translated.net, n.d.-c). The web source was considered reliable due to the involvement of many professional linguists and computer specialists behind as well as its prominent reference clients and was further recommended by a text analytics expert from Mapegy UG (Translated.net, n.d.-a, n.d.-b).

In order to obtain reliable results, only patents that belong to only one cluster were included in the automatic keywords extraction via the online tool[17]. The reason behind is that if a patent belongs to more than one cluster at the same time, its keywords are not unique for one cluster. In other words if a patent was assigned to more than one cluster, it contains keywords from more than one cluster. For instance there could be keywords and phrases from a *Wireless communication* patent that are identified as keywords in the *Battery* cluster. Therefore, to avoid contamination of the results, patents assigned to more than one cluster did not participate in the keyword extraction process as the aim of the extraction process is to obtain only unique keywords for each cluster. Using patents that belong to only one cluster, allowed the researcher to obtain keywords, which are exclusive for each cluster. Thereafter, search for the identified unique keywords was performed in each of all the iPad relevant patents' titles and abstracts in order to evaluate the architectural nature of each patent.

3.3.5. Keywords processing

The keywords extraction process produced some repetitive results. Therefore, a manual cleaning of the extracted keywords was required. They were grouped together by cluster, sorted in alphabetical order and manually cleaned. The aim of the cleaning process is to obtain only the unique and most informative keywords and phrases for each cluster. The cleaning consisted of removing of invaluable entries. Such entries are duplicate entries within clusters or entries that do not provide constructive information for the cluster they were found in. Additionally, terms found in more than one cluster were removed to preserve the uniqueness of the keywords for each cluster. For instance the single word "layer" was found to be a keyword for cluster 2 – *"Casing"*. In the same time this word was part of keyword phrases like "core metal layer" or "flowable adhesive layer", which belong to other two different clusters. Due to the fact that the last two keyword phrases consisted of more than one word and hence are considered more informative, the first word "layer" was removed from the keywords dataset, providing the opportunity to not

[17] *www.labs.translated.net/terminology-extraction*

skew the results. Similarly, the word “configured” was removed from the dataset as it is considered too general and it was found in many patents from different clusters. The same procedure was repeated for every single-phrase keyword in the data set. Another procedure of the cleaning was performed in case a single word is present in many entries in combination with other words but within one single cluster. Example of such is the word “battery”, which was found in cluster 4 – *“Battery”.* Besides this single word, there were entries that contained the word, for example “battery cell”, “battery cells”, “battery pouch”, “battery powered device” and so on. In order to ease the data processing, each instance from the cluster that contained a phrase with the keyword was cleaned from the dataset leaving one instance with one single keyword to be used for the search process. The complete list of cleaned unique keywords is available in table 5, whereas the full list of non-cleaned keywords as extracted is available in table 15 in the appendix.

3.3.6. Creation of the “Score of architectureness – Keywords”

The complete process of keyword extraction and the creation of the Score of Architectureness using keywords is described in figure 7.

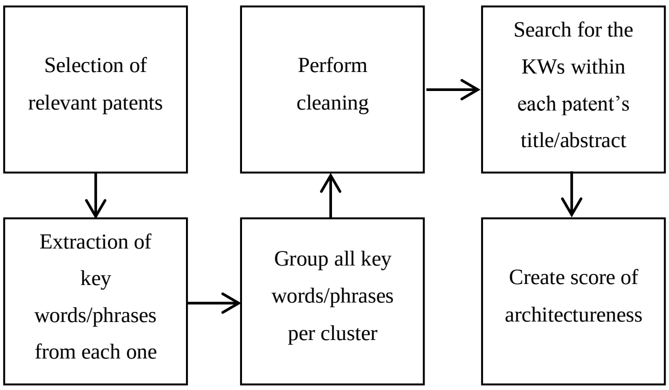

Figure 7 - Keywords extraction and creation of Architectureness score

After assigning each patent to one or more of the iPad’s components and the extraction and the cleaning of the keywords was finished, an attempt to evaluate the architectural level of each patent was performed. Considering the iPad device as a structure or architecture of a complex system with its core components, it is evident that if a patent is related to more than one component of a system, then it is relatively more architectural because it relates to the overall system architecture and the arrangements between components within the system. To measure this, a so called *“Score of Architectureness -*

Keywords" was created for every iPad relevant patent by checking each patent's title and abstract for the presence of any of the identified and cleaned keywords. If the title and the abstract of a patent contain words which are found in multiple keywords clusters, that patent is considered relatively more architectural than patents including keywords from only one cluster. This score was formed in the following manner: for each patent's title/abstract that contains one or more keywords from one cluster, a value of '1' was assigned to this patent for the corresponding cluster. The same process was repeated for each patent and every keyword or key phrase from all clusters. In case a patent contains keywords from several different clusters, then a value of '1' is assigned to every cluster where the respective keyword was present. In other words, if a patent "A" contains in its title/abstract a word found in the keywords for cluster 1 – *"Display"*, a value of '1' is assigned to patent "A" in the column, corresponding to cluster *"Display"*. If the same patent "A" contains words in its title/abstract from keywords dataset for clusters 3 – *"Logic board"* and 5 – *"Wireless communication"* for instance, then '1' is assigned for that patent in both columns corresponding to *"Logic board"* and *"Wireless communication"*. Then the score of architectureness was formed by simply summing every '1' that a patent received for each cluster. Thus, theoretical values of the score are between '0' (if no keywords were found in the patent) and '6' (if keywords from all clusters were found in patent's title and abstract).

3.3.7. Validation of the keywords approach through expert opinion

Due to the fact that qualitative studies comprise text data and its interpretation, the research results based on qualitative studies have relatively weaker validity in comparison to results reached from quantitative studies (Bowen, 2005). In order to mitigate this weakness and improve the results' credibility, the keyword approach was verified through the use of an expert's opinion. To verify the *Keywords approach,* a second Score of Architectureness was created by the researcher. Previously, each patent was clustered by the researcher to one or more of the core components of the iPad device based on the researcher's understanding of the invention after reading each patent's title, abstract, invention description, drawings, claims and present DWPI data. Hence, it is assumed that the researcher has broader view of the patented invention since more information about the invention is gathered in comparison to only title and abstract used in the *Keywords* *approach*. Thus, the patent clustering was used for the creation of a second score of architectureness called *"Score of Architectureness – Expert opinion"*. It was produced per patent as a sum of all clusters that were rated with '1' in the patent clustering process described in section 3.3.4. In other words, if a patent "A" was assigned to clusters 1 – *"Display"*, cluster 3 – *"Logic board"* and cluster 5 – *"Battery"*, this patent has a *Score of Architectureness – Expert* opinion equal to '3' because it is relevant for three clusters, respectively three of the iPad's core components. Theoretical values of this score are between '1' (if a patent was assigned to only one cluster) and '6' (if the patent was assigned to all of the clusters). Thereafter, the Score of Architectureness obtained from the *Keywords* method was compared to a *Score of Architectureness – Expert opinion*.

Applying the described research methodology, some results from the study were obtained. The full results, as well as their validation and interpretation are present in the next chapter.

4. Results: *Keywords approach* and *Expert opinion* score differently

In this chapter all the results from this study are presented and explained. Furthermore, the results are validated using a statistical measure of inter-rater agreement, called Kappa score and their interpretation is further elaborated.

4.1. Study results: asymmetric distribution of patents between clusters

The application of the clustering methodology resulted in all 97 patents being assigned to one or more clusters simultaneously. A complete overview of the patent clustering process showing which patent to which cluster(s) was assigned is presented in table 4. In case a patent was assigned to specific cluster, respectively iPad core component, it was indicated with the presence of ‘1’ in the table. In case a patent was not relevant for the specific cluster, the corresponding field in the table was left empty.

Table 4 - Clustered patents

##	Publication Number	Cl. 1 - Display	Cl. 2 - Casing	Cl. 3 - Logic board	Cl. 4 - Battery	Cl. 5 - Wireless communication	Cl. 6 - Additional sensors
1	US6776660B1		1				
2	US20050007351A1	1					
3	US20050240705A1		1				
4	US20050280146A1			1			
5	US20060197753A1	1	1				
6	US20060197750A1	1	1				
7	US20060238517A1	1					1
8	US20060268528A1		1			1	
9	US20070002636A1				1		
10	US7236154B1						1
11	US20070152984A1	1		1			
12	US20070152978A1	1		1			
13	US20070162652A1			1			
14	US20070180328A1			1			
15	US20070177803A1	1		1			
16	US20070177804A1	1		1			
17	US20070229054A1			1			
18	US7293122B1		1	1			
19	US20070257890A1	1		1			
20	US20070291448A1			1			
21	US20080006453A1	1					
22	US20080007533A1	1					
23	US20080006454A1	1					
24	US20080012774A1		1			1	
25	US20080055164A1					1	
26	US20080062148A1	1		1			
27	US20080062140A1	1		1			
28	US20080064235A1		1				
29	US20080062659A1		1				
30	US20100161886A1			1			
31	US20100289390A1		1				
32	US20110050585A1	1		1			
33	US20110072639A1				1		
34	US20110090626A1		1			1	
35	US20110090142A1	1					
36	US20110110054A1	1					

37	US20110123844A1				1		
38	US20110164365A1	1	1			1	
39	US20110164371A1		1	1			
40	US20110164767A1		1				
41	US20110169703A1		1			1	
42	US20110183169A1				1		
43	US8000598B1		1				
44	US20110210954A1				1		
45	US20110255023A1	1					
46	US20110255252A1		1				
47	US20110290685A1		1				
48	US20110292598A1				1		
49	US20110298727A1	1					
50	US20110304984A1				1		
51	US20120008294A1			1			
52	US20120015223A1				1		
53	US20120013823A1	1	1				
54	US20120024588A1			1			
55	US20120044123A1		1				
56	US20120050988A1	1	1				
57	US20120051025A1		1				
58	US20120128190A1		1				
59	US20120129580A1						1
60	US20120140419A1				1		
61	US20120178503A1	1	1			1	
62	US20120194998A1	1	1			1	
63	US20120194393A1		1			1	
64	US20120268882A1	1	1				
65	US20120276951A1		1				
66	US20120274594A1	1	1	1			
67	US20120295665A1		1	1			
68	US20120297097A1			1			
69	US20120299785A1		1			1	
70	US20120306771A1	1		1			
71	US20120307364A1	1					
72	US20120313911A1	1					
73	US20120319827A1	1	1	1			1
74	US20120327324A1	1	1				
75	US20120327009A1	1		1			
76	US20130004835A1				1		
77	US20130002517A1	1	1			1	
78	US20130007562A1			1			
79	US20130007333A1			1			
80	US8350991B2	1	1				
81	US20130016633A1		1			1	
82	US20130021289A1	1	1				
83	US20130027897A1			1			
84	US20130027303A1	1		1			
85	US20130044063A1	1		1			
86	US20130050050A1		1			1	
87	US20130063920A1	1	1				
88	US20130063876A1		1				
89	US20130063873A1	1	1		1		1
90	US20130063684A1	1					
91	US20130063404A1	1					
92	US20130064390A1		1				
93	US20130076965A1		1	1			
94	US20130077813A1			1			
95	US20130075613A1	1	1				1
96	US20130076646A1	1					
97	US20130082979A1	1		1			1

However, as it is visible from the table, there are some patents that belong to more than one cluster at the same time. The following chart provides an overview of all clustered patents ignoring the fact that single patent can participate in multiple core component clusters – see figure 8.

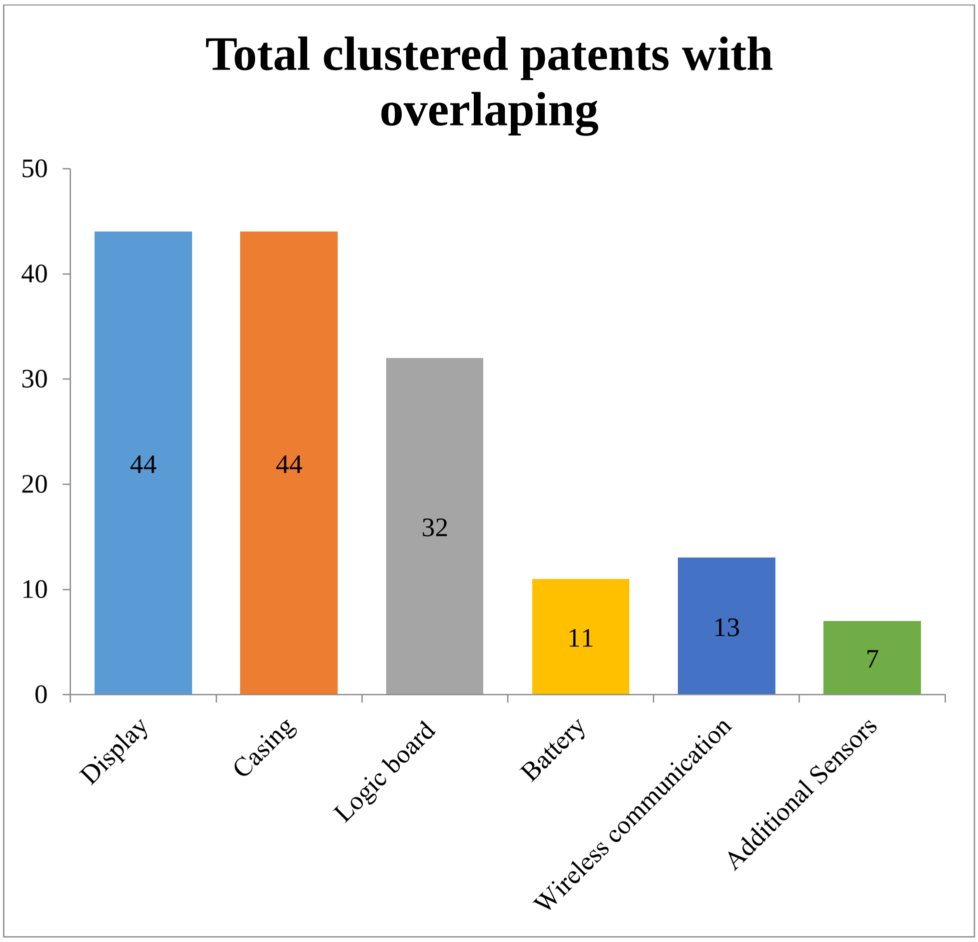

Figure 8 - Total clustered patents with overlapping

As it may be observed from figure 8, the sum of all patents per cluster is greater than the total amount of the patents available in the sample (summing the values of all bars equals 151, where the total number of patents is 97). This is due to the fact that one patent may be assigned to more than one cluster. That means that the invention described in one patent was related to more than one of the iPad's core components, in other words the same patent is relatively more architectural as it penetrates to the overall system architecture. The highest share of patents from this data set pertains to *"Display"* and *"Casing"* clusters with 44 patents belonging to both groups. Next scores the *"Logic board"* cluster with 32 entries, followed by *"Wireless communication"* with 13 patents, *"Battery"* with 11 and *"Additional sensors"* with 7 entries. The fact that one patent is assigned to more than one cluster contributes to relatively higher amount of patents per cluster leading to the obtaining of rather higher amount of extracted keywords. However, as there were patents that belong to more than one cluster, they demand participation in the extraction process for all clusters they are related to. That can contaminate the keywords results endangering the uniqueness of the keywords of each cluster. For instance there could be keywords and phrases from a typical *Display* patent that can be present also in the *Battery* cluster. To avoid this eventual contamination, a filtration of the patent clusters was performed in order to obtain keywords that are exclusive for each cluster. Therefore, as mentioned in the methodology section, these patents that belong to more than one cluster, respectively iPad core component were removed from the keywords extraction process in order to obtain only specific keywords that are unique for each cluster. This resulted in 55 patents that belong to only one single cluster – see figure 9. Nevertheless, all 97 patents from the sample size were used in the calculation of the *Score of Architectureness – Keywords* using the obtained and cleaned unique keywords dataset.

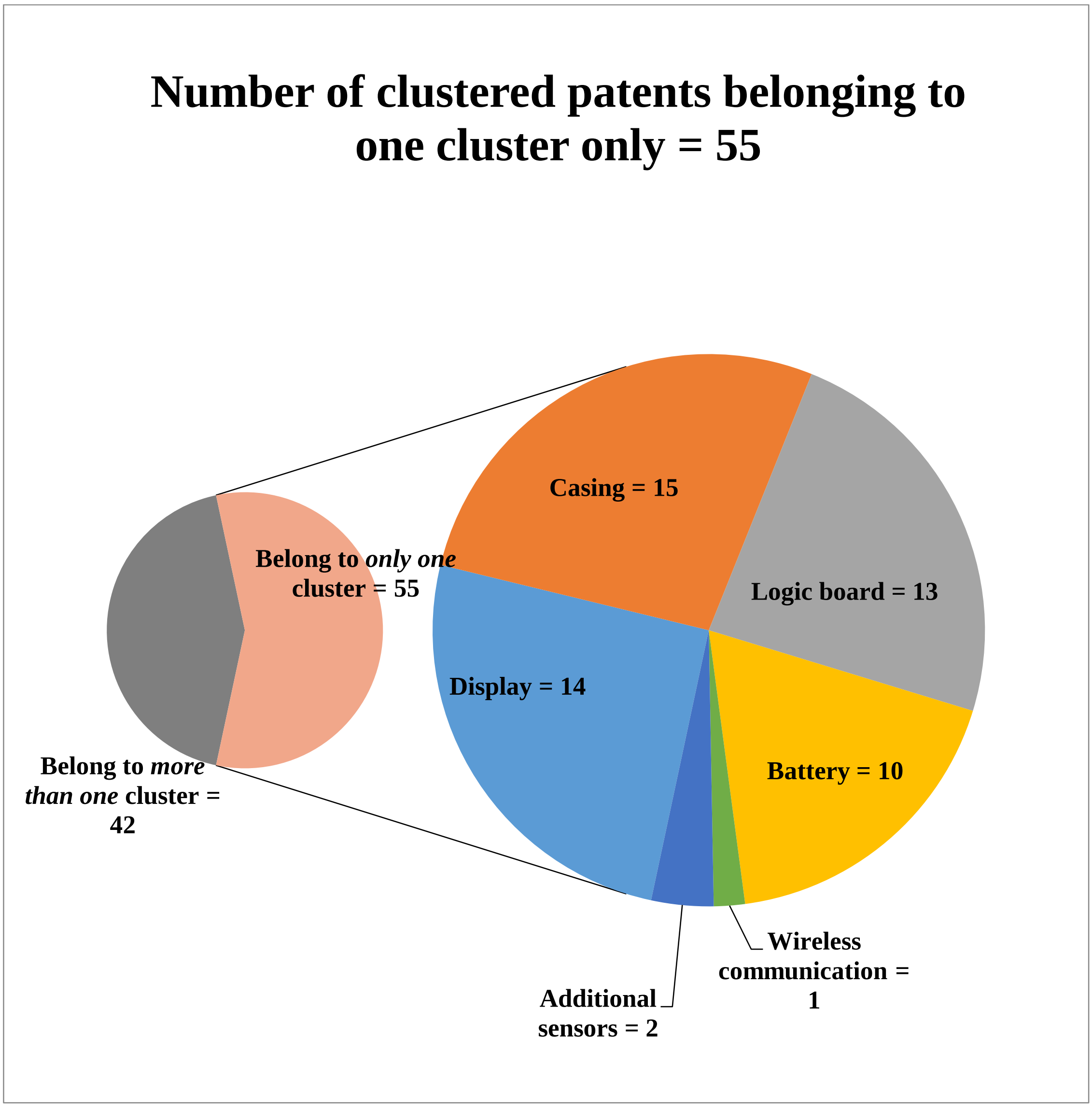

Figure 9 - Overview of clustered patents

Out of all 97 patents, the 42 that belong to more than one cluster were discarded from the keywords extraction process in order to avoid results contamination. The remaining 55 patents were unequally distributed between the different clusters as it is shown on figure 9. The largest portion of the sample has *"Casing"* with 15 patents, followed by *"Display"* with 14, *"Logic board"* with 13, *"Battery"* – 10, *"Additional sensors"* – 2 and *"Wireless communication"* with only 1 patent in the cluster. The so grouped 55 patents, where each belongs exclusively to only one cluster were used for the actual keyword extraction process. It resulted in total of 411 keywords and phrases summed for all clusters (see table 15 in the appendix). However, as explained in the methodology section, a cleaning was performed in order to provide consistent results. The whole keywords cleaning process resulted in 279 usable exclusive keywords and keyword phrases unequally distributed between the core components' clusters – see table 5.

Table 5 - Unique keywords per cluster after cleaning

##	Display - 14 unique patents	Casing - 15 unique patents	Logic board - 13 unique patents	Battery - 10 unique patents	Wireless communication - 1 unique patent	Additional Sensors - 2 unique patents
1	ambient light calibration	acoustic chambers	accommodate folding	active coating	accommodate buttons	detector
2	ambient light incident	air cavity	bypass capacitors	anode	antenna design	opaque layer
3	ambient light sensor	air impermeable	capacitors reduce voltage noise	battery	antenna efficiency	proximity sensor
4	anti-reflection coating	antenna block	circuit board radio-frequency shielding	cathode	antenna tuning	radiation absorber
5	automatic mapping	antenna flex	circuit board substrate	circuit supply voltage	capacitive loading	radiation passing layer
6	automatic pointing device mapping	audio sound output	circuitry external	circuitry associated	compact tunable antenna	
7	backlight	barometric pressure equalization	circuitry region	compressive forces	couple radio-frequency transceiver circuitry	
8	capacitance sensing	bonded	concurrently addressable unit	conductive elements	handheld device	
9	capacitance touch	brush-like baffle	conductive adhesive	conductive pads	handheld electronic	
10	capacitive sensing controller	camera module	conductive cover	conductive tabs	pogo pins	
11	capacitive sensing nodes	causing flare	conductive dam	connector pads	radiating element	
12	capacitive touch sensing	cavity	conductive material stacked	core metal layer	radio-frequency switches	
13	chassis	cfrp skin	conductive tablet	discrete locations	tunable antennas	
14	circuit element	cfrp spine	connect embedded components	electrolyte containment structure		
15	color compensati on techniques	cfrp type material stacked	controller interface	enclosure material		
16	common conductive pathway	compact ejectable component assemblies	disclosed architecture	flex circuit		
17	common electrode	conductive housing	dma	flexible interconnect component		
18	compact display flex	connector element	dome switch	flexible pouch		
19	composite wires	connector including	electrical connections	insulating layer		
20	conductive pathway connecting gates	connector interface system	embedded components	interconnect component		

21	conventional sub-assemblies	connectors	encode data transmitted	jelly roll	
22	device mapping method	curved portion	exterior surface	laminate sheet suitable	
23	display device	detents	generic nvm commands	layer laminate sheet suitable	
24	display module	device enclosure using sandwich	grooves	light-weight metal foil pouch	
25	display pixels	diaphragm	host device	logic circuit	
26	drive electrode	dielectric constant	host interface	metal foil	
27	driver circuitry	dimple formed	host processor	modular components	
28	driver sub-assemblies compact sub-assemblies	distinct acoustic chambers	impedance associated	multi layer laminate sheet	
29	electrode signals	docking connector	impedance calibration circuit	peal	
30	extracted propagating	ejectable component	insulating fill	portable electronic device	
31	fixed voltage	electrical contacts	integrated circuit	pouch	
32	flexible circuits	engagement projection	interface circuit	powered portable devices	
33	force sensor interface	engagement slit	interior printed circuit board	pressure-relief mechanism	
34	gate	flare reduction effect	interposer	pull tabs	
35	graphics tablet	flexible membrane	load impedance	rigid frame	
36	improved color uniformity	flowable adhesive layer	memory controller	safety circuitry	
37	include pass transistors	frame disposed adjacent	memory device	sealant layer	
38	include spacers	functional insertion	memory locations	single pouch	
39	lateral edge	gas cavity	multiple cau architecture	supply voltage	
40	lcd device	headphone cable	non-volatile memory	thermal bonding	
41	light guide plate	hidden screw feature	printed circuit board substrate	thermal transfer	
42	light-extracting elements	image artifacts	radio-frequency shielding	thicknesses	
43	liquid crystal display	image sensor device	reducing voltage noise		
44	liquid crystal material	keying arrangement	rigid printed circuit board		
45	multi-display	layered configuration	shielding circuitry		
46	multifunctional node	layered fiber-in-matrix type material	signal conditioner		
47	multifunctional nodes	lens	slits		
48	multiple light-extracting elements	loaded electrical contact	solder pads		

49	mutual capacitance	locating bracket	source impedance
50	mutual capacitive sensing	microphone assembly	voltage control output
51	mutual capacitive touch	microphone cables	voltage noise
52	non-planar	micro-sim card	
53	opposite lateral edge	mini-sim card	
54	optical effects	modular material antenna	
55	optical retarder	multi-communication device	
56	pass transistors	multi-connector assembly	
57	pixel	multi-pin adapter	
58	pointing device mapping	multi-pin connector	
59	polarized filters	multiple-connector assemblies	
60	polarized sunglasses	non-conductive frame	
61	proximity zone	outer suspension	
62	proximity zones	output audio	
63	quarter-wave retardation film	prevent noncompliant connectors	
64	quarter-wave retardation properties	printed circuit carrier	
65	rectangular opening	rectangular spine	
66	reflection-reducing coatings	remote connector	
67	reflection-reducing configurations	removable module	
68	respective touch sensor electrodes	respective acoustic	
69	retro-propagating light	retainer coupled	
70	segmented common electrode	sandwich construction	
71	sense electrode	screw feature	
72	sensor panel constructed	screw holes	
73	sensors	screw plates	
74	separate quarter-wave retardation	sim tray	

75	single touch pixel	spring loaded electrical
76	spacers	standard headphone cable
77	specular reflector disposed	vent hole
78	stylus	
79	sub-assemblies	
80	thin-film transistor	
81	touch circuitry	
82	touch pixel	
83	touch screen	
84	touch sensing device	
85	touch sensor	
86	touch-display crosstalk clamping	
87	transistor	
88	transistors	
89	transmit stimulation signals	
90	unit color compensati on techniques	
91	wires	

As it may be noticeable from the previous figure and table (figure 9 and table 5), there were 14 unique patents identified for cluster 1 *Display*. After the extraction of keywords out of each of these 14 patents, the resulting cleaned keywords for cluster 1 totaled 91 unique entries. The second cluster – *Casing* have 15 exclusive patents that belong only to this cluster. The process of keywords extraction and the followed cleaning resulted in total of 77 unique keywords related to *Casing*. Cluster 3 – *Logic board* has 13 distinctive patents resulting in 51 unique keyword entries after the cleaning process, followed by cluster 4 – *Battery* – with 10 patents and 42 unique keyword entries after cleaning. The last two clusters resulted in 1 single patent for cluster 5 – *Wireless communication* and 2 patents for cluster 6 – *Additional sensors*, which amount respectively 13 and 5 unique keyword entries after the cleaning. It is interesting to notice that the amount of patents per cluster is not always related to the amount of keywords extracted for each cluster.

Taking into account the last two clusters – *Wireless communication* and *Additional sensors* it is interesting to see that in the cluster 5 – *Wireless communications* there are 13 keywords obtained from only one patent. However, cluster 6 – *Additional sensors* received only 5 unique keywords out of twice as many patent entries in comparison to cluster 5. This is explained partially with the cleaning process, which removed some words from both clusters. Additionally, this can be used as a signal that the two patents that were assigned to cluster 6 – *Additional sensors* were very similar and hence the amount of the extracted unique keywords was limited in number.

After the extraction and the cleaning of the keywords, the process continued with the creation of the *Score of Architectureness – Keywords.* It expresses the architectural nature of a patent based on the match between keywords for each cluster and the patent's title and abstract. As explained in the methodology section 3.3.6, when a patent contains keywords from multiple clusters, its architectural nature increases. The *Score of Architectureness – Keywords* was created for each patent by summing the positive values of each cluster as previously explained in the methodology. This resulted in values between '0' and '2', where the theoretically possible values were between '0' and '6'. The result is visualized in the following table.

Table 6 - Score of Architectureness based on *keywords*

##	Publication Number	Cl. 1 - Display	Cl. 2 - Casing	Cl. 3 - Logic board	Cl. 4 - Battery	Cl. 5 - Wireless communication	Cl. 6 - Additional sensors	Score of Architectureness - *Keywords*
1	US6776660B1		1					1
2	US20050007351A1	1						1
3	US20050240705A1		1					1
4	US20050280146A1			1				1
5	US20060197753A1							0
6	US20060197750A1	1						1
7	US20060238517A1							0
8	US20060268528A1							0
9	US20070002636A1			1	1			2
10	US7236154B1							0
11	US20070152984A1				1			1
12	US20070152978A1				1			1
13	US20070162652A1			1				1
14	US20070180328A1			1				1
15	US20070177803A1							0
16	US20070177804A1							0
17	US20070229054A1			1	1			2
18	US7293122B1		1					1
19	US20070257890A1	1		1				2
20	US20070291448A1			1				1
21	US20080006453A1	1						1
22	US20080007533A1	1						1
23	US20080006454A1	1						1
24	US20080012774A1							0
25	US20080055164A1					1		1
26	US20080062148A1	1						1

27	US20080062140A1	1					1
28	US20080064235A1		1				1
29	US20080062659A1		1				1
30	US20100161886A1			1			1
31	US20100289390A1		1				1
32	US20110050585A1	1					1
33	US20110072639A1				1		1
34	US20110090626A1				1		1
35	US20110090142A1	1					1
36	US20110110054A1	1					1
37	US20110123844A1				1		1
38	US20110164365A1						0
39	US20110164371A1				1		1
40	US20110164767A1		1		1		2
41	US20110169703A1				1		1
42	US20110183169A1				1		1
43	US8000598B1		1				1
44	US20110210954A1				1		1
45	US20110255023A1	1					1
46	US20110255252A1		1				1
47	US20110290685A1		1				1
48	US20110292598A1				1		1
49	US20110298727A1	1					1
50	US20110304984A1				1		1
51	US20120008294A1	1		1			2
52	US20120015223A1				1		1
53	US20120013823A1						0
54	US20120024588A1			1			1
55	US20120044123A1		1		1		2
56	US20120050988A1	1					1
57	US20120051025A1		1				1
58	US20120128190A1		1				1
59	US20120129580A1					1	1
60	US20120140419A1				1		1
61	US20120178503A1						0
62	US20120194998A1						0
63	US20120194393A1						0
64	US20120268882A1	1	1				2
65	US20120276951A1		1				1
66	US20120274594A1	1				1	2
67	US20120295665A1	1				1	2
68	US20120297097A1			1			1
69	US20120299785A1						0
70	US20120306771A1	1					1
71	US20120307364A1	1	1				2
72	US20120313911A1	1					1
73	US20120319827A1						0
74	US20120327324A1	1					1
75	US20120327009A1						0
76	US20130004835A1		1		1		2
77	US20130002517A1		1				1
78	US20130007562A1			1			1
79	US20130007333A1			1			1
80	US8350991B2						0
81	US20130016633A1						0
82	US20130021289A1	1					1
83	US20130027897A1			1	1		2
84	US20130027303A1	1					1
85	US20130044063A1						0
86	US20130050050A1	1					1
87	US20130063920A1	1					1
88	US20130063876A1		1		1		2
89	US20130063873A1						0
90	US20130063684A1	1					1
91	US20130063404A1	1		1			2
92	US20130064390A1		1				1
93	US20130076965A1	1	1				2
94	US20130077813A1	1		1			2
95	US20130075613A1	1					1
96	US20130076646A1	1					1
97	US20130082979A1	1					1

The distribution of the results of the *Score of Architectureness – Keywords* is provided in figure 10 and a summary of the values are provided in the subsequent table – table 7.

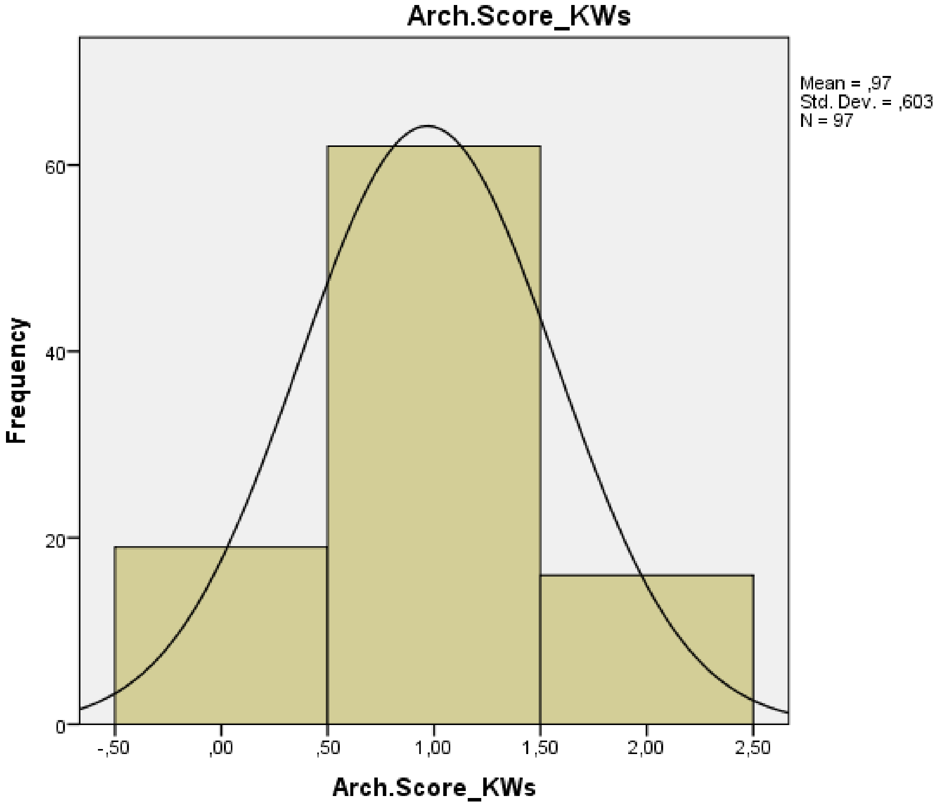

Figure 10 - Results distribution of Score of Architectureness – *Keywords* approach

Table 7 - Summarized results from the *Keywords* approach

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	,00	19	19,6	19,6	19,6
	1,00	62	63,9	63,9	83,5
	2,00	16	16,5	16,5	100,0
	Total	97	100,0	100,0	

From the table above it can be seen that 19 out of 97 patents received a score of '0' from the keyword approach, 62 of 97 got a score of '1' and the rest 16 received a score of '2'. This means that in the title and abstract of 19 out of 97 patents there were found no words matching with previously discussed cleaned keywords data set belonging to the identified core components clusters. For the majority of the population's title and abstract – 62 out of 97 – there were words or phrases found that belong to only one cluster from the keywords data set. The rest 16 patents contained in their title and abstract words belonging to the keywords dataset of more than one cluster, which is an indication that one patent is related to more than one component. This ultimately means that the patent has a relatively higher level of architectureness, describing more than one component of an architecture.

Due to the fact that the number of analyzed patents is relatively low, the obtained results are not representative and cannot be generalized. In order to verify the credibility of the proposed method, a second score based on *expert opinion* was created by summing up of all clusters that one patent was earlier assigned to by the researcher. The *Score of Architectureness – Expert opinion* represents the researcher's understanding of each patent to which core component(s) is related. This was done by taking into account patents' title, abstract, invention description, drawings, claims and the present DWPI data as explained previously in the methodology sections 3.3.4 and 3.3.7. The formation of the score is presented in the following table.

Table 8 - Score of Architectureness based on *Expert* opinion

##	Publication Number	Cl. 1 - Display	Cl. 2 - Casing	Cl. 3 - Logic board	Cl. 4 - Battery	Cl. 5 - Wireless communication	Cl. 6 - Additional sensors	Architectureness score - *Expert opinion*
1	US6776660B1		1					1
2	US20050007351A1	1						1
3	US20050240705A1		1					1
4	US20050280146A1			1				1
5	US20060197753A1	1	1					2
6	US20060197750A1	1	1					2
7	US20060238517A1	1					1	2
8	US20060268528A1		1			1		2
9	US20070002636A1				1			1
10	US7236154B1						1	1
11	US20070152984A1	1		1				2
12	US20070152978A1	1		1				2
13	US20070162652A1			1				1
14	US20070180328A1			1				1
15	US20070177803A1	1		1				2
16	US20070177804A1	1		1				2
17	US20070229054A1			1				1
18	US7293122B1		1	1				2
19	US20070257890A1	1		1				2
20	US20070291448A1			1				1
21	US20080006453A1	1						1
22	US20080007533A1	1						1
23	US20080006454A1	1						1
24	US20080012774A1		1			1		2
25	US20080055164A1					1		1
26	US20080062148A1	1		1				2
27	US20080062140A1	1		1				2
28	US20080064235A1		1					1
29	US20080062659A1		1					1
30	US20100161886A1			1				1

31	US20100289390A1		1					1
32	US20110050585A1	1		1				2
33	US20110072639A1				1			1
34	US20110090626A1		1			1		2
35	US20110090142A1	1						1
36	US20110110054A1	1						1
37	US20110123844A1				1			1
38	US20110164365A1	1	1			1		3
39	US20110164371A1		1	1				2
40	US20110164767A1		1					1
41	US20110169703A1		1			1		2
42	US20110183169A1				1			1
43	US8000598B1		1					1
44	US20110210954A1				1			1
45	US20110255023A1	1						1
46	US20110255252A1		1					1
47	US20110290685A1		1					1
48	US20110292598A1				1			1
49	US20110298727A1	1						1
50	US20110304984A1				1			1
51	US20120008294A1			1				1
52	US20120015223A1				1			1
53	US20120013823A1	1	1					2
54	US20120024588A1			1				1
55	US20120044123A1		1					1
56	US20120050988A1	1	1					2
57	US20120051025A1		1					1
58	US20120128190A1		1					1
59	US20120129580A1						1	1
60	US20120140419A1				1			1
61	US20120178503A1	1	1			1		3
62	US20120194998A1	1	1			1		3
63	US20120194393A1		1			1		2
64	US20120268882A1	1	1					2
65	US20120276951A1		1					1
66	US20120274594A1	1	1	1				3
67	US20120295665A1		1	1				2
68	US20120297097A1			1				1
69	US20120299785A1		1			1		2
70	US20120306771A1	1		1				2
71	US20120307364A1	1						1
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73	US20120319827A1	1	1	1			1	4
74	US20120327324A1	1	1					2
75	US20120327009A1	1		1				2
76	US20130004835A1				1			1
77	US20130002517A1	1	1			1		3
78	US20130007562A1			1				1
79	US20130007333A1			1				1
80	US8350991B2	1	1					2
81	US20130016633A1		1			1		2
82	US20130021289A1	1	1					2
83	US20130027897A1			1				1
84	US20130027303A1	1		1				2
85	US20130044063A1	1		1				2
86	US20130050050A1		1			1		2
87	US20130063920A1	1	1					2
88	US20130063876A1		1					1
89	US20130063873A1	1	1		1		1	4
90	US20130063684A1	1						1
91	US20130063404A1	1						1
92	US20130064390A1		1					1
93	US20130076965A1		1	1				2
94	US20130077813A1			1				1
95	US20130075613A1	1	1				1	3
96	US20130076646A1	1						1
97	US20130082979A1	1		1			1	3

The distribution of the results of the *Expert opinion* process is provided in the following figure – figure 11 and a summary of the values is provided in the subsequent table – table 9.

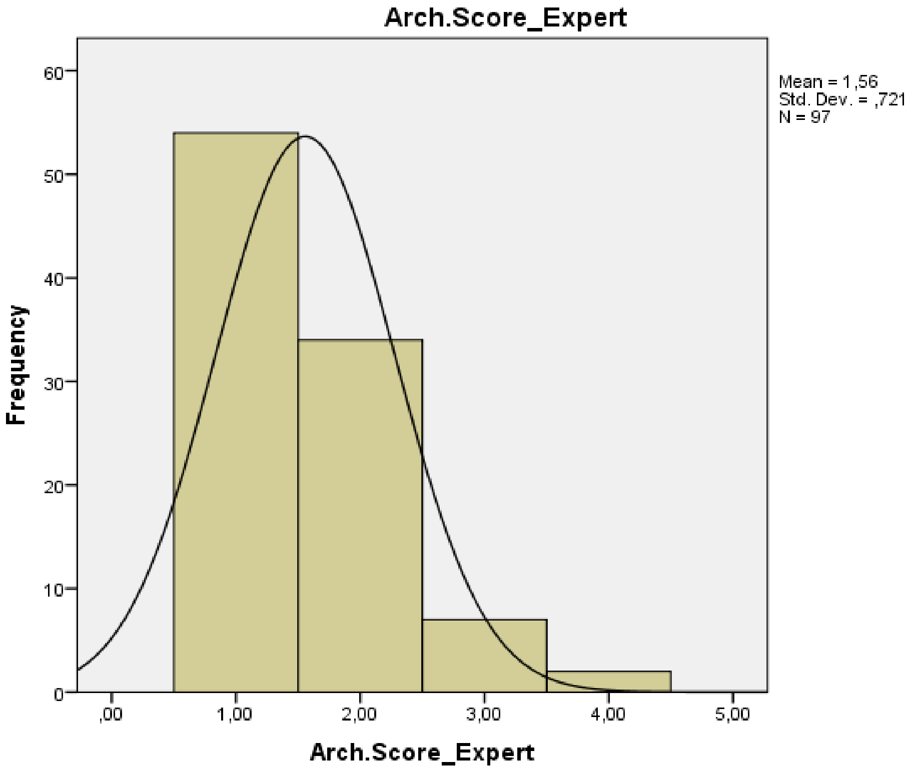

Figure 11 - Results distribution of Score of Architectureness – *Expert* opinion

Table 9 - Summarized results from the *Expert opinion* approach

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1,00	54	55,7	55,7	55,7
	2,00	34	35,1	35,1	90,7
	3,00	7	7,2	7,2	97,9
	4,00	2	2,1	2,1	100,0
	Total	97	100,0	100,0	

With the *Expert opinion* approach, there are no patents that do not belong to any cluster. There were 54 patents that score '1', 34 patents that score '2', 7 patents that score '3' and 2 patents that score '4'. With this approach, in contrast to the *Keywords approach*, values of 3's and 4's are present. This can be explained by the more thorough forming of this score, as it takes into consideration more fields in the patent document, such as *Background of the invention*, *Summary of the invention*, *Drawings*, *Derwent Information and in some cases Claims,* which are excluded from the *Keywords approach*. To remind the reader, the *Keywords approach* uses only the patent's title and abstract to evaluate the architectural level of a patent.

From tables 6 – 9 and figures 10 – 11, it is visible that the two approaches score differently. Table 10 shows how each approach scored for every patent and where do both methods match in their rating. A "match" is considered when the score of one patent is identical from both approaches. For "no match" is considered when a patent has different scores from both approaches. For instance a "no match" is when a patent has a score of '2' from the keywords approach and '3' from the expert opinion approach, despite the fact that in this case both scores indicate of an architectural nature of a patent.

Table 10 - Scores and matches of both approaches

##	Publication Number	Architectureness score - *Expert opinion*	Architectureness score *Keywords*	Match
1	US6776660B1	1	1	1
2	US20050007351A1	1	1	1
3	US20050240705A1	1	1	1
4	US20050280146A1	1	1	1
5	US20060197753A1	2		
6	US20060197750A1	2	1	
7	US20060238517A1	2		
8	US20060268528A1	2		
9	US20070002636A1	1	2	
10	US7236154B1	1		
11	US20070152984A1	2	1	
12	US20070152978A1	2	1	
13	US20070162652A1	1	1	1
14	US20070180328A1	1	1	1
15	US20070177803A1	2		
16	US20070177804A1	2		
17	US20070229054A1	1	2	
18	US7293122B1	2	1	
19	US20070257890A1	2	2	1
20	US20070291448A1	1	1	1
21	US20080006453A1	1	1	1
22	US20080007533A1	1	1	1
23	US20080006454A1	1	1	1
24	US20080012774A1	2		
25	US20080055164A1	1	1	1
26	US20080062148A1	2	1	
27	US20080062140A1	2	1	
28	US20080064235A1	1	1	1
29	US20080062659A1	1	1	1
30	US20100161886A1	1	1	1
31	US20100289390A1	1	1	1
32	US20110050585A1	2	1	
33	US20110072639A1	1	1	1
34	US20110090626A1	2	1	
35	US20110090142A1	1	1	1
36	US20110110054A1	1	1	1

37	US20110123844A1	1	1	1
38	US20110164365A1	3		
39	US20110164371A1	2	1	
40	US20110164767A1	1	2	
41	US20110169703A1	2	1	
42	US20110183169A1	1	1	1
43	US8000598B1	1	1	1
44	US20110210954A1	1	1	1
45	US20110255023A1	1	1	1
46	US20110255252A1	1	1	1
47	US20110290685A1	1	1	1
48	US20110292598A1	1	1	1
49	US20110298727A1	1	1	1
50	US20110304984A1	1	1	1
51	US20120008294A1	1	2	
52	US20120015223A1	1	1	1
53	US20120013823A1	2		
54	US20120024588A1	1	1	1
55	US20120044123A1	1	2	
56	US20120050988A1	2	1	
57	US20120051025A1	1	1	1
58	US20120128190A1	1	1	1
59	US20120129580A1	1	1	1
60	US20120140419A1	1	1	1
61	US20120178503A1	3		
62	US20120194998A1	3		
63	US20120194393A1	2		
64	US20120268882A1	2	2	1
65	US20120276951A1	1	1	1
66	US20120274594A1	3	2	
67	US20120295665A1	2	2	1
68	US20120297097A1	1	1	1
69	US20120299785A1	2		
70	US20120306771A1	2	1	
71	US20120307364A1	1	2	
72	US20120313911A1	1	1	1
73	US20120319827A1	4		
74	US20120327324A1	2	1	
75	US20120327009A1	2		
76	US20130004835A1	1	2	
77	US20130002517A1	3	1	
78	US20130007562A1	1	1	1
79	US20130007333A1	1	1	1
80	US8350991B2	2		
81	US20130016633A1	2		
82	US20130021289A1	2	1	
83	US20130027897A1	1	2	
84	US20130027303A1	2	1	
85	US20130044063A1	2		
86	US20130050050A1	2	1	
87	US20130063920A1	2	1	
88	US20130063876A1	1	2	
89	US20130063873A1	4		
90	US20130063684A1	1	1	1
91	US20130063404A1	1	2	
92	US20130064390A1	1	1	1
93	US20130076965A1	2	2	1
94	US20130077813A1	1	2	
95	US20130075613A1	3	1	
96	US20130076646A1	1	1	1
97	US20130082979A1	3	1	

Considering the fact that the two approaches for rating patents scored differently, a further analysis of these results is required. One possible way to summarizing the agreement between the two approaches is by simply calculate the percentage of agreement between the two approaches (University of York Department of Health Sciences, n.d.). The number and the proportion of matches and disagreements are visualized on the figure 12.

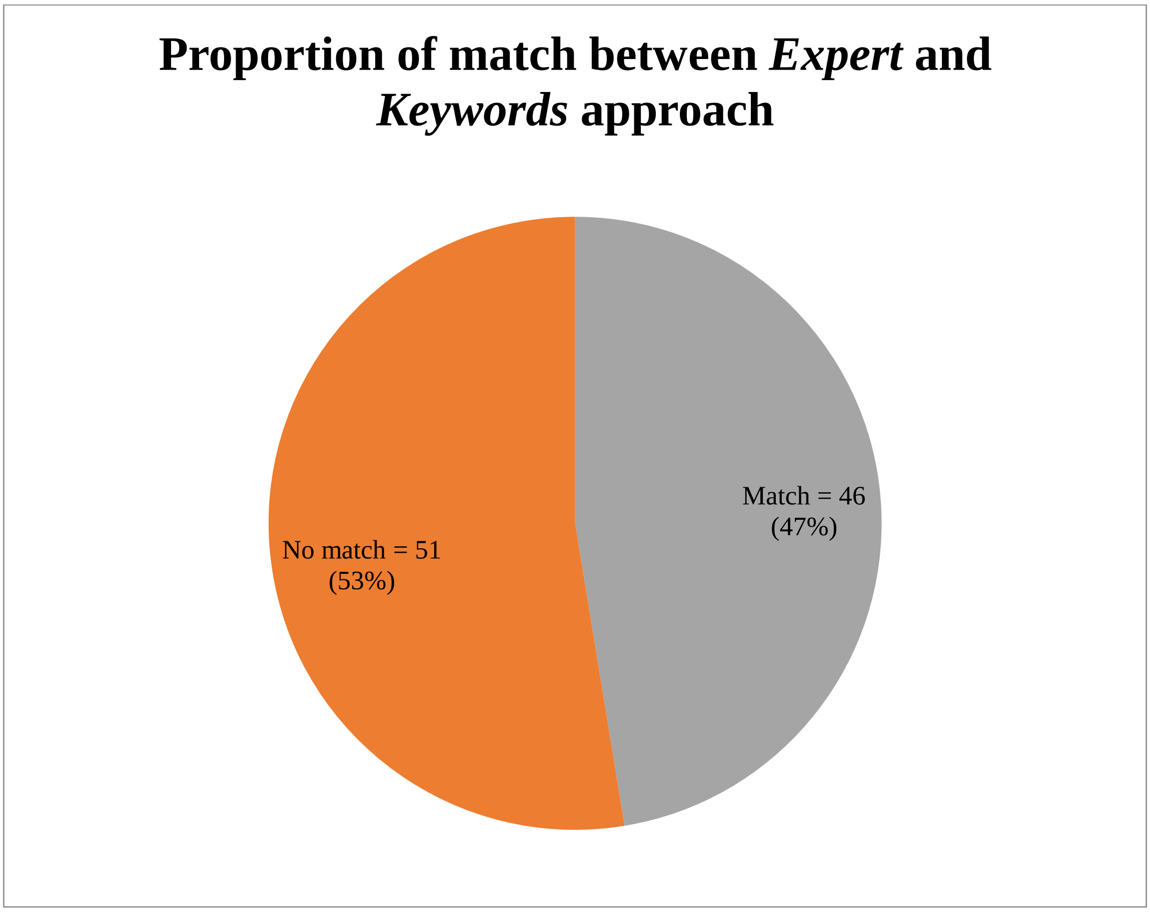

Figure 12 - Match between *Expert* and *Keywords* approach

It is evident from the chart above that the two approaches show different results, namely the two approaches do not match for the bigger portion of patents. The next section is looking into the details and analyzes what could be possible reasons of such high rate of discrepancy and furthermore what do the results mean.

4.2. Results validation and interpretation: disagreement between approaches – not necessary a bad result

A method described by Jacob Cohen in 1960's tests the reliability or reproducibility of the results made by two researchers for nominal scale variables (J. Cohen, 1960). The method is applicable in testing results of two independent raters and suggests a determination of *"degree, significance, and sampling stability of their agreement"* (J.

Cohen, 1960, p. 37). Applying this method for testing the *Keywords* and *Expert opinion* approaches corresponds to the method conditions, namely independent and mutually exclusive and exhaustive units and the independent operation of the two approaches (J. Cohen, 1960). The formula for calculation of *kappa* is:

$$\kappa = \frac{p_o - p_c}{1 - p_c}$$

Where:

p_o is *"the proportion of units in which the judges agreed"*

p_c is *"the proportion of units for which agreement is expected by chance"* (J. Cohen, 1960, pp. 39–40). Here as "judges" are considered the two approaches of creating the Score of Architectureness.

The *kappa* coefficient has values between 0 and 1, but there is no agreement how to interpret the values between different authors in the literature. For instance Landis and Koch (1977) indicate the level of agreement of *kappa* between 0 and 0.20 as *"slight"*, between 0.21 and 0.40 as "fair", from 0.41 to 0.60 as *"moderate"*, 0.61–0.80 as *"substantial"*, and 0.81–1 as *"almost perfect"* agreement. Fleiss, Levin and Paik (2003) argue that *kappa* below 0.4 is *"poor"*; between 0.4 and 0.75 is *"fair to good"* and over 0.75 is *"excellent"*.

In order to calculate the *kappa* coefficient measuring the level of agreement of the two approaches the software product SPSS version 21 was used. The results from the automated calculation are presented in the following tables (table 11 – table 14).

Table 11 - Descriptive Statistics - *kappa*

	N	Range	Minimum	Maximum	Mean	Std. Deviation	Variance
Arch.Score_Expert	97	3,00	1,00	4,00	1,5567	,72124	,520
Arch.Score_KWs	97	2,00	,00	2,00	,9691	,60301	,364
Valid N (listwise)	97						

Table 11 shows the number of patents in the sample set N = 97, the minimum and maximum value for each score, as well as the mean value, standard deviation and variance for each method.

Table 12 - Case Processing Summary

	Cases					
	Valid		Missing		Total	
	N	Percent	N	Percent	N	Percent
Arch.Score_Expert * Arch.Score_KWs	97	100,0%	0	0,0%	97	100,0%

Table 12 provides information about the valid vs. missing numbers in the calculation process and their percentage view.

Table 13 - Cross tabulation

		Arch.Score_KWs			Total
		,00	1,00	2,00	
Arch.Score_Expert	1,00	1	42	11	54
	2,00	13	17	4	34
	3,00	3	3	1	7
	4,00	2	0	0	2
Total		19	62	16	97

Table 13 presents the cross tabulation between the two approaches and shows for which values both approaches agreed and the how many agreements are there per each.

Table 14 - Symmetric Measures

		Value	Asymp. Std. Error[a]	Approx. T[b]	Approx. Sig.
Measure of Agreement	Kappa	,103	,060	1,659	,097
N of Valid Cases		97			

a. Not assuming the null hypothesis.

b. Using the asymptotic standard error assuming the null hypothesis.

Table 14 presents the actual *kappa* score. A value of 0,103 is calculated for the agreement between the two approaches. Taking a look into previously discussed *kappa* interpretation scores from Landis and Koch (1977) and Fleiss, Levin and Paik (2003), it falls into a category of *slight/poor* agreement between the *Keywords* and the *Expert opinion* approach. This can be explained by taking a closer look at the results from both methods and the cross tabulation (Table 7, table 9 and table 13). It is visible that the *Keywords* approach scores maximum 2 out of 6, where the *Expert opinion* approach – maximum 4 out of 6.

Taking a closer look into the results, it is evident that a patent with number *US20130063873A1* scores ‘4’ with the *Expert opinion* approach and in the same time ‘0’ with the *Keywords* approach. Looking into the patent’s abstract: *“Accurate and reliable techniques for wirelessly powering a tablet device are disclosed”*, it is obvious that the patent’s abstract is extremely short. It consists of only 12 words in total! Similar is the case for a patent with number *US20060197750A1*, which scores ‘1’ for *Keywords* approach and ‘2’ for *Expert opinion* approach, and *US20060268528A1*, scoring respectively ‘0’ and ‘2’. Their abstracts contain respectively 28 and 24 words. These abstracts sizes are considered insufficient for the success of the *Keywords* approach, in comparison to the maximum allowed word count for a patent abstract, amounting of 150 words.

The relatively higher score of the *Expert opinion* approach can be explained through the use of more patent fields for the evaluation and classification of each patent, namely *Title, Abstract, Background of the invention, Summary of the invention, Drawings, Derwent Information.* These provide a broader picture of the described invention, which eventually resulted in higher amount of relatively more architectural patents found in comparison to the *Keywords* approach.

The relatively lower scores of the *Keywords* approach can be explained with the limited number of patents participating in the keywords extraction process. Additionally, the uneven amount of patents in each cluster affected the volume of extracted keywords per cluster. To remind the reader, nearly half of the patents had to be discarded from the keywords extraction process because they participated in more than one cluster. Consequently, the biggest one consists of 15 patents, whereas the smallest – only 1 patent. Such uneven distribution of patents between the clusters most certainly disturbs the results as the number of keywords obtained from 1 patent is much smaller in comparison to the number of keywords obtained out of 15 patents. Smaller number of extracted keywords led to smaller amount of matching between keywords and patents' abstracts, which ultimately lead to lower score of architectureness using this method. If the same logic for keywords extraction is followed using a fixed equal number of patents per cluster, this would result in different number of extracted keywords per cluster, which would eventually lead to different conformity between the two approaches.

Combining these facts leads to different results from the two methods and lower level of congruence between the two approaches. However, the lower level of compliance does not mean that the overall result of the study is negative. On figure 13 it can be observed that the *Keywords* approach actually leads to positive results in terms of discovering architectural inventions.

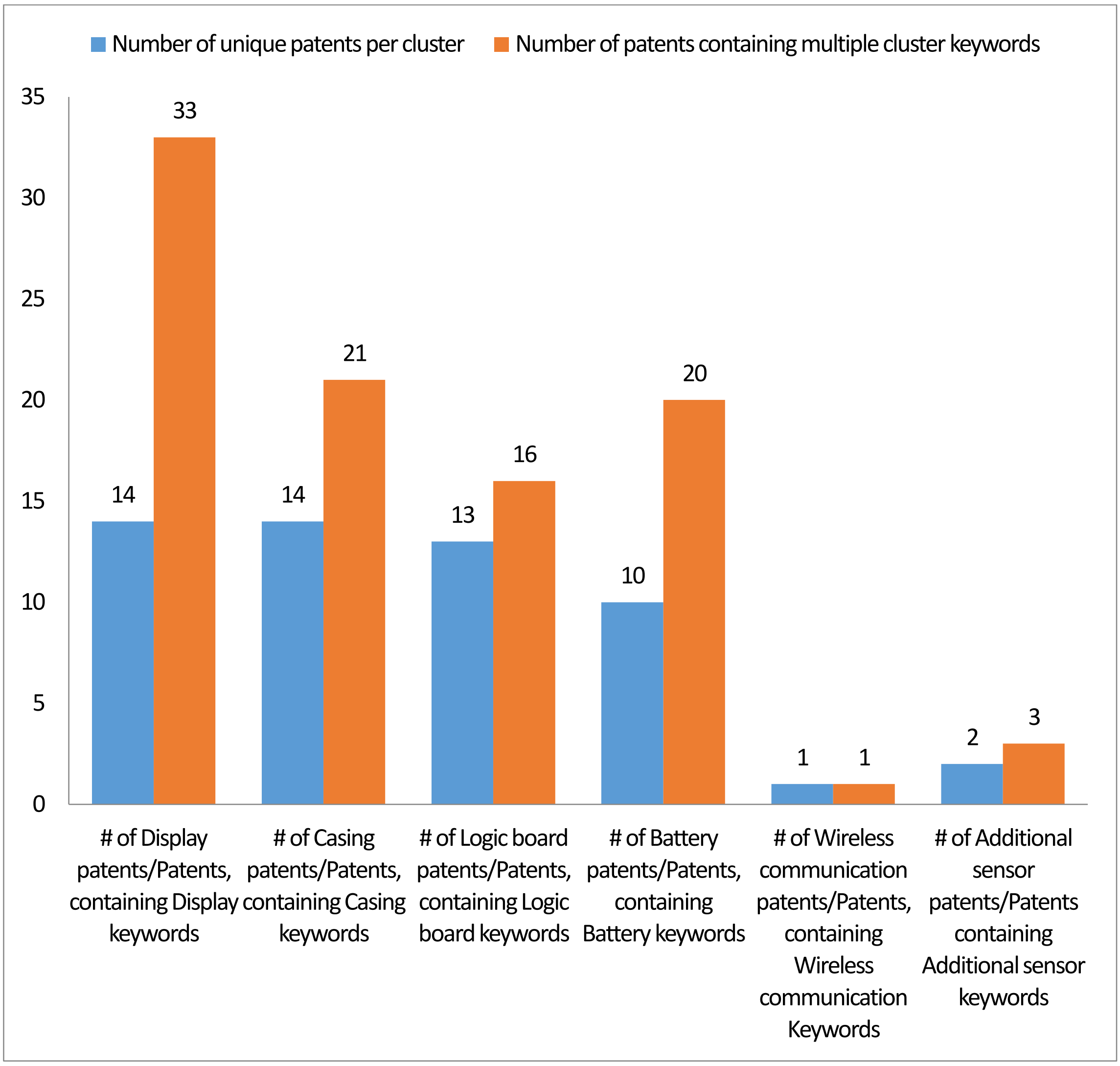

Figure 13 - Unique vs. "*architectural*" patents

As it is shown on the figure above, there are 14 unique patents belonging only to cluster *Display*. However, there are more than twice as many patents that contain keywords from that cluster, meaning that these patents contain keywords from multiple clusters. Almost the same situation occurs for cluster *Battery*, where there are 10 unique patents and in total 20 patents that contain keywords that are unique for this cluster. Similar situation is observed in nearly all clusters – the unique patents per cluster are considerably less than the number of patents that contain keywords from the same cluster. The situation is a bit different for cluster *Additional sensors*, where only 2 patents are unique and keywords from this cluster are found in 3 patents. Furthermore, in cluster *Wireless communication* the number of unique patent is equal to the number of patents containing *Wireless* *communication* keywords. That can be explained with the small number of patents participating in the keyword extraction process, leading to lower amount of keywords for these two clusters, which ultimately leads to less matches of keywords with patent abstracts. An important conclusion is that despite the low agreement rate between the two approaches, the *Keywords method* actually indicates some positive results. This can be seen from the presence of patents that contain keywords from multiple clusters. In other words, if one patent belongs to different clusters by containing keywords from more than one cluster, respectively iPad's core components, it is a clear indication of the architectural nature of the patent. However, to clearly approve or deny such an approach, further research is required.

5. Discussion and conclusion: factors influencing the study results

In this chapter the limitations of the obtained results are discussed. Possibilities for future research are also elaborated. Additionally, answers to the main research question and the sub-questions are provided concluding the findings of the study.

5.1. Discussion, limitations of the results and possibility for future research

There were found different types of patents describing numerous inventions in diverse technology fields in the Apple patent dataset used for this research. Hence, the length of the patents' abstract varied – some contained abstract of less than 15 words whereas others were around 150 words. Additionally, some patents were found to have almost the same abstracts describing similar inventions. These facts highly influence the amount of keywords that were extracted from a patent, which have a direct impact on the results of the research. In addition, the number of patents assigned to each cluster, respectively the number of patents participating in the keywords extraction, highly affects the number of obtained keywords for each cluster. As it is shown on figures 9 and 13, some clusters contained very limited amount of patents used for keywords extraction. These are clusters 5 and 6 – *Wireless communication* and *Additional sensors*, containing respectively 1 and 2 patents only, which negatively influenced the results for these clusters. If more unique keywords were found, that would have resulted in higher *Score of Architectureness – Keywords*, which could result in different degree of congruence between both scores – *Keywords* and *Expert opinion.* This leads to an important conclusion that **every cluster has to contain a critical minimum of unique patents used for extraction of keywords**.

Another factor that would highly impact the result of the study is the manual process of selection and the amount of identified core components in a complex system. In case there are few but rather complex core components identified, meaning that the level of abstraction of core components is high, the chance a patent to address only one component within the identified set could be relatively higher. And vice versa. If there is a complex technological invention present and the level of abstraction of core components is low, this might lead to the identification of many core components. Consequently, this may suggest a penetration of one patent into more than one core component, respectively a higher architectural nature of the invention. Nevertheless, **the identification of core**

components of a complex system is a critical step in deriving text-based indicators in the form of keywords used for further assessing the architectural nature of a patent. Furthermore, it requires broad knowledge of the overall system under analysis and its manual decomposition to distinct components suitable for analysis. Consequently, the system decomposition and the number of identified core components can affect significantly the potential outcomes.

The values coming out of the two approaches differ in magnitude. The *Expert opinion* approach scored relatively higher in determining how many core components one patent is related to. However, as previously stated, this approach uses more input data as well as the researcher's interpretation of the data. That leads to the conclusion that **in the applied research settings, the use of patents' titles and abstracts seems to be not enough to correctly determine the architectural level of a patent.** The provided definition for architectural invention was not enough for the researcher to classify a patent as architectural or not using only its title and abstract as the inventions described in patents use complex language and often patents describing similar inventions have similar abstracts. Thus, a deeper look into other patent field was required leading to the usage of invention description, drawings, claims and DWPI data in order to classify a patent as architectural or non-architectural one. This fact suggests that **a higher portion of a patent document needs to be mined for keywords in order the *Keywords approach* to be more successful.** This includes standard patent fields like *Description of the invention* and *Background of the invention,* but certainly, when possible, additional fields like DWPI is recommended to be used for better results.

Another factor influencing the results of this study is the fact that not all technologies used in the Apple iPad device were taken into consideration. As the iPad is a complex device, it is not possible to embrace only technologies owned by Apple. It is mostly certain that external patented technological know-how is included in such a complex device through licensing agreements. However, as there is no method allowing the identification of all patented technological inventions within a finished and marketed product, the licensed-in technologies included in iPad were not object of analysis of this research. Hence, only inventions by Apple were analyzed in this project. Additionally, not all Apple patents were studied. The chosen time frame between 2002 and 2012 was assumed to include the most relevant patents that may be implemented in the iPad – namely 5666 inventions. Nevertheless, in total of 4166 patents, representing 74% of all Apple patents for the chosen time period were studied leaving a possibility potential iPad important patents with valuable keywords to be accidently omitted by this research.

Up to the researcher's knowledge there is no possible way to link a patented invention with a marketed product, meaning that one cannot know how many and which patents stand behind one product. Thus, the initial classification of patents as iPad relevant or not as well as architectural and non-architectural patents was performed by the researcher based on his experience and interpretation on each patented invention. Objectivity in judgment was tried to be at high level but no matter this fact, the classification process itself could lead to researcher's bias, which may influence the results of the study. Nevertheless, the results are inconclusive and further research on the topic is required before this method is approved or rejected.

All mentioned facts influencing the research are seen as limitations of this research. As this is an initial research in this area aiming at theory building, larger scale further studies are required in order to verify the applicability of the *keywords approach*.

Summarizing, the limitations of the study are its theoretical aspect and the highly specific area of analysis. In order the results from this study to be validated and further generalized, a quantitative study would be necessary, taking into account the findings of this study. Therefore, as future research opportunities, tests of the applicability of the *keywords approach* can be performed in larger data set and for different complex products coming from industries, reflecting the abovementioned limitations. In case of success, the process could be automated with the help of software algorithms. Potential findings from the studies could be very beneficial for the innovation and R&D managers in different companies to identify probable disruption based on architectural inventions and further guide them into taking the right strategic and development decisions.

5.2. Conclusion: indecisive results require additional research

This thesis studied a complex problem of deriving indicators for the architectural nature of an invention obtained from patent documents. It presented an overview of the patent system according to the patent law and details regarding patent documents and their structure were described. Furthermore, different innovation concepts and frameworks were discussed but it turned out that there is no literature existing, which deals with this particular problem. Hence, adaptation of present frameworks was performed and new definitions that suit for the purpose of the analysis were provided. Additionally, the research methodology was presented elaborating on the research design and providing detailed information on the steps of the analysis. At the final section of this thesis, the results of the study were present along with their validation and interpretation. Within the scope of this thesis, it was possible to provide answers to all the sub-questions. The characteristics of an architectural invention were identified through a new definition of architectural inventions, which further distinguishes between incremental, modular and radical inventions. In addition, the core components of the iPad were identified and compared for two generations of the Apple's device. Furthermore, keywords that are unique for each of the iPad's core components were derived from the examined patented inventions and a way to rate each patent as architectural was presented and elaborated. Summing these all up, it was possible to provide answer to the main research question. However, the study shows potential but in the same time low congruence between the two approaches. Therefore, no conclusive answer can be provided whether the proposed method is generally applicable or not. It is visible that the *keywords method* may work in identifying the architectural nature of a patented invention, but further refinement and additional research is needed.

Appendix

Table 15 - List of ALL extracted keywords, grouped per cluster prior to keywords cleaning

###	Display - ALL (14 unique for patents)	Casing - ALL (15 unique patents)	Logic board - ALL (13 unique patents)	Battery - ALL (10 unique patents)	Wireless communication - ALL (1 unique patent)	Additional Sensors - ALL (2 unique patents)
1	ambient light calibration	acoustic chambers	accommodate folding	active coating	accommodate buttons	computing device
2	ambient light incident	air cavity	board radio-frequency shielding	adhesive layer	antenna	detector
3	ambient light sensor	air cavity separated	bypass capacitors	anode	antenna design	light opaque layer
4	anti-reflection coating	air impermeable	bypass capacitors reduce voltage	battery	antenna efficiency	light sensor
5	automatic mapping	antenna block	capacitors reduce voltage noise	battery cell	antenna tuning	opaque layer
6	automatic pointing device mapping	antenna flex	circuit board radio-frequency shielding	battery cells	capacitive loading	proximity sensor
7	backlight	audio sound output	circuit board substrate	battery connector align	compact tunable antenna	proximity sensor arrangement
8	backlight driver	barometric pressure equalization	circuitry external	battery pack	compact tunable antennas	radiation absorber
9	backlight unit	bonded	circuitry region	battery pouch	conductive structure	radiation passing layer
10	backlight unit color compensation	brush-like baffle	concurrently addressable unit	battery pouch sheet	couple radio-frequency transceiver circuitry	
11	capacitance sensing	camera module	conductive	battery pouch sheet edge	handheld device	
12	capacitance sensing circuit	causing flare	conductive adhesive	battery powered portable	handheld device using springs	
13	capacitance sensing electrode	cavity	conductive cover	battery powered portable devices	handheld devices	
14	capacitance touch	cavity separated	conductive dam	cathode	handheld electronic	
15	capacitance touch sensing	cfrp skin	conductive material stacked	circuit supply voltage	handheld electronic device	
16	capacitance touch sensing device	cfrp spine	conductive structures	circuitry associated	pogo pins	
17	capacitive sensing controller	cfrp type material stacked	conductive tablet	compressive forces	radiating element	
18	capacitive sensing nodes	circuit	configured	compressive forces applied	radiating element formed	
19	capacitive sensing nodes set	circuit board	connect embedded components	computing device	radio-frequency switches	
20	capacitive touch sensing	compact ejectable component assemblies	controller interface	conductive elements	tunable antennas	
21	capacitive touch sensing device	conductive housing	controller interface providing	conductive pads		
22	chassis	conductive housing form	disclosed architecture	conductive tab coupled		
23	circuit element	conductive material	dma	conductive tabs		

24	color compensation techniques	connector element	dma controller	connector pads
25	common conductive pathway	connector including	dome switch	core metal layer
26	common conductive pathway connecting	connector interface system	dome switch member	disclosed embodiments
27	common electrode	connectors	electrical components	discrete locations
28	common electrode signals	couple multiple connectors	electrical connections	electrode jelly roll
29	compact display flex	curved portion	embedded components	electrode jelly roll edges
30	composite wires	detents	embodiments	electrolyte containment structure
31	conductive pathway connecting gates	device enclosure using sandwich	encode data transmitted	embedded battery
32	controlled chassis reflections	diaphragm	exterior surface	enclosure material
33	conventional sub-assemblies	dielectric constant	flex circuit	flex circuit
34	device mapping method	dimple formed	generic nvm commands	flexible interconnect component
35	display device	distinct acoustic chambers	grooves	flexible pouch
36	display module	docking connector	host device	insulating layer
37	display pixels	ejectable component	host device interface	integrated embedded battery
38	distribute common electrode	ejectable component assemblies	host interface	interconnect component
39	distribute common electrode signals	ejectable component assembly	host interface adapted	jelly roll
40	drive electrode	electrical component	host processor	jelly roll comprising layers
41	driver circuitry	electrical contacts	impedance associated	jelly rolls
42	driver sub-assemblies compact sub-assemblies	electronic device enclosure	impedance calibration circuit	jelly rolls enclosed
43	edge-lit backlight unit	embodiments	insulating fill	laminate sheet suitable
44	efficient display device	enclosure	integrated circuit	layer laminate sheet suitable
45	electrode signals	enclosure surrounding	interface circuit	light-weight metal foil pouch
46	embodiments	enclosure using sandwich construction	interior printed circuit board	lithium-polymer battery cells
47	extracted propagating	engagement projection	interposer	logic circuit
48	extracted propagating light	engagement slit	interposer containing bypass capacitors	logic circuit supply voltage
49	fixed voltage	flare reduction effect	load impedance	metal foil
50	flexible circuits	flexible membrane	load impedance associated	metal foil sleeve
51	force sensor interface	flowable adhesive layer	managed non-volatile memory	modular components
52	gate	frame disposed adjacent	memory controller	multi layer laminate sheet

53	gate driver circuitry	functional insertion	memory device	multiple jelly rolls	
54	gate line	gas cavity	memory locations	peal	
55	graphics tablet	headphone cable	multiple cau architecture	portable computing device	
56	improved color uniformity	hidden screw feature	non-volatile memory	portable electronic device	
57	include pass transistors	image artifacts	non-volatile memory device	pouch	
58	include spacers	image sensor device	perform dma transfers	pouch cell battery	
59	internal ambient light sensor	integrated microphone assembly	printed circuit board substrate	pouch cell battery design	
60	lateral edge	keying arrangement	radio-frequency shielding	pouch cell battery designs	
61	lcd device	layer	radio-frequency shielding structure	pouch sheet edge	
62	light guide plate	layered configuration	radio-frequency shielding structures	pouch sheet edge insulation	
63	light-extracting elements	layered fiber-in-matrix type material	radio-frequency shielding structures electrical	powered portable devices	
64	liquid crystal display	lens	reducing voltage noise	pre-formed battery contact	
65	liquid crystal material	lens baffle	rigid printed circuit board	pre-formed battery contact shaped	
66	multi-display	loaded electrical contact	shielding circuitry	pressure-relief mechanism	
67	multifunctional node	locating bracket	shielding circuitry from interference	pull tabs	
68	multifunctional nodes	microphone assembly	signal conditioner	rechargeable battery cell	
69	multiple light-extracting elements	microphone cables	slits	rigid frame	
70	mutual capacitance	micro-sim card	solder pads	safety circuitry	
71	mutual capacitance sensing circuit	mini-sim card	source impedance	sealant layer	
72	mutual capacitance touch	modular material antenna	source impedance associated	single pouch	
73	mutual capacitance touch sensing	modular material antenna assembly	supply voltage	supply voltage	
74	mutual capacitive sensing	multi-communication device	unified dma	thermal bonding	
75	mutual capacitive sensing controller	multi-connector assembly	voltage control output	thermal bonding method	
76	mutual capacitive sensing nodes	multi-pin adapter	voltage noise	thermal transfer	
77	mutual capacitive touch	multi-pin adapter associated		thicknesses	

78	non-planar	multi-pin connector	unconnected battery
79	opposite lateral edge	multi-pin connector assembly	unconnected battery cells
80	optical effects	multiple-connector assemblies	
81	optical retarder	non-conductive frame	
82	pass transistors	outer suspension	
83	pass transistors controlled	output audio	
84	pixel	output audio opening	
85	pointing device mapping	portable electronic device	
86	pointing device mapping method	prevent noncompliant connectors	
87	polarized filters	printed circuit carrier	
88	polarized sunglasses	rectangular spine	
89	proximity zone	remote connector	
90	proximity zones	removable module	
91	quarter-wave retardation film	respective acoustic	
92	quarter-wave retardation properties	respective acoustic chamber	
93	rectangular opening	respective acoustic chambers	
94	reflection-reducing coatings	retainer coupled	
95	reflection-reducing configurations	sandwich construction	
96	respective touch sensor electrodes	screw feature	
97	retro-propagating light	screw holes	
98	segmented common electrode	screw plates	
99	sense electrode	sim tray	
100	sensor panel constructed	sim tray slot	
101	sensors	spring loaded electrical	
102	separate quarter-wave retardation	standard headphone cable	
103	separate quarter-wave retardation film	vent hole	
104	single touch pixel		
105	spacers		
106	specular reflector disposed		
107	stylus		
108	sub-assemblies		
109	thin-film transistor		
110	thin-film transistor circuitry		

111	touch circuitry	
112	touch pixel	
113	touch screen	
114	touch sensing device	
115	touch sensor	
116	touch sensor panel	
117	touch sensors	
118	touch-display crosstalk clamping	
119	transistor	
120	transistors	
121	transmit stimulation signals	
122	unit color compensation techniques	
123	wires	
124	wires disposed	

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