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Teaching thermal analysis: Flash® virtual instruments and movies

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Abstract

Using the computer and Internet to teach and train students is becoming increasingly more popular. Nevertheless, the number of faculty who take full advantage of the inherent power of the computers is limited, even in science and engineering disciplines. This paper describes movies and virtual instruments (VIs) developed by the author using Flash®, in particular in the thermal analysis area. Flash® movies have been available for some time but it is only relatively recently that the scripting ability of Flash® has been recognized as a route to VIs. Up to this point Labview® has been the primary tool for preparing such VIs. This paper also compares the relative utility of Flash® and Labview® in this regard.

Keywords: Virtual instruments; Animation; Educational materials; DSC and DTA

1. Introduction

Increasing number of faculty recognize the internet/web's potential and are attempting to take advantage of it in teaching. However, these attempts often result in what is termed 'shovel ware'; notes, drawings, transparencies, etc. are turned into a Power Point® presentation or PDF file and put on a web site to be downloaded. The next level of complexity starts to use the power of the computer to perform rapid computations. Spreadsheets and databases are linked for students to more easily try 'what if' types of experiment in this format. I have been working for a number of years to take further advantage of computer and Internet as an effective teaching tool. The fast computational speed of the computer can be translated into virtual instruments (VIs). Currently, the majority of VIs are prepared using Labview®; it will be shown that Flash® offers a significant alternative approach for VI production. As a follow on from computational speed, animation as exhibited in Flash® movies is another way to take better advantage of the computer/Internet system.

The downside is that it takes time and some expertise for individual faculty to fully use the computer and we would like to be sure that all this effort is worthwhile. To date there are relatively few assessments of effectiveness; however, the few that exist support the idea that students benefit from using VIs and animation of concepts. Nevertheless, it is appropriate to consider certain constraints before committing to develop Flash® VIs or movies.

2. Labview® VIs

The trigger for VI development is that it is generally agreed that one of the best ways to learn is to do it yourself. However, that approach can be inefficient given the time scale of some experiments, the availability and cost of modern instruments, and the

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potential danger when you put instruments into untrained hands. The standard academic approach is 'the lecture' but that removes active participation. One alternative is to provide 'VIs'; the term VI is used here to describe software that is written to accept input from on-screen controls (knobs, sliders, etc.) whose values are changed using the computer mouse. These inputs are then used in a set of equations that define instrument or equipment response. Results are output to a screen in an appropriate form (graph, table, indicator, warning signal, etc.). Like any software, its utility is only as good as the equations used to describe the situation (GIGO—garbage in, garbage out).

Until recently the most widely available program for VI construction was Labview® from National Instruments. Historically, the program has been an industry 'standard' in controlling equipment or instruments through IO boards. For VI construction Labview® was used in a stand-alone mode; no connection to an instrument, everything is contained in the software or on disk. Labview® is a 'connect the dots' visual basic type of program and it is probably noteworthy that most of the VIs that have been reported are of the electrical engineering type. However, this author has constructed a suite of seven thermal instruments previously described in the literature [1]. The front panel of this suite is shown in Fig. 1.

In my VI development two different types of VI have been produced. The first kind allows the representation of complex equations with a number of input variables so that students can 'get a feel' for the effect of changing variables on output results; the 'copolymer equation' and 'Avrami equation' VIs contained in the suite above are typical examples. The second type is more realistic 'instruments' or 'processes' where students control instrument, process and material variables and observe results as a strip-chart, meter, graph, alarm, etc. Experience suggests that we carefully choose the instrument to be developed; there is a significant commitment in time and effort. Nevertheless, the list of thermal and other VIs so far completed and listed in Table 1, would cost $500,000 as a 'hardcopy', physical version.

Naturally, the cost savings identified above represent one of the advantages of using VIs. Further, a variety of VIs corresponding to different instruments can be contained on a single CD, with additional savings in cost and a corresponding increase in availability. VIs are not intended to replace hands-on experiments in the lab but rather to expand and complement a typical lecture or lab. VIs have a place in exposing students to a wide variety of conditions and materials that they normally would not encounter because of time or cost constraints. Additionally, the ability of

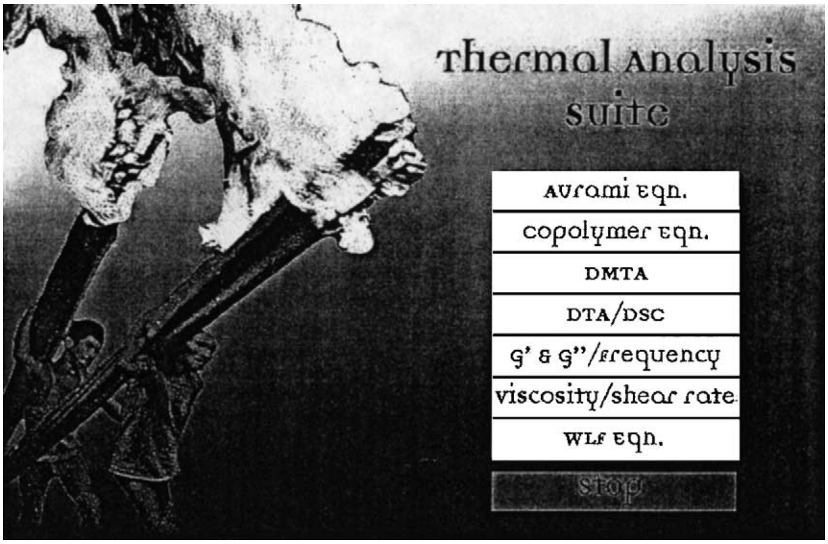

Fig. 1. Front panel of a suite of Labview® thermal VIs.

Table 1
Existing Labview® VIs

Thermal suite
DTA/DSC
Viscosity vs. shear rate
Avrami
G'/G'' vs. frequency
DMTA
WLF
Copolymer equation
Barrier properties
Key transport variables
Multilayer film (unfinished)
Unsteady state
Database
Blown film line
Copolymer/TREF
Starch branching

VIs to decrease time required to complete a project in a real lab; to minimize required assistance in the real lab; and to increase the level of satisfaction that students have with the real lab has been documented [2].

Probably, the only program choice to prepare VIs at the time I started instrument "construction" was Labview®. However, for much of what is needed from an educational perspective this program is overkill. In addition, if a VI needs to be controlled over the web (distance education) there is a large memory penalty; approximately 6meg minimum is required to perform web-based control. We will see that Flash® is an alternative way to prepare VIs and has distinct memory advantages. Before discussing VIs prepared using Flash® it is appropriate to review general features of Flash® and particularly its use for movie preparation.

3. Macromedia Flash® movies

With the basic premise that a picture is worth a thousand words, there are a number of ways to introduce animation into a presentation for more descriptive and understandable content. One of the direct advantages of Flash® is that it is vector-based and therefore produces relatively small files. Another plus is that several different formats can be produced when the file is 'published'. Following in Table 2 is a list of some options and the memory required; the example used is of the largest module produced so far. An HTML page is also produced (194 KB) that contains all text used in the 'movie' and controls Base.swf through a browser; removing text makes the file 30 KB. GIF, JPEG and PNG images are exportable for single frames; later figures shown in this paper are JPEG images exported from flash movies.

Table 2
Memory requirements of various Flash® files

File	Memory	Application
Base	1.5 MB	This is the unpublished working file from Flash®
Base.swf	388 KB	This file is playable through >97% of new browsers
Base.exe	776 KB	A file that is executable through 'Windows'
Base projector	868 KB	A 'stand alone' projector played on a Mac
Base.mov	582 KB	QuickTime movie

This particular 'Base' module, if used as 'lecture notes', that is, as a replacement for 'overheads' or a PowerPoint® presentation, takes approximately three lecture hours of time to deliver. Control buttons are built into the movie to give students and faculty control of the time they spend in different parts of the movie and to allow them to return to points of interest or concern for further review. In contrast, total playing time is 257 s, this is the time taken to simply show all frames with no pauses, no time allowed to read content, and no time taken to observe 'looping' actions built into the movie. These movies are typically shown at 12 frames per second and in this case the movie consists of 3083 frames.

3.1. Delivery

A wide variety of options are available. Currently, Base.swf movies are published on my web page (Page Mill® and Fetch® are used to assemble and deliver the page to the university server). Students have access to the material in the movie through the Internet, via the browser of their computer. The page could be password protected to limit access. Alternatively, Base.swf or Base.exe files can be put on the web to be downloaded. As another option I have sent individual Base.swf, Base.exe and stand alone Base Projectors to individuals using e-mail (Eudora®). Finally, the material could be 'burned' on a CD-ROM or copied to a Zip® disk or 'floppy' for delivery. Flash® movies can be embedded in a number of other applications, in particular Power Point®.

3.2. Additional materials

I typically provide students with a hard copy of all the text and some key pictures taken from the movie modules. This gives students the option of writing their own notes as they see fit while viewing the movie either in class or on their own. This hard copy material probably should be reworked after a decision has been made regarding picture format (color or gray scale). I am currently using color in Microsoft word that gets converted to gray scale at the printer; the images are not ideal and could be reworked in PhotoShop®. Text material could also be delivered over the web or on disk, etc. as a PDF file; in general students seem to prefer purchasing a hard copy directly, as opposed to printing their own. An internal self-test/evaluation package could be developed. However, I typically use a computer-based quiz run through the university testing systems office. A hard copy test booklet provided as a PDF file is another alternative.

3.3. Completed Flash® movies

A list of currently completed and 'in the works' movies is given in Table 3. This list is broken into a number of different topics; the vast majority are polymer related. Each movie consists of a number of 'scenes'; the 'Index' page from the characterization methods and thermal analysis movie shows such a list in Table 4.

The list shown in Table 4 is not meant to imply that all necessary material is covered in the thermal analysis movie. For example, polymer properties and structure and morphology, contains scenes on crystallinity, lamella, spherulites and row nucleated structures; characterization methods and infrared has a scene on chain conformation, etc. All movies listed above behave in a similar manner. There are links from topics identified in the index, for example, as shown in Table 4, to the particular scene in the movie. Users can move freely from scene to scene in any order or follow a prescribed route. The topics covered in the movie represent those that the author has taught as an introduction to thermal analysis for undergraduates, particularly as it pertains to DSC and DTA as applied to polymeric materials.

Table 3
Completed and 'under construction' Flash® movies

Polymer properties
States of matter
Synthesis and molecular mobility
Structure and morphology
Transitions: specific volume vs. temperature plots
Modulus vs. temperature: molecular structure
Simple models for mechanical behavior
Boltzmann and WLF superposition principles
Molecular weight, polymer properties and melt index
Rheological characteristics
Materials science
Periodic table and bonding
Semiconductors and devices
Characterization methods
Temperature rising elution fractionation (TREF)
Thermal analysis: DSC and DTA
X-ray scattering: introduction to wide angle X-ray scattering (WAXS)
X-ray scattering: orientation using WAXS
Infrared methods
Processing methods
Extrusion and rotational molding
Under construction
Gel permeation or size exclusion chromatography
NMR
Density measurements
Mechanical testing

Table 4
Index page from characterization methods and thermal analysis

Introduction	Defining melting point (T_m)
Experimental method	Reorganization
Idealized thermogram	Percentage crystallinity
Conductivity and viscosity	Measuring T_m°

4. Flash VIs

By animation program standards Flash® is highly programmable and contains its own language Action Script that has a number of the general features of Basic and C. Action Script is not optimized for mathematical manipulation and computation but

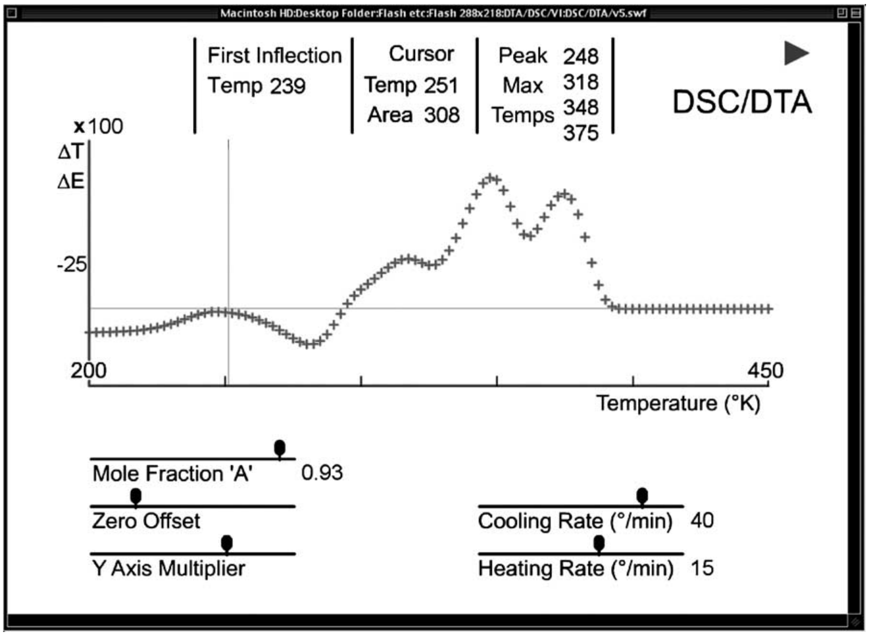

Fig. 2. Main operating screen of the Flash® VI shown in inverted gray scale.

nevertheless performs enough mathematical functions to be generally useful in science and engineering disciplines. Using Action Script it has been possible to emulate essentially all the options that were available in the DTA/DSC VI in the Labview® Thermal Suite (Table 1). Details of the assumptions and equations used in this latter module have been covered previously [1]. The main operating screen from the Flash® DSC/DTA VI is shown in Fig. 2.

As previously stated, details of the equations and assumptions used have been given elsewhere, however, it is perhaps appropriate to identify both general and more specific features of the VI in order that the reader can understand how such a VI can be used as a 'do it yourself' learning project for students (Table 5). Needless to say the thermogram is updated in real time as students change input parameters using slider controls.

As stated above, details of assumptions and equations used have been reported elsewhere [1] and results can be considered semi-quantitative. Changes in peaks as a result of instrument effects have been ignored. For example, a sample heated quickly shows less reorganization or annealing and therefore lower melting point. The sample is not allowed to show an increase in apparent melting from 'instrument lag' as a result of real life thermal conductivity or heat flow problems. It is assumed that the instrument is 'perfect' or has been appropriately corrected.

5. Assessment

Labview® VIs and Flash® movies but not yet Flash® VIs have been used in polymer science courses for the past 3 or 4 years. As a general statement students find both VIs and Flash® movies to be helpful in understanding material. Positive comments for Flash® movies included statements such as "the movies made some difficult concepts easier to understand"; "great visual aid, almost a class substitute"; and "movies were great, especially for those subjects that required good visualization of what is going on in order to understand them". On the negative side, students felt the need "to back up one slide only instead of the whole section" and commented that "movies were excellent, would be well supplemented with better notes". All movies are being reworked to allow students to return from each stopping point to the previous stopping point. The notes that are currently used will be reviewed and expanded. The 'Periodic Table

Table 5
Features of Flash® DSC/DTA

General
Zero offset shifts data along *Y*-axis
Multiplies signal by the stated amount
Signal size is proportional to heating rate
First ‘inflection’ point temperature identified (T_g)
Up to four peak maxima temperatures reported (T_m)
Area given from cursor to highest temperature; area above horizontal cursor minus area below
At slowest cooling rate and fastest heating rate
T_m and T_g are a function of composition (assumed random A/B copolymer)
Percentage crystallinity is a function of composition
T_m width increases as copolymer becomes richer in non-crystallizable B component
T_g represents composition in the amorphous phase not overall copolymer composition
With increasing cooling rate while maintaining the fastest heating rate
With increased but still low cooling rates, T_m decreases
As cooling rate further increases, T_m continues to decrease; some crystallinity is quenched out
For pure ‘A’ melting, peak becomes broader with increased cooling rate
For compositions richer in ‘B’, peak narrows on increased cooling
If crystallinity is ‘quenched out’ amorphous phase composition is adjusted and T_g changes
While varying cooling rate and heating rate
If heating rate is greater than cooling rate
Peaks become lower in temperature and broader with increased heating rate
If heating rate is less than cooling rate and if cooling rate does not quench out crystallinity
A portion of the original peak is allowed to thicken (anneal) and its melting point increases
Annealing portion size is proportional to the difference between heating and cooling rates
Peak width behaves as if the sample had been cooled at the same rate as it is being heated
If cooling rate does quench out crystallinity
A portion of the crystallinity that was quenched out is allowed to recrystallize and remelt. The size of the recrystallize/remelt portion is proportional to the difference between heating and cooling rates. A portion of that part of the original peak that did not quench out is still allowed to anneal and its melting point increase as above

and Bonding’ movie (Table 3, Materials Science) has been used with a class of over 500 students in several sections with and without the movie version. Preliminary testing suggests that the Flash® sections score 20% higher than non-Flash® sections tested on identical material. Clearly a significant improvement if this preliminary observation continues to hold.

6. Conclusions

While Labview® is a very powerful program, particularly as it applies to instrument control, its potential is significantly under-utilized when used to construct VIs for teaching purposes. Additionally, Labview® VIs need a lot of memory; the Thermal Instrument Suite needs 8.3Meg of disk space. Flash® Action Script is increasingly able to handle more complex action and for conceptual animations is more than sufficient. In addition, Action Script has been used to ‘read’ the position of a slider on the screen and convert that position to a numeric value in real time. This ability has been translated into a number of VIs for student use; only one is reported on here. A key advantage of Flash® in VI construction is the relatively small amount of memory required. A “test” screen with seven input variables needed only 28 KB.

Flash® VIs and movies are valuable tools that help students to discover for themselves and provide animation of difficult concepts, respectively. Students appear to respond to these approaches and appreciate the interactions. An independent evaluation of the bottom line; ‘is it worth the effort’ is difficult if not impossible to achieve and for now I rely on 30 years teaching experience to make that decision. The increased ability of Flash® Action Script to handle complex procedures means that the Flash® equivalent of VIs is possible, accompanied by a tremendous saving in memory and a correspondingly more rapid web download time.

7. Availability of VIs and movies

Labview® VIs are not available over the web because of the memory limitations listed earlier. However, many Flash® movies and VIs can be seen either at the authors main web page at http://www.personal.psu.edu/faculty/i/r/irh1/ or by linking from this page to PLMSE 407 and then from the left-hand side of the split page link to Assorted Animations. Even viewing these low memory movies and VIs over the Internet can sometimes be frustrating given the volume of traffic and corresponding reduction in speed. The author is considering distribution of CDs containing this material or allowing users to download movies and VIs for personal use only.

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