InterMath: A Mathematics Tutorial System

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Higher education needs the support of technology in the delivery of teaching materials. In the UK economic pressures are pushing an increasing number of students who come from a variety of backgrounds through an education system which strives to maintain academic standards, but has fewer and fewer staff at its disposal. Yet there are more and more personal computers available to the student population, both on and off campus. The question we need to ask is 'what sort of teaching materials will exploit this resource and will be sufficiently attractive and rich in content to compete and replace conventional teaching'.

InterMath is a hybrid tutorial system dealing with Mathematics course content that is conventionally taught to students of Science and Engineering at first-year level in UK universities. The term 'hybrid' is used because the materials, which are in a hypertext format, are contained partly on a remote Web-site and partly on a local CDROM. The term 'tutorial' is used because the teaching has an overall tutorial style, based primarily on guided learning and investigations rather than on repetitive exercises or training.

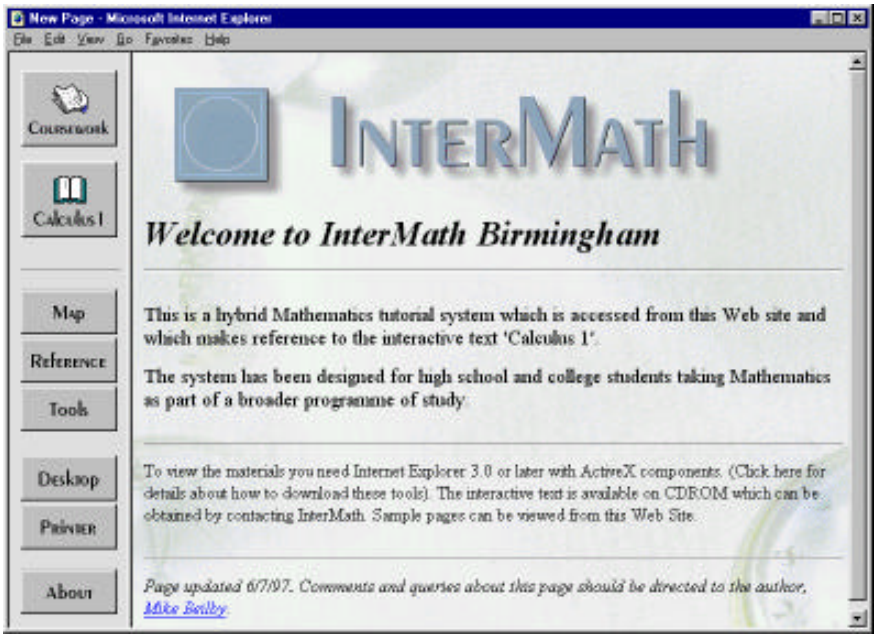

Fig. 1 InterMath opening page

A hybrid tutorial system

The World Wide Web is an enormously attractive medium. Materials based on the Web are widely accessible, and can be read on institutional networks and at home. Web pages are flexible and can be changed with editors which are commonly available and are well understood.

The problem is that because of the high level of traffic the bandwidth on the link between Web server and user is usually low. Data transfer rates can be frustratingly slow.

By way of contrast, CDROMs are cheap to produce, can be quickly read and can hold a large amount of information. Certainly, the content of a typical first-year Calculus textbook will fit on one CDROM, but, like a textbook, it will be static and the materials will be arranged to suit a narrow group of students.

InterMath itself is based on the Web. Its opening page is a Web page, and the 'coursework' content is layed out on Web pages which resemble hand-outs distributed during the introductory lectures of conventional courses. There can be several sets of coursework pages, each adapted to the needs of specific groups of students. The pages are personalised and contain instructions. They contain phrases like 'Read this first', 'You should check you have understood this by trying these exercises', 'You might like to look at ...' and 'Now move on to ....'.

All the subtantial content is contained on a CDROM, and this will normally be located on the local machine. On its own the CDROM will provide a fairly full introduction to first-year Calculus with its own structure which is more like a traditional textbook, where the topics are structured linearly albeit with diversions to supplementary material and exercises. However, in InterMath the student is directed to topics on the CDROM from hotwords on the coursework Web pages and can interact with the content in a manner more closely related to a specific course.

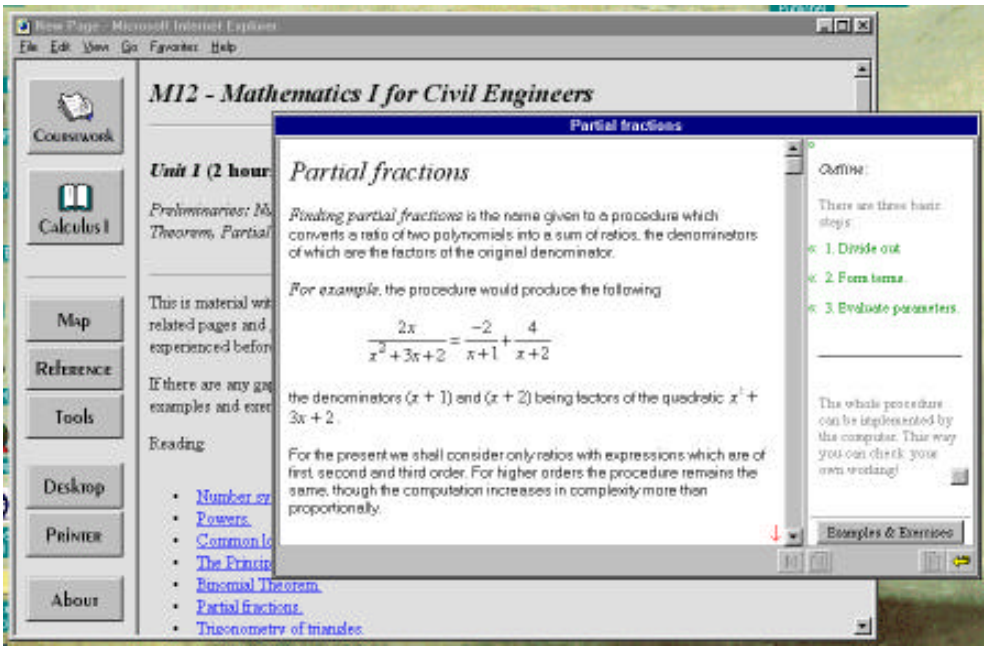

Fig. 2 Coursework content

The effect is to make available a body of material which is rich in content, which is adaptable, which is interesting, and which is suited to higher education.

Overall technical structure

The natural choice for developing the system is Asymetrix Toolbook. It is a medium in which functional screens can be quickly designed and yet can still exploit a full range of features of the Windows system. The core Calculus text has been, and is still being, composed using Toolbook II. Basically, there are 10 chapters. For each chapter there is a content book and two supplementary books, which contain illustrations and notes. In addition there are exercise books with worked examples and questions which relate to topics in the chapters.

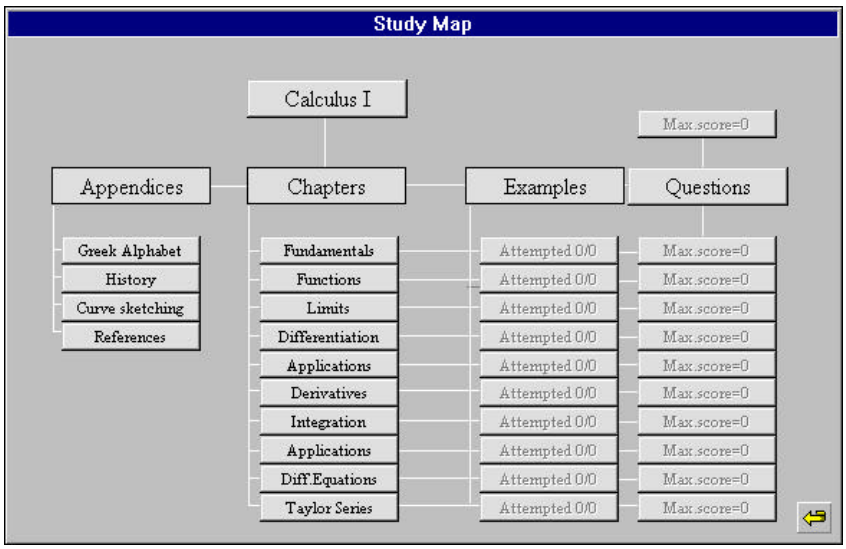

Fig 3. Map of Calculus materials

The Toolbook pages that make up the Calculus text are viewed from a hierarchy of windows. One central window is used as a base (the Toolbook 'mainWindow') for the 'instance' of ths application instance and the chapter pages, supplementary pages, exercises etc. are displayed in popup windows which are 'children' of that base window.

Currently the Toolbook pages are all called from the InterMath Web pages using Neuron 5.0, the runtime version of Toolbook which can operate from inside a Web browser. There can be up to two instances of Toolbook active at any time. One instance is active all the time and is based on the facility menu in the left-hand frame. The other instance is available some of the time and is based on the Calculus contents menu displayed in the right-hand frame.

The facility menu is taken as the primary instance of Neuron and is the route by which 'persistent' data, e.g. student progress, indexing, and objects dragged from the pages, is accessed. It is also the parent of all popup windows.

The Web pages operate in Microsoft's Internet Explorer 3.01. Neuron is an ActiveX application. Within the HTML there are links to Calculus pages, and these are implemented by specially written ActiveX components which send a Windows message to the primary instance

of Neuron i.e. the instance with the facility menu. These messages contain codes which determine the precise Toolbook page that is required and the viewer that is to show it.

The special ActiveX components have been written in Delphi 3.0. Communication between the 32-bit ActiveX controls and 16-bit Toolbook is hard to arrange. For example, because of the different memory structures, it is difficult to send text strings from 32-bit to 16-bit applications. For simplicity, therefore, the cross-references have been coded as numeric values.

In addition, there is a set of 16-bit DLLs which provide special facilities and extend Toolbook. Some of these facilities are needed to hold together the files that make up the system, e.g. by providing a central database of topics, and some are needed for the delivery of Mathematics coursework, e.g. by facilitating graphics animations and handling mathematical notation. These DLLs have been written in Delphi 1.0 and are linked to the Neuron books in a conventional manner.

A Centralised Indexing System

Currently InterMath is only partly complete and already contains more than 100 files arranged in 12 subdirectories. Each file contains several topics. Coordination is achieved through a centralised index built from the information contained in INI files. Each topic is given a 9-character reference code and is described by a set of keywords. Cross references can be made by a specific reference code, by a range of reference codes or by a keyword search.

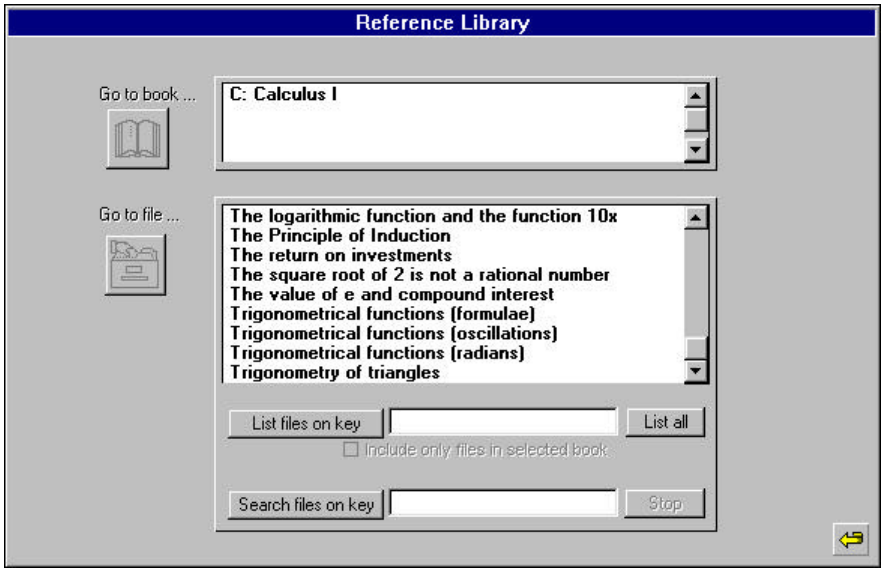

Fig.4 Keywords in the central Reference Library

One advantage of having a central system is that substitutions can be programmed. This is useful if there are updates, bug-fixes, or customisation. A directory on the hard disk is designated as a cache. Also in the cache area is a list of replacement files and this list is consulted whenever a link is made between Toolbook books. Certain reference codes can be intercepted and diverted to files downloaded to the cache.

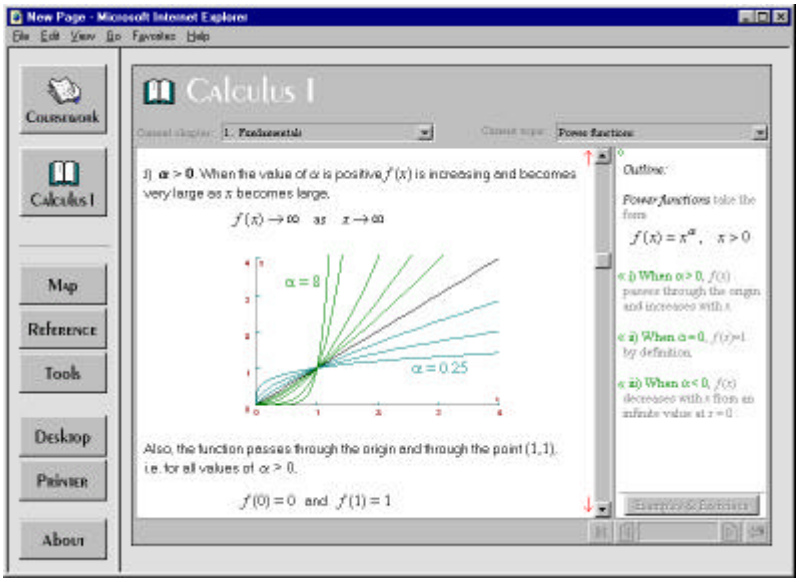

Fig. 5 A page from the Calculus text

Student Desktop

One aspect of InterMath is that students are expected to browse, collect notes and compose reports. They can do this by dragging text items onto a student desktop. This desktop can be accessed through the facility menu. The objects are chunks of RTF text copied between Toolbook recordfields.

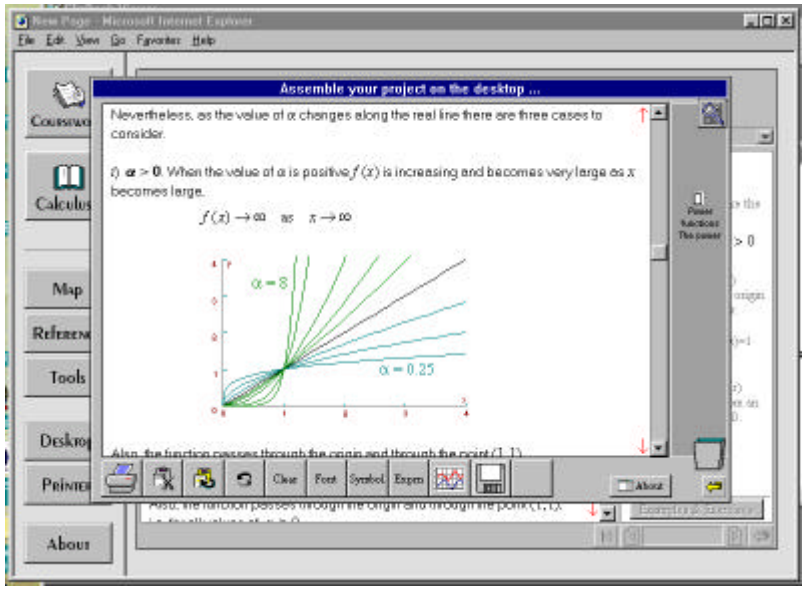

Fig. 6 'Power functions' text dragged to the desktop.

Of course, clicking and dragging in Toolbook can take place between objects in the same instances even when the objects are in different viewers. So it is quite possible to drag from a Toolbook window opened from a Web link onto the facility menu.

However, there is a problem when attempting to drag an object from the 'Calculus' instance in the right Explorer frame to the 'facility menu' instance in the left Explorer frame. In InterMath

this problem is overcome by generating a covering viewer in the second instance. The object is then dropped on a button in this viewer and is added to the associated desktop page. Because the Toolbook pages are only held once in memory, the same desktop page is shared between the two instances. Therefore the object is successfully displayed when the 'Desktop' button is clicked in the facility menu.

Extensions

A number of extensions have been incorporated to cope with the Mathematics. They are provided in routines linked in 16-bit Windows DLL files.

A suite of graphics routines (known as *KGraph*) provide dynamic two- and three-dimensional graph drawing. Graphs of mathematical functions and data can be drawn on top of the Toolbook page using Windows GDI routines, or can be embedded in the page using a VBX control. These routines work just as well in a Neuron Web-page environment as they do under Toolbook II. (This suite of routines can be obtained for use in higher education from the Web site *http://www.bham.ac.uk/CBLProjects*).

A suite of mathematical routines (known as *Kmath*) provide for the input and display of mathematical expressions in 'pretty' format, and for the comparison of expressions. These routines are mainly used for controlling experiments and for collecting answers to exercises in an open format. (This suite of routines is available from the author).

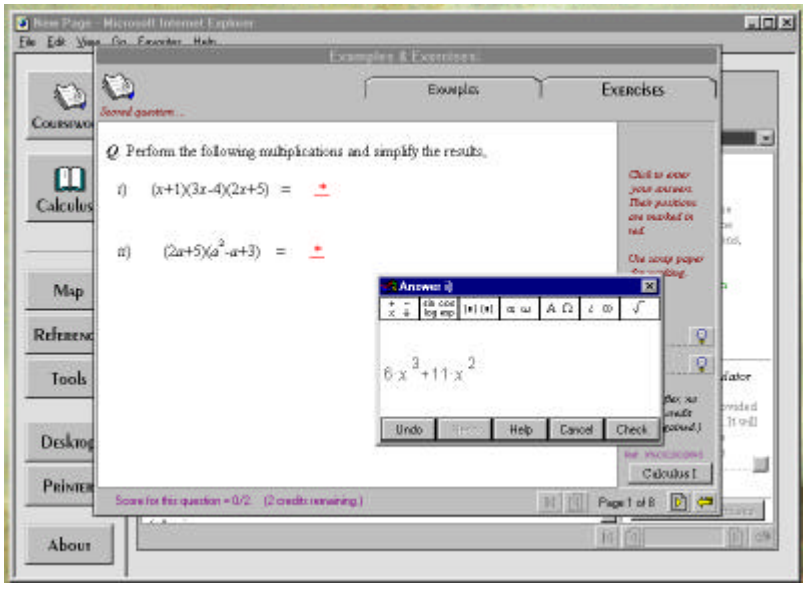

Fig. 7. Inputting mathematical expressions.

In addition, the Windows 95 file options are set so that files with the .RTF extension are opened with Wordpad, and files with the .MS extension are opened with MapleV. Thus, additional materials can be downloaded from the Web server. For example, the RTF files can contain course assignments and the MS files can contain Maple worksheets, both of which are displayed alongside the pages from the Calculus text.

The InterMath project

The project has now been running for two years and has undergone local field trials at the University. In the present phase the basic Calculus materials (which are currently only partly complete) are being set up in the manner described above ready for more extensive trials in October. It is expected students will work with the 'coursework' tutorials located on a Web server and the mathematical materials located on CDROM as described above. Nevertheless, to provide a preview, it is proposed to make both the coursework and the Calculus text materials available on the Web, but it is expected that in most cases, access in this mode will too slow for study.

Issues

The development of hybrid tutorial systems is in its early stages, and the subject of Mathematics places heavy demands on any computer-based teaching interface. Toolbook copes particularly well, and provides a refined approach to authoring. Nevertheless there are issues.

When working with the Internet Explorer - Toolbook interface it is clear that there is an uneasy alliance between 32-bit and 16-bit configurations. Of course, the differences are not of Asymetrix's making, and arise because Windows 95 is basically different to Windows 3.1, but it is difficult to communicate 32 to 16, something that is required, say, when an ActiveX control on the Web page is to send a message to a Neuron instance. At present the Web-Toolbook interaction is unfortunately one-way.

Substantive Web-Toolbook interaction can only take place on a medium-high specification Windows 95 multimedia machine. For example, Windows 95 is needed to cope with the necessary plugins and ActiveX components. Also, at least 16-bit colour graphics is needed to avoid the palette flash that intrudes when using two or more applications. Are we expecting the delivery machines to be too high a specification?

Postscript

The technology is itself moving quickly. We seem to be reaching a difficult time where the changes in technology occur over a time cycle which is less than the time it takes to author a piece of work! For example, the move to Web technology has taken place since I started authoring the Calculus materials. For this reason it is important that developers are able to adapt their work, rather than rewrite it. Thankfully, Toolbook has provided a fairly stable basic functionality over several years now, and I for one are keen to hear that future developments are to be extensions of that functionality rather than revisions..