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Student-centered Distance Learning in Health and Medical Informatics

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Abstract

Learning and teaching of health and medical Informatics is currently supported by web based material, which in the main has been derived from traditional texts. Aided by contributions from the expert community, the web site of the handbook of Medical Informatics has been developed to incorporate increased interactivity (with question and answers related to each section). This approach has proved beneficial to both student and teacher. To further increase the interactivity of the WWW we investigate the suitability of authoring tools for developing complex simulations and interactive tutorials, using an example from the area of quantitative decision support (Bayes Theorem). We propose that these tools provide a suitable platform for the preparation and delivery of collaboratively produced HMI courses, which address open and distance learning and pedagogic issues.

Keywords:

Decision support; Authorware; WWW tutorial; Bayes Theorem

Introduction

Health and medical informatics (HMI) is an emerging multidisciplinary topic at the interface between information technology and the various disciplines of medicine and health care. Van Bemmel [1] provides the following definition:

"Medical Informatics comprises the theoretical and practical aspects of information processing and communication, based on knowledge and experience derived from processes in medicine and health care"

Medical informatics draws upon the expertise of health care professionals, augmenting the decision making process with the skills required for the systematic processing of data, information and knowledge. As a result health and medical knowledge has increased rapidly, a trend that is expected to continue (Haux [2]).

Advances in information and communication technologies have already enhanced the quality of health care bringing significant economic benefits. If health care professionals are to exploit new technologies to their full potential then high quality education in HMI is required.

HMI appears on the curriculum of a number of undergraduate courses including medicine and biomedical engineering, as well as advanced postgraduate and professional development programs. The International Medical Informatics Association (IMIA) working group 1 maintains a database on HMI courses. The development of courses in this area has also prompted a TEMPUS conference on Information, Health and Education [3].

Despite a growing interest in HMI, the number of academics and students involved in this discipline is still relatively small compared to traditional core disciplines in informatics, and health care. This forces inter-institutional collaboration in order to afford viable student numbers and pools of teaching expertise, and requires more creative solutions for delivery of teaching material. For example, The European Institute of Health and Medical Sciences (www.eihms.surrey.ac.uk/pinformatics.htm) offers an MSc in Health Informatics delivered jointly by the University of Surrey, the University of Manchester Health Services Management Unit and Erasmus University in Rotterdam.

Learning and Teaching in HMI

Students of HMI tend to come from diverse backgrounds including informatics, engineering, medicine and health care professionals. As a result, their academic achievements range from those with few formal qualifications to highly trained specialists. There is also considerable variation in the mode of delivery of HMI education - some courses are delivered via conventional lectures, but many involve open and distance learning techniques.

In recognition of these challenges, the IMIA Working Group on Health and Medical Informatics Education (www.imia.org/wg1) has established recommendations on education in health and medical informatics [4]. Guidelines have been specified by the EDUCTRA Concerted Action [5]. A range of courses have been considered and learning outcomes (appropriate to health care professionals) have been defined in terms of both knowledge and practical skills.

In common with other disciplines, the Internet is increasingly being used as a medium for the presentation of instructional material in HMI [6] providing a platform, which facilitates:

- update of materials in light of new developments in the field;
- flexible delivery of resources, satisfying the diverse needs of the HMI community;
- sharing of materials between collaborating institutions.

Some web-based instructional material for HMI has been produced.

- Jenders et al [7], Shortliffe et al [8] and Musen et al [9] have provided introductory courses with access to on-line notes and sample assessments;
- Coiera [10] has produced a text with additional web based study material;
- The IT Eductra project [11] has developed comprehensive notes incorporating some simulations on CD-ROM;
- Van Bemmel and Musen have produced a Handbook of Medical Informatics [12], with web access to the material (www.mieur.nl/mihandbook/r_3_3/handbook/home.htm).

For the most part, this on-line material mirrors textual information found in books, without exploiting the full power of the medium. In an applied field such as HMI, it is particularly important that an educational web site should maintain both currency of research topic and appropriate teaching materials. The Handbook of Medical Informatics web site aims to provide up to date information sources together with multimedia demonstrations of real world systems. Thus the standard text has been augmented by:

- Self-assessment questions with feedback to the user;
- Sample demonstrations and videos;
- Interactive exercises.

HMI experts have co-operated to support development of this site by authoring some of the material and submitting this to the editorial board for review. Authors are provided with a template and instructions for information provision.
Initial interactive exercises were developed in Java. However, this proved to be time consuming and for complex exercises (such as altering the sampling parameters of electrocardiograph signals) required the author to have a high level of programming expertise. Medical experts who contributed much of the educational material, therefore required assistance from colleagues with a technical background.

Expansion and maintenance of the site is also of key importance. It would therefore be desirable if the expert community were able to add further demonstrations and videos without the need for complex coding in Java. Equally important was performance as the tutorial is intended for delivery over the web.

The work described in this paper investigates an alternative approach to courseware development using Macromedia Authorware 5 (www.macromedia.com). Authorware was chosen for implementation as it provides:

- Rapid prototype development of screens;
- Methods for interactivity using intuitive Windows techniques;
- Tools for animation;
- Easy porting of software to the web.

Authorware (for a useful introduction, see [13]) is not a complete programming language, although some coding is possible with user defined variables.

Initial tutorials developed for Electronic Medical Records (*in Dutch* [Duisterhout J. and Moorman P.W., personal communication]), indicate that this medium is more suitable for the development of instructional material by an expert community who are competent with Informatics (but who are not expert programmers). An example from the topic of *quantitative decision support* is used to describe this new development approach.

Bayesian Decision Support

The use of data and information processing to assist in the decision process is fundamental to a number of clinical areas and is therefore a key area for HMI education. Bayes theorem has contributed to many of the decision support software products in use in clinical and research environments. These include specific clinical domains, such as the diagnosis of acute abdominal pain [14, 15], and more general systems for internal medicine such as Internist [16], Quick Medical Reference (QMR) [17] and Iliad (see [12, chapter 16]). The theorem relies on the interpretation of population distributions and prior statistics to make better decisions.

Bayes Theorem requires some mathematical understanding and is covered in detail in [12, chapter 15], but experience with students suggest that learning this material benefits from:

- Interacting with these distributions;
- Simulating of the effect of changing parameters;
- Completing exercises, which provide feedback on current understanding.

Design and Implementation

To create an Authorware *"piece"*, the developer begins by producing a storyboard, using a word processor. The multimedia "piece" is then configured using a timeline, thus facilitating a sequential build up of the story. Interaction with the user (achieved via intuitive Windows techniques, such as clicking on “hot spots” or inputting text from the keyboard) ensures that the user remains in control of events. Simple animation techniques can also be easily implemented by building up a "piece" as a number of separate display elements and erasing or moving these elements as required.

The Bayesian Decision Support "piece" was developed within a framework composed of 10 subsections each of which contained a number of pages. Standard navigation buttons enabled the user to move from page to page, skip forward to the next section or retrace steps.

Use of hot text and image build up

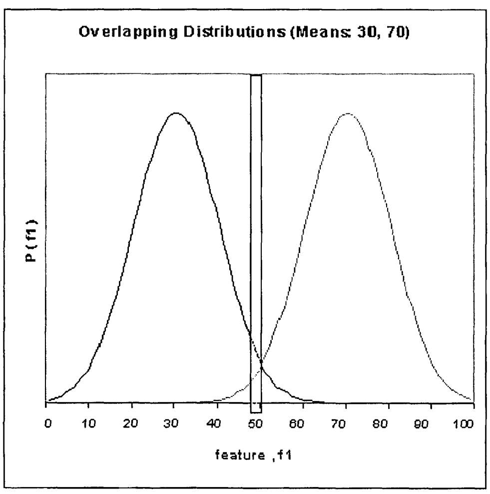

Figure 1 - Overlapping probability distributions

Figure 1 illustrates the distribution of two overlapping populations with a threshold decision line, typical of decisions taken as part of a medical diagnosis. The image can easily be placed on an Authorware canvas by importing in GIF format. In this case the left population represents systolic blood pressures (f1) of hypertensive patients and the right distribution the systolic blood pressure of non-hypertensive patients in a primary care population [12, p242]. Because the distributions overlap, then a decision threshold will result in one of four classifications:

- *True positive*: percentage of people who have the disease, for whom the model makes the correct decision
- *False Negative*: percentage of people who have the disease, for whom the model makes the incorrect decision
- *False Positive*: percentage of people who do not have the disease, for whom the model makes the incorrect decision
- *True Negative:* percentage of people who do not have the disease, for whom the model makes the correct decision

The decision threshold in this example results in True Positive=97.0%, False Positive = 2.6%; True Negative = 97.4%; False Negative =2.1% .The relationship is best illustrated by highlighting the appropriate geometric area when the user selects the required category. This can be achieved by overlaying an appropriately shaded image (produced using a drawing package such as Paint Shop Pro) and aligning with the base image. One overlay image is required for each scenario. The user interacts with the image by clicking on an x-axis ordinate, which is defined as *hot text*, and is provided with the appropriate feedback as the threshold changes, resulting in changes of the numeric variables.

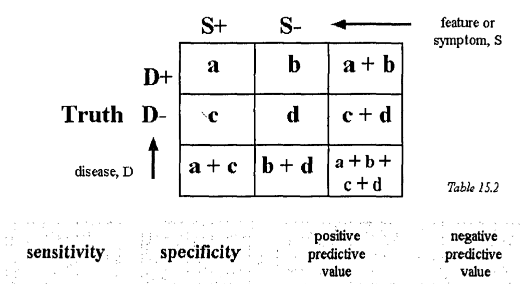

Figure 2 - Variables may be used to permit reuse of elements

Use of variables

If values are used for each category then the performance of the decision model can be given using metrics such as sensitivity, specificity, positive predictive value and negative predictive value. In order to provide a general solution, *variables* are used to represent the input values and the appropriate metrics computed by Authorware. With little further effort a series of examples can be presented, enabling Q&A sessions to promote active learning.

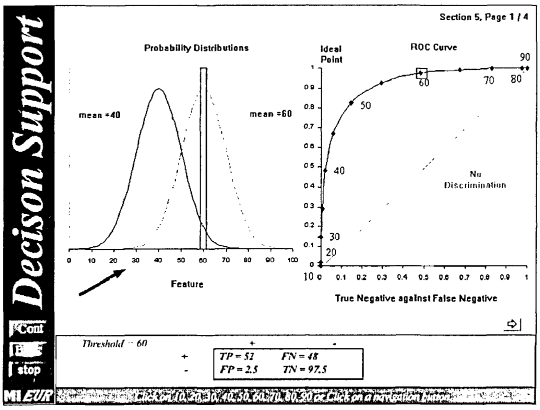

Figure 3 - Overlapping distributions and their relationship to the ROC curve

Hot spot axis

The percentage of False negatives and False positives cannot be minimized independently. If various thresholds are chosen then the relationship can be represented on a Receiver Operating Characteristic (ROC) curve. Associating the threshold with a co-ordinate on the ROC curve is difficult to explain in plain text but can be readily achieved using Authorware. The user can click at a threshold on the distribution and the corresponding ROC co-ordinate is highlighted, see Figure 3. In the example above, the complete axis is specified as a hot spot - the co-ordinates of the spot clicked are then determined and used to highlight the associated ROC co-ordinate. This greatly simplifies the coding effort but necessitates the production of multiple pre-prepared images.

Animation

The relationship between false negative and false positive is complicated by the fact that the locus of the ROC curve is dependent on the separation of the distributions. Animation can usefully demonstrate how the ROC curve moves from the diagonal towards the ideal point (0,1) as the overlapping distributions move further apart. This animation sequence was developed as an incremental prototype. Each section was tested for correctness of computation and program flow both forwards and backwards.

Evaluation

The tutorial was evaluated (for correctness) by a decision support expert and appropriate changes implemented. Crucial to the success of any project is a well-structured and developed evaluation phase that will monitor and evaluate the degree to which the deliverables (in this case the learning materials) are achieving their set objectives. Evaluation of the CBT training materials is on going. A checklist based on CERT (Courseware Evaluation and Review Tool) [18] is currently being used to assess the nature and extent to which the HMI student community is responding to the materials. There are many factors, which need to be taken into account when considering the fitness for purpose of learning technologies to facilitate effective learning. The current evaluation is considering:

- Content
- Learner activities
- Feedback
- Achieved learning
- Motivation
- Structure and adaptability

Following examination of the full evaluation findings any necessary adjustments will be made.

Discussion and Conclusions

Authorware has limited computational structures and it was therefore decided to compute the distributions and ROC curves in Microsoft Excel and pre-plot the curves. This means that the Authorware "piece" is dealing primarily with clickable images and limits the versatility of the tutorial (but increases performance as computation and graphics update have been predetermined).

In addition to providing interactive tutorial material, Authorware can be used to simulate the operation of existing software by capturing screens and providing explanatory text for the user. The Bayesian Decision Support "piece" illustrates how a commercial decision support package (Iliad, copyright Adam software) uses Bayes theorem for decision support.

Compiling an Authorware "piece" does not require the same computing rigor as a true programming language. Nonetheless, appropriate use of programming techniques (e.g. use of variables) provides for more efficient re-usable visual coding elements. Interactivity is easily achieved but requires the user to engage in robust initial design. Likewise, simulation is relatively straightforward, but time consuming as elements to be erased must be separately specified. Developing a "piece" as a number of integral units (subsections) enhances performance as the web client can be loading the next subsection, while the user is working on the current section.

Initial evaluation of the system indicate that overall students appreciate the flexibility offered by this computer-based teaching medium and particularly value the "question and answer" sections. Recognizing the benefits associated with the use of computer-based systems the authors are currently working to establish on-line support for students within the HMI discipline.

To-day's employers have articulated the need for students to improve their communication and team-working skills. Small group intra-institutional project work would provide an ideal platform for developing competencies in these areas. Network-based tools that facilitate Computer Supported Collaborative Learning (CSCL) are particularly useful for the flexible interaction required in distance learning situations. At the University of Ulster, final year students on the MSc Educational Technology (a part-time course where the 3rd year is dedicated to the preparation of a research-based dissertation) use Ezboard [19] to provide a forum for exchange of information and ideas. By employing similar technologies to support inter-institutional collaboration, the authors intend to provide a comprehensive frequently-asked questions section driven by the needs of the community.

Based on our experience with the Bayes tutorial, we propose that the use of authoring tools is preferable to the Java based method for providing WWW based interactive simulations. It facilitates and encourages participation from the expert community who are competent IT users but have not been trained as programmers. However with the Authorware approach, production and alignment of graphics is time consuming and development time may not be substantially reduced. (The current version of the decision support tutorial is available at: www.infj.ulst.ac.uk/~ccjg23/interest.html. Click on Authorware Bayes Tutorial near the bottom of the page.)

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