COMPUTER ASSISTED LEARNING MODULES FOR SATELLITE METEOROLOGY INTERPRETATION

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ABSTRACT

Satellite-observed sequences of cloud patterns are, when properly interpreted, of inestimable value to meteorologists in assessing the development and movement of significant weather systems, especially over areas where conventional meteorological observations are scarce. Courses for training meteorologists and other staff in the interpretation of satellite imagery have traditionally been paper-based, but unfortunately such techniques have significant limitations in their ability to represent dynamic processes such as evolving weather events. This paper describes why, conversely, a computer assisted learning (CAL) approach is well suited to such applications, and goes on to describe the development of CAL modules for training staff in satellite interpretation, and the design principles adopted. The CAL developed makes extensive use of digital video sequences of satellite images, together with a flexible navigation system. An example of one of the modules is presented with details of the module's design, construction and interactivity described.. Some feedback from the first student users of the CAL is also presented.

KEY WORDS

Computer assisted learning (CAL), satellite interpretation, multimedia, meteorology.

1. INTRODUCTION

The science of meteorology is concerned with understanding the atmospheric patterns that produce our weather, and applying fundamental physical laws to the atmosphere in its current state to predict its future evolution. To accurately represent this current state, detailed information is needed on how atmospheric pressure, temperature, moisture and winds vary with location and altitude. Unfortunately, the vast oceanic areas that surround Australia (and indeed, extensive areas of the continent itself) are largely devoid of the meteorological observations needed to accurately describe the atmosphere, and to feed the advanced mathematical models that help predict future weather. In these areas, satellite-observed images of cloud, and in particular, sequences of images, are of inestimable value to meteorologists in assessing the development and movement of significant weather systems (such as low pressure areas, high pressure areas, and fronts). Properly interpreted, such imagery shows not only the location of significant weather systems, but also the locations of atmospheric stability and instability; where significant flows of unusually cold or warm air are occurring; the structure of high and low level wind-fields; and where rapid intensification of weather systems may be taking place, or about to take place. Various techniques for interpreting satellite imagery exist (e.g. Weldon and Holmes (1991), Conway (1997) and various internal technical notes).

The Bureau of Meteorology's Training Centre (BMTC) routinely conducts in-house training courses on satellite imagery interpretation for pre-service meteorologists, operational forecasters and overseas meteorologists. The aim of these courses is to teach learners how to identify different atmospheric features from the appearance of the imagery. Although digitally-based movie loops of satellite imagery have been available for over 10 years, course materials for interpreting the imagery and sequences have traditionally been paper-based. However, such methods have significant limitations in their ability to represent dynamic processes such as evolving weather events, whereas PC-based Computer Assisted Learning (CAL) modules are well suited to studying such phenomena. For this reason, the small CAL Development & Ongoing Education section of BMTC has for more than three years been developing CAL modules for teaching satellite imagery interpretation, using the *Asymetrix Toolbook* multimedia authoring package. A number of training modules have been developed, or are under development. This paper describes the design and structure of such CAL modules, and presents preliminary feedback from students.

2. THE ADVANTAGES OF A CAL APPROACH TO SATELLITE IMAGERY INTERPRETATION

The greatest limitation of paper-based training methods for satellite imagery interpretation is that they attempt to represent complex sequences of events via just a few sample images. Further, the sample images produced tend to be of rather poor quality, because good quality hard copy images are expensive to produce. By contrast, well designed PC-based CAL offers the following advantages:

1. The quality of the images is good, and not dependent on expensive photo reproduction techniques;
2. The imagery comes in digital form, and is easily enhanced to demonstrate particular features;
3. Reproduction is simple (copying a CD-ROM);
4. Extra examples are readily added. In meteorology, every case is different, so from a student's point of view, the more cases they see, the better. CAL approaches make it easy to create a framework whereby extra examples are readily added. Students soon have a veritable library of examples at their disposal;
5. Students can set their own learning pace and depth, accessing more detailed information as necessary. Similarly, the same modules can be used for training staff with different starting levels of knowledge; and
6. The experience more closely resembles the "real environment", in this case of a meteorological office.

3. THE MODULES

A number of modules have so far been developed. These include identification of basic cloud types from different types of satellite imagery, cyclogenesis (i.e., the process by which low pressure systems develop and intensify), and a variety of other features and phenomena. In the remainder of this paper, the Cyclogenesis module will be used to illustrate key design points. Cyclogenesis is an extremely important meteorological process, frequently leading to the onset of heavy rain and gales. An example is the rapid and powerful low pressure development that took place off the coast of New South Wales this August, with the onset of flood rains and gales over Sydney and much of the remainder of eastern New South Wales.

The ability to predict in advance the development of a low pressure system at a time when there is no existing system, with the only clues provided by the cloud patterns, is a most useful - and highly satisfying – skill. One example of cyclogenesis, so-called 'frontal' cyclogenesis, is illustrated in Figure 1. In Figure 1(a), the bright line of cloud in the left of the image is a pre-existing frontal cloud-band; the bulge on the rear (left) edge of this feature at 'C' is a typical precursor to cyclogenesis. About 36 hours later (Figure 1(b)), the band has evolved into the characteristic 'inverted comma' (s) shape of a newly-formed cyclone; the bright 'lumpy' cloud to the left of, and somewhat removed from, this feature, indicates a strong cold air incursion over Tasmania and southern Victoria. An animation consisting of hourly images would show much more clearly the processes by which the system developed than the two widely spaced images shown here.

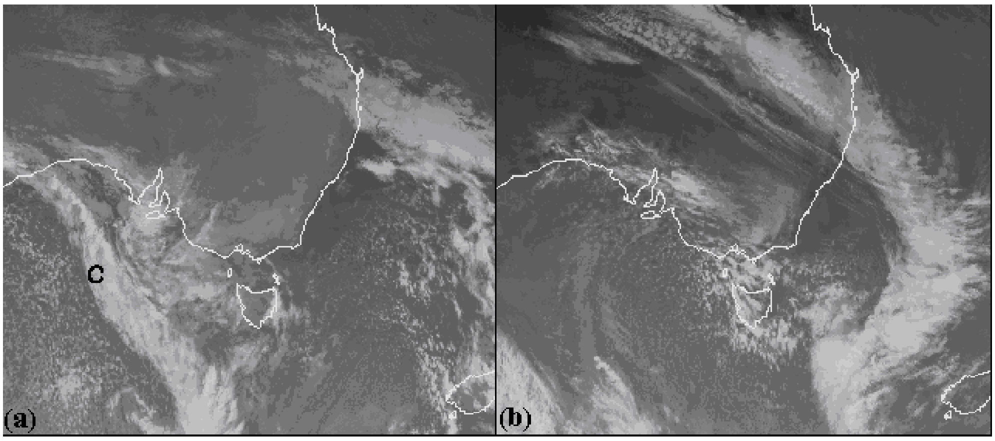

Figure 1: Infrared satellite images showing conditions (a) prior to cyclogenesis taking place, and (b) some 36 hours later, after a significant mid-latitude cyclone has developed.

4. DESIGN CONSIDERATIONS

Satellite meteorology is very much a subject in which different features interact together in complex ways, and is ideally suited to the flexible navigation environment that CAL can provide. An overriding consideration in the design of the CAL modules was therefore that the user be given as much control over what they see as possible, and that they be able to move easily from one subject to another. The other primary design consideration was the need for the module to be flexible, in the sense of being able to fulfil a variety of training needs. Specifically, modules are to be used:

- as a stand-alone training resource (where students work through the material at their own pace);
- as a classroom resource (used in the formal teacher-student training sessions);
- as a consolidation tool, to reinforce learning imparted by 'conventional' training methods; and
- to train different categories of staff, whose levels of starting knowledge and depth of understanding are different.

The design **strategy** employed for each module follows the three 'critical guidelines' for multimedia software design pertaining to the 'Situated Learning' model described by Herrington and Oliver (1997). These guidelines are (taking the cyclogenesis module as an illustration):

1. Establishment of a physical environment, reflecting the way knowledge will ultimately be used:

In most modules it is intended to simulate, as far as possible, the environment of a typical meteorological office. Tools typically available to the meteorologist include satellite imagery of different types, and image loops on a PC screen, together with the ability to overlay weather observations and meteorological fields on the imagery.

2. A non-linear navigation design to preserve the complexity of the real life setting.

The starting menu allows the learner to start anywhere in the module and to move easily from any one section to any other. This mimics the real-life situation, in which different types of weather situation require different types of information.

3. A large number of resources (i.e., different pieces of information, such as images, loops, etc) are used to enable sustained examination from a number of different perspectives.

In the cyclogenesis module, the resources may be grouped as follows:

- conceptual model – physical representation of how cyclone development is believed to occur – including a text description and animation;
- comparison with real-life example, by overlying the animated conceptual model over real-life data;
- examples – satellite imagery illustrating many different cases of cyclone development;
- case studies – in-depth studies of some of the examples, including imagery, charts, atmospheric cross-sections, and observations.

Figure 2 summarizes the resources and navigation system of the cyclogenesis module.

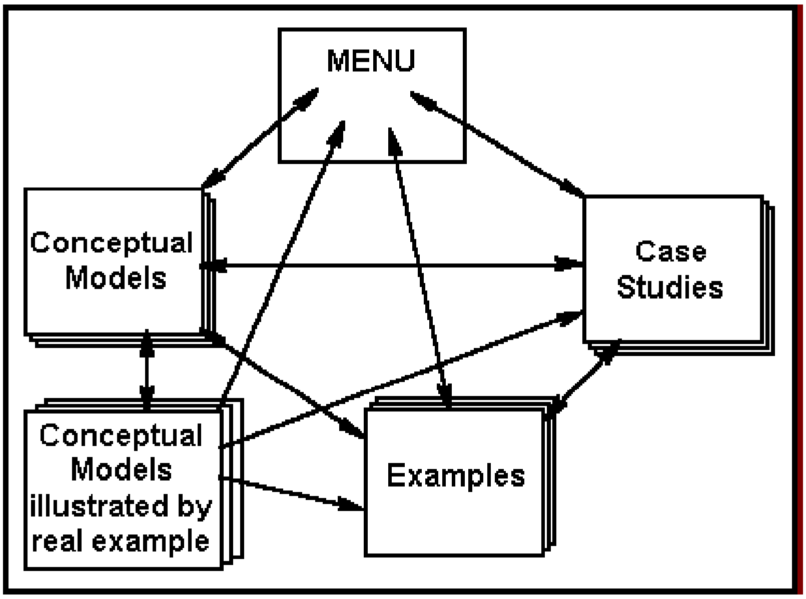

Figure 2: Schematic illustrating the grouping of resources in the cyclogenesis module, and the flexibility of the navigation system such that the learner can move flexibly around the module.

5. DESIGN AND CONSTRUCTION PROCEDURE

Design and construction of the modules has proved to be an iterative process, similar to that described by Harper and Hedberg (1997). The procedure was: an initial assessment of key learning points for students was made, and the modules designed, taking into account the desired learning outcomes, the information and examples to be included, the students' existing level of knowledge, and how the material was to be structured. (A complicating factor here was the disparate academic backgrounds from which different groups of students are drawn). An appropriate presentation strategy was then proposed, including a description of the initial navigational and feedback links. Details of the original design often needed to be modified in the light of this strategy. Finally, the details of the interactivity were built in, linking different pieces of information in a flexible way, a process that often required amendments to the ideas developed in the initial presentation strategy. For instance, as development of a module proceeded, inadequacies in the ability of that module to demonstrate key concepts frequently emerged, requiring reassessment – and to some extent redesigning – of the module. On the other hand, as authoring skills improved, it became possible to incorporate more ambitious design features that could not be considered at an earlier stage of development.

Programming for the modules was via *Asymetrix Toolbook's* Openscript language. As mentioned earlier, it was important in each of the modules to have a substantial number of examples available, and in order to facilitate this process, a 'builder' program was developed in *Asymetrix Toolbook.* This program automatically positions and names images and videos on the screen, sets font sizes and colours, etc, and was designed so that all a developer need do to add an example is to change certain key parameters on a single screen. In this way, extra examples could be added quickly and easily, with a consistent format ensured.

6. EXPERIENCE TO DATE

The completed modules have been, and will continue to be, used in in-house satellite interpretation courses. They have also been used to help train meteorologists from developing countries, such as the South Pacific islands and southeast Asia. Though a formal evaluation has not yet been undertaken, some of the modules have already benefited substantially from the incorporation of feedback received on an *ad hoc* basis from previous users. In general, these previous users have been supportive, even enthusiastic, about the CAL modules, with the following being typical of their comments about using the modules:

- They were happy to use the PC-based 'electronic course' materials – some were so enthused they took copies of the modules away with them after the course!
- Although for some, the flexible navigation system initially required some getting used to, students soon came to consider that this feature, along with the uncomplicated user-interface, are important features.

From a trainer's point of view, we also noted (with some satisfaction) that learning seems to be quicker, in that, on a given topic, students can reproduce knowledge in a shorter period of time, and also ask more advanced questions. At the same time, the social aspects of learning (e.g., informal discussion between two or more students) seem not only to have been retained, but enhanced.

On the down-side, not all teaching staff have been comfortable with using the CAL modules as a teaching resource, mainly reflecting a reluctance among these staff to embrace the new technology, or to be convinced of its value. These staff have adopted the view that they have always carried out their instruction in their own (traditional) way, and will continue to do so.

One other benefit of the project that should be mentioned is that it has provided inspiration to meteorologists in other countries to develop CAL modules for studying notable meteorological phenomena in their own regions. BMTC has hosted meteorologists from New Zealand, Japan, the Philippines and Taiwan eager to learn the techniques and to develop modules relevant to their own countries.

7. FUTURE PLANS

A formal evaluation of the key CAL modules will be carried out during the in-house training courses of 1999, most likely taking the form of a survey of student users (for the smaller modules, it is considered that informal feedback will suffice). On the basis of these assessments, the modules will be reworked to address the feedback received. The improved modules that result from this procedure will naturally continue to be used within BMTC's teaching structure, but it is also planned to disseminate them to the Bureau's Regional Offices via CD-ROM (with future updates provided through an internal Web page). The rationale for this is that forecasters in the Regional Offices will benefit from having specific examples of phenomena to hone their interpretive skills on, or refer to. The modules will also continue to be used as Australian input to international training projects, and indeed, will be made freely available to the international meteorological community.

It is also intended to develop further modules, and to extend the current methodology to the presentation of other meteorological subjects, including weather radar interpretation. We are also currently looking at incorporating a note-taking facility.

8. SUMMARY AND CONCLUDING REMARKS

The development and implementation of CAL modules for the interpretation of satellite imagery has been described. It has been argued that a CAL approach is ideal for the teaching of satellite imagery interpretation, which is very much a visual skill and one where access to many examples improves learning times and depth. Preliminary experience shows that learning has been faster and more complete with this system compared with traditional, paper-based methods. The methodology also sits well with the increasing emphasis on open and distance-learning programs, and has already been included in international programs.

9. ACKNOWLEDGMENTS

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