Int. J. Engng Ed. Vol. 18, No. 3, pp. 331–336, 2002
Printed in Great Britain.
0949-149X/91 $3.00+0.00

Developing and Evaluating a Novel Technique for Recording and Asynchronous Delivery of Lectures*

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A novel and inexpensive technique for recording the handwritten, audio and video information in a lecture is described. The recording may be streamed to a standard, free, multimedia player over any Internet connection (from 56kbaud modem upwards). In being able to handle graphical and mathematical material this method is particularly suited to the delivery of engineering lectures to off-campus students. An evaluation of student impressions of the technique is presented, and conclusions are drawn.

INTRODUCTION

ENGINEERING IS a field driven by rapid technological changes. Practising engineers, therefore, constantly need to update their skills and knowledge. Through their involvement in research and awareness of the latest developments in the field, university engineering departments are well placed to meet the professional engineer's need for 'lifelong learning'.

Universities (with some exceptions, such as the Open University in the UK and the University of Phoenix in the US) are, however, structured to teach a resident and coherent student population. Practising engineers requiring lifelong learning are, in contrast, much more diverse in terms of location, education and availability; they need to choose modules according to their current knowledge and work commitments. Timetabling constraints alone make this difficult for a traditional university to accommodate.

Internet-delivery of learning material can help in addressing this difficulty [1, 2]. However, this generally requires the lecturer, in addition to delivering material to students in a lecture theatre, to author additional Web-based material for remote delivery. This is a duplication of the lecturer's effort and, in requiring research-active staff to employ unfamiliar authoring tools, a major obstacle to meeting the needs of potential students. Given the current lack of support for mathematical notation in Web browsers [3], authoring technical material is especially time-consuming.

While, in time, universities may well restructure around an electronic and student-centred educational model, this will be a protracted process. In the meantime, if remote students are to access the expertise of these institutions, the authors believe that Web-based delivery of material should, if possible, employ authoring and communication techniques familiar to the *lecturer*, while offering a geographically remote student a learning experience close to that of an on-campus equivalent.

The combination of a pen and a whiteboard (replacing chalk and blackboard) is a good example of a well-proven, familiar and flexible piece of authoring technology. Unlike HTML, it permits lecturers to present mathematical notation and diagrams quickly, easily and on the spur of the moment. This contribution, therefore, describes work undertaken by the authors to evaluate whether it was possible to capture the content of a whiteboard-based lecture for subsequent delivery via the Internet.

RECORDING WHITEBOARD, AUDIO AND VIDEO STREAMS

Accomplishing this task required a degree of research and experimentation. It was decided to use a *Mimio* whiteboard digitiser [4] attached to the whiteboard—this recognises the movement of the pens on the board using ultrasonic sensors. The lecturer's voice is recorded using a wireless microphone and a moderate quality video recording is captured using a webcam. The three data streams are recorded by two applications running simultaneously on a general-purpose PC (or

* Accepted 17 August 2001.

Fig. 1. Recording equipment.

laptop). This equipment is shown in Fig. 1 (it is worth noting that the laptop was, by a considerable margin, the most expensive item required).

A SMIL [5] file synchronises the three data streams for playback using the freely available RealPlayer [6] application (see Fig. 2)—this combination of these three streams is unique to the best of the authors' knowledge—representing, for example, a substantial step forward from the achievements of Rosbottom [7].

Although audio may be encoded at as little as 4 kbits/sec, 16 kbits/sec was found to give a more pleasant and natural voice playback. Similarly, there is a bandwidth/quality trade-off for the video capture, 80 kbits/sec being found to be sufficient. The streams may be accessed from a local disk drive (including a CD ROM), a standard web server or—ideally—a RealServer, which will automatically tailor video and audio quality to fit the available connection bandwidth. As a consequence, the lecture recordings may be viewed via a standard telephone modem.

TESTING

Quantitative results

An undergraduate unit (Introductory Electromagnetics), attended by around 70 second-year Electronic Engineering students, was selected to test the concept described herein and all 22 lectures given (by one of the authors) were captured. Using the technique described in the previous section, this process was completed without significant difficulty and all lectures are available from the project's website [8].

Problems encountered were largely trivial ones, such as flat batteries. Perhaps the chief difficulty was that the whiteboard eraser, if not pressed firmly onto the whiteboard, would sometimes not fully erase writing in the recording application. This would manifest itself in occasional fragments of unwanted writing remaining visible upon playback of the recording. As the lecturer learned to be slightly more deliberate in his use of the eraser, this problem was almost completely avoided.

To gather quantitative feedback on the usability of the lecture recordings, two groups of the undergraduate students were asked to fill out questionnaires on one particular lecture. One group (of 12) attended the actual lecture (along with 50 classmates) and the other group (of 12) watched the lecture recording at a later date. Past examination results were taken into account when selecting the members of each group—in order that the average, highest and lowest academic ability in each set were close to identical.

Both groups were asked to state their agreement

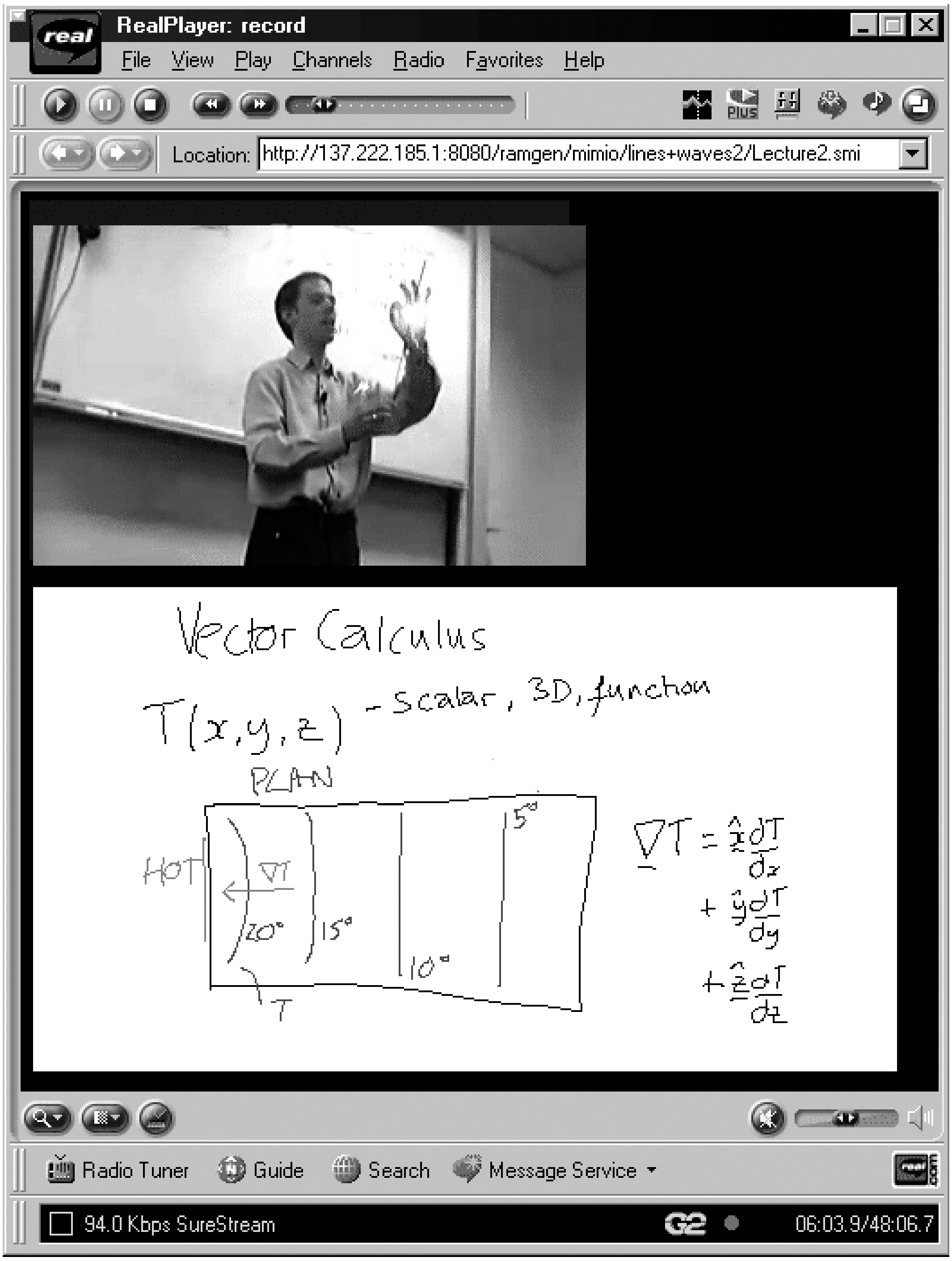

Fig. 2. Client application replaying a recorded lecture (the lecturer is using a sparkler to give a demonstration of divergence in a vector field).

(or disagreement) with a set of 9 statements—these being based on the normal undergraduate-feedback forms that these students regularly complete. The statements were chosen to be equally applicable to both the 'real' and recorded lectures. The mean responses are shown graphically in Fig. 3: 100% indicates strong agreement with the statement, 50% indicates agreement, 0% neutrality, and −100% indicates strong disagreement.

The nine statements referred to in Fig. 3 are as follows:

1. 'The lecturer was clearly audible': both sets of students strongly agreed with this statement (scores of 91% for the recorded lecture and 95% for the real one).
2. 'The lecturer wrote legibly': both sets, on average, agreed with this statement (scores of 41% and 79%). However, one student watching the recording actually disagreed with the statement and three others were undecided. The students watching the recorded lecture clearly found the writing too small at times. This is a factor of

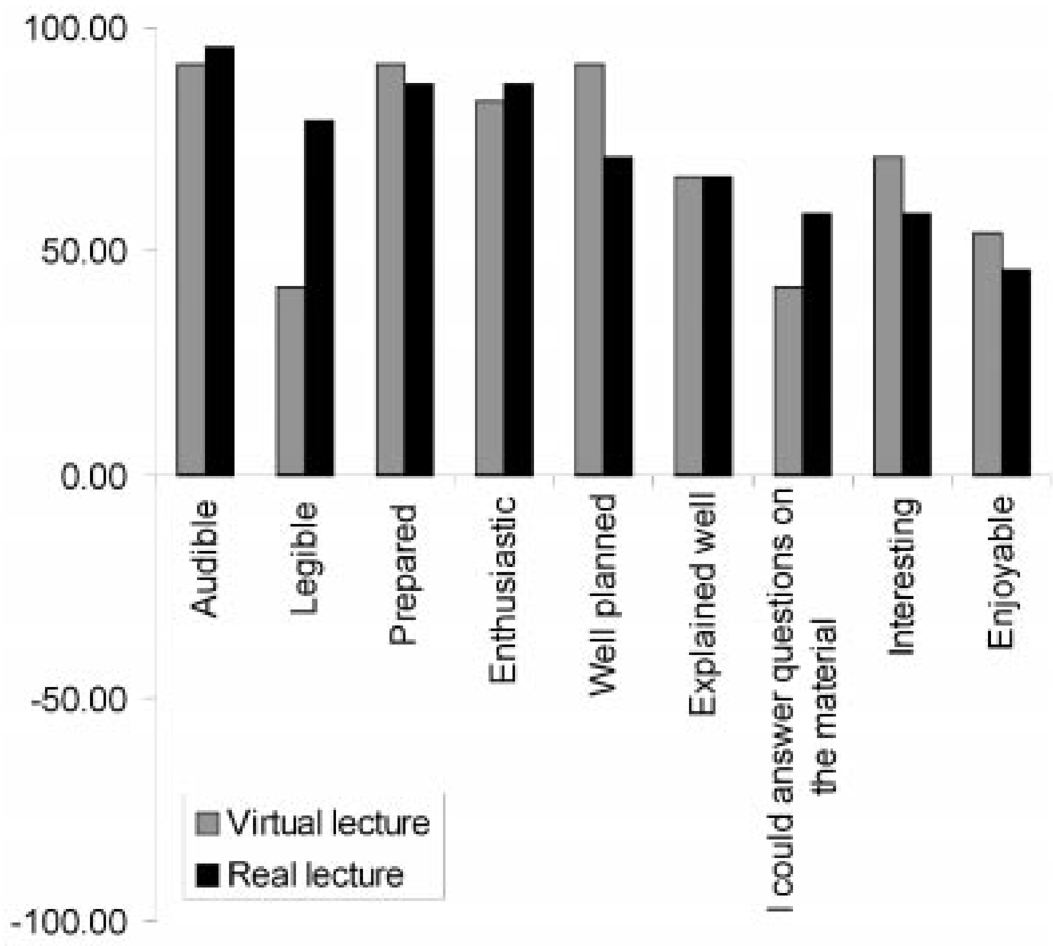

Fig. 3. Questionnaire responses (real and virtual lectures).

which the lecturer should have been more aware.

3. 'The lecturer was well prepared': both sets agreed strongly (only small differences between sets, ratings being 92% and 88%).
4. 'The lecturer was enthusiastic': both sets agreed strongly (no real differences between sets, with mean responses of 83% and 87%).
5. 'The lecture was well planned': both sets agreed strongly. Those watching the recording seemed to agree slightly more strongly—with a mean rating of 91%, against 71% for the real lecture.
6. 'Difficult topics were explained well': both sets of students agreed fairly strongly (with identical mean ratings of 67%).
7. 'I would be able to answer questions on the material': both sets of students agreed. However, those watching the recording seemed slightly less confident (giving an average result for the recorded lecture of 41%, with one student disagreeing with the statement). As there were no significant differences in academic ability in each group, this may have been because of their lack of familiarity with learning in this environment. On inspection, the notes taken during the lecture by both groups of students seemed similar and typical of what would have been expected.
8. 'The lecture was interesting': both sets of students were, on average, in agreement with this statement.
9. 'The lecture was enjoyable': both sets of students were also, on average, in agreement with this statement.

For statements 8 and 9, the students watching the recording were slightly more positive and this may be attributable to the novelty value of watching the lecture on a PC. There is no evidence that students found the recording, for example, boring or difficult to engage with.

Six additional statements were posed to the students watching the lecture recording. These statements were specifically targeted at the technology used in the recording process. The responses are shown in Fig. 4.

1. 'The audio was clear': a mean score of 79%, indicating strong agreement (several students commented on the much lower level of background noise compared to a real lecture).
2. 'The video was good quality': on balance, the students seemed to agree with this; however, several commented—quite correctly—that it was not particularly high-quality video. Hence, a result of 30% was achieved.
3. 'The video was useful': strong agreement (62%).

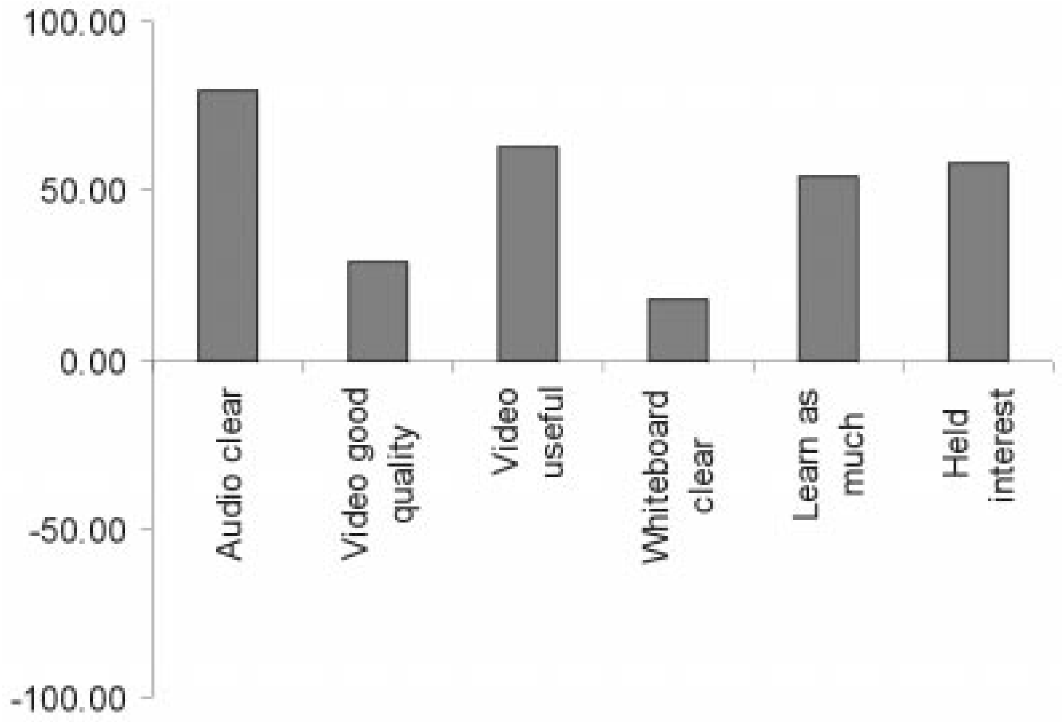

Fig. 4. Additional questions regarding the virtual lecture.

Students commented on the value of seeing the lecturer's hand movements.

4. 'The whiteboard was clear': marginal average agreement was expressed (18%), 7 students agreeing and 2 disagreeing (one strongly). As described above, this was largely attributable to the lecturer's writing being slightly too small.
5. 'I could learn as much as at a normal lecture': good agreement expressed (a score of 54%).
6. 'The lecture held my interest': again, good agreement expressed (58%).

To summarise the results of these questionnaires, both groups found the lecture interesting and enjoyable. They felt that the lecturer was clearly audible and that the explanation of topics was equally good in the real and recorded lectures. The legibility of the recorded handwriting was felt on occasions to be less impressive, due to the lecturer's handwriting being too small.

Interview results

In addition to filling out the questionnaires, the students were also interviewed by an independent party. Some of the questions asked were as follows:

Q1. Do you feel that you learned as much from this lecture as you would have done if you had been in the live audience? How did it compare generally with a face-to-face lecture?

All the students said they had learned the same amount as they would have done in a face-to-face lecture.

Q2. Did you stop the recording at any point? If so, why? If not, did you want to stop it? If so why?

All the students watched the recording straight through without stopping. Three-quarters thought there was no need to stop it, as the lecturer went over things slowly enough for them to take everything in and take notes. They commented that they might want to stop the recording where the lecturer went very fast, and, as an example of where this might be necessary, all of them mentioned lectures which consist of sequences of formulae that follow rapidly one after another.

Other students said that there were times when they felt like stopping the lecture when they did not understand something. However, in the end, they did what they would do in a normal lecture, which was to wait to see if the lecturer would repeat or clarify the point before asking a question. In this case, all the points were clarified eventually.

Q3. What did you think of the audio and video quality? Was the video important?

All students said that the audio quality was fine. Opinions about the video quality were more mixed, but they were agreed that the quality did not matter very much. Two students said that all they needed to see was where the lecturer was pointing on the board and when he was demonstrating things with his hands. Other students agreed that it was not essential to see the video, but one of them said he found himself watching it because it gave him some context and body language.

In general, the group watching the recording felt that they had learned as much as in a real lecture and several commented that the ability to pause and review the lecture would compensate for being unable to ask questions.

CONCLUSIONS

The new technique described in this paper allows a lecturer to give a lecture using a whiteboard and to have the written, audio and video content captured for later delivery over the Internet. This process requires little or no extra effort from the lecturer.

The whiteboard capture has been shown to be successful—although the lecturer must take extra care to write legibly—and especially useful in engineering subjects where much lecture material is mathematical and graphical in nature. The audio quality was found to be entirely satisfactory and, while available bandwidth limits the quality of the video stream, video from a webcam was found to be quite sufficient to communicate the lecturer's body language. The recorded lectures may be distributed on a CD, for example, or streamed over practically any Internet connection.

While face-to-face contact between student and lecturer is obviously important, it is suggested that, along with various techniques for web-based assessment, the technique described herein could play a valuable part in addressing the needs of students (particularly engineers requiring life-long learning) who cannot attend timetabled lectures.

Acknowledgement—This project was funded by the Education Committee of the University of Bristol.

REFERENCES

1. K. C. Gupta, The future of higher education, *IEEE Microwave Magazine*, **2**(1), (June 2000) pp. 52–56.
2. F. Bodendorf and P. H. Swain, Virtual universities in engineering education, *International Journal of Engineering Education*, **1**(17), (2001) pp. 102–107.
3. The W3C Math Working Group (http://www.w3.org/Math/Activity).
4. The Mimio whiteboard digitiser (http://www.mimio.com).
5. SMIL (http://smw.internet.com/smil).
6. RealPlayer (http://www.real.com).
7. J. Rosbottom, Canned lectures: Something gained, something lost, *6th International ALT-C Conference*, Bristol, UK (1999).
8. This project's website is http://www.een.bris.ac.uk/freda.htm.

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