Video Tutoring of Mathematics for Computer Science

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Abstract.

As computer science was developing as a discipline it was often a part of a mathematics department and the students of computer science studied the usual first year mathematics course. At our university, students traditionally enter a specialist discipline specific degree (rather than a more general faculty based program with a "major in a discipline" structure). As a result, the mathematics for computer science students in first year has evolved into two mathematics courses which are designed and run specially for them.

For many years the computer science students did not study the usual first year mathematics which could be variously described as a combination of pre-calculus, calculus and linear algebra or as engineering mathematics. They took a discrete mathematics course which now includes an introduction to coding. As the demand for IT related courses has increased, several versions of computer science, software engineering and IT / multimedia programs have been developed. Innovative delivery includes completely online delivery (through Open Learning Australia, OLA) and a modified online delivery with on campus face to face support of Learning Facilitators at our Vietnam campus. Online delivery through a further platform for off-shore courses are planned with the Global Universities Alliance, GUA.

In response to a request from computer science, a new "Mathematics for Computer Scientists" course was designed and run in first semester 2001 in Melbourne and also in the (different dates) first semester in Ho Chi Minh City. This course (one quarter of the semester's work) includes calculus and an introduction to linear algebra. It is designed to give the students some of the mathematical background necessary to do graphics.

With the delivery in Vietnam of both Discrete Mathematics and Mathematics for Computer Scientists, we started to explore how the teaching and learning of the mathematics courses for computer science students, particularly at our Ho Chi Minh City campus, could be enhanced with some videos prepared by us. At a offshore campus, teaching in English, a video includes audio which gives the students the opportunity to hear a native speaker discuss the topic. Videos have been used widely in teaching: see the comprehensive paper "Virtual Collaborative Learning" by Sipusic et al. (1999).

For the Discrete Mathematics course, the last section on coding is not the traditional textbook material and so we videotaped a presentation of the ideas by following a structured set of examples. For the Mathematics for Computer Scientists course, we selected several topics to illustrate applications to computer science. Our experience with the implementation and student feedback (via survey form) is discussed.

Mathematics Subject Classification (2000): 97U80, 97C80

1. Introduction

The mathematicians at RMIT have been very active with the development of innovative courses and teaching. For about a decade, a particular interest has been the usage of the software packages Maple and Mathematica in teaching and research as we fundamentally change the way we teach. Our incorporation of Maple has included some first year courses [1-3] but mostly higher year courses [4-9]. Since 1998, our mathematics program has included computer laboratory sessions (usually using Maple but also other software such as Matlab toolboxes or commercial software Finite Element Method packages – as appropriate) for almost every course.

Recently we have been developing some of our courses (starting with the first year courses) for online delivery with various delivery platforms. The Discrete Mathematics course for the computer science students has been designed and successfully delivered completely online (with very positive student feedback) for several years [10]. An outline of this course is given in the next section of this paper.

Videos have been used widely in teaching and two comprehensive papers [11,12] have extensive references. The first paper discusses educational issues and instructional technology, producing some guidelines for the application of technology to education and introduces a new methodology called Tutored Video Instruction, TVI (as developed and implemented at Stanford University). The second paper introduces a virtual implementation of the TVI approach and uses a virtual collaborative learning model. These two papers are highly recommended reading. The key element is that a tutor-facilitator leads a small group who watch and frequently stop the video to discuss the subject matter. This engagement of the student with the material is most important and can be achieved in various ways (other than the traditional tutorial). In our experience with Maple assignments we have found that one way of the encouraging "engagement" is to provide paper and pencil tasks linked with the Maple tasks [8].

We started an exploration of how the teaching and learning of the mathematics courses for computer science students, particularly at our Ho Chi Minh City campus, could be enhanced with some videos prepared by us. One attractive feature is the audio which gives the students the opportunity to hear a native speaker discuss the topic. Also, topics not widely treated in textbooks can be supported. We chose topics of two kinds. Firstly, the coding theory material (see sections 2 and 3 of this paper) and the Gaussian elimination material (see sections 4 and 5) is concerned with examinable work. Secondly, the rest of the Mathematics for Computer Scientists video-tape presents topics which are motivational in that the material per se is not on the course but indicates a computer science application. For example, the log function is used.

An attractive feature of the TVI approach is that the video used is just a video-tape of a lecture. We quote William Sutherland (see the Preface of [12]):

'… the "authoring task" for [TVI] is simple: videotape an existing (even boring) lecture. There is no "multi-media" software extravaganza required to create interesting and visual course content to retain the interest and involvement of a solo student. The [TVI methodology] depend on the dynamic interaction of the participants for the involvement and attention of the students rather than the polish of the course material. A tape to teach even a small number of students is an affordable undertaking.'

The TVI video-taping can be contrasted with the usual video production where a team of people carefully script a performance that is video-ed by a full production unit. This can result in a very polished video, but it is expensive! The video is often supported by structured teaching materials (for example, see [13]). We want to achieve the low cost of TVI, but suspect that some accompanying teaching material and/or tasks could enhance the learning environment.

The production of a video to support the teaching of (the last section of) the Discrete Mathematics course is discussed in section 3 of this paper. In September 2001, RMIT started teaching at its new Vietnam Campus. The new course MA263 -- Mathematics for Computer Scientists was offered in the first semester of operation at RMIT Vietnam in Ho Chi Minh City. This course includes calculus and an introduction to vectors and matrices. It is outlined in section 4 and the video(s) and trialing of the video is discussed in section 5 of this paper.

2. Discrete mathematics

MA159 is the fundamental discrete mathematics course which services students of Computer Science and Information Technology. The subject consists of three major parts: Logic; Graphs and Trees; and Algebra, Languages and Coding.The course had its genesis in an earlier subject known as Computing Foundations, which was taught by the then Department of Computer Science to its own students. In 1988 that Department asked the Department of Mathematics to take over the subject and to present it in a rigorous mathematical way.

The Logic part of the subject is foundational, in that it guides students to a more systematic approach to problem-solving. It has direct applications in Proof of Program Correctness, the design of Expert Systems, and the analysis of algorithms by means of finding solutions to Recurrence Relations. Indirectly it contributes to a more structured way of thinking on the part of students, which helps to make them skilled and highly competent professionals.

The section on Graphs and Trees presents one of the most fundamental tools for representing concepts in computing and communications. It covers methods of finding optimal and sub-optimal algorithms, finding planar representations of graphs (which is linked to the development of screen graphics), converting expressions between infix, prefix and postfix forms, efficiently encoding languages, and many other applications.

The final part of the course, on Algebra, Languages and Coding, introduces algebraic structures and their applications in computing and communications. It demonstrates the use of algebra in language theory, and then develops systematic methods of encoding data for the accurate transmission of messages. The material on error-detecting and error-correcting codes is barely covered in the standard text books on Discrete Mathematics. It is an area of study with links to information security, where RMIT mathematicians have been developing a great deal of expertise and obtaining much international recognition in recent years.

The subject MA159 is now very widely taught (under various names) by RMIT's Department of Mathematics. It is a very successful and popular course delivered on-campus as well as online through Open Learning Australia (OLA), and has also been packaged for delivery through the Global University Alliance. It has been studied by students majoring in Mathematics, Computer Science, Information Technology, Information Security, Psychology and Intellectual Disability, and

General Science. Its online presence is constantly being improved through the incorporation of new technology to produce more effective displays of the key mathematical concepts in Discrete Mathematics. In Vietnam, Discrete Mathematics is delivered electronically but with a lot of face-to-face support.

3. Discrete mathematics and our first video(s)

We have a lot of experience teaching discrete mathematics both on-campus and online (with very positive student feedback). Since this course was running in Vietnam, we decided to produce some videotape support for the part of the course that is not well covered in most of the textbooks: the coding theory. As this was our first attempt at producing videos, we readily accepted help from our Learning Technology Services group. Key items of advice were that, firstly, the video needed good lighting with a carefully controlled small area of whiteboard which was to be written on. Secondly, the audio needs special attention so that a quality audio reproduction can be achieved. The services of an experienced camera person was offered and accepted and we produced the videos of six "sessions" following a structured set of examples. These were copied and fitted onto one normal 180 minutes VHS video tape which was sent by courier up to RMIT Vietnam.

Due to various small time delays which were cumulative, the video arrived in Vietnam at the start of the last week of teaching. This was a busy time and, in the event, the video was not used by the students. However the mathematics Learning Facilitator, Dr Nguyen Phuong Anh, and some of the teachers of English viewed the video to provide some (positive, neutral and negative) feedback:

+ the explanation is quite clear and understandable
+ it is possible to use the video
0 the learning facilitators can do all of "that", and be interactive
- the rhythm was too slow
- the board/screen (focus) is too small.

The positive comments are welcome, but the negative comments were ones that we concurred with and addressed in our second attempt at video production.

The teachers of English are familiar with the use of video, so there is a wealth of experience to draw upon. However it appears that the video used in English courses are usually production standard (that is, professional standard) and we are trying to avoid the high costs of this type of video. In the teaching of English, the video can be used for a variety of purposes and to seed several learning tasks: this does not easily transfer directly to mathematics. Nevertheless the provision of coordinated and structured tasks is worthy of consideration. It is used with the videos produced at UTS [13] and this approach was, to some extent, used with our Gaussian Elimination video as discussed below.

The "neutral" comment regarding the learning facilitators doing it (and interactively) is a compliment to the academic staff. However we are endeavoring to provide "additional" specialist support for online and remote delivery.

The approach taken in producing the video material followed a research and development cycle whereby we first developed materials based on our own ideas and examples of good practice, evaluated these materials as used in a teaching situation, then incorporated the results of this

feedback into the redevelopment of the materials for the second teaching experiment. Such an approach has been widely used in mathematics education research projects where the focus is on practical teaching situations. Gravemeijer [14], for example, uses the label "developmental research" and describes this type of research and development activity as "purposeful tinkering."

4. MA263--Mathematics for Computer Scientists

In response to a request from computer science, a new “Mathematics for Computer Scientists” course was designed and run in first semester 2001 in Melbourne and also in the (different dates) first semester in Ho Chi Minh City. This course (one quarter of the semester’s work) includes calculus and an introduction to linear algebra. Amongst other things, it is designed to give the students some of the mathematical background necessary to do graphics. The course was delivered electronically in Vietnam. The Blackboard course information link gave, in great detail, the Teaching Schedule, Course Content (tied closely to a prescribed text), Assessment Tasks, Exam Information and Extra Tutorial. The students attend the campus and so the Learning Facilitators provide a lot of face-to-face support and teaching with small groups (of size about 12 to 15).

5. The videos for MA263

Mathematics for Computer Scientists, MA263, has been taught by us face-to-face on campus in Melbourne and (for some sections) also in Vietnam. In class, several applications to computer science were mentioned or treated briefly. These include projections and homogeneous coordinates (for graphics), binary search counts and information theory (where the log function occurs) and algorithmic complexity (Cramer’s rule and Gaussian elimination). The students were enthusiastic about these “digressions”. The students in Vietnam even went so far as to comment that the discussion of applications in a mathematics class was a new experience for them.

Given that these applications are not usually found in the texts for this first year level mathematics, we decided to produce videos dealing with these applications. We did not follow the TVI methodology in that we taped a special performance for the camera with a few of our video group providing an audience.

In regard to our first videos (on coding theory), we agreed with the feedback that the focus of the camera on a small part of the whiteboard gave a clear picture of high quality, but the video was very static and boring. We decided that our second attempt would be with the camera back further so that a larger part of the whiteboard would be available and the lecturer would be seen with some animation as the lecture was presented. We also decided that we would use our own analogue video camera and do the whole of the production ourselves. This resulted in videos that were much more lively, although the quality of the picture and the sound was lower. We used a TV monitor and decided that the video and audio quality was of an acceptable standard (given the equipment used and the fact that this was our first “in-house” production).

We produced a 16 minute video on each of binary search counts and information theory (where the log function occurs). The topics are NOT on the course. We also produced a 45 min video introducing the Gaussian elimination method (which is on the course) and extending the discussion to a mention of Cramer’s rule and a discussion of operation count

For the Gaussian elimination, a handout was produced (using Maple) – a condensed version is reproduced in Appendix 1 (with the original Maple section formatting removed and the content of most of the sections also removed). Note that a number of exercises are included in this handout.

5. The MA263 videos viewed

5.1 Observations

The videos we produced could be improved with some extra lighting and the audio also needs improvement primarily by more care by the lecturers to avoid low volume comments! We will investigate the use of radio mikes to help with audio quality. We did use a TV monitor and the quality seemed adequate (even though it could be better). These problems very greatly exacerbated by the conditions under which the videos were viewed in Vietnam. Initially a multimedia projector was used in a room with very high light levels (and no blinds to control the brightness). The lighting and audio were disappointingly poor. When we used a room with blinds and a large and high quality TV, the brightness and audio volume could be adjusted to give acceptable reproduction. Our final session used a small TV monitor in a bright room and the presentation was again compromised. This affected the students' responses to our survey.

In the future, careful scheduling will need to be employed to ensure that the viewing conditions are at their best (with a room with blinds and a large and high quality TV). Another difficulty experienced on this occasion was the compressed time frame: the visiting professor was on campus in Ho Chi Minh City for one week. Thus each class used three of their five sessions for the week participating in the video sessions. This was less than ideal since an optimal use might have used about four (partial) sessions over a four week period.

To ensure careful observation, collection of formal and informal feedback and to develop the collaboration between our campuses, it was useful to have one of our Melbourne team on campus in Ho Chi Minh City. However since the visiting professor also appeared in some of the videos, it did lead to sessions where the observing professor was the presenting professor in the video being viewed!

Thus a number of "environmental" factors contributed to a strong contamination of our evaluation of our first trial. This is not an unusual circumstance: Lesh [15] comments that mathematics education research has increasingly come to recognise that "students, teachers, classrooms, courses, curricula, learning tools and minds are all complex systems – taken singly, let alone in combination." We cannot evaluate the effectiveness of certain teaching experiments in isolation but need to consider the impact of the various other environmental factors involved.

5.2 Student feedback

We initially designed a student survey form of 24 items which was a modification of a 44 item survey [8] we designed and used to investigate student attitude to the Maple component of another course. However we decided to reduce this to 3 test items plus "Any other comments". This minimalist approach was taken for two reasons. Firstly, the videos were going to be used atypically (for the first time) during a one week period. Asking the students to also complete a comprehensive feedback survey form seemed a little unreasonable. Secondly, the more detailed survey would have

been an overload because of the English used (even though all of the course in Vietnam is conducted in English). This form and the summary results are given in Appendix 2.

The feedback on Question 1: "I found the video interesting" could be characterized as mixed negative / neutral. On Question 2: "The video helped me understand the mathematics better" the responses were "balanced". A number of negative responses can be understood given the conditions and the "environmental contamination" (as discussed above). Many of these problems are expected to be addressed in a future usage of videos.

Although not distinguished in the feedback survey form, informal feedback indicated that there was less enthusiasm for the videos on the binary search counts and the information theory introduction than for the Gaussian Elimination video. The former videos were on non-examinable (but motivational) material. However our experience at our Melbourne campus has been that this material was well received by the students. Part of this difference in response might be cultural, but part is due to the difference in student backgrounds: students in Melbourne (unlike those in Ho Chi Minh City) have undertaken some study of probability at school before coming to university. The video discussing an information theory introduction uses a sum of terms like p log(p) to find an expected number of bits of information. The students in Vietnam were not as well prepared to be able to appreciate the discussion (and the video production team was unaware of this – but are aware now).

The responses to Question 3: "I found it useful to stop the video and discuss things" were fairly positive. This was despite the fact that the presentation was rushed: one session with the 2 videos on the binary search counts and the information theory introduction meant that there insufficient stoppages of the tape to encourage student engagement with the material. We did a little better with the Gaussian elimination material which was spread across two sessions (and had an accompanying hand-out). However we would normally expect to follow more closely the advice in [11] to have small groups and stop the video (very) often and it appears that the students appreciated this point..

Conclusion

The two mathematics courses (Discrete Mathematics and Mathematics for Computer Scientists) have a very good record with on-campus and online delivery. We identified areas (applications) that are not usually covered in the standard texts and produced some videos – initially for use at RMIT Vietnam. The production and the viewing environment can be improved. The trial reported here was influenced by the presence of a professor involved with the video presentation being present at the Vietnam trials – an atypical occurrence. The students were critical of some aspects of this video support, but we believe that the difficulties can be resolved. Although we did not quite follow the TVI approach [11,12], it certainly was our inspiration.

The costs associated with the high level production of videos (such as in [13]) provides part of our enthusiasm for an approach which is closer to the TVI approach. The TVI approach has also been very successful. We believe that some videos can be developed to successfully provide some specialist support for courses being delivered online or otherwise remotely or "flexibly". The work needed to undertake innovative teaching developments is difficult without the kind of support that we enjoy from our colleagues – in Melbourne and Ho Chi Minh City – and we thank them.

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Appendix 1 – Condensed handout for Gaussian Elimination, Cramer's rule and operation count

RMIT UNIVERSITY

MATHEMATICS — MA 263

Solving linear equations - solve A x = b
Gaussian elimination

Example - manipulate equations

Example - row operations (Gaussian Elimination)

Multiple Right Hand Sides

Exercise - different RHS

Exercise - determinant

Exercise - Gaussian elimination

Another Exercise - Gaussian elimination

Inverse matrix

Operation Count - Optional

for Gaussian elimination

for Cramer's rule

The comparison

multiplicative operation count

Gaussian elimination: $\frac{n^3}{3}$ about 400 for n = 10

Cramer's rule $(n+1)!$ about 40,000,000 for n = 10

Since the computational time depends on the multiplicative operation count, Cramer's rule takes an enormous amount of time to compute and so is NOT used in practice.

Factorial n for large n

EXERCISE:

Appendix 2 - VIDEO-TUTORIAL FEEDBACK

NOTES:

- The video tutorials were done during the week starting **Monday 24th June 2002 (3 50-min sessions for each group of about 15 students).**
- Total number of survey forms handed out: **24.**
- Total number of completed survey forms received: **17 (71% response).**
- Total number of students in MA2070: **37 (2 groups).**

Please place a tick against each statement according to the scale strongly disagree (SD) up to strongly agree (SA). There is also space to make a comment after each question.

1. I found the video interesting

SD				SA
1	8	7	1	0

Comments:

The quality (picture, sound) of the video is bad. The video must be clearer	(6 students)
The screen is too small	(1)
The video provided more knowledge about maths applications than the textbooks	(1)
Why do we watch the video while having a professor standing next to us?	(1)
Just so so	(1)

2. The video helped me understand the mathematics better

SD				SA
0	6	7	4	0

Comments:

Worse than reading a book or teaching	(1)
Need more maths agorithms that can be applied in Comp Sci	(1)
The sound is not clear. Sometimes have to guess what the video is about	(1)
Some of the things the lecturer said are beyond the students' capability to understand	(1)

3. I found it useful to stop the video and discuss things

SD				SA
0	4	4	4	5

Comments:

It's good to stop the video and discuss, as there may be some problems that are hard to understand	(4)
Sometimes useful	(1)
A little bit useful	(1)
Discussion makes it difficult to follow the video (???)	(1)

4. Any other comments?

Comments:

The talk in the video is boring. Want to go to sleep	(1)
The video should have sth funny or some applications in real life	(1)
Can't ask when the video is being played	(1)
Need more activities (not just listen to the lecturer)	(1)
Prefer face to face lectures	(1)
Need a better video	(1)
Should have video tutorial weekly/bi-weekly because it is useful	(2)