Signal Processing Education using a New Self-Directed Learning Methodology

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Abstract – This paper describes initial results of a project involving the development and application of novel signal processing education techniques. The work is part of a collaborative program between the School of Electrical Engineering and Telecommunications at the University of New South Wales (UNSW), Australia, and the Department of Electronic Engineering at the National University of Ireland, Galway (NUI Galway). The paper describes experiences to date with a new software tool, “VCPlayer”, for capture, and self-paced replay of live lecture content in a digital format. This tool has been trialled in both undergraduate and graduate signal processing courses at UNSW, and will shortly be used in further trials at NUI Galway. A detailed analysis of student evaluations following the UNSW trial is reported. The enhancements in student learning and positive feedback from both students and lecturing staff reveal the VCPlayer to be an extremely promising tool for self-directed learning.

Keywords – signal processing education, learning methodologies.

I INTRODUCTION

a) Background to the Research

In recent years, there has been much greater emphasis on the use of technology in support of education, across a wide range of disciplines, in science and engineering, and in the humanities. The authors are currently engaged in a project for the development and application of new tools and strategies for signal processing education, with a particular emphasis on addressing the difficulties that the teaching of certain topics in signal processing presents (for example, multi-rate DSP). The project is part of a collaborative program of research between the School of Electrical Engineering and Telecommunications at the University of New South Wales (UNSW), Australia, and the Dept. of Electronic Engineering at National University of Ireland, Galway (NUI Galway).

Elements of the project include the following:

1. The use of substantially common lecture notes in UNSW and NUI Galway.
2. The development of novel software techniques for capture and dissemination of course material, and the use of these tools across both sites.
3. Surveys of students and staff to establish the value of the techniques.
4. The use of distance learning technology between multiple sites.

This paper discusses the development of novel software techniques for lecture capture and dissemination, as well as results from initial trials of these techniques at a single site.

b) Focus of this Paper

Teaching signal processing courses, whether undergraduate or graduate, whether fundamental or
advanced, always poses challenges. These include the communication of difficult mathematical concepts, maintaining students' attention span, the difficulties of catering for individual student needs in a large classroom environment, different paces of student learning, lack of fluency in spoken and/or written English where there is a large international element in a class, and the loss of continuity due to missed classes. As a result, it can often be the case that only a small percentage of students are able to grasp the key concepts at the time of the live lecture delivery, while the remaining students are left to develop this critical understanding in their own time, with whatever assistance they can find and comprehend.

Educational technology has offered a range of new avenues for alleviating this problem, including Java applets [1] and PDF capture of tutorial discussions [2]. A recent example is the eClass automated note taking service for capture and access in the classroom [3], which has shown that multimedia capture of lecture content at the time of delivery seems to encourage student review activities that are considered helpful for performance.

In [4], the authors described the “VCPlayer” (“Virtual Classroom Player”), a new tool for either capturing live, or pre-recording both the lecturer’s image and annotated slides in digital format using a tablet PC or an electronic whiteboard. This paper extends the previous work by reporting on the results to date of student and staff experiences with the new tool at the University of New South Wales (UNSW), and the related methodology for its use in both undergraduate and post-graduate courses. The VCPlayer substantially augments a video-only approach, which is insufficient to communicate many signal processing concepts if the lecturer’s speech is not linked to graphical and symbolic written material. Previous studies [5] have shown that in practice most annotations are attention marks (e.g. highlighting in a different colour), which provide critical linkage between spoken context and the slide content. We believe that the recording of such rich non-persistent information as video and dynamic annotation can be used to improve self-directed student learning or as preparatory material for more focused lecture/tutorial sessions, offering new possibilities for course delivery. Further, unlike existing reports of some similar tools [6], we have applied the VCPlayer extensively in signal processing teaching and describe an undergraduate and graduate evaluation herein.

In Section II, the main elements of the VCPlayer tool (developed in Java) are introduced, while Section III describes evaluations that have been carried out so far. The results of these evaluations are presented in Section IV, while Section V discusses plans for future work. Conclusions are drawn in Section VI.

II VCPLAYER DESIGN

Development of the VCPlayer was carried out in the University of New South Wales [4]. There are two principal modes of usage of the tool - initial capture of lectures and related material, and playback.

a) Acquisition of Media Streams and Capture Interface

VCPlayer recording can be performed with any PC-based video capture (e.g. a webcam) and any pen-based input device, for example a Tablet PC, electronic whiteboard, eBeam or i-Pen. Lectures can be recorded either in the lecturer’s office, or during the live class, optionally with student participation. The recording process is simple; the lecturer is able to start, stop, pause or resume the simultaneous and synchronous recording with a familiar graphical interface. Upon completion of the recording, the recorded contents can be rapidly prepared for distribution through normal CD, DVD or other media tools.

Through use of the Java Media Framework, which allows the synchronization of multiple time-based media streams, the VCPlayer ensures that the temporal relationship between the captured video and dynamic annotation streams is preserved during playback. In our trials of the VCPlayer, we have mainly made annotations on pre-prepared PowerPoint slides, however blank slides can be used instead, or blank slides can be interleaved with the pre-prepared slides, as desired.

b) VCPlayer Playback

The aim of the VCPlayer is to let students experience the classroom environment as if they were in the real classroom. To this end, the student should be able to view both the lecturer and whiteboard contents simultaneously as shown in Figure 1. The lecture view window can be overlaid on top of the annotated slides in a number of predetermined positions using the toolbar at the bottom of the VCPlayer, or alternatively, it can be positioned to the right of the annotated slides, to avoid obscuring the slides. Unlike some existing interfaces [5], these alternative views can be selected by the student in real time, during playback.

c) Capture of Live Simulations

Because the VCPlayer captures whatever is being displayed on the electronic whiteboard or Tablet PC, if desired the lecturer can switch to other applications, such as MATLAB or Internet-based demonstrations, during the lecture. Thus, simulations and demonstrations can be seamlessly captured, and annotated, for future playback, as seen in Figure 2.
III CASE STUDIES OF SELF-DIRECTED LEARNING IN SIGNAL PROCESSING

So far, the VCPlayer and related methodologies have been trialled in undergraduate and postgraduate lecture programmes at UNSW. Further trials will be carried out at NUI Galway in the next academic year. This Section discusses some of the generic issues associated with each class group used for trials, and comments on some of the case studies that have been used so far.

a) Graduate Issues

Typical graduate-level courses within the Faculty of Engineering at UNSW are 3-hour lectures, once per week for 14 weeks, and are mainly held during the evening. Of the students, roughly half are international, and nearly half will be from industry. Some international students have difficulty understanding graduate material presented in English if it is their first lengthy period spent outside their native country. Students with full-time employment in industry tend to arrive very tired, have difficulty maintaining their concentration span through these long lectures, and tend to be on campus for these classes only.

Both groups of students are dependent on teaching resources that they can review (and/or use to prepare with) outside of the lecture times, and this dependency is even more important when complex signal processing concepts are being presented, requiring repeated review by the students. When English comprehension is an issue, repetition of lecture material can be highly beneficial.

It is normal in UNSW graduate classes, which tend to have a smaller size than the undergraduate classes, that students ask many questions during the lecture, making classes quite interactive. This leads the lecturer to give more verbal and written comments, which the students like to retain for future reference. This fact was taken into consideration when planning graduate classes that made use of the VCPlayer. Accordingly, a mix of pre-recorded and lecture materials captured live were employed in the design of the graduate course.

b) Undergraduate Issues

In undergraduate courses at UNSW, two or three classes of 1-2 hours duration each are held during normal daytime hours each week. Class sizes are large, normally ranging between 75 and 150+ students, depending on the level of the course. Informal surveys and anecdotal evidence has suggested that undergraduate students often find that their individual needs and learning styles are not easily accommodated by these large classes. Furthermore, undergraduate students are generally observed to spend a large proportion of the class time reproducing the lecturer’s writing, in the knowledge that these notes will be main resource they will study for their course assessments. As a result, students miss important moments of their lectures that could significantly improve their fundamental understanding of the content.

These problems motivated the introduction of a new approach, aided by the VCPlayer, in which students were required to watch a pre-recorded lecture before attending a discussion class that replaced what would have been a traditional lecture. The objective was for students to arrive at the discussion class with both a basic understanding of the material and specific questions on it.

c) Specific Examples

As noted already, certain topics in signal processing cause particular difficulty for students (especially at undergraduate level), over and above the generic issues identified above. A good example of such a concept that students have been observed to find difficult initially (and some never grasp it) is the change of sampling rates in multi-rate system analysis. In particular, writing equations for sampling rate changes, producing example
magnitude spectra at different points in the systems, 
and introducing modulation as part of a multi-rate 
system regularly cause trouble for students. In this 
instance, despite efforts by the lecturer to explain 
the individual symbols and spectral details in a step-by-
step manner, even students who can take notes, 
maintain concentration and follow the lecturer's 
exploration, will often still need to revisit 
the explanation to obtain the required depth of 
understanding. Numerous texts on multi-rate systems 
are available, but without guidance from an 
experienced teacher, students informally report that 
these resources alone are not sufficient.

Other topics that the authors have observed students 
having difficulty with include the study of random 
signals and random processes, and some topics in 
speech processing including linear predictive coding 
and auditory masking. These observations from the 
authors' past experience have helped in the selection 
of some of the topics used for initial trials of 
VCPlayer.

IV EVALUATION

a) Objectives and Procedures

The objective of this evaluation was to gauge the 
impact of the VCPlayer-based course design on 
students' learning, the influence on their learning 
behaviour, and the extent of their acceptance of it as 
a mode of delivery.

In the undergraduate class (Signal Processing and 
Transform Methods), 10 lectures were given in the 
traditional live format, and two lectures were 
distributed as pre-recorded CDs with a discussion 
class replacing the live lecture. The two pre-recorded 
lectures covered the topics of multi-rate systems, and 
random processes.

In the postgraduate class (Speech and Audio 
Processing), seven lectures were given in the 
traditional live format, five lectures were distributed 
as a pre-recorded CD with a discussion class 
replacing the live lecture, and one lecture was given 
in the traditional format but recorded using the 
VCPlayer during class and distributed for revision 
purposes after the class. The five pre-recorded 
lectures included linear predictive coding, speech 
compression, time-frequency analysis, auditory 
masking, and audio coding. The lecture recorded live 
and distributed afterwards was on speech analysis.

The main evaluation was conducted using a survey at 
the conclusion of the courses, which was completed 
by 71 undergraduate students and 24 postgraduate 
students. The survey comprised 16 questions in 
multiple-choice format (mainly a 5-point Likert 
scale) and an open-format question for general 
comments.

The survey results are summarised below, with the 
16 questions grouped and discussed under a number 
of headings. Major findings are reported, with more 
detailed breakdowns of responses for some of the 
questions asked.

b) Results – Learning Experience

Among the students surveyed, 96% used the pre-
recorded CD at least once, and 79% of CD users 
used the CD several times in the course of their 
learning. The students found that the pre-recorded 
lectures on the CD (plus a follow-up discussion 
class) were an acceptable alternative to a live lecture 
(73% agreed). The majority of students (85%) agreed 
that having the pre-recorded CDs improved their 
learning experience (fewer than 4% of the students 
disagreed).

The proportion of students who felt that they learnt 
more through the use of the CD was encouraging. 
62% of undergraduate and 63% of graduate students 
agreed or strongly agreed that they learnt more using 
the CD-based lectures. Around 30% of undergraduate 
and 29% of graduate students were unsure, however, only 8% disagreed (see Figure 3 for 
detailed breakdown).

![Figure 3](image-url) 

Figure 3. Results for statement, “I felt that I learnt more 
by using the CD-based lectures, than with live lectures 
alone”.

c) Results – Convenience and Effectiveness of Pre-
Recorded CDs

Responding to the use of pre-recorded lectures with a 
follow-up discussion class, students were generally 
very positive. Some specific results include:

- The majority of both groups of students felt 
that it was more convenient for them to learn 
via a pre-recorded CD than attend a live 
lecture. The figure was slightly higher for the 
post-graduate class, perhaps reflecting the fact 
that many of them were attending lectures 
after finishing work, and therefore the 
availability of adequate “offline” lecture 
material was of greater interest.

- 66% of undergraduate students found that the 
pre-recorded CDs were a more efficient way 
to learn than attending live lectures, however 
54% of postgraduate students were unsure of 
whether there was a difference in the learning 
efficiency of both teaching methods.
• 65% of undergraduate students and 58% of graduate students felt strongly that pre-recorded CD lectures were just as interesting and engaging than live lectures. At the same time, 19% of undergraduate students and 21% of graduate students thought that the pre-recorded CDs were less engaging than a live lecture, and similar numbers were unsure.

• 75% of students felt that they would be more likely to watch 100% of the lectures if they were on a pre-recorded CD than attend live lectures with no CD.

Students generally felt they had more opportunity to ask questions in classes having watched the pre-recorded lectures than in live lectures without the CD, though this was less so with the graduate students. Around 55% of the students liked the opportunity to review the pre-recorded lectures on CD before the live lectures, because live lectures generally produce a more challenging learning environment. Of the student population, 96% felt that the use of the pre-recorded CD allowed them to learn at their own pace.

d) Results – Pre-Recorded vs. Live Lecture Capture

Students were also asked their preference between having a live lecture first and receiving a pre-recorded CD afterwards, or receiving a pre-recorded CD first and having some discussion in class later (but having no live lecture). The results are summarised in Figure 4 and suggest that there is roughly an even division of opinion on these two methods. Note, however, that in both cases, a CD is provided.

![Figure 4](image-url)

Figure 4. Pre-Recorded + Discussion vs. Live Lecture + CD afterwards.

c) Additional Points

Another interesting result from the student survey was that 80% of students recommended the use of pre-recorded CDs (followed by class discussions) for other courses within the school, although undergraduates were marginally more enthusiastic for this than postgraduates (81% vs. 75%).

As well as student feedback, staff also drew some useful pointers from the trial. In order to optimise the use of VCPlayer, well-developed PowerPoint slides that lend themselves easily to annotation are a distinct advantage. In most cases, most cases staff had such slides prepared already, so there was minimal extra preparation required. Furthermore, while there is an overhead in the preparation of the CD, this task only needs to be carried out once and once recorded, a lecture can potentially be re-used as a resource from one year to the next.

The ease of use of the VCPlayer has contributed to wider adoption by staff from across faculty. In particular, since its introduction in UNSW in 2005, 6 out of 30 academic staff members in the School of Electrical Engineering and Telecommunications are using the tool in their lecture courses, and there is interest from faculty members in other disciplines as well. An additional benefit was that staff occasionally wanted to use the review functionality of the VCPlayer in order to check that specific details had been fully explained. Additionally, the VCPlayer can be used in "ad-hoc" mode, e.g. if a lecturer is going to be absent because of, say, attendance at a conference, the VCPlayer can be used to produce a CD for a "missed" lecture, so that scheduling of additional lectures is un-necessary.

V FURTHER WORK

As noted above, the initial trials of VCPlayer presented in this paper are part of an overall collaborative programme in signal processing education between UNSW and NUI Galway. Further work in this programme will include the following.

a) Use of CDs only

While studies to date have involved modules with a mixture of pre-recorded and live lectures, the use of pre-recorded CDs only (no live lectures at all) is currently being evaluated for a third year module with a class of size 110 at UNSW. Results from this evaluation will be reported in a future paper.

b) Use of VCPlayer in Other Sites

In the next academic year, it is planned to use VCPlayer to support teaching of signal processing at undergraduate level at NUI Galway, and to conduct further surveys on the outcome, and staff at NUI Galway have already reviewed the tool, as well as CDs pre-recorded at UNSW, in preparation for its introduction. While many of the issues would be expected to be common to all student groups, there are some differences between the two sites which may provide different insights into student experience with VCPlayer:

• NUI Galway will provide an opportunity to use VCPlayer with a smaller class than at UNSW.

• Students’ lack of fluency in English is an important factor in comprehension of the
material, and one of the motivators for the development of VCPlayer. This is not expected to be such a significant factor with native English speakers, and it will be interesting to see what impact this may have on (e.g.) students preference to pre-recorded vs. live lectures.

In addition, a second trial will permit the opportunity to refine the questionnaire, in the light of the experiences gained in the first trial.

C) Extension to Distance Learning Environment

In parallel with the general development of educational technology, there is increasing use of distance learning modes, in order to widen the availability of educational opportunities, and reduce the reliance on the traditional model of delivery where lecturer and students are co-located. The use of distance learning technology also allows for the possibility of enhancing courses through the inclusion of additional topics or case studies, where the expertise may not exist "locally". The authors have previously been involved in the use of distance learning technology for collaborative signal processing education between Ireland and Australia. For example, [7] reported on the use of videoconferencing between sites within Ireland, while [8] described a "Virtual Teaching Laboratory" which was used in the context of remote lecturing via videoconferencing between Australia and Athlone Institute of Technology in Ireland. However, time difference can present something of a difficulty in a traditional distance-learning scenario between continents, because lecturers and students are present simultaneously at local and remote sites. The use of VCPlayer may provide naturally greater flexibility in the application of distance learning paradigms, since it will allow pre-recording of lectures at one site, and offline use of these lectures by the students at a second site (perhaps with additional tutorials supported by staff at the second site). This may prove particularly useful in the enhancement of courses through CD-based provision of "guest" lectures on topics that may not be part of the syllabus at the second site, and it is planned to examine this methodology in the future.

VI CONCLUSIONS

This paper has described experiences to date with the VCPlayer, a novel tool for the synchronous capture of live lecturer video and electronic annotation and playback. An evaluation of student learning in signal processing courses at both undergraduate and postgraduate levels at UNSW has revealed that students and staff responded very positively to its ease of use, review capability and new educational possibilities. Initial indications of the migration from traditional lecture formats to the format enabled by the VCPlayer show that the student cohort's understanding of key signal processing concepts is improving, evidence by a gradual increase in student grades. Further research and careful monitoring will be required to rigorously substantiate these findings.

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VIII REFERENCES