# Digital Signal Processing Education in Ireland and Australia

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## ABSTRACT

This paper presents our experience in teaching Digital Signal Processing (DSP) in Irish university undergraduate and postgraduate courses, as well as some limited experience of teaching DSP in Australia to undergraduate students. We also present the methodology used in designing and the delivery of the module. Our experience of various methods of delivery, such as traditional " lecture-only" classroom environment, technology based "smart classroom" environment and distance learning via video conferencing is also presented. Current development of Java based DSP education in Australia is outlined.

## 1. INTRODUCTION

Digital signal processing has rapidly become an integral part of all under-graduate programs in electronic engineering and other related disciplines, such as telecommunications engineering, in the Irish third level educational sector. The "traditional" universities and the "newer" Institutes of Technology make up the Irish third level educational sector. The universities would be viewed as being academically equivalent to the "established" universities in the United Kingdom, or in the United States, and offer the usual wide range of academically oriented under-graduate degree, and post-graduate Masters and Ph. D. level, programs. The "Institutes of Technology", on the other hand, are more focused on delivering very technically oriented programs at various levels below the degree level offered by universities (i.e. "certificates" and "diplomas" in various technical fields), but also do offer a very limited number of degree and masters level programs, in very specific technology areas. Historically, a DSP related course would be present in all degree level electronic engineering programs. However, due to an increase in the demand for graduates, particularly post-graduates, with DSP skills from Irish based high technology companies, foundation DSP modules are now being introduced earlier in the degree cycle in universities and also into the more technical diploma courses run by Institutes of Technology in Ireland.

We first introduced the DSP module to the electrical engineering curriculum in 1988 at the National University of Ireland, Galway. The course used our traditional "lecture-only" classroom environment with paper-based assignments. Computer tools such as Loughborough signal processing was introduced in 1990 and subsequently a new DSP curriculum, based on the software tools were designed. Simple and meaningful experiments in digital signal processing were included and the subsequent introduction of speech processing in the DSP course and the associated experiments designed using the software tool gave a good insight to DSP applications. Over the past five years we have been using Matlab as a software tool for teaching DSP. Our experience of teaching DSP for undergraduates then propagated in designing postgraduate courses and Diploma courses in Ireland. We used a menu-based approach in designing DSP course at various levels.

Section 2 of the paper outlines a DSP course, which has been developed specifically for delivery to students undertaking undergraduate and post-graduate programs in electronic or related engineering topics. Sections 3 describes three different masters programs on which this module has been used, and relates some experiences noted in delivering the modules. Section 4 provides some experience in teaching DSP for undergraduate students at the University of New South Wales, Australia and the current

development of Java based DSP education is also discussed.

## 2. OVERVIEW OF THE DSP COURSE

The complete DSP course, which has been designed, provides a comprehensive introduction to the basic concepts of signal processing before moving on to the more advanced areas of signal processing applications. In addition to lecture material, the course is also supplemented with a variety of Matlab programs and examples, which are used to support the theory being conveyed in the lecturing material. In addition to the Matlab laboratories, a number of laboratories, based on digital signal processor teaching kits, have also been developed to support the course material in that area. All lecture material is available to students in printed format and a full set of electronic format slides have also been developed to support the complete course. The lecture materials and associated laboratory sessions cover the following areas:

***DSP Theory***

- Introduction to DSP – Sampling, difference equations, z-transform, filter structures, stability,
  oscillators, impulse responses, basic filter frequency responses etc
- Frequency Domain Analysis – Fourier Transform, DFT, FFT
- Filter Design – FIR and IIR filter design techniques
- Multi-rate Signal Processing – Altering sampling rate, sub-band systems
- Wavelet transforms: Introduction to wavelet theory, time-frequency analysis

***DSP Applications***

- Introductory Speech Processing – Speech parameters, speech production model, overview of applications
- Advanced Speech Processing – Speech recognition, speaker verification, speech coding
- Adaptive Filtering – theory of adaptive filtering, steepest decent algorithm, practical applications of LMS algorithm,
- Wavelet Transform – application of wavelet transform in coding and de-noising applications
- Algorithm Implementation – Digital Signal Processor structure, development tools, issues in real time software development, implementation of basic DSP applications

The course outlined above is a very comprehensive course even in the context of master's level programs in the context of the Irish educational system. For this reason, we have used this course as a "menu" for which to build a number of distinctly different under-graduate and post-graduate DSP courses. The under-graduate modules primarily focus on the theoretical areas (Table 1), while the syllabi for the various post-graduate course which we have delivered have cover the theoretical areas and carefully selected DSP application areas. In the case of the Diploma program, the DSP course was based on Table 1, but restricted to Introduction to DSP and Real time implementation. This is similar to DSP First Approach [1].

## 3. EXPERIENCES DELIVERING THE MASTERS LEVEL DSP MODULE

The material for this course has formed the basis of DSP based modules delivered in three different Masters programs offered through the Athlone Institute of Technology. While the same core material formed the foundation for each of the three courses, the exact module syllabus and laboratory content was distinctly different for each of the three courses. This was due to the fact that the three courses differed distinctly in a number of very important aspects, namely:

- Academic background and level of students attending the module,
- Course delivery methodology,
- Philosophy of individual modules and programs.

The particular three masters courses, for which DSP based modules were designed and delivered, were (see Table 1):

- Masters of Science in Software Engineering,
- Masters of Science in Electronic and Software Systems,
- Masters of Science in Advanced Engineering Techniques.

### 3.1 Masters of Science in Software Engineering Program

The Masters of Science in Software Engineering program was the nearest of the three programs to

a traditional "taught Masters" program. Students who registered for the program were expected to complete a number of core modules, additional optional modules (of which DSP Theory and Application was one) and then complete a substantial research based project. However, the students who were registered for this program were almost exclusively carrying out this program on a part time basis over a number of years. Lectures and laboratory sessions, of two to three hour duration, were completed in the evening time, on a specific evening every week over a fifteen week period. The vast majority of students were mature students who were working in full time employment, typically in software development roles. All students registered for the module were require to hold an honours degree in a relevant engineering, computer science or applied physics, though students which hold pass degrees in these fields, or honours degrees in other related fields, may be considered for entry. In practice, a substantial proportion of students entering the program, and specifically, taking the DSP course may only have completed a very brief signals and analogue systems courses in their undergraduate work. Indeed, only a very small percentage of students will have had any exposure to even an introductory level under-graduate DSP course. In addition, the general mathematical abilities of the students undertaking the module will vary significantly. Some of the students, who were more recent graduates, may have a very good grasp of the basic advanced mathematical techniques required (e.g. Laplace, Fourier Analysis etc.). However, a substantial number of students are graduates of five years or more. For these students, it was necessary to move at a slower pace particularly through the foundation material.

The distinct advantages of this type of traditional course delivery methodology include the high frequency of tutor\student meetings and the scope for extensive laboratory work to support lecture based material. The former allowed any learning issue that arose for particular students to be addressed as soon as possible. The latter allowed the students to complete a number of Matlab based laboratory sessions which would illustrate the DSP techniques being introduced in lectures, and also to leverage the underlying software development skills which most students undertaking this course would already have developed. It was not felt, however, that these particular students would benefit from any in depth exposure to issues relating to the real time implementation of DSP algorithms. In general, the philosophy of the module was to provide the students with a fundamental understanding of DSP theory and some basic applications, and to give them some experience of utilising their general high-level software development skills for the simulation of basic DSP algorithms.

### 3.2 Masters of Science in Electronic and Software Systems Program

The Masters of Science in Electronic and Software Systems program is a new program, which has been offered by a consortium formed by Athlone Institute of Technology and the National University of Ireland, Galway, based in the Irish Republic, and the University of Ulster based in Northern Ireland. It is primarily aimed at mature students with all modules being delivered by remote lecturing technology and a strong ethos of student-centered learning. It is believed to be the first post-graduate course, involving third level educational establishments in the Irish Republic, exclusively delivered using a remote teaching model. All students registered for the course are required to complete a core module delivered by each of the three partner universities\institutes. The core module delivered by Athlone Institute of Technology is in “Signal Processing Theory and Applications”. The Signal Processing module is nominally delivered using video-conferencing technology by three hour lectures periods held over a duration of twelve weeks. A WWW page is used to support the module, with lecture notes and associated material, including Matlab programs, available for downloading by students whenever they require them. In addition to the three hour weekly lecture period, students can contact the module tutor at any stage by email to discuss any problems that they may be having with the material.

A number of different technologies were utilised in delivering the lecture material over the video conferencing link. The primary means of delivery was to interface the lecturer’s PC to the video conferencing system in order to show slides and also to illustrate the operation of Matlab programs relating to the lecture material. The lecturer also utilised an overhead camera system, which was also interfaced to the video conferencing system, to support “unscheduled” teaching material and examples, which might arise during a lecture. A number of alternative remote lecturing facilities (e.g. Net Meeting)

were considered but were not feasible due to a limitation on the necessary PC equipment at the student's location.

In many ways, the experiences of delivering this course were similar to those noted for the Masters of Science in Software Systems. The entry requirements, academic background and age profile of students, undertaking the module, were similar to the module discussed in section 3.1. However, it was noted that, since the overall program involved a substantial electronic systems content, students tended to have a firmer understanding of analogue electronic system analysis and a better mathematical skill set, which facilitated a much quicker covering of the fundamental signal processing material. This allowed the introduction of more advanced signal processing application material to be included in the syllabus, particularly when compared to that the material covered by the Masters of Science in Software Engineering program.

However, the substantial drawback of the remote learning model was that it was not possible to include any organised laboratory sessions. Instead, all students were supplied with a student edition of Matlab and the lecturer supported all class material with example Matlab programs. However, this placed the emphasis on the student to learn the Matlab programming language themselves and to further experiment with the programs. It was not possible to put in place support personnel to help the students with the basics of learning the Matlab programming language (compared to the formal laboratory structure of the module outline in 3.1). Hence, it was felt that it would be unfair to include any evaluation of how the student progressed using Matlab as a signal processing development tool. For this reason, it is questionable as to whether the students gain any useful exposure to Matlab, as such work would have gone un-credited in terms of completing the module. In addition, the lack of formal laboratory sessions meant that only cursory material was provided to students on issues relating to the implementation of signal processing algorithms in software or hardware. The students would gain little from the study of the architecture and operation of a digital signal processors without getting the experience of "hands on" exposure to the device.

### 3.3 Masters of Science in Advanced Engineering Techniques

This final program to which the DSP module has been adapted is substantially different from the previous two, both in the students at which it is aimed and in its delivery mechanism. This masters program is specifically aimed at teachers and lecturers in the newer Irish technical institutes, who may wish to update their post-graduate qualifications. The philosophy of the course is not just to provide the student with an advanced understanding of selected engineering techniques, but also to provide them with ideas on how these areas might be introduced to the under-graduate courses, on which they lecture in their home institutes\universities. The DSP module offered in this program is an optional choice to all participants in the program. In practice, it tends to attract lecturers from the fields of electronic, electrical, computer, communications and software engineering. These students, in general, are more comfortable with dealing with the advanced mathematical basis of DSP, when compared with the students undertaking the modules outlined in 3.1 and 3.2.

However, due to time restrictions on the participants, it is necessary to run this module in a residential manner. The course is delivered in three blocks, each lasting a week, which are spread out over a complete academic year (typically held during holiday periods). The primary focus of the weekly courses is to cover all of the lecture material and to provide the students with tutorials in Matlab. The students are then required to complete a number of Matlab assignments, in their own time, which challenges their theoretical understanding of the course material and their Matlab programming skills. Also the students were required to undertake a mini project entitled " Digital Spectrum Analyser " using 17 critical band filters. The students were given one semester to complete the implementation using Matlab. In addition, due to the particular delivery format and the background of the individuals undertaking the module, a substantial introductory material and laboratory work (based on Analog Devices and\or Texas Instruments devices) on real time DSP implementation is also included in the module syllabus. This allows the student to get some ideas on how they might introduce DSP material, in practical manner, to the courses on which they lecture themselves.

One of the exciting developments in delivering this module was the use of the "smart classroom" technique [2], where each student was assigned a

computer in the classroom. For example, the lectures were provided for 30 to 60 minutes covering the theory of DSP and immediately after that the students were able to carry out Matlab programming implementation to support the theory. We found that the students were able to grasp the DSP theory very quickly using this technique. The switching between lectures and practicals in a continuous manner dramatically changed their thinking and the link between theory and applications became very clear to the students.

## 4. DIGITAL SIGNAL PROCESSING EDUCATION IN AUSTRALIA

The second author, after teaching Digital Signal Processing courses for many years in Ireland, is currently teaching DSP to undergraduate and postgraduate students. at the University of New South Wales (UNSW). The DSP course at UNSW is taught over two semesters; Year 3 and Year 4 of the undergraduate program for both Electrical Engineering and Telecommunications Engineering Students. In each semester 56 hrs are allocated for lectures, tutorials and practicals for the course. At UNSW approximately 200 students take the DSP course in the first semester of Year 3. The contents of the DSP course are similar to Table 1, except the topic in speech processing. Additional sections such as finite word length implementation of filters, complex multi-rate systems are taught in depth. A mini project using the Matlab implementation is an essential part of the DSP course. A limited amount of real-time implementation is introduced as part of the module. The laboratory work using Matlab is done over two semesters thus providing an in depth knowledge of the use of Matlab for DSP applications. Student evaluation methods are based on terminal examination, paper-based assignments, laboratory work and a mini project.

In recent years, it has become popular to develop Internet based education modules and course material to free students from the time and space constraints and to cover increasing access [3]. The current development at UNSW is the DSP education using JAVA, where projects are underway to simulate discrete linear systems using the Java applets. The advantage of the Java program is that it can be integrated in a page on the World Wide Web. Web pages with applets help to make teaching material more interesting and Well-designed applets may illustrate mathematical concepts very well. Also real-time simulations of various discrete time systems can be carried out using applets thus providing a better understanding of the subject. It is envisaged at the end of the project that we will have a complete set of DSP notes developed using Java, on-line simulations and plenty of on-line quizes for testing the understanding of the DSP course and some of the difficult concepts.

## 5. CONCLUSIONS

Our experience of teaching digital signal processing for Diploma, Undergraduate and Postgraduate courses show that the smart classroom based teaching proved to be the best method of delivering DSP concepts. However, the distance learning via video conferencing did work extremely well, with the limitation that the students did not have the opportunity to perform laboratory work in a supervised manner. It is envisaged that a combination of Java based DSP education, to illustrate some difficult DSP concepts, along with distance learning, via video conferencing, may be another avenue worth evaluating.

## 6. REFERENCES


[1] J. McClellan, R. Schafer and M. Yoder, "DSP First: A Multimedia Approach", Prentice Hall, 1998

[2] C. Abdallah et. Al, "Interactive DSP course development/Teaching Environment", Proceedings, ICASSP'97, pp. 2249-2252, May 1997.

[3] A. Clausen, A. Spanias, A. Xavier and M. Tampi, " A Java signal analysis tool for signal processing experiments", ICASSP'99, April 1999

| | BE Electronic Engineering | M. Sc. (Software Eng.) | M. Sc. (Electronics & Software Sys.) | M. Sc. (Advanced Eng. Tech.) |
|---|---|---|---|---|
| ***Delivery Modes*** | "Classroom Environment" | "Classroom environment" | "Video Conferencing" | "Smart Classroom" |
| ***Total Contact hours (Lectures + Tutorials + Labs)*** | 52 hrs | 30 hours | 48 hours | 75 hours |
| ***Syllabus*** | | | | |
| Introduction to DSP | √ | √ | √ | √ |
| Frequency Domain Analysis | √ | √ | √ | √ |
| Filter Design | √ | √ | √ | √ |
| Multi-rate Signal Processing | √ | √ | √ | √ |
| Introductory Speech Processing | √ | √ | √ | √ |
| Advanced Speech Processing | - | - | √ | - |
| Adaptive Filtering | - | - | √ | - |
| Wavelet Transform | - | - | - | √ |
| Algorithm Implementation | √ | - | √ | √ |
| ***Laboratory Material*** | | | | |
| Matlab simulation | √ | √ | - | √ |
| Real time implementation | - | - | - | √ |
| ***Student Evaluation Methods*** | | | | |
| Written Examination | √ | √ | √ | √ |
| Written Assignments | √ | √ | √ | √ |
| Matlab Design\Simulation Assignments | √ | - | - | √ |
| DSP Mini Project | - | - | - | √ |

Table 1: Outline Syllabi, Laboratory Content and Student Evaluation Methods used in various DSP Modules in Ireland