Signal/Digital Processing

Analysing Random Processes using MATLAB at the Master's Level

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Abstract

MATLAB is the chosen simulation environment that is used throughout the Department of Electronic and Electrical Engineering. MATLAB is used by the students at several levels. It is used in earlier years as an 'Engineering' calculator that is useful for scientific calculations and visualisation particularly for complex analysis. As the course develops MATLAB becomes invaluable for investigating the time-frequency characterisation of signals and systems. MATLAB also gives the students an environment that allows them to write programming code in a 'C' like format. Finally MATLAB facilitates greater contextual teaching and problem based learning, which has become increasingly important in current Electronic and Electrical Engineering.

Level of Material: First Year (MSc) and Fourth Year (MEng) (Scotland)

The Execution

The case study involves the use of MATLAB in an attempt to give a better understanding of the fundamental correlation tools that are used to analyse random processes. In order for the students to be able to appreciate the MATLAB code associated with this study they need to have successfully carried out some tutorial questions related to correlation and random processes. Most mainstream engineering students find the mathematics associated with describing and analysing random processes particularly challenging. In our electronic engineering approach we establish correlation through the link with convolution and filtering (the matched filter). These are concepts that the students meet earlier in their courses and for which they have an implicit understanding. While the concept of a stochastic process is accepted by the students it is apparently much more difficult for them to grasp the mathematical tools that are available for analysing random processes. Having covered correlation and its mathematical representation the students are asked to learn how the autocorrelation, cross-correlation and spectral characteristics of a discrete signal are formed. This then forms the basis of the Wiener Khinchine theorem for estimating the spectral characteristics of a stochastic random process. It also allows the mathematical tools for identifying (modelling) stochastic processes to be developed. The basic MATLAB code that is provided to the students in this case study covers both these topics. The students are provided with the case study material early on in the courses and are encouraged to 'play around' with the MATLAB m-files using 'what if' scenarios. In their report they are requested to describe the underlying theory associated with the analysis of random processes and also to describe the MATLAB code and their changes to the code together with a discussion on their experimental observations.

Pre-requisite Knowledge

It is important that the students have a degree of ability with MATLAB and the use of m-files. Even for the weakest of students this appears not to be too problematic. The students need to have successfully covered linear systems theory to at least level 3 (third year Engineering in Scottish Universities). It is assumed that the concept of convolution and filtering is understood both at a mathematical level and contextual level. It is further assumed that the students have grasped the time – frequency dualities associated with signals and systems analysis. The fourth year Engineering Analysis module is made compulsory for the MEng students and optional for the BEng students. It is assumed that the MSc students have graduated with a first degree in Electrical Engineering at a level with at least 2.2 and that they have successfully completed a linear systems course on their first degree.

How Are Students With Different Mathematical Backgrounds Supported?

There is a wide range of mathematical ability within the typical fourth year Engineering Analysis class. The course was designed for the MEng student and particular emphasis has been given to mathematical rigour. In general the MEng cohort of students can cope with the mathematics and it is more an appreciation of the Engineering context that the mathematics fits into that they have problems grasping. The BEng students who opt to take the Engineering Analysis often struggle with some of the mathematical concepts. The use of appropriately phased tutorial questions is essential in order to address the ranges of ability and needs across the relatively large classes. It is also extremely important that properly prepared teaching assistants are employed in the tutorial sessions to address the students' problems. It is often the case that the student can gain more from the answer given by the teaching assistant than that by the lecturer! Finally, the use of email allows the students to get rapid on-line tutorial/classwork.

The students on the Communication, Control and Digital Signal Processing (CCDSP) MSc exhibit a very wide range of mathematical ability. It is important that one-to-one links are made with the relatively small class sizes (~15-20) in order to improve the weaker students' ability. This is again achieved through appropriately phased tutorials and through the email hot line.

What Support Was Needed?

As no formal laboratory sessions accompanied these modules it was important to have a sufficient number of PCs available with the MATLAB environment that will allow the students to experiment with the code at a time and with a pace that suits them. Furthermore it is important that these labs are accessible by the students outside lecture hours. The use of teaching assistants that have the necessary background was fundamental to achieving the learning objectives of the modules. In the case of this study the students needed to have a solid understanding of digital signal processing theory and the MATLAB environment.

The Barriers

The main barrier was the time management skills of the students. It was expected that students would work on material over a period of six weeks. As a result it was anticipated that students would endeavour to accomplish the set objectives by spreading the workload. Due to competing demands from other courses it was found that students often left the work towards the end of the time period.

The Enablers

There is a departmental wide MATLAB site licence in place for using the software for undergraduate teaching. The PC labs are also plentiful and are open until 9pm.

The teaching assistants are recruited from the Institute of Communications and Signal Processing where most researchers use MATLAB in their research. There is a strong Signal Processing Group within this institute, which facilitates good contextual based teaching. The quality of the MEng intake and those taking the CCDSP MSc is very high.

Evidence of Success

It is apparent that the students gain doubly through this case study. Firstly it gives them some hands-on programming which they can import and exploit into their fourth year project work or MSc project work. Secondly and most important it allows the lecturer to bring mathematical concepts associated with random signal analysis into a graphical user interactive simulation arena.

How Can Other Academics Reproduce This?

Appropriate resources must be available for the concept of this approach to project based learning to be successful. Students must be comfortable with MATLAB but not experts! Good quality and motivating research assistants are vital for success. Finally the students that the material described in this study is aimed at are highly qualified.

Quality Assurance

There is continual feedback from the students during the tutorials and their tutorial submissions. Important feedback is obtained from the one-to-one email correspondence that takes place between the teaching staff and the students. There is also a formal QA form that is completed at the end of each course within the Department. This contains useful comments regarding the course material and ways in which it could be enhanced. It is apparent that the students have responded very favourably to MATLAB as an aid to mathematical understanding.

Other Recommendations

- Don't over stretch the students with a piece of work that is going to extend over half a semester in one module.
- Ensure from the outset that ALL students know exactly what is expected from the course material and what they can expect from the teaching staff.
- Employ an early feedback mechanism that allows tracking of the students' efforts or lack of effort on the material.
- Make sure ALL teaching staff are very comfortable with the subject material.

References

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