Wavelet Toolbox Guided Learning Handbook: music technology illustrations

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Acknowledgements: I am grateful to SIGMA for the technology evaluation grant that enabled the purchase of the wavelet toolbox software, the Department of Computing and the Digital Environment for allowing me to undertake the work and to Dr. Syson, Deputy Director of E-Learning at Coventry for his help with migrating the GLH to CURVE.

SIGMA, the Centre for Excellence in Mathematics & Statistics Support, provided in 2007 a Technology Evaluation Project grant for the Wavelet Toolbox software. This is an add-on for Mathworks’ Matlab software. The wavelet transform converts a signal from the time-domain to the scale domain, where various characteristics of the signal become more explicit. It is very good at representing the time-varying nature of engineering signals. A recently developed Guided Learning Handbook website has the purpose of enabling students to bridge the gap between theoretical knowledge of this subject and practical implementation of software that uses the toolbox. This paper describes some new work included in the handbook which has the purpose of starting students off with practical experimentation by feeding pre-produced sound samples into the Wavemenu facility of the toolbox. They can then experiment with various wavelet parameters to examine their effect on the representation. When the signal from an electric guitar is examined using Wavemenu, the original plucking impulse can be clearly identified from one of the wavelet coefficient plots. Student experiments can investigate the effect on the representation of wavelet choice and start to relate this to theoretical considerations. For example, the Biorthogonal wavelet has the property of linear phase which is needed for signal reconstruction.

Introduction

An opportunity came to apply to SIGMA, the Centre for Excellence in Mathematics & Statistics Support [1] for a technology evaluation grant. The grant was provided in 2007 for the purchase of the Wavelet Toolbox add-on for a Faculty of Engineering and Computing Matlab licence. The project that was proposed to make use of the software was the development of a web-based Guided Learning Handbook (GLH). This has been designed to help engineering students appreciate the use and characteristics of a mathematical transform, the wavelet [2]. The wavelet transform is a windowed transform that takes a time-slice view of a signal in order to model the overall signal. If a signal is converted from the time-domain to the scale domain various characteristics of the signal become more explicit. The wavelet transform is good at monitoring the time-variation of signals, and uncovering energy sources. Wavelets are applied in fields like data compression with JPEG 2000 [3], music synthesis and uncovering of seismic events [4].

The GLH is designed to fit in the gap between lectures containing theory about wavelets and Mathwork’s comprehensive help files. As well as the formal work on the GLH by the author, student projects using the wavelet toolbox have been carried out by M.Sc. thesis and B.Eng project students. The GLH is available to new project students in this area. A new M.Sc. module ‘M03CDE Digital Signal Processing Technology’ will include teaching on scale-based processing and the Fast Wavelet Transform and will use the GLH as a resource. This module is included in a new M.Sc. course in Embedded Microelectronics and Wireless Systems.
The Joint Information Systems Committee admits that e-learning is normally an option ‘that extends the range and power of delivery’ [5]. It is not necessarily the be-all and end-all of learning. However, our students nowadays have flexible learning styles and prefer resources they can access at a time of their choosing though the internet. Coventry University has a variety of On-Line systems. The main tool isCUOnline, a very useful tool which is study module-based and has a close relationship with student records systems. There is also a repository-type system called Coventry University repository validation & enhancement (CURVE) [6].

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Making the guided learning handbook interactive with audio

The original GLH was static in nature. It was modelled on another technical information web site [7] in the field of digital music. The GLH contained a comprehensive guide to wavelet theory and guidance on applications. It had details on how the wavelet toolbox could be accessed within the Faculty and some basic user instructions. It also had a comprehensive bibliography. It became clear that some more encouragement of user activity was going to be necessary. As Ian Forsyth says, ‘Interactivity is the critical factor in the use of the internet’ [8]. It was decided to provide three lab sheets, based on analysis of audio signals. Modern personal computer workstations have easily accessible sound input/output facilities so audio seemed a useful medium for experimentation. It also provides a quick and easy means for feedback to students about the difference between what a signal looks like in a wavelet plot and what it sounds like.

It was decided to move the GLH from a departmental web server to the CURVE system, in order to increase the reliability of service and use the Digital Rights Management facilities provided. When students have logged on and have navigated to the Sound Workshop they see the exercises (as shown in Fig 1). A set of useful guitar sound clips had been previously created by the author in connection with a previous poster paper [9].

As an example, if they play the sound clip ‘D9 riff’, they will hear the sound of consecutive Jazz chords being played on the electric guitar with short single-note passages in-between. The lab sheet gives the student a full set of instructions covering:

(a) Details of the rooms in which students can find the software installed.

(b) How to access the ‘wavelet toolbox’ in an off-line processing mode called ‘Wavemenu’. This uses the continuous wavelet transform.

(c) How to load up the sound clip into the toolbox.

(d) Instructions on how to compare the sound that they hear with the screen display they should obtain, given here in Fig 2. They should write down details of what aspects of the signal are now apparent in the wavelet decomposition plot that were not in the original signal. They should pick out, for example, that the original strumming signal appears in the d1 detail coefficient display. This shows the strong time-localisation ability of the wavelet transform.
Another lab sheet encourages students to find out how wavelets can easily detect asymmetry in a signal.

**Computer system requirements**

The official computer system requirements for Matlab version 2008b claim that for Windows XP it will run on an Intel Celeron with 1 GByte RAM being recommended [10]. In practice, the processor requirement is substantially higher. The continuous wavelet transform used in ‘Wavemenu’ is particularly computationally intensive. A delay of up to several minutes can occur whilst the calculation is taking place.

**Conclusions**

These audio example lab sheets have been produced to supplement existing theoretical materials on wavelets in the Guided Learning Handbook. It is important for engineering students to be able to appreciate the utility of wavelets in signal analysis, as the mathematics can be intimidating, with its use of abstract algebra which is outside of their normal mathematics syllabi. Computer requirement issues have been indicated, due to the computationally-intensive nature of the continuous wavelet transform.

In the future the GLH will contain materials about real-time wavelet signal processing in analysis-processing-synthesis configurations, as this is the kind of area that is most relevant to engineers. It is planned that the Guided Learning Handbook will be made available nationally. A questionnaire-based review of the GLH by academic staff and students is planned, after the approval of this by the relevant Coventry University committee. This will provide information for a more formal evaluation of the site, which will be used in connection with planning future developments and a journal paper.

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**References**


