Overview and Development of a Virtual Signal and Pattern Recognition Experimentation Laboratory

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Abstract—**As computers come to be used in more and more settings, the importance of digital signal processing increases in parallel. It has become a fundamental necessity to train both undergraduate and postgraduate engineers in this subject. The article which follows gives one approach to this teaching, a series of web-based practical sessions on signal and pattern recognition in a virtual laboratory (vPSM) using multimedia learning modules. The technology used is conventional web technology together with professional mathematics software, accessed via a universal XML interface developed for the purpose.**

Index Terms— e-Learning Environment, Pattern Classification, Signal Analysis, Virtual Laboratory.

I. Concept and Design

The individual units of the laboratories are concentrated on:

- What is taught is basic signal theory up to the stage of pattern recognition, and how it can be applied to simple, synthetically generated signals.
- As the session allows free variation of the parameters when the signals are produced, it offers maximum flexibility.
- Independent learning through interaction with the virtual laboratory is stimulated by the tasks and problems set.
- The theoretical knowledge gained in the session can be applied to the sort of problems and tasks met in real life.
- It is possible to run audio-visual checks on the signals being processed.
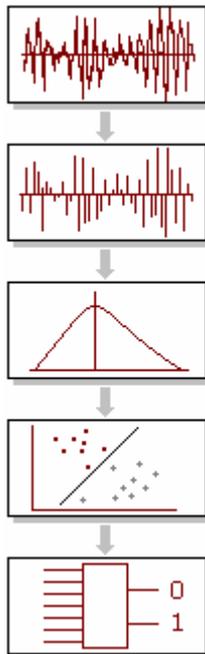
The practical sessions are an important component of the specialised engineer's training „Signal and Pattern Recognition" at the TU Ilmenau. The individual sections can be taken in private study, or to complement seminars and lectures, or to constitute practical sessions. The aim is that the learner should acquire the skill of solving signal processing and signal classification tasks on a practical basis.
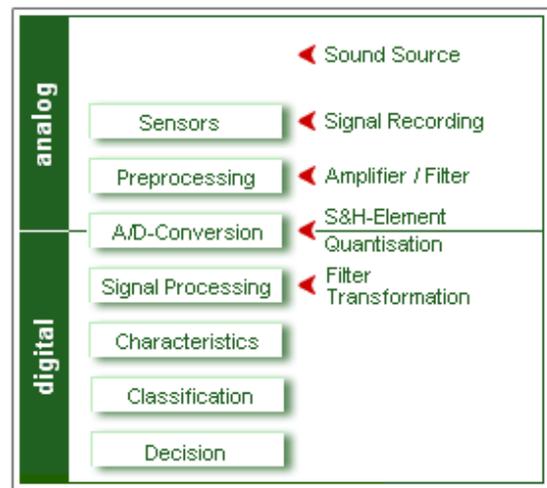

Figure 1. Work Steps of Signal processing

The learner carries out experiments, using virtual tools, to achieve computer-assisted analysis of signals and recorded values. The knowledge given in lectures and seminars "Signal and Pattern Recognition" is a necessary preliminary to the laboratories.

Corresponding with our approach to the signal and pattern recognition the work steps are composite and realized in the following 3 section:

1. Recording and Preprocessing of Signals
2. Calculation and Extraction of Characteristics
3. Classification

II. Structure of the Laboratories

The laboratories are divided into three sections:

- In the first section, fundamentals and certain further details are given -> the information level.

- In the second, the preparatory tasks are taught -> the preparatory level.
- The final section is a practical task and evaluation of how it was completed -> the task level.

A. Information level

At the information level, the actual subject is taught. There is also additional information, supplementary to that given in lectures and seminars.

For example:

- the techniques and methods to be used in measuring and initial processing,
- the reference objects being discussed, with examples to listen to, and animations and
- evaluated references of literature, examples and webLinks

B. Preparatory level

The preparatory tasks are a low-level means of working through the subject. The tasks are exercises with a simple structure and if they are carried out correctly, it is clear that the subject, for example the particular signal theory, has been understood. At this level, the emphasis is on using such interactive modules as the function generator and the signal analyser. This emphasis enables the learner to use virtual signal processing equipment interactively, with the signal parameters freely varied.

As the processing equipment offers considerable interactivity and flexibility, the student can be expected to make a creative input. The signals for which the calculations are made can be checked by direct audiovisual means.

C. Task level

The actual practical work itself is the solving of a complex problem. The intention is that the student should use the knowledge of signal theory gained from the information and preparatory levels to find creative, independent paths to the solution.

The content is built up as the student goes through the 3 levels. This has the effect that as soon as knowledge has been gained it is immediately applied, reinforced and extended. The exercises and problems presented are intended to challenge the student to free experimentation with the interactive virtual devices.

III. TECHNICAL DESCRIPTION

The labs come as a browser-based, multi-layer web application. The essential components of the application are shown in figure 2. Their functions can be summarised as follows:

A. WebServer and JSP-Engine

The Tomcat server is used as web server and JSP engine. User administration and authorisation, together with the design of the layout, are all organised by the JSP and Servlet engines.

For instance, the graphic representation of the signals is encapsulated by means of the Servlet and the acoustic reproduction of the signals is provided by an applet.

B. Java-Layer and Mathematica

At the technical heart of the modules is the fact that a universal XML interface to Mathematica has been developed using Jlink.

This has enormous advantages both for development purposes and for program module reusability:

- The Mathematica code is kept separate, so that the program logic and the mathematical models can also be kept apart.
- It is possible to develop and test the Mathematica code separately on the Mathematica user interface. Mathematica has (a notebook) interface for this and provides development support by means of a comprehensive help and error recognition system.
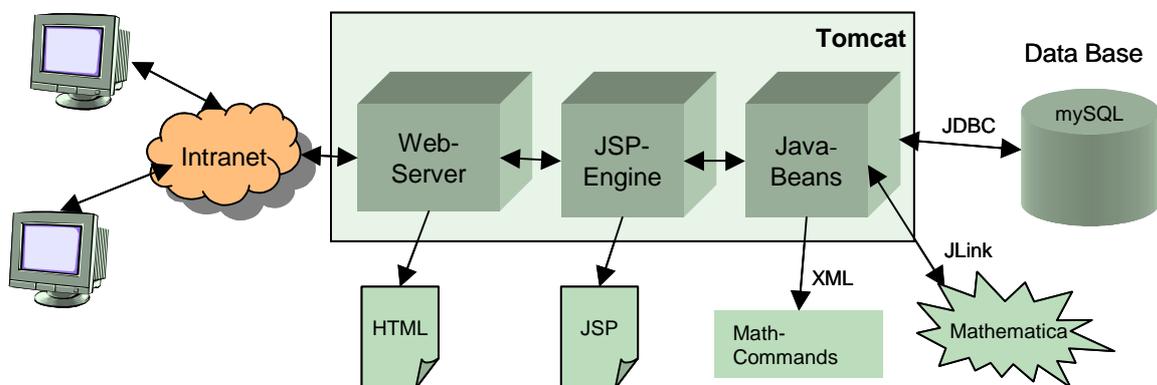

Figure 2. Components of the Web Application

- The range of functions can be freely extended by adding in Mathematica packages. Mathematica, being a professional mathematical tools system, offers numerous specific packages (e.g. arithmetic charts, statistics, neuronal network, fuzzy logic). Packages developed for the purpose of the practicals can be reused for later tasks.

- A powerful visualisation tool is also provided by Mathematica so that data with almost unlimited variations in the parameters can be represented.

C. Database

User administration and authorisation: The database provides regulation of, among other things, the users' access rights to the information level, preparatory section and execution of the final task.

Task management: The pool of exercises is administered under this heading. It is where the tasks are kept and is used to set which tasks the user must carry out.

Data administration:
Input data: e.g., the signal data as measured from particular noises
Output data: results from the preparatory exercises and final practical tasks

IV. EXAMPLE: LAB1 "SIGNAL PRPROCESSING"

A. Execution of a Lab

This stage helps the student to visualise the components described:

The aim of the first lab session is getting to know the methods of signal recording and preprocessing. Taking a simple system as an example, this knowledge is applied for signal recognition.

At the information level the subjects needed for this are signal recording, analogue-digital conversion, filtering, modulation, noise etc. In this situation, the information offered complements what has been taught in lectures. Examples of sound are generated so that their acoustics can be visualised as a means of representing the practical context of the theory.

A selection of actual tasks is found in the preparatory level, and their resolution proves whether the taught material has been understood. What is involved is a task which relates to the subject and concerns simple synthetic signals. The tasks are combined in such a way that they serve as a basis for the eventual completion of the final problem set in the practical sessions.

If they are completed properly, the practical session can be started. In that practical session, there is a complex problem to solve. The steps involved are themselves divided up into small individual tasks. Completion involves the construction of a processing route which will achieve a simple form of speech signal recognition.

B. Demonstration of a simple exercise

Sequence of actions in performing a simple exercise:

Task:
- Create the following periodic square wave signal: U_{max}= 1 V, T = 5 ms as a sum of signals from sine functions.
- Find the Fourier coefficients A_n and φ_n for n = 0, ..., 9 and then produce the individual signals using the function generator.
- Use the signal analyser to produce the sum of signals from the 9 harmonics.

Solution:
- First, start the function generator. Then create the 5 individual signals and save them.
- Then start the signal analyser. Select the 5 signals previously generated, and they will appear in the upper display panel. There is a choice between displaying the signals individually or all at once. In addition, it is possible either to calculate the FFT for the signal immediately and display it, or to listen to the signal via the loudspeakers.
- The formula are now entered using the buttons which are arranged as on a pocket calculator. The lower display shows the resulting signal as calculated.
- The signal can be saved and will then be available for further processing.

V. VIRTUAL DEVICES

Designing the application primarily involved the development of virtual devices which could be universally applied. For the signal preprocessing module, this apparatus was the **function generator** and the **signal analyser**.

They are a flexible tool system, useful not only in this online laboratory but also in seminars and lectures and when students are working on their own issues.

Figure 3. Function Generator

A. *Function Generator*

It is possible to generate any sort of signal with the function generator. These signals can be given any name by the user and stored in the database, and then they are available for all the future stages of the session. Both visualisation and acoustic reproduction of the signal are possible using the function generator.

B. *Signal Analyzer*

The function of the signal analyser is represent the signals and process them further. It is possible to make a mathematical link between any of the signals. Both the input signals and the signals at the results stage are reproduced in both visual and acoustic form. The functions of the signal analyser include FFT and such functions as adding and multiplying of signals. It is possible to print the signal graphs and to download the signal data files.

VI. CONCLUSION

The aim was to create a system that enabled students to learn and research independently, seeing visualisations of complex procedures with signals, without it being necessary for them to install special software for the purpose or to learn a particular programming language.

The resulting individual modules can be taken in private study or to complement seminars and lectures or to constitute practical "laboratory" sessions.

The teaching includes exercises on all the stages from signal theory to pattern recognition with the aim that the student should learn the skill of resolving signal processing and classification problems in practice.

Simple synthetic signals allow the complex theoretical content of signal and pattern recognition to be tested out in an easily understandable way. The primary signals used are acoustic: speech, mechanical noises (the sound of a food mixer, of a gearbox and of a car engine stopping), etc. Reproduction using the soundcard is thus integral to the sessions, to fulfil both teaching and checking functions.

The flexible arrangements of the modules for the practical training enables it to be used for demonstration purposes in seminars or lectures. The learning situations where the virtual laboratory sessions could be used include both university degree courses and postgraduate training for engineers already in professional posts.

The operator skills required are no higher than normal use or a computer or browser.

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