KNOWLEDGE INCUBATION UNDER TEQIP

WORKSHOP: APPLICATIONS OF SIGNALS AND SYSTEMS, 2ND November, 2014, IIT Bombay

IIT Bombay hosted a workshop on application of signals and systems, as part of the MHRD's TEQIP initiative, wherein students from IIT Bombay, pursuing the fundamental course in Signals and Systems, along with students from VJTI, presented the diverse applications of signals and systems analysis in various fields.

The workshop was attended by students from IIT Bombay, VJTI Mumbai, College of Engineering Pune, Babasaheb Ambedkar Technological University (BATU), and Government Engineering College Aurangabad.

Philosophy behind the Workshop

Signals and systems is a vast field, which requires a strong conceptual and mathematical foundation.

Thus, owing to the large amount of diversity in the applications of signal and system analysis, the course is taught in a generalized manner in engineering courses, which involves the understanding and mastering of the abstractions of several fundamental ideas in the field.

Therefore, studying and getting exposure to how the concepts are really applied in engineering, is extremely helpful in grasping and appreciating the true power of the concepts such as Fourier Transforms, Z and Laplace transforms, Sampling, Linearity and many such important ideas taught to students in class.

The workshop was also intended to provide an opportunity to students of the institutes affiliated to IIT Bombay under TEQIP, to showcase their work and also get exposure to the work being done by students at IITB.

Abstracts of topics presented:

- **Application of Fourier Transform in image processing (Medical aspect)**

We all are aware of various tests that are a part of medical science. As technology advances, we see improving test methodologies and with it improving ways to interpret test results. One convenient way for medical practitioners to interpret these results is in the form of images. While it is true that most of the techniques such as electroencephalography (EEG), magneto encephalography (MEG), Electrocardiography (ECG) and others are not meant to produce images, one may use image processing techniques and certain reconstructive algorithms to get the test results in the desired form. The group talks about one such test, tomography, imaging by sections through the use of wave energy.

- **Application of Fourier Transform in speaker recognition**

The project was about taking an input of audio sample of a speaker and to correspondingly give a label as an output as well as store the audio sample in the data base. Whenever a particular speaker speaks the same word the system would recognize the person.
They used the familiar machine learning tool, PCA which is widely used in applications like signal processing, face recognition, etc.

- **Application of Fourier transform in producing Karaoke of songs**

The group demonstrated how frequency-domain analysis of a signal can enable us to detect vocal frequencies and filter them.
Stereo songs were particularly analysed using the discrete Fourier transform, and it was demonstrated how a combination of two signals produces a karaoke song.

- **Fourier transform in infrared absorption spectroscopy**

The technique of Infrared spectroscopy and its application in identifying functional groups within a molecule was explained in this project. The concepts of Fourier and inverse Fourier transforms were used to demonstrate how experimental data can be analysed in identifying or understanding the properties of molecules.

- **Signal Analysis for Islanding Detection Techniques in Electric Grids**

Electric grids are large and complex systems that transmit and distribute power to millions of loads-homes, offices and industries etc.

Renewable energy (Solar PV, Wind etc.) is increasingly supplying power to the grid nowadays. However, the utilities (Electricity distributors) do not have control over their generation. Hence, in the event of a fault in the grid, these Distributed generators (DGs) may still be functioning, creating a sort of island of power. This needs to be prevented, for safety of the maintenance personnel, and avoiding over currents, transients etc. during reconnection.

Detecting this effect involves the use of Fourier transforms and development of fast and reliable algorithms, one if which is explored in this presentation.

- **Application of Fourier Theory to optics**

In this project, the students explored the application of Fourier theory in optics and photonics.

Analogous to Fourier transform being used in music to control the signal using filters, we may apply the same in optics using lenses. The property of lenses of being able to form the Fourier transform in the image plane has been discussed.

- **X ray crystallography**

X ray crystallography is used to determine the atomic and molecular structure of crystals by studying the diffraction pattern of Monochromatic X- rays incident on the crystal.

It has been observed that the diffraction pattern is the Fourier transform of the electron probability density function of the crystal structure in question, and hence taking the inverse Fourier transform of the patter can yield the function we are interested in. However, the obtained Fourier transform lies in something called the reciprocal space and not the frequency domain.

The group has introduced the concept of reciprocal space for the reader and has further discussed the challenges and methods in evaluating the inverse Fourier transform of the diffraction pattern.

- **Application of Fourier Transform in Sound/Audio Processing**

Sound processing is the intentional alteration of audio signals, or sound. This group presented the concept and application of FFT (Fast Fourier Transform), by analysing an audio file. The group also talked about the various applications of audio processing: storage, level compression, data compression, transmission, and enhancement.

- **Applications of fast Fourier transforms in various fields like audio testing, windows media player, image processing**

The group explained the application of Fast Fourier Transform(FFT) in Media players & Image Processing. Describing FFT as one of the most numerical algorithms of our time, they also explained how FFT works in Windows Media Player.

- **Use of Laplace Transform in Attitude Control of a Flying Vehicle**

The attitude of a flying vehicle refers to the way that the vehicle is positioned in 3-dimensional space. The attitude of a vehicle can be described using three angles of rotation about three mutually perpendicular axes, generally referred to as roll, pitch, and yaw angles respectively (with the roll axis in line with the primary engine direction of thrust). A very useful concept in the design and analysis of control systems is the transfer function. The use of Laplace transform and transfer functions was shown for attitude control of an aircraft using a feedback mechanism.

- **Application of Proportional Integral Derivative Controller**

A proportional-integral-derivative controller (PID controller) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an error value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable.

- **Use of Fast Fourier transform in fingerprint scanning**

Fingerprint recognition is one of the most popular methods used for identification with greater degree of success. In practice, due to skin conditions (e.g., wet or dry, cuts, and bruises), sensor noise, incorrect finger pressure, and inherently low-quality fingers (e.g., elderly people, manual workers), a significant percentage of fingerprint images are of poor quality. The goal of an enhancement algorithm is to improve the clarity of the ridge structures in the recoverable regions and mark the unrecoverable regions as too noisy for further processing. Thus in this project, it was demonstrated how Fast Fourier Transform is used in enhancement algorithm of fingerprint scanning.

- **Analysis of Grid Instability using Fourier analysis**

Voltage stability is a phenomenon that causes the electric power grid to fail due to a collapsing (decreasing) voltage which propagates across the grid. Voltage stability is well understood yet challenges remain, including devising ways to best manage the electric power grid to prevent such an event, or to stop it quickly and effectively should one occur.

A grid analysis device computes in real time a Fourier transform of a frequency difference between the first and second frequency data, then computes from the Fourier transform a damping coefficient and predicts a grid instability when the computed damping coefficient decreases.

- **Application of Fourier Transform in High, Low and Band pass filter**

Most of the sound samples contain considerable amount of noise. Using various filters (high pass, low pass, and band pass filter) noise can be removed and highest level of sound clarity can be achieved.

The group demonstrates how signal smoothing can be easily performed with removing completely the frequency components from a certain frequency and up, while the useful (information bearing) low frequency components are retained.

- **Application of Fourier Transform in Diffraction Gratings**

The group investigated 2-Dimensional array diffraction gratings, which can be made to diffract incident light into several beams travelling in different directions to produce a final desired 2-D pattern on a screen. A naturally occurring crystal could exhibit this phenomenon. The resultant field at each co-ordinate on the image plane (with certain approximations) turns out to be the Fourier transform of the aperture distribution in the aperture plane. The concept and approximations used were studied by the group.

- **Application of Fourier Series in solving Navier-Stokes Equation**

Fourier series is the way of representing functions/signals as a sum of sinusoids. In principle, we can use the sinusoids and exponentials to invoke the finite/infinite sum in the functions. Invoking Fourier series, it was applied to the "Navier-Stokes" equation which is one of the most fundamental equations in the fluid mechanics.

- **Calculation of an ECG Spectrum utilizing Fourier Series: A Biomedical Application**

The group demonstrated about an ECG, which is a common test to find and diagnose patients with heart problems.
The ECG converts the heart's electrical signals into line tracings on paper. The spikes and dips create waves, using which ECG can detect the any abnormalities in the heart. Fourier series is applied on an ECG signal, and using the principle of superposition, the various coefficients for each section of ECG waveform were added together to create one Fourier series that models the original ECG waveform.

- **Application of Fourier Transforms in Heat transfer**

The heat transfer phenomenon requires solution of a linear, 2^{nd} order partial differential equation in time and space, subject to initial and boundary conditions. Analytical solution of these equations is very difficult to find, since no simple closed form expressions exist for such equations. However, with the use of Fourier series, the group demonstrated analytical solutions that can be found for several simple geometries with various boundary conditions, which otherwise would have to be approximated numerically.

Conclusion of the Workshop

The exhibition ended at 5 pm. After high tea, Prof. Gadre addressed all the participants and observers with concluding remarks. He applauded the He invited one representative each from all the participating TEQIP institutes to share their experience and suggestions in few words. Professor Gadre strongly suggested that such events be replicated in other TEQIP colleges collaboratively. The pedagogical purpose behind the event was explained by Prof. Gadre (next section). Certificates of participation were handed out by Prof. Gadre to all TEQIP participants. Students of IIT Bombay would be given marks out of 25, graded for their course EE 210 Signals and Systems offered by Prof. Gadre.

Pedagogical Learning from the event

Constructive Collective learning

Conventional academics is based on the philosophy of competitive learning. This rises from the psychology that if a peer can do better than oneself, being from the similar background and provided similar resources, then one can also do the same. Such a philosophy is believed to improve academic performances of students by realising the individual potential.

However, there is also a potential of collective learning which is higher than the sum of individual potentials. To achieve this, constructive collective learning needs to be encouraged, like this workshop has done. The word ‘constructive’ is of importance, since the contrary – destructive collective learning (e.g. copying assignments) is also possible which yields negative results.

Connecting Abstractions to Reality

The objective of academic courses is often to explain reality by some theory or abstractions. This theory is a generic underlying principle which can be applied in multiple contexts. The classroom lectures build strong concepts with rigorous mathematical proofs. At an elementary level, it is important for all students to go through all proofs to know the scope, method and limitations of the theoretical frameworks. “There is no royal road to learning”

In an attempt to cover (or ‘uncover’) topics thoroughly, courses generally lose the touch with reality that they were trying to explain. With such application study assignments, students can know how the concepts learnt in class are practically applied in real life. Hence the basic purpose of academic courses is met by such workshops.