Pedagogical Event on DSP Application

Report

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1. Introduction

Digital signal processing (DSP) is the mathematical manipulation of an information signal to modify or improve it in some way. It is characterized by the representation of discrete time, discrete frequency, or other discrete domain signals by a sequence of numbers or symbols and the processing of these signals. Processing of signals may be done by the use of digital filters, transforms and other techniques.

Under the TEQIP (KITE) initiative of the Ministry of Human Resources Development (MHRD), IIT Bombay has planned and begun to conduct several activities pertaining to pedagogy, educational outreach, educational and institutional academic system reform, research and developmental activities of a collective nature involving TEQIP Institutes and other educational institutes of repute in and around Mumbai.

Digital Signal Processing is a topic that finds its application in a wide variety of areas. In fact, the areas of DSP application are so wide that the event that was conducted under KITE-TEQIP (Knowledge Incubation under TEQIP) to demonstrate various applications of DSP had presentation by more than 150 participants, each displaying a different application:

The participants had created posters, presentations and live demos using MatLab and other tools. This event was attended by students and faculties from many colleges in Maharashtra like Raisoni College, Nagpur; Government College of Engineering, Aurangabad; Sri Guru Gobind Singh College of Engineering, Nanded; Dr. Baba Saheb Ambedkar Technological University; Raja Ram Bapu Institute of Technology, Sanghli and College of Engineering, Pune. All the students who were attending from outside to review the presentations as well as the participants themselves were very enthusiastic and excited to find so many applications of the subject that they had been studying this semester.

2. Summary of applications shown by students

In this section we have given a summary of all the different applications shown by students.

1. Real time Speaker recognition using MFCC and vector quantization on DSP processor: Applications include telephone services, online shopping, remote login of computers
2. Wireless communication with variable carrier frequency: Applications include military communication, wireless security
3. Voice numerics recognizing system
4. Speech enhancement using spectral subtraction method: Applications include mobile communication
5. Noise cancellation using adaptive filters: Using no prior knowledge of noise statistics, they compared several competing algorithms
6. Channel modelling and equalization: Remove distortions using inverse distortions by using an equalizer
7. Speaker recognition using spectral features: Applications include security systems, door lock systems
8. Convolution reverb widely used in music industry to replicate the ambience of a space: Gave a live demo using matlab
9. DSP in genomics and proteomics: Studied recent research applications implementing fourier transform and filters to analyse DNA sequences
10. Image enhancement using DSP: Compared various filtering techniques that can be used to improve sharpness and contrast and noise removal
11. Mimic neuronal behaviour using Von Neumann architecture
12. DSP in finance: Study time series data, predict future stock prices by recent technique, algorithmic trading
13. DSP in space research and astronomy: Requires high precision, They explored algorithms to mitigate RFI
14. Synthesis and analysis of music: Gave a demo showing difference in spectrum of harmonics
15. Fingerprint enhancement using STFT (short time fourier transform): Implemented one algorithm, created presentation, poster and a small simulation
16. Plant disease detection problem: Farmer friendly application, Take a photo of leaf and send using mobile app to know the disease of the plant
17. Speed increase of audio and pitch constance: Gave a live demo of the application

18. Harmonic analysis of voltage waveforms using fourier transform
19. Big data analysis on graph using DSP: Knowledge of volume, variety and velocity, converted large datasets into graph
20. Digital watermarking: digital signature on audio, videos etc
21. Speech processing using STFT: Speech is a non stationary signal, they did format and pitch estimation, compared stft with linear prediction
22. DSP for speaker identification for security purposes and authentication: Involves feature extraction and feature matching
23. Inverse systems for non ideal frequency response : inverse signal a-priori so that it becomes ideal response later
24. Image mosaicing: stitch smaller images to create larger images, Applications include terrain mapping, Also implemented one algorithm
25. Identification of emotional orientation from speech signals: lie detector, psychotherapy sessions, markov models and convolution of neurolets
26. DSP in ECG signal processing: reduce noise and extract meaningful data, digital FIR filter and couple of algorithms implementation
27. Image enhancement and fingerprint recognition : Gave a demo
28. DSP in trading : 7 financial technical indicators and applied on real Indian data
29. Musical and audio effects like wah wah effect implemented using digital filters: Gave a live demo of many audio effects
30. DSP in microphone and its working
31. Removal of image distortion: implemented algorithm using image processing DSP filter and machine learning
32. Motion tracker: implementation of image processing on DSP process and path tracking
33. Wavelets in denoising signal
34. Voice imitation : Use of various digital filters, generated filter coefficients to make filters adaptive
35. Speech enhancement using bandpass equalizers: Applications include mobile communication
36. Reverberation : analyse using algorithm reverb method
37. DSP in unmanned aircraft: filter noise out due to many sources like wings and navigate easily
38. Ground penetrating radar(GPR) :plotting soil surfaces and depth of pipes in wall and metal in ground
39. Spectral Estimation of voice signals
40. Word recognizer : Gave live demos that recognized words said during any speech
41. DSP for audio signal processing hearing impaired people
42. Digital image stabilizer : IMage stabilized by implementing various competent algorithms

3. Details of some applications that we found interesting

In this section we give details of some of the application demonstrated on that day that we found very interesting.

1. **Image Mosaicing Using Fourier Shift Theorem**

By - (Kanhaiya, Khushall, Sudhir, Harsh)

In this project, they took two images as input, which are images of a scene captured through a normal camera such that both of the image have at least 50% part in common. These two images would be misaligned i.e. the images may be translated and rotated versions of each other. Now they found the translation vector and the angle θ between the images using Phase only correlation.

This project was based on Fourier Shift Theorem. Their algorithm uses the fact that shifting a signal in the spatial domain causes change in the phase of the Fourier Transform.

2.**Emotion Orientation Extraction from Speech Signal**

By - (Yash Bhalgat | Navjot Singh | Meet Shah | Kalpesh Patil)

They have implemented a Speech Emotion Recognition System which uses different feature extraction techniques and classifiers for recognition of emotion from a speech signal. The classifiers are used to differentiate emotions such as anger, happiness, sadness, surprise, neutral state, etc.

The extraction technique they used is based on evaluation of MFCC (Mel Frequency Cepstral Coefficients) , which are a commonly used in speech processing tasks. The lower order MFCC features carry phonetic (speech) information, whereas higher order features contain nonspeech (music) information. After obtaining the vectors for the speech signal, they used classification techniques like SVMs. Also they proposed using means clustering for clustering If information on different emotion classes is available.

3. **DSP Application in Finance (Trading Indicators)**

By - (Sudipto Mitral, Debraj Basu, Sakshi Agarwal)

They have described how we can use DSP in Finance, especially in designing trading strategies revolving around ‘technical indicators’. They have described about different indicators used in trading

- SMA simple moving average
- EMA exponential moving average
- Two pole Gaussian Filter
- Two pole Butterworth (and its smooth extension)
- High Pass (and two pole High pass)

They also proposed a product (digital filter) called Swiss Army Knife Filter/Indicator’.

This is application of filters.The transfer function of the the filter they have proposed is given

$$\frac{Y(z)}{X(z)} = \frac{c_0(b_0 + b_1 z^{-1} + b_2 z^{-2}) - c_1 z^{-N}}{1 - a_1 z^{-1} - a_2 z^{-2}}$$

The lccde is

$$y[n] = c_0(b_0 x[n] + b_1 x[n-1] + b_2 x[n-2]) + a_1 y[n-1] + a_2 y[n-2] - c_1 x[n-N]$$

4. **FINGERPRINT ENHANCEMENT**

By - (Surya Iyer, Ayush Shringi, Kalpesh Parihar, Raunak Suryavanshi)

In this project they have described various fingerprint enhancement techniques. Also they have proposed to apply Short time Fourier Transforms analysis for the enhancement of fingerprint images.

There are several reasons that may degrade the quality of a fingerprint image:

- Presence of creases, bruises or wounds may cause ridge discontinuities
- Excessively dry fingers lead to fragmented and low contrast ridges.
- Sweat on fingerprints leads to smudge marks and connects parallel ridges.

The fingerprint image may be thought of as a system of oriented texture with nonstationary properties. Therefore traditional Fourier analysis is not adequate to analyze the image completely.

In the case of 2D signals such as a fingerprint image, the space frequency atoms is given by:

$$X(\tau_1, \tau_2, \omega_1, \omega_2) = \int_{-\infty}^{\infty} \int_{-\infty}^{\infty} I(x, y) W^*(x - \tau_1, y - \tau_2) e^{-j(\omega_1 x + \omega_2 y)} dx dy$$

This project is the direct application of Short Fourier Transforms.

5.**Inverse Systems and their Applications**

By - (Chaitanya Joshi, Krish Narang, Atish Aloor)

They have done a detailed study of inverse systems and the conditions under which such systems can be constructed. They have considered a specific example of a microphone frequency response inverter. This system has heavy application when applied to microphones on mobile devices for which it is difficult to attain near flat frequency response.In measuiring ambient noise levels the frequency reponse of the microphone needs to be inverted beofre doing any analysis.

Their project is also an direct application of the inverse systems which is a prominent topic of study in Digital Signal Processing.

6. **Speaker Recognition**

By - (Sarthak Daga ,Varad Pingale ,Aditya Kale ,Satyam Namdeo)

They have implemented Speaker Recognition which is the task of identifying a user or verifying a user's claimed identity using the individual information present in their voices.

They have used text dependent recognition, which is based on template matching techniques.
Initially they did the following preprocessing tasks
1. Truncation
2. Frame blocking
3. Windowing
4. Fourier Transform

As oscillation of the vocal cords results in an underlying fundamental frequency and a series of harmonics at multiples of this fundamental. The fundamental frequency (eg. 113 Hz) and its harmonics appear as spikes in the spectrum. The location of the fundamental frequency is speaker dependent, and is a function of the dimensions and tension of the vocal chords. They have used this to identify the speaker.

Fourier transform , Windowing, finding fundamental frequency etc are the DSP concepts they used in this project.

7. **DIGITAL AUDIO FILTER FOR SMALL UNMANNED AIRCRAFT**

They have described how we can use digital filtering for audio in unmanned vehicles to solve various problems it face. Like noise due to motors and propellers. In the project they have characteristically identified and then filtered the undesired noises so as to have a smooth flying experience.

The following sections will describe the various aspects of processing used to implement the project:
Vehicle Test bed: In this configuration, a stereo input is obtained through two microphones. This input is given to a DSP board for processing, which is connected to a computer via USB.
Noise Characterization: The motor noise is compared with the ambient noise with rotor rotating at different speeds and the results were analysed.
Audio-Out Filter Design: An audio filter was designed for filtering the audio noise. The sampling frequency was kept equal to 44100 Hz.
Wall proximity filter and detection: The high frequency motor noise was used in the detection of proximity to a wall.

They have used the DSP concepts - Finite impulse response filter and infinite impulse response filter, Convolution and Discrete Time Fourier Transform, Spectrum analysis using Discrete Time Fourier Transform

8.**Fingerprint Matching and Authentication**

By - (Vashishth S. Dudhia, Vivekkumar J. Patel, Ranvir Rana, Abhinav Anupam)

In this project they have discussed about various methods that can be used for fingerprint matching.They have mainly described 3 methods,

- DCT based correlation method: Here they find the Discrete Cosine Transform of the fingerprint images and find the correlation between different fingerprints in the database.
- Phase based matching: Here the phase of the 2D DFT of the image is matched with the database image using POC.
- Pattern based algorithms: Here the patterns in the fingerprints are matched by using various pattern matching techniques.

9. **CONVOLUTION REVERB**

By - (Shubhankit Rathore, Dharmashloka Debashis)

In this project they have implemented and demonstrated convolution reverberation. Convolution reverb is a process used for digitally simulating the reverberation of a physical or virtual space. It is based on the mathematical convolution operation, and uses a pre-recorded audio sample of the impulse response of the space being modelled. The audio signal is convolved with the impulse response of the space. An impulse response is a recording of the reverberation that is caused by an acoustic space when an ideal impulse is played. They have demonstrated in matlab the convolution of an real world signal (sound) and another.

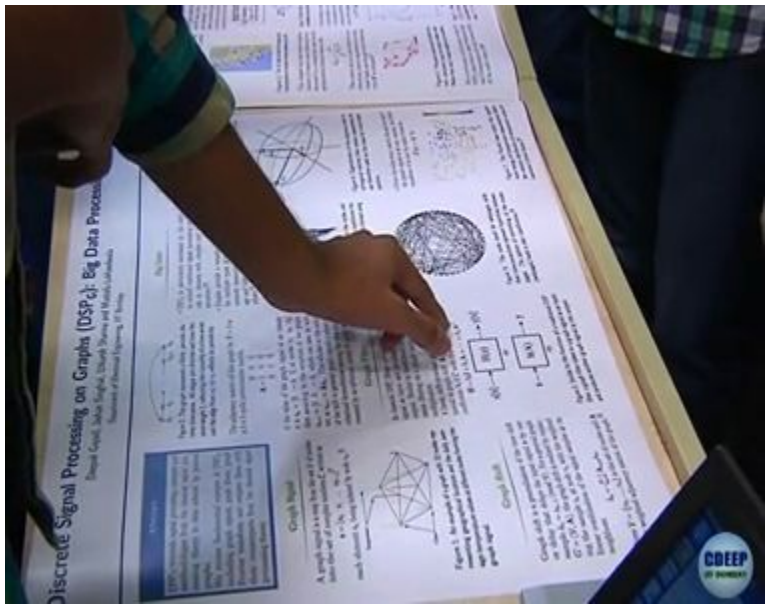
10. **Realization of Analog Domain Operations in Spike Domain using DSP**

By - (Sidharth Prasad, Pranjal Batra)

In this project they have mapped analog domain operations to spike domain operations using a spiking technique called Time Encoding Machine. They have proposed an algorithm for doing the addition operation as well as a method to go back to the time domain. They have also implemented it in a Digital Signal Processor. They talked about various advantages of spike domain over time domain. Such as information can be packed more densely in the spike domain, which can potentially reduce memory sizes. Also numerical operations like addition have much lower complexity in the spike domain.

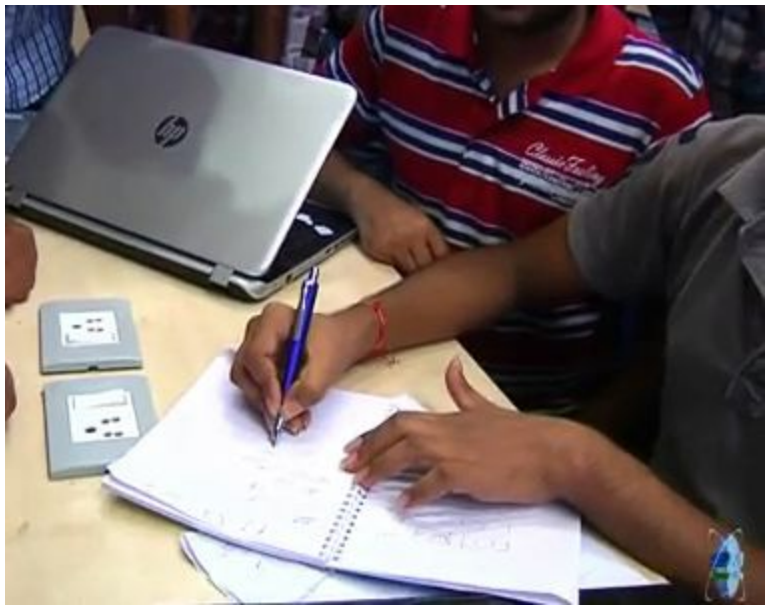
4. Appreciation of the presentations

The students made big posters and explained their applications with its help:



They also explained with the help of presentations made by them on laptop and tablets:

A student explaining the math behind his explanation:



The students who participated in this pedagogical event were highly appreciated by the faculties and students who visited from other institutes. The faculties were impressed by the concepts that were demonstrated and the wide range of ideas. The ease with which students were transiting from time domain to frequency domain and back was particularly appreciated. After seeing so many DSP applications some felt that any application in the real world requires the knowledge of DSP in some way.

The TEQIP institutes that attended the event were encouraged to hold such events in their institutes too so that their students also get the opportunity to take part in such a wonderful pedagogical event. Many of the faculties were pretty excited to do so and one of the institute - college of Engineering Pune has already hosted one such event after getting inspired by Prof. Gadre's one such event last year.

So, all in all this pedagogical event was a huge success as it helped the participating students to understand practically what they are studying during the semester and inspired the visiting students and faculty to conduct such events for other students also.