1 SUMMARY

- An NSF funded Multimedia Signal Processing Laboratory (MSPL) was established at Drexel University. The goal is to introduce to seniors the field of digital signal processing through innovative hands on experiments involving real signals. Classical concepts in signal processing are introduced within the context of processing and interpretation of speech, biomedical signals and images.
- A set of experiments was designed and taught as part of the senior three-term Digital Signal Processing sequence, which was completely restructured to benefit as much as possible from the lab experiments.
- MSPL enhances students education through multimedia cooperative learning based state-of-the-art audio and video equipment.

2 Equipment

The following equipment was purchased:

- One (1) Dell PowerEdge 2200 Base server, with 266 MHz processor, 512 KB cache,
  512 MB RAM, 27 GB Hard Disk Space and 8X SCSI CD-ROM.
- Ten (10) Dell Dimension XPS H266 MHz with Pentium II processor with integrated sound, MMX technology, 512 KB cache, 128 MB RAM and 12-24X CD-ROM.
- One (1) Phaser560 Smart Color Laser Printer from Tektronix.
- Computer screen projector.
- Cameras and scanners.
- A recording studio consisting of:
  - Two microphones and two speakers all on microphone stands for doing measurements.
  - A DAT machine for doing quality A/D and D/A conversion and recording/playing test signals and impulse responses
  - A mixer for microphone pre-amplification and general audio signal routing
  - A pc card for inputing and outputing audio signals from DAT machine or other sources
  - Two speakers to connect to computer for general audio output
  - A**head and torso simulator (model 4100)**, made by Bruel & Kjaer, used for measurement of head-related transfer functions. This equipment come with microphone capsules in the dummy's ears, a pre-amplifier, and a power supply.

The ECE Department renovated a 600 sq.ft. space to house the facility.

3 Goals

- Combine the media of speech and image analysis to introduce the most basic elements in digital signal processing.
- Enhance students education through the multimedia technology and through cooperative learning.

- Introduce students to the interdisciplinary aspect of DSP by designing hands on experiments drawn from diverse disciplines such as biomedical (e.g., analysis of ultrasound, autoradiograms images, computer tomography); OCR (optical character recognition); speech synthesis and recognition; assembly automation and inspection; etc.
- Develop Matlab-based multimedia programming software for a number of image/speech processing applications which will be used to unburden the computational tasks of future course offerings.
- Develop instructional modules for teaching multimedia-based DSP that could be adopted by other institutions.

To achieve these goals the senior DSP sequence was restructured, so that it could benefit the most out of the established laboratory, and a set of experiments was designed to be taught in parallel with the course.

3.1 The reformed DSP sequence (4 credit hours per quarter)

DETERMINISTIC SIGNAL PROC. (1st quarter)	PROJ.
Transforms *(4 weeks)* Unitary; Nonunitary; Z transform	E1
Filter Design *(4 weeks)* IIR, FIR filter design	E2,E3
Projection *(1 week)* Radon Transform, signal reconstruction from projections	E4
Time-Frequency Representation *(1 week)* Short-Time Fourier Transform, Wigner Distribution	E5
STATISTICAL SIGNAL PROCESSING (2nd quarter)	
Autocorrelation, Spectrum *(1 week)*	E6
Conventional Spectral analysis *(2 weeks)* Periodogram; Uncertainty principle of the FT; Resolution	
Parametric Representation of Time series *(4 weeks)* Linear prediction; Levinson-Durbin Recursion; Lattice filter structures	E7,E8
Restoration *(3 weeks)* Wiener Filtering, Kalman Filtering	E9

INFERENCE (3rd quarter)	
Speech Production Modeling *(5 weeks)* Overview of anatomy of speech production; digital model for vowel sounds; short term LPC analysis; cepstral analysis; introduction to speech coding;	E10-E12
Image Modeling and Recognition *(5 weeks)* Edges; Boundary; Recognition and Shape Estimation from Contours; Texture; Recognition and Shape Estimation from Texture; Recognition and Shape Estimation from Stereo; Motion and Object Tracking	E13-E16

3.2 Designed Experiments

Although the experiments are being updated and improved continuously, the following is a list of experiments that have been designed so far.

- [E1] *Image Coding*
  Image compression for fast transmission is an important element in teleconferencing, and the communication super highway. This project deals with the issue of using compact and fast transforms (e.g., unitary transforms such as cosine transforms, Hadamard transforms, discrete Fourier transforms) for image representation. The students experiment with different type of transforms addressing the issues of compactness, speed, and image fidelity.

- [E2] *Restoring the sound quality of an old recording*
  The students are asked to design a filter of prespecified characteristics to improve the sound quality of an old music recording. The goal of this experiment is to exemplify filtering and filter design issues.

- [E3] *Old movie restoration*
  Different types of filtering (FIR, IIR filters) are illustrated via the problem of old movie restoration. The student is given a sequence of frames some of which are defective and is asked to use various filtering ideas to restore the defective frames to their original grandeur.

- [E4] *Reconstruction of the rat brain morphology from images of different brain slices*
  In many applications where only a manifestation of a phenomenon is observed, the problem of reconstructing the phenomenon from its manifestation is of great interest. Such paradigm is, for example, encountered in computer tomography, where the phenomenon is the image of the brain, and the manifestation is the slices along transaxial projections. This project deals with such a problem and expose the students to many aspects of DSP such as filtering, Hilbert transforming, and radon transforms. (The necessary data is available at the Image Processing Inst. at Drexel University)

- [E5] *Tracking a moving target*
  Short-time Fourier transform or Wigner distribution is used to estimate the speed of the target as the first derivative of the chirp frequency.

- [E6] *Estimating vocal tract resonances via conventional spectrum*
  Processing obtained recordings, the students determine the resonant frequencies of their vocal tracts using conventional spectral analysis. This is the first step towards understanding speech modeling.

- [E7]*Estimating vocal tract resonances via AR modeling of speech*
  Experiment E6 is be repeated with a different processing method this time. The results are compared and conclusions on the resolution capabilities of the two methods are drawn.

- [E8] *Modeling the shape deformation of blood cells moving through vessels*
  In this project the student uses stochastic modeling (AR models) to account for systematic random deformation that the object has been subjected to as it undergoes nonrigid motion (e.g., the cells moving through vessels and arteries).

- [E9] *Improving the diagnostic quality of ultrasound images of the breast or liver*
  Ultrasound image, taken from the extensive database available at the Biomedical Engineering and Science Institute (BMESI) at Drexel University, is inverse filtered through the transducer's impulse response (which is provided) in order to improve resolution and enhance visibility of small targets.

- [E10] *Instructing the computer to mimic human voice*
  The students make recordings of various phonemes issued by them, and based on them determine the pitch period and estimate the parameters of their vocal tract model. Then they excite the estimated model with a periodic pulse train and listen to their computerized voice. This project is an application of cepstral analysis and homomorphic filtering.

- [E11] *Extracting speech signatures*
  For various phonemes, the vocal tract parameters (obtained in E7 or E9) are used to develop phoneme signatures. This is the first step towards speech recognition.

- [E12] *Simulating a voice operated door unlocking system*
  Processing a speech segment (name or identification number), a signature is extracted (see project E11) and compared against a database, in order to determine if the entry should be permitted.

- [E13] *Designing an on-ground airport traffic control system*
  The student is asked to come up with a recognition system that classifies different types of aircraft based on their silhouettes. The classifier will take into account the fact that the observed silhouette might appear different than the prototype stored in the data base due the different viewing direction the aircraft is seen from. Different concepts of invariance signal modeling are applied towards that end.

- [E14] *Instructing a robot to recognize an object independent of the object position and viewing angle*
  The concept of invariance allows a machine recognition capabilities despite transformations that the object has been subjected to as a result of motion or change in viewing direction, resulting in a different manifestation of the object than the one stored in the data base of the computer. This project introduces the students to the construction and use of moment invariants for matching objects represented by outlines, support sets, or scattered data, as well as affine invariant Fourier descriptors.

- [E15] *Texture modeling*
  Texture is one the important elements in image modeling. The student here is exposed to deterministic as well as stochastic modeling of texture using Fourier analysis as well time series models. In addition, the student tracks the texture representation when an affine transformation resulting from viewing the texture from a different viewpoint takes place.

- [E16] *Edge Detection*
  The student is exposed to standard edge detection algorithms such as the Sobel and Canny edge detectors. The important issue of edge detection evaluation is also introduced by means of Receiver Operating Characteristic (ROC) curves.

4 Additional Benefits

- A number of other courses also benefit from the established facility, e.g., junior Circuits and Communications.

- A number of senior design projects were developed taking advantage of the multimedia capabilities of the lab.
- The facility is being used as a showcase during open-houses.