

## **DIGITAL SIGNAL PROCESSING & MULTIMEDIA (CE-DSP)**

### **Ivor Page Proposal (September, 2003):**

**CE-DSP0. History and overview of digital signal processing and multimedia [core]**

**CE-DSP1. The sampling theorem, Nyquist Frequency, Aliasing, relationship between time and**

**frequency domain, principle of causality (discrete and continuous spectra, etc.) (3)**

**CE-DSP2. Spectra of the impulse and a square wave. (1)**

**CE-DSP3. The Discrete Fourier Transform, relationship between domains again, (sampled <-> repeated, repeated <-> discrete). (2)**

**CE-DSP4. Implications of assumptions of repeated time series, group sampling of time signals,**

**size of group, how it affects spectra. (2)**

**CE-DSP5. Window functions and their impact on the spectra.**

**CE-DSP6. Convolution and correlation of signals in the frequency domain,**

**CE-DSP7. Case study from speech processing, simulating the vocoder.**

**CE-DSP8. The z transform, relationship between s and z planes. (2)**

**CE-DSP9. FIR filters, frequency and phase response, time domain multi-tap filters, surface acoustic wave filters.**

**CE-DSP10. Poles and zeros in the z plane.**

**CE-DSP11. IIR filters, frequency and phase response.**

**CE-DSP12. Design of IIR Filters.**

### **Original Doug Lyons Proposal:**

**CE-DSP0. History and overview of digital signal processing and multimedia [core]**

**CE-DSP1. Overview of Digital Audio and its application**

**CE-DSP2. Discrete Time Signals (SC9)**

**CE-DSP3. Multimedia programming, data streaming**

**CE-DSP4. Wave Table Generation**

**CE-DSP5. Convolution (SC8)**

**CE-DSP6. Fourier Analysis (SC10, modified)**

**CE-DSP7. Audio Processing**

**CE-DSP8. Generalized Modulations and Demodulations**

**CE-DSP9. LaPlace Transforms (SC12 with modifications)**

**CE-DSP10. Z – transforms (SC13 with modifications)**

**CE-DSP11. Digital Filters (SC14, with modifications)**

**CE-DSP12. Digital Image Processing Fundamentals**

**CE-DSP13. Simple Graphics**

**CE-DSP14. Displaying Images**

**CE-DSP15. Reading and Writing Image Files**

**CE-DSP16. Edge Detection**

**CE-DSP17. Boundary Processing**

**CE-DSP18. Image Enhancement Techniques**

**CE-DSP19. Achromatic and Colored Light**

**CE-DSP20. Thresholding techniques**

**CE-DSP21. Morphological filtering**

**CE-DSP22. Warping**

**CE-DSP23. The Cosine Transform**

**CE-DSP24. The InLine MPEG CODEC**

**CE-DSP25. The Wavelet Transform**

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**Domain: 1D Introduction to Signal Processing + MultiMedia Programming**

Students are introduced to Digital Audio and its application Current state of streaming Audio on the Internet Digital Audio Processing Fundamentals. Transform concepts and applied multi-media object-oriented programming.

Students will apply the theories of Sampling, Spectra, Fast Fourier Transform Class, convolution and frequency space processing, compression and one-dimensional streaming.

Students will apply the theories by creating programs that read processing and write audio streams. They are exposed to the elements of multi-media network delivery of data. They learn about a wide class of FFT algorithms and elementary sound synthesis.

Emphasis is place on good software engineering practices.

Prerequisite – Data Structures and two terms of Calculus.

Learning Objectives:

1. The students will learn the principles of Digital Signal Processing so they can:
  - a. Apply transform concepts in programming situations
  - b. Recognizes interrelationships among signals and spectra
2. The student will become proficient with the usage of an object-oriented language to:
  - a. Demonstrates the ability to utilize in practical signal processing problems.
  - b. Uses appropriate object-oriented design patterns to solve problems.

**Topics :**

**CE-DSP0. History and overview of digital signal processing and multimedia [core]**

*Suggested time:* 1 hour

*Topics:*

- Indicate some reasons for studying digital signal processing and multimedia.
- Highlight some people that influenced or contributed to the area of digital signal processing and multimedia.
- Indicate some important topic areas such as digital audio, multimedia, wave tables, digital filters, image display, chromatic and achromatic lighting, and thresholds.
- Contrast the meanings of analog and digital signals.
- Explain the need for using transforms and why they are different for analog and discrete situations.
- Indicate how the subject relates to simple graphics.

- Contrast image processing from computer graphics.
- Mention some techniques used in transformations such as Fourier, Laplace, and wavelet transforms.
- Explore some additional resources associated with digital signal processing and multimedia.
- Explain the purpose and role of digital signal processing and multimedia in computer engineering.

*Learning objectives:*

- Identify some contributors to digital signal processing and multimedia and relate their achievements to the knowledge area.
- Know the difference between analog and discrete signals.
- Articulate the difference between image processing and computer graphics.
- Indicate some of the characteristics of filters, in particular low- and high-pass filters.
- Describe how computer engineering uses or benefits from digital signal processing and multimedia.

**CE-DSP1. Overview of Digital Audio and its application**

*Suggested time:* 2 hours

*Topics:*

Current state of streaming Audio on the Internet  
Problems and solutions

*Learning Objectives:*

1. To understand the importance of audio processing in society.
2. To understand the limitations introduced by increasing numbers of file formats on browsers

**CE-DSP2. Discrete Time Signals (SC9)**

*Suggested time:* 4 hours

*Topics:*

Representation of signals  
Sampling of signals  
Quantizing  
Aliasing  
Difference Equations

*Learning Objectives:*

1. To understand the discrete-time representation of signals.
2. To understand errors introduced by sampling and quantizing.

**CE-DSP3. Multimedia programming, data streaming**

*Suggested time:* 8 hours

*Topics:*

internal data structures  
the AudioStream  
the AudioPlayer  
building the GUIs  
Audio file formats  
u-law companding in the Sun AU files

decoding u-law  
encoding u-law  
reading  
writing  
playing  
graphing  
Delay, echo vs. reverb

*Learning Objectives:*

1. To understand the companding system and its relationship to the human perceptual system
2. To understand errors introduced by companding.
3. To understand how to build GUI's for playing audio.
4. To understand how to a simple digital audio effect.

**CE-DSP4. Wave Table Generation**

*Suggested time:* 3 hours

*Topics:*

Sine  
Triangle  
Square  
Sawtooth

*Learning Objectives:*

1. To understand the framework for using mathematical functions to generate tones.
2. To understand how sampling rates and wavetable length alter frequency
3. To understand the wavetable length and wavelength relationship.

**CE-DSP5. Convolution (SC8)**

*Suggested time:* 4 hours

*Topics:*

Impulse response  
Convolution integral  
Physically realizable systems  
Graphical methods

*Learning Objectives:*

1. To be able to use the convolution technique to analyze circuits.
2. To be able to represent convolution using graphical techniques.

**CE-DSP6. Fourier Analysis (SC10, modified)**

*Suggested time:* 6 hours

*Topics:*

Signal representation by Fourier series  
Trigometric Fourier series  
Exponential Fourier series  
Definition of the Fourier transform

## Properties of the Fourier transform

### *Learning Objectives:*

1. To understand how Fourier series approximates functions
2. To understand the Fourier transform and its properties.
3. To understand the relationship between the Fourier transform and convolution.

## **CE-DSP7. Audio Processing**

*Suggested time:* 9 hours

The Discrete Fourier Transform  
The Inverse DFT  
The Fast Fourier Transform Class  
The Inverse FFT method  
Fast Convolution using the FFT  
Power Spectral Density  
Frequency shifting using the FFT  
Filtering using FFT  
Additive Synthesis  
Subtractive Synthesis

### *Learning Objectives:*

1. To understand the Discrete Fourier transform and its significance.
2. To understand the Fast Fourier transform and its significance.
3. To understand the difference between additive and subtractive synthesis.
4. To understand the role of the FFT in additive and subtractive synthesis.

## **CE-DSP8. Generalized Modulations and Demodulations**

*Suggested time:* 3 hours

AM  
FM  
Direct Sequence Spread Spectrum ideas

### *Learning Objectives:*

1. To understand the spectral effect of modulation.
2. To understand the mechanism for coding and decoding modulated signals.
3. To understand the role of modulation in society.

## **CE-DSP9. LaPlace Transforms (SC12 with modifications)**

*Suggested Time:* 8 hours

### *Topics:*

LaPlace transform integral  
Impulse response  
Step functions  
Ramp functions  
Inverse transforms

Poles and zeroes  
Initial value theorem  
Final value theorem  
Circuit analysis using Laplace transforms

*Learning Objectives:*

1. To understand the Laplace transform technique and its mathematical representation.
2. To understand the relationship between the Laplace transform and the conformal map

**CE-DSP10. Z – transforms (SC13 with modifications)**

*Suggested time:* 4 hours

*Topics:*

Concept and properties of the z – transform  
Inverse z – transforms  
Difference equations

*Learning Objectives:*

1. To understand the concept, properties and uses of the z – transform.
2. To understand the relationship between Z transform and the conformal map

**CE-DSP11. Digital Filters (SC14, with modifications)**

*Suggested time:* 4 hours

*Topics:*

Frequency response of discrete – time systems  
Recursive filter design  
Nonrecursive filter design  
Windowing

*Learning Objectives:*

1. To understand frequency selective filters in the z – transform domain.
2. To be able to design digital filters that have specified frequency characteristics.

**Domain: Image Processing**

*In an introduction to image processing* students learn:

Image algebra,  
arithmetic operations,  
boolean operations,  
matrix operations,  
Achromatic and Colored Light  
Selecting Intensities, Gamma Correction,  
Chromatic Color, psychophysics, Color models, Color Space Conversion,  
low-level pattern recognition,  
2-D Fast Fourier Transform Class,

2D convolution and frequency space processing,  
compression and 2D streaming.

With a lab emphasis, students will learn enough signal processing to write their image processing applications. They apply the theory by creating programs that read processing and write image streams. They are exposed to the elements of multi-resolution multi-media network streaming. They learn about a wide class of transforms, including Wavelets, DCT, the PFA, FFT and others.

Prerequisite – PreReq: Introduction to Signal Processing

Learning Objectives :

1. The students will learn the principles of Image Processing.  
Expected learning outcomes:
  - a. Applies transform concepts in programming situations
  - b. Recognizes interrelationships among signals and spectra
2. The student will become proficient with the usage of the Java language.  
Expected learning outcomes:
  - a. Demonstrates the ability to utilize programs in practical image processing problems.
  - b. Uses appropriate object-oriented design patterns to solve problems.

Outcomes:

When the course is done, Students will have written applications of their own design. Students will demonstrate a basic understanding of image processing using data structures, linear algebra, design patterns, and 1D signal processing.

### **CE-DSP12. Digital Image Processing Fundamentals**

*Suggested time: 3 hours*

*Topics:*

- Overview of Image Processing and its application
- Image Storage and Display
  - image models
  - cameras video and scanners
- Current state of streaming video on the Internet
  - Problems and solutions
  - Sampling
  - Spectra and Spectra

*Learning Objectives:*

1. To understand the role of the human vision in modern displays.
2. To understand the role of image coding and decoding in society.

### **CE-DSP13. Simple Graphics**

*Suggested time: 3 hours*

*Topics:*

- Test Patterns
  - Color Bars
  - resolution chart
  - multi-burst test chart

Snell and Wilcox test chart

*Learning Objectives:*

1. To understand how to use graphics to create simple images.
2. To understand the role of test patterns in calibration.

### **CE-DSP14. Displaying Images**

*Suggested time: 3 hours*

*Topics:*

oldPixels  
newPixels

*Learning Objectives:*

1. To understand the producer-consumer relationship in image filtering
2. To be able to design digital filters that have specified frequency characteristics.

### **CE-DSP15. Reading and Writing Image Files**

*Suggested time: 3 hours*

*Topics:*

internal data structures  
the ImageStream  
the ImageDataStream  
Image doubleData  
Reading GIF and JPEG  
Writing GIF  
Reading PPM  
Writing PPM

*Learning Objectives:*

1. To understand the image file formats
2. To understand the mechanisms for reading and writing files
3. To understand the lossy coding techniques used in JPEG images
4. To understand the lossless coding methods used in PPM images
5. To understand the color reduction techniques used in for GIF images

### **CE-DSP16. Edge Detection**

*Suggested time: 3 hours*

*Topics:*

Roberts, Prewitt, Frei-Chen,  
Kirsch, Sobel,  
boxcar, pyramid, argyle, Macleod,  
derivative of Gaussian, Robinson,  
Canny  
Laplacian generation, Laplacian of Gaussian  
Hat, Gabor

*Learning Objectives:*

1. To understand the human visual systems response and filter models
2. To understand the sub-band processing in the human visual cortex.
3. To understand how to model orientation filters in the visual cortex

### **CE-DSP17. Boundary Processing**

*Suggested time: 3 hours*

*Topics:*

- XY to Vector Conversion
- vector ordering using Dijkstras' algorithm
- Edge following and Martellis' algorithm
- Divide-and-conquer boundary detection

*Learning Objectives:*

1. To understand the role of heuristics in the search of an edge
2. To understand the role of XY representations vs. Vector representations

### **CE-DSP18. Image Enhancement Techniques**

*Suggested time: 3 hours*

*Topics:*

- Blur, mean, median, unsharp
- smoothing binary images by association
- local area contrast enhancement
- histogram equalization
- lowpass filtering
- highpass filtering
- averaging multiple images

*Learning Objectives:*

1. To understand the elements of convolution kernel design
2. To understand the frame work needed to implement the 2D convolution

### **CE-DSP19. Achromatic and Colored Light**

*Suggested time: 3 hours*

*Topics:*

- Selecting Intensities-Gamma Correction in Java
- Chromatic Color
  - psychophysics
  - Color models (CIE, RGB, YUV, CMY, HSV, YIQ)
- Color coordinate systems
  - RGB to  $L^*u^*v^*$ ,  $L^*u^*v^*$  to RGB
  - RGB to  $L^*a^*b^*$ ,  $L^*a^*b^*$  to RGB
  - RGB to XYZ, XYZ to RGB
  - RGB to YIQ, YIQ to RGB
  - RGB to YUV, YUV to RGB
  - RGB to HSV, HSV to RGB
  - RGB to HLS, HLS to RGB

*Learning Objectives:*

1. To understand the association between psychophysics and color display
2. To understand the color conversion systems
3. To understand black body color temperatures and spectral emission

### **CE-DSP20. Thresholding techniques**

*Suggested time: 3 hours*

*Topics:*

- Global thresholding
- multilevel thresholding
- variable thresholding
- thresholding using image statistics
  - using mean and standard deviation
  - using maximization of between-class variance

*Learning Objectives:*

1. To understand the application of statistics to image data
2. To understand the simple binary image segmentation

### **CE-DSP21. Morphological filtering**

*Suggested time: 3 hours*

*Topics:*

- set theory
- arithmetic operations
- boolean operations
- erosion and dilation
- medial axis transform
- skeletonization

*Learning Objectives:*

1. To understand set algebra
2. To understand the association between robotic path planning and skeletonization

### **CE-DSP22. Warping**

*Suggested time: 3 hours*

*Topics:*

- scaling
- rotation
- shear
- cutting and pasting
- conformal image mapping
- warping

*Learning Objectives:*

1. To understand the role of warping in society
2. To understand the transform mathematics
3. To understand the 4 point-bilinear inverse affine transforms role in remote sensing.

### **CE-DSP23. The Cosine Transform**

*Suggested time: 3 hours*

*Topics:*

- The Discrete Cosine Transform
- The Inverse Discrete Cosine Transform
- The Fast Cosine Transform Class
- Reading and Writing JPEG Images

*Learning Objectives:*

1. To understand the theory of the DCT
2. To understand the role of the DCT in the JPEG coding

#### **CE-DSP24. The InLine MPEG CODEC**

*Suggested time: 3 hours*

*Topics:*

- Compressed MPEG movies images
  - decoding MPEG
  - encoding MPEG
- reading MPEG files
- writing MPEG files
- displaying MPEG files
- measuring loss

*Learning Objectives:*

1. To understand the mechanisms for implementing MPEG
2. To understand the motion-prediction procedures in MPEG
3. To understand the limits and advantages of motion prediction

#### **CE-DSP25. The Wavelet Transform**

*Suggested time: 3 hours*

*Topics:*

- The Discrete Wavelet Transform
- The Inverse Discrete Wavelet Transform
- The Fast Wavelet Transform Class
- Writing a wavelet encoded file
- Decoding the wavelet encoded file
- Incorporating the decoder with the data
- Distribution of wavelet images on the Net.

*Learning Objectives:*

1. To understand the mathematics of the DWT
2. To understand the multi-resolution stream concept
3. To understand the advantages and disadvantages of lifting transforms.