DIGITAL SIGNAL PROCESSING LAB

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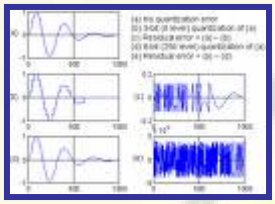
Introduction:

The area of digital signal processing has advanced rapidly over the last four decades. This advancement is attributed to the progress in digital computer technology and integrated circuit fabrications. There are many reasons why the digital processing of an analog signal is preferred over the signal processing directly in analog domain. The advantages of DSP are common to many digital systems and include:

Versatility:

- digital systems can be reprogrammed for other applications (at least where programmable DSP chips are used)
- digital systems can be ported to different hardware



Repeatability:

- digital systems can be easily duplicated

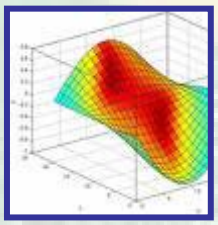
Accuracy:

- Digital systems provide much better accuracy requirement. Tolerances in the analog components make it much difficult for the system designer to control

the accuracy of an analog processing system. DSP is used in a very wide variety of applications.

Objectives:

This lab introduces students to DSP design and analysis techniques that are core knowledge



for DSP engineers, and which serve as solid grounding for advanced level work in DSP. This lab aims at supporting the teaching and research activities in the area of DSP, which are either currently being. This lab is established with **wireless communication lab with a funding of $ 600,000**. As such, the lab aims at achieving the following objectives:

1. To emphasize the **teaching of key DSP concepts**, such as overview of discrete time signal and systems in time domain, and frequency domain, sampling and reconstruction of analog signals, signal and systems representation in complex frequency domain, solution of differential equations using z transform, computation of Fourier transform and its efficient implementation, Discrete Fourier transform and Fast Fourier transform, Structure for the implementation of digital filters, FIR Filter design and IIR Filter Design.

2. To provide an understanding of how to design signal processing systems and process data in a **software simulation like using MATLAB®**, including how to:Create and analyze signals Create and analyze filters Apply signal and filter specifications to real-world designs and to implement the DSP algorithms in software and to familiarize key DSP Concepts in a practical way with matlab examples and computer demonstrations and **MATLAB®,**techniques to analyze z and inverse z transforms,

3. To give students an introduction to **real-time DSP requirements** by exposing them to the use of some educational DSP kits with real-time capability, which will help them get acquainted with the programming of theses devices and some typical hardware and functions found in practical applications such as I/O interface cards (A/D, D/A, I/O filters), types of DSP processors and their different characteristics, interrupts, etc.

4. To heighten students' awareness of the vast array of diverse practical DSP applications by exposing them to some practical DSP demos, hardware and operations involved in this area and also to provide students with a learning platform on which to further

experiment with DSP through course work, design projects, theses, etc. and appreciate the inter-disciplinary nature of the field, its vast array of industrial applications and its growing importance in today's world.

Lab Facilities & Equipment:

The Digital Signal Processing Lab comprises of test and measurement equipment for doing advanced research and development work in digital signal processing field. The Lab is equipped with complete set of Hardware and Software to perform DSP experiments.

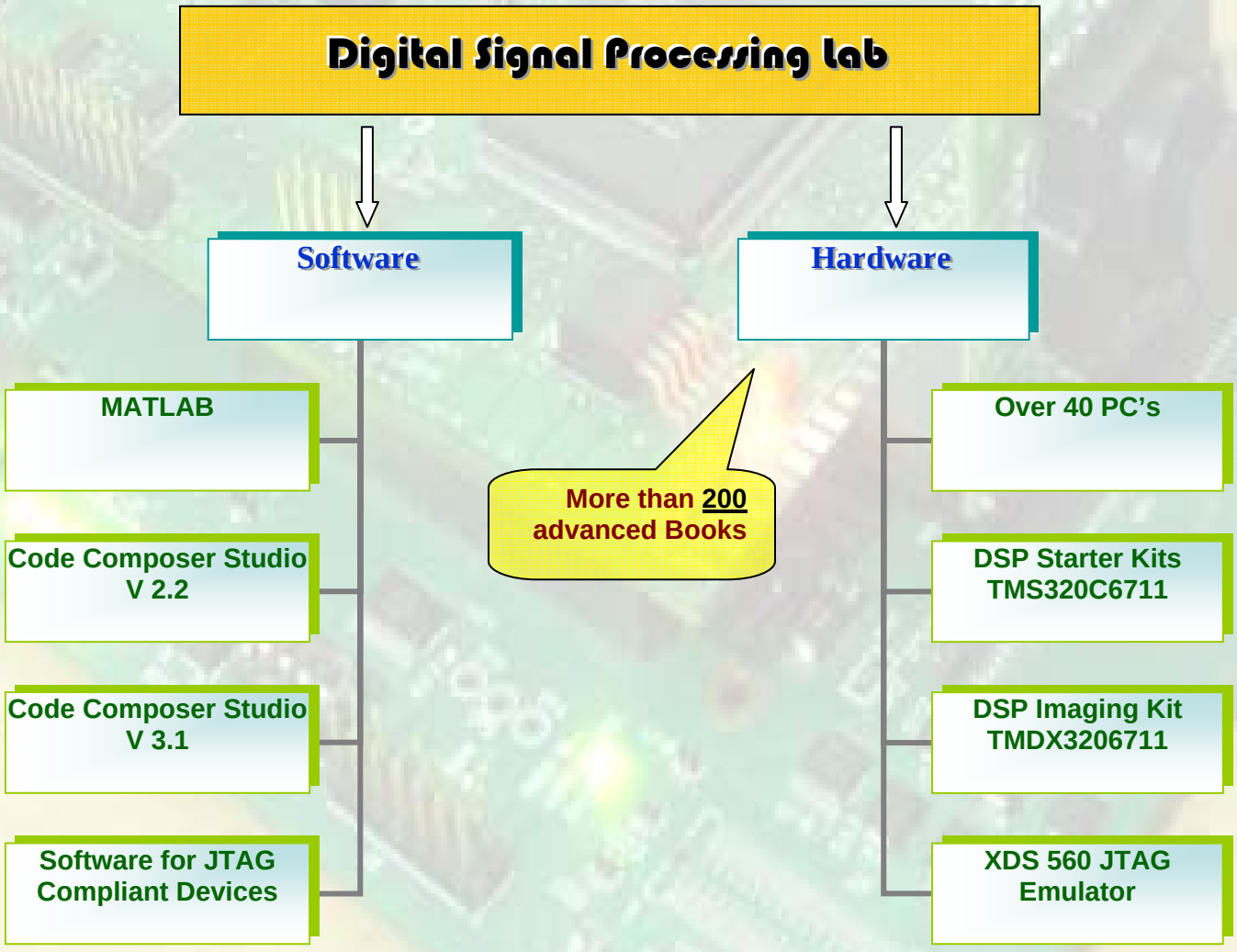


Fig: Lab Facilities in the DSP Lab

Software:

MATLAB 7

MATLAB is a numerical computing environment and programming language. Created by The Math Works, MATLAB allows easy matrix manipulation, plotting of functions and data, implementation of algorithms, creation of user interfaces, and interfacing with programs in other languages. Although it is numeric only, an optional toolbox interfaces with the Maple symbolic engine, allowing access to computer algebra capabilities. All the PCs are equipped with MATLAB 7 and its associated tool boxes and Simulink.

Code Composer Studio V 2.2

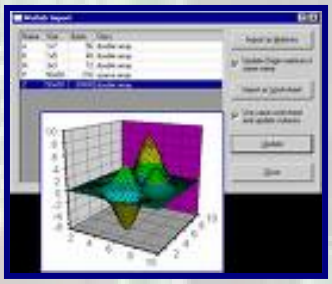
Performance is an area of concern for embedded programmers. It is difficult for the programmer to locate and isolate the problems that can cause poor performance due to the complexity. Many of today's programs need to be completed in a certain number of cycles. In some situations, if time constraints are not met, the consequences can be catastrophic. To a lesser degree, when a program fails to meet time constraints, many different outcomes can occur from major to minor importance - from device failures to system crashes.

Profiling and the proper use of the profiler will help reduce the time a programmer will need to find and resolve performance bottlenecks. The Code Composer Studio Profiler analyzes the execution of your program and shows you where the "hotspots" or the areas where all the cycles are being used occur. The profiler can show the developer how many cycles a function takes to execute, as well as how often it is called.

Texas Instrument has a variety of development tools available that enable quick movement through the digital signal processor (DSP) based application design process from concept, to code/ build, through debug analysis, tuning, and on to testing. Many of the tools are part of TI's real-time eXpressDSP™ software and development tool strategy, which is very helpful in quickly getting started as well as saving valuable time in the design process. TI's real-time eXpressDSP Software and Development Tool strategy includes three components that allow developers to use the full potential of TMS320™ DSPs:

JTAG Compliant Devises:

Boundary-Scan Testing, also known as the JTAG standard, or simply "JTAG", refers to the IEEE Standard 1149.1, which is a standard that defines a set of design rules for facilitating the testing, programming, and debugging of a semiconductor device at the chip, board, and systems level.



Boundary-scan testing basically involves embedding of special test circuits at chip level that would facilitate board-level testing of the chip and the board itself. These additional circuits allow input and output signals to be scanned into and out of the I/O circuits of a device in a serial manner, letting the device to be tested with a small number of accessible pins.

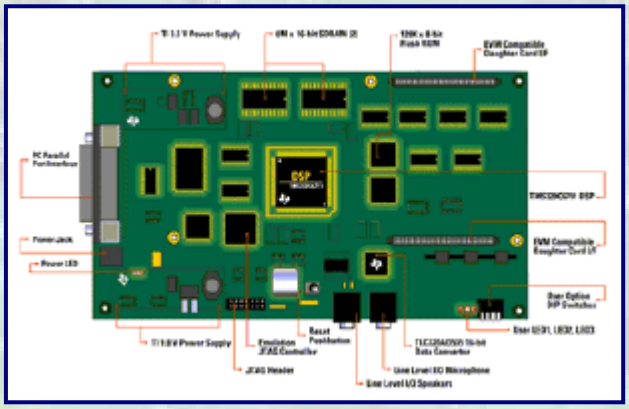
A JTAG-compliant device has: 1) a boundary cell on each of its I/O pins; 2) a 'scan path' or 'scan chain' that connects these boundary cells together in serial manner; 3) 4 or 5 additional pins to handle the JTAG signals; 4) a Test Access Port

(TAP) for controlling the JTAG signals used in boundary-scan testing; and 5) a 16-state TAP controller or state machine that controls the states of operation of the boundary-scan testing.

Hardware:

DSP Starter Kits TMS320C6711

The **DSK C6711** board is a Texas Instruments external DSK board with 150 MHz 'C6711 processor and 2-channel 16-bit analog I/O (codec). The DSK C6711 board connects to the host PC using EPP (enhanced parallel port). The C6711 performs 32 x 32 floating-point multipliers and stores a 32-bit floating-point result. It's instruction set is a superset of the C6211 device.



DSP Imaging Kit TMDX3206711

The Digital Imaging Kit has been developed as a platform for development and demonstration of imaging/video processing applications on TMS3206000 DSP's.

XDS 560 JTAG Emulator

The XDS560 emulator is a PCI-based ext- generation emulation controller that supports igh- speed RTDX on an enabled processor for real-time data rates of over 2 MB/second. It provide an unparalleled level of real-time visibility into an executing application to assist developers in debugging real-time systems. The XDS560 can achieve code download speeds of up to 500 Kbytes per second improving start-up times for larger applications and thus speeding development. The XDS560 also enables real-time non-intrusive Advanced Event Triggering capabilities, including event sequence detection, extended benchmarking

Compatible Products

The XDS560 emulator supports these ISA processor families and devices:

High-speed RTDX-Enabled Processors Supported

- 'C621x, C671x
- 'C55x v2 (driver included in C55x Chip Support Package available via Update Advisor)

Basic Emulation-Enabled Processors Supported

- 'C64x v1.0
- 'C620x
- 'C670x
- 'C54x
- OMAP" 1510
- ARM7/ARM9

Planned Support for New High-speed RTDX-Enabled Processors

- 'C64x (future versions)
  The C64x family will be high-speed RTDX-enabled on the silicon, and will deliver 2 Mbyte/second high-speed RTDX when XDS560 driver support

Processors Not Supported by XDS560

'C2x, 'C20x, 'C3x, 'C4x, 'C5x, 'C8x
These processor families will not be supported by the XDS560 JTAG emulator.

capabilities, and program range breakpoints. The XDS560 is compatible with existing XDS510-class emulators

The XDS560 JTAG emulator also allows developers to build real-time DSP applications conveniently with an advanced host-target connection featuring the popular PCI bus and a highly flexible 5-1/2 foot (1.5+ m) cable. The lightweight cable assembly and credit-card-size pod puts virtually no pressure on the target hardware, even when hanging from it. Additionally, with support for voltages ranging from 0.5 to 5V, the XDS560 offers excellent support for TI's low-voltage device roadmap. The XDS560 also supports the full range of standard emulation and debugging capabilities, including both software and real-time hardware breakpoints and trace points, single-step execution, loading/inspecting/modification of all registers and memory, software breakpoint/trace on all program and data addresses, benchmarking of execution time of clock cycles, and heterogeneous multiprocessor debugging with global running, stepping and breakpoints. All of these capabilities are fully integrated with the Code Composer Studio debugger interface.

DSP Starter Kits TMDX320C5402

C5402 DSK gives students and new DSP designers access to the industry's most powerful DSP specifically optimized for applications that need the best combination of power/performance/area. The 100 MIPS processing power of C5402 enables it to be used in a variety of signal processing development areas including speech compression / decompression speech recognition, text-to-speech, fax/data conversion, modem, protocol conversion, tone generation/detection and echo cancellation. The C5402 device features:

- 100Mhz
- 40-bit ALU
- 16K x 16 Bit dual access on chip

RAM
- 4K x 16 Bit on chip ROM
- Advanced multibus architecture with 3 separate 16-bit Data memory busses and 1 Program Memory Bus
- 2 McBSP, 6 DMA controllers, 8 bit host port interface, 2 16 bit timers
- Ordering Information: TMDX320005402 includes a standard US power cord, TMDX32005402E version includes both UK & European power cords

Library

In addition to, advanced software and hardware equipment, the lab is comprised of more than **200** international books. These books cover different areas of Digital Signal Processing, Image Processing, Signal and Systems and advanced topics of Wireless Communications, including Satellite Communications, Mobile Communications and Radar.

The DSP Lab is also equipped with more than **40 PCs** that are equipped with all the necessary softwares and interconnected through a LAN. They are used to carry out the experiments and other research activities.

List of Experiments

Experiments are designed in order to cover the following topics:

- Introduction: Signal types, DSP objectives, DSP applications,.
- Discrete Fourier Transform, Circular convolution, and filtering via the DFT.
- Fast Fourier Transform: decimation in time and frequency algorithms
- Butterworth, Chebyshev and Elliptic filters.
- FIR filters design methods.
- IIR Filter design methods.
- Discrete-time filter structures and finite precision effects.

Experiments

Introduction to MATLAB

To get familiar with the MATLAB working environment. Use the help system to study basic MATLAB commands and syntax. Declare and process matrices. Simple plot commands.

Signal plotting of continuous & discrete time signals

To declare Continuous and discrete signals on MATLAB and plot various continuous and discrete signals.

M- files creation

To get familiar with M files. Create different types of M files on MATLAB and analyze them.

Discrete Time Signal & Systems

To provide an overview of discrete time signals and systems on MATLAB. To analyze various properties of discrete signals and verify them on MATLAB.

Z – Transform

To analyze unilateral and bilateral z transforms of various signals. Also to analyze how unilateral z transform can be used to obtain system responses with initial conditions or changing inputs.

Discrete Time Fourier Transform

To form a routine of discrete time Fourier transform on Matlab and find discrete time Fourier transform of various signals on Matlab. Also analyze different application of discrete time Fourier transforms.

Properties Of Discrete Time Fourier Transform

To study various properties of discrete time Fourier transform and verify these properties on various signals on Matlab.

Discrete Fourier Transform

To form a routine of discrete Fourier transform on Matlab and find discrete Fourier transform of various signals on Matlab. Also analyze different properties of discrete Fourier transform.

Fast Fourier Transform

To analyze fast Fourier algorithms and see how it can efficiently be used to calculate discrete Fourier transform.

Analog Filter Design

To design and simulate chebychev and Butterworth filters and analyze their responses on Matlab.

Digital Filter Design

To design and simulate Infinite Impulse Response (IIR) Filters and Finite Impulse Response (FIR) filters and analyzes their responses on Matlab.

Introduction to SIMULINK

To get familiar with SIMULINK working environment. Construction of different models in SIMULINK. Simulate and observe the responses.

Applications to SIMULINK

To see how different tool boxes can be used and to find various transforms on simulink by using different tool boxes.

Introduction and Applications of DSP Boards

To give basic introduction of DSP boards, their applications and implementation of some applications on DSP boards.

Research Work:

The facilities available in the lab provide excellent opportunities to the undergraduate students to enhance their understanding of DSP concepts by performing experiments and working on various projects. These facilities are also quite conducive for the graduate students to carry out their research. Some of the recently completed projects are as under:

- **Implementation of an OFDM Modem on DSP Processor:**

OFDM has developed into a popular scheme for wideband digital communication, whether wireless or over copper wires, used in applications such as digital television and audio broadcasting, wireless networking and broadband internet access.

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions — for example, attenuation of high frequencies in a long copper wire, narrowband interference and frequency-selective fading due to multipath without complex equalization filters.

In this project, OFDM Modem is first simulated on the MATLAB, then implemented on the DSP Board C6713.

- **Implementation and Simulation of QPSK Modem on DSP Board C6713:**

This project has two basic parts: Modulator and Demodulator. In the modulator, base-band signal is first pulse-shaped and then multiplied by the carriers of the specific frequency. The two signals then add up to form the QPSK signal. In the Demodulator, the carrier recovery is done by using "Costas Loop". The clock recovery is carried out by using "Early-Late gate method". Finally, the signal is detected.

In this project, MATLAB is used for simulation and Code Composer studio for the implementation.

- **Implementation of WiMax Channel Coding on DSP Board:**

WiMax uses concatenated codes for channel coding i.e. convolutional coding concatenated with Reed-Solomon (255,239). This project implements MATLAB simulation and DSK (TMS320C6711) implementation of an 8-bit error correcting Reed-Solomon encoder and decoder architecture for use in WiMax Channel Coding.

- **Implementation of Turbo Codes on a DSP Chip:**

In order to have reliable communications, channel coding is often employed. Turbo code as a powerful coding technique has been widely studied and used in communication systems. Turbo code decoder algorithm is studied in details this thesis. The performance of Turbo code used in IS-2000 Code Division Multiple Access (CDMA) reverse or forward link under Additive White Gaussian Noise (AWGN) and slow fading channels is evaluated. The bit error rates (BER) of Turbo code at low signal-to-noise ratio (SNR) are obtained by simulations on MATLAB.

In this project, a detailed study about Turbo Codes is carried out. The Turbo Encoder which includes Recursive Systematic Code (RSC) Encoder, interleaver and puncturing is introduced, simulated and implemented on a DSP Board. Finally, the turbo decoding algorithm is simulated and implemented.

- **Implementation of Adaptive Filter using LMS Algorithm:**

Adaptive Filtering is an important technique that has several applications in engineering areas such as Wireless Communications, Mobile Communications, Satellite Communications, Control and Bio-medical Engineering etc. It has found its use in System Identification, Inverse System Modeling, Linear Prediction, Adaptive Noise Canceller, Adaptive Echo Canceller, and Adaptive Equalization for highly dispersive channels, and adaptive canceling of narrowband interference in direct sequence spread spectrum systems.

In this project, adaptive filter is simulated and implemented using LMS algorithm and its performance is compared with the other algorithms like NLMS, RLS, Block RLS, Constant Modulus Algorithm (CMA) and Lattice methods.

- **Implementation of MIMO Communication System using Space Time Coding:**
- **Design and implementation of Remote Optical Loop Tester:**
- **Study and implementation of Software Defined Radio using Digital Signal Processor.**
- **Demodulation of BPSK using DSP:**
- **Implementation of different techniques for contrast adjustment in Image Processing.**

In addition to the above mentioned projects, many other sessional and final year projects were carried out in this lab.

Introduction to Researchers:

Dr. Noor Muhammad Sheikh

Dr. Noor Muhammad Sheikh is a Dean of Faculty of Electrical Engineering at UET Lahore. He did his PhD in 1979 from University of Engineering & Technology, Lahore. His research interests include Communication System, Digital Communication, Digital Signal Processing, Signal and System, Detection and Estimation and Communication Theory. He has a large number of publications in the above area in International Journals and Conferences.

Dr. Muhammad Saleem Mian

Dr Mohammad Saleem Mian is a Chairman of Department of Electrical Engineering UET Lahore, Pakistan. He completed his Doctorate from University of Manchester U. K. in 1998. He has a vast experience of working with the modern trend and technologies in the area of Digital Signal Processing and has a number of International Publications in this area. He worked in a DSP research group for audio compression in University of Manchester UK. 1993-1998

He designed and developed a secure script machine for Government of the Punjab and won a research prize of Rs: 100,000/- from UET in Convocation 2002. He is also working as consultant in a DSP research group for development of a secure phone and indigenous Security Algorithm.

Dr. Muhammad Imran Sheikh

Dr. Muhammad Imran Sheikh is a Professor in the Electrical Engineering Department, UET Lahore. He completed his Doctorate in wireless communications from the University of Birmingham, Birmingham, U.K. in 1997. He is a director of DSP and Wireless Communication Lab and Played a vital role to establishment of the Laboratory. The laboratory provides an integrated environment for the development of a variety of wireless communication systems.

His research interests include Antenna Theory Analysis and Design, Array Signal Processing, Digital Signal Processing, Wireless Communication Systems, Information Theory and Design. He holds a number of research publications to his name in International Conferences and Journals.

Lab Engineers:

Omer Waqar:

Mr.Omer has passed out his BSc (with Honours) in September 2007 from UET, Lahore. Since then, he has been actively involved in doing research work in the field of Digital Signal Processing and its applications in Wireless Communications.

He is expert in using Code Composer Studio with the floating-point and the fixed point DSP Processors. He has also expertise in using JTAG Emulator with the DSP Board for the debugging purposes. He teaches MATLAB and its applications to the undergraduates. He has implemented adaptive filter using LMS algorithm. His final year project is "Simulation and Implementation of QPSK Modem on a DSP Board C6713".

Waseem Abbas

He graduated in Electrical Engineering with Honors from UET Lahore. He has an experience of working in Pakistan Mobile Communications (Mobilink).

His research interests include Non Linear Dynamical Systems and Digital Signal Processing. He has also won 2nd best paper award in All Pakistan Engineering Conference held in GIKI in Nov. 2006 and has publications in International Conferences.

Other **Lab Engineers** actively participating in the research activities are :

Sohaib Ghani: Graduated in Electrical Engineering from UET Lahore. Research interests include advanced signal processing theory

Ali Arshad Nasir: Graduated in Electrical Engineering from UET Lahore. Research interests include image processing.

Fahad Ijaz: Graduated in Electrical Engineering from UET Lahore. Research interests include array signal processing.

Future Plans:

The future plan is to build and establish an “Audio and Speech Processing Lab”, “Image Processing Lab”, “Multimedia Signal Processing Lab” and “Acoustic Lab” as part of a Digital Processing lab. The main purpose of an “Audio and Speech Processing Lab” is to carry out research and projects like Voice Conversion, Auditory Signal Modeling and objective evaluation of perceived speech quality, and Very low bit rate speech coding, etc.

The purpose of “Image Processing lab” and “Multimedia Signal Processing Lab” will be to research that covers a broad spectrum of multimedia signal processing and analysis. In recent years, researchers in the lab have pioneered the development of feature extraction with application to image registration, segmentation, steganography and information retrieval from large multimedia databases. The researchers in the lab participate in several interdisciplinary projects including the Bio-image informatics project whose goal is to develop, test and deploy a unique, fully operational distributed digital library of bio-molecular image data accessible to researchers around the world, and the graduate training program in Interactive Digital Multimedia.