MULTI-DISCIPLINARY APPROACH FOR COLLABORATIVE RESEARCH AND TEACHING

Venkatesan Muthukumar[1] *and Emma Regentova*[2]

Abstract — *This work discusses a new infrastructure featured by incorporated research, and learning methods via collaborative knowledge mining and exchanging instructional blocks between courses. The core idea of such a curriculum is to expose students to the goal/application oriented study at both undergraduate and graduate levels. In collaborative curriculum development, an approach is applied of viewing to system design issues from different application perspectives and involving several disciplines to attain the most efficient solution. Software, hardware and co-design tasks are considered in conjunction. The outcome of such a research and educational endeavors is expected in the form of an advanced, continuously upgraded Research/Educational Knowledge Base which can be shared by faculty and students. Curriculum and student evaluation and assessment methods are also presented.*

Index Terms ¾ *Collaborative research and teaching, Course design, Knowledge base based teaching.*

INTRODUCTION

The information age we live in is featured by extensive use of image data. Application domains utilizing electronic images include aerospace, remote sensing, digital library, medicine and entertainment. The main issues associated with *Image Processing* (IP) are- capture, compression, analysis, storage and retrieval. With the growth of wireless web and high bandwidth communication systems, more efficient IP algorithms with deterministic response-time are required. To push the efficiency of IP algorithms, one can (a) investigate nontraditional but fast ways to perform IP, and (b) design special purpose hardware to realize such methods in real time. Traditional methods of hardware acceleration include microprocessor-based systems and special-purpose architectures. These methods are expensive and inflexible. On the other hand, reconfigurable devices like Field Programmable Gate Arrays (FPGAs) offer flexibility and high performance at reasonable cost. The fast developing Electronic Design Automation tools for design of such systems enable one to map software into hardware directly. Systems designed by software-hardware co-design are shown to be reliable, adaptive, cost effective and efficient [1]. System design using FPGAs to accelerate IP tasks indicate that FPGA-based systems are much more effective than some high-speed microprocessor based design [2]. IP tasks implemented using hardware include: graphic engines, real-time video compression units, video controllers, JPEG and MPEG compression engines, custom morphological processors, coprocessor for 2D/3D images and many more real world application [3][4][5].

The objective of this work is to develop an infrastructure for multi-disciplinary collaborative research and teaching program within the computer engineering curriculum at UNLV. Building such an infrastructure requires induction of new courses that support several disciplines. Considering the current faculty area of research specialization and interest within the CE program, the research and teaching area addressed is Image Processing Systems (IPS). The new courses to be introduced are the undergraduate *Algorithms and Architectures for Image Processing Systems* (AAIPS) and *Advanced Digital System Design Laboratory* (ADSDL). To provide an application-oriented learning platform for students and to develop industry-oriented projects, digital design courses are modified in conjunction with the proposed courses. The digital design courses include Digital System Design, and Embedded System Design (ESD).

The *Algorithms and Architectures for Image Processing Systems* course covers IP algorithms and its implementation using high level programming languages. The students are introduced to various tasks such as compression, preprocessing, feature extraction, classification and application problems. Students taking the AAIPS course will go on to take digital design courses where they learn how to realize image processing algorithms using embedded systems, reconfigurable logic and advanced computer architectures.

Embedded systems are used in a myriad of applications like consumer electronics, communication systems, automotives, military, industry (controls and monitoring), and medical instrumentation. Embedded technologies are now commonly used to accelerate computationally extensive tasks (hardware-acceleration). In most of these applications, signal/image processing is an integral task. The programmability of such systems makes them a viable design alternative for many applications.

Digital System Design based on programmable and reconfigurable architecture (FPGAs, PLDs) has been utilized in a variety of IP applications wherein special constraints are dictated by application. The modified *Digital Systems*

1 Venkatesan Muthukumar, Department of Electrical and Computer Engineering, University of Nevada Las Vegas, NV – USA. venkim@egr.unlv.edu

2 Emma Regentova, Department of Electrical and Computer Engineering, University of Nevada Las Vegas, NV – USA. regent@egr.unlv.edu

Design course and its proposed Advanced *Digital Systems Design* Laboratory address various issues related to image processing and FPGA-based system design.
A number of IP tasks and algorithms have been developed and standardized. Hardware implementation of algorithms requires knowledge of specific and general computer architectures. It is also evident that some IP tasks lend themselves to efficient execution using advanced computer systems and parallel computer architectures. The Advanced Computer Architecture course address issues related to such design consideration.

The curriculum addressed is a problem oriented. On the other hand, the design solutions should meet application requirements. That is, project assignments are viewed as a complex system design problems with several disciplines involved. The output from one course can provide inputs (guidelines) to others courses, making courses conjunctive and continuously alterable on design solutions and implementations. The pivotal goals and methodology issues considered in developing the new curriculum are to display this interrelationship to students and make them participate in the process. This can be implemented by creating and maintaining a Knowledge Database (KD) on various projects (lab assignments, course projects), instructional materials and supportive tools. The modular structure of the Knowledge Database enables an effective adoption and development of these modules in other disciplines across departments, colleges and universities. The major component of the curriculum is to incorporate innovative research ideas and modern software and hardware tools into the curriculum and exposed students to research/application oriented studies.

BACKGROUND

The Computer Engineering (CoE) program is designed to provide students with the educational foundation necessary to enter either professional computer engineering employment or an engineering graduate program upon graduation. The program also provides students with the educational foundation necessary to continue a lifetime of education in the engineering profession. The computer engineering program (72 electrical/computer engineering credits in 8 semesters) is divided into three major components, namely 1) fundamental (47 credits), 2) concentration (12 credits) and 3) electives (13 credits). The concentration consists of three areas, 1) Digital Design, 2) Computer Networks and 3) Software Engineering. The current undergraduate curriculum on Digital Design includes Computer Architecture and Organization, Microprocessor System Design, Digital System Design, and Introduction to VLSI System Design. The graduate curriculum includes Introduction to VLSI System Design, Special topics in Electrical Engineering, Advanced Computer Architectures, Reliable Design of Digital Systems and Fault-tolerant computing.

Faculty involved in building the new infrastructure have accumulated a bold body of research and development experience via implementing research projects on image processing and digital system design issues. This integral knowledge will serve for further collaborative study and research on advanced image processing and digital system design that will allow to produce effective and efficient design solutions for various applications of computer vision technologies and to expose students to the research activities carrying out at the department. Previously developed models and codes, demo materials, technical reports and publications are elements of the Knowledge Base, which will be uninterruptedly growing, and advancing with new research and teaching activities involved.

COLLABORATIVE RESEARCH AND TEACHING INFRASTRUCTURE

The New Look

One of the objectives of the new infrastructure is to achieve ABET accredited, multidisciplinary curriculum with opportunities for some modest specialization in digital system design and image processing. One new upper-level-undergraduate *Algorithms and Architectures for Image Processing Systems* and one new lower-level-graduate/upper-level-undergraduate course (*Advanced Digital System Design Laboratory*) are introduced. The courses to be modified are two undergraduate/graduate courses (*Digital System Design* and *Embedded Systems*). To maintain the number of core credits the same as before, no new courses are added to the CoE fundamental component. Instead, a new CoE concentration called *Image Processing Systems* is added. (see Figure 1). Introduction of the new CoE concentration in a level lower than the CoE elective component (*Advanced Digital System Design Laboratory*) allows for establishing the foundation for implementing image processing tasks in digital systems. This foundation also provides a good platform for undergraduate students to develop state-of-the-art senior design projects based on image processing and digital system design (see Figure 2).

Innovative Teaching Methods and Instructional Resources

As an individual is engaged in many activities in today's society, time management becomes critical. The proposed teaching methodology will utilize the possibilities provided by the web to participate in a virtual classroom at any time and in any place. This is particularly suitable to the type of students attending UNLV, who are mostly part-time. Learning will be goal-based and application driven. Collaboration with industry is employed to motivate and familiarize students with real world problems.

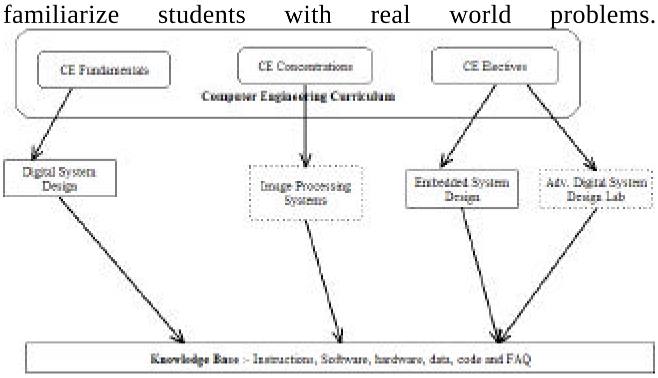

Figure 1: Computer Engineering Curriculum

A core idea of the curriculum development is to integrate research and teaching by incorporating innovative ideas and research components into the lectures, laboratory work and course projects. As an example, non-traditional but time and memory-effective methods of processing and analyzing images directly in the compressed domains are introduced. There are two parallel lines that students study, investigate and compare, i.e. raster image and code processing methods. An extent and complexity of studying and applying of this paradigm vary for undergraduate and advanced image processing courses. For example, for the undergraduate course, document image processing via analyzing standard facsimile compressed files is introduced. For advanced courses cosine and wavelet transforms and their applications for various tasks including image coding and analysis are presented. Associated with real-time applications, such as emergency response environmental, military or medical computer vision systems, or on-board (satellite or air-craft) implementation co-design tasks are considered in Advanced Digital Design Laboratory and Embedded System design courses.

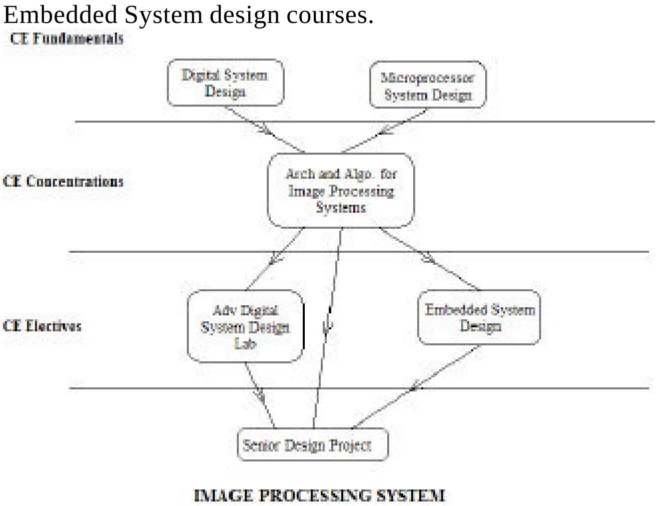

Figure 2: IPS course framework

Courses that are designed and modified are structured similarly for facilitating interaction and sharing common resources called "*Knowledge Base*" (KB). Its major components are information, software, hardware and instruction modules. Each module comprises instructional units that can be modified, replaced and used in different combinations. A block diagram explaining how modules are shared among different courses in the curriculum is shown in Figure2.

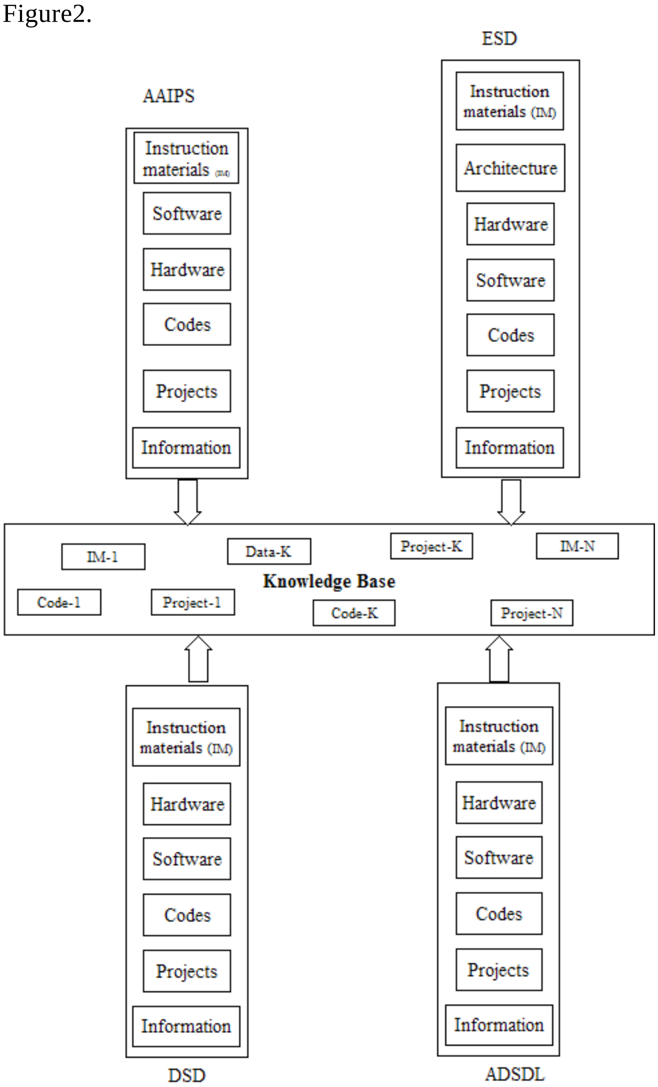

Figure 3:Creating and Sharing modules via KB

For example, information module consists of a database of different image classes, research publications, and references to the web pages in electronic form. Documentation on implementation and data structures for the image processing algorithms, data sheet of development boards and devices are described. The software module contains tutorials, installation guides, 'tips-and-tricks' of available packages, such as Adobe Photoshop, Matlab (Image Processing and Wavelet toolboxes), VHDL simulation and synthesis package and high-level synthesis compilers and synthesizers.

The software module also contains developed codes (C, C++, VHDL, Verilog, HandelC, etc) to support laboratory work and codes continuously added via lab assignments. Interactive tools consist of frequently asked questions and a discussion forum that will be available via WEB.

A typical project flow is described in Figure 4. Students are assigned to solve a problem, determined by the faculty in-charge of AAIPS. Software codes are to be developed. Performance evaluation is done. The results, reports, source code, performance measures, benchmarks are made public via the Knowledge Base. Computationally expensive tasks and hardware designable task are listed in the Knowledge Base. Students involved in DSD/ADSDL/ESD courses will base some of their projects on these image processing problems. Students taking DSD/ADSDL courses will represent the AAIPS problems in VHDL, simulate, synthesize and implement using FPGAs. Results, reports, source code, timing and performance measures, are made public via the Knowledge Base. Students taking the ESD course will divide the problem into software and hardware components. Software and hardware components are synthesized using software and hardware synthesizers respectively. Software synthesizers map high-level specifications (HandelC) to instruction set sequence, and hardware synthesizers convert hardware description into layout data for gate arrays, FPGAs or custom ASIC using physical design tools.

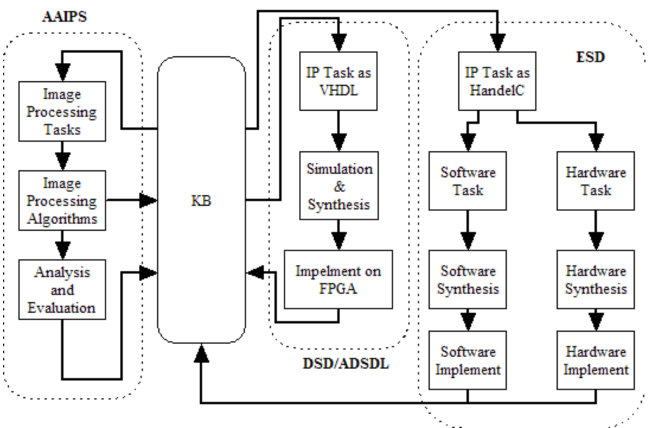

Figure 4: Block diagram of a typical research project flow

The following paradigms underlying our approach for course development address different groups of learning styles [6]. (a) Designing course structure appropriate for both sequential and hierarchical learning manners. This structure accommodates both serialists', who prefer to learn in a sequential fashion, and holists' preferring to learn in a top-down manner. (b) A proper balance for field independence (analytical) and field dependence (global fashion). (c) Establishing highly structured instructional environments for upper undergraduates; conversely, a low structure environment for lower level graduates. The main focus of the course development and teaching strategy is combining individual and collaborative (group) learning. This is implemented via homework and lab assignments. Both individual assignments in sequential order and project-type group assignments that lead to in-depth study will be implemented during the course period. The group assignments lead gradually to more complex and finally to the system-level task solutions. The level of the individual work and the level for micro-group assignments will be applied for undergraduate/graduate students, while the third level (system-level projects) is the appropriate for graduates' assignments only

STUDENT EVALUATION

Two levels of evaluation are required, i.e., student performance and curriculum effectiveness.

Dissatisfaction with traditional decontextualized testing has led to a revolution in the field of assessment. Researchers are calling for alternative assessments which reflect current thinking about students learning and curriculum reform. These alternative tests reflect real-life experiences and are performance-based in that students are expected to show their ability to solve real world problems indicative of those they will encounter in their profession.

Student assessment needs to match the theoretical and practical goals of the project. Given the applied nature of the curriculum and the goals of fostering research, analytic, and development skills in program graduates, it is important that student assessment be project-based. Three types of projects will be required throughout the curriculum: 1) research projects, 2) analysis projects, and 3) design and implementation projects. Research projects will require students to propose and evaluate a hypothesis which could be, for example, the assertion that a particular method developed for optical images can be efficiently applied to hyperspectral imagery. Analysis projects will require students to critically evaluate and compare traditional methods of processing data in spatial and spectral domains with the new methods of processing compressed data. Design and implementation projects will require students to develop their own codes and presentations in electronic form, making them available via Knowledge Base.

Performance assessments will be rubric scored rather than assigned letter grades. A rubric articulates levels of performance (such as exemplary, very good, satisfactory, needs improvement) with sufficient detail that students are clear on expectations for performance and have a guide for improving their work. Projects will include individual, small group, and large group formats. The varied activities and formats allow students to engage in a variety of formats that capitalize on different learning styles.

CURRICULUM EVALUATION

In addition to student learning, it is important to evaluate the success of the curriculum overall. A variety of methods will be used to determine the curriculum strengths and weaknesses, so that curriculum revision can be formative and on going. While participating in the program, students will be asked to provide their evaluation of the courses in relation to the rest of the curriculum. These course evaluations will be developed to supplement those evaluations all students complete each semester. Comments from students and visiting scholars and outside evaluators - qualified researchers experienced in teaching methodology will be utilized to revise course content, activities, and student assessments. Samples of students' projects will be collected and analyzed as part of curriculum evaluation. As a measure of success, the curriculum will be presented to the ABET for accreditation

CONCLUSION

The implementation of the proposed methodology and renovation of existing Computer Engineering curriculum will allow to produce students who are well informed on modern information and digital system design technologies. They will evaluate integral interdisciplinary approach to complex design problem solution. *Knowledge Base* is an effective information and development media for collaborative research and teaching. Its permanently growing performance and accumulating knowledge will offer in the long run equal opportunities for individual studies and collaborative learning and research. Industry involvement into the problem statement and the evaluation of design solutions makes academic educational more real-world oriented, and graduates more prepared for independent engineering carrier in public and private sectors.

ACKNOWLEDGEMENT

Authors thank Drs. Henry Selvaraj and Shahram Latifi, Department of Electrical and Computer Engineering, University of Nevada Las Vegas, USA for their collaboration in developing this curriculum. The authors also wish to thank Dr. Gale Sinatra for her valuable assistance in developing the assessment and evaluation methodology.

REFERENCES

[1] Ron Hawkins, The Software is the Hardware Hardware Description Languages for Real-Time Systems, VisiCom Computer Products Division, <http://www.titansystemscorp.com/divisions/apd/products/imaging/softwarehardware.html>

[2] Knittel, G., A PCI-compatible FPGA-Coprocessor for 2D/3D Image Processing, <http://www.gris.uni-tuebingen.de/data/jb/jb95/ node20.html>

[3] Insight Design Services, <http://www.insight-electronics.com/services>

[4] Plexus Corp, <http://www.plexus.com>

[5] Rapid Prototypes, <http://www.fpga.com>

[6] Dunn, R. and Dunn, K. , The Complete Guide to the Learning Strategies in Service System, (Boston: Allyn & Bacon, 1999)