The University Senate of Michigan Technological University

Proposal 5-09

(Voting Units: Academic)

"Proposal for a Master's Degree Program in Computer Engineering"

1 Introduction

1.1 General Description

This is a proposal to establish a Master of Science (MS) program in Computer Engineering (CpE) within Michigan Technological University's Department of Electrical and Computer Engineering (ECE). The mission of the proposed graduate program is to train engineers in the science and technology of this field and to recognize their achievement by creating an advanced Computer Engineering degree at Michigan Tech. Graduates of the program will have the necessary skills and will be highly qualified to perform scientific and technologically advanced research to solve problems in the design, development, and implementation of complete computer-based systems and application domains.

1.2 Rationale

Computer Engineering (CpE) is a hybrid discipline, born of two parent disciplines, Computer Science (CS) and Electrical Engineering (EE). It has, for decades, been recognized by the Accreditation Board for Engineering and Technology (ABET) as a separate discipline, with academic content distinct from both EE and CS [1].

1.2.1 National Trends

As of October 2006, there were 188 ABET-accredited undergraduate CpE degree programs in the United States [2]. In addition, between 1996 and 2006, the number of programs in Computer Engineering and Technology increased 111%, making it *the fastest growing single discipline* reported by ABET [2].

Nationally, of the 252 universities with graduate engineering programs, the overwhelming majority offer Computer Engineering graduate degrees in one form or another. Most of these programs bundle CpE with either CS or EE under an umbrella title, such as *Computer Science and Engineering*, or *Electrical and Computer Engineering*. However, there are now 75 standalone master's degree programs in Computer Engineering [3]. In Michigan, the University of Michigan-Dearborn, Wayne State University, and Western Michigan University offer graduate degrees in computer engineering. In 2006-2007 1479 graduate degrees in computer engineering were awarded nationally.

1.2.2 Related Graduate Programs

Tech currently offers MS degrees in CS, and EE. In addition, a proposal is in progress to establish an MS program *Computational Science and Engineering* (CS&E). Graduate study in computer engineering is now included within the EE degree program.

This mix of computing disciplines is typical of programs at other universities. These inter-related disciplines can be defined by where their particular focus area lies within the broad spectrum of computing topics. Although there can be considerable overlap between the different computing fields, the *differences* are best described relative to the "center of mass" of each field. For example:

- Computer Science traditionally focuses on the theoretical and software aspects of the *process of computing*, rather than on the computer system itself. While some computer scientists do delve into computer architecture, the center of mass is toward hardware-independent topics, with little emphasis on hardware architectures, and even less interest in electronic circuitry.

- Electrical Engineering traditionally represents the opposite extreme, focusing on the physics, electronics, circuitry, and related aspects of both analog and digital hardware, with little or no emphasis on software design, hardware/software integration, or computational theory.

- Computational Science and Engineering focuses on the *application and use* of high performance computing platforms to solve scientific and engineering problems. In this field, the computer is simply a tool used to achieve some research goal in an unrelated scientific or engineering field; thus, the computer system is merely a *means to an end*, not the end in itself.

- Computer Engineering treats a computer-based system as one spanning a continuum of technologies on both sides of the traditional *analog/digital* systems boundary as well as the traditional *hardware/software* boundary. Thus, a computer engineer studies the *whole computer system* in its entirety, is equally comfortable working with both hardware and software, and has an intimate understanding of how the hardware and software interact with each other. S/he can thus integrate all of these technologies into a single system, write hardware-dependent software, evaluate hardware/software trade-offs, and engage in *hardware/software co-design*. These abilities make the Computer Engineer uniquely qualified to conceive, design, and build complete computer-based systems to serve a wide variety of applications.

1.3 Projected Enrollment

While exact enrollment numbers are difficult to predict, estimates can be extrapolated from national trends in graduate enrollment, from Tech's own undergraduate enrollment statistics and from the long-term growth plans in the ECE department.

1.3.1 National MS Trends

Nationally, of those universities offering standalone MS programs in CpE, 6.2% of all engineering MS degrees are in CpE [3].

1.3.2 Michigan Tech BS Trends

Tech undergraduate enrollment statistics show similar trends at the baccalaureate level [4], as seen nationwide at the MS level. Figure 1 shows the contribution of the CpE bachelor's degree program to all first-time freshmen enrolled in the College of Engineering. This figure shows that, following the startup transient in 2001, the contribution of the CpE program has oscillated about the 7% mark.

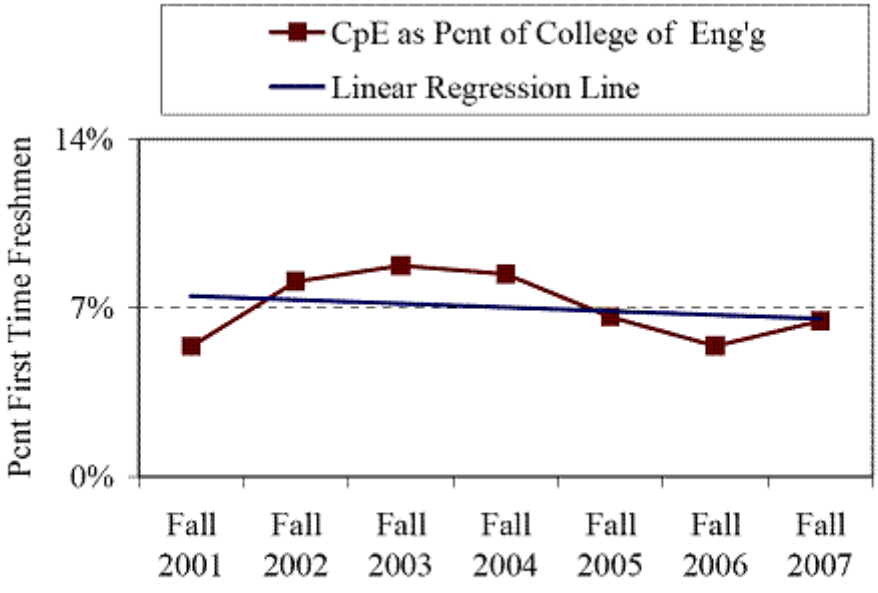

Figure 1: Michigan Tech CpE Freshman Enrollment Relative to College of

Figure 2 illustrates the impact of the CpE BS program and other computing majors on each other, in terms of Freshman Enrollment. In addition to CpE, CS, and EE, the chart includes Computer System Science (CSS) and Software Engineering (SE) majors in the CS department. It shows a startup transient in which CpE enrollment increased at the expense of EE and CS enrollment. This was primarily due to "defections" from the other majors into the new program. Following the startup transient, CpE enrollment stabilized at about 25% of all computing majors.

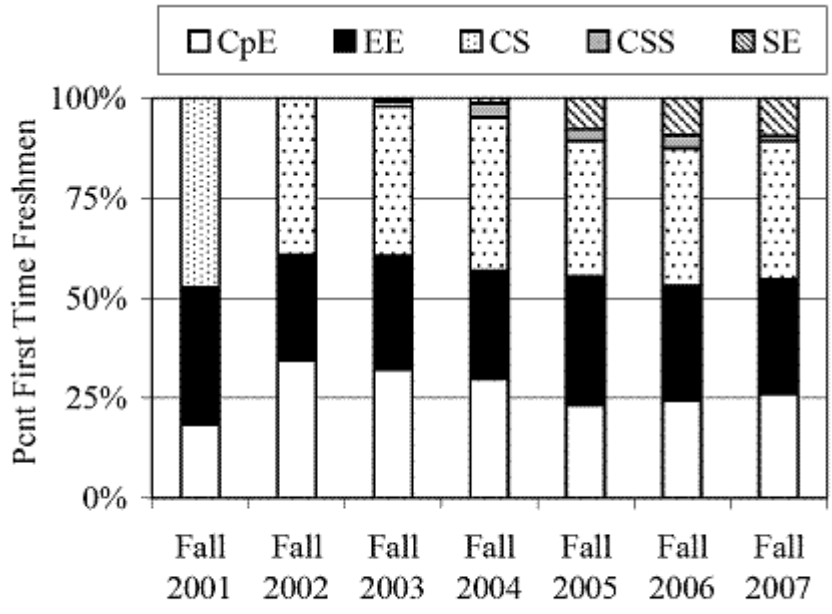

Figure 2: First-Time Freshman Enrollment Percentages Across Computing Majors at Michigan Tech

Enrollment Extrapolation

The ECE department has 89 enrolled MSEE students in Fall 2008. At least eight of these are studying with ECE faculty members under Plan A (thesis option) in computer engineering topics. These students comprise 3% of engineering MS students and 10.4% of computing MS students. Although exact numbers are difficult to ascertain, a significant fraction of the remaining MSEE students, primarily under Plan D (course option) may have interests in computer engineering topics. If Michigan Tech undergraduate students may be used as a guide, then roughly one-third, or 30, of the MSEE students will switch from the EE to the CpE program.

Based on national and local trends and the ECE department growth plan, we anticipate having anywhere from 30 to 60 MSCpE students regularly enrolled 3-5 years from now. Currently the department has roughly twice as many MSEE students as PhD students. Projecting this ratio forward to our long term goal of 24 PhD CpE students (See the companion proposal for a PhD program in computer engineering), we expect a total of 48 MSCpE students. Several of these may be PhD students who earn the MS "along the way". The majority of the remaining terminal MS students will be Plan D (course option) students.

2 Implementation

2.1 Planned Implementation Date

This program is intended to begin as soon as it is approved. At that time, currently enrolled students will be invited to change degree programs to CpE, subject to eligibility. New students will be accepted at the beginning of the first complete term following approval of this program.

2.2 Scheduling Plans

This program will be implemented through normally scheduled daytime classes.

2.3 Faculty

All faculty in the Department of Electrical and Computer Engineering are responsible for the success of all curricular programs in the department. Those expected to be most involved in the proposed graduate degrees in computer engineering include:

- Associate Professor Roger Kieckhafer specializes in fault-tolerant computing systems, including safety critical, high assurance and high integrity systems and the theoretical foundations of fault tolerance. He also does reliability modeling and formal design methods and does interdisciplinary research with the physics department.

- Associate Professor Tricia Chigan, an NSF Career award winner, studies computer/communication networks and network security. Her work includes vehicular ad hoc networks, wireless ad hoc and sensor networks, wireless network security, adaptive protocol design for cognitive radio networks, dependable computing and communication systems, and network resource allocation and management.

- Associate Professor Jindong Tan's research focuses on robotic sensor networks and body area sensor networks; his research in robotic sensor networks investigates the coordination of mobile robots and sensor networks for coordinate sensing and communication. His research in body sensor networks focuses on ultra lower design for a hybrid of wearable, ingestible and implantable wireless miniature sensors, which collectively monitor the medical condition of a patient and provide physicians with immediate feedback. He collaborates with the departments of Biomedical Engineering, Cognitive and Learning Sciences, Computer Science, Civil and Environmental Engineering.

- Associate Professor Ashok Goel models interconnects, currently for nanoscale integrated circuits. He is the author of a highly acclaimed graduate text on VLSI interconnects.

- Assistant Professor Shiyan Hu studies computer-aided design of VLSI circuits and combinatorial optimizations. He focuses on nanoscale circuit design challenges, such as interconnect optimization and design for manufacturability.

- Assistant Professor Bo Chen, whose primary appointment is in ME-EM, works on distributed sensing and actuation systems. Current research of the Laboratory of Intelligent Mechatronic and Embedded Systems concerns developing an autonomous network framework for distributed sensing and actuation systems.

Curricula Vitae of the CpE faculty are at: http://www.ece.mtu.edu/faculty/rmkieckh/Grad/ , http://www.ece.mtu.edu/faculty/goel/resume.htm, http://www.me.mtu.edu/meem/facultybio/b_chen.html,

In addition, all ECE faculty of professorial rank may be involved in the program. In addition to those faculty listed above these faculty are Professors Dan Fuhrmann, Warren Perger, Mike Roggemann, Martha Sloan, and Dennis Wiitanen; Associate Professors Paul Bergstrom, Jeff Burl, Anand Kulkarni, John Lukowski, Bruce Mork, Gerry Tian and Reza Zekavat; and Assistant Professors Chris Middlebrook, Wayne Weaver and Zack Zhao.

Professorial rank faculty in Computer Science who may be involved in the program are Professors Steve Carr and Linda Ott; Associate Professors Jean Mayo, Phillip Merkey, Nilufer Onder, Soner Onder, Dave Poplawski, Steve Seidel, C K Shene, and Chuck Wallace; and Assistant Professors Ali Ebnenasir, Robert Pastel and Zhenlin Wang.

2.4 Curriculum Design

All requirements for the number of credits required, credit distributions, theses, reports, examinations, acceptable grades, time-to-degree, and other degree requirements are *identical to existing graduate school requirements policies and procedures* [5], except as modified or enhanced by this proposal.

CpE is currently bundled into the EE degree program.

2.4.1 Admission Requirements

All applicants for full admission have completed courses in the set of prerequisite topics specified in Table 1. Applicants who have not completed all of the prerequisites may receive "provisional" admission and complete the missing topics at MTU. Those topics with an "MTU Equivalent" course at less than the 3,000 level may not be taken for MS degree credit, while those at or above the 3,000 level may count for degree credit within the constraints of all other applicable course distribution requirements.

Table 1: Prerequisite Courses

Prerequisite Topic	MTU Equivalent
Linear Algebra	MA-2321
Differential Equations	MA-3521
Probability and Statistics	MA-3710 or 3720
Discrete Math or Structures	CS-2311

Data Structures	CS-2321
Computer Organization	CS-3421
Digital Logic	EE-2171 or 2173
Electronics	EE-3130
Microcontroller Interfacing	EE-3170 or 3173

Given the prerequisite topics listed, students with a baccalaureate degree in computer engineering from an accredited college or university will generally be eligible for full admission to this program. Those with a degree in computer science, electrical engineering, or a closely related field, will usually be eligible for provisional admission. Applicants with degrees from other disciplines may be considered for provisional admission to the program on a case by case basis. The ECE department has an established program of admitting graduate students with extenuating circumstances at the discretion of the graduate program director under the provision that they perform well their first year; their performance is tracked by the graduate program director. Provisional students are not awarded GRAs or GTAs so that they may concentrate on their studies.

2.4.2 Required Courses

All students must participate in EE 5970, Computer Engineering Seminar, 1 cr., offered Fall and Spring. This course and all elective courses listed below are currently existing courses .

The identity and total number of courses required to be taken must be approved by the student's advisor.

2.4.3 Elective Course Distributions

In addition to graduate school requirements for MS course distributions [5] http://www.gradschool.mtu.edu/catalog/ms-science.html , the following breadth criteria are required for all CpE MS degrees:

1. At least 10 credits in the ECE department from the list of currently existing courses below, including the required seminar.

EE 4252 – Digital Signal Processing and Its Applications, 4 cr., Fall
EE 4255 – Wireless Communications, 3 cr., Spring
EE 4257 – Digital Image Processing, 3 cr., Spring
EE 4271 – VLSI Design, 4 cr., Fall, Summer
EE 4272 – Computer Networks, 3 cr., Fall
EE5522 – Digital Image Processing, 3 cr., Spring
EE 5525 – Wireless Communications, 3 cr., Spring
EE 5527 – Digital Communications, 3 cr., Fall
EE 5535 – Wireless Communications II, 3 cr., Spring
EE 5711 – Mathematical Techniques for Computer Networks, 3 cr., Fall
EE 5722 – Computer Networks, 3 cr., Fall
EE 5723 – Computer and Network Security, 3 cr., Spring
EE 5725 – Mobile Robotics & Mobile Robot Systems, 3 cr., On Demand
EE 5726 – Embedded Sensor Networks, 3 cr., On Demand
EE 5731 – Real-Time and Embedded Systems, 4 cr., On Demand
EE 5732 – Real-Time System Design, 4 cr., Fall, Spring
EE 5751 – Verilog HDL Design, 3 cr., Spring
EE 5752 – Digital Storage Technologies, 3 cr., Fall, even-numbered years
EE 5755 – Fault-Tolerant Systems, 3 cr., On Demand
EE 5772 – Parallel Computer Organizations, 3 cr., Fall, odd-numbered years

2. At least 6 credits in the CS department, 4000-level or above.
CS 4090 – Special Topics in Computer Science, 3 cr., On Demand
CS 4121 – Programming Languages, 3 cr., Fall, Spring
CS 4131 – Compiler Construction, 4 cr., Spring
CS 4311 – Introduction to Computation Theory, 3 cr., Fall
CS 4321 – Introduction to Algorithms, 3 cr., Fall, Spring
CS 4331 – Introduction to Parallel Programming, 3 cr., On Demand
CS 4411 – Introduction to Operating Systems, 3 cr., Fall, Spring
CS 4421 – Database Systems, 3 cr., Spring
CS 4431 – Computer Architecture, 4 cr., Fall, Spring
CS 4481 – Computer and Network Performance Analysis, 4 cr., Spring

CS 4611 – Computer Graphics: Foundations of Computer Graphics, 3 cr., Fall
CS 4710 – Model-Driven Software Development, 3 cr., On Demand
CS 4711 – Software Processes and Management, 3 cr., Spring
CS 4712 – Software Quality Assurance, 3 cr., On Demand
CS 4760—Human-Computer Interactions, 3 cr., Spring
CS 4811 – Artificial Intelligence, 3 cr., Spring
CS 5090 – Special Topics in Computer Science, 3 cr., On Demand
CS 5131 – Compiler Optimization, 3 cr., Fall, Spring
CS 5311 – Theory of Computation, 3 cr., On Demand
CS 5321 – Advanced Algorithms, 3 cr., Fall
CS 5331 – Parallel Algorithms, 3 cr., Spring
CS 5411 – Advanced Operating Systems, 3 cr., Spring
CS 5431 – Advanced Computer Architecture, 3 cr., Spring
CS 5441 – Distributed Systems, 3 cr., Fall, Spring
CS 5461 – Mobile Networks, 3 cr., Fall, odd-numbered years
CS 5611 – Computer Graphics: Advanced Rendering and Animation, 3 cr., Spring
CS 5711 – Advanced Software Engineering, 3 cr., Fall
CS5760 – Human-Computer Interactions and Usability Testing, 3 cr., Spring
CS 5811 – Advanced Artificial Intelligence
CS 6090 –Special Topics in Computer Science, variable up to 3 cr., On Demand
CS 5461 – Advanced Computer Networks, 3 cr., Fall even-numbered years

2.4.4 Program Completion Verification

Completion of all requirements shall be certified by the student's advisor using a degree audit form. The completed form shall be forwarded to the ECE graduate program committee.

3 Resource Requirements

3.1 Library and Other Learning Resources

No new Library resources are required. The library already subscribes to online versions of the leading journals in this field.

3.2 Computing Access Fee

The computing access fee will be the same as the access fee for EE graduate degrees.

3.3 Available and Needed Equipment

The *Department of Electrical and Computer Engineering* has a full range of research facilities including several Sun workstations and PCs running both Linux and MS Windows. Each faculty member and graduate student has at least one PC, workstation and/or laptop in his/her office and/or lab. Other PCs and servers are available to students through several user laboratories throughout the building and across campus. Faculty and students also have access to a high-speed Linux cluster and a Beowulf cluster for research purposes. The Michigan Tech campus is completely networked, allowing wired and wireless access to all services from anywhere on campus, and to secure remote access via SSH, FTP and other protocols. A wide range of research-relevant application software is also available to both faculty and students.

No additional equipment is required for this program.

3.4 Space

No additional space is required for this program.

3.5 Accreditation requirements

Not Applicable

3.6 Program Costs, Years 1, 2, and 3

No additional costs will be imposed, as all faculty, equipment, and facilities are already in place for the introduction of this program. The growth in enrollment will mirror the growth in ECE faculty for which there is already a university commitment. (See the companion proposal for a PhD program in Computer Engineering.)

4 References

1. *Criteria for Accrediting Engineering Programs*, Accreditation Board for Engineering and Technology, Approved Nov 3, 2007, available at http://abet.org/Linked%20Documents-UPDATE/Criteria%20and%20PP/E001%2008-09%20EAC%20Criteria%2012-04-07.pdf .

2. *2006 Accreditation Statistics*, Accreditation Board for Engineering and Technology, available at http://abet.org/Linked%20Documents-UPDATE/Stats/06-AR%20Stats.pdf .

3. "Engineering Data Management System Login", American Society of Engineering Education, Apr 2008, http://www.asee.org/datamining/ .

4. "Enrollment Statistics", Office of Student Records and Registration, Michigan Technological University, Apr 2008, http://www.admin.mtu.edu/em/services/erlstat/ .

5. "Master of Science", Graduate School, Michigan Technological University, Apr 2008, http://www.gradschool.mtu.edu/catalog/ms-science.html .

6. "PhD Comprehensive Examination", Department of Electrical and Computer Engineering, Michigan Technological University, Apr 2008, http://www.ece.mtu.edu/pages/graduate/PhD_Exam_Guidelines/index.htm .

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