A PROPOSAL FOR

Master of Science Program
In
Embedded Systems

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August 2000
Revised January 2001

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ABSTRACT

Although the embedded systems have been around for a long time, it is only in recent years that the demand for computer scientists and engineers with training and background in embedded systems has risen rapidly. One of the driving factors behind such a rapid growth in the demand is the emergence of information or Internet appliances, such as wireless personal digital assistants (PDAs) and remote monitoring and controlling devices.

The Department of Computer Science and Engineering (CSE) at Oakland University is eminently suited to meet the growing demand for computer scientists and engineers with training and background in embedded systems because of its proximity to high technology industries and the expertise of its faculty. Discussions with nearby industries, for example EDS[1], have generated highly enthusiastic response leading to believe that an MS program in embedded systems is certain to attract sufficient enrollment to justify its existence.

The proposed master in embedded systems (MS in ES) is designed to prepare students with gaining specialized knowledge related to the design and development of embedded systems. The program will strive to seek a balance between the software and hardware aspects of embedded systems. The program will be particularly suitable for students who have received a baccalaureate degree in computer engineering or electrical and computer engineering. It will be also suitable for computer science majors who at work are involved in designing different programmable devices for automobile, communication, and medical applications.

To our knowledge, there is no MS program in embedded systems in the state of Michigan, and in the entire country only University of California at Irvine currently offers a master's program in embedded systems. Given the growing demand for scientists and engineers for embedded systems, it is believed that several universities in the country will very soon have such programs. By being first in Michigan, Oakland University will be able to establish its leadership in this subdiscipline of computer science and engineering and reap the benefits that come with being a leader.

[1] Discussions are currently underway with EDS for an on-site MS program in embedded systems at its facility in Troy.

1. RATIONALE

a. Program Need

An embedded system refers to a self-contained microprocessor-based system used to provide flexibility in function and control of numerous devices and products such as automobiles, televisions, microwave ovens, fax machines, and medical and industrial instruments. The number of such systems has been rising rapidly since early seventies; however, with the emergence of information or Internet appliances, such as wireless personal digital assistants (PDAs), handheld internet pads, and digital TV, the growth in embedded systems has been phenomenal. Consequently, the demand for computer scientists and engineers with training and background in embedded systems is growing rapidly. Thus many universities and industry organizations are considering establishing specialized graduate or training programs in the area of embedded systems. For example, University of California at Irvine has been offering a master's in embedded systems for over two years now. An annual industry conference and trade show with a large focus on training in embedded systems has been going on successfully for several years now. To meet the growing need several companies have joined to form an online training resource, *Embedded University* (http://www.embeddedu.com) that has been in operation now over for two years.

The consideration of a master's program in embedded systems at Oakland University began several months ago during contacts with local industry leaders. Several companies including EDS, Visteon, and Delphi have showed considerable interest in a master's in embedded systems. Upon learning about our plans for a master in embedded systems, employees of many local companies have been inquiring about the program and its start date. It, thus, appears that an M.S. in embedded systems is certain to attract sufficient enrollment to justify its existence.

b. How the Program Will Help Promote the Role and Mission of the University

The role and mission of the university identifies four essential ingredients: excellent and relevant instruction; high-quality basic and applied research and scholarship; responsive and effective public and community service; and a comprehensive schedule of student development activities.

The proposed M.S. program in embedded systems is consistent with the role and mission of the university. It will provide excellent instruction in a focused discipline and help further develop applied engineering research, scholarship, and practice. It is being proposed in response to the needs of local industry and as a community service to the state and nation.

c. Program Goals

The goal of this program is to prepare students with a comprehensive understanding of the hardware and software technologies used in embedded systems. The program will strive to seek a balance between the software and hardware aspects of embedded systems. The program will be particularly suitable for students who have received a baccalaureate degree in computer engineering or electrical and computer engineering. It will be also suitable for computer science majors who at work are involved in designing different programmable devices for automobile, communication, and medical applications.

The additional goals of the program are: (i) increase the enrolment; (ii) create more visibility for the department and the university by being a leader; (iii) improve the level of research and funding; and (iv) stimulate additional interaction with local industry.

d. Comparison to Similar Programs

Currently, no other school in the state offers a specialized master's program in embedded systems. However, both Michigan State University and University of Michigan at Ann Arbor offer few graduate-level courses in areas close to embedded systems. The only known program in the country at present is at University of California, Irvine. Our program is similar to this program in many respects but with a focus on automotive related embedded systems and their applications. Thus, the program is expected to serve the local and regional needs.

e. Source of Students

Two main sources of students are envisioned. The first source is engineers and computer scientists working in local industry. The second source is graduating students, domestic and international, who will find our embedded systems program attractive from future job prospects and career growth. Additionally, many of our students who have already completed their master's degree from Oakland University are expected to join the program for a second master.

2. SELF STUDY OF THE ACADEMIC UNIT

The Computer Science and Engineering Department in the School of Engineering and Computer Science currently offers two bachelor's and two master's programs. The bachelor's programs are a B.S. program in computer science accredited by the Computer Science Accreditation Board (CSAB) and a B.S. program in computer engineering accredited by the Accrediting Board for Engineering Training (ABET). The master's programs are an M.S. program in computer science and engineering and an M.S. program in software engineering. The M.S. in computer science and engineering is a broad-based program that affords a student to pursue a flexible program of study to suit individual needs and interests. The M.S. in software engineering, in contrast, is a highly specialized program aimed almost exclusively to provide a student proficiency in theories and methodologies of large-scale software development in a team environment. Students graduating from the above programs are in demand by industry and well prepared for additional graduate study.

a. How the Goals of the Unit Are Served by the Program

A current goal of the department is to increase its visibility to attract a larger pool of students, new faculty, and more research contracts and grants. The proposed program serves well to meet this goal by tapping into additional students – locally, regionally, and internationally, who will be attracted to this unique program. The faculty – existing and the future hires, will find more avenues for cooperation and interaction with local industries.

b. Staffing Needs

For this new program, four new courses are planned. These new courses have been prepared by the existing faculty members whose teaching and research interests lie in the area of embedded systems. These faculty members are expected to teach the new courses in the near term. In order to accommodate these new courses, the frequencies of offerings of certain other courses with relatively lower enrolment will be changed. The department is also aggressively pursuing local industry experts to make them adjunct faculty to capitalize on their experience and knowledge. If needed, adjunct faculty will teach some courses.

Although we do not anticipate any new faculty position for the next three years for this program, new positions may be sought if the program is wildly successful with a heavy increase in the enrolment.

c. Faculty Qualifications

The current CSE faculty members have the required expertise to teach the courses for this new program. Our faculty currently teaches all of the courses, except for the four new courses proposed. Professors Ganesan and Haskell who do research in embedded systems can teach the new courses. We are also hiring three new faculty members in the current year and one more next year. We expect at least one of the new hires to be proficient in embedded systems.

d. Library Holdings

Although far from an ideal, the library resources in terms of books and journals seem adequate. Furthermore, there is a vast amount of easily accessible literature – technical papers, position papers, and design methodologies, on Internet. The library also has a provision for inter-library loans. Thus, we consider library resources adequate for the new program.

e. Classroom, Laboratory and/or Studio Space

With the addition of the new Science and Engineering building and offering of courses at the Macomb Community College (MCC) – University Center, we do not anticipate any need for any additional or special classroom or laboratory space. In the future, even if the enrollment increases significantly, the new Science and Engineering building and MCC will be able to absorb the demand for the classroom and computer laboratory space.

f. Equipment

No new computer hardware and software are required for this program. Any special need arising in the future will be met through course fee money proposals, project funds, and gift money.

g. Impact on the Current Programs Offered by CSE Department

We do not anticipate any major impact on the existing master's programs in the department. The students will have the option of choosing one of the master's programs in the department. We expect students with more flair for hardware/engineering to opt for the embedded systems program.

3. PROGRAM PLAN

a. Admission Requirements

To be accepted into the M.S. program in embedded systems, an entering student must satisfy the following requirements:

- BS in Computer Science (CS) or Computer Engineering (CE). Applicants with a bachelor's degree from other engineering discipline would be considered after successfully completing the prerequisite courses as determined by the departmental admission committee.
- Undergraduate GPA of 3.0 or better.
- All applicants must meet the University requirement for English language proficiency. Additionally, GRE scores are required of applicants having the qualifying degree from an institution outside North America.

b. Degree Requirements

To fulfill the requirements for a M.S. degree in embedded systems, a student must:
- Successfully complete at least 32 credits of graduate coursework and earn a cumulative grade point of at least 3.0.
- The graduate coursework must satisfy the core and depth requirements as given below.
- Core requirement: Must complete CSE 547, CSE 550, and CSE 564 from common core. (12 credit hours)
- Breadth requirements; Must do a course from one of the non-embedded system specialty groups. (4 credit hours)
- Depth requirement: Must complete remaining courses from the embedded system group. (16 credit hours)

A listing of all graduate courses applicable to this program is provided in Appendix A.

c. Course Descriptions

A complete description of all courses is given in Appendix B.

d. Support of Other Departments

Other departments offer no required courses for this program.

e. Recruiting Plans

The program will be publicized through: (i) mailing fliers to local industries and schools; (ii) departmental web site; and (iii) special e-mail listings on Internet.

f. Planned Enrollment Levels

A conservative estimate of enrollment in this program is 16 new students per year. This implies a stable population of 48 students in the program at the end of third year of the program.

4. NEEDS AND COSTS OF THE PROGRAM

a. Additional Resources for the Program

No additional resources in terms of faculty, staff, and graduate assistants are requested for the first three years of the program. Beginning with the fourth year one additional faculty position and one graduate assistant position would be needed. No new classroom or laboratory space is being requested; additional needs, if any, would be met by access to classrooms at MCC

University Center. No special need for special hardware or software for the program is envisioned at this time.

b. How the Resources are to be Met

We believe that the program would generate sufficient revenues for the university (Please see Table I and II). Hence we hope the university to meet the above expenses.

Table I Estimated Revenue from the Proposed M.S. in Embedded Systems

Year	Student Enrolled	Credits per student	Rate per cr. hr.*	Revenue	Cumulative Revenue
1	16	12	$221	$42,432	$42,432
2	32	12	$221	$84,864	$127,296
3	48	12	$221	$127,296	$254,592
4	48	12	$221	$127,296	$381,888
5	48	12	$221	$127,296	$508,184

*The rate is based on 1999-2000 tuition rates.

Table II Estimated Expenses for the Proposed M.S. in Embedded Systems

Year	Faculty Salary Including Fringe Benefits	Part Time Instructor /GTA/ Secretarial Support	Other Operating Expenses	Total Expenses	Cumulative Expenses
1	0	$6000	$3240	$9740	$9740
2	0	$6000	$3240	$9740	$19,480
3	0	$6000	$3240	$9740	$29,220
4	87,100*	$18,000	$3240	$108,340	$137,560
5	87,100	$18,000	$3240	$108,340	$245,900

*Based on a salary of $65,000 and fringe benefits @ 34%.

c. Anticipated Revenues from the Program

Table I shows the anticipated revenues from the program. The revenue estimates are based on a yearly enrolment of 16 students in the program. We also assume that each student on an average will carry a yearly load of 12 credit hours.

d. Analyze Increased Support from the Program to the University

The proposed program will generate a net income for the university from the first year of its implementation. As shown in Table II, the expenses for the program will stabilize at $108,340 while the revenues will be stable at 127,296 if no tuition increases are made in the future. In addition to net income to the university, the program will also strengthen the existing research and improve prospects for increased research grants to Oakland University.

5. IMPLEMENTATION

We would like to start the program as soon as possible, preferably from Fall-2000. There should not be any logistic problem for doing so because some of the core courses for the proposed program are currently offered by the department and are already included in Fall-2000 schedule of classes.

Appendix A
Letters of Support

Appendix A

Letters of Support

Appendix B

Course Descriptions

500-700 Level Courses

The following is the complete list of 500-700 level courses offered by the department.
The prerequisite courses do not give any graduate credit. These are meant for students lacking sufficient background in computer science and engineering. Please consult the degree requirements to see how best to choose courses for your program of study.

PREREQUISTE COURSES	
CSE501	Programming and Data Structures
CSE502	Microprocessors, Computer Organization and Assembly Language Programming
CSE504	Discrete Structures and Foundations of Computer Science
CORE COURSES.	
CSE510	Fundamentals of SE Modeling
CSE511	Design & Analysis of Algorithms
CSE 535	Topics in Programming Languages
CSE 539	Software Engineering
CSE 547	Computer Communications
CSE 550	Operating Systems
CSE 551	Web design and applications
CSE 545	Database Systems I
CSE 564	Computer Organization and Architecture
CSE 522	Object Oriented Analysis & Design
Networking and Systems Group	
CSE 549	Multimedia and Networks
CSE 565	Compiler Design
CSE 647	Advanced Computer Communications
CSE 650	Distributed Systems
CSE 664	Parallel Processing
CSE 666	Real-time Computer Systems
Embedded Systems Group	
CSE 570	Microprocessor-based System Design
CSE 571	Design of Embedded Systems
CSE 670	Embedded Systems Design Using FPGAs
CSE 671	DSP in Embedded Systems
CSE 672	Hardware/Software Co-Design in Embedded Systems
CSE 665	Real-time Computer Systems
Information System Engineering Group	
CSE 581	Data Mining and Knowledge Discovery
CSE 582	Information Retrieval

CSE 681	Information Security
CSE 542	Rapid Prototyping & Component Software
CSE 583	E-Commerce and ERP
CSE 645	Database Systems II
Software Engineering Group	
CSE 521	Software Requirements Engineering
CSE 537	Systematic Software Development
CSE 538	Software Verification & Testing
CSE 540	Software Quality Assurance
CSE 541	Software Project Planning and Management
CSE 640	Software Architecture
CSE 639	Software Maintenance & Reuse
Intelligent Computing Group	
CSE 512	AI in Manufacturing
CSE 516	Artificial Intelligence
CSE 517	Agent-Based Systems
CSE 513	Soft Computing
CSE 555	Computer Graphics I
CSE 556	Computer Graphics II
CSE 616	Applied Pattern Recognition
CSE 618	Visual Computing
CSE 718	Advanced Visual Computing
Miscellaneous	
CSE 594	Independent Study
CSE 594	Special Topics
CSE 690	Graduate Project
CSE 691	Thesis
CSE 794	Independent Study
CSE 795	Special Topics

CSE 501 Programming and Data Structures (4)
Introduction to the C++ programming language, iteration and recursion, functions, strings, structures, pointers, concepts of abstract data type and object- oriented programming. Data structures including lists, stacks, queues, binary trees and their traversal, and searching and sorting. Applications including stack-based algorithms, binary search trees, expression trees, and heaps. An accelerated course intended to provide working knowledge in programming using data structures. Credit not applicable toward an M. S. degree in the CSE department. Prerequisites: Math 155 and knowledge of at least one high- level programming language.

CSE 502 Microprocessors, Computer Organization and Assembly Language Programming (4)
An accelerated course in computer organization, hardware design, and low- level programming. Assembly level machine organization, representation of data, memory organization and mapping, instruction set and programming, concepts of RISC and CISC machines, Boolean functions and circuits, minimization and design, flip- flops, excitation tables, design of synchronous sequential circuits, shift registers, study of single processor architectures, interfacing and communication. Credit not applicable toward an M. S. degree in the CSE department. Prerequisite: CSE 501 or equivalent.

CSE 504 Discrete Structures and Foundations of Computer Science (4)
An accelerated course presenting fundamental mathematical background for computer science. Propositions, truth tables, implication, equivalence, logical proofs, quantifiers, mathematical induction. Sets, relations, functions, orderings, equivalences. Cardinality, counting, combinations, permutations, binomial coefficients, inclusion and exclusion principles. Digraphs, isomorphism, paths, cycles, adjacency matrices. Time orders of algorithms, NP- completeness, iteration versus recursion. Finite automaton acceptors and regular sets, context- free grammars and languages, pushdown automata, Turing machines, unsolvable problems. Credit not applicable toward an M. S. degree in the CSE department. Prerequisite: CSE 501 or equivalent.

CSE 510 Fundamentals of SE Modeling (4)
A graduate- level presentation of basic mathematical background for the study of computer science, computer engineering, and software engineering. Boolean expressions; propositional calculus; proofs; formal logic; quantification; predicate calculus; predicates and programming; sets, relations, functions, orderings, and equivalence relations; mathematical induction; integers and sequences; graph theory. Prerequisite: CSE 504 or equivalent.

CSE 511 Design and Analysis of Algorithms (4)
This course covers computer algorithms, their design, and their analysis. Different strategies for constructing algorithmic solutions including Divide- and- Conquer, Dynamic Programming, and Greedy Algorithms are discussed and illustrated using graph and artificial intelligence problems. The development of algorithms for parallel and distributed architectures is also discussed. Computational complexity, as it pertains to time and space, is used to evaluate algorithms. Amortized analysis (aggregate and accounting methods) is introduced and used to evaluate data structures implementations. A general overview of complexity classes is given. The course emphasizes algorithm design rather than implementation. Prerequisites: CSE 501 and 504 or equivalent.

CSE 512 Artificial Intelligence in Manufacturing (4)
This course focuses on the integration of the techniques and methodologies from artificial intelligence and manufacturing engineering. On the manufacturing side, issues of design, manufacturability, process planning, and cost analysis are cast around feature- based CAD/ CAM technologies. The artificial intelligence techniques include standard transparent representation schemes of rule bases and semantic networks as well as the most up- to- date opaque representations of neural networks and genetic algorithms, both areas integrated with issues of fuzzy logic and control. Involves a large class project. Prerequisite: Background in artificial intelligence, manufacturing, or business.

CSE 513 Soft Computing (4)
This course studies algorithms that can be used to add humanlike intelligence to computer systems. Topics covered include fuzzy logic, artificial neural networks, genetic algorithms, and classification and regression

trees. Applications to machine learning, pattern recognition, and intelligent automation. Prerequisites: CSE 501 and 504 or equivalent.

CSE 516 Artificial Intelligence (4)
Introduction to artificial intelligence techniques including knowledge representation using semantic networks, scripts, frames, predicate calculus, production and expert systems, and procedures; learning via symbolic and adaptive algorithms; natural language understanding; and game playing and other searching problems. Prerequisite: CSE 335 or equivalent.

CSE 517 Agent Based Systems (4)
Introduction to intelligent agents and multiagent systems; distributed problem solving and planning; search algorithms for agents; interaction and cooperation; action and behavior modeling of agents; learning and knowledge acquisition; applications. Prerequisites: CSE 501 and 504 or equivalent.

CSE 521 Software Requirements Engineering (4)
This course studies the mechanisms underlying programming decisions and presents systematic procedures for making these decisions. The procedures studied cover the design of iterative loops, and sequence statements, along with general heuristics that represent problem solving strategies. The course uses the formalism of relational algebra. The relational algebra is covered in class. Prerequisites: CSE 501 and 504 or equivalent.

CSE 522 Object Oriented Analysis and Design (4)
This course covers the methodologies of object oriented (OO) modeling during the planning, analysis and design stages of software systems development. Predominant methodologies and techniques such as the Unified Modeling Language (UML) will be surveyed. OO programming using an OO language such as C++ or Java is not covered in this course. Topics include both process oriented issues, such as the application of use case modeling during OO requirements analysis, and product oriented issues, such as the definition of an OO design using class diagrams. Prerequisites: CSE 501 and 504 or equivalent.

CSE 535 Topics in Programming Languages (4)
Modern topics in programming languages such as: object- oriented languages, functional programming logic programming, parallel programming, concurrent programming in a distributed environment, formal syntax and semantics, exception handling, client- server programming. Prerequisites: CSE 231, 335 and 343.

CSE 537 Systematic Software Development (4)
A project- driven, language- independent, top- down software development method based on specifications and refinement of every step of design. It involves user- defined Abstract Operations and Abstract Data types. A variant of the Vienna Development Method (VDM) is used. Specification techniques are introduced gradually, in step with a nontrivial term project. An emphasis is placed on practical applications of the method. Prerequisites: Fluency in programming and a good command of data structures; APM 563 a plus.

CSE 538 Software Verification and Testing (4)
Systematic methods of software verification, testing and analysis and the supporting CASE tools. Topics: principles of formal verification, static program analysis and dynamic program analysis (testing and debugging). A significant part of the course is its lab component. Prerequisite: CSE 501 or equivalent.

CSE 539 Software Engineering (4)
An overview of software development processes, tools, and techniques from the perspective of learning what they can and cannot do; deciding when, how and why to apply them; and selecting among the available alternatives. Requirements analysis and specification techniques; life- cycle models; process modeling; software design methods; project planning and management; quality assurance; configuration management; program and system testing. Prerequisite: CSE 501 or equivalent.

CSE 540 Software Quality Assurance (4)

Intended for students who have mastered fundamental design and programming skills. The impact of software design and construction techniques on structural quality for both object- oriented and traditional decomposition. The relationship between software structure and software maintainability (modifiability and readability) and reusability is emphasized. Topics include software design, object- oriented design and its impact on reuse and modifiability, information hiding, layers of abstraction, coupling and cohesion, polymorphism and inheritance hierarchies for reuse, designing reusable components and libraries, structuring code for maintenance, coding for readability, modularity, abstraction mechanisms in design, software complexity. Prerequisite: CSE 501 or equivalent.

CSE 541 Software Project Planning and Management (4)
Software project planning and management topics include uncertainty and risk analysis; planning a software project; project modeling, scheduling, and milestones; resource allocation; software cost estimation; mechanisms for monitoring and controlling schedule, budget, quality, and productivity; staffing, leadership, motivation, and team building; communication management and project documentation. Prerequisite: CSE 539 or equivalent.

CSE 542 Rapid Prototyping and Component Software (4)
Methodologies for rapid prototyping and component software use. Topics include: platforms for rapid prototyping and object-oriented software development; available software components; object request brokers (COM/CORBA/OLE); data modeling, transaction processing and federated database; client and server web technologies. A theory and project oriented course.
Prerequisite: CSE 501 or equivalent.

CSE 545 Database Systems I (4)
Study of the design and implementation of relational, hierarchical, and network database systems. Query/ update languages; conceptual data models; physical storage methods; database system architecture; database security and integrity. Includes the study of existing systems. Prerequisites: CSE 501 and CSE 504 or equivalent.

CSE 547 Computer Communications (4)
A study of data communications and computer networks with emphasis on the functional characteristics of communications hardware and the design of communications control software. Standard protocols and interfaces. Case studies of local area networks and wide area networks. Communications software is designed and implemented as student projects.
Prerequisite: CSE 550 or permission of the instructor.

CSE 549 Multimedia and Networks (4)
Multimedia system requirements, data representation and compression, input/output and devices, network load implications, Multimedia authoring, web design and presentation of multimedia, collaborative multimedia sessions, graphical user interface design using Tcl/Tk and Java. Prerequisite: CSE 547

CSE 550 Operating Systems (4)
Introduction to the concepts and design of multi- programmed operating systems. Typical topics include: historical perspectives; sequential processes; concurrent processes; processor management; store management; scheduling; file management; resource protection; a case study. Prerequisites: CSE 501 and 502 or equivalent.

CSE 551 Web Design and Applications (4)
Advanced concepts in WEB design, creation and use of WEB development ools, simple and advance application design will be covered. The students will do a design project during the second half of the semester. This course assumes prior knowledge of WEB programming. Prerequisite: CSE 501

CSE 555 Computer Graphics I (4)
Introduction to the concepts underlying two- and three- dimensional computer graphics. Topics include an overview of graphics hardware and software; capabilities and algorithms of a two- dimensional raster graphics package; basics of three- dimensional raster graphics; algorithms for simple three- dimensional

raster graphics; introduction to computer animation. Prerequisites: MTH 256 and CSE 231 or permission of instructor.

CSE 556 Computer Graphics II (4)
Continuation of CSE 555. Topics covered include realistic rendering techniques (hidden line/ surface, lighting, shading, texture mapping); mathematics and data structures for curve, surface, and solid representation (including B- spline and Bezier techniques), advanced animation techniques (key- frame animation, morphing). Prerequisites: CSE 555 or permission of instructor.

CSE 564 Computer Organization and Architecture (4)
Stored program computers, theory and design of arithmetic- logic and control units, hardwired design and microprogrammed design, performance metrics and scalability, pipelined computer design, interfacing input/ output units with processors, parallel processing. Emphasis of this course is on hardware design and organization. Prerequisite: CSE 502 or equivalent.

CSE 565 Compiler Design (4)
This is a project oriented course in which the student develops a compiler for a simple language. Formal language and regular grammars; finite-state machines and lexical analysis; context-free grammars and parsing; syntax-directed translation and decorated parse-trees; symbol-table design; quadruples and other intermediate forms; simple optimizations. Prerequisite: CSE 504 or equivalent.

CSE 570 Microprocessor- based Systems Design (4)
Application of microprocessors and microcomputers to the solution of typical problems; interfacing microprocessors with external systems such as sensors, displays and keyboards; programming considerations, microcomputer system and memory system design. A laboratory design course; several short design projects and one large design project. This course integrates concepts learned in required courses and provides a design experience. The large design project includes cost/ trade- off analysis, submitting a detailed written report and oral presentation of the project. Credit cannot be earned for more than one of CSE 470/ 570 and EE 470/ 570. Offered fall, winter. Prerequisite: CSE/ EE 378 or CSE 502 or equivalent.

CSE 571 Design of Embedded Software Computer Systems (4)
Design of real- time systems with microcontrollers such as the 68HC11 and 68332. Object- oriented software development using both assembly language and high- level languages. Use of interrupts. Project oriented course. Offered winter. Prerequisite: CSE 570 or equivalent.

CSE 581 Data Mining and Knowledge Discovery (4)
This course provides a background in data warehousing technologies, and their applications in knowledge discovery using data mining algorithms. Data preparation, reduction, and transformation concepts are presented as integral component of the discovery lifecycle. Data mining algorithms, including association rules, decision trees, link analysis, clustering, regression, and neural models are covered. The theoretical concepts presented are supplemented with adequate hands-on experience with software tools for data mining.

CSE 582 Information Retrieval (4)
Introduction; information retrieval models; retrieval evaluation; query languages; query operations; text and multimedia documents; indexing and searching; visualization; web search engines.

CSE 583 E-Commerce and ERP (4)
This course focuses on the evolving technologies on the world wide web that support new models of business. These models include 1) electronic commerce with concerns of fault tolerance, security, and 24-7 availability and 2) ERP with concerns of financial, human resource, and manufacturing systems integrating together into inter-company supply chain systems.

CSE 594 Independent Study (2 to 4)

Independent study in a special area of computer science and engineering. Topic must be approved prior to registration.

CSE 595 Special Topics (2 to 4)
Study of special topics in computer science and engineering. May be taken more than once.

CSE 616 Applied Pattern Recognition (4)
Pattern recognition system model; feature extraction; taxonomy of classification methods; parametric and nonparametric classifiers; clustering techniques; performance evaluation; applications in image and speech recognition.

CSE 618 Visual Computing (4)
Introduction; image representation, image formats and image coding; manipulating image appearance; computation of image properties such as shape, color, and texture; image segmentation.

CSE 639 Software Maintenance & Reuse (4)
This course discusses issues related to the reuse and maintenance of software, including techniques and processes to comprehend the purpose, utilization and interdependencies of software components. Topics include software development paradigms as they relate to reuse and maintenance; methodologies and tools for building for and with reuse; methods for the reengineering and evolution of existing software; and methods and tools for assessing and measuring products and processes.

CSE 640 Software Architecture (4)
Software architecture captures the fundamental high-level structure and behavior of software systems. Topics covered in this course include role of the architecture in the software lifecycle; different architectural styles for single as well as distributed processes; and architecture description languages for various architectural viewpoints. Topics include architectural styles for both single process and distributed systems, such as pipe/filter, data flow, data centered, client-server and distributed objects.

CSE 645 Database Systems II (4)
Concurrency control, recovery, and query optimization for database systems; distributed database systems; object- oriented database systems; knowledge- base systems; optimization of conjunctive queries and linear recursions; experimental knowledge- base systems; the universal relation as a user interface. Students will create and conduct studies of standard relational databases as a laboratory component of this course. Prerequisite: CSE 545 or equivalent.

CSE 647 Advanced Computer Communications (4)
Data communications networking technology; protocols and architecture; protocol specification and verification; network performance measurement and predication- analysis, simulation, and modeling. Prerequisite: CSE 547 or equivalent.

CSE 650 Advanced Operating Systems (4)
This course focuses on distributed operating systems. Communication protocols such as message systems and RPC; synchronization of distributed systems; processes and processors; distributed file systems; distributed shared memory. Prerequisite: CSE 550 or equivalent.

CSE 664 Parallel and Distributed Processing (4)
Classes of computer systems, SIMD parallel and MIMD computers, interconnection networks and parallel memories, parallel algorithms; performance evaluation of parallel systems; parallel computers such as Illiac IV, PEPE, and STARAN; pipelined computers; multiprocessing by tight and loose coupling; distributed systems; data flow machines; architecture and software considerations. Prerequisite: CSE 564.

CSE 666 Real Time Computer Systems (4)
This course emphasizes hard and soft real time computer system design for uniprocessor embedded system applications and distributed real time systems. Topics covered include characterizing real-time systems, performance measure, task assigning, scheduling, fault tolerant scheduling, run-time error handling, run-

time support, compiler, linker, debugger, kernel, real-time databases, real-time communication, software development techniques; practical applications. Prerequisite: CSE 570 or 571

CSE 670 Embedded Systems Design Using FPGAs (4)
The use of hardware description languages such as VHDL in the design of embedded systems containing both an FPGA and a microprocessor; high-level design tools to specify, simulate, and synthesize designs to FPGAs; design examples.

CSE 671 DSP in Embedded Systems (4)
This course emphasizes design of embedded systems using Digital Signal Processing microprocessors, and special DSP FPGA chips. Topics covered include, DSP microprocessor architecture, advanced instructions, addressing modes, interrupt, system design considerations, interfacing serial and parallel I/O, memory structure, arithmetic manipulations, software development tools, multiple DSP processor system design, and embedded system applications. Applications include automotive, multimedia, and wireless communications. Performance measurement, benchmarking and DSP system simulation, testing and debugging. Design of DSP embedded system using Synopsys COSSAP tools. The students will do a set of lab projects and a large embedded system design project.

CSE 672 Hardware/Software Co-Design in Embedded Systems (4)
This research-oriented course will study hardware/software co-design issues and explore the use of FPGAs in the design of low-cost, high-performance embedded systems. Pre-requisite: CSE 670 and CSE 571.

CSE 681 Information Security (4)
Introduction to cryptography; message authentication; digital signatures and authentication protocols; e-mail security; IP security; web security; intruders, viruses and worms; firewalls

CSE 690 Graduate Computer Science and Engineering Project (2 to 12)
Independent work on an advanced computer science and engineering project. Topic must be approved prior to registration.

CSE 691 Master's Thesis Research (2 to 8)
Directed research leading to a master's thesis. Topic must be approved prior to registration.

CSE 794 Independent Study (2 to 4)
Advanced independent study in a special area of computer science and engineering. Topic must be approved prior to registration.

CSE 795 Special Topics (2 to 4)
Advanced study of special topics in computer science and engineering. May be taken more than once.

CSE 718 Advanced Visual Computing (4)
2-D and 3-D object recognition; stuff detectors; video representation, video formats and coding; motion; image and video analysis for content-based retrieval. Prerequisite: CSE 618

Appendix C

Faculty Vitae