Master of Science: Software Engineering

Joint program between:
The College of Arts & Science and the College of Engineering

I. Description

The Association of Computing Machinery (ACM), the premier professional organization for computer science, defines software engineering as follows:

> *Software engineering (SE) is concerned with developing and maintaining software systems that behave reliably and efficiently, are affordable to develop and maintain, and satisfy all the requirements that customers have defined for them. It is important because of the impact of large, expensive software systems and the role of software in safety-critical applications. It integrates significant mathematics, computer science and practices whose origins are in engineering.*

Similarly, the United States Bureau of Labor Statistics provides this description of software engineering careers:

> *Computer software engineers are one of the occupations projected to grow the fastest and add the most new jobs over the 2006-16 decade. … Software engineers apply the principles of computer science and mathematical analysis to the design, development, testing, and evaluation of the software and systems that make computers work. The tasks performed by these workers evolve quickly, reflecting new areas of specialization or changes in technology, as well as the preferences and practices of employers. Software engineers can be involved in the design and development of many types of software, including computer games, word processing and business applications, operating systems and network distribution, and compilers, which convert programs to machine language for execution on a computer.*

We propose to create a Master of Science degree in Software Engineering (MSSE), with the degree to be granted by both the College of Arts & Science and the College of Engineering. The degree program is composed of a common core of fundamental courses (15 credits), is supplemented by a specialization track (12 credits) of the student's choosing, and includes a practicum (3 credits). This degree leverages strengths of the Departments of Computer & Information Sciences (CIS) and Electrical and Computer Engineering (ECE) by focusing both on the core subjects of software engineering and related topics in computer science and computer engineering. The program will be administered by a Joint Graduate Committee on Software Engineering (JGCSE) as described in section II.G.1 of this proposal.

Objective: To prepare students for a professional career as a practicing software engineer. Graduates of this program can expect to have expanded career options and responsibilities involving any or all aspects of software engineering.

II. Rationale & Demand

A. Institutional Factors

1. Mission Compatibility

   Offering an MS in Software Engineering will assist the University in fulfilling its mission to "disseminate scientific, humanistic, and social knowledge for the benefit of the larger society"; to produce graduates who "are prepared to contribute to a global society"; and, as an "institution engaged in addressing the critical needs of the state, nation and global community".

2. Planning Process

   Representatives of the CIS and ECE Departments began meeting in Spring 2008 and then regularly during Fall 2008 and Spring 2009 to discuss the proposed degree. The group included CIS Professors Pollock and Siegel, who conduct research in software engineering and who already teach courses in software engineering. Their expertise was invaluable. ECE's Professors Bohacek and Sincoski provided input regarding current and planned ELEG and CPEG courses that are relevant to the proposed degree. As part of the design process, existing software engineering programs at other institutions were studied. Interspersed throughout the process were multiple meetings with representatives of various U.S. Army groups located at Ft. Monmouth who will be moving to Aberdeen, Maryland over the next couple of years. In addition, numerous corporate contacts provided valuable input, not only regarding the design of specialization tracks they considered valuable in the proposed program, but also detailing the education benefits available to the employees in the respective organizations. Without exception, the following organizations indicated that the MSSE would be considered a valuable asset for their employees: BAE Systems, Boeing, Computer Sciences Corporation (CSC), Lockheed Martin, the U.S. Navy, Raytheon, Service Engineering, and others, many of which are Army contractors. Through Engineering Outreach, where an infrastructure already exists for engineering professionals to pursue "professionally convenient" part-time graduate education, additional leads for prospective MSSE students as well as suggestions for course options that could be added to the MSSE program in the future continued to emerge. After much discussion, study, and negotiation, the group arrived at the plan presented in this document.

3. Impact on other UD programs

   The proposed MSSE is not expected to impact programs outside of the CIS and ECE Departments. The Deans of both colleges are aware of the MSSE planning.

4. Utilizing existing resources

   The proposed curriculum leverages strengths of both the CIS and ECE Departments, including existing expertise in software engineering, and outstanding faculty with broad expertise in computer science and engineering.

B. Student Demand

We conservatively project (see below) that in the steady state there will be 30 students entering the MSSE program each year. Most of these students will be part-time, and include both Army personnel and employees of local corporations (see "Planning Process" above). Each part-time student will take 3 to 6 credits per semester. Thus, the MSSE degree program will generate approximately 300 credits from part-time students in the first year, building to 900 credits per year steady-state, after three years. Part-time students who are Army personnel are expected to graduate in approximately 2.5 years, while most corporate employees pursuing degrees part-time take 3-5 years to complete.

The steady state projection of 30 students entering the MSSE program each year was derived in two ways: a) from our analysis based on demographics of the move of 'Team C4ISR' (see below); and b) from direct discussions with Army management personnel. In both cases the analysis shows that 30 entering students per year is a conservative projection. The two subsections below provide details.

Demographic based demand analysis

The Army organization moving from Ft. Monmouth to Aberdeen Proving Ground (APG) refers to itself as 'Team C4ISR'. We have obtained detailed demographic information on their employee base. Team C4ISR consists of 10,330 civilian and 257 military personnel, 5200 of whom are located at Ft. Monmouth and whose jobs are moving to APG. Team C4ISR is made up of five sub-organizations, all of which are engaged in the development, acquisition, deployment and field support of the Army's battlefield electronics, computers, software, and communications equipment. Among these five sub-organizations, CERDEC (Communications Electronics Research, Development and Engineering Center) is the most engineering intensive.

Team C4ISR currently employs 2540 *engineers and scientists*, of which 79% have degrees in ECE or Computer Science. There are also 2859 Technical and Subject Matter Experts in Team C4ISR. Within CERDEC alone, 1639 jobs will be moving to APG, and of these 1405 are engineers and scientists. Of the 1135 engineers and scientists within Team C4ISR who are not part of CERDEC, we estimate that 50% will be moving to APG (we do not have exact information on the locations of these people, but 50.3% of Team C4ISR personnel in total are being moved to APG). Thus we estimate a population of 1972 (1405 + .5*1135) engineers and scientists will be moving to APG.

We have data as of 2006 on the numbers of engineers and scientists enrolled in graduate school from two organizations within CERDEC (STCD and I2WD). Of 642 employees in these organizations, 71 (11.0%) were enrolled in MS programs, and 14 (2.2%) were enrolled in PhD programs. If we extrapolate this to the base of 1,972 engineers and scientists moving to APG, we would predict 260 (13.2%) to be enrolled in graduate programs on a steady state basis.

The number of 260 total UD engineering and science students is conservative for two reasons. Due to the move to Aberdeen, CERDEC is expecting to lose over 50% of their employees through attrition. Consequently, CERDEC will need to hire a significant number of new "younger" employees, which will considerably increase the need for continuing education and training. Furthermore, there is a large defense contractor base that will build up around APG in support of Team C4ISR. This base will include many scientists and engineers, some of whom will also enroll in graduate schools. We are thus comfortable with a conservative estimate of 300 total graduate students as the addressable market.

We do not have good information on the distribution and selection of graduate schools among the current student population at APG. However, UD is the closest university to APG, and the commute is significantly easier than to Baltimore area schools. For the purposes of this proposal, we assume that UD will be able to attract 2/3, or 200 students, steady state. The distribution of students by discipline is also of interest. The degree profile of existing CERDEC engineering employees shows 24% with degrees in Computer Science or Computer Engineering, and 55% with degrees in Electronic or Electrical Engineering. Most, if not all, of these employees would meet the criteria for admission into the MS in Software Engineering program. Software engineering is a key area of interest in the software industry and DoD in general, but is underserved by universities. Thus, the proposed SE program serves not only the needs of the Army, but also fills an unmet need of the local software industry. Conservatively we estimate that 15-20% of the projected 200 students attracted to UD will pursue the MSSE, thus yielding at least 30 entering students each year.

CERDEC direct demand analysis

Over the past year, we have engaged in multiple discussions with CERDEC management about the establishment of the proposed MSSE program. CERDEC is currently served by Monmouth University's software engineering program, and is actively seeking a new university partner in the Aberdeen area to develop a similar program. CERDEC's own estimated enrollment for this masters program is 40 students per year, with students coming from CERDEC's Software Engineering Directorate and CECOM's Software Engineering Center, as well as non-Army sources.

In conclusion, we believe that our estimate of 30 MSSE students enrolling per year at UD is conservative and supported by the detailed information we have obtained from the Army.

C. Transferability

Prior to application/admission to the MSSE program, a prospective student can be approved by the JGCSE to take up to 9 UD graduate credits that, if/when admitted to the degree program, could be applied to that degree. Once the student has

successfully completed 9 approved graduate UD credits and been admitted to the degree program, then, with the approval of the JGCSE, a maximum of 9 graduate credits can be transferred into the MSSE program from another institution.

D. Graduate and Professional Program Access

Although there may be some full time students, it is expected that a majority of the students enrolled in the MSSE program will already be employed in industry or government and for them the MSSE will be a terminal degree. We anticipate that a very small number of students will decide to pursue the PhD in either CIS or ECE.

E. Demand & Employment Factors

We have incorporated our discussion of these factors in section B above.

F. Regional/State/National Factors

1. Advantages Over Regional Programs

No other university in the State of Delaware offers an MS in Software Engineering. In our immediate region Drexel, Towson, and George Mason offer this degree. Given the driving involved, none of these programs are easily accessible to Delaware residents (or even to Department of Defense employees who are located at Aberdeen). In addition, the University of Maryland and Towson offer a graduate certificate in software engineering. These certificates are intended primarily as an "add on" for students pursuing other advanced degrees at those institutions. Finally, we note that Drexel offers an on-line version of its MS in SE program. We believe that, while on-line education has a place for some courses, a traditional classroom-based education is a preferred means of delivering most of the MSSE courses.

2. Accrediting/Professional Mandates

The curriculum was designed after careful study of software engineering curricula in other institutions. The ACM does not have guidelines for Master's degrees in software engineering, nor are there accreditation standards. The Accreditation Board for Engineering and Technology (ABET) lists accredited BSSE programs, but does not currently provide accreditation guidelines for Master's degrees in software engineering.

G. Other Strengths

1. Special Features

A special feature of the proposed program is its close coordination and collaboration between the CIS and ECE. These two departments have along history of working together well and this program will further enhance that relationship.

The proposed MSSE degree will be managed by a Joint Graduate Committee on Software Engineering (JGCSE). This committee will administer the program in collaboration with the Chairs of CIS and ECE. The JGCSE will

consist of two faculty members each from CIS and ECE. The Assistant Dean for Engineering Outreach will serve as an ex-officio member. The JGCSE will be chaired by one of the CIS or ECE faculty with the chair's position rotating between the two departments every two years. The JGCSE, in collaboration with the Chairs of CIS and ECE, will be responsible for all aspects of the MSSE program including: admissions; course scheduling; advising; establishing policies and procedures of the MSSE program; revising the program as appropriate; and approving student-driven specialization tracks and practicum experience.

2. Collaborative Arrangements

This proposal is presented by the Department of Electrical and Computer Engineering in the College of Engineering and the Department of Computer & Information Sciences in the College of Arts & Science. This collaboration creates one of the key strengths of the program.

III. Enrollments, Admissions and Financial Aid

A. Enrollment Limitations/Criteria

Enrollments will be limited to approximately 30 new students per academic year. Enrollments above that number will require additional new faculty beyond the two discussed in this proposal (see section V.B.).

B. Admissions Requirements

1. Criteria

The following are the general requirements for admission:

- A bachelor's degree from a recognized four-year college or university with a minimum grade average of 3.0 is required.
- Scholarly competence in mathematics and computer programming. Applicants without a degree in computer science or computer engineering or a related area, are expected to know the material covered by at least one undergraduate course in each of the following topics:

  structured high-level language programming
  data structures
  analysis of algorithms
  discrete mathematics

- The following minimum scores are expected on the GRE (Graduate Record Examination) test:

  Quantitative: 650
  Verbal + Quantitative: 1150

Analytical Writing: 3.0
No GRE subject test is required.

Those who don't meet the score expectations but have other evidence of readiness for the program are encouraged to apply.

- For applicants whose first language is not English, and who have not received a degree at a U.S. college or university, a TOEFL score of 100 or better on the Internet test, or 250 or better on the computer test, or 600 or better on the old paper test is required. In addition, for applicants who have not graduated from an institution whose principal language of instruction is English, the Test of Spoken English is required.

- Three letters of recommendation are required from professors, employers, or others who have had a supervisory relationship with the applicant and are able to assess the applicant's potential for success in graduate studies.

- The applicant will apply to the MSSE program with the understanding (as reinforced during the application process) that this is an "interdisciplinary graduate program" overseen by the JGCSE. The student will remain in the "interdisciplinary graduate program" matriculation until later in the program, when the practicum project is defined and a faculty advisor is designated for the practicum. At that time, the student's matriculation will be changed to match the college of that practicum faculty advisor.

2. Transfer Policy

   Up to 9 relevant UD graduate credits can be taken as a CEND (continuing education non-degree) or Graduate/Non-degree student prior to application/admission to the degree program. In addition, a maximum of 9 credits can be transferred from other institutions with the approval of the JGCSE after matriculation.

3. Retention Policy

   No retention policy is associated with this program.

C. Student Expenses and Financial Aid

1. Extraordinary Required Student Expenses

   None.

2. Student Financial Support

   None.

IV. Curriculum Specific

A Degree Awarded

The Master of Science is the degree to be awarded to students who successfully complete the MSSE program. The degree will be awarded by either the College of Arts and Science or by the College of Engineering. The Master of Science degree currently exists in both colleges. The awarding college for a particular student will be Arts and Science if the student's practicum is supervised by a faculty member in CIS and the awarding college will be Engineering if the student's practicum is supervised by a faculty member in ECE.

B Curriculum

1. Requirements

The program requires the completion of 30 graduate credits divided among three required components:

- Core requirements courses (15 credits)
- A specialization track of courses (12 credits)
- Practicum (3 credits)

The core courses may be taken in any order. However, all core courses must be completed before the student begins the practicum. The specialization courses may be taken at any time and in any order, as long as all course pre- and co-requisites are respected.

The core courses are the following:

CISC 611/CPEG 611	Software Process and Project Management.....3
CISC 612/CPEG 612	Software Design.....3
CISC 613/CPEG 613	Software Requirements Engineering.....3
CISC 614/CPEG 614	Software Verification.....3
CISC 615/CPEG 615	Software Testing and Maintenance.....3

Course catalog descriptions for each core course are given in the Appendix.

The specialization track is determined by the student's interests and must be approved by the student's advisor. The selected courses should form a coherent whole giving the student a degree of expertise in a single area. See the following section for examples of specialization tracks.

The practicum (CISC/CPEG 691) will be guided by the individual student's interests. It must be arranged with, and approved by, a CIS or ECE faculty member. The student will contribute to a significant software engineering project

either on campus or in association with an off-campus organization such as a private business or government agency.

2. Sample Curriculum

The following is a sample curriculum with a specialization in scientific and high performance computing:

CPEG 611	Software Process and Project Management	3
CISC 612	Software Design	3
CPEG 613	Software Requirements Engineering	3
CPEG 614	Software Verification	3
CISC 615	Software Testing and Maintenance	3
MATH 607	Survey of Scientific Computing	3
CISC 662	Computer Systems Architecture	3
CISC 879	Parallel and Distributed Computing	3
ELEG 867	Empirical Program Optimization	3
CISC 691	Practicum	3

Several sample specialization tracks (12 credits each) are listed below. Recall that students will design their specific specialization track in conjunction with a faculty advisor. We expect that during the 2009/2010 academic year, the JGCSE will establish a program website that will list refined versions of these and additional sample tracks.

Networks Track:

CISC 650 Computer Networks....3

Any 3 of the following....9

CISC 853	Network Management (3)
CISC 856	TCP/IP and Upper Layer Protocols (3)
ELEG 819	Topics in Networking I (3)
CISC 861	Wireless Networks and Mobile Computing (3)
ELEG 812	Wireless Digital Communications (3)
CISC 664	Introduction to Network Security (3)

Scientific and High Performance Computing Track:

Any 4 of the following....12

CISC 662	Computer Systems: Architecture (3)
CISC 879	Parallel and Distributed Computing ? (3)
CISC 672	Compiler Construction (3)
ELEG 867	Empirical Program Optimization (3)
MATH 607	Survey of Scientific Computing (3)
CPEG 655	High-Performance Computing with Commodity Hardware (3)
ELEG 652	Principles of Parallel Computer Architectures (3)

Communications and Signal Processing Track

Any 4 of the following: 12

ELEG 833	Nonlinear Signal Processing (3)
ELEG 832	Wavelets and Filter Banks (3)
ELEG 630	Information Theory (3)
ELEG 631	Digital Signal Processing (3)
ELEG 632	Mathematical Methods for Signal Processing (3)
ELEG 633	Image Processing (3)
ELEG 634	Signals and Systems (3)
ELEG 635	Digital Communication (3)
ELEG 636	Statistical Signal Processing (3)
ELEG 811	Channel Coding Theory and Practice (3)
ELEG 812	Wireless Digital Communication (3)

Information Sciences/AI Track:

Any 4 of the following.....12

CISC 888	Machine Learning (3)
CISC 683	Introduction to Data Mining (3)
CISC 637	Database Systems (3)
ELEG 657	Search Engine Technology (3)
CISC 681	Artificial Intelligence (3)
CISC 886	Multi-Agent Systems (3)
CISC 882	Natural Language Processing (3)

Systems and Architecture Track:

Any 4 of the following.....12

CISC 663	Operating Systems (3)
CISC 662	Computer Systems: Architecture (3)
ELEG 652	Principles of Parallel Computer Architectures (3)
CISC 672	Compiler Construction (3)
CPEG 622	Computer System Design II (3)
ELEG 653	Computer System Security (3)

Computer Science Track:

Any 4 of the following: 12

CISC 662	Computer Systems: Architecture (3)
CISC 663	Operating Systems (3)
CISC 650	Computer Networks (3)
CISC 681	Artificial Intelligence (3)
CISC 640	Computer Graphics (3)
CISC 672	Compiler Construction (3)

CISC 601	Elements of the Theory of Computation (3)
CISC 604	Logic in Computer Science (3)
CISC 621	Algorithm Design and Analysis (3)

3. University/College/Department Requirements

   For this graduate degree there are no core or related requirements at any level.

4. Approval from Affected Departments

   This degree is a collaborative project by the CIS and ECE Departments. The program does not impact any other units within the University.

V. Resources Available

A. Learning Resources

There are no special Learning Resources required to support this major.

A Library Assessment has been completed. Per a memo of February 26, 2009 from Susan Brynteson, Vice Provost and May Morris Director of Libraries: "The University of Delaware Library is well able to support the proposed new program."

B. Faculty/Administrative Resources

Two of the five courses in the core curriculum are currently offered roughly every other year in CIS. In the new program each of the core courses will be taught every year. The faculty currently teaching these courses, Professors Pollock and Siegel, would continue to teach these courses on an every other year basis, with other MSSE faculty teaching those courses in the intervening years.

Courses that form the specialization tracks will all be courses currently offered by the CIS and ECE departments. The total enrollment each year from the MSSE program in specialization track courses will be approximately 120 (30 students per year, 4 courses in a track). With roughly 50 computer science or computer engineering graduate courses being offered each academic year, and with most of the classes having at least a few available seats, the demand from MSSE students can be managed by existing classes.

C. External Funding

No external funding is involved.

VI. Resources Required

A. Learning Resources

Students in the program will utilize standard University computing systems. No new learning resources are required.

B. Personnel Resources

Two new tenure-track faculty will be required, one position each in CIS and ECE. These faculty will have primary responsibility for offering three of the five courses in the MSSE core curriculum. These two new faculty are essential to the offering of the MSSE program.

Each core course will be offered once each academic year. Over a two year period there would thus be a total of 10 offerings of the MSSE core courses. Of these, 5 will be offered in CIS and 5 will be offered in ECE. The JGCSE and the Chairs of CIS and ECE will be responsible for determining the details.

With roughly 30 new students beginning the MSSE program each year, and with 5 to 10 students in the regular CIS and ECE graduate programs taking each course, we anticipate that each core course offering will have a class size of 35 to 40 students.

VII. Implementation and Evaluation

A. Implementation Plan

The MSSE degree program is slated to be phased in beginning in the Fall semester of 2009 with the enrollment of a small number of Army employees in regular CIS and ECE graduate programs. This date corresponds with the beginning of the movement of Army personnel from Ft. Monmouth to Aberdeen. Based on our discussions with the Army, we expect that a full complement of 30 students will begin the MSSE program in the Fall of 2010.

Prior to Fall 2010, the two new faculty need to be hired. In addition, the JGCSE needs to get up and running, establishing policies of their operation and for the program, and coordinating with the CIS and ECE chairs about course offerings.

Simultaneously with this proposal, Faculty Senate approval will be sought for the five core courses and the practicum course in the MSSE program.

B. Assessment

The following plan was developed with the assistance of Gordana Copic and Kathleen Pusecker from the UD Office of Educational Assessment.

Program Objective: To prepare students for a professional career as a practicing software engineer. Graduates of this program can expect to have expanded career options and responsibilities involving any or all aspects of software engineering.

Learning Outcomes: As graduates of UD Master of Software Engineering program, students should be able to successfully:

1. Plan and manage a large software project, including scheduling, effort estimation, risk management, project personnel and organization, software configuration management, and project control.

2. Design large, complex software applications using principles of good design, software architecture and architectural notations and languages.

3. Utilize rigorous methods to elicit, analyze, and specify requirements of a software system.

4. Apply formal verification approaches to show that a computer application meets its specification, using state-of-the-art verification tools.

5. Identify and apply appropriate state-of-the-art test case generation, test oracles, test coverage analysis, and regression testing techniques to systematically expose faults in software, particularly throughout maintenance.

6. Use creative and critical thinking skills to contribute to a problem-solving software engineering team in a real-life setting.

Assessment plan:

- Direct and indirect assessment of learning outcomes and program objective.

- Potential assessment questions:
  i. To what degree are students achieving the program learning outcomes?
  ii. To what degree is the program meeting its objectives of "preparing students for a professional career as a practicing software engineer and expanding career options and responsibilities involving any or all aspects of software engineering for program graduates."?
  iii. What are the students' perspectives on their preparedness and their achievement of the program learning outcomes?
  iv. What is the impact of the program on student learning and preparedness related to the software engineering field?
  v. What are our faculty's perceptions about the success of the program, student learning, effectiveness of teaching methods, etc?

- Potential measures and sources of information for each assessment question:
  i. To what degree are students achieving the program learning outcomes?

- Source of information: Authentic student work: projects, plans, tangible products
- Measuring instrument: Common rubric

ii. To what degree is the program meeting its objectives of "preparing students for a professional career as a practicing software engineer and expanding career options and responsibilities involving any or all aspects of software engineering for program graduates."?
   - Sources of information: Alumni, graduating students, faculty, employers (their perceptions, placement, career success)
   - Measuring instrument: Alumni questionnaire on preparedness, questionnaire of employers evaluating the graduates and satisfaction with their work, focus groups/interviews of graduates confidence and preparedness to enter the field

iii. What are the students' perspectives on their preparedness and their achievement of the program learning outcomes?
   - Source of information: Students' perceptions/reflections from professional journals or other work that contains students' opinions and thoughts
   - Measuring instrument: Questionnaire for students to rate their knowledge, understanding, confidence on each learning outcome

iv. What is the impact of the program on student learning and preparedness related to the software engineering field? (From student perspective or direct)
   - Source of information: Students' perception of their abilities and knowledge on stated learning outcomes, campus community partner who would rate students' preparedness
   - Measuring instrument: Students' pre-post questionnaire/test addressing the learning outcomes and Community Partners' survey of students' preparedness

v. What are faculty perceptions on the success of the program, student learning, effectiveness of teaching methods, etc?
   - Source of information: Faculty perceptions/thoughts reflections
   - Measuring instrument: Documented conversations/discussions that address student learning, teaching, etc. or surveys

Appendix - MSSE Core Course Descriptions

CISC611/CPEG611 - Software Process and Project Management (3 credits)

Software management studies processes and concepts for planning and monitoring all software life-cycle phases. Topics include management models and structures, project planning including scheduling, effort estimation and risk management, project personnel and organization, project control (monitoring, measurement, correction and performance standards), software configuration management, and process description languages and tools.

CISC612/CPEG612 - Software Design (3 credits)

Key software design concepts are introduced. Topics include basic design concepts, principles of good design, design strategies, software architecture and styles of architectural design, and design and architectural notations and languages. Detailed design, including design patterns and component design are also covered. Implementation issues that affect the design, including design support tools and tools for analyzing designs are discussed.

CISC613/CPEG613 - Software Requirements Engineering (3 credits)

Rigorous methods to elicit, analyze, and specify the requirements of a software system. The tasks range from identifying stakeholders and their goals producing a precise software specification document. Topics may include data flow diagrams, use cases, UML sequence and collaboration diagrams, finite state machines, requirements for real-time and concurrent systems, entity-relationship diagrams, and logic-based specifications, as well as the analysis of specifications for consistency and completeness.

CISC614/CPEG614 - Software Verification (3 credits)

(currently offered as CISC603)

Software verification entails showing that a computer program meets its specification; it is one of the most essential tasks in any software engineering endeavor. This class focuses on more formal verification approaches, such as temporal logic specification and model checking, symbolic execution, and static analysis. In addition to learning the theoretical foundations of these techniques, students will gain practical experience using state-of-the-art verification tools.

CISC615/CPEG615 - Software Testing and Maintenance (3 credits)

Study of software testing and maintenance methodologies for object- oriented, component-based, concurrent, distributed, and web software. Topics include approaches to automatic test case generation, test oracles, test coverage analysis, regression testing, impact analysis, program understanding, and software maintenance tools. A primary focus will be program-based software testing and maintenance approaches.