The University Senate of Michigan Technological University

Proposal 30-23

Establishment of a Master of Science in Applied Computer Science

Submitted by: Department of Computer Science

Basic Program Information

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Program/Degree type: M.S.

Program Title: Master of Science in Applied Computer Science

Planned Implementation Date : Fall 2023

Program location/modality : On-campus

Target student population : We anticipate several primary sources of students.

a. Many international students apply to our current MS in CS degree program with a BS degree in a field other than computer science. These students are looking for a degree that would give them computing credentials to increase their career opportunities. The MS in Applied Computer Science provides them the opportunity to obtain credentials in an appropriate subset of computer science applicable to their original discipline without the need to take coursework across the breadth of computer science.
b. Students completing a BS degree at Michigan Tech in a field outside of computer science who want to add computing credentials to their BS degree.
c. A third potential source of students are students who complete a 9-credit graduate certificate (e.g., the recently approved engineering certificates). The courses taken to meet the certificate requirements could meet the application area requirements in the MS in Applied Computer Science.

General description and characteristics of program

This degree aims to prepare students to apply computer science within a chosen application domain. Graduates of the program will meet the following learning goals.

1. Identify and apply principles in computer science and an application domain to develop a rigorous solution to a problem in that application domain.
2. Communicate principles in computer science and an application domain in both oral and written formats.

Rationale

Computer hardware and software have evolved so that they are vital components of diverse systems. Due to advances in data collection and analysis, along with ever increasing computational power and availability, computers are being used in new ways to solve problems in virtually every industry. However, the rigorous application of computing to solve problems in another science, or virtually any domain, requires both foundational and advanced knowledge in computer science (CS), as well as within the application domain.

Our existing MS in CS is not appropriate to these goals because it does not provide advanced study in the application area. Rather, the MS in CS requires broad knowledge in CS and advanced knowledge in the core areas of theory and algorithms. This proposed degree facilitates study only in those areas of CS relevant to a particular application, while also including topics from the application area. Further, the proposed degree requires students to demonstrate proficiency in the application of computer science through completion of a project under the supervision of a faculty member. This component is not required by the MS in CS. An MS in CS report typically focuses on a project in CS fields. Even though the project can be an application of CS, the core part of the project and its main contribution must be in CS. An MSACS project can instead focus on the application domain.

Related programs: within MTU and at other institutions

1. Michigan Tech.

   Michigan Tech currently offers four degrees that contain a significant computer science component: the MS in CS, the MS in Cybersecurity, the PhD in Computational Science and Engineering (CSE), and the PhD in CS. The MS in Cybersecurity focuses on a narrow subfield of computer science. The MS in CS and the PhD in CS require students to be broadly knowledgeable in computer science and to demonstrate mastery of advanced knowledge in the core areas of algorithms and theory. The proposed Master of Science in Applied Computer Science will allow students to study only those areas within computer science that are relevant to their application domain and will not require mastery of advanced knowledge in algorithms or theory. The PhD in Computational Science and Engineering applies computer science to sciences and engineering. In addition, the PhD in CSE is a research-oriented degree while the MSACS is a professional degree. The MSACS includes application domains outside of sciences and engineering.

   Michigan Tech also offers the MS in Data Science. Data science is aimed at understanding and analyzing phenomena. The program is focused at the boundary of mathematics, business and computer science, as reflected in the core curriculum

requirements. The MSACS supports a broader range of applications of computing and requires a significant project.

2. Other institutions.

   The increasing diversity of applications of computer sciences has led to the creation of MS programs across the country that are similar to the one proposed here. Some of these programs do not limit the focus area. Others identify a small subset of emerging areas.

   Programs from 28 universities including 13 from the state of Michigan and 15 outside Michigan were studied. Programs similar to the proposed Master of Science in Applied Computer Science (MSACS) exist both within the state of Michigan and outside. Regular Master of Science (MS) in Computer Science (CS) or equivalent programs with relaxed requirements allowing students to select 3 or more related non-departmental courses in a program that requires passing 10 courses or an equivalent ratio have been considered as *interdisciplinary* programs for the purpose of this study. Programs offering a CS major along with an unrelated minor and vice-versa have not been considered interdisciplinary for the purpose of this study. Similarly, MS programs dealing with Information Systems where no more than two non-computing courses are allowed have been disregarded. Programs that offered computing courses along with non-computing courses but did not have a project component or the requirement of selecting non-computing courses related to the computing courses have also been disregarded.

   Programs in Michigan

   Grand Valley State University's MS in Computer Information System (CIS) program is designed for computer professionals. Courses from both CS and Information Systems form the curriculum. The program requires students from non-computational related backgrounds to take foundation courses. Course completion requirement contains 9 credits from core courses, 9 credits from a concentration, 3-6 credits from a capstone project and 3-6 credits from a list of selected elective courses. One of the concentrations is Biomedical Informatics offering courses such as Clinical Information Systems, Information Visualization and High-Performance Computing.

   Michigan State University has a MS in Computational Science and Engineering (CSE) program offered by the Department of Computational Mathematics, Engineering and Science (CMSE). The goal of the program is to enable students to apply discipline-focused or methodology-focused topics in computational and data science to solve problems in the student's application domain of choice. A student is accordingly required to take 3 out of 4 core courses and complete a minimum of 12 credits in complementary coursework approved by the student's advisor.

Saginaw Valley State University has a 30-credit coursework MS in Computer Science and Information System offered by the College of Science, Engineering and Technology. This program is developed for students interested in having a career in IT industries and hence focuses on improving appropriate technical and managerial skills. Students are required to obtain 12 credits from core courses and can take the Information Systems Concentration worth 9 credits as part of their elective with the remaining credits taken from various elective courses such as Financial Accounting Concepts, Managerial Accounting, Technology Leadership Management, etc.

University of Detroit Mercy offers a 30-credit coursework Master of Electrical and Computer Engineering (MECE) program hosted by College of Engineering and Science which offers specialization in one of the following three areas: signals and systems, computer engineering and robotics and mechatronic systems. Additionally, students may take elective courses worth 13-15 credits from other departments such as mechanical engineering or mathematics with advisor approval.

The ECE department at Wayne State University offers a 32-credit MS in Computer Engineering program wherein students can take up to eight credits worth of courses from a pre-approved list of non-departmental courses including courses in biomedical engineering, chemical engineering, electric vehicle engineering, industrial engineering, etc. These courses are chosen such that they provide students diversification in the topics studied, but are yet related to the core courses of the program.

Michigan State University (MSU) and the University of Michigan Ann Arbor (UofM) offer nine-credit certificates. The department of CMSE at MSU offers two certificate programs: Graduate Certificate (GC) in Computational Modelling (CM) and Graduate Certificate in High Performance Computing (HPC). The GC in CM program is intended for students with little or no prior programming or computational modeling experience. The goal of this certification is to teach students data visualization and computational modeling methodologies. The GC in HPC is intended for students with significant computational experience. Its goal is to provide students exposure to parallel programming methodology and challenges requiring parallel and/or high-performance computing.

The University of Michigan Ann Arbor certificate programs are the Graduate Certificate in Computational Discovery and Engineering (CDE) offered by the Michigan Institute for Computational Discovery and Engineering (MICDE) and the Graduate Certificate in Computational Neuroscience offered jointly by the MICDE and the Neuroscience Graduate Program. The GC in CDE is designed to teach students applications of high-performance computing enabling them to conduct computationally intensive (multidisciplinary) research and product development across various branches of natural sciences and engineering. The GC in Computational Neuroscience aims to provide students training specifically in the field of experimental neuroscience and associated

quantitative science programs such as physics, biophysics, mathematics and engineering. Students are required to take at least one core neuroscience computational course and additional related courses based on the student's level of knowledge and interest.

Our study indicated that similar programs do not exist at Andrews University, Central Michigan University, Kettering University, Lawrence Technological University, Northern Michigan University, University of Michigan Dearborn, or Western Michigan University.

Programs Outside Michigan

Similar programs exist across the US. Interdisciplinary programs from studied universities tend to fall into one of the following categories: programs allowing students to apply computer science and computing principles to problems in various engineering and natural science fields, programs that offer a combination of computing courses with courses in one specific area of interest like business, biology, economics, etc. and regular graduate programs with relaxed elective constraints allowing students to select non-computing courses related to the selected computing courses. Of the interdisciplinary courses offered by the studied universities, bioinformatics/computational biology programs are the most commonly offered programs. Most interdisciplinary programs lack a project component. Many universities have very recently approved interdisciplinary programs involving computing and computational courses.

Projected Enrollment

Capacity for the program is 10 students with no additional resources and 30 students with an additional faculty position.

Specialized Accreditation Requirements

There are no program-specific accreditation requirements.

Professional Licensure Requirements

This is not a licensed profession.

Curriculum Details

Learning Goals

The MS Graduate Learning Objectives of this program are:

1. Demonstrate disciplinary knowledge in an application domain

2. Demonstrate advanced proficiency in the knowledge and practice of Computer Science
    a. Demonstrate ability to identify and apply relevant CS theory in execution of a project in an application area
    b. Critically analyze and evaluate one's own contribution (project option)
    c. Demonstrate knowledge of subject matter in selected, elective areas (coursework option)
3. Demonstrate professional skills
    a. Effective written communication skill
    b. Effective oral communication skills
4. Demonstrate responsible conduct of research (RCR)

Assessment Plan

An assessment committee comprised of the members of the graduate committee and two additional faculty will review the graduate student outcomes data annually. The results of the evaluation will be reported to the faculty and discussed in a department meeting.

The following data will be collected.

1. Grade data will be collected from Banner. A summary will be generated that indicates the number of students that are deficient, marginal, satisfactory, and excellent depending on the grades in the relevant courses
2. Degree Schedules will be collected for students in the coursework option of the MS program to verify advanced proficiency in both computer science and the application domain. The committee will anonymize the forms and collect data on the number of graduate courses completed for each coursework option student.
3. Assessment forms for MS Projects will be distributed to faculty involved in the evaluation. The completed forms are anonymous and will be collected and stored in the department office.
4. Communication skills. Information will be compiled from an MS student classroom presentation evaluation form. The assessment committee will make sure that every graduate student has made at least one public presentation that was evaluated by a faculty member. Typically this will be in the required course CS 5010.

Curriculum Design

The degree requires 30 hours of coursework which can be completed by three to four semesters in residence. The program will initially be on-campus only. We will reevaluate the online option three years after we launch the on-campus program.

After the degree is approved, we will seek approval for adding the accelerated format. Any Michigan Tech undergraduate student that has completed the minor in CS will be eligible.[1]

The Master of Science in Applied Computer Science will be offered under the Report and Coursework options. The students are allowed to switch between the two options during the course of their study. Both options require a solution to a significant problem, typically a software solution. Students in the Coursework option complete this requirement through CS 5010. Students in the Report option complete this work under the individual supervision of a faculty member. Both options require thirty credit hours. The course requirements are given below.

Required Courses	Report Option (credit hours)	Coursework Option (credit hours)
CS 4321 Algorithms	3	3
CS Electives [a]	12-15*	12-15
Application Area Electives [b]	9-12*	9-12
CS 5010 (New course)	0 (Does not count) [c]	3-6 [c, d]
CS 5990 Masters Research in Computer Science	3-6	0 (Does not count)
Total	30	30

*a maximum of 9 credits may be at the 3000-4000 level

a. Electives may be any CS course at the 4000-level or above or CS 3311 Formal Models of Computation.

[1] A student with a BS in CS would also be eligible. However, the coursework required to reach the 4000-level courses in the application domain may require significant coursework in the application domain area.

b. Any course at the 4000-level or above outside the Department of Computer Science. Students will be encouraged to prepare a plan of study during an orientation prior to their first semester in residence with advisor approval.

c. The CS5010 credits cannot count toward the Report Option.

d. The CS5010 credits can be repeated once.

Students in the Report option must additionally prepare a project proposal, a written project report, and must defend the report in a public forum. The report defense includes two question and answer sessions: the first consists of both students and faculty; the second being closed to the general audience consists of faculty only.

New Course Descriptions

The program requires the addition of one new course, CS 5010 Applied Computer Science. This will be a three-hour course with a laboratory component in which students identify and complete a project, as well as present the project results. These will typically be programming projects focused on problems in the application area.

Model Schedule

The degree is aimed at students with an undergraduate degree outside CS, though it can accommodate CS students that want to develop expertise outside CS. Here we discuss the timeline for students with a minor in CS at MTU and an undergraduate degree outside CS. Additionally, we assume that the maximum length of the timeline is determined by the selected CS courses and is not affected by the application domain coursework.

An example schedule is given in the table below. It assumes a student with a BS in Civil and Environmental Engineering from MTU as well as a minor in computer science. They are interested in applying their background in CEE toward analysis of data from automated and connected vehicles.

Year 1, Semester 1	Credits	Year 1, Semester 2	Credits
CEE 4402 Traffic Engineering	3	MA 5781 Time Series Analysis and Forecasting	3
CS 4321 Algorithms	3		
CS 4611 Graphics	3	CS 4821 Data Mining	3
		SU 5010 Geospatial Concepts, Technology and Data	3
Year 2, Semester 1		Year 2, Semester 2	
CS 5631 Data Visualization	3	CS 5010 Applied Computer Science	3
CS 5841 Machine Learning	3		
CEE 5402 Traffic Flow Theory	3		

The following table identifies coursework that develops expertise in selected areas of Computer Science that are commonly applied within other disciplines. Each collection fulfills 15 of the 12-15 credits in CS that are required. Combined with 9-12 hours of coursework outside CS and 3-6 hours of CS 5010 or CS 5990, the degree requirements will be met.

These course groupings could, for example, be combined with one of the recently created graduate engineering certificates to complete the requirements for the MSACS. For example, Automated System and Controls certificate courses could be combined with the Artificial Intelligence course group or the Quality Engineering courses could be combined with the Human Experience course group. These are examples only. It is expected that students might choose other collections of CS courses or other certificates to combine with these course groupings.

A student with the minor in CS from MTU can complete any of these course groupings within two years[2]. Note that some of these groupings require specific choices for one or more of the two electives that are part of the CS minor.

Artificial Intelligence	***Human Experience***
CS 4811 Artificial Intelligence	CS 4611 Computer Graphics
CS 5811 Advanced Artificial Intelligence	CS 4760 User Interface Design and Implementation
CS 5821 Computational Intelligence	CS 5611 Computer Graphics: Advanced Rendering and Modeling
CS 5831 Advanced Data Mining	CS 5641 Immersive Virtual Environments
CS 5841 Machine Learning	CS 5760 Human-Computer Interactions and Usability Testing

[2] Note that a student with a minor in CS may not be able to complete these courses in less than three or four semesters due to standard scheduling of graduate courses within the CS department. For example, CS 5811 is only offered in the Fall. Its prerequisite, CS 4811 is offered both in Fall and Spring.

Faculty Qualifications

Faculty resumes for CS faculty are available at:
https://www.mtu.edu/cs/department/people/

A number of MTU faculty are working on the boundary between computer science and another discipline. Many of these faculty are members of MTU's Institute of Computing and Cybersystems (ICC). Following is a list of faculty from the ICC that have already expressed support for the degree. We anticipate additional support when the program is approved and becomes more widely known across campus.

- Jeremy Bos, Electrical and Computer Engr (www.mtu.edu/ece/department/faculty/)
- Yu Cai, Applied Computing (www.mtu.edu/computing/about/faculty/cai/)
- Benjamin Ong, Mathematical Sciences (www.mtu.edu/math/department/faculty/)
- Thomas Oommen, Geological Engineering (www.mtu.edu/geo/department/faculty/)
- Hairong Wei, School of Forest Resources and Environmental Science (www.mtu.edu/forest/about/faculty-staff/faculty)
- Kuilin Zhang, Civil and Environmental Engineering (www.mtu.edu/ece/department/faculty/}

Program-specific policies, regulations, and rules

Students must demonstrate basic computer knowledge, as listed in all four categories below, prior to admission. The MTU courses listed below provide this basic knowledge. None of these courses can be applied toward the MSACS.

a. Programming: **One** of the following courses.

(CS 1131, Accelerated Introduction to Programming) Students must know a high-level language and be able to use it as a problem-solving tool, including design, coding, documentation, debugging, and testing of programs. Required knowledge includes data abstraction, list, stack, queue and tree data structures, complexity-based algorithm and data structure choices, and recursion.

(CS 1142 Programming at the Hardware Software Interface) Students must be familiar with programming in a low-level language including: binary number encodings, instruction set architecture, assembly language programming, instruction encodings, preprocessing, arrays and structures, pointers, input/output, and dynamic memory management.

b. Data Structures: (CS 2321) Students must know fundamental concepts in data structures including: abstract data types (priority queues, dictionaries and graphs) and their implementations, algorithm analysis, sorting, and text processing.

c. Discrete Mathematics: (CS 2311) Students must know fundamental concepts in discrete structures that are used in computer science, including: sets, trees, graphs, functions, relations, recurrences, proof techniques, logic, combinatorics, and probability.

d. Basic Calculus and Linear Algebra.

Students with a BS in Computer Science, a BS in Computer Engineering or MTU's minor in computer science are expected to have met this requirement.

Resources Needed

Library and other learning resources needed

Students enrolled in the MS in Applied Computer Science program will have access to the same resources as students in the MS in Computer Science program. We do not expect any additional library resources.

Suitability of existing space, facilities, and equipment

The Department of Computer Science has adequate classroom space and computer laboratories to support this program. No additional equipment is required. No additional space is required.

Program Costs

- Year 1 -- No new costs. Students who enroll in the program the first year will be enrolling in courses already being offered for other degree programs. We anticipate the additional load for CS and any other department will be minimal. Initial marketing will be aimed at graduating Michigan Tech students.

- Year 2 -- One new course is required for this degree (CS5010). The first offering will be during the second year of the program. Assuming the initial enrollment is 10 or fewer students, the department can cover this additional cost. We anticipate that additional teaching load for CS and any other department will be well within the existing teaching capacity.

- Year 3 and beyond -- When enrollments in the program exceed 10 students, additional faculty resources will be needed to cover the additional teaching load for students in CS 5010 and for the additional load on existing CS courses. These additional faculty will be provided through the normal faculty allocation process that Academic Affairs has recently implemented.

  Each student enrolled in this program will generate approximately $25,000 in tuition per year. The initial request is one additional faculty member when enrollment in this program exceeds 10 students.

108.1.2: Criteria for Financial Evaluation Proposed Academic Programs

1. **Relation to University Strategic Plan**
   a. **Relation of program to the university's educational and research goals.**
      When the College of Computing was created, one of the expectations was that the College would broadly impact computing across campus. This degree program is one way we aim to accomplish that. This program provides an opportunity for students from across campus to get computer science credentials to support their careers in whatever discipline they may be in. Some students may apply their newly developed computer science knowledge to research projects across campus in need of computing solutions.

   b. **Consistency with the university's resource allocation criteria.**
      With the exception of CS5010 (a new project course), students will be taking courses that are offered in support of other degree programs (primarily, but not limited to, Computer Science). Thus the resource needs can be considered as part of the overall needs for a unit.

2. **Impact on University Enrollment**
   a. **Projected number of students in the program.**
      We anticipate 5 students initially growing to 20 students.

   b. **Source of new students; in particular, will the students be drawn from existing programs, or will they be students who would otherwise not have come to MTU?**
      We anticipate several primary sources of students.

      i. Many international students apply to our current MS in CS degree program with a BS degree in a field other than computer science. These students are looking for a degree that would give them computing credentials to increase their career opportunities. The MS in Applied Computer Science provides them the opportunity to obtain credentials in an appropriate subset of computer science

applicable to their original discipline without the need to take coursework across the breadth of computer science.

ii. Students completing a BS degree at Michigan Tech in a field outside of computer science who want to add computing credentials to their BS degree.

iii. A third potential source of students are students who complete a 9-credit graduate certificate (e.g., the recently approved engineering certificates). The courses taken to meet the certificate requirements could meet the application area requirements in the MS in Applied Computer Science.

c. **What is the likely correlation between demand for the new program and existing enrollment patterns at MTU?**

The demand for this program will likely strongly correlate with the job market for computing graduates. The demand for computing graduates strongly correlates with the enrollments in the Department of Computer Science.

d. What is the current enrollment in the unit?

The department offers degrees in computer science, cybersecurity, data science, and software engineering. As of Fall 2022, the enrollments are:

BS in Computer Science:	438
BS in Software Engineering:	118
MS in Computer Science:	26
MS in Cybersecurity	7
MS in Data Science	39
PhD in Computer Science:	29

3. Impact on Resources Required by Department in Which the Program is housed. This would include, but not be limited to:

a. Faculty lines.

Since all the courses (except CS5010) are taken by students in our other degree programs, the need for new faculty lines will be a function of the overall growth in enrollment in our Department.

b. Faculty and student labs, including ongoing maintenance.

Most student coursework will utilize general purpose computing. Students working on computational solutions for research projects may require special hardware and software. When these projects are in support of ongoing research programs, we expect the necessary hardware and software to be made available by the researcher in charge of the project. For students doing non-research related projects, identification of the appropriate resources will be part of the initial project scoping.

c. Advising.

Initially advising will be done by the CS Graduate Director. Once the program reaches a critical mass, a faculty member will be assigned to be the Graduate Director for this program and a separate Graduate Committee will be formed to oversee this program.

d. Assessment.

An assessment plan has been developed. Until a separate Graduate Committee is formed, the CS Graduate Committee will be responsible for assessment.

4. Impact on Resources Required By other Units Within the University. This analysis would include, but not necessarily be limited to, the impacts on:

a. Other academic (e.g., Gen Ed) units with regard to faculty, labs and assessment. (NOTE: The current Student to Faculty ratio for the university as a whole is approximately 12:1 per Institutional Analysis.)

Students will be taking courses in an application area. Since it is likely that students enrolled in the MS in Applied Computer Science program will be choosing a range of application areas, we anticipate that the impact on other departments will be an extra student or two enrolled in a few courses.

b. Information Technology, the Library, central administration and career planning with respect to the impact on the need for computing services, library resources, advising, record keeping, development of employer relations etc.

Students enrolled in the MS in Applied Computer Science program will have access to the same resources as students in the MS in Computer Science program. Graduates of this program will likely be employed by the same corporations that already employ Michigan Tech graduates. We do not anticipate a need to develop new employer relations.

5. Assessment of the ability to obtain the necessary resources assuming requested funds are obtained

a. For high demand fields (e.g., business fields, etc.), will it be possible to fill allocated lines

We have been able to fill open positions the past four years.

6. Past proposals. Has the department initiated any other new degree programs in the last five years? If so:

In 2017 the Department added an MS in Cybersecurity. This was a joint effort with ECE and what is now Applied Computing. The projection is to ultimately have 20 MS students in the program.

a. Describe the extent to which the new program has met the original goals with respect to:

i. **Enrollment --** Current enrollment is 7 MS students

ii. **Costs** -- There were no additional funds allocated for the program.

iii. **New faculty --** There were no new faculty allocated for the program.

iv. **Other resources required for the program**

There were no other new resources required for this program.

Although the program has not yet met the original enrollment goals, the recently awarded $3.3 million NSF Cybercorps Scholarship for Service grant will have a substantial impact on the enrollment in the MS in Cybersecurity program. In addition, it is anticipated that the BS in Cybersecurity will also be a source of new students.

Indeed, the increased emphasis on cybersecurity has resulted in a substantial amount of NSF funding both for education and research in cybersecurity related fields.

b. How have degree programs added in the past five years affected total enrollment in the department?

Fall 2016 -- 22 MS students in CS

Fall 2022-- 26 MS in CS students, 7 MS in Cybersecurity students, 39 MS in Data Science

Although we have fewer students in the MS in Cybersecurity than projected, the program is having a positive impact on the overall growth of our MS programs. Courses added in support of the MS in Cybersecurity degree program are popular with other students. For example, the following enrollments from Fall 2022 indicate this:

CS5001: Cybersecurity Policy and Law - 9 students

CS5471: Computer Security -- 13 students

7. Departmental Budget contribution

a. What is the department's total general fund budget?

S&W: $2,640,133

Fringe: $1,122457

SSE: $19,092

Total: $3,781,682

b. How much tuition does the department generate? This information should be provided for both the credit hours taught by the department and the number of credit hours taken by the department's majors.

Tuition generated based on majors: $16,951,003

Tuition based on SCH: $9,653,527

8. **How do the benefits from this program compare to other alternatives that are currently under consideration or development. Will approval and allocation of resources to this program preclude the development of other programs?**

   A BS in Data Science is also under development. Resources for this program are not likely to detract from the development of the BS in Data Science program.