The University Senate of Michigan Technological University Proposal 73-21

Establishment of a New Graduate Certificate in Control Systems

Submitted by:
Department of Mechanical Engineering-Engineering Mechanics
&
Department of Electrical and Computer Engineering

1. Proposal Date: originally considered May 29, 2020; updated Feb 26, 2021

2. Proposing Contacts and Departments

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3. Sponsor Department Approvals: May 29, 2020

4. General Description and Characteristics of Certificate

The Graduate Certificate in Control Systems is designed to prepare students for careers related to advanced control of dynamic systems within a multitude of application areas within Mechanical and Electrical Engineering. For example, students will be able to apply control systems in automotive, energy, aerospace, robotics and manufacturing sectors. Topics include modeling, analysis, simulation and feedback control design of dynamic systems, including design in the frequency and time domains of linear and nonlinear systems in a wide variety of engineering systems applications. When complete, students will be able to mathematically model and analytically analyze complex linear and nonlinear dynamic processes and apply feedback control laws that are capable of stabilizing the system and achieving performance goals. It compliments the more extensive and industry-specific Graduate Certificate in Automotive Systems and Controls. This certificate will be able to be used with other nine-credit certificates being developed in the Electrical and Computer Engineering (ECE) and Mechanical Engineering - Engineering Mechanics (MEEM) departments as well as other department

to provide graduate students with interim certifications that can be applied directly to a MS degree or a Ph.D. All classes in this certificate will be available online.

The certificate is submitted jointly by the MEEM and the ECE departments. The MEEM department will have primary responsibility for administering the certificate and will collaborate with the ECE department in major changes to the curriculum.

5. Rationale for the Certificate

MTU already has many graduate certificate programs; this will be an additional offering to those graduate certificates available in an online instruction format. https://www.mtu.edu/gradschool/programs/certificates/

Control systems are ubiquitous among many science and engineering disciplines. Currently enrolled students from MEEM and ECE departments, as well as others within the College of Engineering, such as Civil Engineering students, could use this program to gain knowledge in control systems to enhance their work in their respective discipline.

Anecdotal evidence, including discussions with constituent employers in external advisory committee meetings, suggests that students and employers value graduate certificate programs as a way to achieve competency in specific areas. In fact, it may be that certificates are easier for prospective employers to understand as they represent a specific arc of coursework and competency that may in some cases be hard to glean from a quick look at a transcript. We propose to serve this market by implementing this certificate and others so that in the final state it will be possible to apply a given set of three certificates and one additional class to obtain a Master's degree. We believe that this clear statement will in the long run improve recruiting for both the residence and online graduate programs.

Certificate-seeking students can use this certificate program to enhance their skills and use it as a foundation to continue towards a degree. Control systems are fundamental to many engineering disciplines and can serve as a foundation or starting point to a multitude of degree programs. This approach would best serve online students who perhaps are not committed to a degree program yet but want to achieve a certificate before choosing to enter a degree program.

6. Related Programs

There are several other online certificate programs in controls. Within Michigan, the University of Michigan-Dearborn (UMD)offers a similar program (https://umdearborn.edu/cecs/graduate-programs/certificates/control-systems) for a 12

credit certificate. The main difference with the proposed MTU certificate is that the UMD program includes optional courses in fuzzy logic, neural net and artificial intelligence while this proposal includes optional courses in controls-heavy application areas such as digital image processing and power systems/power electronics.

Other similar programs are offered at:

- Missouri S&T (12 credit – Control Systems) https://dce.mst.edu/credit/certificates/controlsystems/
- Stanford (12 credits - Guidance and Control Graduate Certificate) : https://scpd.stanford.edu/public/category/courseCategoryCertificateProfile.do?metho d=load&certificateId=1211168
- University of Florida (9 credit – Control Systems) https://mae.ufl.edu/sites/default/files/custom/Brochure%20-%20Control%20Sys.pdf
- Rensselaer Polytechnic Institute,12-credits, http://catalog.rpi.edu/preview_program.php?catoid=8&poid=1713&returnto=185 ● Villanova, 12-credits, Interdisciplinary https://www1.villanova.edu/villanova/engineering/grad/certificates/ndc.htm

l Internationally

- Dalhousie University – Nova Scotia (12 credit – Process Instrumentation and Control) https://www.dal.ca/faculty/cce/programs/process-instrumentation-and control/process-instrumentation-and-control-certificate-program.html

7. Projected Enrollments

Initially, the program will have most of the enrollment from currently enrolled Michigan Tech graduate students. An online offering will expand the number of students enrolled. Given the current level of interest, we expect the program to grow before stabilizing enrollment. If interest exceeds this projected enrollment, particularly through online enrollment, additional resources will be required (see section 15 below).

Semester	On-campus Enrollment	On-line Enrollment
Fall 2021	5	0
Fall 2022	5	3
Fall 2023	8	5
Fall 2024	10	5
Fall 2025	15	10

8. Scheduling Plans

The proposed certificate can be completed on the existing course schedule. The on campus coursework will be offered during regular instructional time periods and will not require changes to scheduling of classes. Online offerings will be added to existing on-campus courses starting in Fall 2021.

9. Curriculum Design

This 9-credit certificate consists of one 3-credit required course and two 3-credit electives. Only three credits may be at the 4000 level. The required and elective course list with the course descriptions are given below. It is expected that students will work with the program advisor to select courses that fit their interests and prerequisite skills.

***Required course* – 3 credits**

- MEEM/EE 5715 - Linear Systems Theory and Design (3cr, Fall)

***Select two of the following courses* – 6 credits**

- MEEM 4775* - Analysis & Design of Feedback Control Systems (3cr, Fall)
- MEEM 5730 - Dynamic System Simulation Methods (3cr, Spring)

- MEEM/EE 5812 - Automotive Control Systems (3cr, Spring)
- MEEM/EE 6702 - Nonlinear Systems Analysis & Control (3cr, Spring)
- EE5500 Probability and Stochastic Processes (3cr, Fall, Spring)
- EE5522 Digital Image Processing (3cr, Fall, Spring)
- EE6210 Power Systems Dynamics and Stability (3cr. On Demand)
- EE5227 Advanced Power Electronics (3cr, Fall alt yrs)

10. Course Descriptions

MEEM/EE 5715 - Linear Systems Theory and Design - 3 credits
Overview of linear algebra, modern control; state-based design of linear systems, observability, controllability, pole placement, observer design, stability theory of linear time-varying systems, Lyapunov stability, optimal control, linear quadratic regulator, Kalman filter.

MEEM 4775* - Analysis & Design of Feedback Control Systems – 3 credits This course covers topics of control systems design. Course includes a review for modeling of dynamical systems, stability, and root locus design. Also covers control systems design in the frequency domain, fundamentals of digital control and nonlinear systems. (*** This is the no-lab, online version of MEEM 4775 and was offered for the first time in Fall 2019.)**

MEEM 5730 - Dynamic System Simulation Methods – 3 credits

Simulating dynamic systems described by ordinary differential equations using numerical integration are developed. Quantifying simulation errors for both batch and real-time, control system applications is covered along with numerical optimization strategies for model validation. MATLAB and Simulink are used to illustrate key concepts. **This was offered online starting Spring 2020.**

MEEM 5812 - Automotive Control Systems – 3 credits
Introduction to automotive control systems. Modeling and control methods are presented for: air-fuel ratio, transient fuel, spark timing, idle speed, transmission, cruise speed, anti-lock brakes, traction, active suspension systems, and hybrid electric vehicles, Advanced control methodologies are introduced for appropriate applications.

MEEM/EE 6702 - Nonlinear Systems Analysis & Control – 3 credits Studies nonlinear systems from perspective of analysis/control system design. Explores fundamental properties for nonlinear differential equations in addition to describing functions, phase plane analysis, stability/instability theorems. Develops and applies control system design approaches for nonlinear systems, including feedback linearization and sliding mode control.

EE5500 Probability and Stochastic Processes – 3 credits
Theory of probability, random variables, and stochastic processes, with applications in electrical and computer engineering. Probability measure and probability spaces. Random variables, distributions, expectations. Random vectors and sequences. Stochastic processes, including Gaussian and Poisson processes. Stochastic processes in linear systems, Markov chains and related topics.

EE5522 Digital Image Processing – 3 credits
Fundamentals of image processing are covered including image representation, geometric transformations, binary image processing, compression, space and frequency domain processing. Computer programming in MATLAB and Python required.

EE6210 Power System Dynamics and Stability – 3 credits
A study of the dynamic behavior of power systems. A review of synchronous machine modeling, system dynamic equations, and method of analysis. Examines overall system behavior via small signal and transient stability and energy functions, voltage stability and non-linear effects.

EE 5227 - Advanced Power Electronics – 3 credits
Advanced topics of circuits for electrical energy processing. Covers switching converter principles for dc-dc, ac-dc, and dc-ac power conversion. Other topics include harmonics, pulse-width modulation, classical feedback control,

nonlinear control, magnetic components, power semiconductors, and digital simulation.

11. Model Schedule Demonstrating Completion Time

The Certificate can be completed in a three-semester sequence. The courses are offered in the semester listed below.

Fall Semester

MEEM/EE 5715 Linear Systems Theory and Design
MEEM 4775 Analysis & Design of Feedback Control Systems
EE5500 Probability and Stochastic Processes
EE5522 Digital Image Processing
EE6210 Power System Dynamics and Stability
EE5227 Advanced Power Electronics

Spring Semester

MEEM 5730 Dynamic System Simulation Methods
MEEM/EE 5812 Automotive Control Systems
MEEM/EE 6702 Nonlinear Systems Analysis & Control
EE5500 Probability and Stochastic Processes
EE5522 Digital Image Processing

One possible model schedule would be:

Fall Semester 1: MEEM/EE 5715 Linear Systems Theory and Design
Spring Semester: MEEM/EE 6702 Nonlinear Systems Analysis & Control
Fall Semester 2: EE 5500 Probability and Stochastic Processes

12. Library and other Learning Resources

Center for Teaching and Learning resources will be used to help develop the courses to online format.

13. Faculty Resumes

The curriculum vitae of the faculty members may be found here:

https://www.mtu.edu/mechanical/people/faculty/
https://www.mtu.edu/ece/department/faculty/

Graduate Faculty serving this program will be the same as the existing MS and Ph.D. degrees in the department of Mechanical Engineering-Engineering Mechanics, and Electrical and Computer Engineering. The University has implemented special certification requirements for faculty teaching on-line courses. This certification is

completed by the appropriate faculty in advance of running an on-line course. In the near term, courses are currently delivered by the following faculty members:

Wayne Weaver , Associate Professor, MEEM
https://www.mtu.edu/mechanical/people/faculty/weaver/

Gordon Parker, John and Cathi Drake Chair Professor of Mechanical Engineering
https://www.mtu.edu/mechanical/people/faculty/parker/

Jeffrey Burl, Associate Professor of Electrical and Computer Engineering
https://www.mtu.edu/mobility/staff/burl.html

Michael Roggemann, Professor of Electrical and Computer Engineering https://www.mtu.edu/ece/department/faculty/roggemann/

Timothy Schulz, University Professor, Electrical and Computer Engineering
https://www.mtu.edu/ece/department/faculty/schulz/

14. Equipment

No additional equipment is required.

15. Program Costs

Initial costs for offering the certificate to on-campus students will not incur additional costs but will require continued funding of graduate teaching support and positions in control systems courses. The online offering of the certificate will also require continued backing of the graduate teaching support as well as agreement and support between the respective departments and Graduate School for faculty teaching loads for the online sections.

We anticipate that the initial enrollment load can be covered with our current faculty.

16. Space

No additional space will be required.

17. Policies, Regulations, and Rules

Not applicable

18. Accreditation Requirements

Michigan Tech is accredited by the Higher Learning Commission (HLC): https://www.mtu.edu/provost/accreditation/hlcommission/
The proposed certificate will not require additional accreditation and will meet HLC criteria 3 and 4.

19. Planned Implementation Date

Fall 2021

20. Assessment

Upon completion of this certificate, students will be able to:

1. Mathematically model and analyze complex dynamic processes.

2. Apply feedback control laws that are capable of stabilizing the system and achieving performance goals.

Department approvals: May 29, 2020

Engineering council approvals: Nov. 11, 2020