MEMORANDUM

TO: Darryll Pines
    Dean, A. James Clark School of Engineering

FROM: Elizabeth Beise
       Associate Provost for Academic Planning and Programs

SUBJECT: Proposal to Establish a Robotics Option for the Professional Master of Engineering (PCC log no. 12055)

Your proposal to establish a Robotics Option for the Professional Master of Engineering has been administratively approved. A copy of the approved proposal is attached.

The change is effective Fall 2013. Please ensure that the change is fully described in all relevant descriptive materials, and that all advisors are informed.

MDC/

Enclosure

cc: William Idsardi, Chair, Senate PCC Committee
    Sarah Bauder, Office of Student Financial Aid
    Reka Montfort, University Senate
    Erin Howard, Division of Information Technology
    Pam Phillips, Institutional Research, Planning & Assessment
    Anne Turkos, University Archives
    Linda Yokoi, Office of the Registrar
    Alex Chen, Graduate School
    William Fourney, A. James Clark School of Engineering
    George Syrmos, Office of Advanced Engineering Education
The creation of an academic option in Robotics to the existing Professional Master of Engineering program through the Office of Advanced Engineering Education.
Proposal for a New Specialization in Robotics in the Professional Master of Engineering Program

I. Overview and Rationale

We propose the creation of a Master of Engineering in Robotics academic option that will be a complement to the research work being done by the Clark School of Engineer's Maryland Robotics Center (http://www.robotics.umd.edu). The mission of the center is to advance robotic systems, underlying component technologies, and applications of robotics through research and educational programs that are interdisciplinary in nature and based on a systems approach. The center's research activities include all aspects of robotics including development of component technologies (e.g., sensors, actuators, structures, and communication), novel robotic platforms, and intelligence and autonomy for robotic systems. The center consists of faculty members spanning the following academic departments: Aerospace Engineering, Bioengineering, Biology, Civil and Environmental Engineering, Computer Science, Electrical and Computer Engineering, Kinesiology and Mechanical Engineering. Robotics is expected to play an increasing important role in national defense, healthcare, food production and safety, space exploration, and manufacturing. The proximity of our campus to DoD labs, NIH, NIST, FDA, and NASA-Goddard is expected to generate many new growth opportunities in the robotics related areas. Robots have also emerged as very useful tools for teaching principles behind interdisciplinary product design and enable project based learning. Areas of particular expertise are in (1) Collaborative, Cooperative, Networked Robotics: bio-inspired robotics concepts, time-delayed robotics, robotic swarms, robotic cooperation under limited communication, and distributed robotics; (2) Medical Robotics: MRI-compatible surgical robotics, haptics-enabled AFM, exoskeletons for rehabilitation, and magnetic micromanipulation for drug delivery; (3) Miniature Robotics: mesoscale robots; bio-inspired sensing, actuation, and locomotion; cell manipulation (optical, AFM based, and micro fluidics); and micro and nano manipulation (optical and magnetic); (4) Robotics for Extreme Environments: space robotics and autonomous deep-submergence sampling systems; and (5) Unmanned Vehicles: micro air vehicles, unmanned sea surface vehicles, unmanned underwater vehicles, and planetary surface rovers.

Part of the leadership in research of Robotics technologies is to develop the educational curriculum for a program that will allow the dissemination of these advances to the engineering/technology community. The Maryland Robotics Center has developed four fundamental courses in robot modeling, controls, perception, and planning to serve as an introduction to the existing advanced courses already being offered in a variety of robotics areas (see the attached list). Students expected to participate in the program are engineers, computer scientists, and technical professionals interested in robotics.

II. Program Audience

Based on our internal review, which included discussions with faculty, research sponsors, experts in industry and government as well as evaluation of competing higher education
institutions and a search of robotics related technical jobs currently available, we believe there is a high-demand for engineers and technical professionals with a graduate level expertise in Robotics and a lack of adequate academic programs to fill this need. The target audience is adults who have completed at least a Bachelor's degree in engineering, computer science, applied mathematics, mathematics, or physics. This program will be of interest to working engineers and technical professionals as an opportunity to gain knowledge in a new area and advance their careers as well as recent graduates who desire a career in Robotics.

III. Program Administration

This new academic option will be administered through the Office of Advanced Engineering Education (OAEE) making sure that the necessary student services are provided. As with all programs in OAEE, curriculum and academic oversight for the core and elective courses in the series will be through a faculty advisory committee that will collaborate with the OAEE Executive Director, making sure that both commitment to support this new specialization and academic excellence are in place. Evaluation and assessment of this option will be performed by the faculty and more specifically the Director of the Maryland Robotic Center and OAEE (see the attached Assessment Plan approved for all OAEE academic options). The new specialization will comply with all UMCP policies and requirements for graduate admission, time of study, and graduation requirements.

IV. Curriculum

The curriculum presented represents the beginning of what will be an evolving program that will continue to offer the latest developments in this rapidly changing and critically important field of study. Students in the Master of Engineering - Robotics program (10 courses or 30 credits) will complete four core courses (Introduction to Robotics Modeling, Control of Robotic Systems, Planning for Autonomous Robots, and Perception for Autonomous Robots), followed by two robotics-related elective courses from the list attached and four other graduate engineering or computer science courses where students can specialize in a content area that is relevant to their career. All electives will require prior approval by the academic advisor assigned by the Maryland Robotics Center to insure a well-defined curriculum is completed. Professor Nuno Martins will be the initial academic advisor for the Robotics academic option. The attached list of technical electives highlights areas of specialization available to the students. Other areas of specialization will be considered on a case-by-case basis with the approval of the academic advisor. Students must also meet the prerequisites for any technical elective course they wish to take. If appropriate, the prerequisite course may be included as an elective.

V. Budget Resources

The Office of Advanced Engineering Education is a self-support program and the Master of Engineering programs are administered through its resources. OAEE began offering
the Master of Engineering degree in 1994. There are now over 1600 graduates of the
growing list of twenty-one academic options for the Master of Engineering degree and
over 600 students currently enrolled in our programs. We offer courses on campus, at
remote education sites in Maryland, and completely online through the state-of-the-
technology Siegel Learning Center. You can learn more about our programs at
ENPM 808A Introduction to Robot Modeling

Synopsis
This course introduces basic principles for modeling a robot. Most of the course is focused on modeling manipulators based on serial mechanisms. The course begins with a description of the homogenous transformation and rigid motions. It then introduces concepts related to kinematics, inverse kinematics, and Jacobians. This course then introduces Eulerian and Lagrangian Dynamics. Finally, the course concludes by introducing basic principles for modeling manipulators based on parallel mechanisms. The concepts introduced in this course are subsequently utilized in control and planning courses.

Topics
- Rigid Motions and Homogenous Transformations
- Forward Kinematics
- Inverse Kinematics
- Jacobians
- Dynamics
- Modeling of Parallel Mechanism Based Manipulators

References

Home Works and Projects
- Ten Homeworks (25% of the overall grade)
- Two Exams (50% of the overall grade)
- Implementation Project (20% of the overall grade)
- Attendance and Class Participation (5% of the overall grade)
ENPM 808B Control of Robotic Systems

Synopsis
This is a basic course on the design of controllers for robotic systems. The course starts with mainstay principles of linear control, with focus on PD and PID structures, and discusses applications to independent joint control. The second part of the course introduces a physics-based approach to control design that uses energy and optimization principles to tackle the design of controllers that exploit the underlying dynamics of robotic systems. The course ends with an introduction to force control and basic principles of geometric control if time allows.

Topics
- Basic principles of linear control design (PD, PID).
- Independent joint control (tracking, state-space design).
- Fundamentals of Eulerian and Lagrangian Methods
- Newton-Euler Formulation
- Inverse Dynamics and Control
- Passivity-Based Motion Control
- Coordinate Frames and Constraints
- Principles of Force Control
- Basics of Geometric Nonlinear Control (as time permits)

References

Home Works and Projects
- Ten Homeworks (25% of the overall grade)
- Two Exams (50% of the overall grade)
- Implementation Project (20% of the overall grade)
- Attendance and Class Participation (5% of the overall grade)
ENPM 808C Planning for Autonomous Robots

Synopsis

Planning is a fundamental capability needed to realize autonomous robots. Planning in the context of autonomous robots is carried out at multiple different levels. At the top level, task planning is performed to identify and sequence the tasks needed to meet the mission requirements. At the next level, planning is performed to determine a sequence of motion goals that satisfy individual task goals and constraints. Finally, at the lowest level, trajectory planning is performed to determine actuator actions to realize the motion goals. Different algorithms are used to achieve planning at different levels. This graduate course will introduce planning techniques for realizing autonomous robots. In addition to covering traditional motion planning techniques, this course will emphasize the role of physics in the planning process. This course will also discuss how the planning component is integrated with control component. Mobile robots will be used as examples to illustrate the concepts during this course. However, techniques introduced in the course will be equally applicable to robot manipulators.

Topics

- Motion Goal Planning in Static Environments
- Motion Goal Planning in Dynamic Environments
- Motion Goal Planning under Uncertainty
- Modeling and Simulation of Mobile Robots
- Trajectory Planning under Terrain-Independent Differential Constraints
- Trajectory Planning with Dynamically Feasible Actions
- Integration of Motion Planning with Task Planning
- Integration of Behavior-Based Control with Planning

References


Home Works and Projects
• Nine Home Works (30% of the overall Grade)
• Literature Review Project (30% of the overall Grade)
• Implementation Project (35% of the overall Grade)
• Attendance and Class Participation (5% of the overall Grade)
ENPM 808D Perception for Autonomous Robots

Synopsis
Perception is a basic fundamental capability for the design of autonomous robots. Perception begins at the sensor level and the class will examine a variety of sensors including inertial sensors and accelerometers, sonar sensors (based on sound), visual sensors (based on light) and depth sensors (laser, time of flight). Perception, in the context of autonomous robots, is carried out in a number of different levels. We begin with the capabilities related to the perception of the robot’s own body and its state. Perception contributes to kinetic stabilization and ego-motion (self motion) estimation. Next come the capabilities needed for developing representations for the spatial layout of the robot’s immediate environment. These capabilities contribute to navigation, i.e. the ability of the robot to go from one location to another. During navigation, the robot needs to recognize obstacles, detect independently moving objects, as well as make a map of the space it is exploring and localize itself in that map. Finally, perception allows the segmentation and recognition of objects in the environment as well as their three dimensional descriptions that can be used for manipulation activities. The course will introduce techniques with hands on projects that cover the capabilities listed before.

Topics
- Sensors and their characteristics. Introduction to visual, acoustic and depth sensors
- Images and Imaging operations, Filtering, Thresholding, Edge detection, Hough Transforms.
- Cameras, Calibration, Stereo, Texture descriptions
- Robots in motion: Introduction to optical flow and image correspondence
- Kinetic Stabilization and Ego-motion.
- Obstacle avoidance and motion segmentation.
- Localization and Mapping (SLAM techniques)
- Structure from motion: Making 3D models
- Attention and Object Segmentation
- Object Recognition
- Human Activity Recognition
- HCI: Robots with language

References

**Home Works and Projects**

• Ten Homeworks (25% of the overall grade)
• Two Exams (50% of the overall grade)
• Implementation Project (20% of the overall grade)
• Attendance and Class Participation (5% of the overall grade)
List of Robotics Related Electives

Optimization and Algorithms

ENME696 Planning for Autonomous Robots
CMSC651 Analysis of Algorithms
CMSC712 Distributed Algorithms and Verification
CMSC722 Artificial Intelligence Planning
ENAE681 Engineering Optimization
ENME610 Engineering Optimization
ENME607 Engineering Decision Making
ENEE662 Convex Optimization

Performance Analysis and Design Methods

ENME600 Engineering Design Methods
ENME695 Failure Mechanisms and Reliability
ENAE697 Space Human Factors and Life Support
ENSE621 Systems Concepts, Issues, and Processes

Modeling, Systems and Control

ENME675 A Mathematical Introduction to Robotics
ENME605 Advanced Systems Control
ENEE660 System Theory
ENME664 Dynamics
ENEE661 Nonlinear Control Systems
ENEE664 Optimal Control
ENEE765 Adaptive Control
EEN679R Advanced Topics in Controls: Principles and Algorithms for Collectives

**Vision and Perception**

CMSC733 Computer Processing of Pictorial Information

CMSC734 Information Visualization

EEN631 Digital Image and Video Processing

EEN633 Statistical Pattern Recognition

EEN6731 Image Understanding

**Advanced Topics in Robotics**

ENME 489O/808O Micro/Nano Robotics

ENME808M Advanced Topics in Mechanical Engineering: Medical Robotics
Program Contact: George Syrmos
Phone: 5-3633
E-mail: syrmos@umd.edu

Date submitted to Academic Unit Head: March 10, 2006

Program Goals:

1. Address the continuing education needs of working engineers and technical professionals.

2. Deliver this program in a variety of ways so to make it accessible regardless of location.

Relevance of goals to the mission statements and/or strategic plans of the University, College, or Program as applicable:

The goals of the Professional Master of Engineering (ENPM) Program are directly related to the Clark School’s mission, which is to address the continuing education needs of working engineers and technical professionals. In particular, ENPM is a practice-oriented, part-time graduate program designed to assist engineers and technical professionals in the development of their careers and to provide the expertise needed in the rapidly changing business, government, and industrial environments. The Graduates of the ENPM Program will have acquired sufficient knowledge to “retool” and keep current with the latest technological developments in their field, or perhaps to develop a new area of expertise so as to further their careers. The ENPM Program provides a variety of delivery methods where students can take a class live, either on campus or at a remote site, web-assisted, or completely online.

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<tr>
<th>Student Learning Outcomes</th>
<th>Assessment Measures and Criteria</th>
<th>Assessment Schedule</th>
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<td>(list the three-to-five most important)</td>
<td>(describe one or more measures for each outcome and criteria for success)</td>
<td>(initial year, and subsequent cycle)</td>
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| 1. Demonstrate knowledge of advanced principles in engineering. | **Criterion:** 90% of the Master of Engineering students should have a GPA equal or greater than 3.0  
**Measure:** GPA.                                         | 2006, each semester |
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| **2.** Demonstrate continued retention of students and progress towards degree completion. | **Criterion:** 80% enrollment by existing students each semester  
**Measure:** Registrar’s Enrollment Records. | 2006, each semester |
| **3.** Demonstrate completion of degree program. | **Criterion:** 80% graduation rate of students within the five year limit for Masters students.  
**Measure:** Registrar’s Graduation Records | 2006, each semester |
| **4.** Anonymous evaluation by students of each instructor in a course for feedback on course instruction and content. Results are tallied and summarized (using a 4.0 grading system) for each instructor and comments typed by the office staff and given to each instructor to give feedback regarding their classroom instruction. | **Criterion:** achieve a 3.0 grade for all instructors.  
**Measure:** Course Evaluations | 2006, each semester |
| **5.** Point-of-graduation survey. The survey is a web based survey. Graduating students, prior to then end of the semester are sent the web site in which to fill in the appropriate information and submit the survey electronically. The survey seeks to ascertain a student’s experiences in the ENPM program regarding the quality of courses, the general program, faculty, and staff. The survey also collects information on employment (position, salary, etc.) at graduation. | **Criterion:** 50% response rate by graduating students  
**Measure:** Graduation Survey | 2006, each semester |
Dear Betsy,

Thank you for handling this process.

For the MS program, students are required to take a total of 4 electives in addition to the 4 certificate courses that are part of the certificate program. Of the 4 electives 2 must be selected from the list of robotics related courses, and the other 2 are to be chosen in consultation with the advisor and may not be restricted to the list of robotics related options. There are no pre-specified theme restrictions beyond the aforementioned requirements. All the electives constitute existing courses that are already offered by the University. The robotics related options are graduate courses currently offered by the Clark School and CMNS. The frequency and times of the courses offered vary and should factor in the plan of studies of each student so as to meet his/hers timeline and objectives. Most of the most basic courses are offered annually, and in some cases every semester. In some cases, courses are offered conditionally on enrollment. George also knows of specific mechanisms that can be adopted in consultation with the Departments to offer courses in the evening.

My apologies for the late response. Please let me know should you have any further questions.

Best regards,

Nuno

Nuno C. Martins

Director of the Maryland Robotics Center Associate Professor Department of Electrical and Computer Engineering Institute for Systems Research University of Maryland, College Park

Contact information can be found at: http://terpconnect.umd.edu/~nmartins/Nuno_C_Martins_University_of_Maryland_Personal_Site/Nuno_C_Martins.html

From: George Syrmos
Sent: Friday, April 12, 2013 6:14 PM
To: Elizabeth Jane Beise
Cc: Michael D Colson; Paul A. Easterling; Nuno Miguel L C Martins; Jenna Dolan; Sarah Hirschman Libes; George Syrmos
Subject: RE: M.Eng. and GCEN in robotics

Betsy,

Are my answers along with the forwarded evaluation and assessment plan from Paul sufficient?

If so, in this reply, I am asking Dr. Nuno Martins to answer the questions at the very bottom of your email.

George
Dr. George Syroms  
Executive Director  
OAEE  
syroms@umd.edu  
301.405.3633

-----Original Message-----
From: Elizabeth Jane Beise  
Sent: Friday, April 12, 2013 3:30 PM  
To: George Syroms  
Cc: Michael D Colson; Paul A. Easterling; Nuno Miguel L C Martins; Jenna Dolan; Sarah Hirschman Libes  
Subject: Re: M.Eng. and GCEN in robotics

The next Grad PCC meeting is April 23, which nominally would mean we'd need the information by this coming Tuesday (April 16). Thanks, Betsy

On 4/11/2013 4:40 PM, George Syroms wrote:
> Betsy,
> > When do you need this information by as I will need to discuss with Dr. Nuno Martins who has academic oversight and Mr. Paul Easterling who handles the proposals?
> > Let me address some of your questions.
> > 1) The courses will take place at College Park in DETS classrooms, webcast, and delivered via VTC to remote sites.
> > 2) The intent is to start both programs in Fall 2013.
> > 3) Regular and adjunct faculty.
> > 4) Initial enrollment of 8-12 students.
> > Thanks.
> > George
> > Dr. George Syroms  
> Executive Director  
> OAEE  
syroms@umd.edu  
301.405.3633
> 
> -----Original Message-----
> From: Elizabeth Jane Beise  
> Sent: Thursday, April 11, 2013 3:09 PM  
> To: George Syroms  
> Cc: Michael D Colson  
> Subject: M.Eng. and GCEN in robotics
> 
> Dear George: We received the two proposals for specializations in Robotics in the M.Eng and GCEN programs. We need more information on the following:
> * delivery method and location  
> * learning outcomes and assessment -- there is reference to an "attached evaluation and assessment plan" but it was not attached.
* who will teach in this track
* when do you intend to start
* How big do you expect the enrollment to be

It would be good to know more about the electives, how often are they offered, are these courses part of the MS in Engineering curriculum, are you co-mingling students, etc. Also for the electives, can students take any two courses or do you expect them to stick with two within a particular theme?

Betsy

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