Academic Planning and Faculty Development
Martin Hall Room 239
University of Louisiana at Lafayette
104 University Circle
Lafayette, LA 70504

Dear Mr. Robert McKinney and Educational Development Grant Review Committee,

Enclosed you will find a Course/Curriculum Design proposal for the Educational Development Grant for the 2013-2014 academic year. Through this proposal, the foundation of a robotics kit for use in a new class in the Department of Mechanical Engineering will be purchased. The new class, *MCHE 201: Introduction to Engineering Design*, will teach mechanical design and technical communication through a series of robotics projects.

The expansion of the kit beyond what is available to students in off-the-shelf offerings is needed to create a sufficiently-open design solution space for the student projects. Creating a open solution space is critical to reinforcing the necessity of a objective and iterative design process.

If you have any questions, please feel free to contact me.

Sincerely,

Joshua Vaughan, PhD
Assistant Professor
Dept. of Mechanical Engineering
joshua.vaughan@louisiana.edu

Sally Anne McInerny, PE, PhD
Department Head, Professor
Dept. of Mechanical Engineering
smcinerny@louisiana.edu

Using Hands-on Robotics Projects to Teach Mechanical Design and Technical Communication

Course/Curriculum Design

Joshua Vaughan

Department of Mechanical Engineering

joshua.vaughan@louisiana.edu

Abstract

Robotics projects provide an excellent vehicle to teach both mechanical design and technical communication. The complexity of even basic robotics projects enforces the necessity of a formal and objective design process. This complexity also necessitates clear and concise communication. However, to include any significant robotics projects in classes of 50+ students per semester, a significant investment in both time and money is required.

This proposal seeks to fund the purchase of the core components needed for 25 robotics kits for use in *MCHE 201: Introduction to Engineering Design*, a new, required class in the recently-revised Mechanical Engineering curriculum at UL Lafayette. In initial versions of the class, students will be asked to buy a basic robotic kit instead of a textbook. However, this student-purchased kit needs to be supplemented in order to create a sufficiently-open design space for student projects. The openness of the design space is crucial to reinforcing the high-level mechanical design process that the students are learning. The student teams will also be required to report on their design activities.

1 Introduction

One subject in which robotics naturally serves as a vehicle for course material is mechanical design. Students can be taught traditional mechanical design techniques, such as planning tools, evaluation matrices, and functional decomposition through the use of robotic examples and projects. The inclusion of robotic projects benefits students, who are able to practice the design concepts that they have been taught, while forming a strong foundation in robotics principles. The projects are also rewarding, as they often afford the students their first opportunity to design and build a computer-controlled machine. However, the integration of such projects into the course poses significant challenges. For example, the basic mechatronic concepts, such as electric motor operation and control-system programming, must be taught in addition to the mechanical design material.

Design courses also provide an opportunity to integrate oral and written technical communication with a two-fold benefit for the students. First, the students gain experience in the basic tasks of describing and presenting designs. Second, in presenting the design tools used to develop their robots, the students display their understanding of the course material, allowing instructors to assess student learning and revisit those topics that the students have not mastered. Robot projects provide an excellent vehicle for the benefits listed above for two main reasons. One reason is that much of the project cannot be seen, such as computer code, making clear and concise description a necessity. The second reason is that such robotic projects can become complex, necessitating thorough, but concise, presentations and reports. The project complexity also provides the opportunity to require interim reports and presentations, providing the students with additional technical communication experience.

2 Project Objectives and Description

Providing the tools necessary to include a large-scale robotics project into a required undergraduate course that typically has 50 students per term is a large expense. This proposal seeks to fund the development of a course that includes such projects, including a 6-8 week final project ending in a competition to which area K-12 students, industry, and student families and friends will be invited.

The initial funding sought here will be used to establish a core kit of robotic components to use in the course.

2.1 Objectives

The primary objective of this project is to enhance the undergraduate mechanical design education through support of the design and initial implementation of a new course. This new class, *MCHE 201: Introduction to Engineering Design*, will use hands-on robotics projects to teach mechanical design and technical communication.

A secondary objective is to establish a strong base from which to approach potential industrial sponsors for the class. A key ingredient to supporting a class requiring the resources of the one under development is support from outside sources. The funding requested through this proposal will not only fund an immediate improvement in the student experience, it will also help demonstrate the vision for what the class can become. Demonstrating this vision, and the University's support of it, will be a key ingredient to attracting industrial sponsors.

2.2 Project Description

More specifically, this proposal will fund the purchase of the core of a robotics kit that will be issued to teams of 3-4 students in *MCHE 201* during their enrollment in the class. To illustrate the type of components that a mature version of this kit would contain, the kit issued to students in a similar class that the PI helped develop at Georgia Tech is shown in Figure 1 [1]. At the heart of the kit is a controller box that includes a micro-controller, motor drives, A/D converters, and digital I/O needed to utilize the remainder of the kit. The controller box is is-

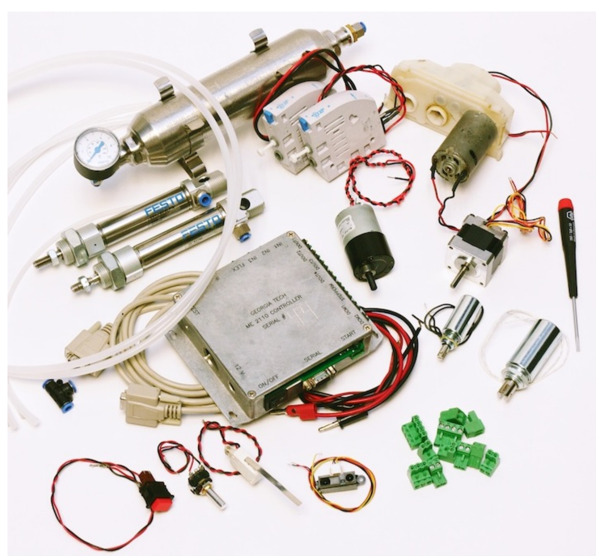

Figure 1: The Kit Issued to Students in ME2110 at Georgia Tech

sued along with several DC motors, a stepper motor, two solenoids, an IR distance sensor, two types of switches, and an encoder. Also included are the components to use two pneumatic actuators, including the pressure vessel, pneumatic valves, and tubing. To highlight the costs of creating and maintaining such a kit, the total cost of each of these kits exceeds $1,000, and Georgia Tech keeps approximately 80 kits operational for their 200-225 students enrolled in the class each term.

At Georgia Tech, the large expense of buying and maintaining the robotics kits is funded through industry sponsorship of the course. As mentioned, this is the ultimate goal for *MCHE 201* as well. Partnerships with industry for such courses are beneficial to the school, students, and the industry sponsors. Students are exposed to key industry companies, while receiving experience that is valued by employers.

The kits at Georgia Tech were developed over several years of increasing industry support; a model that will also be followed here. However, even the foundation components of the kit can provide interesting and exciting hands-on experiences and enhance student learning. It is this foundation that this proposal seeks to build.

3 Statement of Need

Fortunately, the expected class sizes here at UL Lafayette are much smaller than those at Georgia Tech. However, facilitating hands-on learning for a class of even 50 students per semester requires significant time, effort, and funding. In a current robotics special-topics course in MCHE, students are asked to purchase the kit in Figure 2 instead of a textbook. This simple kit costs approximately the same as a textbook and provides a baseline from which to teach

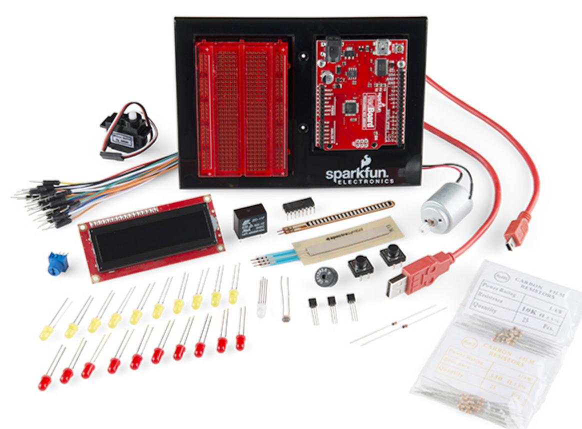

Figure 2: The Kit Purchased by Students in MCHE Robotics Course

many robotics concepts.

While the long-term goal is to provide students with all the components that they need during the class, this model will also be followed in *MCHE 201* during its initial offering. Until sufficient funding is raised to supply each team with a complete set of components, students will be asked to buy the kit in Figure 2 instead of a textbook. This student-purchased portion of the initial *ME 201* kit includes some of the core components needed, including the micro-controller and several sensors. However, the kit is missing pieces critical to the design and build of a robust robotic platform. For example, only a small unidirectional DC motor is included, and no motor-drive is included. Without these pieces, the scope of the mechanical designs available to the students is severely limited. Limiting the scope of the possible mechanical designs *dramatically* reduces the impact of the design concepts being taught.

The design concepts being taught in *MCHE 201* are high-level design tools, those used to distill engineering requirements from a nebulous project description and/or customer needs. Without the proper flexibility in the possible solution space, designs are automatically constrained toward easily identifiable requirements and solutions. When this happens, the necessity of an objective process to determine specifications, the very purpose of the tools being taught, is made significantly less clear to the students. Put another way, allowing a wider range of design solutions through a more capable kit forces the students to use the design tools and process being taught, as they are needed to clarify the project requirements.

4 Plan and Timetable

The timetable for the work proposed here is shown in Table 1. Immediately following the funding decision in October, the specifications of the selected components will be finalized and purchase of them will begin. If this process happens quickly enough, the DC motors will be made available to teams in *MCHE 470: Robotics* for use in their final projects this term.

During the spring semester of 2014, both interactive and pdf versions of a kit manual that integrates

Table 1: Proposed Project Timeline

Task	2013			2014											
	Oct	Nov	Dec	Jan	Feb	Mar	April	May	Jun	July	Aug	Sept	Oct	Nov	Dec
Final Component Selection and Purchase															
Finalize selection of hardware	■														
Purchase a single kit		■													
Purchase one set of DC motors	■	■													
Verify component compatibility/ease of use		■	■												
Purchase remaining kit components				■											
Class Planning															
Develop kit manual				■	■	■	■	■	■	■					
Develop example code for use with kit					■	■	■	■	■	■					
Develop kit laboratory exercises						■	■	■	■	■					
Fundraising															
Develop promotional information about the class	■	■	■								■	■			■
Meet with local industry about supporting the class				■	■	■	■	■	■	■	■	■	■	■	■
Invite local industry to class final competition	■	■											■	■	
Milestones															
MCHE 470: Robotics Final Competition		♦-11/21													
Beginning of MCHE 201											♦-Mid-August				
MCHE 201 Final Robot Competition															Early Dec. - ♦

the new components and the student-purchased portion of the kit will be developed. In addition, a series of lab exercises will be developed that leads the students through the use of the various components and prepares them to use the full kit in the construction of their robot for the final project of the class.

In the fall semester of 2014, *MCHE 201* will be offered for the first time, fitting its place in the new MCHE curriculum at UL Lafayette. The first final-design contest utilizing the kits will be held in December 2014.

5 Budget and Justification

Through this proposal, core components for 25 kits will be purchased. The components to be purchased are summarized in Table 2. This assortment of components includes two reversible DC motors, a high-amperage motor driver to power them, an IR distance sensor and cable, and power supplies.

Table 2: Components to be Purchased

Item	Price Per	Quantity	Sub-Total
Motor Driver	$22.46	25	$561.50
Right-Angle DC Gearmotor	$14.95	25	$373.75
Face-Mount DC Gearmotor	$12.50	25	$312.50
Short Range IR Distance Sensor	$12.56	25	$314.00
IR Sensor Cable	$1.35	25	$33.75
12V 5A Power Supplies	$22.46	25	$561.50
		Total	$2,157.00

The necessity of more powerful and reversible DC motors was addressed previously; the motors included in the student-purchased portion of the kit are severely limited. In addition, the student-purchased portion of the kit does not include a sensor that is a capable of measuring distance. This is a major need for most robotics projects. To fill that place in the kit, a short-range (3-40cm) IR distance sensor is ideal. Cables for these sensors are also included in the budget.

Finally, the student-purchased kits do not come with a power supply. They are designed to run from a USB port. This power source is not enough once the more powerful motors and motor drive are added. The issued portion of the kit will include a higher-current power supply for use on the student robots.

References

[1] J. Vaughan, J. Fortgang, W. Singhose, J. Donnell, and T. Kurfess, "Using mechatronics to teach mechanical design and technical communication," *Mechatronics*, vol. 18, no. 4, pp. 179–186, May 2008.

Joshua E. Vaughan
Assistant Professor
Dept. of Mechanical Engineering
University of Louisiana at Lafayette
P.O. Box 44170, Lafayette, LA 70504
joshua.vaughan@louisiana.edu
http://www.ucs.louisiana.edu/~jev9637/

Education

Ph.D., Mechanical Engineering, August 2008
Georgia Institute of Technology
Atlanta, Georgia
- Thesis: *Dynamics and Control of Mobile Cranes*
- Advisor: Dr. William Singhose
- Committee: Drs. Kok-Meng Lee, Rhett Mayor, John-Paul Clarke, Patricio Vela
- Concentration: System Dynamics and Control

M.S., Mechanical Engineering, May 2004
Georgia Institute of Technology
Atlanta, Georgia
- Thesis: *Active and Semi-Active Control to Counter Vehicle Payload Variation*
- Advisors: Dr. Nader Sadegh and Dr. William Singhose
- Concentration: System Dynamics and Control

B.S., Physics with Honors, May 2002
B.S., Applied Mathematics, May 2002
Hampden-Sydney College
Hampden-Sydney, Virginia
- Honors Thesis: *Trace Detection of Gaseous CS_2 with an Optoacoustic Technique*
- Graduated *Magna Cum Laude*

Research Experience

8/2012 – present Assistant Professor
Department of Mechanical Engineering – University of Louisiana at Lafayette

4/2010 – 8/2012 Postdoctoral Research Engineer
Boeing Aerospace Research Center – Georgia Institute of Technology
- Procured and installed equipment in a manufacturing research facility
- Investigated control and coordination of multiple material handling systems
- Investigated interaction between human operators and control systems

3/2009 – 3/2010 Japan Society for the Promotion of Science (JSPS) Postdoctoral Fellow
Tokyo Institute of Technology – Hirose-Fukushima Laboratory
- Developed controllers for a mobile, semi-autonomous demining robot
- Reduced endpoint vibration of a long-reach, robotic scanning arm
- Investigated methods for landmine discrimination

9/2008 – 3/2009 Siemens Energy and Automation Postdoctoral Fellow
Georgia Institute of Technology
- Led development of a mobile boom crane experimental platform
- Developed input shapers to improve crane payload positioning accuracy
- Designed Graphical User Interfaces to improve crane operator performance

5/2006 – 8/2008 Siemens Energy and Automation Fellow
Georgia Institute of Technology

11/2006 – 2/2007 NSF Doctoral Dissertation Enhancement Project (DDEP) Sponsored Researcher
Tokyo Institute of Technology – Hirose-Fukushima Laboratory

9/2002 – 5/2006 Graduate Researcher
Georgia Institute of Technology

Teaching Experience

8/2013 – present	*MCHE 470: Special Topics – Robotics* Assistant Professor University of Louisiana at Lafayette
8/2012 – 5/2013	*MCHE 485: Mechanical Vibrations* Assistant Professor University of Louisiana at Lafayette
1/2013 – present	*MCHE 484: Engineering Projects* Project Advisor University of Louisiana at Lafayette
8/2011 – 8/2012 1/2011 – 5/2011 8/2010 – 12/2010	*ME2110: Creative Decisions and Design* Studio Section Instructor Georgia Institute of Technology
2/2012	*APPH8803: Special Topics - Assistive Technology Design* Guest Lecturer Georgia Institute of Technology
11/2011 10/2008 11/2007	*ME6404: Advanced Control Design and Implementation* Guest Lecturer Georgia Institute of Technology
1/2011 – 5/2011	*APPH8803: Special Topics - Assistive Technology Design* Co-Lecturer Georgia Institute of Technology
2/2011	*ME8843: Advanced Mechatronics* Guest Lecturer Georgia Institute of Technology
8/2010 – 12/2010	*ME6404: Advanced Control Design and Implementation* Co-Lecturer Georgia Institute of Technology
10/2010	*2.998: Command Shaping, Theory and Applications* Guest Lecturer Massachusetts Institute of Technology
8/2010 – 12/2010 1/2009 – 5/2009	*ME4182: Capstone Design* Project Advisor Georgia Institute of Technology
2/2009, 10/2010	*ME2110: Creative Decisions and Design* Guest Lecturer Georgia Institute of Technology
8/2006 – 5/2007	*ME6404: Advanced Control Design and Implementation* Teaching Associate Georgia Institute of Technology
8/2005 – 8/2006 1/2004 – 5/2004	*ME2110: Creative Decisions and Design* Head Graduate Teaching Assistant Georgia Institute of Technology
5/2005 – 8/2005 9/2002 – 12/2003	*ME2110: Creative Decisions and Design* Graduate Teaching Assistant Georgia Institute of Technology

5/2004 – 5/2005 Cedar Grove High School & Georgia Institute of Technology
NSF STEP Fellow

Current Advisees

8/2012 - present Ali Khayat Baheri Irani, Ph.D. Student

8/2013 - present Nicholas Bergeron, M.S. Student

8/2013 - present Dare Olaonipekun, M.S. Student

8/2013 - present Mohammad Sazzad Rahman, M.S. Student

8/2012 - present Ninad Dhundur, M.S. Student

8/2012 - present Nolan Edwards, Undergraduate Student

8/2012 - present James Whipple, Undergraduate Student

8/2013 - present Elijah Manuel, Undergraduate Student

Selected Publications

Joshua Vaughan, Paul Jurek, and William Singhose. Reducing overshoot in human-operated flexible systems. *Journal of Dynamic Systems, Measurement, and Control*, 133(1):011010, 2011.

William Singhose, Joshua Vaughan, Kelvin Chen Chih Peng, Brice Pridgen, Urs Glauser, Juan de Juanes Marquez, and Seong-Wook Hong. Use of cranes in education and international collaborations. *J. of Robotics and Mechatronics*, 23(5):881–892, 2011.

W. Singhose and J. Vaughan. Reducing vibration by digital filtering and input shaping. *Control Systems Technology, IEEE Transactions on*, 19(6):1410 –1420, nov. 2011.

Joshua Vaughan, Dooroo Kim, and William Singhose. Control of tower cranes with double-pendulum payload dynamics. *Control Systems Technology, IEEE Transactions on*, 18(6):1345 –1358, 2010.

J. Vaughan, A. Smith, S. J. Kang, and W. Singhose. Predictive graphical user interface elements to improve crane operator performance. *Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions on*, PP(99):1 –8, October 2010.

Abhishek Dhanda, Joshua Vaughan, and William Singhose. Time-optimal and near time-optimal vibration reduction control for non-zero initial conditions. *Under Revision*, 2010.

Joshua Vaughan, Aika Yano, and William Singhose. Robust negative input shapers for vibration suppression. *Journal of Dynamic Systems, Measurement, and Control*, 131(3):031014, 2009.

Joshua Vaughan, Aika Yano, and William Singhose. Comparison of robust input shapers. *Journal of Sound and Vibration*, 315(4-5):797 – 815, 2008.

Joshua Vaughan, Joel Fortgang, William Singhose, Jeffrey Donnell, and Thomas Kurfess. Using mechatronics to teach mechanical design and technical communication. *Mechatronics*, 18(4):179–186, May 2008.

Patents

"Methods and Systems for Improving Positioning Accuracy." Patent pending, serial number 13/155,898. Filed June 8, 2011.

"Methods for Controlling Cooperative Crane Systems." Invention Disclosure, GTRC ID 6122. Filed July 3, 2012.