UNIVERSITY OF LOUISIANA AT LAFAYETTE

STEP Committee

Technology Fee Application

Improving the Core Robotics Kit in the Mechanical Engineering Curriculum

Title

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Name of Submitter
(Faculty or Staff Only)

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Organization

Title: Improving the Core Robotics Kit in the Mechanical Engineering Curriculum Date: 01/17/17

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ABSTRACT (250 words or less):

In MCHE 201: Introduction to Engineering Design, students are taught high-level mechanical design and technical communication, as well as basic robotics skills, through a series of robotics projects. The course ends in a 6-8 week final project and associated robot contest, in which teams of 3-4 students compete. Each of these teams is issued a kit of robotics components for use during the final project. This proposal seeks to fund the purchase of components needed to dramatically improve the core of these robotics kits, directly benefiting the approximately 150 students per academic year that enroll in MCHE201.

In current versions of MCHE201, students are asked to buy a basic robotic kit instead of a textbook. For the final project, the student-purchased kit is supplemented in order to create a sufficiently-open design space for student projects. However, the existing kits rely on breadboard wiring and utilize a hobby-level microcontroller. This proposal would correct these deficiencies, pushing the kit closer to the types of systems students will see in their professional careers, while improving its robustness and substantially reducing semester-to-semester maintenance costs.

Improving the Core Robotics Kit in the Mechanical Engineering Curriculum

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1 Introduction

Objective, formalized mechanical design techniques, such as the House of Quality, functional decomposition, morphological charts, and evaluation matrices are critical components of modern engineering design. In *MCHE201: Introduction to Engineering Design*, students are taught these methods 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. For many, *MCHE201* is their first opportunity to design and build a computer-controlled machine. The class also ends in a final robotics contest, which has been well attended in past semesters by not just students, but family members, friends, and industry partners. For example, Figure 1 shows one round of a the final robotics contest from the fall 2016 section of *MCHE201: Introduction to Engineering Design*.

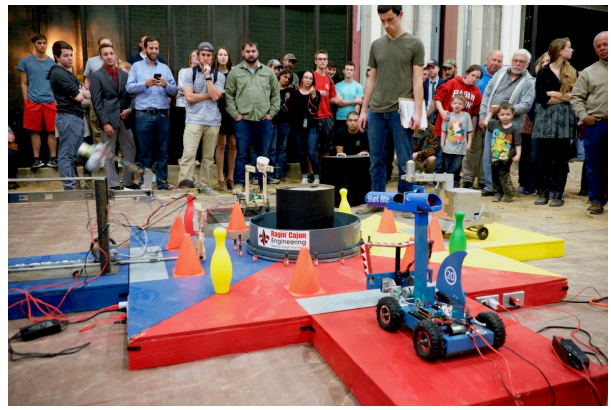

Figure 1: One Round of the Final Robot Contest from *MCHE201*

Having hands-on experiences to reinforce more-traditional, lecture-style classes is invaluable. Furthermore, the skills developed through this class and extended through the purchases proposed here are valuable and highly-marketable in the modern engineering workplace. Finally, the proposed purchases will allow students to explore more creative solutions to engineering problems, making the design process and related projects more fun for all those involved.

2 Purpose of Grant and Impact on Student Body

This proposal seeks to fund the continued expansion of a robotics kit provided to students in *MCHE201: Introduction to Engineering Design*. The purchase will push the kit in a more-capable, more-professional direction. The hobby-level, Arduino-based system will be replaced with a more-capable microcontroller. The breadboard and hand-wiring necessary to date will be replaced with a custom carrier board, enclosure, and screw-terminal connections.

These changes will drive the kit to be more similar to the types of electronics that the students will see in their professional lives. The custom carrier board, similar to the one shown in Figure 2 developed by the PI's lab for research, will also facilitate the long-term maintenance of the kits. The carrier board allows individual components to be replaced when needed, rather than entire boards, as is the current, expensive practice. In addition, the new microcontroller is programmed

in Python, a popular, general-purpose programming language that is not only used later in the MCHE curriculum, but also used extensively by top technology companies, including the autonomous cars projects at Google, Tesla, and Uber.

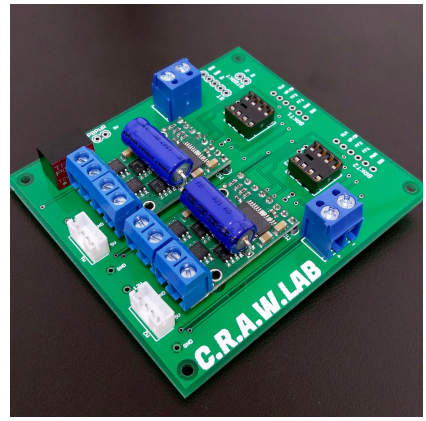

Figure 2: Custom Carrier Board, Similar to the One Proposed for *MCHE201*

Increasing the capabilities of the robotics kit will directly impact the approximately 150 students who will take *MCHE201: Introduction to Engineering Design* each academic year. In addition to the direct impact the kit will have on the students enrolled in *MCHE201*, the kit will enable these students to enhance later design courses, such as *MCHE482: Senior Projects I* and *MCHE484: Senior Projects II*, with the knowledge they have gained through using the kits. The solder reflow oven requested will also be made available to the senior design students in *MCHE482* and *MCHE484*. Finally, the class is scheduled to become a requirement for the under-development Robotics minor in the College of Engineering. Once this minor is approved, the number of students directly impacted by this project will further increase.

2.1 Grant Objectives

The primary objective of this project is to provide students with an enhanced undergraduate mechanical design education. This will be accomplished through the continued evolution and extension of *MCHE201: Introduction to Engineering Design*, primarily through expansion and improvement of a kit of robotics components that are issued to teams of students in the class.

A secondary objective is to establish a strong base from which to approach potential industrial sponsors for the class. 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, is a key ingredient to attracting industrial sponsors.

2.2 Impact on Student Body

More specifically, this proposal will fund the purchases for improving the robotics kit that is issued to teams of 3-4 students in *MCHE201: Introduction to Engineering Design* 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 3 [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 issued along with several DC motors, a stepper motor, two solenoids, an IR distance sensor, two types of

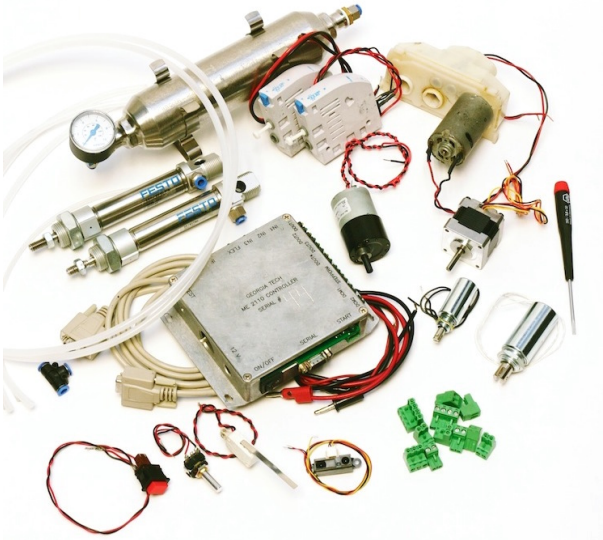

Figure 3: The Kit Issued to Students in ME2110 at Georgia Tech

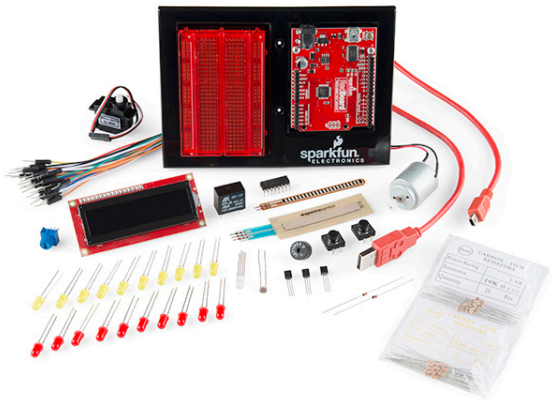

Figure 4: The Kit Currently Purchased by Students
(Image from SparkFun.com)

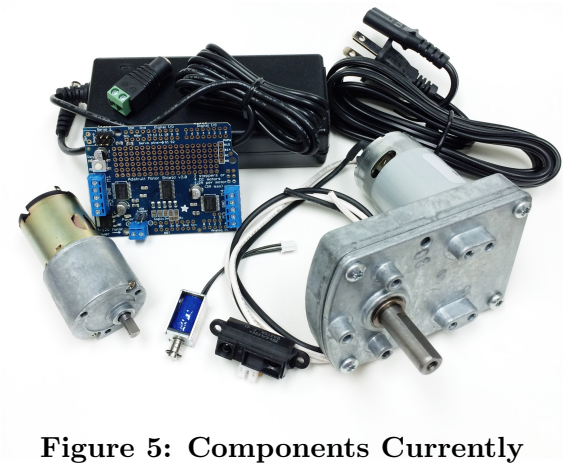

Figure 5: Components Currently Included in the *MCHE201* Kit

switches, and an encoder. Also included are the components to use two pneumatic actuators, including the pressure vessel, pneumatic valves, and tubing.

While the long-term goal is to provide students with all of the components that they need during the class, *MCHE201* students are currently asked to purchase the kit in Figure 4 instead of a textbook. This student-purchased kit includes some of the core components needed for robot development, including the hobby-level micro-controller and several sensors. However, the kit is missing pieces critical to the design and build of robust robotic platforms. For example, only a single small, weak DC motor is included. So, each student team is currently issued the components shown in Figure 5, which include two DC motors, a small solenoid, an IR sensor, a power supply, and a motor driver. In the last round of STEP Grants, the PI was awarded funding to purchase additional motors, linear actuators, and circuit protections to add to the kit in Figure 5.

These addition components will dramatically improve the electromechanical parts of the kit, pushing it to near the capability of the mature Georgia Tech kit. There is currently a proposal to the National Fluid Power Association under development to fund the purchase of the pneumatic components. So, the focus of this proposal is in improving the infrastructure behind the kit and making it more robust to the use the components receive each semester.

If funded, this proposal would allow students to purchase a more-capable, but actually lower cost, kit than the one shown in Figure 4. The proposed carrier board would leverage some of the components of their purchased kit, while enabling more-robust connections than the current breadboard wiring. In talking with students about the current kit, they spend significant amounts of time troubleshooting breadboard wiring, rather than concentrating on the design process and higher-level aspects of the design. The changes proposed here will help students return focus to the design itself.

3 Projected Lifetime and Timetable

All the components requested through this proposal would be purchased during the first year. However, the useful lifetime of the components acquired is approximately seven years. The majority of the components are robust and can continue to be used from one semester to the next. Students are made personally responsible for care of the kit components; the students' robot performance largely depends on their kits being well cared for, providing significant motivation to do so.

During the fall semester of 2017, both interactive and pdf versions of a manual that that introduces the current kit and how to use it with the student-purchased portion of the kit will be revised for the new components and micro-controller. In addition, the current series of lab exercises that have been developed to lead 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 will be updated to include the new components.

The primary maintenance costs for this project are the replacement of components. Most components are fairly robust, but the motor drivers are susceptible to over-currenting damage through improper use. In the last few semesters, up to 20% these motor drivers have needed to be replaced each semester and departmental funds have used cover their replacement. The newly-developed carrier board and enclosure will allow just the damaged parts to be replaced, rather than having to replace the entire driver, *dramatically* reducing the maintenance costs.

4 Responsibilities

The person responsible for *i.)* Implementation, *ii.)* Installation, *iii.)* Maintenance, *iv.)* Operation, and *v.)* Training is the PI, Dr. Joshua Vaughan. Dr. Vaughan is responsible for the *MCHE201* class and has extensive robotics experience, through both research and teaching.

5 Budget Justification

Through this proposal, the core components for 50 kits will be purchased. The components to be purchased are summarized in Table 1. The custom carrier board will be printed using the same internet-order system used to print the one shown previously in Figure 2. The connectors and other components to populate the board are also included. In addition, the electrical components for low-current motor drivers, a high-amp motor driver, an analog-to-digital converter, and a 3-axis accelerometer are all requested. All of these components will be fitted to the custom carrier board, for which Hammond 1590BB aluminum enclosures will be purchased. Finally, for the assembly and maintainence of the custom board, a solder reflow oven is requested.

6 Conclusion

Robotics presents an excellent tool to teach, and learn, about a wide variety of mechanical engineering topics. It is also a rapidly-expanding area of need for both local and global industry. The experience of building a robot while learning about mechanical design and technical communication has significant benefits for students, while providing an *extremely* fun way to learn. This project

Table 1: Components to be Purchased

Item	Price Per	Quantity	Sub-Total
Custom circuit board printing	$3.00	50	$150.00
Custom circuit board components	$25.00	50	$1250.00
Enclosures	$7.68	50	$384.00
DC & stepper motor driver circuit	$15.00	50	$750.00
High-amp DC driver	$23.96	50	$1,198.00
12-bit Analog-to-Digital converter	$8.96	50	$448.00
3-axis accelerometer	$4.46	50	$223.00
Solder reflow oven	$500.00	1	$500.00
		Total	$4,903.00

seeks to improve the core of a kit currently offered in *MCHE201: Introduction to Engineering Design* by moving to a more capable microcontroller and carrier board system. This move will improve the maintainence costs of the current kit, enabling a larger number of students to be impacted by it. In addition, the more-robust nature of the proposed kit will help students focus on higher-level aspects of the design, thus improving the design education and their understanding of methods taught in *MCHE201*.

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.

Budget Proposal

1.	**Equipment**	**$**
2.	**Software**	**$**
3.	**Supplies**	**$ 4,903.00**
4.	**Maintenance**	**$**
5.	**Personnel**	**$**
6.	**Other**	**$**
TOTAL:		**$ 4,903.00**

Additional Information

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Additional information on the class to be improved by the extension of the robotics kit can be found at:

http://www.ucs.louisiana.edu/~jev9637/MCHE201.html

Flickr photosets from past sections of the class can be found at:

- Fall 2016 – https://flic.kr/s/aHskGKmP4m
- Spring 2016 – https://flic.kr/s/aHskp9KxSN
- Fall 2015 – https://flic.kr/s/aHskhxxhi7
- Spring 2015 – https://flic.kr/s/aHsjWAuyU8

Pictures and video from an earlier, related special-topics course can be found at:

- Pictures – https://flic.kr/s/aHsjHJq5Ph
- Video – https://youtu.be/u8LExuKTDqw

Prior-funded STEP Projects

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Dr. Vaughan recently received funding in the amount of $6,662.32 for a STEP project titled *Supporting Hands-on Robotics Projects in the Mechanical Engineering Curriculum*. That project, just awarded in the fall semester of 2016, is funding the purchase of components for the *MCHE201* kit, including wireless communication modules, a linear actuator, a stepper motor, and associated components required to support those. That award makes the continued expansion and improvements of the *MCHE201* kit proposed here possible.