Robotics as a Vehicle for Engineering Education

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An important factor in an engineering education is the students' ability to apply their theoretical knowledge to solving real world problems. Unfortunately, many schools are unable to provide full laboratories for experimental experiences due to a variety of constraints. This is a serious problem for educators who wish to provide practical learning for their students. One of the more commonly employed methods of providing a "hands-on" approach to learning is through the use of educational kits. As technology changes and advances, it is important to keep adapting the educational topics in engineering majors to contemporary subjects such as robotics. This paper discusses the development and use of robotic kits for the classroom environment. Different platforms presently exist which provide systems for educators to use as a teaching vehicle for their lessons. In addition to currently available kits, designing or adapting kits for use in specific courses provides engineering educators a customized tool for the classroom and an opportunity for their students to help instruct their peers. Using robotics kits in the classroom encompasses the full spectrum of fields including the project design process, mechanics, electronics, and computer programming. This allows students to gain exposure to their field of interest while acquiring a basic knowledge and respect for other disciplines.

Introduction

Robotics as an area of interest encompasses every field of engineering, and requires a well calculated plan to implement a successful robot. The diversified nature of robotics gives students a comprehensive view of an entire system, rather than just their component disciplines. Skills in specific areas such as mechanics, programming, system design, and the human interactions required to work in multidisciplinary groups can all be learned through hands-on exposure with robotics. This experience also has the potential to expose students to the interactive nature of engineering in the real world.

The use of kits in engineering classroom education has become more prevalent recently, since less expensive kits are being developed for fun and as replacements for expensive lab equipment. Educators can introduce various concepts to be mastered and build one skill upon another. Students can explore design ideas, develop hypotheses, and validate them with their kit robots. Once students are more familiar with the kits, it is easy to teach advanced concepts because the projects are fun and the students become more creative. One practical and innovative robotics kit, the VEX Robotics Design System™, (VEX), which was designed and marketed by Innovation First, Inc. (IFI) , is a proven platform for multidisciplinary studies. VEX is sold as a base kit, with enough components to make small, simple robots with further accessory kits available to expand the basic features. This kit encompasses many different elements of engineering design and processes, and retails for approximately $300.00 USD so it is affordable as a classroom tool. The VEX kit (Figure 1.1) uses perforated metal for its base structure and includes plastic and metal components for mechanical construction. A programmable microcontroller with radio joystick interface provides the flexibility to “build and go” or the opportunity to incorporate many different sensors and program specific functionality into the robot.

Figure 1.1 VEX Robotics Design System™ starter kit

The Department of Mechanical Engineering Technology at the Rochester Institute of Technology allows undergraduate students to complete independent research studies on MET topics of their choice. Through prior contacts involving robotics projects and competitions, the author contacted Innovation First's engineering design team and developed an independent study project in conjunction with them. A major focus and application of this study involved a redesign of the company's VEX pneumatics accessory kit. The scope of this project involved all phases of product development, from an analysis of the current product and performing customer research to determining designs for manufacturability and possible classroom uses of new or additional components. Working through this design process and personally evaluating past experiences with robotic activities outside of the educational realm led to a realization of how valuable hands-on instruction using robotics is.

VEX Pneumatics Kit Development

The scope of the independent study project required an analysis of the present VEX pneumatics kit, with the intention of ultimately creating improved and new custom parts and reducing overall cost of manufacture. This research and development occurred over a two-month period, during which various tools such as CAD modeling and Rapid Prototyping were utilized

The current kit offered for sale by IFI consists of various industrial pneumatic components manufactured by the SMC Corporation (Figure 1.2). The individual cost of these components is the limiting factor in large volume sales of these kits. These kits were originally designed with the intention of delivering an opportunity to have a scalable system that utilized pneumatics within the robotics kit. The cylinder bores and subsequent forces delivered are in relationship to the estimated size and weight of the VEX robots. Using the original specifications of the system (Table 1.1) new components could be designed to meet the needs of consumers.

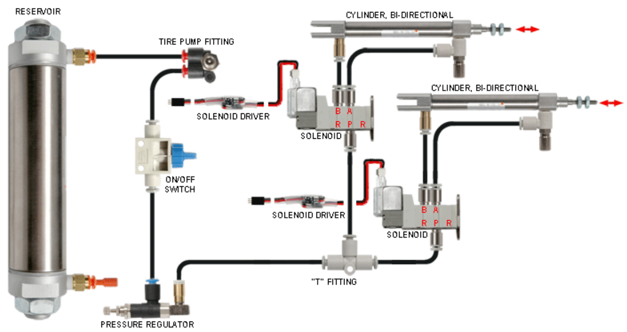

Figure 1.2 VEX pneumatics add-on kit currently for sale

System Pressure (max)	689 kN/m	100 psi
Tank Volume	150mL	9.153 in^3
Cylinder Bore	10 mm	.394 in
Cylinder Stroke	50 mm	1.987 in
Cylinder Max Force	54 N	12 lbf
Dbl Acting Cylinder Length	Compressed 6.125	Extended 8.25 in
Valve Control	Connects to controller I/O port	

Table 1.1 Specifications for VEX pneumatics add-on kit currently available for sale

In reviewing these specifications, it was determined that costs could be reduced if the major components of the system were evaluated and/or replaced. The process then followed to investigate the tank, cylinders, and valves to determine how this could be accomplished. A target goal, determined in communications with IFI, was to try and create functional plastic components wherever possible, following the style of the kit in addition to the use of current manufacturing facilities.

VEX kit components include specific features, which are necessary to maintain in any redesigns, providing for seamless integration into the current kit of parts. The axle rods in VEX are made from 1/8 inch square key stock that creates a tight fit with plastic components. Keeping the system within the same operating parameters took precedence over exact part matching. The major changes that were made included adjusting the cylinder bore and maximum pressure to accommodate plastic's material strength and manufacturing. While the current pneumatics solution requires modifications, the integration of these parts into custom designs was an additional factor making this process favorable. While determining the required dimensions and specification the target specifications changed.

CAD was used for the pneumatic cylinder layout and design, which enabled virtual interfacing with the current kit components. Calculations based on material properties and working pressures were performed in order to dictate the required thicknesses of parts for this loading application. Fortunately, in this application, plastics have a unique feature of flexibility with force, which can be modified by changing surface and wall thicknesses. In order to test the parts' physical connections and benchmark the proposed changes, Rapid Prototyping was utilized. Utilizing RIT's Rapid Prototyping machines, three-dimensional models could be "printed" and then analyzed for proper fits and tolerances. Changes to the design were frequent and problems with strength and best fit to the kit were the driving factors of design, easily modified using CAD. 3D printers allow for plastic physical models to be built up very quickly, layer by layer, matching predetermined specifications exactly. Using these prototypes (Figure 1.3), part fits, seals and tolerances could all be checked without the need for tool manufacturing. This process is used by many product design companies as an inexpensive way to avoid major problems and expense when crafting parts and creating molds.

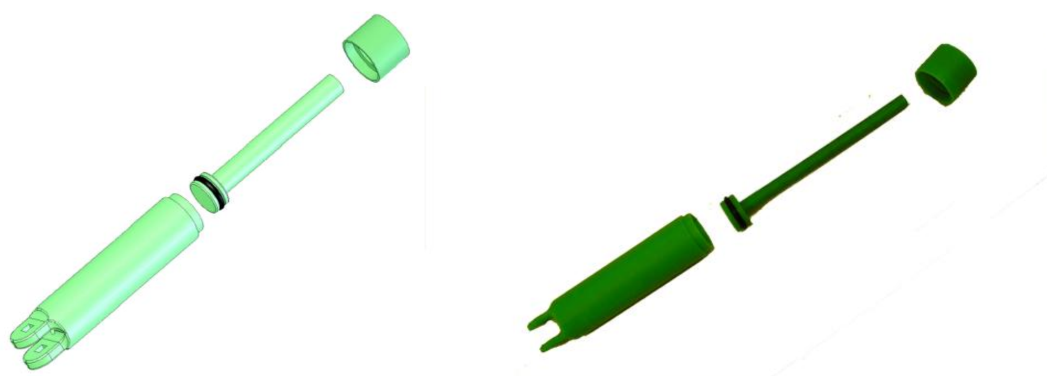

Figure 1.3 CAD rendering and Rapid Prototype model of newly designed pneumatic cylinder

The pneumatic storage tank (figure 1.4) was analyzed and designed using a similar process. Assembly methods during manufacturing for these components were selected to be sonic welding. This process presented interesting challenges, as there is very little information available on making plastic pressure vessels, and even less on the break strength of sonic welding in this application. It was decided that further study of that aspect would have to be completed before the consideration for manufacturing occurs.

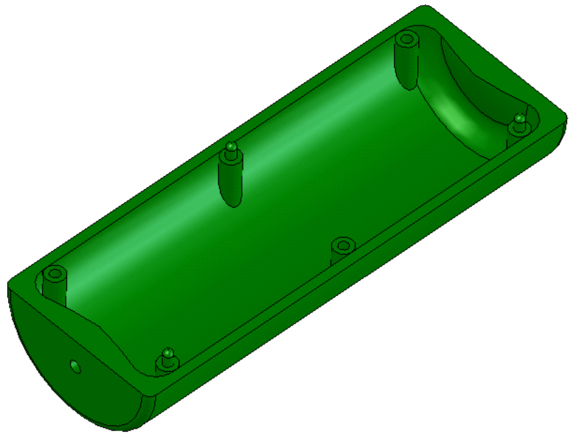

Figure 1.4 CAD rendering of pneumatics storage tank (1 of 2 interlocking parts).

Throughout the development of this product many different engineering tools were used with gives the experience of applying book learning to an actual problem. The coordination of design with an outside institution or company can provide students with a strong educational experience. Interpreting a problem from a systematic view, especially with components which must interface with current designs provides a significant challenge and supplement to an engineering education. The design proposed is under review by Innovation First Inc. and more design iterations are happening.

Robotics in Engineering Education

Many engineering students lack practical experience with innovative technologies and express interest in taking classes which provide hands-on labs and experimentation. Today, real world engineering problems are complex and integrate components of all engineering disciplines. As teams of engineers work together to solve problems, it becomes necessary to have a basic knowledge outside of a person's specific field of study. One of the main advantages of robotics is that it can provide exposure to the various aspects of engineering. Students do not need a thorough background in all engineering fields - teachers can introduce these through the robotics platform, and teach mechanical techniques and basic programming to achieve their goals. Educators can take advantage of their students' enthusiasm for blending theory with practice by incorporating a study of robotics in the classroom. Creating small robots that can be designed, built, programmed, tested and then redesigned and rebuilt allows students to experiment freely, without the risk of breaking expensive equipment or being a safety hazard to those in the surrounding area.

Specific engineering concepts can be taught using kits such as the previously discussed VEX system, or kits developed for specific courses. Mechanical Engineering/Engineering Technology majors spend a good deal of time focusing on the mathematical principles behind how things work, before designing alternative solutions to problems. The high cost of design mistakes previously discouraged educators from allowing students to test their theories, despite the obvious reinforcement that hands-on applications provide. The use of robotics kits provides a low cost, effective alternative in teaching concepts such as the relationship between speed and torque in a gearbox. Applying simple dynamics formulae can determine the relationship, but many students do not understand the concept until build a gearbox and observe how the gears and motors relate to each other. The VEX and other systems include gears which mate easily to demonstrate such concepts. The layout of materials in the kits makes it easy to transform from one gear ratio to another with minor alterations. There is no need to worry about proper material tolerances or machine shop work. While the scale of the robotics kits is such that it may appear as a simple toy using the system as an educational tool can elevate some students' topic frustrations with ease.

Modern systems are transitioning from strictly mechanical or electrical to a hybrid of multiple required components. Many of these new applications of technology require the use of microcontrollers and software. For students in non-computer related majors, programming can be daunting. At the same time, teaching programming to someone without experience can be frustrating for the professor or a tutor as well. Robotics kits provide a simple solution which can have great rewards. The programming of robotics can be made very simple through graphical interface software such as EasyC™ (Figure 1.4) or NQC™, which allow students to successfully program without needing to have coding experience. In most cases, it is more important for a non-computer engineering student to learn the flow of problem solving then the actual coding, due to the various natures of systems as a whole. Using drag and drop "block" programming teaches students a basic understanding of how commands in the programming work together, and allows them to learning while acting in a simple environment.

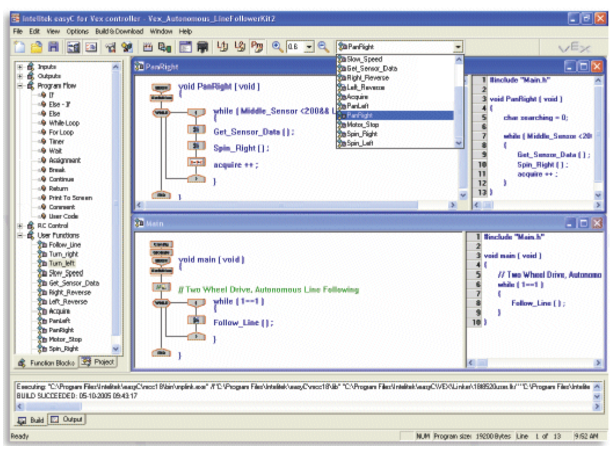

Figure 1.4 Screen shot of EasyC™ for VEX programming

In addition to the programming and mechanical teaching values of these styles of robotics kit, many different activities in the classroom can utilize this teaching tool. Teaming students from different fields together to focus on a common goal can help to turn students into teachers and encourage a sense of accomplishment. Those students who are more knowledgeable in a particular field of study will gladly share their knowledge with other group members, without overwhelming them.

Robotic competitions provide a setting for innovation and provide students with goals, planning deadlines, personal interaction, and a motivation to succeed in the endeavors. Competitions can range from simpler, remote control style robots to fully autonomously controlled machines. Many different competitions already exist which provide engineering students with the ability to apply their theoretical education to practical projects, and educators can use their own creativity to develop additional unique opportunities to challenge their students. Many of the different competitions encourage students to work individually or in teams to directly design and work on robots or assist K-12 students in their competitive development and designs. A number of the competitive governing bodies which organize robotic competitions also provide students with connections and networking which will ultimately help in their career decision-making.

Conclusion

Robotics is an important tool in engineering education. Experiential opportunities, especially using robotic kits, enhance the students' education by allowing them to learn multidisciplinary concepts, and integrate those components into a comprehensive view of the engineering profession. Students have fun and exercise their creativity with classroom projects and through robotics competitions. In particular, competitions allow the students to further develop their skills and network with others who may be instrumental in determining their future goals.

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Gregory E. Needel is a fall 2007 graduate of the Rochester Institute of Technology (RIT) with a B.S. in Mechanical Engineering Technology. He has been active in robotics development and competitions since 2001.