

Developing and Teaching Modular Robots

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Abstract

This study focuses on development and teaching modular industrial robots to students from a variety of levels including high school and college. Initially, MOSS modular robotics system, a robotic toy, was chosen as the development platform. However, it was not found to be adequate for most of the industrial robot configurations, excluding the articulated robot arm. Thus, additional components were designed by two engineering students and made to be interfaced with the existing MOSS modules to accomplish configurations like selectively compliant articulated robot arm (SCARA) and cylindrical robots. The newly developed robot configurations are programmed through C programming language within the Visual Studio coding environment. MOSS robotics system was utilized due to its user-configurable modular robotic structure giving an additional dimension to the learning experience since it is a true modular robotic system. After the initial development work, a high-school workshop was conducted in collaboration with a neighboring school district led by the two engineering students who designed the modifications. The current development efforts include design of an Arduino-based modular structure and possible use of self-configuration. This paper includes the detailed sketch of the development efforts, engineering students' reflections on the development project, design and delivery of the high school workshop including high school student feedback, and possible future college level curricular designs for modular industrial robotics for industrial, mechanical, and manufacturing engineering programs. The paper is concluded with future work concepts including possible kinematics and dynamics modeling of these industrial robot configurations through simulation tools such as DELMIA or MapleSIM, along with use of machine learning for self-configuration.

Background

The modular robot is a fairly new type employed to extend the utilization of robots into additional areas. The history of modular robots starts in 1972 when the active chain chord mechanism (ACM) was developed, leading to future development of chain-type modular robots. [1] The modular robot research started to gain momentum in the late 1980s, followed by the development of Cellular Robotic System (CEBOT), which was characterized by self-organization, self-evaluation and functional amplification where multiple modules collaborated to accomplish the task. [2]

Modular robots are mostly reconfigurable and thus more adaptable. There are two distinct types: user-configurable and self-configuring:

- User-configurable robots are configured by their operators to perform desired tasks. The users modify the physical and functional configuration by adjusting their hardware and software components, becoming a part of the robot's behavior.[3] Each module (i.e. power supply, processor, sensor, or actuator) has mechanisms for connecting to other modules and comes with its own electronics. Modular robot behavior relies on such aspects as size and abstraction levels of the modules (granularity), connectivity and interaction of the modules, ease of construction, algorithms that control autonomy, and

mobility patterns. [3][4] Affordance or invitation to the user along with transparency of the functionality of the modules are also critical for the user-configurable types. [3]

- The concept of self-configuring robots is self-explanatory. Self-configuring modular robots are further adaptable when compared to their user-configurable counterparts since they use morphing algorithms. [5][6][7] A fairly recently developed self-configured modular robot employs adaptive locomotion with Bluetooth technology built into each module. [8]

This project was originally envisioned as a reverse engineering effort focusing on two commercially available modular robotic toys, Cubelets and MOSS from Modular Robotics. After learning about their structure and detail designs, the focus was shifted to utilizing MOSS modules in teaching industrial robot configurations (i.e. articulated robots including Selectively Compliant Articulated Robot Arm (SCARA) manipulators) at high school and college levels. MOSS was selected due to its greater flexibility including availability of larger number of module types. During the process of developing industrial configurations, the team realized that the current MOSS modules could not support construction of some of the industrial robot configurations without re-engineering. Additional components had to be designed and built by 3D printing for enhancing functionality of standard MOSS modules .

As the team studied the structures of MOSS components, a comprehensive literature review on modular robotics was carried out and a large amount of research was found on the subject including reconfigurable modular robots [9]. A second literature review was focused on utilization of modular robots in education. The results of the second study yielded a small number of literature, which encouraged the project team to continue their work. The four most relevant papers found in the literature review are summarized below. Only a pair of the four papers found are directly related to the objective of this paper, while the other two are based on a modular building block system in developing robots or machines; the system they are based is not a true modular robotic system, even though it is user-configurable. It is similar to LEGOs.

Nielsen and Lund developed I-BLOCKS, a modular robotic system for use as an educational tool.[10] They evaluated their designs at schools and hospitals and in multiple countries with the goal of recommending improvements to their designs. However, their study did not center on teaching industrial robotics through modular robotics. In another study by Correll et al.[11], computer scientists from the University of Colorado at Boulder used Cubelets modular robot construction kit to teach middle school students computer science. The work focused not on modular robots, but on quickly preparing and delivering a short robotics session to middle school students. Hsieh [12], from Texas A & M University, has been teaching reconfigurable and scalable systems projects as a part of the industrial automation and controls curriculum while applying a comprehensive approach that addresses multiple learning styles and integrates knowledge and skills. The most intriguing part of Hsieh's research is not the project based approach but the tool he used to teach reconfigurable and scalable systems. Fischertechnik is a modular construction system similar to LEGOs that can be used in building and simulating industrial robotic work-cells and machines, including industrial and mobile robots, as well as punching machines, indexing lines, pneumatic processing centers, and automated warehouses. In

another effort, Xiao et al. [13] also used the Fischertechnik system to cultivate mechanical innovation through projects after teaching the basic knowledge behind creativity, innovation, and ideation. Student works built with the modular blocks were submitted to the National Undergraduate Mechanical Innovation Design Competition in China and included industrial machines such as machining centers or rubbish cleaning machines.

The MOSS System

The objective of the MOSS system is “to impart intuitive understanding of complex systems and design principles” according to its maker – Modular Robotics. [14][15][16] Children are exposed to “mechanical construction, basic circuitry, kinematic motion, robotics, software integration, and programming” through modular robot design and construction. [17] It is an interesting tool for creative robot building and understanding modular robots. [14][15][16] A variety of blocks are available including the ones for power/light sources, control, and sensing (Table 1, Figure 1 and 2) as well as structural MOSS blocks, power/data interfaces, and magnetic sphere connectors (Table 2 and Figure 3) :

Block type	Functionality
Extended battery	Extended LiPo battery
Flashlight	Glows brightly when energized. Used in lighting the robot’s path or triggering a brightness sensor.
Double brain	Microprocessor with Bluetooth communication ability
Motor	Motor with an attached axle which can spin around one axis
Axle	Used in transmitting rotational motion
Pivot	Used to create steering mechanisms or powered hinges
Wheel	Used in translating the rotation of an axle to a motor
Brightness sensor	Tuned to respond to bright light sources including the sun or a flashlight
Mic sensor	Sound sensor that can measure the level of noise around it
Knob sensor	Potentiometer that can control an input value
Proximity sensor	Used in measuring distance between the robot and the closest object

Table 1. MOSS blocks for control, power, and sensing [18]



Figure 1. MOSS blocks: knob sensor, mic sensor, motor, power, double-brain blocks. [14][15][16]

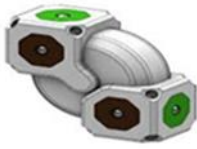


Figure 2. Pivot blocks, wheels [14][15][16]

Block type	Functionality
Magnetic spheres	Used in connecting blocks
Corner block	A connector block that can link and support nearby faces of other blocks
Hub	A connector block that can link nearby faces of other blocks. These blocks can split, connect, or average signals to multiple blocks.
Long flexy	A connector block that allows a connection to power or data across 4 block lengths
Short flexy	A connector block that allows a connection to power or data across 2 block lengths
Long brace	Used in strengthening the areas of the robot. Spans 3 block lengths.
Short brace	Provides connective support for up to 6 magnetic spheres. Spans 2 block lengths
Corner brace	Spans 3 block lengths with a 90 degree bend in the middle

Table 2. Structural MOSS blocks, power/data interfaces, and magnetic sphere connectors [18]

Some MOSS parts are designed to pass power and data amongst the other blocks such as the flexy and hub blocks, while corner blocks pass signals and act as structural support. Braces are only used for structural purposes. Each block interface is color-coded based on its functionality, as shown in Figure 4. A green interface sends and receives power. A brown interface receives data signals from a red interface. A blue interface is designed to pass through those signals it is receiving. MOSS components are connected to each other using magnetic spheres shown in Figure 3.



Figure 3. Additional parts and blocks: spheres, flexy, corner block, hub, and brace blocks. [14][15][16]



Figure 4. Interface color coding scheme for power (green), data in (brown), data out (red), and pass through (blue) blocks. [14][15][16]

Developing Industrial Robot Configurations

After completing the reverse engineering stage by studying the MOSS patents along with disassembly and analysis of existing modules, the design team started working on the main objective of the work: development of modular industrial robot configurations. This section describes the activities involved in adjusting these modular robotic toys for industrial robot instruction.

Articulated Modular Robot Development

The first industrial robot configuration robot targeted was the articulated robot configuration. A vertically articulated robot is a manipulator with three rotary joints in its major axes as illustrated in Table 3. This robot type has three rotational joints for base rotation, elevation, and reach angles respectively. These joints mimic human joints - waist, shoulder, and elbow. The articulated modular robot was constructed of 12 distinct blocks and 32 magnetic spheres. These parts are summarized in the Bill of Materials (BOM) shown in the table along with the construction details given below. Two pivots were added to the design to reduce the weight of the elevation and reach angle joints. Pivots are basically rotating actuators or powered hinges.

Construction details are as follows:

- Each motor and pivot needs to connect with a power and a double-brain block to get the power and positional data they require.
- The base rotation motor was directly connected to the power block through the green power interface.
- In order to send data from the double-brain block, the brown data-in interface of the motor is attached to the interface 7 of the double-brain block by a corner block.
- The green interface of the pivot used for the elevation angle (shoulder) joint was connected to the power block directly and a short flexy connected its brown data-in interface to the interface 3 of the double-brain block.
- The second pivot used for the reach angle (elbow) joint was connected to the power through its green interface via the first pivot's green interface. A long flexy was utilized for connecting the interface 2 of the double-brain block and brown data-in interface of the second pivot.
- Since both pivots were connected to different data interfaces of the double-brain block, they would be programmed and moved independently of the other. The assembly of the pieces was realized through magnetic spheres limiting the robot's ability to handle its weight and inertia forces that were generated during its motion. However, use of lightweight pivots as actuators for the elevation and reach angles helped robot to stabilize during operation along with careful programming including slower speeds.

Modular SCARA Robot Development

The second robot configuration built was the SCARA manipulator, a horizontally articulated robot arm. The SCARA acronym stands for selectively compliant assembly robot arm or selective compliance articulated robot arm. It has two rotational joints (degrees of freedom – D.O.F) in base rotation and reach angle as shown in Table 4. Also, there is a linear motion at the wrist (or the base of the robot) for elevation. The first two joints of the version given below are similar to those of the articulated robots. Since the current MOSS system components do not

include a circular to linear motion conversion mechanism, a new rack and pinion gearing system was designed in Autodesk Inventor. After the completion of the design of new gears and their casing, the parts were printed using an UPrint SE FDM machine and ABS material (Figure 5). The rack gear had to be attached to the MOSS motor using the same spheres as the standard MOSS parts. The casing of the added gearing made the weight of the linear joint unsupportable; however, the casing was extended to act as a support column by itself. The programming of the SCARA was handled similarly to the articulated robot program. The amount of the linear motion had to be programmed using the rotation motion driving it.

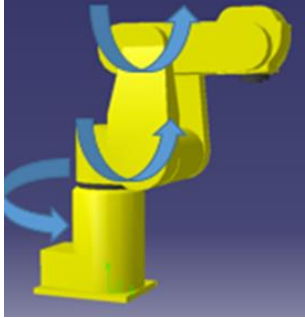

Articulated Robot Arm Model		MOSS Articulated Robot Arm	
			
Part Name	Count	Functionality	
Double-brain block	1	Controller	
Power block	1	Power supply	
Motor block	1	Actuator for base rotation	
Wheel	1	Base rotation joint	
Pivot	2	Actuator for elevation and reach angles	
Long flexy	1	Passing power and control signals	
Short flexy	1	Passing power and control signals	
Long brace	1	Structural support	
Short brace	1	Structural support	
Corner brace	1	Structural support	
Corner block	1	Passing control signals and structural support	
Sphere	32	Structural connection	

Table 3. MOSS Articulated Robot Arm Design and its BOM

Programming of MOSS Robots

Programming the MOSS Robotics configuration is a fairly simple process. C programming language was employed for programming within the Visual Studio coding environment. C was chosen because it is easy to understand, manipulate, and modify in controlling robot operation.

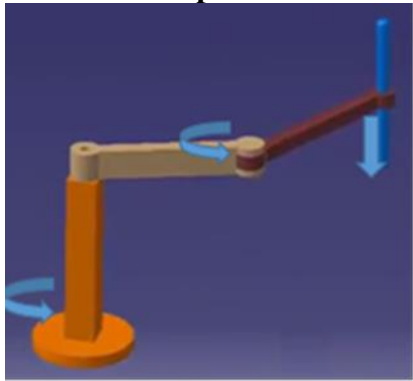

SCARA Manipulator Model		MOSS SCARA Manipulator	
			
Part Name	Count	Functionality	
Double-brain block	1	Controller	
Power block	1	Power supply	
Motor block	1	Base rotation and the rotational movement that drives the rack and pinon gearing for elevation	
Pivot	1	Actuator for reach angle	
Long flexy	3	Passing power and control signals	
Short flexy	1	Passing power and control signals	
Short brace	1	Structural support	
Corner block	1	Passing control signals and structural support	
Hub	1	Connecting and passing signals to multiple blocks	
Sphere	48	Structural connection	

Table 4. MOSS Articulated Robot Arm Design and its B.O.M.

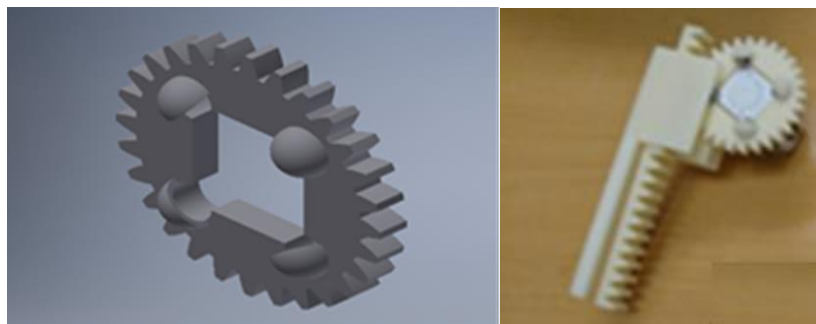


Figure 5. Rack gear designed for the elevation joint of the SCARA along with its printed assembly

The MOSS double-brain block is used as the main device to control the articulated arm autonomously. The main difference between the double-brain and other similar controllers is that the interface of the brain block to be employed to send the data needs to be prescribed in the program (Figure 6), i.e., Motor = Face_3 in place of the output port number for a similar controller. Pivots and motors are programmed by using integers varying from 0 to 255. Pivots rotate through a range of 180 degrees alike RC servos. The integer value of 180/255 represents a resolution of 0.70 degrees. For a motor, 0 and 255 represent full-power clockwise and counter clockwise motion, respectively. 127 is used to stop the motion. The code shown in Figure 6 moves the reach angle (elbow) joint pivot and the second pivot for the elevation angle (shoulder) joint for the first robot configuration. The base motor is then rotated slowly at lower power values close to 127 before stopping. A MOSS Control app is also available and can be also utilized to control the motors interactively or through a program. However, its touch panel is found to be too sensitive to move the motor slowly and is suited for younger students mainly in the early elementary range.

```
uint8_t Motor;
uint8_t Motor2;
uint8_t baseMotor;

void loop()
{
  Motor = FACE_3;
  Motor2 = FACE_2;
  baseMotor = FACE_6;

  set_face_state(Motor, OUTPUT);
  set_face_value(Motor, 50);
  wait(2000);
  set_face_value(Motor, 200);

  set_face_state(Motor2, OUTPUT);
  set_face_value(Motor2, 70);
  wait(2000); //two seconds
  set_face_value(Motor2, 190);

  set_face_state(baseMotor, OUTPUT);
  set_face_value(baseMotor, 139);
  wait(2000);
  set_face_value(baseMotor, 127);
  wait(2000);
  set_face_value(baseMotor, 123);
  wait(2000);
  set_face_value(baseMotor, 127);
}

void setup()
{
}
```

Figure 6. Sample MOSS code

Student Feedback

This section details the feedback obtained from the design team made up of two engineering students in addition to a workshop conducted with students in grades 9-12. While the design team wrote about their design experience, the high schools students commented on the modular robotics workshop intended to teach them the user configurable modular robots and the newly designed industrial configurations.

Reflections from the Design Team

The team members reflected about two different parts of their design experience: what they learned and what they could have done differently. Summary of the statements given below pointing out two complex problem solving activities and creativity in a real-life like situation in which they had to design industrial robot configurations based on MOSS modular robotics components.

- Team Member #1: Throughout the project, I have learned plenty of skills. Some skills that I strengthened during this project were problem solving, designing of new parts, and integrating creative ideas to simulate something in the real world. Problem solving skills are essential to everyday life and especially in the field of engineering. These skills within this project showed through the process of designing the modular pieces to become something truly relevant in the real world and it proved to be difficult at some times. Throughout my high school and college career, I've loved designing new parts by using applications such as SolidWorks and Autodesk Inventor. By designing the new parts such as spur gears, rack gears, and other components to easily combine blocks, my design skills have become more useful and I've learned much more about the applications themselves. Simulating the real world applications of different industrial robots, the creativeness of this project has sufficiently helped me understand that it is very important to simulate something before making it a reality.

Some things that I would have done differently are re-engineering the MOSS blocks themselves to create more sophisticated pieces and spend more time thinking of better ways to recreate the robots. Some problems we came across while completing this project were that some pieces were too small and many times the blocks became too top heavy and would ruin the integrity when the motors and blocks would move. Therefore, re-engineering these blocks to what would have been a great help in the process.

Overall this project was helpful in learning new processes, thinking outside of the box, and problem solving. I had a great experience completing this project and have future plans to make the modular pieces self-configuring with sensors and other new technology.

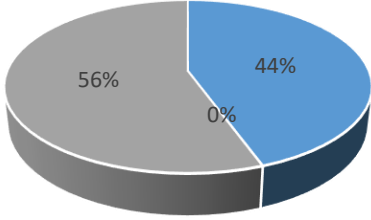
- Team Member #2: This project was very helpful for learning how industrial robots work. At the beginning, I spent time doing research about industrial robots which were SCARA, articulated, spherical, cylindrical, Cartesian, and parallel robot type. Each robot has a different joint configuration and features. MOSS, a robot toy from Modular Robotics, was a useful tool in designing small industrial robots for an educational purpose. I learned how the toy worked and how the components could be applied to create small industrial robots. Most of the robots' joint configurations can be driven by the motor and pivot blocks. However, some robots could not be built only by the MOSS parts. Thus, 3D printing played an important role in this project. During the process of designing and printing new parts process, I learned how to reengineer using trial and

error, over and over again. For example, when 3D printed parts were too heavy to embed into the robot, I made another one which was less heavy by printing hollow blocks or making holes while keeping their function. Programming was also a large task in this project. The MOSS program is based on the C language code. I gained a good knowledge about the programming language. In addition, understanding how the code worked was a difficult process. The robot needed to move like an actual industrial robot. Likewise, in the designing process, there were many times trial and error was used in the programming process. I developed engineering skills through the project. I learned each industrial robot’s characteristics and how to design new parts.

If I were to do this project again, I would probably have done it following a simpler design. I spent a lot of time designing and printing new parts because I was not familiar with design software and 3D printer. Furthermore, choosing some prototypes was taking plenty of time while figuring out how to build the robots. The design process had also time constraints. Thus, I would think more straightforward and complete more industrial robot designs in the project next time although I enjoyed learning from complicated tasks that I did in the project.

High School Modular Robotics Workshop

Nine high-school students from Moon Area High School located in suburban Pittsburgh, Pennsylvania participated in a four-hour workshop on modular robotics based on the newly designed configurations. The group was composed of three 12th graders, three 11th graders, one 10th grader, and two 9th graders. The participants were asked to complete a pre-workshop survey gauging their understanding of robots including modular and industrial robots as well as computer programming. A description of modular robots including user and auto configuring types was also given to the participants along with the pre-workshop survey. A summary of the survey results is presented below in the following table – Table 5. Pre-workshop survey indicated (through questions 1, 2, and 3) that the participants have had some exposure to educational robotics, construction toys, and computer programming as expected. However, none of the 9 participants were exposed to modular robotics and industrial environments.

Survey Questions									
1- Have you had any experiences in robotics (including but not limited to LEGO Mindstorms/NXT, VEX, TETRIX) prior to receiving this survey?	 <table border="1" data-bbox="917 1772 1312 1797"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Strongly Agree</td> <td>44%</td> </tr> <tr> <td>Agree</td> <td>0%</td> </tr> <tr> <td>Disagree</td> <td>56%</td> </tr> </tbody> </table>	Response	Percentage	Strongly Agree	44%	Agree	0%	Disagree	56%
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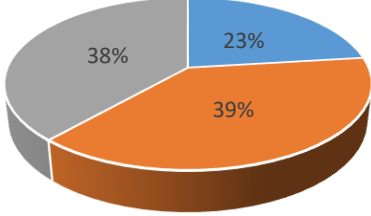
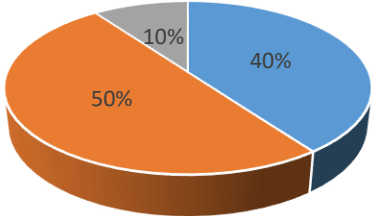
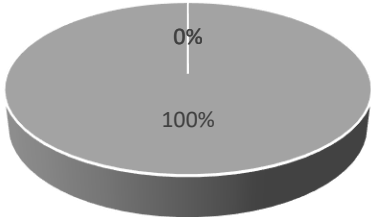
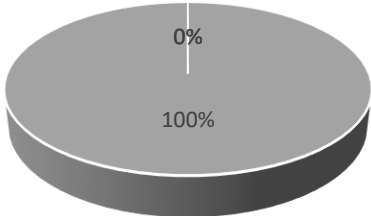
<p>2- Do you like building with construction toys (including but not limited to LEGO, K'NEX)?</p>	 <p>■ Strongly Agree ■ Agree ■ Disagree</p> <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Strongly Agree</td> <td>23%</td> </tr> <tr> <td>Agree</td> <td>39%</td> </tr> <tr> <td>Disagree</td> <td>38%</td> </tr> </tbody> </table>	Response	Percentage	Strongly Agree	23%	Agree	39%	Disagree	38%
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<p>3- Have you had experiences in computer programming?</p>	 <p>■ Strongly Agree ■ Agree ■ Disagree</p> <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Strongly Agree</td> <td>40%</td> </tr> <tr> <td>Agree</td> <td>50%</td> </tr> <tr> <td>Disagree</td> <td>10%</td> </tr> </tbody> </table>	Response	Percentage	Strongly Agree	40%	Agree	50%	Disagree	10%
Response	Percentage								
Strongly Agree	40%								
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<p>4- Based on the information given, have you had any exposure to modular robots prior to receiving this survey?</p>	 <p>■ Strongly Agree ■ Agree ■ Disagree</p> <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Strongly Agree</td> <td>0%</td> </tr> <tr> <td>Agree</td> <td>0%</td> </tr> <tr> <td>Disagree</td> <td>100%</td> </tr> </tbody> </table>	Response	Percentage	Strongly Agree	0%	Agree	0%	Disagree	100%
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<p>5- Have you had exposure to industrial robotics (robots used in plants including factories, mills) robots prior to receiving this survey?</p>	 <p>■ Strongly Agree ■ Agree ■ Disagree</p> <table border="1"> <thead> <tr> <th>Response</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Strongly Agree</td> <td>0%</td> </tr> <tr> <td>Agree</td> <td>0%</td> </tr> <tr> <td>Disagree</td> <td>100%</td> </tr> </tbody> </table>	Response	Percentage	Strongly Agree	0%	Agree	0%	Disagree	100%
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Table 5. Pre-workshop survey results

After a combination of short presentations (on MOSS modular robots, industrial robot configurations available in house) and building and programming activities of MOSS industrial robot configurations, students were given a post survey that included two questions. The first question was intended to see how the students perceived the workshop's value. The second question was used to gauge their understanding of the modular robots in a deeper way, since all of the participants demonstrated good understanding of both modular and industrial robot basics, along with good programming skills. Tables 6 and 7 document the responses of the participants. The post survey indicated that the students were kept engaged while learning about the modular robots and the newly designed industrial robot configurations. They positively responded to the hands-on activities including problem solving for modifying modular robot configurations, programming of the new configurations, and free time where they built additional modular robot designs of their own.

Participant Responses
The lesson of how real business and industries use modular robots in everyday use
Learning the different ways to problem solve
Hands-on activities with building the modular robots
Getting to talk to college students and learn about the aspects of modular robots in a working situation
I really liked the free time at the end of the workshop where we were allowed to do whatever we wanted with the modular robots.
I found that the most useful for me was actually working with the modular robots, hand-on. That includes constructing and programming the robots in our groups. I feel that it is difficult to learn about them without actually seeing what is behind the scenes and doing it for yourself.

Table 6. Post Survey Question 1: What Aspects of this Workshop Were Most Useful or Valuable?

Participant Responses
They are easy to use and can be used for many different things.
I think it is a great idea. Applications that can benefit from modular robotics are hospitals and assembly lines.
Modular robots have a wide variety of applications and uses in industry. They can be integrated in the wider society, although this would likely be difficult. More menial jobs might be able to be taken over by modular robotics, and this would allow people to produce products of higher quality and quantity.
Very useful in industry; all applications can benefit especially those that need (likely) more inexpensive robots with specific function as modular robots are able do a variety tasks depending on how they are arranged.

They could improve manufacturing and potentially be used in medical situations.
I think that it is a good idea as long as they are able to stay together. They could be used for natural disasters or in the medical field.
I feel that modular robotics can be useful in industry. With the right toolset of modular robots one could easily configure robots when needed based on the application. Also, one could build a robot for one job and then quickly disassemble and reassemble another robot for a different task using the same materials. The biggest benefit would be the ease of maneuverability and the ability to quickly change the robots for different tasks.

Table 7. Post Survey Question 2: What is Your Opinion about Modular Robots Being in Industry? What Applications Can Benefit from Modular Robotics?

Student feedback presented in Table 7 indicates that students envisioned possible applications in industrial and medical needs along with natural disaster help, with expansion to wider use into other fields. Multiple students commented on modular robots being flexible and adaptable, and thus efficient for handling a variety of applications with quick changeover, both in configurations and tooling. The author has been satisfied with student performance and feedback in this first outreach effort. The main negative comment received was due to magnetic spheres, as participants experienced occasional failure to keep the modules together.

Arduino Based Modular Robot Concept

After the completion of the first phase presented above including work on cylindrical and spherical (polar) configurations, the design team shifted its focus to use of MOSS modular robots in developing self-configuring applications. The concept was based on a basic robot design with multiple modules including controls, mobility with motor modules, and sensing ability to be responding to its environment. Based on the feedback from its environment, the logic envisioned was to channel the robot to build itself differently. This concept since then has been modified to include Arduino based own modules and the exploration of machine learning to be added to the work. Limited information is presented in this paper, since this propriety work is still in progress. The base module design is shown in Figure 7 while the hollow hexagon patterns represent the modules to be attached.

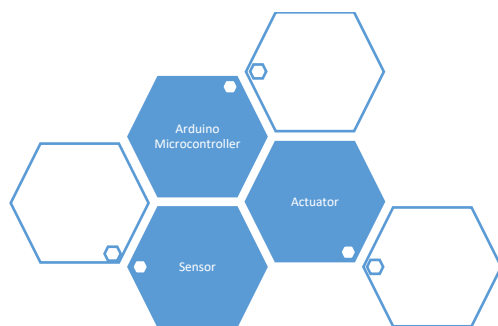


Figure 7. Arduino-based modular robot concept with its base module

Conclusions and Future Work

As mentioned previously, the project team included two engineering students, each of whom brought different interests and talents to the study. After studying the original design of the MOSS system, students took on the complex task of utilizing the system in building industrial robot configurations. With the completion of the articulated robot, the team realized that existing MOSS modules could not support the building the SCARA and other configurations. New parts were designed and interfaced with the existing MOSS modules using magnetic spheres and additional pieces. In the process of designing new components, the student team members had to deal with statics, dynamics, assembly, and programming issues to achieve the industrial robot configurations. The main objective of using MOSS modular robots in developing industrial robot configurations was partially accomplished with the completion of articulated and SCARA designs. Further work was completed on spherical and cylindrical robot configurations. These configurations will also be used in teaching industrial robotics to high achieving middle school students, high school students, and college students. The pilot high school workshop detailed in this article was successfully conducted and was well received by the students and the teachers, as evident in their post survey feedback. One of the main advantages of the workshop approach is that the MOSS allows building of a variety of industrial robot configurations and the robots built are portable to carry to any school and can be used in traveling outreach activities.

In addition to designing and building physical industrial robot configurations including Arduino based modular ones, the author has been considering employing DELMIA or MapleSIM programs in teaching robot kinematics and dynamics of these configurations for college students through an elective Robotics and Automation course. Models will soon be prepared for these activities.

In summary, students at different educational levels have been exposed to modular robots and industrial robot configurations by possibly redesigning the configurations, rebuilding them, and programming them through C programming language.

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