Jacob M Abel Internship Summer 2016:  
The Addition of Robotic Arm Labs to MEAM 520 Curriculum  
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The Issue

MEAM 520, Introduction to Robotics, is a popular elective used to fill a MEAM Upper Level requirement, and is part of the Masters in Robotics curriculum. It typically has 100 to 120 students coming from different backgrounds, such as robotics master’s students, junior and senior MEAM undergraduates, several bioengineers and some computer science majors. Coursework is comprised of written problem sets, simulations coded in MATLAB, and two projects with physical robots. From past semesters of MEAM 520, a common piece of feedback was to incorporate more opportunities to work with real hardware beyond the two existing projects.

One of the robotic arms currently used for an inverse kinematics project, the Unimate PUMA 260, is a 6 degree of freedom robotic arm in an articulated configuration with a spherical wrist. It is a relatively old and industrial robot that was adapted to work for the class. However, due to its size and strength, it can be dangerous and needs to be operated with a teaching assistant present. There is also only one PUMA to be shared among all the students, not giving each individual lots of time to interact with the robot.

Goals

The main goal for the summer was to find a way to introduce more hands-on robotic examples that meet the following qualifications:
- Multiple copies of this new hardware so each student can spend more time using it
- Can be controlled with MATLAB
- Not dangerous, can be operated without a TA present
- A similar configuration to the PUMA
- Cost effective

Exploration

To ensure as many of the goals were met as possible, an extensive search of what is currently available from different online vendors was conducted. The search covered robots from $30 to larger industrial multi-thousand dollar machines to get a complete picture of what is available. Kits for individual groups to assemble, ready-made arms, as well as an arm we could design and fabricate here at Penn were all considered as viable options.
The focus was initially on low cost kits to build many articulated robots with spherical wrists to be replacements for the PUMA. After further deliberation it was decided the best route would be to get a different type of robot to use for additional projects while keeping the PUMA and its accompanying assignment. This would allow students to not only gain more experience with robots in general, but also acquire a variety of skills by quickly adapting to new types of mechanisms and tasks to complete throughout the semester.

With this new broadened criteria, the search expanded to manipulators with any number of degrees of freedom and any configuration. The best option turned out to be the LynxMotion AL5D arm with the Heavy Duty Wrist Rotate Upgrade (affectionately called The Lynx). It is in the desired price range and ships as a kit of parts, similar to a robot version of IKEA furniture. It has 5 degrees of freedom plus an actuated gripper. It is a lightweight and relatively small manipulator with a median reach of about 10.25 inches, eliminating some of the concerns seen with the PUMA and making it more likely for students in the class to be able to independently operate the arm.

**Process**

Once the decision to go with The Lynx was made, one was ordered and assembled. The arm came with an SSC-32U LynxMotion motor controller to interact with the 6 position servo motors through serial commands. These serial commands are rather cryptic as they tell the servos a position in units of microseconds corresponding to a pulse width signal that then instruct the motor how far to turn. Controlling a robotic arm through these means are outside the scope of the class. By using a USB to TTL cable and writing a MATLAB function that converts a position input in radians to microseconds to send to the SSC-32U, the students can now interact with the arm directly from MATLAB code. Once everything was successfully up and running, two more Lynx kits were ordered and assembled to create a fleet of three Lynx arms.

**Reflection**

Through this process, I have learned a lot about how servos work and learned much more about MATLAB. I got a very good introduction to robotic manipulators and the terminology used to describe different types of configurations. I also became familiar with methods used to direct a robot to a position using forward kinematics.

I am excited to see how the three Lynx robots enhance MEAM 520 and improve students’ learning experience!
Acknowledgements

I would like to acknowledge my faculty advisor, Dr. Katherine Kuchenbecker for all her help and guidance with this project. Many thanks also to Balaji Sharma, James Kristoff, and Elvira Osuna-Highley from MathWorks for their advice on any MATLAB related issue that came up throughout the summer.