ModRob: An Inexpensive and Modular Robotic Arm for Hobbyists

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Introduction

Today's robotics industry is applications-centric where companies provide custom solutions for each customer. This business model requires requires high investment in time and money for a single industrial robotic arm model, and the highly customized solution results in low demand from other customers. The result is that the cost per robot arm remains high (anywhere from $25,000-$400,000[1]) and becomes limited in other potential applications. The robotics industry is moving towards lower-cost solutions, including robots that can be mass produced, as well as developing software frameworks that can make reprogramming a robot for other applications easier.

Objectives

1. To perform customer discovery and assess a desire for a modular, mass-producible robot arm.
2. To provide a robot arm model that is general enough for mass production and higher volume sales.
3. To provide a robot arm model that is easy to assemble and configure for different tasks.

Materials and Methods

Customer Discovery and Market Evaluation: Customer discovery and market evaluation are arguably the most important steps of the project. The purpose behind this step is to estimate the market demand and desire (need) to purchase the robotic arm. It also serves as a guide to develop and market different features or products to customer segments. To perform customer discovery the following steps were taken:
1. Provide a survey to assess the current process of building and prototyping robotic arms. The survey benchmarks customer willingness to spend less time and/or money during the prototyping and building process. It also gathers some information about who the users are such that different customer profiles could be built, each of which could be marketed to separately.
2. Process the data from the survey to build different customer profiles, if applicable. This is done by summarizing the data into quantitative or discrete results, and using pivot tables to give a top-level overview and find trends within the results.
3. Perform a literature review, using library databases to assess the overall market for educational robots and the potential for inexpensive modular robotic arms.

Building the Prototype: The second project component is to build the prototype, based on the results of customer discovery, and assuming no pivots away from the project are needed. The design of the robot can be summarized in Figure 1. The main aspects of the prototype include:
1. Using a servo motor to physically move the robotic arm joints.
2. Using electronics to coordinate and control joint movement of the robotic arm, and to provide power to each joint. Each joint contains an ESP8266 to control the joint's servo movement, and a Raspberry Pi to act as a conductor and oversee the overall arm movement. The ESP8266 and the Raspberry Pi communicate wirelessly through a software package called ROS (Robot Operating System).
3. Using a 3D-printed casing made out of polylactic acid (PLA) to package the electronics and servo motor together.

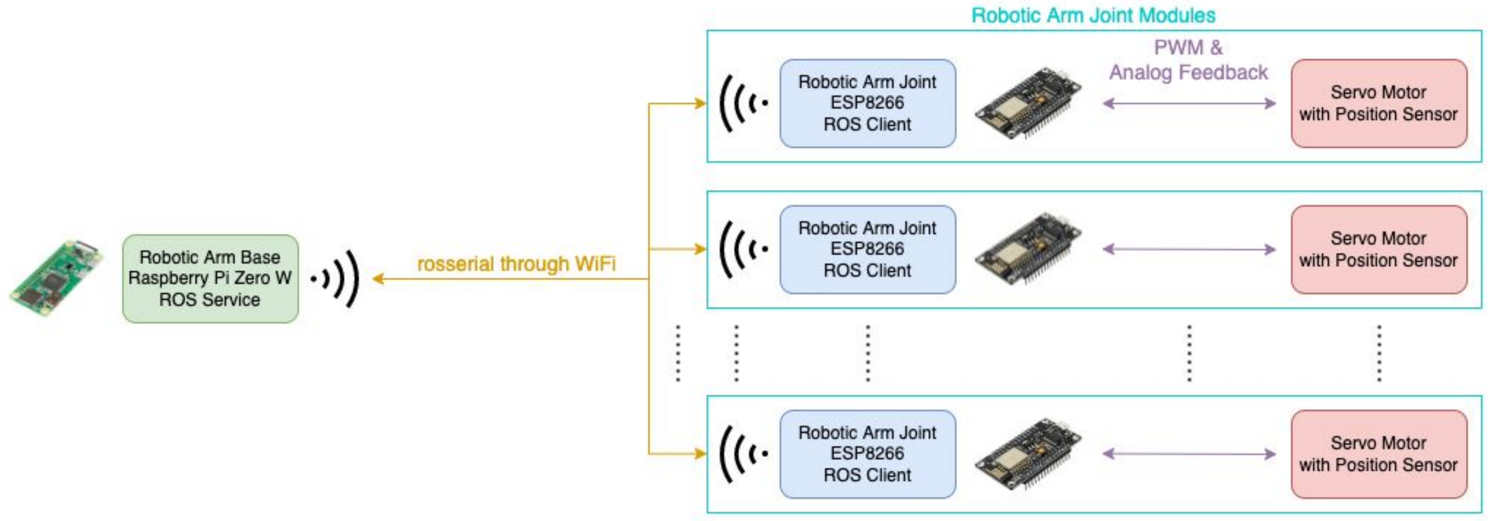

Figure 1: ModRob System Architecture

Results

Customer Discovery and Market Evaluation:
- Currently, 8 people have responded to the survey
- All people who responded have been affiliated with the University of Michigan in some aspect
- Two customer profiles: High School Student/Teacher, and Graduate/College Robotics Researcher
- 26 documents from the University of Michigan's Library database were included in the literature review

Table 1: Money Spent vs. Customer Profiles Pivot Table

Count of MONEY SPENT - NEVER, <$100, $100 - $500, $500+	Column Labels				
Row Labels	**NEVER**	**<$100**	**$100-$500**	**$500+**	**Grand Total**
HIGH SCHOOL		1		1	2
GRADUATE COLLEGE ROBOTICS	1	1	1	3	6
Grand Total	**1**	**2**	**1**	**4**	**8**

Table 2: Willingness to Spend vs. Customer Profiles Pivot Table

Count of WILLINGNESS to SPEND - NEVER, LOW (<$500), HIGH (>=$500)	Willigness to Spend			
Archetypes	**NEVER**	**LOW**	**HIGH**	**Grand Total**
HIGH SCHOOL		1	1	2
GRADUATE COLLEGE ROBOTICS	1	1	4	6
Grand Total	**1**	**2**	**5**	**8**

Building the Prototype:
- All electronics obtained and working individually
- At the time of this writing, the 3D-printed casing design is complete and is in the process of being printed

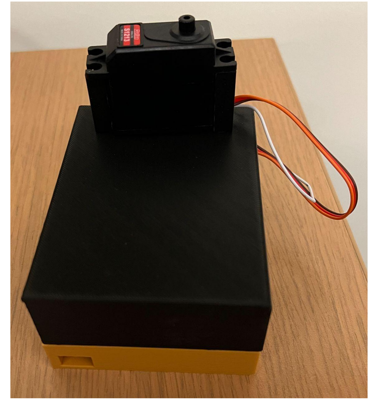

Figure 2: ModRob Joint Prototype

- Wireless communication between the Raspberry Pi and the ESP8266 has been achieved, although not yet through ROS

Discussion and Conclusions

Customer Discovery and Market Evaluation:
- Those who work with robotic arms on the college/graduate level seem to be willing to spend more on an inexpensive robotic arm that would take less time to assemble and program
- Two different products would be helpful to address the needs of both customer profiles: a less expensive product (<$100 total price) for the high school profile and a more expensive product ($500+ total price) for the college robotics researcher customer profile
- More responses from individuals with institutional affiliations outside of the University of Michigan would be helpful to support or oppose the conclusions from the initial survey
- Literature review indicates that inexpensive, modular robots are an emerging technology given recent publication dates and have the potential to impact a wide variety of fields including the educational and medical spaces
- Expanding the robotic arms technology analysis would be helpful for assessing feature and price competitiveness of ModRob

Building the Prototype:
- Each arm joint costs ~$43, and the arm controller costs ~$18. A full arm assembly could cost less than $200. These costs can be lowered significantly through using custom printed circuit boards and through high volume production

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References

[1] K. Thayer, "What is the real cost of an industrial robot arm?," Engineering360, 27-Apr-2017. [Online]. Available: https://insights.globalspec.com/article/4788/what-is-the-real-cost-of-an-industrial-robot-arm.