Design Team
Thomas Manner
Ka Kei Yeung
Daniel Phan
Ali Alsatarwah

Sponsored by:

RCPD Representative: Professor Stephen Blosser

Executive Summary:
The goal of our project is to construct a wall mounted robotic arm to help a quadriplegic person be more independent. The arm is designed to help him cook and lift heavy object such as a pot of boiling water. This arm will move in X-Y-Z directions, and will have a gripper that rotates. It will be operated using a wireless joystick controller, with knobs that are designed specifically for people with limited muscular movements.

Pre-Proposal
February 03, 2011
ECE 480 Team 3
Facilitator: Professor Lixin Dong

i. Table of Contents
1. Introduction
   1.1 Customer Needs/Requirements
2. Background
3. Design Specifications
1. Safety
2. Function
3. Quality/Reliability
4. Energy Consumption
5. Aesthetic/Size
6. Human Interaction

4. FAST Diagram
5. Conceptual Design Descriptions
6. Comparison of Conceptual Designs
7. Proposed Design Solution
8. Risk Analysis
   1. Power
   2. Speed
   3. Gripper
   4. Torque
   5. Testing
9. Project Management Plan
10. Budget
11. References
1. Introduction

For Doug, who is a young quadriplegic man, independence is of the utmost importance. One desire that Doug has is to be able to cook independently without help from anyone. Although the house that is being built for Doug will have accommodations for his quadriplegia, he would an assistance for cooking. Doug cannot generate enough muscle power to lift and move heavy pots of water, food, and other items in his kitchen.

The goal of our design project is to build a wall mounted robotic arm to assist Doug in lifting and moving items within the confines of his countertop, stove, and sink. The robotic arm should be interfaced with a three joystick wireless controller that is designed for easy operation.

1.1 Customer Needs/Requirements

The idea of the design project is to build a robotic arm to assist a quadriplegic person named Doug in cooking his own food. In order to assess the customer needs and requirements, an interview with Doug and the sponsor is necessary. In the interview with the sponsor, the basic requirements of the robotic arm will need to be established. Examples of the following are listed below:

- The lifting strength of the robotic arm

- Whether the movements of the robotic arm will be Cartesian or Joint
• How many degrees of freedom will the robotic arm have
• What microcontroller and software should be used

In the interview with Doug, who is to receive the end product, questions should be more on a functionality basis. Examples would include the following:

• What kind of joystick will make the robotic arm easier to operate?
• Would a wireless controller make it easier to operate?
• What other functions besides lifting heavy pots would be needed to assist him in cooking?

The constraints for this design project are mainly monetary and time issues. The motors, amplifiers, microcontroller, and other mechanical parts will push our budget to its limits. As for the time issue, the amount of features of the robotic arm will have to be limited to ensure completion of the robot arm.

The criteria for determining the feasibility of the project design is whether the robotic arm can accomplish its basic functions in the most efficient way. Since the mechanical parts are most expensive, the design of the actual robotic arm will need to be efficient.

The criteria for ranking the feasible designs would include the following:

• Is the design an efficient in its movements?
• Will the robotic arm be simple to operate?
• Can the robotic arm accomplish all the basic functions specified by the customer?
• Are there too many unnecessary features that cannot be realistically accomplished within the semester?

One conceptual design for a Cartesian Robotic Arm is drawn below: (fig.1)
A conceptual design for a joint robotic arm is drawn below: (fig.2)
3. Design Specifications:

*Important specifications in designing the Doug’s Kitchen robot need to be achieved are: Safety, function quality/ reliability, Aesthetics/size, Energy consumption, and human operation of the robot.*

3.1 Safety

The safety concern about robotic arm is mainly on the risk of electrical shock and the unexpected movement or the failure of the robotic arm. An electrical shock could result from uses of high voltage and high current, as well as water conductances. To solve this issue, fuses are being considered in many parts of our circuit as they are convenient, inexpensive and easy to replace. A fuse works will terminate its short circuit connection and thus create an open circuit to block the flow of current. Dealing with water or any conductive liquid is one of the sources of electrical shock or a device malfunction. The team is aiming to
utilise waterproof component especially with the gripper and the arm in the z direction, which might have contact with water and vapor. In addition, enclosure and isolation of the components using nonconductive materials greatly minimize the probability of any potential danger. These design precautions will protect the system itself and most importantly, the end user.

The other concern regarding safety is the potential force of the arm movement or the likelihood of mechanical failure. Sensors would be used to reject illegal inputs or unexpected movement. Automatic termination will be implemented should such cases arise. The structure and the material used in the design will take into account the minimization of the any potential risk to the user.

3.2 Function

The robotic arm will be based on Cartesian robotic designs and thus moves in the X, Y and Z directions. A gripper will be installed on the bottom of the Z arm, which is designed to rotate clockwise and counter clockwise. The robotic arm would be able to achieve the requested function such as lifting and moving pots of water, food and other items that require the level muscular power that a quadriplegia’s person cannot generate.

3.3 Quality/ Reliability

In order to achieve a reliable system, the team would attempt to avoid the use of complex system or structure to reduce the chance of malfunctioning and reduce the debugging process. Simplicity in the design also encourages simpler procedure in identifying and fixing bugs and other issues. This promotes the possibility of modification and expansion in the long term. In addition, the robotic arm would be constructed from cheap and readily available component such as (car windows motors, sliding actuators
and grippers and power supplies (car parties)) to achieve a robust device. The control device would be wireless with a Bluetooth transmission so the user has the freedom and ability control the device from a distance, and would not have to deal dealing with clumsy cables or interface.

3.4 Energy Consumption

The use of DC motors for the robotic arm requires a significant amount of current and thus power supply. However, to minimize energy consumption, it is essential to reduce the number for the motors in the design and to purchase models whose specifications are closest to what are necessary. In addition, power supply and circuit manipulation will be attempted to avoid unnecessary energy consumption.

3.5 Aesthetics/Size

The size of the device would be sufficiently small so it would not interfere with other house furniture or obstruct (or be obstructed by) other kitchen appliances. On the other hand, the team would attempt to create an aesthetically pleasing device so it is suitable for a comfortable home environment.

3.6 Human Interaction

Similar to the design ideals outlined in 3.3, the interaction between the end user and the robotic arm would be as simple as it is technically permissible. This ideal extends to the possibility that the device should be easily useable by people other than quadriplegics. The wireless control interface consists of three joysticks and reset bottom. One design option includes joystick1= left-right (x-direction) , joystick2= in-out (y-direction), joystick3=up-down and cw-ccw rotation.
4. FAST Diagram

*This section will be added in the final proposal*
5. Conceptual Design

Two major possible designs for the robot arm were suggested in the preliminary meetings. The first is a jointed arm (fig 2) with a shoulder and elbow that both rotate laterally and a wrist that rotates along the axis of the arm and a gripper on the end. This arm would have the shoulder attached to a track on the wall. The other is a Cartesian arm (fig 1) that could move in 3 directions essentially along tracks, and would have the same rotating wrist and gripper as above. This type of arm is mechanically much simpler and is easier to operate because each axis of motion is independent in hardware.

6. Comparison of Conceptual Designs*

*
Calculations of forces in the articulated robot arm are complex, as the force required to lift is dependant on the current angle of the arm segments. With the Cartesian( Stewart) arm the force equations become much simpler. All lifting will require a force that is only dependant on the weight, because the gripper and the motor doing the lifting will always be directly above the object. By using a linear actuator or a track actuator for the x and y directions, the force needed to drive the payload becomes quite small. This force could be further reduced by placing wheels or bearings to reduce friction between the cart and the track. For example, a realistic weight of water plus pot plus the z component of the arm is roughly 30 lbs, which requires a force of around 138 N. Seven watts of power will be necessary to lift that load and transport it at two inches per second. In order to ensure that the motor capable of performing this task easily, a minimum 15 watts of power delivered to the shaft would be ideal.

There are two types of gripper that would work in this application, a two finger and a three finger. Both grippers consist of a solid bottom half and a mobile top half. In the three finger design, two of the digits are immovable and lie in the same plane while the third moves perpendicularly into the gap between them. The three finger variant offers more stability because it has three points of contact, and is less likely to fail because the third digit may overlap the other two so that the weight is not being supported by the contact point.

The controller interface has several options associated with it. The first one discussed was whether the controller should be wireless or wired. A wireless controller adds a small cost to the project but greatly increases the possibilities, allowing the user to move freely and operate the robot at the same time. A wired controller would limit the range of operation considerably and would pose a potential safety risk because of the cable(s) over the counter. To negate that risk the controller could be mounted to a surface but this would also greatly limit operable area. Two platforms have been suggested for the controller to be built around, LEGO® Mindstorms™ and the Arduino development platform. Both platforms are very
powerful tools with many options for customization and easy to use interfaces. The LEGO platform has 4 input ports and 3 output ports. Each of these outputs is expandable to address 7 additional devices using the I²C serial addressing protocol. This functionality is available but requires custom made hardware to interpret the signal. It is also compatible with Bluetooth for wireless transmission of data between the brick and a computer or multiple bricks. The Arduino platform has many variations, the one that suits this project the best is the Arduino Fio. The Fio has eight analog input pins and 14 digital output pins, six of which have pulse width modulation built in. This particular board also has a preconfigured socket for an XBee wireless chip to allow wireless communication between the chip and a computer or with another Arduino board which is simple to implement. The robot will have at minimum five motors in it, therefore output extension will need to be done to the LEGO NXT brick if this platform is chosen, while the Arduino solution has six pulse width modulation outputs and another eight strictly digital outputs. In addition, the LEGO system costs $150 for each brick, whereas the Arduino Fio is $25 and an additional $23 for the XBee radio.

*A ranking comparison will be included/in replacement of the previous section.

7. Proposed Design Solution

Combining assessment made based on flexibility, functionality and mostly importantly the limitation of budget, the team decided that the most feasible combination is a Cartesian arm with a three finger gripper and a wireless controller based on the Arduino platform.
8. Risk Analysis

8.1 Power

The amount of power required to run the robotic arm is a concern. Since the current driving the motors is relatively high, the need for safe wiring and encasement is critical. The encasement would have to be waterproof and the leads of the wires shrink wrapped to prevent shorts.

8.2 Speed

Another concern is a safe operating speed for the robot. The robot will need to carry a pot of hot
water at a safe speed, so that it will not spill on and burn the operator. The robotic arm would need to be variable speed, but kept within a certain safe speed range. Preferably the operator would need to let the water cool before draining.

8.3 Gripper

There were concerns regarding the gripper during the development of the conceptual design. The type of gripper needed depends on what the specific function it is designed to perform. A three finger gripper would be safer in lifting a heavy pot. It is also necessary to waterproof the gripper as well its motors. Since the gripper will be at close proximity to the food it handles, it will most likely come in contact with water or vapor. Precautions will need to be taken to keep the motor from getting wet and thus prevents shorting circuits and other malfunctioning.

8.4 Torque

The amount of torque applied to the robotic arm concerned our design team. The weight of the arm itself, would put a lot of torque on the certain parts of the robotic arm. The Cartesian robot design would help to control the amount of torque applied to the robot, whereas the joint robot would have problems.

8.5 Testing

One of the challenges of the project is the great cost of materials required to build the robotic arm. The budget limitation might lead to insufficient funds to support prototyping of the design. Testing and debugging performed on the joystick controllers with smaller motors could indicate if the controller is bug free. Once the controller is proven to work, the signal can be amplified and applied to the larger motors of the robot arm. This means testing and debugging is essential at every stage of development of the robotic
arm to ensure its proper functionality.

9. Project Management Plan

9.1 Personnel

<table>
<thead>
<tr>
<th>Name</th>
<th>Technical Role*</th>
<th>Non-Technical Role</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thomas Manner</td>
<td>Interface and Coding</td>
<td>Management</td>
</tr>
<tr>
<td>Ali Alsatarwah</td>
<td>Parts Assembly</td>
<td>Webmaster</td>
</tr>
<tr>
<td>Ka Kei Yeung</td>
<td>Testing and Debugging</td>
<td>Document Preparation</td>
</tr>
<tr>
<td>Daniel Phan</td>
<td>Power Management and Safety</td>
<td>Presentation Preparation</td>
</tr>
</tbody>
</table>
9.2 Schedule*

To meet our deadlines, the team would decide on the parts to obtain by the end of week 5. Oral presentation preparation and interface coding assembly process should proceed simultaneously during week 6. The core of the project, namely the assembly, testing, and debugging would begin as soon as oral presentations are over. Such design will also obey safety guidelines especially those concerning a quadriplegic user. The final product will aim to be finished approximately one week before Design Day, which gives us time to correct any malfunctioning or bugs that prevails.

*Rough guidelines only, a Gantt chart will present more specifications in the final proposal

10. Budget

10.1 Budget Table*

<table>
<thead>
<tr>
<th></th>
<th>Unit Price</th>
<th>Quantity</th>
<th>Item Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arduino Fio</td>
<td>$25</td>
<td>2</td>
<td>$50</td>
</tr>
<tr>
<td>XBee Radio</td>
<td>$23</td>
<td>1</td>
<td>$23</td>
</tr>
<tr>
<td>Linear Actuator (40” and 20”)</td>
<td>$130</td>
<td>2</td>
<td>$260</td>
</tr>
<tr>
<td>Cylindrical Actuator</td>
<td>$80</td>
<td>1</td>
<td>$80</td>
</tr>
<tr>
<td>Item</td>
<td>Donated</td>
<td>Qty</td>
<td>Cost</td>
</tr>
<tr>
<td>--------------------------</td>
<td>---------</td>
<td>-----</td>
<td>------</td>
</tr>
<tr>
<td>Robostir</td>
<td></td>
<td>1</td>
<td>$0</td>
</tr>
<tr>
<td>Joysticks</td>
<td>$25</td>
<td>3</td>
<td>$75</td>
</tr>
<tr>
<td>Miscellaneous Components</td>
<td>$40</td>
<td>1</td>
<td>$40</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td>$528</td>
</tr>
</tbody>
</table>

*Certain items are of estimated value. Decisions on choices of parts are not finalized.

10.2 Justification

This project requires implementation of robotic arms that are able to lift heavy loads (20lbs or more). This requires more expensive robotic parts that puts a severe limitation on the choices. While choosing between LEGO NXT and Arduino boards, the team chose Arduino based on its apparently lower cost. The choice of a 40” linear actuator is due to the limitation on budget. This dimension is only for the design sample to show case its functionality. When sufficient funds are available to purchase a larger actuator, the scaled up product shall be implemented in Doug’s kitchen.

Citation:
1. [http://news.ucf.edu/UCFnews/index?page=article&id=0024004107a42ec8a01289848d7ab07cd1](http://news.ucf.edu/UCFnews/index?page=article&id=0024004107a42ec8a01289848d7ab07cd1)