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Design Issues Paper

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Introduction

According to USA today, “about 5.6 million Americans have some degree of paralysis.”¹ Although there are numerous non-profit organizations that provide assistance in everyday living for the physically disabled, many prefer to have some form of independence in their everyday lives. To remedy this situation, our team designed a robotic arm to help them cook and handle other difficult kitchen work.

The primary design criteria that were considered in this paper are Product Lifecycle Management, Universal Design Principle and Product Safety. These criteria will demonstrate the directions our team is heading, which eventually ascertain the specifications of the final design.

Product Lifecycle Management

One of the most important aspects in designing a consumer product is its Product Lifecycle Management (PLM). During the development of a brand-new product, focuses should not be placed solely on its functionality or the technical properties. Other aspects such as design, production, distribution, consumption and the retirement are all factors that direct the commercial success of the product.

During the preliminary stage of our designing process, the team carefully assessed the needs of the customer. This product is specifically designed for people with quadriplegia, which means that the control and other specifications would be dramatically different from a robot arm operated by a person with no physical inhibition. The specific consumer spectrum also limits the cost of the product and therefore the cost of production. This is because our users (due to physical immobility) usually have lower incomes than those who are more mobile. They often also require financial assistance from the government or other organizations. Other than cost, we also elected to use components that are more energy efficient to ensure environmental friendliness. Twelve volt automotive window motors were used only on parts where heavy payload will be required. Microcontrollers with low energy consumption and smaller motors are installed

on remaining sections of the robotic arm.

As mentioned above, manufacturing cost is of great consideration so we can deliver affordable product. This robotic arm will be constructed from readily available electrical and mechanical components (grippers, car window motors, etc.). Additionally, other construction materials, such as plastic and aluminum used are abundant in the market and are recyclable. That being said, in order to maintain the company's good reputation, the team does not compromise on quality and reliability of the design. This designing principle will ensure satisfied consumers.

Since this product is specifically designed for people with disabilities, the demand on which the production is based is also unequivocal. The cost and time of transportation are determined by the sources of orders. This means we should set up our distribution hubs in accordance to locations where demands are highest. We must also not neglect the possibility of global demands. As a starting product with a narrow consumer spectrum, our factory locations must be strategic and cost-effective.

Our design aims for simplicity and user friendliness. This is especially essential as our target customers are expected to have certain physical disabilities. The size and shape of the controller console (joysticks) is expanded and modified to accommodate to their physical capability. The knobs are sufficiently large while the shaft is elongated to a point where the user could easily operate them. The soft plastic padding on the knob also provides better comfort for prolonged operations.

The interface and the concept of arm movements would be visually easy to learn. Each joystick would be clearly labeled to indicate which direction(s) it controls. For example, one joystick would control the arm to move left or right, while another would be used to move the arm towards and away from the wall. These directional instructions using the joystick, along with understanding the on/off and reset switches would be the only customer training (or adaptation) required to fully operate the product.

Due to the choice of commercially available electronic components (motors, grippers, Arduino Fio etc.), replacement of parts is relatively simple. The programming of the microcontroller uses open source Arduino code. Since this code is easy to understand for

those with basic C++/C coding experience, it is possible to solve any programming bugs without consulting the original programmer. This also leaves the product the potential to be further upgraded and reduces the cost and time to train employees assigned to customer service.

The major cost of maintenance would be the wearing of the mechanical components. We would assign very specific measurements and useable materials (cheapest available) which would be kept confidentially in our company. These specifications will be tested and re-assessed regularly to ensure further upgrades and production would be made at lowest cost possible (monetary and other resources). Therefore, users would necessarily contact our specialists for repair and maintenance services. However, the product is designed to be robust and should last at least ten years. The purpose of our repair and maintenance services is mostly to address improper uses by consumers.

The lifetime of the robotic arm is estimated at minimum of ten years. Since the price of the robotic arm will be relatively high and the demand relatively low, an option for regular maintenance will be available to customer at a cost. The cost of those services would depend on whether parts on the robotic arm needed to be replaced. Examples of those would be replacing the motors and the controller battery. For upgrades to the robotic arm, the programming specialists in our design team could provide software upgrades. These upgrades might be a trivial task such as implementing a park button, where a button would overwrite its previous command and place the robotic arm in a designated “home” position. As long as the owner agrees on the charges, these customer services will be made available. When the lifecycle of the robotic arm ends, parts from the arm can be recycled. Those parts include scrap metal, the dc motor, and possibly the lithium ion battery. Proper disposal of batteries will be needed when the batteries are dead.

Universal Design Principle

In the design of the robotic arm, consideration towards Universal Design Principle was paramount since the robotic arm is aimed at improving the lives of physically limited people. Our team had to consider the physical limitations of such a person and design a robotic arm that could help him or her to overcome those limitations. These physical limitations include dexterity in hand and arm movements, sitting in a wheelchair, and the strength to lift heavy wares. In order to make the robotic arm accessible to a quadriplegic person, physical limitations would need to be considered in the features of the controller and robotic arm itself.

The first design our team chose to implement was a wireless controller using two Arduino FIO microcontrollers with XBee RF radios. In our decision to choose a wireless control, we considered the limited mobility of a person in a wheelchair. The wireless controller allows freedom of movement and does not tether the user to the control box of the robotic arm. This feature of our design allows the user to control the robotic arm from a preferred mobile location.

Another feature to the controller is the design of the joysticks. In this, our team considered the limited dexterity of quadriplegic person's hands. The three joysticks of the controller are spaced apart so as to make each joystick easier to use. The joystick was also extended and a foam covering was added for better gripping. In the programming of the joysticks, our team decided that only one joystick will be active at a time, to limit the accidental movement of the robotic arm. These design features will help make the robotic arm more accessible to a person with limited dexterity of the hands.

Throughout the design process, our design team considered what capabilities the robotic arm must have. Since the robotic arm will be used in the kitchen, it must be able to lift heavy wares and pots of water. Different motors were considered to provide the torque needed to lift these heavy wares. This capability will help the user overcome the limited strength and dexterity in his arms. A rotating gripper will be implemented so that the operator can stir food without fatiguing his arms. These features are designed to make cooking independently accessible to people.

Making the robotic arm accessible to everyone is not plausible. However, the simplicity in the features means the design could be further developed into a wider range of product. This means more individuals could eventually benefit from this design.

Design Safety

Safety is of grave concern, especially since the product is designed for quadriplegic users. These users commonly have very limited mobility and muscular control and thus require a more robust design to account for higher chance of accidents.

In order to transport a robotic arm, high power motors such as power window motors would be used. These motors commonly run at 12V which is relatively low. However, at a higher payload (or even just to move the metallic arm against gravity) to maintain the same speed, the motors could draw a high amount of current. This current could surge as high as 10A. Experimentally it would take as little as 15mA to cause the loss of muscular control, and around 50mA to 100mA to cause ventricular fibrillation². This means any direct human contact with the exposed power cord would be potentially fatal. For this reason, it is absolutely crucial to enclose the entire power cord with insulating material. This also includes the connection points with the motors and with the power supply. A safety case was specifically constructed to cover the connection terminals on the 12V AC/DC adaptor in our product. The opening of the case are enough to fit through insulated power cords (which are smaller than adult fingers) only. Flesh-to-metal contact is therefore impossible unless one deliberately destroy this safety guard. Similarly, the connect terminals on the motors would not be exposed to human touch providing that the entire length of the power cord is insulated.

The speed at which the robotic arm operates should also be adjusted for safety. There are two motivations for this adjustment. First of all, even though sturdily attached hooks would be designated to hold heavy items, there is a limit at how fast the arm could travel. When this speed is exceeded, heavy items could come off the hook or hot items such as a pot of boiling water could potentially spill over. Should the user accidentally commanded the arm to operate at full speed, this speed should be steady and slow enough

that the item it carries would remain restrained. The second motivation is that the arm speed should be reasonably slower than the response time of the user. When the user sees a potential obstacle (object or human) along the arm's path of movement, he or she should have enough time to stop the movement.

The possibility of obstacle blocking the arm's movement raises another safety issue. Interrupt sensing feature will be included in the design. When the arm would move against a sturdy obstacle that significantly slows down or stops the arm, the motor interrupt sensors (using motor choppers paired with optical sensors) would detect either undesirable direction (from forward to stop) or speed. This would interrupt the microcontroller and thus stop the mechanical arm (and motor) from moving, regardless of the commands given by the joystick control.

Aside from the joystick controller, the gripper would generally be closest to the user since it would be used to deliver items to the user. Therefore a gripper model was chosen based on its relatively weak gripping force. The Lynxmotion gripper uses a HS-645MG servo motor with a maximum torque of 133oz.in. With this low torque, the closing grip would not cause any pain on a human hand (tested) accidentally placed in between, which is a probable scenario.

Due to these safety measures, our design would appeal to consumers who are previously uncertain about similar products. People with physical disability commonly fear technology of which they have a potential to lose control. An aggressive promotion and emphasis on these safety features to the market could warrant positive outcome. The threshold of "safe arm movement speed" could be further manipulated in software to create models with various speeds. These variants could then target a wider consumer range, including people of different levels of mobility and cognitive capability (which affect their response time).

Reference

1. http://www.usatoday.com/news/health/2009-04-21-paralysis-survey_N.htm
2. <http://www.elec-toolbox.com/Safety/safety.htm>