Smart Grip Prosthetic Hand

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***Abstract*- In a fast paced world, an accident can happen to anyone of us, changing and impacting our lives negatively. Some of these accidents have irreversible consequences, like the amputation of a limb. Recent studies show that there are about 16 amputations per 100,000 people in Lebanon. Through the decades, engineers and scientists have come up with different solutions to make the lives of amputees somewhat easier, specifically transradial amputation. Unfortunately, fully functional prosthetic hands cost anywhere from $5000-$120000. The current project proposes a solution at a reasonably affordable cost for a highly durable prosthesis that can satisfy the needs of an amputee coming from any financial background. To manufacture a durable prosthesis, we used aluminum to machine the parts of the inner skeleton. To make the cover, we used fiberglass molding and finished it off with a glossy paint job. The aluminum parts are connected to each other by steel bearings and stainless steel rivets, nuts, and bolts. The fingers are actuated by steel cables, which are pulled by servo motors. The fingers are reset to their initial positions by spring loaded steel cables. The smart grip system, which is the main innovative characteristic of the prostheses, senses the presence and the slipping of an object between the fingers. The whole system is controlled by an Arduino microcontroller. In addition, the smart grip system can be used in many other industrial applications related to the fields of robotics. With this project, we managed to prove our concept of the smart grip system, but there is still room for improvement.**

I. INTRODUCTION

In an imperfect world, an accident can happen to anyone of us, changing our lives to worse. Some of these accidents may be severe and have irreversible consequences like the amputation of a limb. The ingenuity of humankind has led us to different solutions to problems that were thought to be unsolvable. Throughout history, people have come up with different methods to make the lives of amputees somewhat easier. For example, in the case of hand amputation, people used a hook to perform simple tasks, or a wooden hand for cosmetic reasons. Prosthetics have come a long way since then.

Nowadays, there are much more advanced methods to solve this problem, prosthetics can range from metal hooks and purely cosmetic hands to fully functional thought controlled prosthetics, and in between, there are still method to be explored in order to find the soft spot of prosthetics, that is, to find the method that can meet the requirements of an amputee at a reasonable price. Presently, the cost of a functional prosthetic hand can range from $4,000 to $12,0000 [1]- [4].

According to most human rights doctrines, all people should have an equal opportunity to a normal life. Unfortunately, this is not always the case as the privileged have the luxury to afford any solution to any problem since they have the financial means of doing so. In this paper, the researchers propose an optimal solution at the lowest cost for a highly durable prosthesis that can satisfy the requirements of an amputee, especially the ones with limited financial resources. To achieve this objective, a durable and affordable functional prosthetic hand will be presented. The durability of the prostheses will come from its lightweight aluminum skeleton with composite cover, and the functionality will be derived from a simple smart grip system integrated with the finger drive. Also, the smart grip system can be used in many other industrial applications in most of the robotic fields.

II. AMPUTATION AND PROSTHETICS

Knowledge of amputation and the history of prosthetics will help to emphasize the importance of the availability of prosthetics to amputees.

A. Amputation

Amputees can be found all over the world. Some people are born with a missing limb, but also limb loss can be the result of different types of accidents such as wars, vehicle accidents, diseases, or sports related accidents (mountain climbing, soccer, etc.).

According to the statistics done by Eastern Mediterranean Health journal [5], there are about 1.6 amputations per 10,000 persons in Lebanon. Amputations are categorized as upper limb amputations and lower limbs amputations, and each of these two types have different subcategories. Each of the above mentioned amputation types are usually handled by specific types of devices, which are called prosthetic devices. Transradial amputations, for example, were initially solved with wooden prosthetics, metallic prosthetics, cosmetic prosthetics, hook prosthetics and – today – myoelectric prosthetics. Nowadays, prostheses

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Figure 1. Palm and Forearm

fall in different categories and they differ by quality, functionality, cost and other specifications.

In this paper, a smart prosthetic hand with good grip is presented. Usually, the user needs to grab items that can have different textures and geometrical shapes. The smart grip system will provide the simplicity of grabbing any kind of object without the fear of loss of control over the item grabbed, be it a hot coffee mug, a plastic bottle, an egg, etc. A hot coffee mug, for example, will exert heat on the prosthesis, and hence the choice of materials that will be used to manufacture the prosthesis should be such that it will not be affected by temperatures that a normal human hand can withstand. Being smart does not mean that prostheses will be independent; the user interface will control different modes of operation that will satisfy the amputee.

In brief, the aim of proposed model is mainly to provide the average amputee with a prosthesis that is durable and functional, at an affordable price.

III. MATERIALS AND METHODS

The materials and methods chosen for this project have a direct effect on its success, thus they are discussed in detail in the subsections below.

A. Manufactring:

From a manufacturing point of view, the proposed model aims to achieve four main objectives: heat resistance, durability, weight, and mechanism.

- **Heat Resistance**: heat resistance is important, because it gives the user a wider range of activities that he/she can perform with the prosthesis, rather than being limited by a certain temperature range. By heat resistance we do not mean that the prosthesis must be totally fireproof, but it must be able to withstand the normal temperatures that a human being encounters in his daily life, e.g., holding a mug containing a hot beverage, an accidental spill of hot water, or getting your hand close to naked flame for a short period of time. The target temperature range will be up to 70˚C.
- **Durability**: durability is also a key factor in functionality and user satisfaction. Durability is important, because the user can encounter high forces through accidents and this can damage the prosthesis. By durability, it is meant that the prosthesis must endure certain rages and types of forces. This however, can limit the range of activities the user can perform with the device, for example, when a finger gets wedged in a doorway, or if a door is slam-closed on a finger.
- **Weight**: weight plays a big role in comfort and this is a major factor in functionality and user satisfaction. Simply, if the prosthesis is heavy, the user will not be comfortable carrying it around on his/her arm.
- **Mechanism**: the importance of the mechanism is indirect rather than direct in user satisfaction context. The smooth operation of the hand is crucial for a semi-humanlike motion of the fingers. The mechanism must be reliable to ensure accuracy, consistency, and repeatability.

B. Control

The device control can be divided into three parts: user interface, processing, and smart grip system.

- **User Interface**: a system that will allow the user to control the prosthesis through simple commands.
- **Processing**: a control module that must combine the smart grip system (mentioned below), the drive system, and the user interface.
- **Smart Grip System**: a unit that allows the person to actuate the right amount of force to provide sufficient grip to grab a given item depending on its weight, texture, and geometrical shape. The aim of having a smart grip system is to eliminate the margin of human error during the grabbing action. This system will be able to grab an object regardless of its shape, surface texture, or weight.

IV. IMPLEMENTATION

The manufacturing methods and implementation protocols are being filed for patenting and, thus, will not be disclosed now. In this paper, only the various phases will be mentioned and discussed briefly:

Phase 1

1.1 Machining (Figure 1)

The machining was done with a lathe and milling machine. The measurements, along with the 90 degree angles, had to be accurate to a tenth of a millimeter to ensure the smooth operation of the fingers.

1.2 Smart grip system design and testing

The smart grip system is a combination of three

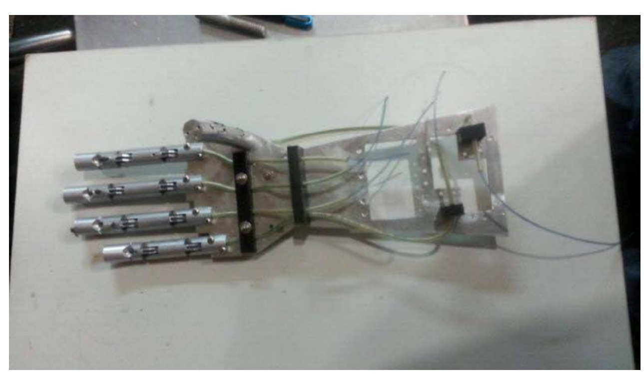

Figure 2. Assembled Aluminum Skeleton

elements; object sensing, slip sensing, and data acquisition system. The object sensing is accomplished by micro switches in the fingertips. The slip sensing is accomplished by a modified optical mouse. The data acquisition is done by an Arduino microcontroller.

Phase 2

2.1 Assembling the aluminum skeleton (Figure 2)

After assembling the machined finger section together, the fingers were placed on the palm and forearm plate. Then the cable system was assembled on the plate.

2.2 Integrating the smart grip system (Figure 3)

The micro switches were fitted on the finger tips and the optical mouse was modified to fit into the composite cover of the index finger.

Phase 3

3.1 Integration of the drive system with the skeleton

After fitting the servo motors onto the palm and forearm plate and temporarily fixing the modified optical mouse on the tip of the index finger, the drive cables were connected to the arms of the servo motors and each finger preload was calibrated.

3.2 Further smart grip system testing

After integrating the mechanism with the smart grip system, tests were done on the system to find some coding bugs and fix them.

Phase 4

Composite cover design and testing

The composite cover design phase was dedicated mostly to find the right design that would be humanlike, proportional in size, strong, light weight, and big enough to contain all the elements of the system. This was done by hand laying fiberglass on positive and negative molds made of plaster of Paris and molding clay.

Figure 3. Integrating the Slip Sensor

Phase 5

Integration of the optical mouse in the index finger as shown in Figure 3

The most important aspect of this stage was to calibrate the exact distance of the lens of the optical mouse, from the surface of the hand. This distance has a direct effect on the information transmitted by the sensor.

Phase 6

Cosmetic finishing of the composite cover.

The cosmetic finish was handed over to a professional painter in a body shop.

V. CONLUSION

Although the current prototype, as shown in Figure 4, is not ready for the market and is in need of more research and testing to improve some aspects, it served as a "proof of concept" that can later be subjected to further development and amelioration.

Figure 4. The Prosthetic Hand

From a manufacturing point of view, the researchers had four main objectives: 1) Heat resistance, 2) Durability, 3) Weight, and 4) Mechanism, all but one – weight – were achieved. From an electronic systems point of view, two of the three main objectives: 1) User interface (not achieved), 2) Processing, and 3) were achieved. The two objectives that were not successfully completed were the expense of durability and time limitation. These incomplete objectives will be the target of future work.

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