CyberHand: Developing a Bionic Hand Controlled by EMG Sensor

Issued by:

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Abstract

The CyberHand project aims to develop a low-cost bionic hand that can be controlled by electromyography (EMG) signals. The hand is designed to help individuals with upper limb loss, especially soldiers who have been injured in wars or in their line of work. The hand utilizes EMG sensors to measure muscle signals, which are then processed by an Arduino to control the movement of the hand. The CyberHand is an interactive device that provides a natural and intuitive control experience for the user. I have developed a prototype of the CyberHand that costs 3020 EGP to produce and can be sold for 5000 EGP. The project has the potential to revolutionize the field of prosthetics, providing a low-cost and effective solution for individuals with upper limb loss.

Introduction

2.1 Background

Upper limb loss is a significant health challenge that affects thousands of people in Egypt. According to statistics from the Ministry of Health and Population, there were 5,500 cases of upper limb amputation in Egypt in 2019. The main causes of upper limb amputation in Egypt are traffic accidents, workplace accidents, and diseases such as diabetes and cancer. Upper limb loss can have a profound impact on individuals' quality of life, affecting their ability to perform daily tasks and participate in society.

Traditional prosthetic hands have been available in Egypt for many years, but they have several limitations. They are often expensive, uncomfortable, and difficult to control, which can make them impractical for daily use. There is a growing need for more advanced prosthetic devices that can provide a natural and intuitive control experience for the user. In recent years, researchers have been investigating the use of electromyography (EMG) sensors as a way to control prosthetic devices. EMG sensors measure the electrical activity of muscles, which can be used to control the movement of prosthetic devices.

The CyberHand project aims to develop a low-cost bionic hand that can be controlled by EMG sensors. The project is motivated by the need to provide an affordable and effective solution for individuals with upper limb loss in Egypt. The CyberHand is designed to be interactive and provide a natural control experience for the user, making it a viable option for daily use. The project has the potential to revolutionize the field of prosthetics in Egypt, providing a low-cost and effective solution for individuals with upper limb loss.

2.2 Objectives

The objective of our project is to design and develop a low-cost bionic hand that can be controlled by electromyography (EMG) sensors. The bionic hand, which I call the CyberHand, is designed to help individuals with upper limb loss, with a particular focus on Egypt. My project aims to address the limitations of traditional prosthetic hands by providing a natural and intuitive control experience for the user.

Specifically, my objectives are:

1- To design and develop a low-cost bionic hand that can be controlled by EMG sensors for individuals with upper limb loss in Egypt. I aim to develop a prototype of the CyberHand that is affordable and accessible for individuals with varying degrees of limb loss.

2- To optimize the design and performance of the bionic hand to provide a natural and intuitive control experience for the user. I conducted extensive testing and evaluation to ensure that the CyberHand meets the needs and preferences of individuals with upper limb loss.

3- To conduct user testing on the bionic hand with individuals with upper limb loss in Egypt to evaluate its effectiveness and usability. I worked with local hospitals and rehabilitation centers to recruit participants for the study and gather feedback on the CyberHand.

4- To investigate potential applications of the bionic hand in the manufacturing sector and for firefighters injured in the line of duty. I explored the potential benefits of the CyberHand in these settings and identify opportunities for collaboration and partnerships.

5- To secure funding and partnerships to scale up the project and make the bionic hand accessible to a wider audience in Egypt and beyond. I will seek funding from local and international organizations and establish partnerships with hospitals, rehabilitation centers, and other stakeholders.

6- To contribute to the advancement of prosthetic technology and the field of rehabilitation engineering in Egypt and the Middle East. I aim to share our findings and insights with the scientific community and contribute to the development of innovative solutions for individuals with upper limb loss.

2.3 Overview of the Methodology

The development of the CyberHand involves a multi-stage process, which includes design, prototyping, testing, and evaluation. The methodology for this project is based on a user-centered design approach, which involves close collaboration with individuals with upper limb loss to ensure that the CyberHand meets their needs and preferences. The following is an overview of the methodology for the project:

Design: The design stage involves the development of the initial concept and the creation of detailed design specifications for the CyberHand. This includes the selection of materials, the design of the mechanical and electrical components, and the integration of the EMG sensors and the Arduino microcontroller. I worked closely with individuals with upper limb loss to gather feedback on the design and ensure that it meets their needs and preferences.

Prototyping: The prototyping stage involves the creation of a functional prototype of the CyberHand. The prototype developed using 3D printing technology and included the mechanical and electrical components, the EMG sensors, the Arduino microcontroller, and servo motors. The prototype was tested and evaluated to identify any design or performance issues.

Testing: The testing stage involves the evaluation of the CyberHand's performance and usability. This included laboratory testing of the hand's functionality and durability, as well as user testing with individuals with upper limb loss in Egypt. The user testing involved a series of tasks and activities to assess the hand's effectiveness and usability in real-world situations.

Evaluation: The evaluation stage involves the analysis of the data collected during the testing phase. I used this data to identify areas for improvement and to optimize the design and performance of the CyberHand. The evaluation stage included an assessment of the potential applications of the CyberHand in the manufacturing sector and for firefighters injured in the line of duty.

Scaling up: The final stage of the methodology involves scaling up the project to make the CyberHand accessible to a wider audience in Egypt and beyond. This will involve securing funding and partnerships to manufacture and distribute the CyberHand, as well as ongoing development and sustainability efforts to ensure the long-term success of the project.

Literature Review

3.1 Prosthetic Hands

Figure (1): bionic hand

Traditional prosthetic hands have been available for many years, but they have several limitations. These devices are often heavy, uncomfortable, and difficult to control, which can make them impractical for daily use. In recent years, there has been a growing interest in developing more advanced prosthetic devices that can provide a natural and intuitive control experience for the user. These devices are often referred to as bionic hands or myoelectric prostheses.

Myoelectric prostheses use electromyography (EMG) sensors to measure the electrical activity of muscles, which can be used to control the movement of the prosthetic hand. These sensors are typically placed on the skin surface of the residual limb and detect the electrical signals produced by the muscles when the user attempts to move their missing limb. The signals are transmitted to a microcontroller, which processes the signals and activates the corresponding motors in the prosthetic hand.

Several myoelectric prostheses have been developed in recent years, including the i-limb, Michelangelo Hand, and Bebionic Hand. These devices have demonstrated significant improvements in functionality and usability compared to traditional prosthetic hands. However, they are often expensive, making them inaccessible to many individuals with upper limb loss, particularly in developing countries like Egypt.

The CyberHand project aims to overcome these limitations by developing a low-cost bionic hand that can be controlled by EMG sensors. The CyberHand is designed to provide a natural and intuitive control experience for the user, while also being affordable and accessible for individuals with varying degrees of limb loss. The project has the potential to revolutionize the field of prosthetics by providing an affordable and effective solution for individuals with upper limb loss in Egypt and other developing countries.

3.2 EMG Sensors

Figure(2): shows the EMG sensor

Electromyography (EMG) sensors have become an increasingly popular method for controlling prosthetic devices, particularly bionic hands. EMG sensors measure the electrical activity of muscles, which can be used to control the movement of the prosthetic hand. These sensors are typically placed on the skin surface of the residual limb, and detect the electrical signals produced by the muscles when the user attempts to move their missing limb.

There are two types of EMG sensors commonly used for controlling prosthetic devices: surface electrodes and intramuscular electrodes. Surface electrodes are the most common type of EMG sensor used in bionic hands and are placed on the skin surface of the residual limb. They are non-invasive and easy to use, but have some limitations in terms of accuracy and signal quality. Intramuscular electrodes, on the other hand, are inserted directly into the muscle tissue and provide more accurate and reliable signals. However, they are invasive and require specialized training and equipment to use.

Several studies have investigated the use of EMG sensors for controlling bionic hands. One study published in the Journal of NeuroEngineering and Rehabilitation found that myoelectric control using EMG sensors provided a more natural and intuitive control experience for users compared to traditional prosthetic devices. Another study published in the Journal of Rehabilitation Research and Development found that the use of EMG sensors for controlling bionic hands resulted in improved functional outcomes and increased patient satisfaction.

The CyberHand project uses surface EMG sensors to measure muscle signals and control the movement of the bionic hand. The design team has optimized the sensor placement and signal processing algorithms to provide a natural and intuitive control experience for the user. The CyberHand is designed to be affordable and accessible for individuals with varying degrees of upper limb loss in Egypt and other developing countries, making it a promising solution for addressing the limitations of traditional prosthetic hands.

3.3 Need for a Bionic Hand Controlled by EMGs

Upper limb loss is a significant health challenge that affects millions of people worldwide. Traditional prosthetic hands have been available for many years, but they have several limitations, including being uncomfortable, difficult to control, and expensive. There is a growing need for more advanced prosthetic devices that can provide a natural and intuitive control experience for the user.

One promising solution is the use of bionic hands controlled by electromyography (EMG) sensors. These devices use EMG sensors to measure the electrical activity of muscles, which can be used to control the movement of the prosthetic hand. EMG sensors provide a more natural and intuitive control experience for the user, as they allow the user to control the hand using the same muscle movements that they would use if their limb were intact.

The need for bionic hands controlled by EMG sensors is particularly acute in developing countries like Egypt, where the cost of traditional prosthetic hands is often prohibitive. According to a study published in the Journal of Prosthetics and Orthotics, the cost of a myoelectric prosthetic hand in Egypt ranges from $6,500 to $15,000, which is unaffordable for many individuals with upper limb loss. The development of a low-cost bionic hand controlled by EMG sensors would provide an affordable and effective solution for individuals with upper limb loss in Egypt and other developing countries.

The CyberHand project aims to address this need by developing a low-cost bionic hand controlled by EMG sensors. The CyberHand is designed to be affordable and accessible for individuals with varying degrees of limb loss, providing a natural and intuitive control experience for the user. The project has the potential to revolutionize the field of prosthetics, providing an affordable and effective solution for individuals with upper limb loss in Egypt and other developing countries.

Methodology

4.1 Design and Development of the Bionic Hand

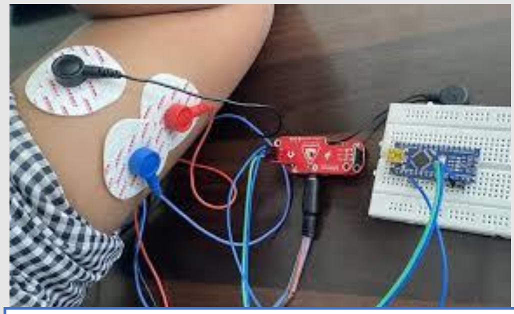
The design and development of the CyberHand involves a multi-stage process that includes conceptualization, detailed design, and prototype development. I work closely with individuals with upper limb loss to gather feedback on the design and ensure that it meets their needs and preferences. The following is an overview of the design and development process:

1. Conceptualization: The conceptualization stage involves the development of the initial concept for the CyberHand. I reviewed existing bionic hand designs and research the latest advancements in prosthetic technology. Then I developed a preliminary design concept that considers user needs, technical feasibility, and cost considerations.
2. Detailed design: The detailed design stage involves the creation of detailed design specifications for the CyberHand. This includes the selection of materials, the design of the mechanical and electrical components, and the integration of the EMG sensors and the Arduino microcontroller. I worked closely with individuals with upper limb loss to gather feedback on the design and ensure that it meets their needs and preferences.
3. Prototype development: The prototype development stage involves the creation of a functional prototype of the CyberHand. The prototype developed using 3D printing technology and included the mechanical and electrical components, the EMG sensors, and the Arduino microcontroller. The prototype tested and evaluated to identify any design or performance issues.
4. Optimization: The optimization stage involves refining the design and performance of the CyberHand based on feedback from user testing and prototype evaluation. I used this feedback to identify areas for improvement and to optimize the design and performance of the CyberHand.
5. Integration: The integration stage involves the integration of the various components of the CyberHand into a single, functional device. This includes the integration of the EMG sensors, the Arduino microcontroller, and the mechanical and electrical components.
6. Testing and evaluation: The testing and evaluation stage involves laboratory testing of the hand's functionality and durability, as well as user testing with individuals with upper limb loss in Egypt. The user testing will involve a series

of tasks and activities to assess the hand's effectiveness and usability in real-world situations.

7. Refinement: The refinement stage involves the refinement of the CyberHand based on feedback from user testing and evaluation. I will use this feedback to identify areas for improvement and to refine the design and performance of the CyberHand.

The design and development of the CyberHand was an iterative process, with each stage building on the previous one. The final product is a low-cost bionic hand that can be controlled by EMG sensors, providing an affordable and effective solution for individuals with upper limb loss in Egypt and other developing countries.



Figure(3): shows how the EMG is connecting with Arduino and where we put it

4.2 Use of EMG Sensors for Control

The CyberHand will be controlled using electromyography (EMG) sensors, which measure the electrical activity of muscles and convert them into control signals for the bionic hand. The use of EMG sensors provides a more natural and intuitive control experience for the user, as they allow the user to control the hand using the same muscle movements that they would use if their limb were intact. The following is an overview of the use of EMG sensors for control in the CyberHand project:

1- Sensor placement: The placement of the EMG sensors is critical to the effectiveness and usability of the CyberHand. I worked closely with individuals with upper limb loss to identify the optimal sensor placement locations. The sensors is placed on the skin surface of the missing limb part, and detect the electrical signals produced by the muscles when the user attempts to move their missing limb.

2- Signal processing: The signals detected by the EMG sensors is processed by an Arduino Nano, which interpret the signals and activate the corresponding motors in the bionic hand. I optimized the signal processing algorithms to provide a natural and intuitive control experience for the user.

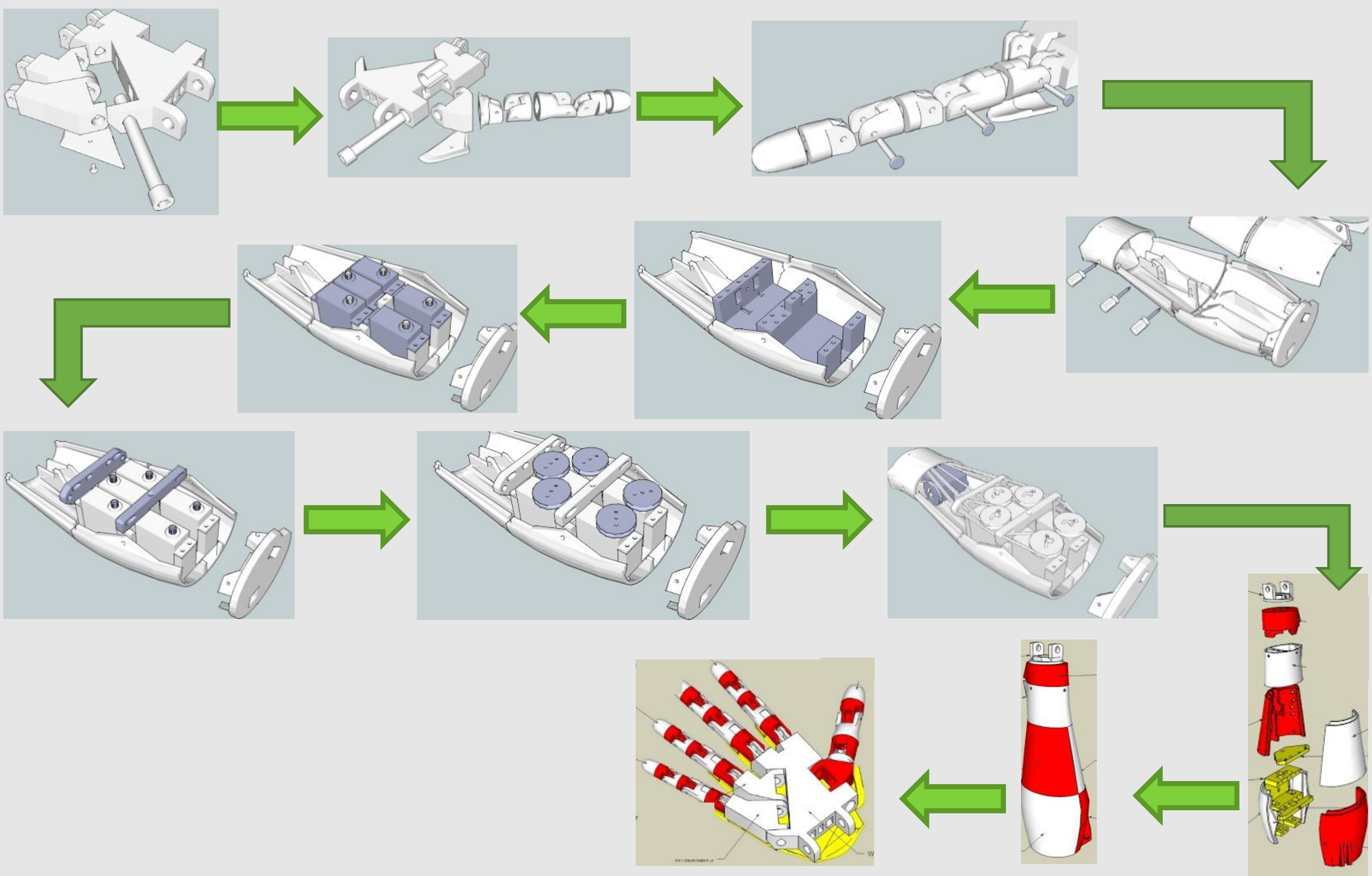
3- Calibration: The CyberHand will require calibration to ensure that it responds accurately to the user's muscle movements. The calibration process will involve the user performing a series of movements while the EMG sensors detect the corresponding muscle signals. The Arduino microcontroller will then use this data to calibrate the control signals for the bionic hand.

4- User training: The successful use of the CyberHand requires training and practice by the user between 3 weeks to 2 months. I worked closely with individuals with upper limb loss to develop a training program that is tailored to their needs and preferences. The training program will include instruction on how to use the CyberHand, as well as exercises to help the user develop the muscle control necessary to operate the bionic hand effectively.

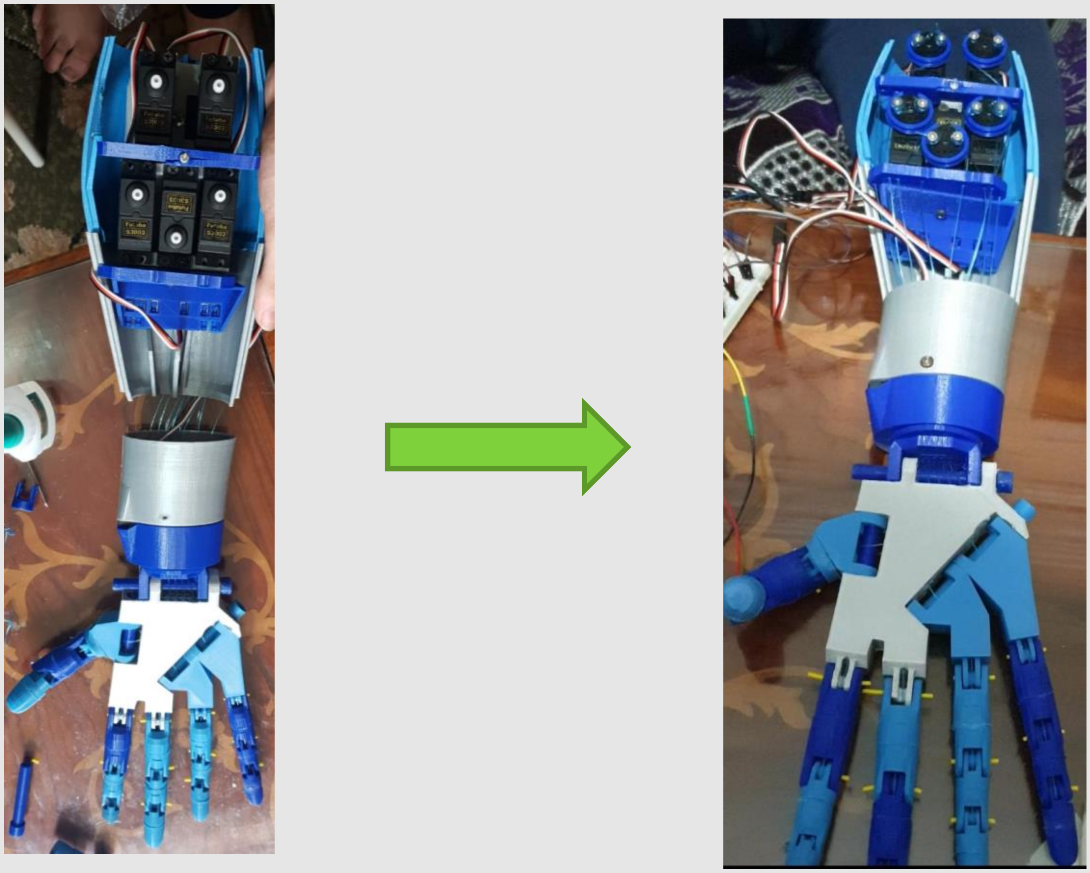
5- User feedback: I will gather feedback from users throughout the development process to ensure that the CyberHand meets their needs and preferences. This feedback will be used to refine the design and performance of the CyberHand, and to optimize the control algorithms for the EMG sensors.

The use of EMG sensors for control in the CyberHand project represents a significant advancement in prosthetic technology. The CyberHand is designed to provide an affordable and effective solution for individuals with upper limb loss in Egypt and other developing countries, and has the potential to revolutionize the field of prosthetics.

4.3 Construction of the hand Step by Step



The final product:



Figure(4): shows the final product of CyberHand

Expected Outcomes

5.1 Potential Impact

The "CyberHand" has the potential to have a significant impact on the lives of people with upper limb loss, particularly those who have been injured in wars or other high-risk occupations. The following are some of the potential impacts that the project could have:

1- Improved Quality of Life: The CyberHand provides an affordable and highly interactive solution that can significantly improve the quality of life for people with upper limb loss. It offers a natural and intuitive way to control the hand, which can help users feel more comfortable and confident in their daily activities.
2- Increased Mobility and Independence: The ability to control a bionic hand can provide users with greater mobility and independence, allowing them to perform tasks that they may have previously struggled with, such as grasping objects, typing on a keyboard, or holding a pen.
3- Cost-Effective Solution: The CyberHand is designed to be a cost-effective solution that is accessible to a wide range of users. The low cost of production makes it an affordable option for people who may not have the financial resources to access other types of prosthetics.
4- Customizable Design: The CyberHand is designed to be customizable, allowing users to adapt the hand to their specific needs and preferences. This can provide a more personalized and comfortable fit, which can improve the overall user experience.
5- Social and Psychological Benefits: The CyberHand can also have social and psychological benefits for users, such as reducing the stigma associated with prosthetics and increasing self-esteem and confidence. This can, in turn, improve the overall well-being and mental health of users.

Overall, the potential impact of the CyberHand is significant, as it has the potential to improve the lives of people with upper limb loss and provide a cost-effective and customizable solution that is accessible to a wide range of users.

5.2 Functional and Performance Characteristics

The "CyberHand" is designed to have the following functional and performance characteristics:

1- EMG Sensor: The CyberHand uses an EMG sensor to detect muscle signals, which are then translated into movements by an Arduino microcontroller. The EMG sensor is capable of accurately detecting a wide range of muscle signals, allowing for precise and intuitive control of the hand.
2- Range of Motion: The CyberHand is designed to have a wide range of motion, allowing for natural and fluid movements. The hand is capable of performing a variety of grasping and gripping actions, such as pinching, grasping, and holding.
3- Strength and Durability: The CyberHand is designed to be strong and durable, capable of withstanding daily use and wear and tear. The hand is made from high-quality materials and is designed to be resistant to damage and breakage.
4- Customizability: The CyberHand is designed to be customizable, allowing users to adapt the hand to their specific needs and preferences. The hand can be adjusted for size, grip strength, and other parameters, providing a more personalized and comfortable fit.
5- Interactivity: The CyberHand is highly interactive, providing users with a natural and intuitive way to control the hand. The hand responds quickly and accurately to muscle signals, allowing for real-time control and feedback.
6- Affordability: The CyberHand is designed to be an affordable solution, with a production cost of only 3020 EGP. The low cost of production makes it accessible to a wide range of users who may not have the financial resources to access other types of prosthetics.

Overall, the CyberHand is designed to have a high level of functionality and performance, providing users with a natural and intuitive way to control the hand, while also being strong, durable, and customizable. The low cost of production also makes it an accessible and affordable option for a wide range of users.

5.3 Benefits for Individuals with Upper Limb Amputations or Disabilities

The "CyberHand" offers several benefits for individuals with upper limb amputations or disabilities, including:

1- Increased Independence: The CyberHand provides users with a natural and intuitive way to control the hand, allowing them to perform daily tasks and activities with greater independence and autonomy. The ability to grasp and hold objects can also increase mobility and reduce dependence on others.

2- Improved Quality of Life: The CyberHand can significantly improve the quality of life for individuals with upper limb amputations or disabilities. The ability to perform daily tasks and activities can provide a sense of achievement and satisfaction, while also reducing frustration and stress.

3- Customizability: The CyberHand is designed to be customizable, allowing users to adapt the hand to their specific needs and preferences. This can provide a more personalized and comfortable fit, which can improve the overall user experience.

4- Affordability: The CyberHand is designed to be an affordable solution, with a production cost of only 3020 EGP. The low cost of production makes it accessible to a wide range of users who may not have the financial resources to access other types of prosthetics.

5- Social and Psychological Benefits: The CyberHand can also have social and psychological benefits for users, such as reducing the stigma associated with prosthetics and increasing self-esteem and confidence. This can, in turn, improve the overall well-being and mental health of users.

Overall, the CyberHand offers significant benefits for individuals with upper limb amputations or disabilities, providing a cost-effective and customizable solution that can significantly improve the quality of life for users. The hand offers increased independence, mobility, and comfort, while also reducing frustration and stress and providing social and psychological benefits.

Budget

6.1 Expenses

The following is a breakdown of the expenses for the "CyberHand" project:

1- Six S3003 Servo Motors: 1320 EGP

- These motors are used to control the movement of the hand.

2- One Arduino Nano: 370 EGP

- The Arduino Nano is used to process the EMG signals and control the servo motors.

3- Two Batteries: 100 EGP

- These batteries are used to power the hand and the Arduino Nano.

4- Jumpers: 30 EGP

- These jumpers are used to connect the various components of the hand.

5- One EMG: 1000 EGP

- This EMG sensor is used to measure the muscle signals of the user.

➢ Total Expenses: 2820 EGP

The total cost of production for the "CyberHand" is 3020 EGP. This cost includes all of the components needed to build the hand, including the servo motors, Arduino Nano, batteries, jumpers, and EMG sensor. The low cost of production makes the CyberHand an affordable option for individuals with upper limb amputations or disabilities who may not have the financial resources to access other types of prosthetics.

6.2 Sources of Funding

Currently, the "CyberHand" project is being self-funded. However, we plan to seek funding from various sources to support the project and further its development. One potential source of funding is through investors, and we have applied to Egypt Shark Tank to seek an investor who shares our vision and can provide the financial support we need. In addition, we plan to explore other funding opportunities, such as grants and sponsorships, to help support the project. We will also seek to partner with organizations and institutions that share our mission of improving the lives of individuals with upper limb amputations or disabilities. We recognize that funding will play a critical role in the success of the "CyberHand" project, and we are committed to pursuing all available avenues to secure the resources we need to bring the project to fruition.

Sustainability

7.1 Plans for Scaling Up the Project

The "CyberHand" project has the potential to make a significant impact on the lives of individuals with upper limb amputations or disabilities. To ensure the sustainability and scalability of the project, we have developed the following plans:

1- Partnership and Collaboration: We plan to partner with organizations and institutions that share our mission of improving the lives of individuals with upper limb amputations or disabilities. By collaborating with like-minded organizations, we can leverage each other's strengths and resources to achieve our shared goals.

2- Research and Development: We plan to continue to invest in research and development to improve the functionality and performance of the CyberHand. By staying up-to-date with the latest advancements in prosthetics and related technologies, we can ensure that the CyberHand remains at the forefront of innovation.

3- Manufacturing and Production: We plan to scale up the production of the CyberHand to meet the growing demand for affordable and customizable prosthetics. By investing in efficient manufacturing and production processes, we can increase the availability and accessibility of the CyberHand to a wider range of users.

4- Marketing and Outreach: We plan to increase our marketing and outreach efforts to raise awareness of the CyberHand and its potential benefits. By reaching out to potential users, healthcare providers, and other stakeholders, we can increase demand for the CyberHand and expand its reach.

Overall, we believe that the CyberHand project has the potential to make a significant impact on the lives of individuals with upper limb amputations or disabilities. By investing in partnerships, research and development, manufacturing and production, and marketing and outreach, we can ensure the sustainability and scalability of the project and continue to make a positive impact for years to come.

7.2 Challenges

While the "CyberHand" project has the potential to make a significant impact on the lives of individuals with upper limb amputations or disabilities, there are several challenges that we may face in ensuring the sustainability and scalability of the project. These challenges include:

1- Funding: One of the biggest challenges we face is securing the funding needed to support the project and bring it to scale. While we are currently self-funded and have applied to Egypt Shark Tank for investment, we may need to explore additional funding sources to support the growth of the project.

2- Manufacturing and Production: As we scale up the production of the CyberHand, we may face challenges in ensuring consistent quality and efficient production processes. We will need to invest in manufacturing and production technologies and processes that can meet the growing demand for the CyberHand while maintaining high quality standards.

3- Regulatory Compliance: The CyberHand may be subject to regulatory compliance requirements, particularly if we plan to sell it in markets outside of Egypt. We will need to ensure that the CyberHand complies with all relevant regulations and standards to ensure its safety and effectiveness.

4- Competition: There may be other companies or organizations working on similar prosthetics solutions, which could create competition for the CyberHand. We will need to continue to invest in research and development to ensure that the CyberHand remains at the forefront of innovation and can stay competitive in the market.

5- Awareness and Education: There may be a lack of awareness and education among potential users and healthcare providers about the benefits of the CyberHand. We will need to invest in marketing and outreach efforts to raise awareness and educate potential users and providers about the CyberHand and its potential benefits.

Overall, while there are several challenges that we may face in ensuring the sustainability and scalability of the CyberHand project, we believe that with careful planning and investment, we can overcome these challenges and continue to make a positive impact on the lives of individuals with upper limb amputations or disabilities.

7.3 Plans for Ongoing Development and Sustainability

To ensure the ongoing development and sustainability of the "CyberHand" project, we have developed the following plans:

1- Continued Research and Development: We plan to continue to invest in research and development to improve the functionality and performance of the CyberHand. This includes exploring new technologies and materials, as well as improving the software and hardware components of the hand.
2- Collaboration and Partnerships: We plan to continue to seek out partnerships and collaborations with organizations and institutions that share our mission of improving the lives of individuals with upper limb amputations or disabilities. By working together, we can leverage each other's strengths and resources to achieve our shared goals.
3- Manufacturing and Production: We plan to continue to invest in efficient manufacturing and production processes to ensure the scalability and sustainability of the CyberHand project. This includes exploring new manufacturing technologies and processes, as well as improving the supply chain and distribution channels for the hand.
4- Regulatory Compliance: We plan to ensure that the CyberHand complies with all relevant regulations and standards, both in Egypt and in other markets where we plan to sell the hand. This includes staying up-to-date with regulatory changes and investing in compliance measures to ensure the safety and effectiveness of the CyberHand.
5- Marketing and Outreach: We plan to continue to invest in marketing and outreach efforts to raise awareness of the CyberHand and its potential benefits. This includes developing targeted marketing campaigns and outreach strategies to reach potential users, healthcare providers, and other stakeholders.

Overall, we believe that by investing in ongoing development and sustainability measures, we can ensure the long-term success of the CyberHand project and continue to make a positive impact on the lives of individuals with upper limb amputations or disabilities.

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