Handsome Technology
School of Engineering Science
Simon Fraser University Burnaby
British Columbia V5A 1S6

June 23, 2017

Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University Burnaby
British Columbia V5A 1S6

Re: Requirements Specification for Handsome 1.0

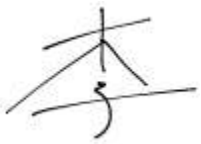
Dear Dr. Rawicz,

The attached document, Requirement Spec for Handsome 1.0, outlines the detail product requirements for our ENSC 440 (Capstone Engineering Science Project). Our primary goal is to research the approach of a prosthetic forearm for those who work in environments with safety concerns. Therefore they can be protected from the contamination and the risks while performing operations with their hands.

The requirements specification will describe the proof-of-concept and production phases of development and production device phase by listing the requirement of function, electrical and physical aspects. Our engineers will use this document as a guide for design and development activities.

Handsome Technology Inc consists of four innovative and intelligent engineering students: Yi Luo, Dantong Huang, Bairong Li, Cyrus Chan. If you have any questions or concerns about our requirement specification, please feel free to contact me by phone at 778-9199-9133 or by email at bairongl@sfu.ca.

Sincerely,



CEO
Handsome Technology Inc

Enclosure: Requirements Specification for Handsome 1.0

Requirement Specification

for the Handsome 1.0 Prosthetic Hand

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Date June 23, 2017

Executive Summary

Imagine yourself as a born maker and tinkerer, who loves engineering and playing basketball. How would losing your hand one day affect your life [1]? According to National Center for Health Statistic, there are about 50000 new amputations every year in the USA [2]. Most common is partial hand amputation with the loss of 1 or more fingers [2]. For those who work in an environment with potential risks such as builders, roofers, and electric welders, one careless decision made at work will lead to loss of fingers or hands. We came up the approach to design multifunctional and adaptive prosthetic hands that take place in human hand to perform tasks. There is a variety of prosthetic limbs existing in the market. They are primarily designed to function as a person's replacement limb. However, we believe rather than replacing people's missing limbs with artificial limbs, we can protect them from losing their own limbs.

Motivated by this thought, our company designs and manufactures prosthetic forearm named Handsome 1.0, which protects those who work in environments with safety concerns from potential risks while being able to perform operations as using their hands. Due the budget and time constraints, a Handsome 1.0 hand will not be dexterous enough to realize the behaviour of a human hand. However, it will be able to pose several hand gestures, wrist gestures, and grab objects with some constraints. The details will be covered in the Requirement Specification.

The development cycle of Handsome 1.0 uses the waterfall methodology which makes the process easier to manage [3]. This breaks down into five phases:

i. **Concept Exploration** – *Team identifies the idea and need for high level solution.*
ii. **Requirements Analysis** – Team gathers, specifies and analyzes the requirements as well as developing functionality and scope of the product
iii. **Hardware and Software Design** –Team designs how to structure the hardware and software to meet the requirements
iv. **Implementation** – Team builds the product, programming the Bluetooth Low Energy, EMG sensor and embedded system.
v. **Testing** – Testing individual module, group of modules combinations and the whole system

This document will provide hardware and software requirements specification with their subcategories. Our team will follow these requirements specification as the guidelines in developing Handsome 1.0 for the best solution.

Table of Content

Glossary

CPSC	Consumer Product Safety Commission
CSA	Canadian Standards Association
BLE	Bluetooth Low Energy
EIA	Electronic Industries Alliance [4]
EMG	Surface Electromyography
InMoov	The first Open Source 3D printed life-size robot [5]
RoHS	Restriction of Hazardous Substances
Prosthetic hand	The robotic hand that partially realize human hand functionality or behaviour

List of Figure

1 Introduction

Handsome 1.0 is a prosthetic hand is capable of grabbing objects with certain size and weights and performs some basic hand gestures. To use Handsome 1.0 prosthetic hand, a user needs to attach surface Electromyography (EMG) sensor electrodes, as well as the gravity sensors to specific locations on his forearm and wrist. The sensors will analyze the signals collected while the user is moving his hand, and sends instructions to the robotic hand to change its gestures. The force sensitive resistors on the fingertips of the prosthetic hand will ensure the object is held when grabbing objects. The requirements of using Handsome 1.0 will be covered in this document

1.1 Scope

This document includes the details in functions, behaviours and appearance in the design of the Handsome 1.0 to give audience instructions for the goal of the project. Preparations and conditions for the usage of each part of the product are also covered in this document to assist the audience to perform system tests. The listed requirement will be traceable on our final product.

1.2 Intended Audience

The functional specification is intended for all members in the developing team of Handsome 1.0 project. Functional details listed in the documentation are used to arrange and distribute tasks to each member through the development. All the members shall keep in mind with the requirements listed to design, test and to assess the completeness of their tasks. Any changes made to the functional details included in this documentation must be discussed and agreed by each team member.

1.3 Requirements Classification

We separate our design of Handsome 1.0 into two stages. The first stage we will produce a proof-of –concept product and the second stage we will produce a final product. To clarify the goals in each stage for the audience, the following convention shall be used to denote the requirements throughout the documentation: 7

[Rn-p] A requirement

Where n is the functional requirement number, and p is the priority of the functional requirement as denoted by one of three values:

- I - The requirement apply to the proof-of-concept system only.
- II - The requirement applies to both the proof-of-concept system and the final production system.

- III - The requirement applies to the final production system only.

2 System Overview

The Handsome 1.0 prosthetic hand consists of two ends that communicate through Bluetooth devices.

The user end device contains two channels of EMG sensors. The user needs to locate the sensor on his right arm as the following picture shown to get the best results. After the electrodes are placed properly, the user can turn on the device and start calibration.

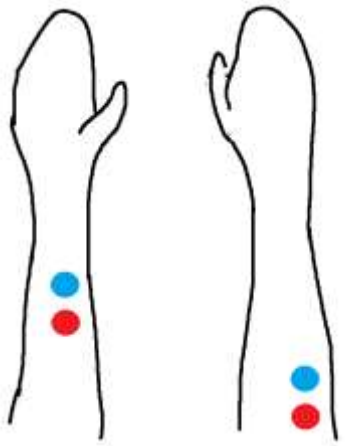

Figure 1, position of electrodes

Due to the budget constraints, in the first stage of our design, the system can only identify the following six gestures by analyzing the EMG signals from the two channels. If the user poses another gesture, the sensor will likely to recognize it as one of these six gestures.

Figure 2, six hand gestures

Besides the hand gestures, wrist gesture will also be added in the production device. The sensor can decide if the hand is facing upwards or downwards.

The other end of the device is the robotic hand. We used InMoov 3D hand and forearm model driven by a blue tooth device and a microcontroller. The motion of the fingers and wrists in InMoov hand model is controlled by pulling the strings connected through the joints. The motors that drive the robotic hands are placed inside of the forearm.

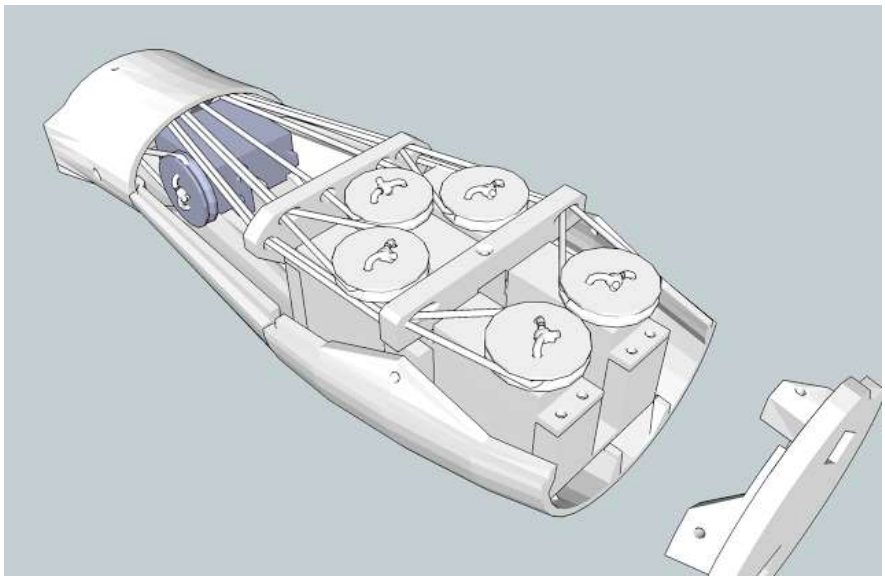

Figure 3, motor placement in InMoov forearm [5]

The design is easy to implement and good for some common gestures and grabbing objects. However, some movements, such as lateral motions of fingers and lifting the fingers in the direction of the back of the hand are constrained due to the design.

After locating the sensor and turning on the device, the user can move the prosthetic hand in one of the above gestures or grab object by posing his hand to the gesture.

2.1 General Requirement

[R1-II]	The robotic hand shall have an idle state with all fingers straightened. The robotic hand must return to its idle state before shutting down the system.
[R2-II]	The user must not be diagnosed having muscle or never diseases on the right arm.
[R3-II]	The robotic hand shall respond to the motion of the user within 1 second.
[R4-II]	The total cost of Handsome 1.0 shall not exceed 600 CAD.

2.2 Physical Requirement

[R5-III]	The total weight of the device shall not exceed 3 kg.
[R6-III]	The sensor kit and the prosthetic hand shall remain in two parts.
[R7-II]	The appearance of the design of the two parts shall be consistent.

2.3 Electrical Requirements

[R8-II]	The power supply for the prosthetic hand the sensor kit shall remain isolated.
[R9-III]	The batteries used shall be easy to replace.
[R10-III]	All electrical components and wiring of shall be concealed.

2.4 Mechanical Requirements

[R11-II]	The product shall maintain its current state until user changes his gesture.
[R12-III]	All parts that are not automatically adjustable shall only be move through knobs or other pre-existing mechanisms.
[R13-III]	The mechanical components of the product should not be physically obtrusive.

2.5 Environmental Requirements

[R14-II] The product shall operate normally under room temperature (15 – 30 ℃).

[R15-III] Noise generated by the movement of the product shall be minimized.

[R16-III] Noise generated by the movement of the product shall be under 50dB.

[R17-III] All the materials that are used for prosthetic hand and the sensor kit shall be environmental friendly.

[R18-II] The product must not be used under water.

[R19-II] The product shall be silent when it is inactive.

[R20-II] The product shall be used in both indoor and outdoor situation.

2.6 Standards

[R25-II] The BLE device shall conform to the EIA Standards [5].

[R21-II] All components should be RoHS compliant [6].

[R22-II] Handsome 1.0 shall conform to CSA standards [7].

[R23-II] Handsome 1.0 shall conform to CPSC standards [8].

2.7 Reliability and Durability

[R26-III] The product shall achieve listed gestures on the user manual.

[R27-III] The product shall be able to withstand day-to-day usage.

[R28-III] The prosthetic hand shall be remaining on and active for at least 2 hours when using a portable power source.

[R29-III] The system shall be serviceable by trained technicians.

[R30-III] The whole product shall last for at least three years without needing parts replacement.

[R31-III] The product shall prevent interference from potential signals generated by the ambience.

2.8 Safety Requirements

[R32-II] The product shall not cause bodily harm to user.

[R33-II] The product shall not spontaneously combust or fall apart.

[R34-II] The prosthetic hand shall stop squeezing when the squeezing force exceeds the pre-set threshold.

[R35-II] The product shall not produce significant radiation when it is active or inactive.

[R36-III] All electronic components must be enclosed.

2.9 Performance Requirements

[R37-II] The response time for the prosthetic hand performing a specific gesture shall not be exceed 1 s.

[R38-III] The prosthetic hand shall remain initial state when an unknown gesture is detected.

[R39-III] The prosthetic hand shall be able to lift a cylindrical object under 1.5 lb.

[R40-III] The prosthetic hand shall not lift a spherical object under 1.5 lb.

[R41-III] The prosthetic hand shall not lift object smaller than tennis ball.

2.10 Usability Requirements

[R42-II] The surface of the skin shall be cleaned before attaching the electrodes.

[R43-II] The electrodes shall be placed at the correct positions to obtain useful muscle signals.

[R44-II] The prosthetic hand shall be dismountable when a user is relocating it to different place.

[R45-III] The firmware of the product shall be upgradeable by the engineer.

3 The Prosthetic Hand Requirements

The prosthetic hand is a significant part of the product. We used Inmoov 3D printed hand and forearm as our model for the prosthetic hand for simpler design and implementation. The model has pre-designed slots to hold six motors that control the motion of the hands. Each finger is controlled by a string connecting through the joints the motor. The the prosthetic hand receives the encoded gesture information from the sensor kit and moves the motors certain degrees to reproduce the gesture. All the gestures are predefined and stored in a look up table; the hand only needs to decode the information from the Sensor Kit and search for a match in the look up table.

Following six gestures are registered in the prof-of-concept Product (refer to figure 2):

- Cylindrical grasp
- Spherical grasp
- Thumb
- Middle

More gestures including the following will be added in the final product.

- Index
- Bent-thumb
- Wrist motion

3.1 General Requirements

[R46-III] The prosthetic hand shall be 3D printed and integrated by the engineers.

[R47-II] Five fishing lines shall connect the servo motors with the finger joints respectively.

[R48-III] The maximum time to curl or straighten a finger shall not exceed 1 second.

[R49-III] The maximum time to perform a known gesture shall not exceed 1 second.

[R50-III] Wrist rotation shall be controlled by one servo motor.

[R51-III] The maximum time for a full wrist rotation from a palm up to a palm down position shall not exceed 1 second.

[R52-III] Elbow rotation shall be controlled by one servo motor.

3.2 Physical Requirements

[R53-III] The length of the prosthetic hand shall not exceed 60 cm.

[R54-III] The weight of the prosthetic hand shall not exceed 1.5 kg.

[R55-III] The appearance of the prosthetic hand shall be sexy.

3.3 Electrical Requirements

[R56-III] The power supply shall be sufficient to support the movement of the prosthetic hand.

[R57-III] The power adapter shall be usable with a wall supply of 110V/120V at 60Hz DC.

[R58-III] Portable power source for the prosthetic hand shall provide at least 4.8 V supply voltage to power the servo motors.

[R59-III] The portable power source for the prosthetic hand shall be rechargeable.

[R60-III] The battery life for the prosthetic hand shall be at least 2 hours before requiring batteries recharging.

4 The Sensor Kit Requirements

The sensor kit is separate device which has its own power supply. The sensor kit contains the following parts:

- surface EMG sensors
- gravity sensors
- Bluetooth module

While the sensors are contacting directly with the user, the associated hardware signal processing circuits and signal classification system are concealed in the kit. The sensor is

responsible of collecting the signal, identifying and encoding the gesture for the robotic hand inputs.

4.1 General Requirements

[R61-III] The sensor shall identify and report the bad channel during operation using identifier LEDs.

[R62-II] The sensor shall support serial port for debugging purposes.

4.2 Physical Requirements

[R63-III] Circuitries and wires excluding sensor wires shall not be exposed.

[R64-III] The total weight of the sensor shall not exceed 1 kg.

4.4 Electrical Requirements

[R65-III] The sensor shall be power by 5V button batteries.

5 BLE Requirements

Bluetooth Low Energy serves several important functions, including the following:

- To Scan the BLE devices available
- To establish a link between the sensor kit and the prosthetic hand
- To perform reliable wireless data transmission between two devices

5.1 General Requirements

[R66-II] All BLE devices shall have an electronic output compatible with the sensor kit and the prosthetic hand.

[R67-II] The scanning range of all BLE devices should be at least 100 meters.

[R68-III] All BLE devices shall have frequency between 2.402 GHz and 2.481GHz.

[R69-III] The BLE devices shall have maximum data rate at 1 Mbit/s.

[R70-III] The pairing between the BLE module and the BLE dongle shall be completed within 1minute.

[R71-III] The BLE module shall have adjustable baud rate.

[R72-III] The BLE module shall be able to send string back and forth.

5.2 Physical Requirements

[R73-III] The length of the BLE device shall be less than 60mm.

[R74-III] The width of the BLE device shall be less than 25mm.

[R75-III] The height of the BLE device shall be less than 6mm.
[R76-III] The weight of the BLE device shall be less than 5g.

5.3 Electrical Requirements

[R77-III] The BLE device shall be supplied with an external power source of at least 5V.
[R78-III] The RX/TX pin shall connect to a voltage divider to get supply voltage of 3.3V.

6 User interface Unit Requirements

The user interface unit shall include a set of power on and off switches, reset buttons for EMG sensors and prosthetic hand and Bluetooth pairing button. Error displaying shall also be included.

6.1 Usability Requirements

[R79-III] Power switches shall be turned on when the sensors and prosthetic hand are ready to be used.
[R80-III] Bluetooth pairing button shall be pressed to establish Bluetooth connection between sensor side and prosthetic hand side.
[R81-III] Reset buttons shall be pressed when an unexpected error occurs.

6.2 Physical Requirements

[R82-III] The power switch for the prosthetic hand shall be placed near the elbow.
[R83-III] The power switch for the sensor side shall be placed outside of the battery holder.
[R84-III] The LED shall be placed next to the power switch of the prosthetic hand.
[R85-III] The reset button of the sensor side shall be placed outside of the battery holder.
[R86-III] The rest button of the prosthetic hand shall be placed next to the power switch.

7 User Documentations

[R87-III] The User documentation shall include a website with general support information and a user manual, both written in English.
[R88-III] The User documentation shall include details of product installation.

[R89-III] The user manual shall be written for an audience with minimal knowledge.

8 Conclusions

The requirements specification of Handsome 1.0 provides a clear set of functionalities. The requirements in each section are categorized under proof of concept, prototype, and final production. Our engineers will use this document as the guidance while designing and implementing phase of Handsome 1.0. Therefore, top priority features will be developed first in order to build a functional product. The prototyping model is in progress and it is expected that all requirements specification mentioned above applying to the final product will be built by the expected completion date of December 12, 2017.

Reference

[1] "Open Bionics - James Dyson Award", *James Dyson Award*, 2017. [Online]. Available: https://jamesdysonaward.org/projects/open-bionics-3/. [Accessed: 28- May- 2017]

[2] "Statistics on hand and arm loss", *Ishn.com*, 2017. [Online]. Available: http://www.ishn.com/articles/97844-statistics-on-hand-and-arm-loss. [Accessed: 28-May- 2017]

[3] Wikipedia, “Waterfall model,” [Online]. Available: https://en.wikipedia.org/wiki/Waterfall_model

[4] "List of EIA Standards - ECIA", ECIA, 2017. [Online]. Available: https://www.ecianow.org/list-eia-standards/. [Accessed: 27- Jun- 2017].

[5] "InMoov | open-source 3D printed life-size robot", Inmoov.fr, 2017. [Online]. Available: http://inmoov.fr/. [Accessed: 23- Jun- 2017]

[6] RoHS, “RoHS Guide Complicance”, 2015. [Online]. Available: http://www.rohsguide.com. [Accessed: 21- June- 2017]

[7] "CSA Group", En.wikipedia.org, 2017. [Online]. Available: https://en.wikipedia.org/wiki/CSA_Group. [Accessed: 24- Jun- 2017].

[8] "U.S. Consumer Product Safety Commission", En.wikipedia.org, 2017. [Online]. Available: https://en.wikipedia.org/wiki/U.S._Consumer_Product_Safety_Commission. [Accessed: 24- Jun- 2017].

Appendix

Functions we will demonstrate for proof-of-concept product:

1. A whole 3D print right forearm can be used to be the prosthetic product
2. The prosthetic forearm can be remote controlled
3. The prosthetic hand can do following gesture:
    i. Spherical grasp
    ii. Cylindrical grasp
    iii. Thumb
    iv. Index
4. The user can use the prosthetic product to grab cylindrical item that is less than 1.5kg
5. The user can use the prosthetic product to grab cylindrical item that is in the diameter range from 6cm to 8cm

Functions we will not demonstrate for proof-of-concept product:

1. Not breaking any delicate objects when grasping
2. Concealed circuits and micro-controllers
3. Wrist orientation of the prosthetic hand
4. Other hand gestures