June 16, 2018
Dr. Andrew Rawicz
School of Engineering Science
Simon Fraser University
British Columbia, V5A 1S6

RE: ENSC 405W/440 Requirements Specification for OptiCue

Dear Dr. Rawicz,

This requirement specification document for OptiCue was prepared by Aperture Solutions for ENSC 405W/440. Our goal for the capstone project is to use real-time facial expression recognition as a solution for autistic individuals who cannot recognize social cues. OptiCue is meant to be an accessible tool to be used in a learning or therapeutic environment, or individually on a day-to-day basis.

OptiCue will use a camera to send image data to a microprocessor to perform real-time facial expression detection. It will then provide feedback to the user on the expression of the individual they are interacting with using audio output.

The requirements specification will cover requirements from the proof of concept to the prototype to the final product, which will provide a timeline for the deliverables for our project. This document will review general requirements as well as more specific requirements such as those for our software and electronic components. Lastly, this document will also discuss safety and sustainability requirements, as well as the engineering standards our product will be conforming to.

Our team would like to thank you in advance for taking the time to review our requirements specification. If you have any questions, please feel free to email me at mparkhur@sfu.ca.

Sincerely,

Maggie Parkhurst-Bartel

Maggie Parkhurst-Bartel
CEO
Aperture Solutions

APERTURE
SOLUTIONS INC.

# Requirements Specification:
# OptiCue


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# Abstract

This document specifies the functional requirements of the wearable device for facial expression recognition, OptiCue. First, it will present the requirements that describe OptiCue's core functionality, then the requirements for each component will be analyzed separately in the subsequent sections. This document will also detail the Engineering Standards, and Sustainability and Safety factors that our product must meet. The goal of this document is to give the reader a detailed understanding of the device, its purpose, and its operation, while omitting the design details that will be described at a later date.

The OptiCue is a system comprised of three parts: a camera to capture the image of the subject's face, a microcontroller to perform the image processing and derive the facial expression of the subject, and an audio output portion that provides feedback to the user on the current emotions of the subject. The user interface will consist of a power button and a button to start/stop analyzing faces. This makes the device simple and intuitive to use, requiring no background or expertise from our consumer.

The requirements for OptiCue include the following main components:

- General Requirements: including system and functional requirements.
- Software Requirements: including general, image processing, and performance requirements.
- Electrical Requirements: including general, power, and output requirements.

This document will conclude by discussing the planned deliverable for the proof of concept to be shown in August 2018.

# List of Figures



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# Glossary

The following table includes a list of terms mentioned throughout the paper.

| Term | Definition |
|---|---|
| Alexithymia | The inability to recognize emotions and their subtleties and textures |
| EMC | A microcontroller is a compact integrated circuit designed to govern a specific operation in an embedded system |
| Microcontroller | Relating to a system in which input data is processed within milliseconds so that it is available virtually immediately as feedback |
| RPi | Raspberry Pi |

# Contents

# 1 Introduction

By providing facial expression recognition in a user and cost friendly device, Aperture Solutions has been able to create OptiCue. This compact and wearable device uses a small and discrete camera to capture images of the individual the user is interacting with. These images are then sent to a microcontroller which performs some image processing using a facial detection API. Finally, based-off of the image processing, will send feedback to the user regarding the current expression.

With an emphasis on an intuitive and user-friendly interface, and on compactness and portability of the device, Aperture Solutions aims to make the OptiCue a tool for everyone. It is also our hope to keep the cost of the device low, and therefore make it accessible to everyone.

## 1.1 Background

Following Moore's law, hardware has become increasingly small and lightweight with each passing decade. This trend has made it possible for small handheld chips to hold enough processing power to run complex modern software and perform computationally intensive operations in real time. Using this modern hardware capability, the team at Aperture developed the OptiCue wearable device, an innovative solution to help the lives of those living with Autism and similar conditions that prevent them from recognizing social cues.

To date, there has been very little development in technology that help people living with Autism and similar conditions. OptiCue aims to provide assistance in helping the user recognize social cues and read facial expressions. To achieve this, OptiCue will process the images of the face of the person that the user is interacting with, use image processing to determine the person's emotions, and provide feedback back to the user in real time.

## 1.2 Scope

This document outlines the functional requirements of OptiCue to be met by our team at Aperture Solutions. This includes the general functional requirements that must be met by the system as a whole, as well as the requirement specifications for each component. These requirements will also be categorized by their stage of development, i.e. proof of concept, prototype, and finished product. The document also outlines the compliance with Engineering Standards and efforts towards Sustainability/Safety.

## 1.3 Intended Audience

This document serves as OptiCue's functional requirements for Aperture Solutions Inc. members, its potential clients and partners, Steve Whitmore, Dr. Andrew Rawicz, and teaching assistants.  Future revisions will draw from the framework detailed in this document.

## 1.4 Requirement Classification

The requirements in this document will follow the following convention:

**Req {Section}.{Subsection}.{Requirement Number} {Stage of Development}**

The different stages of development are outlined in the table below:

| Encoding | Stage of Development |
|---|---|
| C | Proof of Concept |
| P | Prototype |
| F | Final Product |

**Table 1.4.1** - Development Stage Encoding

The Proof of Concept requirements specify the requirements that must be met by the end of ENSC 405W. The Prototype requirements specify the requirements that must be met by the prototype by the end of ENSC 440W. The Final Product requirements specify the requirements that must be met by the device once it is in production.

# 2 System Overview

OptiCue is a small wearable device used to detect facial expressions and alert the user when the other parties facial expression changes. The OptiCue is designed for those with disorders, such as autism, which prevent them from recognizing emotion and social cues, a condition known as alexithymia. With the proper training, especially at a young age, people suffering from alexithymia can learn to recognize certain facial expressions. It is our goal to provide a small, low-cost, and easy-to-use device to aid people with alexithymia in their social endeavors.


**Figure 2.1** - OptiCue Concept 3D Model

Figure 2.1 shows a concept design for the OptiCue. This device is 70mm tall, 45mm wide and 20mm in depth. We might require more flexibility in camera placement as we have yet to do any real-world testing, but this design shows the simplicity of the device we hope to achieve. The only actions the user needs to take to use the device should be to power it on, attach it to their clothing and plug in a set of headphones. The OptiCue will automatically start to analyze the incoming images and send alerts to the user through the headphones.

The OptiCue's hardware was specifically chosen to perform the task of facial expression detection. Powered by a Raspberry Pi (RPi) Zero, the OptiCue will be able to record and analyze images taken with its onboard 5 MP camera. Operating at 1 GHz on a single core, the RPi should be able to handle the processing of an image in near real-time. Using custom circuitry, the Raspberry Pi will also be capable of outputting audio to a headphone jack which will be used to send the user alerts. Additionally, provided we have enough time, we would like to use the RPi's built in Bluetooth capabilities to communicate with the user's smartphone to track detection data and change device settings. Given the

low current draw of the Raspberry Pi Zero and all of the peripherals we will be adding, we should be able to get a full day of usage out of the 2200 mAh battery that will be included with the OptiCue. See figure 2.2 below for a visual representation of the OptiCue's hardware.

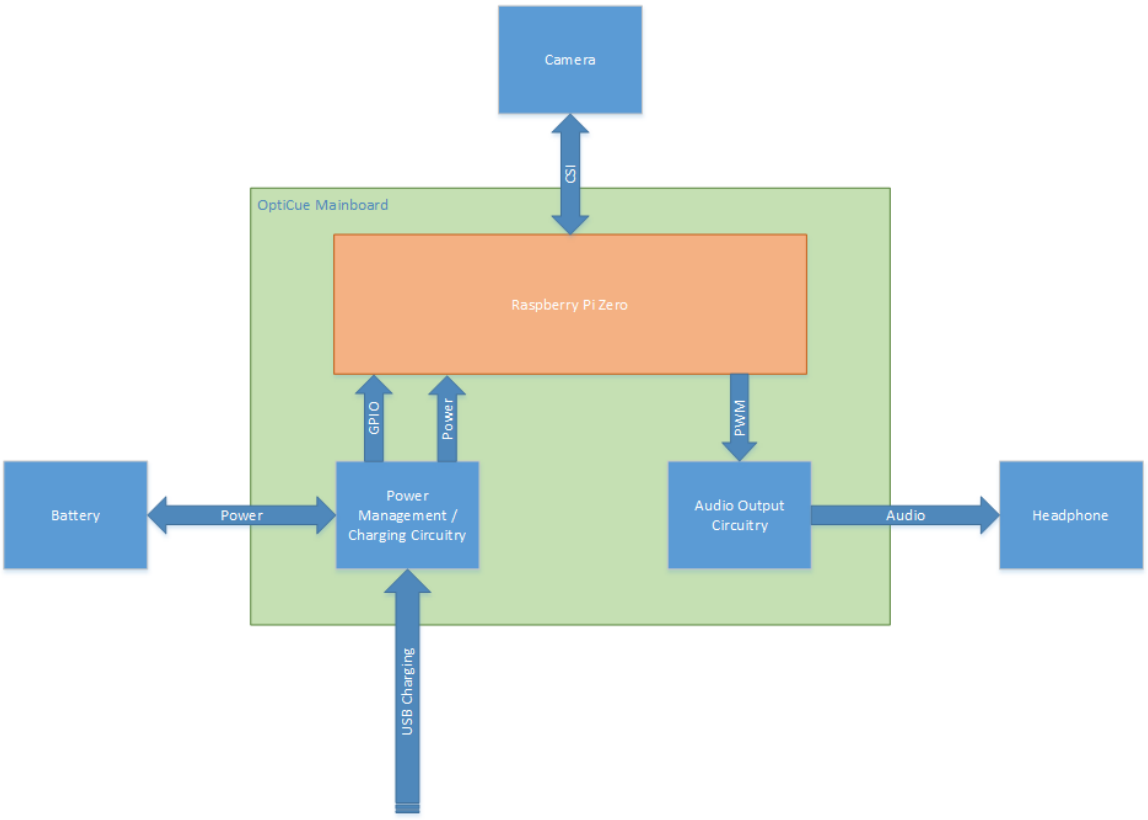


**Figure 2.2** - OptiCue System Block Diagram

The OptiCue is small, powerful tool built specifically for those with alexithymia. Its small form factor coupled with its robust internals make it a perfect wearable solution for everyday use. With the OptiCue, patients will be able to train themselves to recognize basic emotional expressions and react appropriately. Our objective is to make life a little bit more manageable for people who struggle with emotional recognition.

# 3 General Requirements

This section describes the general requirements for the system as a whole. The requirements for each component of the system will be detailed in the following sections.

## 3.1 System Requirements

The following table includes the general requirements for the system.

| Requirement ID | Requirement Description |
|---|---|
| **Req 3.1.1 P** | The system will consist of a microcontroller, a camera, an audio output, a charger, and a battery. |
| **Req 3.1.2 P** | The device must determine the face of the person that the user is interacting with. |
| **Req 3.1.3 P** | The device must determine the emotion from the facial expressions on the person's face. |
| **Req 3.1.4 P** | The device must provide audio feedback to the user about the emotion of the person that the device is analyzing. |
| **Req 3.1.5 P** | The device will have an on/off button and a start/stop button. |
| **Req 3.1.6 P** | The device must fit within a breast pocket. |
| **Req 3.1.7 P** | The price of the final product must be under $200. |
| **Req 3.1.8 P** | The device must have a battery life of 12 hours. |

**Table 3.1** - System Requirements and Progress

## 3.2 Functional Requirements

The following table includes the general requirements for the system's functionality.

| Requirement ID | Requirement Description |
|---|---|
| **Req 3.2.1 P** | Correctly determine which face in the image the person is talking to from the faces that are in the background. |
| **Req 3.2.2 P** | Complete the image processing and determine the emotion within a delay of 0.5 seconds. |

**Table 3.2** - Operational Requirements and Progress

# 4 Software Requirements

The software will make use of the OpenCV, which is a highly optimized library for performing image processing, facial recognition, and emotion classification. To meet the performance requirements, the software will be written in C++, which runs much more efficiently than dynamically typed languages like python and takes advantage of compiler optimizations which interpreted languages cannot.

While the device is powered on, but not actively detecting facial expressions, the software will enter sleep mode to conserve battery power.

The software will attempt to handle any exceptions and resume normal operations if possible. In the event where the exception cannot be recovered from, the software will inform the user by audio that a critical failure has occurred.

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## 4.1 General Requirements

The following table includes the general requirements for the system software.

| Requirement ID | Requirement Description |
|---|---|
| **Req 4.1.1 C** | The software must be able to run on basic desktop computer |
| **Req 4.1.2 C** | The software must be able to find the face in am image and determine the facial key points. |
| **Req 4.1.3 P** | The software must determine the facial expression using facial key points determined from the image |
| **Req 4.1.4 P** | External memory for Raspberry Pi must be large enough to contain software and several images. |
| **Req 4.1.5 P** | Software, hardware, and GPIO interrupts will not result in undefined system behaviour. |
| **Req 4.1.6 P** | The software must inform the user using audio if it encounters an exception that it cannot be recover from without a reboot. |
| **Req 4.1.7 P** | The software must send an audio signal to the audio jack to provide the feedback to the user. |
| **Req 4.1.8 P** | The software must choose the correct audio signal to send when providing feedback to the user. |

**Table 4.1** - General Software Requirements and Progress

## 4.2 Image Processing Requirements

The software will use computer vision techniques detect faces. Facial recognition technology has become extremely precise in the past two decades, with the results from the Face Recognition Grand Challenge in 2006 having a ten-fold improvement in accuracy compared to those in 2002, with some algorithms even outperforming humans [1].

The following table includes the image processing requirements for the system software.

| Requirement ID | Requirement Description |
|---|---|
| **Req 4.2.1 C** | The software must be able to correctly identify a face in an image. |
| **Req 4.2.2 C** | The software must classify expression images with an 80% success rate. |
| **Req 4.2.3 P** | The software will use the OpenCV library algorithms. |

**Table 4.2** - Image Processing Requirements and Progress

## 4.3 Performance

The following table includes the performance requirements for the system software.

| Requirement ID | Requirement Description |
|---|---|
| **Req 4.3.1 P** | The software must have a startup time of less than 10 seconds. |
| **Req 4.3.2 P** | The software must recover from an idle state within 4 seconds. |
| **Req 4.3.3 F** | The software will automatically restart in the event of a deadlock. |

**Table 4.3** - Software Performance Requirements and Progress

# 5 Electrical Requirements

The heart of our device is the software analysis used to identify emotions and facial expressions real-time during a conversation. To make this possible as a portable product, there needs to be a lot of thought put into the hardware used to run the necessary programs. As a small wearable device, the hardware used must not be bulky and power efficiency is key in the design.

For the proof of concept, we do not expect to be using any specialized hardware, as we only intend to demo the software capabilities at that stage. The prototype however, will have all necessary circuit to efficiently run our specialized software, as well as the audio output circuitry used for feedback to the user.

## 5.1 General

The following table includes the general requirements for the system's electronics.

| Requirement ID | Requirement Description |
|---|---|
| **Req 5.1.1 P** | Circuit protection for all specialized hardware (Raspberry Pi, Camera, Audio) |
| **Req 5.1.2 P** | Circuit protection in case of electrical failures |
| **Req 5.1.3 P** | Wiring Standards must be upheld |
| **Req 5.1.4 F** | Printed Circuit Board must be EMC compliant |

**Table 5.1** - General Electrical Requirements and Progress

## 5.2 Power Supply

The following table includes the power requirements for the system's electronics.

| Requirement ID | Requirement Description |
|---|---|
| **Req 5.2.1 P** | The supply circuit must supply a minimum 500mA of current |
| **Req 5.2.2 P** | The Raspberry Pi needs between 5V to 3.3V to operate |
| **Req 5.2.3 P** | Battery life capable of sourcing current for at least a full day |
| **Req 5.2.4 P** | Battery must be charged with constant voltage and current at a rate of 1A |

**Table 5.2** - Power Supply Requirements and Progress

## 5.3 Audio Output

The following table includes the audio requirements for the system's electronics.

| Requirement ID | Requirement Description |
|---|---|
| **Req 5.3.1 P** | Output signal must be between 1V to 2V in amplitude to drive the headphones |
| **Req 5.3.2 P** | Output signal must not exceed current limits of the Raspberry Pi GPIO pins |
| **Req 5.3.3 P** | Filtering circuits must be used to attenuate any unwanted noise |

**Table 5.3** - Audio Requirements and Progress

# 6 Safety and Sustainability

Our device contains electronic components, which may pose an electrical hazard if the user comes in contact with the wiring, and a fire hazard if the electronic overheats. We will require the final product to hide all circuitry to prevent users from coming in contact with the wiring, and the device to monitor the temperature of the microcontroller and shut down should the temperature exceed the safe operating temperature.

The following table includes the safety and sustainability requirements for the system.

| Requirement ID | Requirement Description |
|---|---|
| **Req 6.1.1 P** | The packaging of the small components shall display warnings for choking hazard. |
| **Req 6.1.2 F** | The device shall not have sharp edges that may hurt a user. |
| **Req 6.1.3 F** | The electronics shall be fully enclosed and under normal operating conditions shall not pose an electrical hazard. |
| **Req 6.1.4 F** | The battery and circuitry shall not pose a fire or explosion hazard under normal environmental conditions. |
| **Req 6.1.5 F** | The packaging must conform to the product labeling requirements as outlined by ISO 28219:2017 |
| **Req 6.1.6 F** | The device shall not be constructed using any materials that are toxic to a human. |
| **Req 6.1.7 F** | The device shall safely power off in the event where any electronic components overheat. |

**Table 6.1** - Safety and Sustainability Requirements and Progress

# 7 Engineering Standards

To sell OptiCue in Canada, we would need to adhere to Canadian laws and standards. Being that this device is to be worn by humans, we must take every precaution necessary with respect to health and safety. The following standards will be met to the best of our ability as we move forward with our prototype.

## 7.1 Electrical

The following table includes the electrical standards required for the project.

| Standard | Description |
|---|---|
| CAN/CSA-C22.2 NO. 61508-1:17 | Functional safety of electrical/electronic/programmable electronic safety related systems — Part 1: General requirements [5] |
| CSA C22.2 NO. 0.23-15 | General requirements for battery-powered appliances |
| CAN/CSA-C22.2 NO. 0-10 | General requirements - Canadian electrical code, part II |

**Table 7.1** - Electrical Standards

## 7.2 Environmental

The following table includes the environmental standards required for the project.

| Standard | Description |
|---|---|
| CAN/CSA-ISO/TR 14062-03 (R2013) | Environmental Management - Integrating Environmental Aspects into Product Design and Development (Adopted ISO/TR 14062:2002, first edition, 2002-11-01) [3] |
| CAN/CSA-ISO 14040-06 (R2016) | Environmental Management - Life Cycle Assessment - Principles and Framework (Adopted ISO 14040:2006, second edition, 2006-07-01) [4] |

**Table 7.2** - Environmental Standards

## 7.3 Wireless

The following table includes the wireless standards required for the project.

| Standard | Description |
|---|---|
| ISO/IEC 8802-2:1998 | Information technology - Telecommunications and information exchange between systems -- Local and metropolitan area networks - Specific requirements - Part 2: Logical link control [6] |

**Table 7.3** - Wireless Standards

# 8 Conclusion

The OptiCue is meant to be an educational aid, a tool to help the emotional development of those diagnosed with Autism and similar disorders. Our device will be user-friendly, intuitive, and non-intrusive. We want to focus on a minimal design that will act as an accessory during controlled social situations, in order to complement the emotional development of the user.

Aperture solutions believes in affordable products available to consumers from all economic groups. The design will be cost effective. The central processing unit is carefully selected to provide the necessary processing power to perform the facial analysis. All functional blocks of the OptiCue, hardware and software, will be designed for efficiency.

As a company we wish for our products to leave a mark, we strive to provide real solutions to real problems. The OptiCue is characterized by its efficient, affordable, and intuitive design. A device that can be integrated into a daily routine. Our driven team of engineers will deliver a quality product that meets all requirements outlined in this document.

# 9 Appendix

## 9.1 Proof of Concept Deliverables

For the proof of concept deliverable which will be presented on August 2nd, Aperture Solutions will be presenting the following deliverables:

- Facial recognition algorithm operating on laptop
- Audio circuit demo working
- Proof of Concept battery charging circuit operational

# 10 References


[1] Mark Williams Pontin, “Better Face-Recognition Software”, MIT Technology Review, 2007, [Online], https://www.technologyreview.com/s/407976/better-face-recognition-software/

[2] CSA Group, “CAN/CSA-C22.2 No. 61508-1:17”, CSA, 2017, [Online], https://www.scc.ca/en/standardsdb/standards/28870

[3] CSA Group, "CAN/CSA-ISO/TR 14062-03 (R2013) - Environmental Management - Integrating Environmental Aspects into Product Design and Development (Adopted ISO/TR 14062:2002, first edition, 2002-11-01)," CSA, Mississauga, 2013.

[4] CSA Group, "CAN/CSA-ISO 14040-06 (R2016) - Environmental Management - Life Cycle Assessment - Principles and Framework (Adopted ISO 14040:2006, second edition, 2006-07-01)," CSA, Mississauga, 2016.

[5] CSA Group, Functional safety of electrical/electronic/programmable electronic safety related systems, 2017, [Online], https://www.scc.ca/en/standardsdb/standards/28870

[6] International Organization for Standardization, “ISO/IEC 8802-2:1998(en)”, ISO, 1998 [Online], https://www.iso.org/obp/ui/#iso:std:iso-iec:8802:-2:ed-3:v1:en