NavEYEgation Technologies

October 19, 2015

Dr. Andrew Rawicz
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RE: ENSC 440W Capstone Project Functional Specification for the Gaze-controlled mouse

Dear Dr. Rawicz,

The attached document is a Functional Specification for NavEYEgation Technologies' Gaze-controlled Mouse System. This system will allow the user to operate a mouse using only their eyes without the need for costly eye-tracking hardware.

The Functional Specification details high-level requirements for the prototype and production models. As such, this document will be used as a guide throughout the design and test phases of development.

NavEYEgation Technologies is comprised of five dedicated 4th and 5th year engineering students: Ramin Nazarali, Nathan Samchek, Sunny Chowdhury, Mani Ahuja, and myself. If you have any questions or comments please feel free to contact me at msantiag@sfu.ca.

Sincerely,

Monica Santiago
CEO, NavEYEgation Technologies

Enclosure: *Functional Specification for the Gaze-controlled Mouse*

NavEYEgation Technologies

Functional Specification for the *Gaze-controlled Mouse*

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Executive Summary

NavEYEgation Technologies was founded by five bright engineering students who wanted to make a difference by providing a system that helps individuals use their personal computers using just their own eyes. We call this a gaze-controlled mouse. NavEYEgation Technologies' proposed gaze-controlled mouse will eliminate the need of using your hand to navigate the mouse; instead it will use the individual's eyes. This can be of extreme importance to patients who are suffering from conditions such as motor degeneration disease, arthritis, and carpal tunnel syndrome. These conditions make the use of one's hands painful or nearly impossible.

Our system will consist of two aspects: hardware and software. This is to ensure ease of integration and for response as well as efficiency. A small camera, which will accompany a microprocessor, will be mounted on the host computer that will read the pupil/iris and capture its coordinates. Instructions and image processing will be done using the microprocessor which will project the mouse cursor on the screen accordingly, adjusting to the user's eyes.

The development cycle will consist of various stages categorized into different phases. The first phase will consist of face detection and pupil/iris reading which is of the highest priority. The next phase will consist of computational instructions being conducted by the image processor which will show the mouse cursor according to the users' eye. Additional features and functionality may be added depending on project time and the necessity as well as efficiency and ease of use.

This document will serve as the outline of the functional specifications which are required to ensure a fully working product is designed well and up to strict standards. Several other topics will also be covered, such as sustainability conditions and engineering standards. This document will also serve as the basis for the next stage: the design specifications.

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Glossary

IEEE – Institute of Electrical and Electronics Engineers

IEC – International Electrotechnical Commission

ISO – International Organization for Standardization

Point-of-Gaze – Point on the screen where the user is looking

Effective Resolution – The number of pixels from the camera's video image that contain the user's face and eyes

1. Introduction

A gaze-controlled mouse is a system that uses eyes to control a personal computer. The system is made up of a software component as well as a hardware component to ease the integration and enhance the user experience. It will use the position of the pupils relative to the rest of the eye as well as the rotation of the head to correctly map the mouse cursor on a computer. Additionally, it will use a combination of blinks, dwell time, or other methods to interact with the user's computer.

The system is primarily designed for individuals with musculoskeletal, inflammation, or motor degeneration issues such as Parkinson's disease, arthritis, and carpal tunnel syndrome where the use of hands is painful or impossible. The functional specifications for this gaze-controlled mouse will be outlined in this document, as proposed by NavEYEgation Technologies.

1.1 Scope

This document describes the functional specifications of the gaze-controlled mouse. The final product must meet and uphold strict standards, as well as fulfill several different classes of requirements. This document will explain the proof of concept and serve as a reference which will be used extensively in the next stage to ensure a fully working product has been designed.

1.2 Intended Audience

This document will be used as a guide for all team members of NavEYEgation Technologies during the design and testing phases of development. During the design phase it will be used to keep track of design goals and restrictions. During the testing phases it will be used to verify that these goals have been met and that the restrictions have been followed.

1.3 Classification of Specifications

The following notation will be used to indicate functional requirements:

R[n-p] A functional requirement

where **n** denotes the functional requirement number and **p** the priority of the functional requirement. **P** can have one of three of the following values:

I Requirement will be met for the prototype – iteration I
II Requirement will be met for the prototype – iteration II
III Requirement will be met in the production model

2. System Requirements

2.1 System Overview

A single camera (potentially infrared) is mounted next to the output screen intended to be controlled through gaze-tracking as shown in the Figure 1 below.

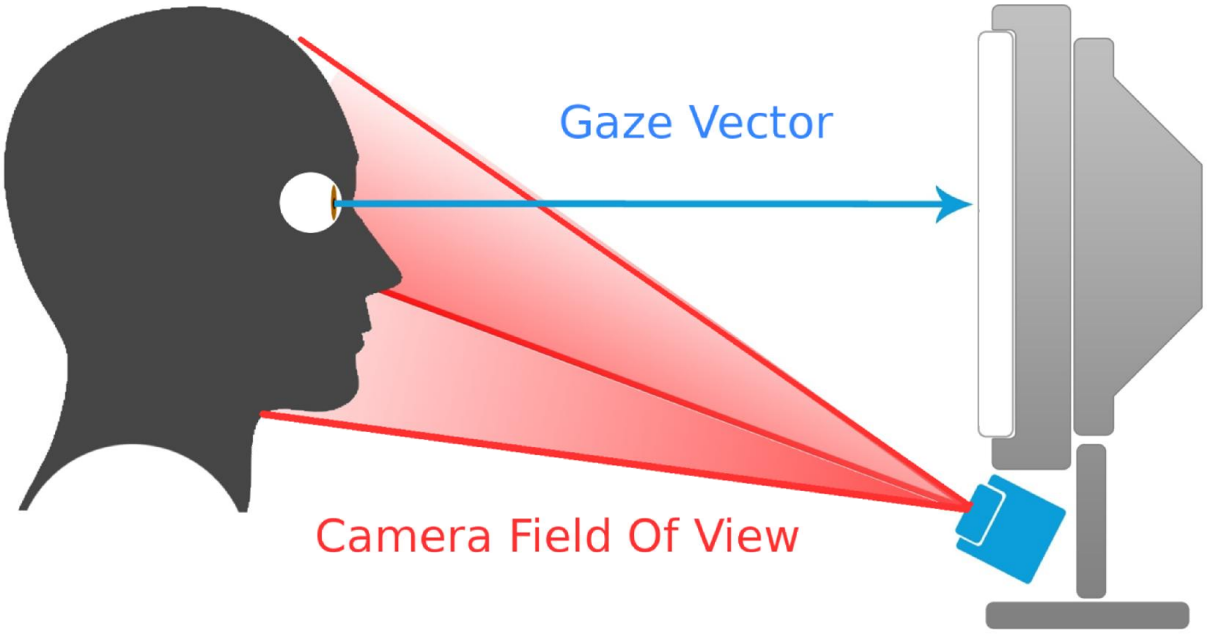

Figure 1: Gaze-Controlled Mouse System

The user's full face will be visible within the mounted camera's field of view and the input from this camera will be fed through a software image processing algorithm shown in Figure 2 to determine the user's point of gaze.

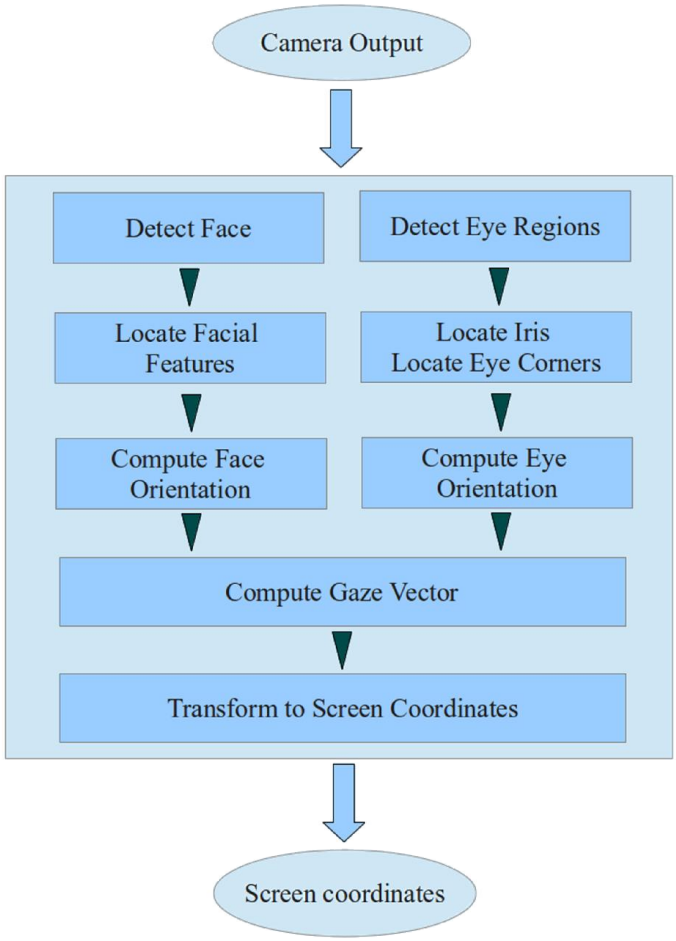

Figure 2: Algorithm for determining point of gaze on screen

Upon using the gaze-tracking solution for the first time, a one-time calibration step must be performed. This calibration step would consist of looking at several sequentially displayed points on the screen the user is intending to use. The gaze of the user during this step would be recorded and used to establish the screen's position relative to the camera.

The screen coordinates provided as output by the algorithm in Figure 2 would control the location of the computer's cursor, thereby achieving a gaze controlled cursor. In order to allow the user to perform "click" or "drag" actions with the cursor, different eye states will be mapped to these different actions. For example blinking both eyes twice can translate to a single click of the cursor, and closing one eye completely can correspond to a drag action.

2.2 General Requirements

R[1-I] The system will enable the user to move the cursor
R[2-I] The system must work when the face is illuminated by a source with a wavelength between 400-900 nm.
R[3-I] The system must work in a room illuminated to a luminous flux of at least 200 lux [1].
R[4-II] The user will be able to Right click
R[5-II] The user will be able to Left click
R[6-II] The user will be able to Double Click
R[7-II] The user will be able to click and drag
R[8-III] The user will be able to scroll up or down
R[9-III] The system should be customizable to user's tastes (key mapping/different cameras)

2.3 Environmental Requirements

R[10-I] The system will work indoors at room temperature (21°C - 23°C) [2]
R[11-I] The system will work indoors at normal humidity (50%) [2]
R[12-III] The system will work between 15°C - 35°C
R[13-III] The system will work at 0% - 70% humidity

2.4 Standards

R[14-I] The system's software will be developed in accordance with ISO/IEC 12207 [3]
R[15-II] The interface will adhere to the IEEE Fundamental Usability Guidelines for UI Design [4]

2.5 Reliability Requirements

R[16-I] The system will find user's eyes after the one-time calibration
R[17-II] The system will immediately find the user's point of gaze upon reacquiring the user's eyes/face
R[18-III] The system will reset cursor position when user looks off the screen

2.6 Performance Requirements

R[19-I] The user will be able to move the cursor to within 2 degrees of the point of gaze
R[20-II] The cursor will move smoothly
R[21-III] The cursor will react to pupil movement in real-time exempting cases when the host system is under high loads (100% CPU Usage)
R[22-III] The user will be able to move the mouse to within 0.5 degree of the point of gaze

2.7 Usability Requirements

R[23-I] The system will work for any person regardless of physical characteristics with the exception of blind people
R[24-I] The system will work with users wearing hats that do not cover their faces
R[25-II] The user will be able to utilize the system after going through a tutorial/wizard mode once
R[26-II] The system will work for users wearing non-tinted glasses

3. Camera

The camera provides a readily-available, relatively inexpensive, and non-invasive means of determining the position, movement, and general state of the head, eyes, and pupils. As such, the following requirements must be met to track eye and pupil movements precisely and accurately.

3.1 General Requirements

R[27-I] The camera's frame rate must be least 30 fps
R[28-I] The camera's viewing angle must be between 60 and 135 degrees
R[29-I] The camera will track the user's eyes at a distance between 25 cm – 150 cm
R[30-I] The camera will draw no more than 2 W of power
R[31-II] The camera must have at least 1080p resolution
R[32-III] The camera must have at least 480p resolution

The camera's viewing angle must be broad enough to continue tracking the user's face and eyes when they shift positions in their seat, but not so broad that effective resolution is significantly reduced. The distance from the user to the camera must be small enough to not significantly reduce effective resolution, but far enough that the user's whole face is within the field of view. The camera must draw less than 2 W of power to maintain compatibility with USB 2.0 standard. A minimum resolution of at least 480p is required to increase compatibility with cheaper pre-existing cameras. This is relaxed to a resolution of at least 1080p to make prototyping easier.

3.2 Physical Requirements

R[33-I] The camera will weigh less than 200 g
R[34-I] The camera will fit inside a 15 x 15 x 15 cm volume

3.3 Performance Requirements

R[35-I] The camera will detect face and pupil movement in real time
R[36-II] The camera will detect pupil movement for 7 mm movements in gaze

3.5 Sustainability Requirements

R[37-III] The camera's components must be reusable or recyclable
R[38-III] The camera's components will comply with restrictions set by the Restriction of Hazardous Substances (RoHS) Directive

4. Software Requirements

4.1 General Requirements

R[39-I] The algorithm will determine the location of the user's gaze

R[40-I] The software will not crash without warning

R[41-I] The software will recover from non-fatal errors without crashing

R[42-III] The software will run in Windows, Mac, Linux, Android and iOS

4.2 Security Requirements

R[43-III] The software will not cause the host computer to become more susceptible to malware

5. User Documentation

R[44-III] The user documentation will exhaustively describe steps required to make use of the gaze-controlled mouse

R[45-III] The user documentation will be available in softcopy

6. Conclusion

In conclusion, a gaze-controlled mouse can be an essential tool for individuals who have difficulty using their hands to navigate a personal computer. This is a revolutionary product if implemented properly for a commercial setting such as elder-care facility as well as for consumer purposes to just use it at the users' convenience in the comfort of their own homes.

At NavEYEgation Technologies, we keep in mind that safety and standards are of utmost importance and must be handled with great care to create a fully functional product that can be used to its full potential and its intended purpose.

All the requirements that are outlined in this document describe in detail the key functions of the gaze-controlled mouse as well as the requirements necessary to achieve said functions. These key functions will be implemented in three stages/iterations as shown in Table 1. Functions required for the first and second iteration prototype are essential. Functions required for the Production model are primarily there to serve for extra features or aesthetics. This document will serve as a guide in the design and implementation stages to ensure every requirement is satisfied.

Table 1: Key Features at each Development Iteration

Development Iteration	Key Features
Prototype I	• Move cursor while keeping head stationary
Prototype II	• Move cursor while moving head • Right click • Left click • Double click • Click and drag
III (Production Model)	• Move cursor while moving their head • Right click • Left click • Double click • Click and drag • Scroll • Additional actions customizable to the user's tastes

References

[1] "Canadian Centre for Occupational Health and Safety - Lighting Ergonomics - Survey and Solutions," [Online]. Available: http://www.ccohs.ca/oshanswers/ergonomics/lighting_survey.html. [Accessed 15 October 2015].

[2] "Canadian Centre for Occupational Health and Safety - Thermal Comfort for Office Work," [Online]. Available: http://www.ccohs.ca/oshanswers/phys_agents/thermal_comfort.html. [Accessed 15 October 2015].

[3] *ISO/IEC 12207-2008 Systems and Software engineering - Software life cycle processes,* 2008.

[4] "Fundamental Usability Guidelines for User Interface Design," in *International Conference on Computational Sciences and Its Applications ICCSA*, 2008.

