Augmented Communication Device

ECE4007 Senior Design Project

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Executive Summary

Currently, most computer input devices like keyboards and mice require the user to be able to use their hands. The Augmented Communication Device is a small, lightweight, inexpensive, human interface device. It will enable persons with spinal cord injuries or other impairments that cause limited head movement to control a computer cursor with head movements, and facial gestures. It will be designed to look similar in form to a Bluetooth headset for cell phones. An on-board microcontroller will use data obtained from an Inertial Momentum Unit (IMU) and an Optical Flow Sensor (OFS) to determine the appropriate movement of the cursor. Software will be written and implemented on the microcontroller to acquire and process IMU and OFS data. The IMU will track nodding and rotating of the head to guide the cursor. The OFS will be placed slightly below the temple, in line with the eyes and used to recognize eyebrow raises as left clicks, and wincing, i.e. closing eyes quickly and tightly, as right clicks. The software used for the OFS will be adapted from an open-source device, called the Wouse. The final product will be a prototype device that will cost $170 to develop, whose capabilities will be demonstrated by playing a simple computer game.

Augmented Communication Device

1 Introduction

The Augmented Communication Device team will design a prototype system capable of tracking the user's head movements and facial gestures, like wincing and raising eyebrows, to control a computer cursor and mimic mouse clicks. The team is requesting $170 to develop a prototype of the system.

1.1 Objective

The Augmented Communication Device is a prototype that allows persons with spinal cord injuries or other impairments that cause limited head movement to interface with a computer with ease. It mounts to the user's ear, much like a cell phone Bluetooth headset, for instance the Jabra BT2080 [1], and connects to the computer via USB. The device tracks the user's head orientation and translates the motion into cursor movements. It also recognizes facial gestures like wincing, i.e. closing the eyes quickly and tightly, and eyebrow raises to imitate mouse clicks.

1.2 Motivation

Individuals with high-level paralysis are unable to communicate with computers using conventional methods such as a mouse and keyboard. If a motor impaired patient has the ability to move his/her head, this movement can be recognized and translated into cursor movements on a computer screen by the proposed Augmented Communication Device.

Existing commercially available devices such as those discussed in [2] and [3] are difficult to use and restrictive. An example of the device from [2] is shown in Figure 1. Another solution, the HeadMouse Extreme system, shown in Figure 2. consists of a webcam that tracks the user’s head movements using Computer Vision. It costs $1225, and the user must directly face the webcam for the system to function properly [4]. The Augmented Communication Device prototype will be an improvement both in terms of cost and in terms of size and capability.

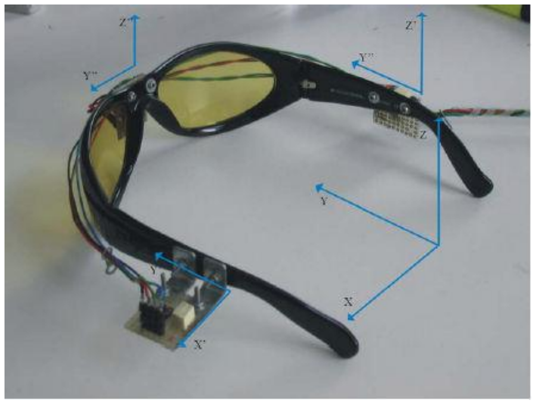

Figure 1. System developed for head tracking used in [2].

Figure 2. HeadMouse Extreme system uses a webcam to track user’s head movements.

1.3 Background

The Wouse is a wearable open source device and software library developed by Georgia Tech in collaboration with other researchers [5]. It uses an Optical Mouse Sensor mounted near the user’s temple to detect wincing. It uses support vector machines to discriminate between facial gestures.

Paper [6] describes a headset that uses gyroscopes to control a computer cursor based on angular velocities of the head. The system includes an infrared ray transceiver pointed at a location near the user’s eyes to detect blinking to imitate mouse clicks. Another paper [2] describes a system which uses accelerometers to detect the user’s head tilt to control a computer cursor. They also have a touch switch oriented to point at the user’s right cheek to detect a puffing action to perform mouse clicks.

Figure 3. A puff-to-click system being used as an alternative to clicking using a mouse.

Eye tracking is a recent technological development to help disabled people with human computer interaction. It uses a set of hardware such as cameras and sensors in conjunction with computer algorithms to compute the point of focus of the user [7]. This allows only the eyes to be used as a mouse. Such eye tracking devices costs around $3000 [8].

2 Project Description and Goals

The Augmented Communication Device is a portable, lightweight, and wearable system that enables persons with disabilities to control a cursor on a computer screen with just their head movements and facial gestures. Being compact and mountable on the user's ear, the device will not reduce the user's field of view during operation.

The system will integrate an accelerometer, a gyroscope, and a magnetometer, all contained within an Inertial Momentum Unit (IMU) with an Optical Flow Sensor. It will also contain an on-board microcontroller and will be connected to the user's computer via USB. The IMU will primarily be used to track the rotation of the user's head and nodding motion in order to control the computer cursor. These head motions are shown in Figure 4. The Optical Flow Sensor will be pointed at the temple next to the user's eyes. It will track skin movement to recognize wincing and eyebrow raises. These facial gestures will be translated into mouse clicks.

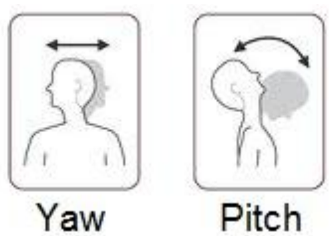

Figure 4. Left to right motion of the user's head, i.e. the Yaw, will be translated to horizontal movement of the cursor. Nodding motion of the user's head, i.e. the Pitch, will be translated to vertical cursor movement.

The Augmented Communication Device will have the following features:

- Determines the user's exact head orientation
- Translates head movements to computer cursor movements
- Detects facial gestures, for instance wincing and eyebrow raises

- Translates facial gestures to mouse clicks
- Works on Linux based machines
- Connects to the computer using a USB Port
- Costs $170 to prototype

3 Technical Specifications

The Augmented Communication Device will consist of three major components: An inertial momentum unit, an optical flow sensor and a microcontroller. The required technical specifications for the device and its major constituent components are presented in the following tables.

Hardware	
Device Dimensions	< 80mm x 40mm x 15mm
Device Weight	< 7 oz.

Sensors	
Accelerometer Resolution	4 mg/LSB
Gyroscope Sensitivity	14.375 LSBs per °/sec
Magnetometer Resolution	2 milligauss
Optical Flow Sensor	2000 counts-per-inch (cpi)

Interface	
Microcontroller-Sensors	I^2C, SPI
Computer-Microcontroller	USB

Power	
Optical Flow Sensor	3.012 mW (1.44mA @ 2.1V)
Inertial Momentum Unit	22 mW (6.5mA @ 3.3V)
Microcontroller	1.65 W (500mA @ 3.3 V)

Performance	
Processor Clock	60 MHz
Device Response Time	< 400 ms

Software	
Operating System	Linux

4 Design Approach and Details

4.1 Design Approach

4.1.1 System Overview

The Augmented Communication Device will take the form similar to a cell phone Bluetooth headset [1]. The device will consist of an Inertial Momentum Unit (IMU) and an Optical Flow Sensor (OFS) connected to a microcontroller. The microcontroller will take the outputs from the IMU and the OFS and determine on how to move the cursor on the computer screen. The device will then interface with the computer via USB. Figure 5. shows the block diagram of the system hardware.

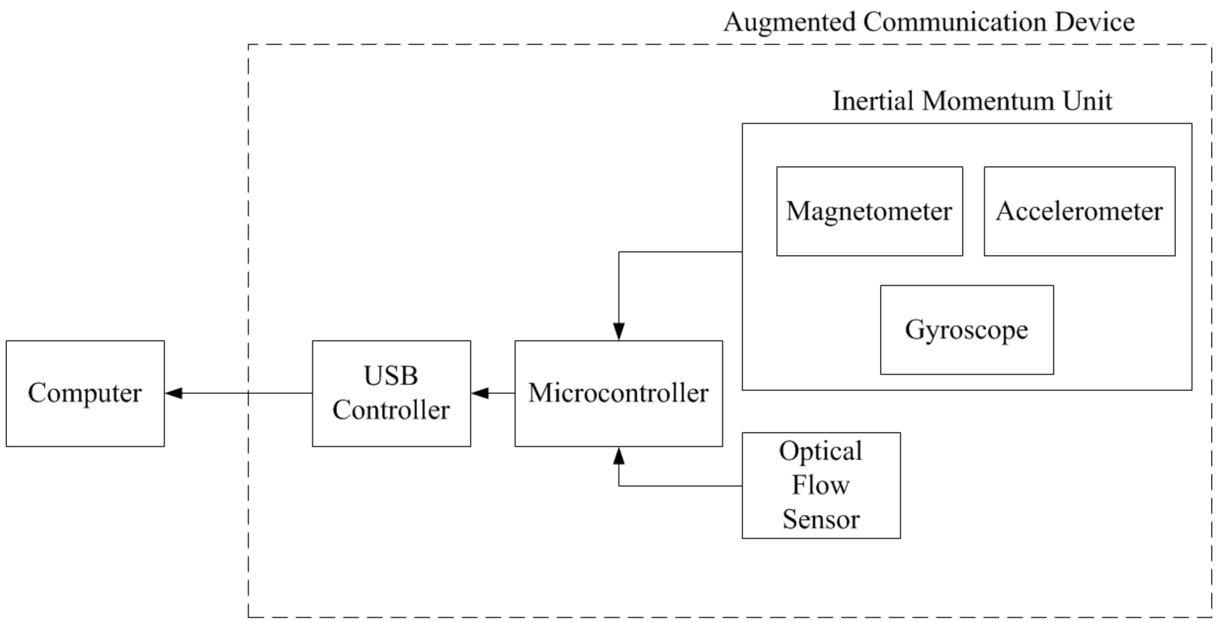

Figure 5. Block diagram of the Augmented Communication Device hardware components.

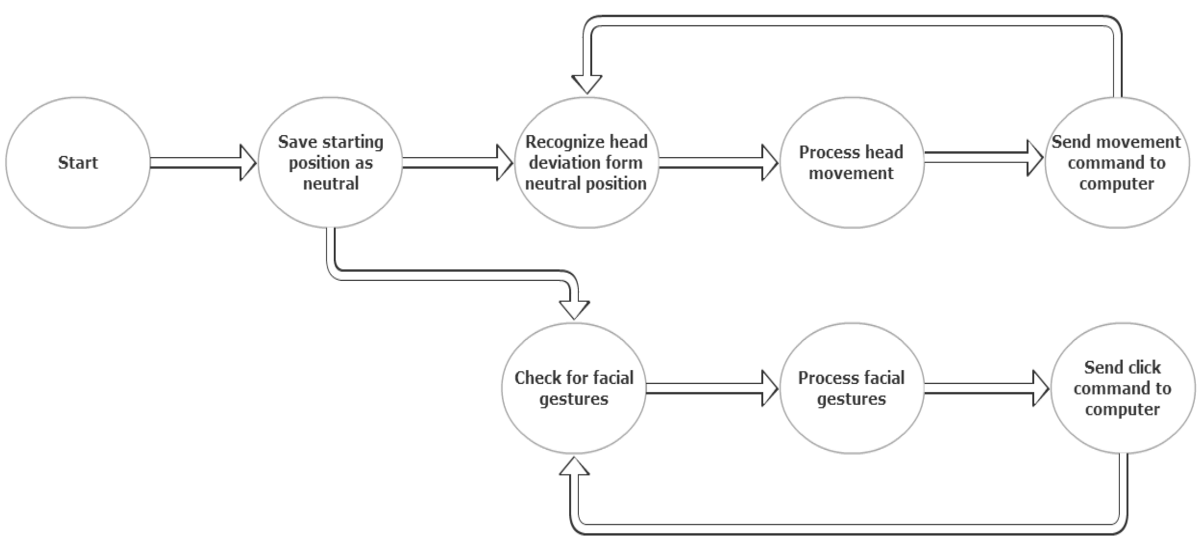

Figure 6. Flowchart of the control software process of the Augmented Communication Device.

4.1.2 Inertial Momentum Unit (IMU)

The 9 Degrees of Freedom Sensor Stick IMU from Sparkfun features an accelerometer (ADXL345) [9], a gyroscope (ITG-3200) [10] and a magnetometer (HMC5883L) [11]. It is a lightweight, small (34.6mm x 10.6mm x 2.36mm) and high accuracy sensor capable of detecting head orientation with up to 1° of accuracy. The output of this device will be processed by the Arduino Due.

When the device is powered up, the IMU will be used to establish an initial head orientation, called the neutral position. From that point onwards, based on the data received from the IMU, the Augmented Communication Device will be capable of operating in two modes – scaled control and un-scaled control. Both these modes of operation are inspired by the operation of a joystick. Joystick-like positioning systems for pointing devices require less precision than absolute positioning systems [6]. In the un-scaled mode of operation, after the neutral position is established when the device is powered on, if the user tilts his/her head past a certain threshold degree, the cursor will begin moving with a constant velocity in the corresponding direction on the screen. As compared to this mode, in the scaled mode of operation the velocity of the cursor movement is a function of the displacement of the user's head from the neutral position, that is, the more the user moves his/her head in a particular direction the faster the computer cursor will move in the corresponding direction. In either mode, after the device detects a deviation from the neutral position, and translates it into x-axis and y-axis cursor displacements, these signals will be sent to the computer via the USB interface.

4.1.2.1 Accelerometer

The ADXL345 is an accelerometer with 13 bits of resolution and a sensitivity that can be set to ±2g, ±4g, ±8g or ±16g. For the purpose of measuring head tilt, the accelerometer will be set at ±2g to get maximum sensitivity. The chosen accelerometer measures acceleration on three orthogonal axes, and is thus capable of determining the user's head's roll and pitch. It also uses an SPI interface, which enables it to talk to the microcontroller.

4.1.2.2 Gyroscope

The ITG-3200 is a 3-axis gyroscope with 16 bits of resolution. It is capable of detecting ±2000°/sec. This sensor will be primarily used to detect the user's head's rate of rotation and yaw motion.

4.1.2.3 Magnetometer

The HMC5883L is a digital compass with than 2° compass heading accuracy. This sensor will not be interfaced with directly, but it helps prevent drifting phenomenon in the gyroscope.

4.1.3 Optical Flow Sensor (OFS)

The ADNS-3000 [12] is a low power optical flow sensor from Avago Technologies. It is capable of detecting up to 30 inches-per-second (ips) of motion and has a resolution of up to 2000 counts-per-inch (cpi). The sensor is available as an 8-pin dual in-line package chip, capable of connecting to the microcontroller through an SPI interface. The data obtained from the OFS will be processed with an open source library for detecting facial gestures, called Wouse. This library, which is based on support vector machines, will help determine wincing and eyebrow raise gestures that will be translated to left and right mouse clicks, respectively.

4.1.4 Microcontroller

Arduino Due microcontroller has a 32-bit ARM CPU (AT91SAM3X8E) and an 84MHz clock [13]. It also has 512KB of Flash Memory. The selected board is compatible with I^2C as well as SPI interfaces and will thus be able to interface with the other components.

4.1.5 Communicating with the computer

Communication with the computer will be accomplished through the USB protocol and physically connecting the microcontroller with the computer using a USB wire.

4.2 Codes and Standards

The Augmented Communication Device will make use of the following standards for general electrical safely:

1. OSHA 1910.335(a)(1)(iv): Employees shall wear nonconductive head protection wherever there is a danger of head injury from electric shock or burns due to contact with exposed energized parts
2. OSHA 1910.335(a)(1)(v): Employees shall wear protective equipment for the eyes or face wherever there is danger of injury to the eyes or face from electric arcs or flashes or from flying objects resulting from electrical explosion
3. Employers should use ground-fault circuit interrupters (GFCI's) on all 120-volt, single-phase, and 15- and 20-ampere receptacles
4. The ground-fault circuit interrupter, or GFCI, is a fast-acting circuit breaker designed to shut off electric power in the event of a ground-fault and prevent injury to the worker
5. With the ground wire disconnected, the chassis leakage is limited to 100 uA and the patient lead leakage must not exceed 50 uA

The Augmented Communication Device will make use of the following standards for intra and inter device communication:

1. USB HID (Human Interface Device) Class interface for mouse communication

2 Inter-Integrated Circuit (I^2C) protocol between the Inertial Momentum Unit and the ARM microprocessor

3 Serial Peripheral Interface (SPI) protocol between the optical flow sensor and the ARM microprocessor and between the ARM processor and the USB controller

The following programming languages will be used for data processing and communication:

1 C for all microcontroller operations, for instance obtaining data from the sensors, processing IMU data, communicating the cursor movements to the host computer

2 Python to interface with the Wouse library to process the data received from the microcontroller

USB protocol was chosen for the interface between the device and the computer due to its widely available documentation, ease of use and conventionality. All current computers come with USB ports.

4.3 Constraints, Alternatives, and Tradeoffs

There is a temporal constraint on the setup time. The Wouse system uses a support vector machine algorithm, which requires training data to develop a model to classify different facial gestures. The training time might be as long as 10-15 minutes. Optical Flow Sensors watch for skin movement, which differ from one user to another. Thus, the training data must be collected on a per user basis.

The Augmented Communication Device would need to have a small response time for a seamless experience for the user. The response time is based on the processing of the Optical Flow Sensor data, mapping of the accelerometer data to cursor movements and the speed of communication between the device and the computer. We are proposing to do all processing on the microcontroller on the device. If this increases the lag beyond the proposed 300ms, we will consider the alternative of moving the processing from the microcontroller to the computer.

There was also a decision for the team to focus on a wired USB interface instead of transmitting a wireless signal. This allows for simplification of the system since USB would be able to provide onboard power. Consequently, the team does not need to focus on power management.

5 Schedule, Tasks, and Milestones

The project schedule is formatted in a Gantt chart which can be found in appendix A.

6 Project Demonstration

The Augmented Communication Device will be portable and able to interface with any Linux based computer. A formal demonstration of the device will take place in the Georgia Tech McCamish Pavilion on April 25 during the Capstone Design Expo.

1. The device will be mounted on a demonstrator's ear and be connected to a computer
2. The demonstrator will use the device to control the cursor and interact with various computer software, for instance a web browser
3. Advanced capabilities will also be demonstrated by playing a simple computer game, for instance Solitaire, or by composing an email

Figure 7. An artist's illustration of how the Augmented Communication Device would look.

The dimensions of the device will be confirmed using a set of calipers and the weight will be measured using a scale. While the team has not determined an accurate way to monitor the total delay between the user making the clicking gestures and the corresponding click occurring on screen, using logic analyzers the team will determine the delay from when the OFS sends the data and when the corresponding click occurs. This method will be used to determine a relative response time for the device. A similar setup will be used to measure the response time of the IMU, though the team believes the OFS will be the bottleneck in terms of response time.

7 Marketing and Cost Analysis

7.1 Marketing Analysis

To be announced after prototyping is finished

7.2 Prototyping Cost Analysis

Table 1. Breakdown of Prototyping Cost

Item	**Cost**
Inertial Momentum Unit	$99.00
Optical Flow Sensor	$0.00 (Donated)
Arduino Due	$50.00
Printed Circuit Board	$20.00
3D Printed Casing	$0.00 (Donated)
Total	**$170.00**

8 Current Status

All the parts necessary for the functional implementation of the device implementation have been determined and ordered. They are either being shipped or in the process of being shipped from their respective distributors. Currently, the team has written a simple program to read the data output from a 3-axis accelerometer and once the IMU arrives that code will be modified as needed.

9 References

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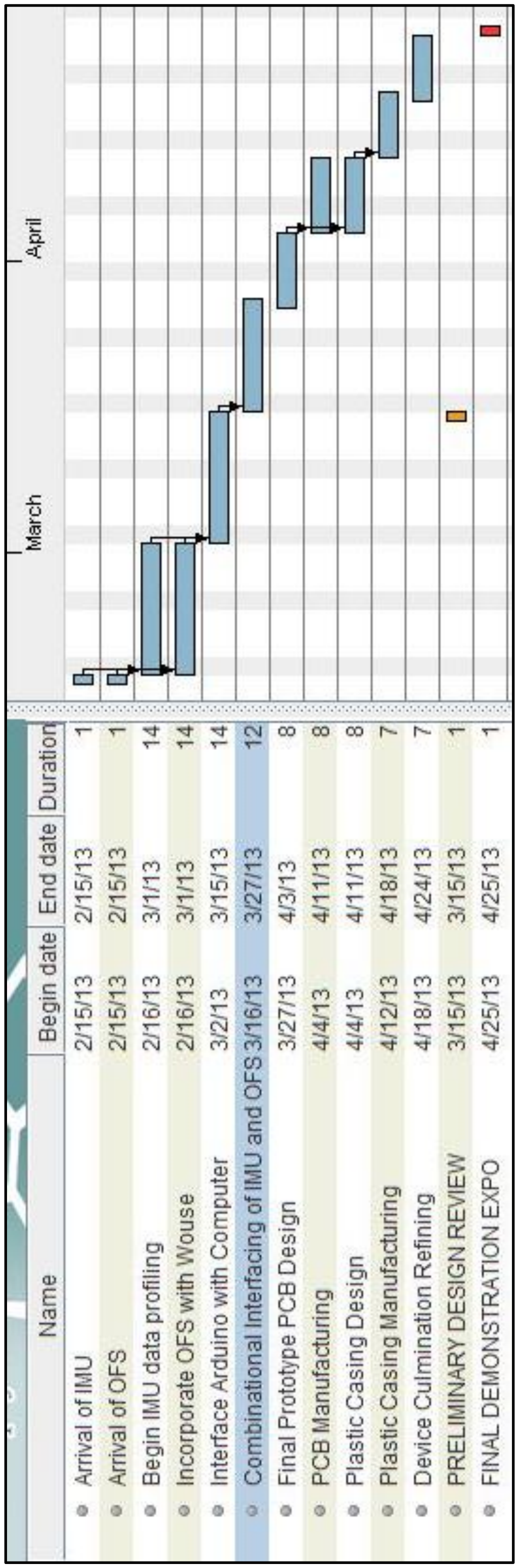
Appendix A – Gant Chart



Name	Begin date	End date	Duration
Arrival of IMU	2/15/13	2/15/13	1
Arrival of OFS	2/15/13	2/15/13	1
Begin IMU data profiling	2/16/13	3/1/13	14
Incorporate OFS with Wouse	2/16/13	3/1/13	14
Interface Arduino with Computer	3/2/13	3/15/13	14
Combinational Interfacing of IMU and OFS	3/16/13	3/27/13	12
Final Prototype PCB Design	3/27/13	4/3/13	8
PCB Manufacturing	4/4/13	4/11/13	8
Plastic Casing Design	4/4/13	4/11/13	8
Plastic Casing Manufacturing	4/12/13	4/18/13	7
Device Culmination Refining	4/18/13	4/24/13	7
PRELIMINARY DESIGN REVIEW	3/15/13	3/15/13	1
FINAL DEMONSTRATION EXPO	4/25/13	4/25/13	1