Head-Controlled Mouse

ECE 445 Project Proposal

Team 44
Amanda Favila (afavila2)
Asher Mai (hanlinm2)
Lauren Wilcox (lwilcox4)

TA: Sainath Barbhai
Professor: Victor Gruev

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1. Introduction

1.1. Problem

There are many reasons why someone would want to use a head-controlled mouse. Some people want to increase the rate at which they can move their mouse across the screen. Others may frequently switch between clicking and typing, and not having to take their hands off of the keyboard will save them time. Disabilities in particular can make using the standard computer mouse or trackpad difficult. According to the CDC, 24% of adults in the United States have arthritis, which is the leading cause of work disability [2]. Teamstage asserts that “about 50% of jobs need employees to have technology skills, but it’s estimated that by 2030, 75% will have such requirements” [3]. Because so much work uses computers these days, there is a need for computer accessibility products for people with such disabilities to utilize for both entertainment and work purposes. On top of arthritis, there are many other conditions or disabilities that inhibit arm and hand movement and interfere with computer use such as carpal tunnel, partial paralysis due to spinal cord injury, Parkinson’s disease, Huntington’s disease, amyotrophic lateral sclerosis, cerebral palsy, and stroke-related motor cortex damage, as listed by Frontiers [4].

Although eye and head-controlled mice have been invented to curb these issues, these products typically use headbands, require an expensive camera setup, and the programs are not universal to any device from Mac to PC to iPad. Some examples of such products are Smyle mouse [5] and Mouseware [6]. Headbands may not be the most comfortable solution for everyone, so our product will not use one. Many people dislike using cameras due to privacy concerns, so the camera component of this solution can be eliminated by substituting accelerometers and gyroscopes. There is also a way to make this technology more universally accessible to all devices, via a USB wireless receiver. All three of these changes are what will set our product apart from similar ones on the market.

1.2. Solution

Our solution is to create a device that will process the user’s head motions to control the cursor on whichever device they are using. This device will be attached to a hat, which is more comfortable for the user than the typical headband, is quicker and more convenient to put on and take off, and can balance the weight of the device and its battery more evenly. After calibration, this device will track when the user turns their head up, down, left, and right to move the cursor on their screen accordingly, and then use a specific head tilt to click.

More specifically, the head motions will be tracked on the hat using a combination of gyroscopes and accelerometers, such as the SCC1300-D02 gyroscope and the ADXL335 accelerometer. The hat will be powered with a standard battery pack, which will be separate from the hat and attached via wires in order to reduce the weight of the hat. The hat will also contain a microcontroller that processes the head movements and will send signals to the wireless USB dongle which will then move the mouse accordingly. We will utilize a voltage regulator as well on our PCB to step the voltage down depending on the needs of our components.

1.3. Visual Aid

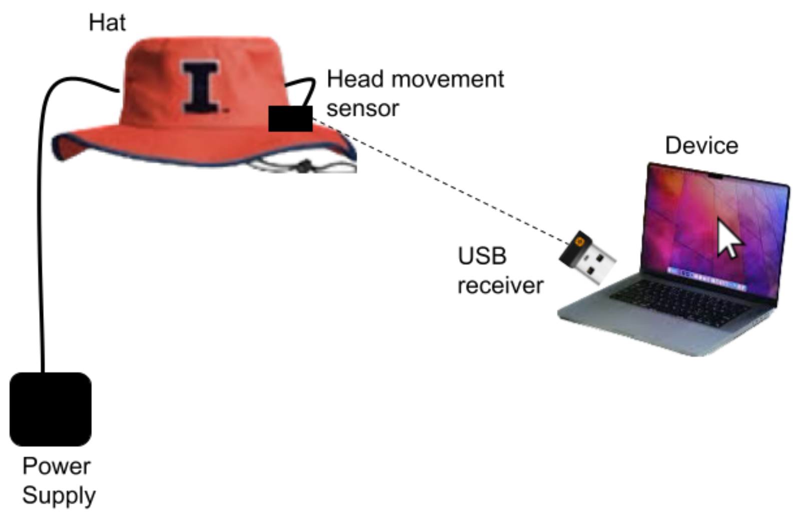

Figure 1: Visual Aid of Head-Controlled Mouse device

1.4. High-Level Requirements

- The device must have a successful calibration sequence that calculates appropriate distances and speeds for the cursor to move based on the user's specific head movements.
- The device must be able to accurately move and click the mouse cursor based on the user's head movements. This means that when the user moves their head up, down, left, and right, the mouse cursor will move up, down, left, and right, respectively.
- The device must be able to be used on both Macs and PCs.
- The device must utilize user adjustable sensitivity that can map different cursor speed to the same head rotation speed.

2. Design

2.1. Block Diagram

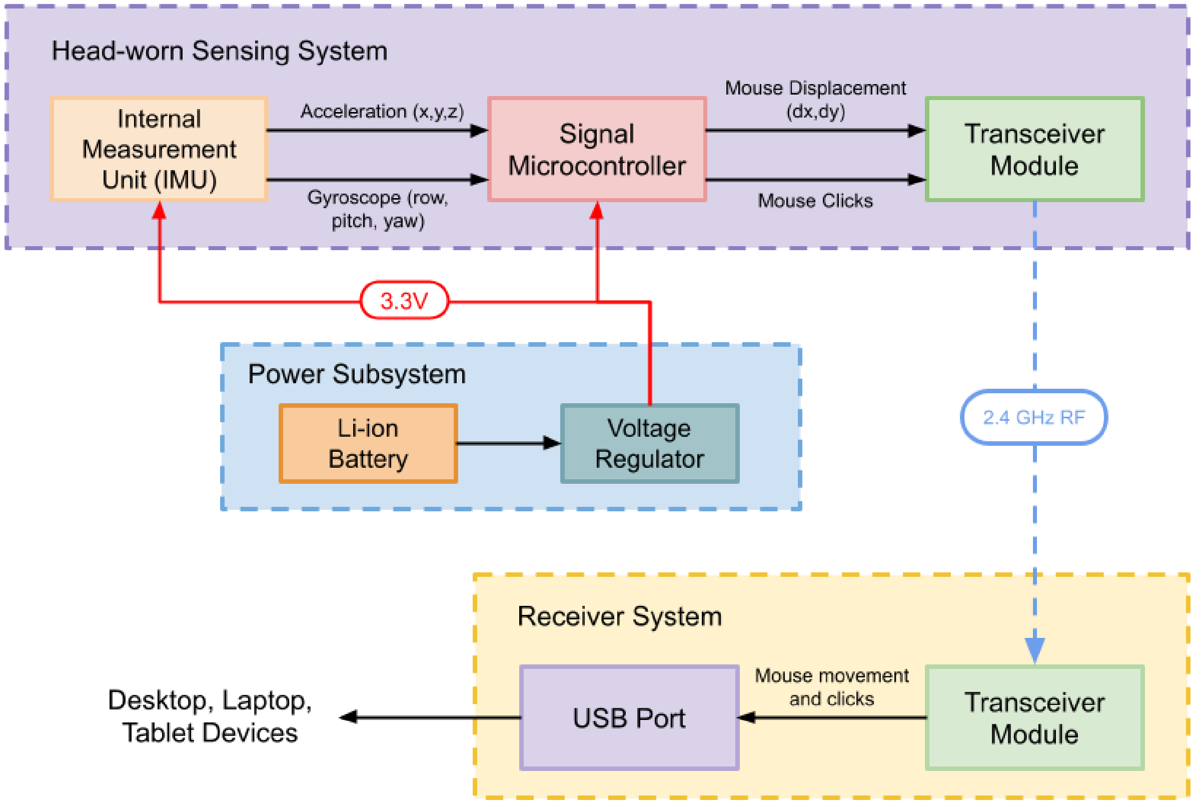

Figure 2: Block Diagram

2.2. Subsystem Overview

1. Internal Measurement Unit (IMU)

   An IMU is needed to measure the head rotations of the user. This will be attached to the hat and include an angular velocity sensor in the form of a gyroscope and accelerometer which we will then grab data from. The acceleration and gyroscope data will then be sent to the signal microcontroller, which will process and send it through to the transceiver. The IMU will receive power from the power supply subsystem.

2. Microcontroller

   The microcontroller is a programmable chip that will carry out our desired functions of mapping the gyroscope and accelerometer data from the IMU to the desired mouse position on the screen. This transformation will require a bit of trial and error to get the desired results.

3. Transceiver

The transceiver will receive the output of the microcontroller data, which includes both the position of the mouse as well as whether or not the mouse is clicked. It will operate at 2.4 GHz RF. It then transfers this data to the receiver.

4. Power

   The power subsystem is what contains the potential difference that allows all of the circuitry to be powered. It will contain a rechargeable li-ion battery. It will also contain a voltage regulator, which will ensure a steady constant voltage supply at the correct voltages needed for the components we choose.

5. Receiver

   The receiver includes the USB dongle, which will receive the data from the transceiver and deliver it to the user's computer. This part of the process will work in the same way that a regular wireless mouse functions.

2.3. Subsystem Requirements

1. Internal Measurement Unit (IMU)

   The IMU will be essential to map the user's head movements to the mouse cursor on the display. The IMU must read accurate acceleration and gyroscope data in order for the processor to output accurate displacement instructions to the mouse cursor.

2. Microcontroller

   The Microcontroller needs to be able to take input of accelerometer data in the x, y, and z directions as well as the gyroscope data in terms of the row, pitch and yaw axes and output mouse displacement in dx, dy, as well as mouse clicking data.

3. Transceiver

   The transceiver has to send mouse action data, including mouse cursor displacement and left/right mouse button clicking, from the Head-worn Sensing System to the Receiver that is plugged into the laptop, desktop or tablet devices.

4. Power

   The power subsystem will consist of the Li-ion battery itself as well as a voltage regulator. It will supply power to the entire system so that it is able to run. The power will specifically be supplied to both the IMU and the microcontroller, both at around 3.3V. The power subsystem must be able to supply at least 300 mA to the rest of the system continuously at 3.3V +/- 0.1 V, which will be kept consistent by the voltage regulator.

5. Receiver

   The receiver will include the USB dongle in the USB port. This will receive all of the processed data from the transceiver, which would be the mouse displacement (dx, dy) in pixels as well as the mouse clicks (boolean values). This subsystem will then communicate this data to the computer itself so that the mouse on the screen will move on the screen according to the processed data.

2.4. Tolerance Analysis

One aspect of the design that poses a risk to successful completion of the project is the accuracy of the cursor movements compared to the head movements of the specific user. We plan to mitigate this issue using a calibration function during the setup of our device. Note the axes in figure 3 below, where the sensor on the user's head will act as the origin, and they face the screen along the roll axis. The bounds of these definitions are:

- $-180° \leq roll \leq 180°$
- $-90° \leq pitch \leq 90°$
- $-180° \leq yaw \leq 180°$

We can generally define the user functions as follows:

- Rest (mouse stays idle): roll = 0°, pitch = 0, yaw = 0°
- Up (mouse moves up): roll = 0°, $0° < pitch \leq 90°$, yaw = 0°
- Down (mouse moves down): roll = 0°, $-90° \leq pitch < 0°$, yaw = 0°
- Left (mouse moves left): roll = 0°, pitch = 0°, $-180° \leq yaw < 0°$
- Right (mouse moves right): roll = 0°, pitch = 0°, $0° \leq yaw \leq 180°$
- Tilt left (left click): $-180° \leq roll < 0°$, pitch = 0°, yaw = 0°
- Tilt right (right click): $0° \leq roll \leq 180°$, pitch = 0°, yaw = 0°

Note that we will have to alter these definitions of positive and negative directions according to the parameters of the specific gyroscope that we use.

We will have to account for noise in this situation. It is unrealistic to expect the user to sit completely still all of the time. Therefore, we can implement a sort of high pass filter that will only allow intentional movements to control the mouse. The goal of this filter can be to disregard any movements that are less than about 5°. This number will change after testing the device out, and may also change based on the calibration of the specific individual.

Our calibration will work by prompting the user to give samples when they are facing forward at rest, as well as when they are looking up, down, left, right, tilting their head left, and tilting their head right. The data taken from the user at rest will be useful in filtering out any additional noise that is specific to the movement of the user. All of the calibration measurements will give our program a good baseline for how to interpret the user's movements, since people have different abilities. After taking a calibration of the user, the above definitions of motion will become more specific based on what the user's specific range of motion is.

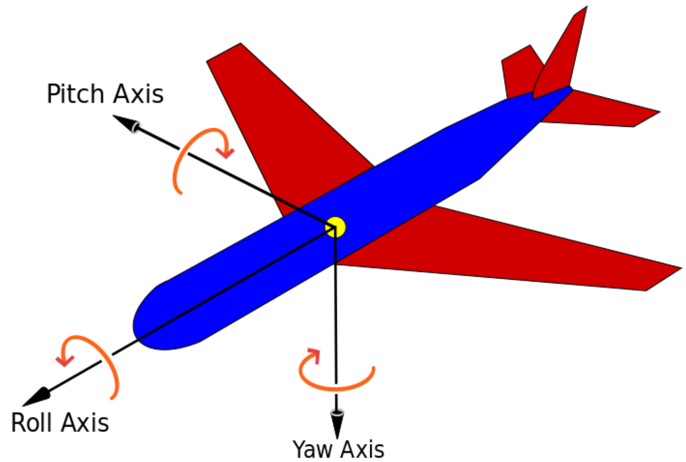

Figure 3: Illustration of roll, pitch, and yaw of gyroscopic motion

3. Ethics and Safety

Our team carefully took the IEEE Code of Ethics into consideration when developing our head-controlled sensor.[1] The safety of the users is important so we had to consider the different head movements that would cause the cursor to move so that they would not cause headaches or chronic discomfort. This also includes using safe batteries in enclosures that will not incur any burns and a well-balanced weight distribution of the device on the hat.

We also work in a peer and faculty-reviewed system to ensure that our technical work is legitimate and safe with realistic claims, as stated in section 5 of the IEEE code.[1] Each part of our project will be looked over by all people on our team and we will be open to criticisms and suggestions for improvement. Our team has also undertaken all relevant CAD, lab safety, and other technical training needed to keep everyone safe when working on the project and to be in compliance with campus policies in the labs. This way we will ensure that our technical competence is at a level reliable to be successful in our project as mandated by section 6 of the IEEE code.[1]

The ethical implications of our project are something we thought of seriously when developing the concept of our device, and it was a big factor in implementing a camera-free design. This will mitigate privacy concerns with being on camera and where that data may go. By only tracking the data of the head's direction which will be processed into a mouse displacement, we will avoid ethical breaches in any personal data.

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