OmniMouse

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Group 74
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**Objective**

Computing technologies has become an important aspect of daily life for many people across the world, an estimated 3.5 billion people are connected to the internet [1], and there are likely many more who have access to a computer that is not connected. For those using devices such as desktop or laptop computers, one of the most common ways to interface with a computer is through the use of a mouse. The operating a standard mouse crosses the user's ulna and radius bones and requires repetitive motions such as clicking and moving the device to give input. Over time, these movements can lead to discomfort or permanent damage. This is a result of the repetitive motions that the user undergoes, which leads to strain and microscopic tears throughout the utilized regions [2]. Research has suggested that to minimize these kinds of injuries, one should minimize wrist movement, offload strain to multiple locations, have a light grip, and avoiding positions that prevent proper circulation [3].

Our goal is to create a mouse that minimizes strain and injury for the user through varied non-repetitive motions and lessened hand pressures. We plan to address the various points of stress for using a mouse individually to create a final product that will hopefully help prevent and reduce the prevalence of stress due to computer mouse use.

**Background**

The main issues that we want to address are the minimization of wrist movement, strain being offloaded to multiple locations, the use of a light grip, and providing a position that promotes proper circulation. Our design is a stationary mouse with capacitive sensors around the base of the mouse, allowing the user to keep their hand in one position, minimizing any wrist movement. Since the mouse is stationary, little grip from the user is needed, further lowering strain on the user’s hand. Movement input is done through the capacitive sensors detecting how close the user’s hand is, and through the data of multiple sensors, we can map the location of the hand on the mouse. Using this data lets us calculate what direction to move the mouse cursor. This offloads strain to multiple locations since every direction the user goes can be controlled with a different part of the hand. The angle and shape of the mouse will be optimized to provide the user with a neutral resting position while using the device, which allows for the best circulation within the whole arm.
High Level Requirements

1. The mouse should be ergonomic and shouldn't strain the wrist or any other area.
2. Function like a standard laser based mouse, with a minimum polling rate of 60hz, and an ideal polling rate of 125hz.
3. Battery should last at least 4 hours, and will be operational while charging.
4. The mouse should have basic functions like “moving”, “clicking” and “scrolling”.
5. The mouse should work on any type of surface.
6. The use of the mouse should be intuitive.

Block Diagram

Omni Mouse Block Diagram
Diagram Description

In our design, there are four major components to be implemented, Power, Control, Connection and Input. The power supply and power circuit provide power to our system, through a lithium ion battery. This battery is rechargeable through USB power. When the USB is plugged into a compatible computer, it will both recharge and act as a wired mouse. Our control unit is our microcontroller. Our Teensy 3.2 will handle all the IO and data processing needed to transmit data to our mouse driver on the connected computer. The Input section is designed to track hand movement of the user. Our algorithm will be designed to process data from this sensor array and translate it into a two dimensional plane for our mouse driver. Finally, the communication module handles the switch between wired connection and wireless connection. Wireless connection will be done using Bluetooth LE, and the wired connection will be through USB OTG, with the switch occurring when the user connects/removes the USB cable to a compatible device.
**Control Flow**

**Diagram Description:**
This diagram depicts the process in which data is obtained from the sensors of the device and sent to the connected device. Upon mouse startup, initial calculations are done to tune the accuracy of the sensors. After these are complete, the mouse is free to connect with a device, after which it will continuously send the sensor data to be processed by the computer driver.
Circuit Schematic

Figure 3: Protection Circuit when DC supply drops below 3.0 V (R6 representing the load)

Figure 4: USB Charging Circuit [4]
Teensy 3.2 Pinout

Pins: 0, 1, 14, 15, 16, 17, 18, 19, 22, 23, 25, 32, 33 - Capacitive Sensors
Pins: 7, 8 - RX, TX for Bluetooth Module
GND: Ground
Vin: Power Block (Battery)

Teensy 3.2 Pinout [5]
Functional Overview

I. Input

Our input consists of the capacitive sensor array and a gesture button. The sensor array takes input from the user and sends it to the microcontrollers, which process the input into mouse movements that can be sent to the computer. The gesture button will be located near the mouse center, and will be actuated to enable the use of gestures. These gestures will activate mouse inputs such as click, right click, and scroll (the basic inputs, additional inputs can also be created and implemented through other gestures).
We have included our test results and physical design options in the supporting material section. More test would be conducted on the sensor input to get maximum precision and responsiveness. Right now we haven’t decided which physical layout to use.

II. Power

Our power circuit consists of an li-ion battery, a charging circuit, and a safety circuit. The power block consists of our battery, which is used to power the device while in wireless mode, and charges when it is in wired mode. The charging circuit takes care of the charging through the USB port, and the safety circuit monitors the temperatures and voltages to make sure they are within safe usage levels.

Power Calculation:

We used the datasheet provided numbers to calculate the estimated power consumption and total on-time of our device. This calculation is done using the MPR121 infrared ambient temperature sensor that we are considering in our IR design.

Teensy Maximum Power:

\[
P = V \times I = 3.3 \, V \times 185\, mA = 0.611 \, W
\]  

\(\text{(EQ. 1)}\)

Wireless Module Power (GM-205810-000):

\[
P = V \times I = 3.3 \, V \times 85\, mA = 0.281 \, W
\]  

\(\text{(EQ. 2)}\)

If power efficiency is assumed to be 80 % and voltage regulator / dc-dc converter efficiency to be 90%, the estimated maximum total power is:

\[
P_{\text{total}} = \frac{(0.611+0.281)}{(80\% \times 90\%)} = 1.239 \, W
\]  

\(\text{(EQ. 3)}\)
This indicates that an 1500 mAh DC battery will support the whole circuit (in full-load operation) by a period of:

\[
1.5 \text{ Ah} \times 3.6 \text{V} / 1.239 \text{ W} = 4.358 \text{ hr} \quad (EQ. \ 4)
\]

However, one should expect the cycle to be longer since this is the worst case scenario of having the whole circuit on full load. This is also while using the Teensy board, which will be replaced by an Atmega328 or similar microprocessor in the final design, which will require much lower power consumption and will result in a longer battery life for the device. We will be designing for a high on-time to give the best user experience.

### III. Control

The control unit uses Teensy 3.2 microcontroller as the processor. The microcontroller and its peripheral module will provide an interface between the capacitive sensors array and computer, by taking in input data via analog input port. A high level algorithm will be created to map the input information to two dimensional direction outputs. Eventually the output will be sent via serial bus to communication module. Ideally, we will try to break out a MK20 chip from teensy 3.2 microcontroller to interact with other modules. Figure 6 shows the breakout circuit schematic for MK20DX256VLH7 chip and we will be using this schematic as our reference.

### IV. Communication

The communication block consists of two connecting modules: Serial communication and Wireless Bluetooth communication. Both modules are considered peripheral modules to the control block. The USB module will also be part of rechargeable circuit, which we have previously mentioned. Further, we would use USB 2.0, and HC-06 Bluetooth module as transmitter in current design. On the PC side, we will implement a mouse driver under Linux(UNIX) to handle our device input.
## Block Level Requirements and Verifications

### Input

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Microcontroller should process sensor data at at least 60Hz.</td>
<td>Read raw transmitted data on connected computer, check for at least 60 packets of sensor data per second.</td>
</tr>
<tr>
<td>Gesture Button should send button input data.</td>
<td>Read transmitted data for button actuations.</td>
</tr>
</tbody>
</table>

### Power

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Protection circuit will disconnect the load if DC battery voltage drops below 3.0V</td>
<td>Replace the battery with DC supply equipment. Sweep the voltage from 5 V to 1V, measure the load voltage to check if it drops to 0 when supply voltage drops below 3.0V (full cutoff from power supply)</td>
</tr>
<tr>
<td>Battery lasts at least 4 hours before charging is needed</td>
<td>Fully charge the battery and let the mouse run in wireless mode. Measure the time duration when the circuit is cut by the protection circuit, i.e. voltage drops below 3.0V</td>
</tr>
<tr>
<td>Battery will automatically disconnect when above 60°C while discharging and above 45°C while charging [10]</td>
<td>Replace battery with heating element and check for circuit completeness around the element after temperature reaches thresholds.</td>
</tr>
</tbody>
</table>
Control

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Driver on the computer should fetch continuous moving signals and operate the cursor in correct way.</td>
<td>We will write a small program to fetch input signals and visualization each user movement.</td>
</tr>
</tbody>
</table>

Requirements and Verifications

Communication

<table>
<thead>
<tr>
<th>Requirement</th>
<th>Verification</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The communication should work with in the range of 1 meter.</td>
<td>1. Test the functionality of HC-06 bluetooth module as a transmitter in various distances. Especially within 1m range.</td>
</tr>
<tr>
<td>2. The USB mouse driver should be robust and consistent to use.</td>
<td>2. Test mouse under multiple programs and multiple machines</td>
</tr>
</tbody>
</table>

Block Level Requirements and Verifications

Tolerance Analysis

The most critical parts of our design in terms of safety and accuracy are the sensors and the battery/safety circuit. This is because the sensors are providing the raw data that the user will see as mouse movements, and the battery/safety circuit prevents any possible damage done from the lithium based battery.

With a 1500 mAh battery, we expect to get around 4.358 hours of on time at the minimum (see EQ. 5). Ideally, we would hope for at least 1 average work day's worth of charge, around 8 hours. To guarantee this, a battery of 2750~ mAh will be needed.

Since we are using Bluetooth, we can model our operational range using the datasheet provided values, and the Free-Space Path Loss Formula. The datasheet specifies −80db for the bluetooth signal [8], giving us the following equation:
\[
FSPL (db) = 10 \log_{10} \left( \left( \frac{4\pi df}{c} \right)^2 \right) \quad (EQ. 4)
\]
\[
FSPL = 20 \log_{10}(d) + 20 \log_{10}(f) + 20 \log_{10} \left( \frac{4\pi}{c} \right) \quad (EQ. 5)
\]

We have -80db at 2.4GHz for Bluetooth's signal, with the speed of light at 3E8, giving us:
\[
\log_{10}(d) = 4 - \log(2.4E9) - \log_{10} \left( \frac{4\pi}{3E8} \right) \quad (EQ. 6)
\]
\[
\log_{10}(d) = 4 - 9.3802 + 7.378 = 1.998
\]
\[10^{1.998} = 99.54 \text{ meters} \quad (EQ. 7)
\]

Bluetooth gives us a range of 100- meters under perfect conditions. Since we are operating as a computer mouse, realistically we don't expect the user to be much more than a meter or two away from the device they are interfacing. As such, we do not expect there to be any issues with Bluetooth signal for our device.

**Supporting Material for Sensor**

**Materials Testing**

In order to decide on which materials worked well for capacitive sensing, we did some data collection utilizing various metals. We tested steel, copper and aluminum, as well as aluminum with a sheet of acrylic acting as the dielectric. From our data, it was clear that materials with higher conductivity were much more sensitive to touch, and that the size of the conductive surface also played a large role in the data we received. Data that was obtained with using air as the dielectric had more significant variance than when we used the sheet of acrylic, which suggests that the best solution for our sensor would be to utilize a highly conductive material such as a copper or aluminum plate/sheet, with a dielectric such as acrylic or glass.

<table>
<thead>
<tr>
<th>Material Used and Resulting Capacitance (Averaged, normalized)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Material Used: Steel (Rod), Copper (Penny), Aluminum (Sheet), Aluminum (Sheet with Acrylic)</td>
</tr>
<tr>
<td>Conductivity (Relation to copper) [9]: 3-15%, 100%, 61%, 61%</td>
</tr>
<tr>
<td>No Contact: 200, 480, 26000, 18500</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td><strong>Finger Contact</strong></td>
</tr>
<tr>
<td><strong>Full Arm Contact</strong></td>
</tr>
</tbody>
</table>

(Copper conductivity being 58.5E6 Siemens/m)

: Average values of recorded normalized capacitance of Materials

**Sensor Design Testing**

Figure 7: Sensor Bar V1, Bar Sensor

Figure 8: Sensor Bar V2, Dual Strip Sensor
We have iterated through a few designs for our capacitive sensors so far. The three above shown images depict the three styles that have been tested so far. Our materials testing showed that materials that conduct well, such as aluminum and copper, will have the best sensitivity for our sensor. Due to this finding, we tested our possible sensor designs using common household aluminum foil for the purposes of quick prototyping.

We currently have two design choices: 1. Use 6 pairs of sensor bars to form a sensor bar array. Each bar has negative end and positive end which could be used to sense relative
position change. 2. Use multiple dots system to keep track of user input. In this way, we will create a more complicated algorithm to register each user movement.

Physical dimensions are expected to be an oblong dome shape with a base size of 5in x 4.8in and a height of 3in with a base tilt of 30° up from the right edge of the device. The chassis will be made primarily of clear acrylic that acts as a dielectric for our capacitive sensors.

However, we are still in the research and testing phase, so further changes may be made on this physical design.

**Cost and Schedule**

**Costs**

Labor: Estimating the hourly salary of each team member to be equal to the average graduating ECE student [11] and the average work hours in a year to be 2087 [12], we calculate that the hourly salary of the team would be $112.84. There are approximately 80 days between the beginning of the project and the final demonstration. Estimating an average of 2 hours worked per day, we arrive at a total of $18054.40 in salary for our team of three. Multiplied by 2.5, we get $45136 in labor.

<table>
<thead>
<tr>
<th>Name</th>
<th>Quantity</th>
<th>Cost (Total)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teensy 3.2 Microcontroller</td>
<td>1</td>
<td>$30</td>
</tr>
<tr>
<td>2500mAh Li-Ion Battery</td>
<td>1</td>
<td>$15</td>
</tr>
<tr>
<td>LD1117 3.3v Regulator</td>
<td>1</td>
<td>$1.95</td>
</tr>
<tr>
<td>Mouse Chassis</td>
<td>1</td>
<td>$15</td>
</tr>
<tr>
<td>Capacitive Sensors</td>
<td>12</td>
<td>$6</td>
</tr>
<tr>
<td>HC-06 Bluetooth Module</td>
<td>1</td>
<td>$8.99</td>
</tr>
<tr>
<td>Micro-USB-B to USB-A</td>
<td>1</td>
<td>$1</td>
</tr>
<tr>
<td>Max 1555 USB Charging Chip</td>
<td>1</td>
<td>$1.20</td>
</tr>
<tr>
<td>Linear Technology 1495</td>
<td>1</td>
<td>$3</td>
</tr>
<tr>
<td>Various Resistors, Diodes,</td>
<td>~</td>
<td>$5</td>
</tr>
<tr>
<td>Wires, Solder, etc</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Our total cost for parts and labor are: $45136 + $87.15 = $45223.15.

### Schedule

<table>
<thead>
<tr>
<th>Date</th>
<th>Task Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3/3</td>
<td>Sensor array ready, power circuit tested on breadboard</td>
</tr>
<tr>
<td>3/10</td>
<td>Mouse cursor algorithm ready</td>
</tr>
<tr>
<td>3/17</td>
<td>Assemble all parts, test and debug</td>
</tr>
<tr>
<td>3/24</td>
<td>Assemble all parts, test and debug</td>
</tr>
<tr>
<td>4/1</td>
<td>Hand to machine shop for final circuit printout</td>
</tr>
<tr>
<td>4/4</td>
<td>Fully assemble the device</td>
</tr>
<tr>
<td>4/10</td>
<td>Prepare for Mock Demo and Final Paper</td>
</tr>
<tr>
<td>4/17</td>
<td>Prepare for Final Demo and finish Final Paper</td>
</tr>
</tbody>
</table>

### Ethics and Safety

Following the IEEE Code of Ethics [13], there are a few safety issues that we must address in our project. The first and foremost being the responsibilities as engineers to make decisions based on the safety and welfare of the public in mind. Thorough research on ergonomics of the human hand and the ideal positioning and angles of movement will be done for the design of the shell of the mouse. So while the original idea envisions an almost half-sphere dome for the shell, it is very likely that the best shape may be more ovular and raised at an angle from the horizontal. The movement as well as gestures must be non-fatiguing, or at least minimally fatiguing for the user to fit in with our objective. Proper warnings for potential dangers will also be included in the documentation for the device.
Since we plan to utilize a li-ion battery into our mouse to allow for wireless connectivity through bluetooth, we must take battery safety into consideration. As outlined from the Battery Safety document located on the course website [14], Li-ion batteries are well known to be explosive if exposed to the wrong conditions. To combat this, we follow the provided guidelines, making sure to keep the battery temperature and voltage within safe ranges (3-4.2v) as well have a hardware switch to entirely turn off the wireless mode (and therefore bypassing the need for the battery, if the user so chooses). Additional measures, such as shielding and isolating the power circuitry will eliminate the risk of electric shock. These precautions should allow for the safe operation of our li-ion battery by itself, and in conjunction with our charging circuit.
Citations


