

Wireless Mouse for People with Upper Limb Amputation

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Abstract: The paper presents a study which is aimed at designing a wireless Arduino Nano powered device that enables people with limited use of their hands to access and control a computer. To the user, the device consists of two parts. These parts are the receiver and the transmitter. The user wears the transmitter which holds the Arduino NANO, the modules such as the NRF24L01 2.4GHz Wireless Communication Module, the MPU6050 Gyroscope/Accelerometer module, the TP4056 – Micro USB 5V 1A Lithium Battery Charger Module, and the 0.9V-5V to 5V 600mA DC-DC Converter Step Up Boost Module with USB port interface. The paper focuses on creating a system which is composed of hardware, software, and database related components. The interconnection of these components was made possible by using the NRF24L01 Wireless Communication module and interfacing the Arduino Nano, which collects the raw data using the MPU6050 Gyroscope/Accelerometer module, with a JAVA based Widget that converts the collected data into a Human Interface Device (HID) function such as mouse clicks and movements. The researchers used an iterative method in which every feedback in each test, resulted into another requirement that was designed and developed, tested, and implemented. This method enabled the researchers to improve the debugging and troubleshooting of the system, as problems occur at a certain phase and not carry that software or hardware problem to the next phase. The research developed a device which offer an affordable and convenient alternative to assistive and adaptive technologies for people with limited use their hands.

Key Words: Arduino; motion; wireless; HID; mouse; PWD; alternative.

1. INTRODUCTION

1.1 Background of the Study

Computers have become a very important part of today's life. From work related aspects to just passing the time, computers are used. Using a computer is normally an easy task that requires basic control using a mouse and keyboard to do what a user wants the computer to do. A quote in the IBM training manual 1991 states "For people without disabilities, technology makes things easier. For people with disabilities, technology makes things possible." Computers are pieces of technology put together to work as a system. Their controls are made for majority of the population and not many

adaptive technologies are available for people with disabilities.

1.2 Review of Related Literature

Based on the 2010 Census of Population and Housing (CPH), "There are 935, 551 people classified as (PWD) in the 2000 CPH records. Out of this, 3.83%are those with one or both arms/hands missing." The scope of disability covered are those that limit the use of a person's hands. This includes amputees and burn victims that lost control of the fingers. Although the availability of adaptive and assistive technologies cannot be compared with everyday technology, many researches are done to make assistive and adaptive technologies. The scope

of this study is closely related to Human-Computer Interaction studies. These assistive and adaptive technologies can depend on the use of a person's eye, foot, head, or a limb to control devices other than the traditional use of a mouse or keyboard. There was a device created by Morales et al. (2013) called AsTeRICS that uses multiple sensors to accommodate the user. The thing that stood out at the time was the use of a webcam mouse to control a computer. This uses image processing that translates head movement into mouse gestures. Another very interesting assistive device was filed back in (2015) assigned under Qualcomm Inc for Forutanpour, Farley and Balasubramanyam (2015) with the title "Gesture-based device control using pressure-sensitive sensors". This device uses muscle activity to control a connected computer or peripheral.

1.3 Objectives

The main objective of the research is to develop a device that controls the mouse pointer and enable people with limited use of their hands to operate a computer with ease in comparison to using the regular peripherals. In order to close the gap between regular peripherals and assistive and adaptive peripherals, the researchers proposed to make a portable wireless device that the user can wear anywhere on their arm below the shoulder. Being a wearable device, the size and weight of the device are factors that were brought into consideration. The device will depend on movement from the users to move the mouse pointer on a computer. This is going to be accomplished by using a gyroscope to collect information of the user's movements. This information is later converted into mouse coordinates on the user's computer. The conversion of information from the gyroscope is converted using a software prepared by the researchers that translates the information to mouse coordinates. This software will act as a control system in which users can choose their proposed sensitivity and mode in which to use the device. The device is wireless to not restrict the user's movements. Different disabilities have different movement constraints. Going with a wireless device not only reduces clutter but also eliminates some of the user's movement constraints.

1.4 Scope and Limitations

The study aimed to develop a device that is lightweight and easy to wear and the supporting

User Interface (UI)/Widget that connects to a database used to store the time log, power consumption and user priority of the device.

The respondents of the study are the people with physical disability, specifically the amputees. Our study covered either Congenital or Acquired with either Trans-humeral (Above Elbow), or Trans-radial (Below Elbow) Amputees. Therefore, our study was for Upper Limb Amputees. Researchers conducted a study in Dasmariñas City with the help of AMP4LIFE support group. Other disabilities were not covered by the research.

2. METHODOLOGY

The researchers used a mixed method approach which utilizes qualitative, quantitative, and experimental methods. The experimental method of the system is composed of three parts which are the hardware, software, and the database.

For the population of the research, it was based on the availability of the respondents. Due to the limited number of participants available the researchers were assisted by a local organization with the name of *AMP4LIFE*. The members of this organization gave multiple insights that lead to further enhance the overall functions of the proposed device. Data gathering was composed of questionnaires and interviews. Since respondents were limited, the researchers did their best to incorporate the inputs of each respondent in the overall device. Interviews and consultation was also conducted with the expert evaluator Ma'am Sheena Pilar Andrade – Olitoquit RN, CPO, CWAT, a member of *AMP4LIFE* and a Faculty at *De La Salle Health Science Institute*. Her expertise and inputs also helped the researchers to develop the device, making it more user friendly and comfortable for the users.

2.1 Hardware Design

2.1.1 Hardware Components

2.1.1.1 Arduino NANO microcontroller

The Arduino NANO was used for the main function of the receiver circuit. It processed the data received from the device for the PC to classify it as an HID. The size of this component is ideal for the compatibility feature of the design. The micro USB is

Presented at the 6th DLSU Innovation and Technology Fair 2018
De La Salle University, Manila, Philippines
November 22 & 23, 2018

needed for the supply power that will be attached to the USB port of a PC.



Fig 1. Arduino NANO v3.0 CH340G

2.1.1.2 MPU-6050 Module

The MPU-6050, a 3-Axis gyroscope & accelerometer sensor was used to gather input data. It detects the movement by capturing the x, y, and z channel at the same time. The sensor provides data through I2C serial bus. The researchers used the Arduino wire library to communicate with the sensor using the Arduino NANO microcontroller.



Fig 2. MPU-6050 – 3-Axis Gyroscope and Accelerometer Module

2.1.1.3 NRF24L01 Wireless Module

The NRF24L01 is a highly integrated, ultra-low power 2Mbps RF transceiver IC for the 2.4GHz ISM band. This module was used for the high-speed communication of the transmitter and receiver circuit of the device. This component can cover a range up to 50-200 feet.



Fig 3. NRF24L01 2.4GHz Wireless Communication Module

2.1.1.4 Lithium Ion Battery

The Lithium Ion Battery was used as the power source of the transmitter circuit. These batteries are thin, light, and powerful ideal for the proposed design. The output voltage ranges from 3.7V to 4.2V when fully charged, has a capacity of ~800mAh, a weight of 25g.



Fig 4. Lithium Ion Battery – 3.7v 800mAh

2.1.1.5 TP4056 –Lithium Battery Charger Module

The TP4056 was used to charge the battery of the transmitter circuit. It has a micro USB interface for the input voltage of 5V. The charging cut-off voltage is 4.2V and maximum charge current of 1000mA. It also comes with protection for the battery over-discharge voltage of 2.5V and overcurrent protection current of 3A.



Fig 5. TP4056 – Micro USB 5V 1A Lithium Battery Charger Module with Protection

2.1.1.6 DC-DC Converter Step Up Boost Module

The 0.9v to 5v DC- to DC booster was used to power-up the Arduino Nano since the Arduino Nano runs at a running voltage of 5v. Any voltage less than 5v will cause the Arduino to malfunction.



Fig 6. 0.9V-5V to 5V 600mA DC-DC Converter Step Up Boost Module with USB

2.2 System Design

2.2.1 System Block Diagram

The overall system is represented by Figure 7. The input for this system is motion. Movement is detected by the motion sensor. It will send a 3-axis coordinate, such as X, Y, and Z axis to the transmitter's Arduino NANO. The data is passed to the receiver module to be processed by the second Arduino NANO. The second Arduino NANO analyzes the received data and passes it to the Widget. The Widget translates the received data into HID mouse instructions and allows the user to change their preferred settings. The widget also displays status such as time, date, power level, and user ID that also stored to the local database. The local database passes the information to the web database which is only available for the system administrator. The output of the system is the interaction between the user and the computer through the adaptive device.

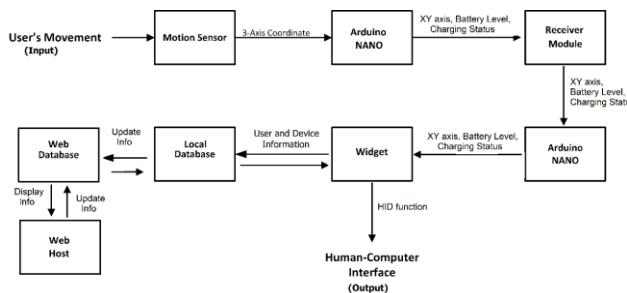


Fig 7. System Block Diagram

2.2.2 System Flowchart

The overall system flow is interpreted by Figure 8 in which the system initializes and begins the parsing of data. A timer shows the time consumed by the user when using the device. The time consumed was computed by getting the current time at the start of using the proposed device minus the current time at the time of turning the device off ($End_Time - Start_Time = Time\ consumed$). The system waits until the user performs a movement through the motion sensor. When a movement is detected, the system translates the movement data into a type of data necessary to perform a Human-Interface Device function between the user and the

computer. For every function that the device performs, the system displays the remaining power level. Finally, the system identifies if there is a change in settings through the user interface. The system sends a command for the device to change or adjust a specific function specified by the user. The system function ends when the remaining power level of the device reaches zero or the device is turned off.

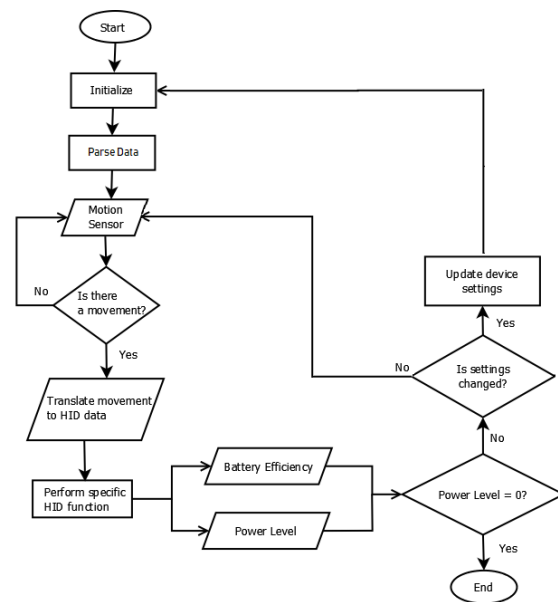


Fig 8. System Flow Chart

2.3 Hardware Design

2.3.1 Schematic Diagram

In Figure 9, the transmitter circuit is used by the device attached to the user. The MPU-6050 captures the motion of the user. The Arduino NANO detects the movement from MPU-6050 and sends the data to the NRF24L01 transceiver module. A flip switch was used for the convenience of the user and for to switch the power of the device ON and vice-versa. The transmitted signal is sent to the receiver circuit shown in Figure 10. The NRF24L01 receives the transmitted signal that is to be processed by the Arduino NANO. The NANO outputs the data into the serial monitor in which the Widget translates the data to function as a Human-Interface Device for the PC. This circuit will be attached to a PC using the USB port of the NANO.

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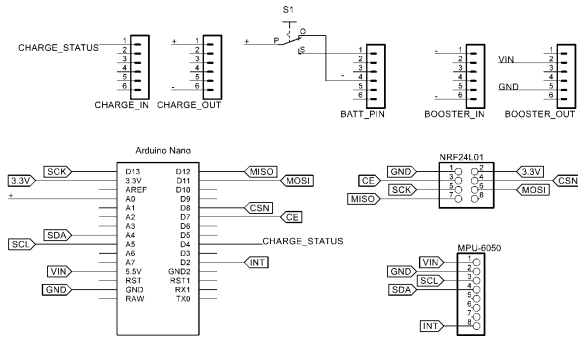


Fig. 9 Transmitter Circuit Diagram

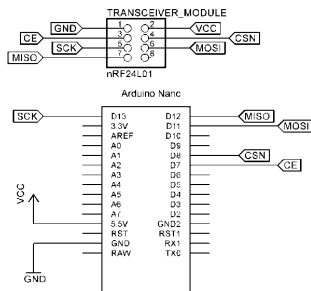


Fig. 10 Receiver Circuit Diagram

2.3.2 Actual Device

The actual device is shown in Figure 11 and Figure 12. The material used to hold the device is the strap that is attached to the user's limb.



Fig. 11 Transmitter Top and Bottom View



Fig. 12 Transmitter Front View

2.4 Software Design

The system's software interaction is represented by Figure 13 in which the package "Wireless Adaptive and Assistive Device System" has three actors in the diagram (Special User, Administrators, and Assistive System). Contents of the Rounded Rectangles represent the activities of which the Special User will take in. Before anything else, the Special User logs in to the Computer with the startup program. The startup program and its interface will be launched automatically after the user log into his or her computer. Assuming the Special User has connected the USB Receiver of the Device in the computer, the program records the starting time of his or her usage. The Researchers used the <include> relationship between the "Log-In computer" and "Monitor Start of Time" activity. The included Use Case activity "Monitor Start of Time" cannot stand alone and is dependent if the Special User would turn the computer on. Through that, the Special User can access the computer in ease. The user can also monitor the battery level since the levels in the interface would be in real-time. The user can also monitor the efficiency of the battery. Notice that the Researchers' used <extends> relationship in Use Case. Extends relationship is somewhat optional because it extends the behavior of the activity.

The Administrators were able to Sign Up or login his or her account. After that, User Interface Data Log is displayed in the screen, which monitors the information of the devices with their users. If allowed by the user, the administrator can assist him or her by managing the settings of the device in the widget (sensitivity, left click and right click options).

The actor "Assistive System" has three activities: Monitor Start Time, Monitor Battery Level, and Monitor Battery Efficiency. The assistive system also monitors the (3) activities like what the Special User do. This system also stores the information in the database. An overview of the data type stored in the database is shown in Figure 14.

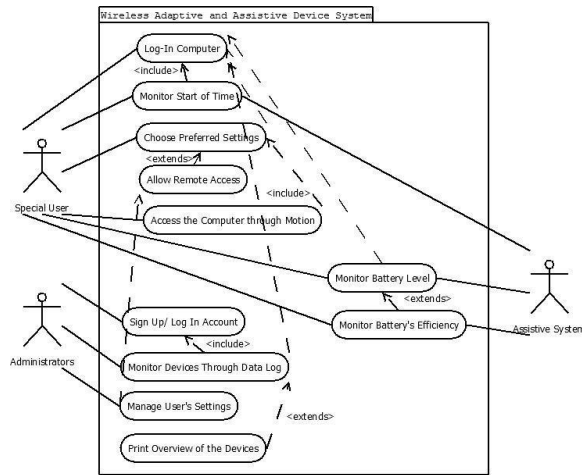


Fig. 13 System Use Case Diagram

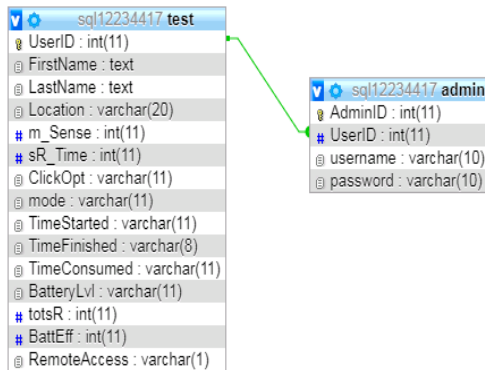


Fig. 14 Database Schema

2.5 User Interface Design

Figure 15 shows the User Interface of the startup program. The first program that appears in the Desktop is the Log-In or Sign-Up. For the old users, they retrieve their previous account in the drop down menu. For the new users, they could sign in for a new account by filling the required information below (First Name and Last Name). An on-Screen Keyboard is also included in the Startup for the convenience of the users. These accounts are stored in the Database. The main startup interface consists of Time Connected, Status of Device, User ID, Power Level, Last Name, First Name and Settings connected to the Device. The time starts if the Receiver in the Computer has already been set up, and the Computer is logged in. That is the time that the status of the device changed from

Disconnected to Connected. Power Level Percentage is real-time, together with the battery icon. As percentage decreases, the bar also decreases. Settings (Sensitivity, Click Options, Mode) is set through the movement of the user. These settings are stored in the Database to allow the setting to be accessed again when the user logs in next time. First Name and Last Name of user is filled out for personalization. Another feature on the widget is the option of remote access for changing the settings in the case the user faces difficulties. The user has the option of allowing the administrator access with the click of a button.

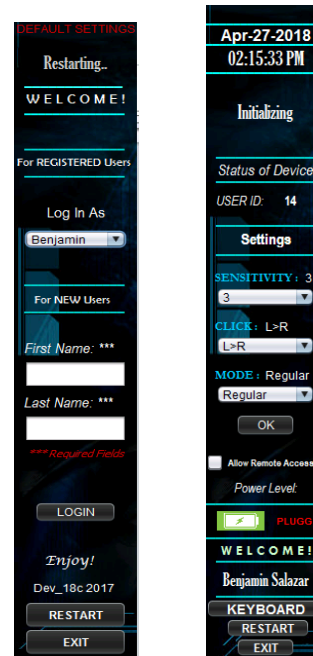


Fig. 15 Widget Interface

3. RESULTS AND DISCUSSION

3.1 Power Consumption

The chart in Figure 16 displays the battery discharge depending on the type of usage. Since the Arduino Nano does not have a built-in sleep mode to save power. A discharge test was conducted to shows the device working at standby mode, where there is no collected input while the Active mode is when the device is at maximum usage. The maximum time for

the battery to sustain the device is ~8 hours for Standby mode and ~7.5 hours for Active mode.

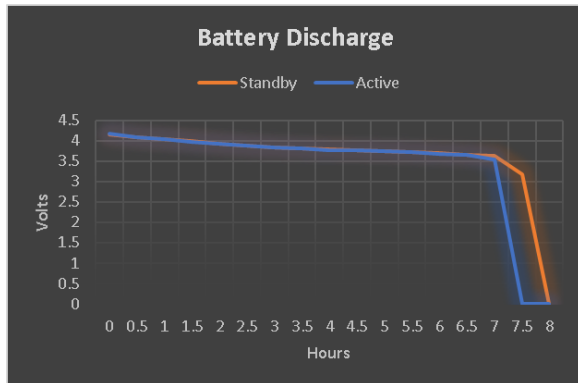


Fig. 16 Battery Discharge

The chart in Figure 17 shows the device working at standby mode, where there is no collected input while the Active mode is when the device is at maximum usage. The maximum time for the battery to reach the maximum capacity is ~1.5 hours for Standby mode and ~2 hours for Active mode.

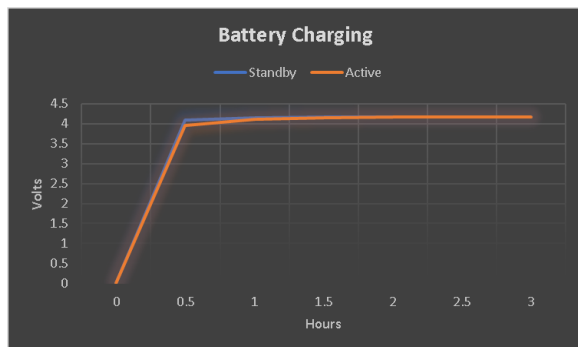
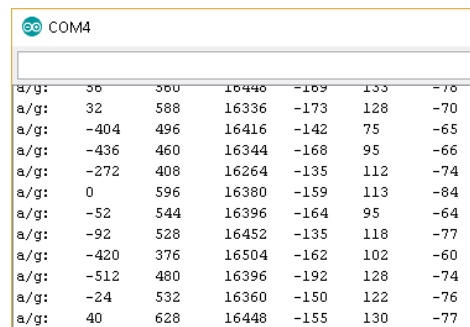


Fig. 17 Battery Charging

3.2 MPU6050 Raw Data Conversion

Figure 18 shows the raw data collected from the MPU6050 through the Arduino Nano using the Arduino IDE at baud rate 38400. The researchers used an example sketch that is available on the IDE by the name of MPU6050_raw. This sketch prints out the raw values from the two sensors on the MPU6050, namely the accelerometer and the gyroscope. The readings are ax, ay, az, gx, gy, and gz from left to right, as can be seen on Figure 4.2.3. The letter “a”, stands for the accelerometer while the letter “g”, stand for gyroscope. The letters “x”, “y”,

and “z” indicates what axis is being measured. The researchers chose to utilize the data collected by the accelerometer since the accelerometer measures linear motion and gravity. This means that the data collected is based on gravity which makes the orientation of a person’s movement easier to discern.



a/g:	36	560	16446	-169	133	-76
a/g:	32	588	16336	-173	128	-70
a/g:	-404	496	16416	-142	75	-65
a/g:	-436	460	16344	-168	95	-66
a/g:	-272	408	16264	-135	112	-74
a/g:	0	596	16380	-159	113	-84
a/g:	-52	544	16396	-164	95	-64
a/g:	-92	528	16452	-135	118	-77
a/g:	-420	376	16504	-162	102	-60
a/g:	-512	480	16396	-192	128	-74
a/g:	-24	532	16360	-150	122	-76
a/g:	40	628	16448	-155	130	-77

Fig. 18 MPU6050 Raw Data

The data collected from the Arduino Nano is displayed using Figure 19. This data represents five important factors needed for the widget to translate. These factors from left to right are the X coordinates, Y coordinates, Battery levels, Charging indicator, and lastly the Location.

For the X and Y axis, they are derived from the raw values of the MPU6050’s accelerometer’s x and y axis shown in Figure 4.2.3. Although the values of the X and Y accelerometer’s values are very large, reaching tens of thousands makes the values very large to control. Hence, the researchers created a condition in which the output simply becomes 1 for a positive value in the axis, -1 for a negative value in the axis, and finally 0 when the values received are very close to each other indicating a standby. These values are later translated in the Widget into mouse movement based on the translated data from the MPU6050.

The next factor is the Battery levels, which ranges from a value of 0 to 100. Data for the Battery levels are taken by the Arduino Nano using one of its analog pin to read the current battery levels. This is made possible by mapping the receive readings to match the type of battery connected. In the case of this device, the device uses a lithium ion battery that is fully charged at 4.2v and functions till 3.0v. Using this as a mapping reference, the researchers could get the battery levels. Although the readings

5. ACKNOWLEDGMENTS

This thesis became a reality with the help and support of many individuals and groups. The researchers would like to extend their sincere gratitude to all of them.

First and foremost, the researchers would like to thank GOD Almighty for bestowing upon them the strength, wisdom, and good health in order to finish the research entitled “Wireless Adaptive and Assistive Arduino Controlled Device for People with Disabilities”.

The researchers would like to express their gratitude towards the following people; their families for their unending support and encouragement from the beginning of the research till the completion of the research.

The researcher’s adviser, Engr. Dwight Sabio who always provide countless pieces of advice, improvements and accommodated the researchers for consultation.

Distinguished members of the panel, headed by Engr. Kathleen Ann G. Villanueva together with Engr. Amelia Liwanag and Engr. Earl Jayson Alvaran for the approval of the researchers’ work and the inputs and suggestion provided that can better improve their study.

Sheena Pilar Andrade – Olitoquit RN, CPO, CWAT, a member of AMP4LIFE and Instructor at De La Salle Health Science Institute who has imparted her knowledge and expertise that helped the researchers identify respondents and improve the scope of the study.

Many thanks to the members of People with Disabilities Association Office (PDAO) in Dasmariñas, Imus, Salawag, also, to the barangay heads of Brgy. Sta Fe, Brgy. Fatima I & II, Brgy St. Peters, and Brgy San Agustin.

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