Sign Language Interpreter Glove (SLIG)

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***Abstract* — The objective of the Sign Language Interpreter Glove (SLIG) project is to create a device that will aid in the communication barrier between vocal and sign language speakers. This project demonstrates the application of a glove equipped with multiple sensors such that it can be worn on a person's hand and has the ability to recognize the American Sign Language (ASL) signs performed by the user. Whatever signs the glove has recognized will be displayed through the designated user interface. The project was chosen with two purposes in mind; the first being to help ASL speakers communicate with those who do not understand ASL and the second to help non-ASL speakers learn and practice signing.**

***Index Terms* — Accelerometers, Bluetooth, Data gloves, Flexible electronics, Lithium batteries, Regulators.**

I. INTRODUCTION

The Sign Language Interpreter Glove allows the user to translate the American Sign Language (ASL) sign of the letters of the alphabet to an Android mobile device application. This glove is equipped with a series of flex sensors, an accelerometer, an embedded processor on a printed circuit board and wireless technology that combine to give the user the ability to accurately communicate to any individual who does not understand American Sign Language. At the same time, the SLIG can also help the user learn ASL. The original motivation to pursue this project comes from one of our team members who has experienced the difficulty of communicating with his speech-impaired sister. This project got the team thinking along the lines of wearable technology and opened the door for our extensive research in the area.

Through research, the team has developed a design that will allow the SLIG to function according to the objectives and requirements previously mentioned. SLIG will require the use of flex sensors, an accelerometer, a gyroscope and contact sensors to capture all of the necessary information to identify each ASL hand gesture of the alphabet. All the information collected through these sensors will be processed by an MCU that is integrated into our PCB, bringing all of the components together. The glove will be Bluetooth capable and will transmit all data wirelessly to an Android smartphone application where the final interpretation will be displayed visually. A lithium-ion battery will power all the electronics on SLIG. The rest of the supporting electronics will include voltage regulators, analog to digital converters and others of that nature.

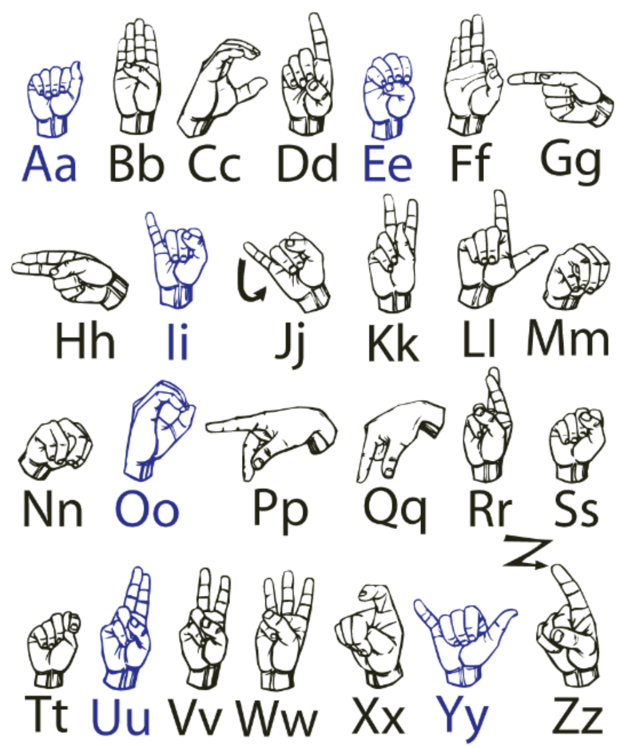

Fig. 1. The American Sign Language Alphabet

II. HARDWARE OVERVIEW

A. Flex Sensors

Flex sensors will be the primary sensors employed in this project. They will be used to detect the degree to which each finger is bent on the hand performing the sign language. The combination of different degrees of flex for each finger will be the identifying mark for most of the letters. This will be the main method in determining which letter of the alphabet the user is trying to sign. For example, if the user wanted to form the sign for the letter 'A' he or she would have to completely bend down every finger except for his or her thumb. The flex sensors corresponding to these four fingers would increase their internal resistance as they are bent and in turn the circuit will output lower voltages that could be measured and ultimately recognized as the signal configuration for the letter A.

B. Accelerometer & Gyroscope

Though flex sensors are a great way to capture many useful pieces of information from the physical state of the user's hand, they are limited in the range of motions that they are capable of sensing. The flex sensors can only detect how much bending they are experiencing and so they neglect motions like tilting the hand back and forth at different angles. Instead, accelerometers and gyroscopes can be used to measure this type of motion, which are crucial in identifying certain sign language letters such as "j" and "z". The two parts work in conjunction with one another where accelerometers can sense the orientation or tilt of the users hands and fingers while the gyroscope actually measure the angular motion of the wrist movements. Below are some figures that partially illustrate how an accelerometer and how a gyroscope would function.

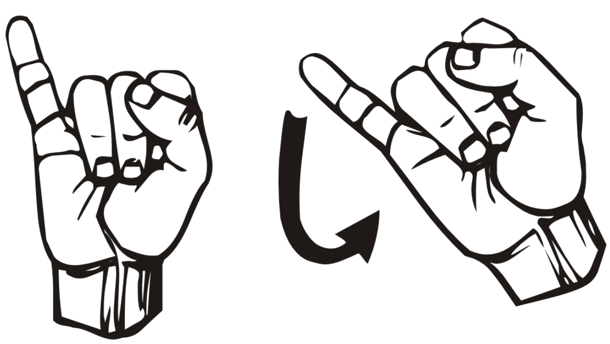

Fig. 2. The American Sign Language letters I vs. J

C. Contact Sensors

Due to the fact there are a few pairs or groups of sign language letters that are not distinguishable by the degree a person's finger is bent nor any tilting motion, we will need to implement contact sensors. These can identify when two or more fingers are touching and may be precise enough to detect where along each finger the contact is being made. These type of sensors will be helpful if not crucial in telling apart the following pairs of sign language: R and U, S and T and M and N.

D. Bluetooth Low Energy

Bluetooth is used in almost everything nowadays and is perfect to use for devices that only need to communicate over a short distance, like the Sign Language Interpreter Glove. Bluetooth low energy is what allows developers to create tiny sensors that can run off a small coin cell battery for months or sometimes even years. The main difference between Bluetooth Low Energy and BR/EDR is that not only BLE is much more energy efficient, but also is built on a new development framework.

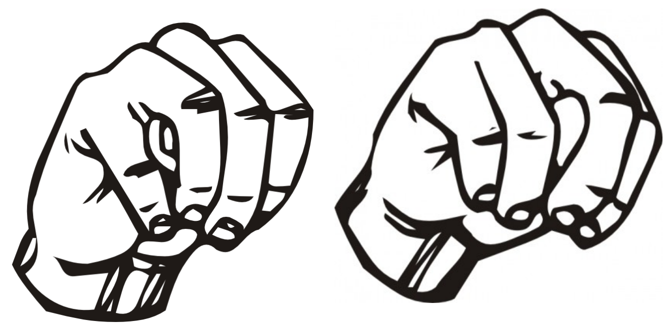

Fig. 3. The American Sign Language letters M vs. N

E. Microcontroller Unit

There were many options available to us when it came to choosing an appropriate microcontroller unit for the SLIG. The unit chosen was the ATMega32 because it employs the 6 minimum analog input pins (with analog to digital converters for each) that the SLIG needs, it has digital outputs, and it is also able to output information through the use of serial communication. The ATMega32 also features a RAM of 2.5KB, an 8 bits data bus and an operating a speed of 16MHz. Another appealing factor was its ability to allow many forms of cross-platform development including Windows, iOS, Linus et al. Lastly, the group was able to program the ATMega32 using an Arduino Uno board and simply transition the process unto the PCB board greatly facilitating the PCB design and constraints.

F. Power Source

The power source is one the most important parts of this project. Without a power source, none of the components use in the project would be able to operate. Also if the group does not give it the right amount of power then the components will fail. It is crucial to also make sure the group gets the most out of the battery. A charging station will also be needed to recharge the battery of the Sign Language Interpreter Glove.

The group decided on using a polymer li-ion battery to power the SLIG. The reason for using this type of battery is because polymer li-ion batteries are one of the thinnest batteries available in the market. Polymer cells are much thinner than prismatic cells which means they are much lighter. At the same time, polymer li-ion batteries are able to store more energy than nickel-based batteries. Polymer li-ion batteries also retain their charge for longer.

A 3.7 volts polymer lithium ion battery – 2000 mAh from SparkFun is powering the SLIG. The battery is super slim and light weight. The battery includes a build in protection circuit for minimum voltage, over voltage and over current. Rated at 2C continuous discharged, our polymer lithium ion battery has what it takes to power all the components required by the Sign Language Interpreter Glove.

G. Charging

Charging lithium-ion batteries requires a voltage-limiting device, very similar to the charger used in lead acid batteries. The exception is that a lithium-ion battery charger will have a higher voltage per cell with more voltage tolerance and no trickle at full charge. Lithium-ion batteries do not accept overcharge, therefore manufactures are very strict when it comes to the voltage cut off unlike lead acid batteries which offer some flexibility. A prolonged charging above 3% (4.3 Volts) on a 4.20 volts per cell lithium-ion battery will cause plate metallic lithium on the anode. The reason for this is because the cathode material loses stability and becomes an oxidizing agent that produces carbon dioxide. Also a prolonged charging will cause the cell pressure to rise.

Current interrupt devices (CID) are responsible for the safety of the battery, they should stop current from flowing at about 145-200 psi. Some lithium-ion batteries even have a safety membrane to avoid the battery from catching on fire, which opens the battery at about 500 psi. Just like lead acid batteries, nickel cadmium batteries and nickel metal hydrate batteries; lithium-ion batteries will melt down and might catch on fire when overcharged.

A lithium-ion battery is done charging once the current drops to 3% of rated current or when it drops to a set level. Sometimes, elevated internal resistance can cause the temperature of the lithium-ion battery to rise by 9º F. Nevertheless, the lithium-ion battery and/or the charger should be decreasing when a rise of 18º F occurs. As previously stated, it is not desirable to fully charge a lithium-ion battery because high voltage stresses the battery. A portable device should be turned off when charging to avoid stress on the battery because a parasitic load confuses the charger, causing it to continue charging a battery although the battery is already full charged.

H. Regulators

The purpose of voltage regulators is to keep a constant voltage level. Voltage regulator can be used to regulate either alternating current or direct current voltages. Computer power supplies use electronic voltage regulators to stabilize the direct current voltage that is used by the processor. In a distribution substation, large size voltage regulators are used to make sure that the customers receive stable voltage no matter how much power is taken away from the line. The reason why voltage regulators will be use in this project is to make sure that each component gets the appropriate voltage it needs to function and operate properly.

III. SOFTWARE OVERVIEW

There are two main software components in this project: the gesture recognition process and the mobile application. One of the biggest decisions made in regards to the software side of SLIG was to use either on-board or external processing. This decision was important because it determined whether the sensor data would be processed using the on-board processor of the microcontroller unit (MCU) or an external processor (the mobile device) with more computing power to process the data. Since our group is composed of four electrical engineers it made more sense to stick with the more familiar territory and do the processing on the MCU's processor.

A. Gesture Recognition Processing

The gesture recognition process for the SLIG will employ a few functions, which the group will write itself. These functions will be used to 'map' the range of values retrieved from the user in the calibration phase. The calibration process will involve the user closing and opening their hand, as to provide the system with information about how much bend will be present on that person's hand. The function will be provided with parameters for the minimum and maximum amount of bend that was measured from the user during the calibration process. The function will then take this data and it will "normalize" it through the use of some arithmetic, to make it represent the 'standard' maximum and minimum values. The team will have to determine these standard values to go along with the implementation of the project and get a feel for what is normal for most users. Once these standard values are established from the sensors and the general behavior of the calibration system is known, an implementation of the hand-gesture recognition can be done without the calibration process.

The mapping function mentioned above is the implementation of the algorithm that takes in the minimum and maximum values (after being normalized by the calibration process) and breaks up that range of values into a certain amount of "levels". In our preliminary planning, the group believes that about 4 different 'levels' of bend can be appropriate and enough to determine what position each finger is currently placed on. For example, after going through the calibration function and through this mapping function, a gesture performed by the user will produce an output such as "1, 2, 3, or 4".

Even through the range in voltages being read from the sensors varies greatly within each one of these 'levels', each of the four levels are distinguishable enough so that the system can easily tell if the finger is fully straight, slightly curved, halfway bent, or fully bent. This is all that is necessary for the determination of what hand gesture the user is trying to perform. If this can be accomplished successfully and accurately, then actually having the infinite loop make decisions on what hand gesture is being performed by the user becomes exponentially less difficult. At this point the infinite loop can be populated with a series of conditional statements that inquire about the state of each sensor, only using 1 of 4 possible outputs from the sensor. If the group did a good job of providing an accurate depiction of each position of bend as an integer between 1 and 4, then this part should go by fairly smoothly.

B. Mobile Application

The mobile application is an important feature of this project that will serve as the user interface for the sign language glove. The functionality of the glove will be determined by the success of the mobile application which is easily forgotten in many technical applications. Many designers are concerned with meeting the technical specifications and requirements of their design but forget that the user (consumer) is the end-goal of the project. In order for the mobile application to be successful, the design of the app should consider the user, be simple and elegant, and meet all design requirements.

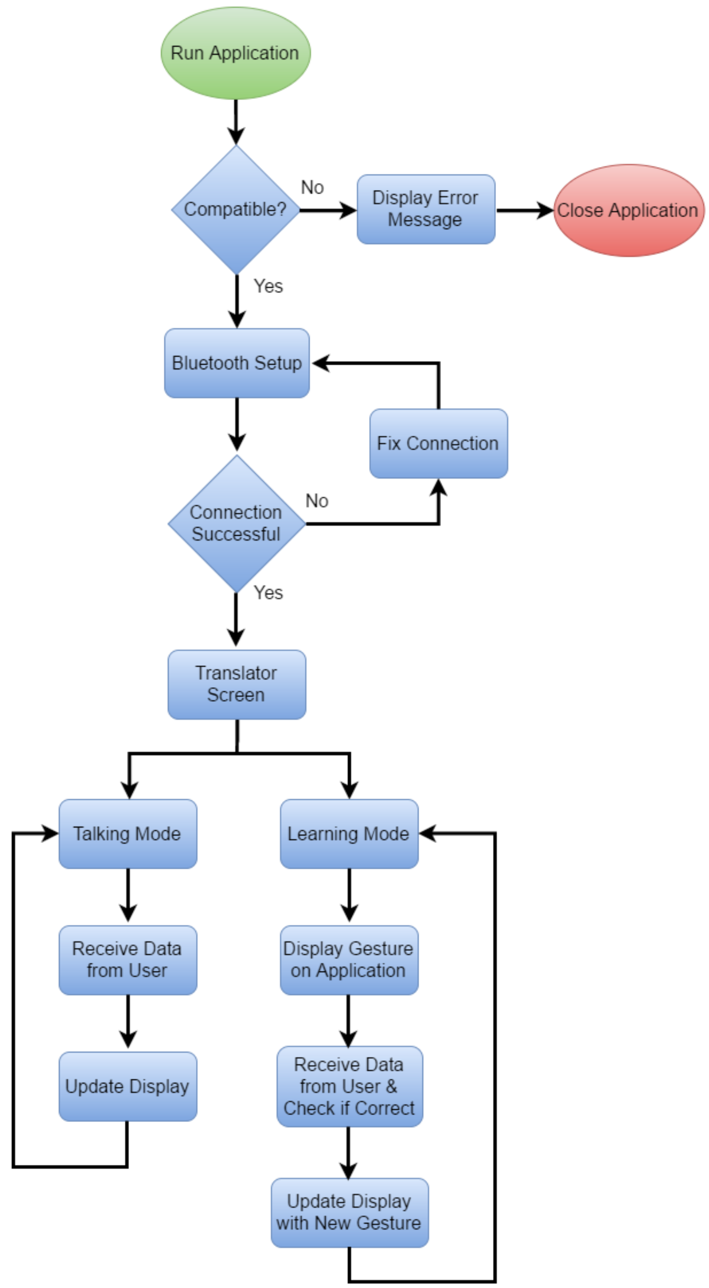

Fig. 4. System Processes of the Mobile Application of SLIG

Since the goal of our project is to create a working prototype that demonstrates our knowledge of electrical engineering, our investment into this project should only be for educational purposes and not for a profitable business model. Therefore, creating a mobile application for educational purposes makes Android the ideal choice because all of the open source resources that are available to our developers. These resources will help smooth out some of the more time consuming parts of the mobile app development process and give more time for learning and helping out with other parts of the design; plus, we can give back by adding our finished mobile app to the Android open source community.

The responsibilities of the mobile application are receiving data via Bluetooth, converting this data into text, and displaying the gesture onto the screen and constantly updating the value. The main design features of the mobile application are the graphical user interface and Bluetooth communication. Both of these features have a lot of details involved in the background but the main idea is to make the mobile application as simple for the user to use as possible such that it doesn't take away from the functionality of the glove. Please refer to Figure 4, for a graphical representation of the processes the mobile application will have to execute during normal operation.

IV. HARDWARE DESIGN

A. The Glove

The glove of course will serve the purpose of holding all of the different electronics and sensors and making this project a usable device. In choosing a glove we must consider certain important features of said glove to make sure the electronics function properly and that the end results is a comfortable but efficient product. These features include but are not limited to the size, type of the material and number of layers of the glove. To elaborate, this project would require a glove that could fit most people but definitely be large enough to hold all required electronics. Furthermore, different materials could possibly conduct heat differently and so some may prove less than optimal for working along with electronics and sensors. Lastly, the team has noticed that there are some gloves available with two layers which would be convenient in the sense that the electronics can be placed between the two layers improving the overall aesthetics of the glove.

B. PCB

The PCB for this project will integrate all the major components of the glove including the different set of sensors employed in the glove, the MCU, the Bluetooth module, the power supply and the charging circuit. From the beginning, the group agreed that a basic two layer board that measures roughly 3in by 4in would be the best option for the SLIG. A four layer board that would have dedicated two of the middle layers to just power and ground was briefly discussed but it was decided that our board's complexity didn't require this extra feature that could easily double the price of the board. It was also decided that the majority of the components for the board would be through hole mounted. More group members had experience with soldering through-hole parts than surface mount technologies and felt the former would leave less room for error.

The group used the Eagle CAD software to design the schematic for the glove's printed circuit board. The same program was used to design the layout of the board and generate the Gerber files and bill of materials. Eagle CAD was chosen since it's a very popular program with a plethora of support materials and additional libraries (discussed further below) that could facilitate the board design process.

In order to design the PCB board, additional libraries with specific parts were downloaded into the Eagle CAD software. The most critical one was the ATmega MCU library which helped manage the multiple pins. After the schematic was developed, the group used the autowire feature of the Eagle program to initiate the layout of the PCB board. From that point the last remaining connections were routed manually using multiple vias from the top and bottom layers.

Once the board was fully designed, the group ordered a set of four boards from Bay Area Circuits. This company had a reliable reputation for accurate and timely PCB board production. To source all the parts for the board, the group made use of Eagle CAD's design link feature which matches each component used in the schematic to the closest matching part in the Newark database. This was used mostly as reference and the group still had to manually search for many parts that weren't assigned a correct match. The actual orders were made through Mouser.com and Digikey as these proved to have a much wider selection of parts.

The PCB board was assembled using the equipment at the TI Innovation lab in UCF's Engineering II building. When it came to testing the board, the sensors were fixed on the glove and connected through a set of cables and headers that would match those on the board. From there the board was tested to ensure it was designed and assembled properly and that the glove had all functionalities.

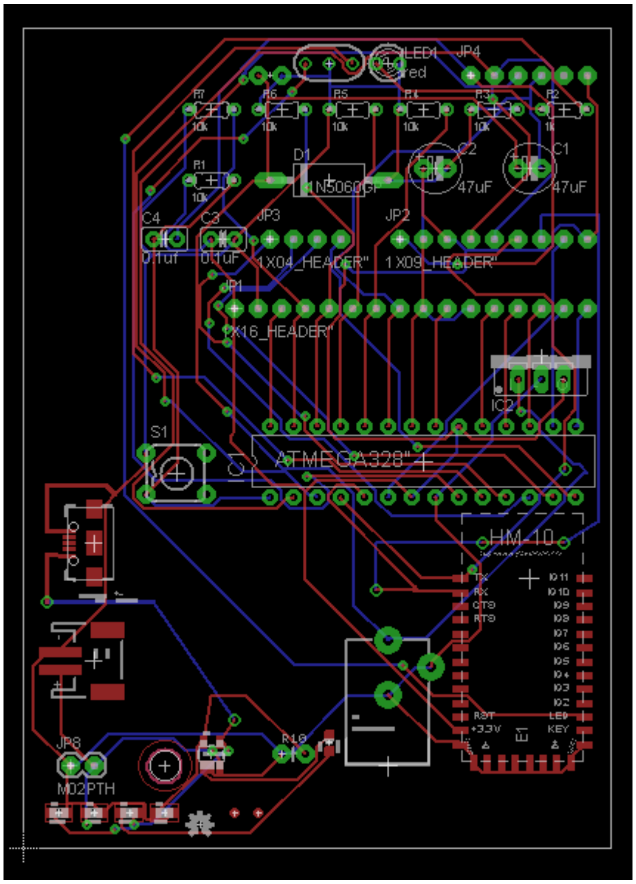

Fig. 5. PCB Design in Eagle

V. SOFTWARE DESIGN

A. Bluetooth

The first requirement for our mobile application to communicate with the Bluetooth module is to ensure that they are both compatible. After this has been established, the Bluetooth module on the glove must connect with the mobile device and maintain a stable connection so that the mobile application is ready to be used. Making a connection with the Bluetooth adapter on the glove requires calling methods in Java that use the Generic Attribute Profile (GATT). Once the mobile device has made a connection with the glove, the mobile application is still not allowed to use this connection for sending or receiving information; the application must be given permission to use the Bluetooth connection within the source code to ensure security.

The Bluetooth module selected for the Sign Language Interpreter Glove (SLIG) will be using Bluetooth Low Energy (BLE), which was adopted into the main Bluetooth Standard in 2010 along with the adoption of the Bluetooth Core Specification Version 4.0. In order for the mobile phone to be compatible with BLE, the version of Android on the device must be Android 4.3 or newer; Bluetooth Low Energy is not backwards compatible unfortunately. Most phones on the market today are compatible with BLE but there could be other software compatibility issues if the Android API level used for the application is newer than the API used by the device. The API level determines which versions of Android that an application is compatible with and can be used as a tradeoff between having more features or more compatible devices.

B. Graphical User Interface

The graphical user interface (GUI) is a type of interface for applications and programs that uses visual features to control the application/program instead of text-based instructions. The main purpose of a GUI is to offer users an interactive and user-friendly navigation system for an application that gives the user control of the available features. Some examples of a GUI are Windows and Mac OS for computers which both have a visual interface with icons, buttons, and much more that are used to navigate and perform tasks. The main design considerations when it comes to the graphical user interface are the menu layout schemes, appearance and the usability of the application. The menu layout will be one of the first impressions of the application where users will have a choice to receive gesture inputs from the Sign Language Interpreter Glove, manage the Bluetooth connection and more; so it is important to make the menus easy to use and look good.

When it comes to designing the appearance of the GUI, it is critical to make the application proportionally fit the screen size of the phone or else everything else will appear distorted. For example, an application UI that was designed for a mobile phone would not fit onto a tablet screen without being fit for a bigger screen size and vice versa. Having to adapt the screen size to every Android mobile device on the market would be a hassle because each cell phone carrier has their own line of smart phones and each smart phone has multiple generations of models with varying screen sizes and resolutions. Thankfully, Android provides APIs that support multiple screen sizes and will simplify this process by splitting the range of screen sizes and densities into four groups: small, normal, large, and extra-large.

VII. CONCLUSION

In conclusion, the Sign Language Interpreter glove is a lightweight, portable glove that can be worn by individuals to serve as a translator of the American Sign Language Alphabet into text. This text is displayed on a mobile application that runs on Android smartphone devices. The intended purposes of the glove are for either communicating or learning ASL. The Sign Language Interpreter Glove consists of flex sensors, which are variable resistors that change their resistance in proportion to the amount of bend that is currently present on the sensors. This allows the control system of the glove to determine how much bend is present on each finger. The accelerometer is another hardware componenet that will be used to determine what hand gesture is currently being performed by the user. The accelerometer will determine the X, Y, Z position of the hand at all times, which is important in determining when certain hand gestures are being made that require a specific movement of the hand in addition to simply bending the fingers in certain ways.

In addition to the flex sensors and accelerometer, the SLIG has contact sensors that determine when two fingers are touching or not. This is necessary because there are certain letters that have very similar amount of bend on each finger, and the only way to determine between them is the actual position of the fingers relative to each other. By using contact sensors, the control system of the SLIG determines which of these very similar hand gestures is currently being performed.

The control system of the SLIG is an ATMEGA microcontroller unit. This unit already comes equipped with the necessary analog to digital conversion hardware that is needed to convert the analog signals that is coming from the sensors into a digital signal that can be analyzed and processed by the microcontroller unit. The ATMEGA goes through its program which is designed to determine which of the many possible hand gestures is currently being performed, and it will constantly be sending the output out to the mobile android application.

The Android application receives the data that is being transmitted from the microcontroller through a Bluetooth connection and it displays it on the screen for the receiver of the message to read. Our mobile application is capable of wirelessly receiving the information that is being sent out from the Sign Language Interpreter Glove so that communication between the person holding the glove and the person using the application will not be hindered. The mobile application was written using the programming languages Java and XML through the Android Studio IDE.

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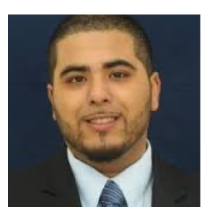
We also want to acknowledge Dr. Christopher Hontgas, Dr. Damla Turgut, Dr. Michael Haralambous and Dr. Mikhael Wasfy for taking time from their busy schedules to be part of our committee.

Finally, we want to recognize and also thank Boeing and Leidos for sponsoring our project as well as our families, classmates and friends for all their support.

BIOGRAPHY

Christopher Delgado – Electrical Engineering

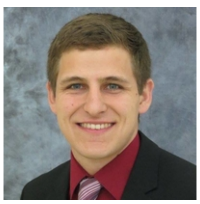
Christopher Delgado is a first generation electrical engineering undergraduate student at the University of Central Florida. He has been part of the Burnett Honors College since the beginning. Since the summer semester of 2015, he has been working as a System Performance intern for Verizon Wireless and has gained valuable experience in networking. Prior to his internship with Verizon, Christopher worked as a tutor for the SDES TRIO Center in UCF where he helped other students improve their performance in their physics, calculus and elementary engineering courses. His years at UCF have given him the background knowledge and learning skills to contribute to the success of Group 24 and the creation of the SLIG. Christopher has been assigned the task of researching, selecting and designing for the different sensors the SLIG will require. His successful completion of both Electronics I and II and their accompanying laboratories have prepared Christopher to deal with the hardware components to the SLIG.



Emmanuel Hernandez – Electrical Engineering

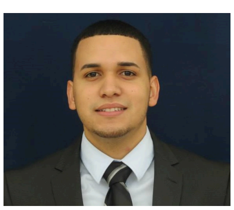
Emmanuel Hernandez is an electrical engineering undergraduate student. He has been a mathematics tutor at the UCF Mathematics Assistance & Learning Lab (MALL) since 2012, and has completed 3 semesters of internships with two different companies. During the first internship at The

Walt Disney Company, Emmanuel was given the opportunity to work with programmable logic controllers (PLC). In this time he gained his first experiences with control systems, although it doesn't have much to do with microcontrollers. About a year later, he was given the opportunity to participate in an internship at Florida Power & Light Company, where he was given the opportunity to work with microprocessor relays and get more of an experience with control logic, and this time a little more in-depth in the microprocessor side of control systems. This being said, Emmanuel was responsible for the control system aspect of the Sign Language Interpreter Glove. In the building and implementation part of the project, he was responsible for programming the microcontroller to make decisions on what hand gestures are currently being performed.



Jason Balog – Electrical Engineering

Jason Balog is an undergraduate student majoring in Electrical Engineering and minoring in Mathematics at the University of Central Florida. He has focused on learning about power systems and computer simulation in his technical elective courses which has prepared him to take on the software application portion of the project. There are two main software components to the project – the mobile application and gesture recognition. The mobile application will be more software intensive than the gesture recognition feature and will require a good background in computer programming. Since all four of the team members are majoring in Electrical Engineering, no one on the team is well equipped with the required programming skills to write an Android application using the languages Java and XML. However, Jason has taken multiple elective courses that required programming in Matlab and other software along with some programming experience on his own which gives him the best opportunity to successfully complete the mobile application.



Ramon Santana – Electrical Engineering

Ramon Santana is a first generation, electrical engineer student at the University of Central Florida. He has maintained leadership presence on campus in numerous ways. Santana was a Teaching Assistant for two engineering classes. Currently, Santana is a Peer Mentor and Peer Tutor for engineering students at the office of PRIME STEM at UCF. Santana is the Mentoring Program Coordinator for the Society of Hispanic and Professional Engineers at UCF. Santana is also a brother of Lambda Theta Phi Latin Fraternity Incorporated. During the summer of 2015, Santana did an internship for NextEra Energy as a Protection and Control Engineer. His responsibilities at that time were to make sure that all the equipment inside transmission and distribution substations were working and functioning properly; by performing maintenance on feeder breakers, calibrating relays, completing trip by lockouts and much more. His hands-on experience and leadership skills were a significant contribution to the implementation of the SLIG. He was responsible for the powering, charging and the wireless communication of our project. After UCF, Santana will continue working for NextEra Energy as a Distribution Engineer.

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