GuardMat

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***Abstract* — The document characterizes how the passive security device, GuardMat functions and its involved system components. The GuardMat is a passive security system capable of streaming live video feeds to any mobile devices. The system's live feed is triggered by a pressure sensitive mat which upon activation will in turn activate the Raspberry Pi, the single-board computer, to activate the camera and commence video streaming. Video feeds are sent to user via short messaging service (SMS) which contains a uniform resource locator (URL) directed to the site where the video is hosted.**

***Index Terms* — Access Control, Pressure Sensors, Sensor Systems, Tactile Sensors, Twilio, Velostat**

I. Introduction

The Guard Mat is designed as a security system for homeowners to alert them of any presence at their door. The Guard Mat is a system that includes a mat, that is connected to a central microcontroller, that upon activation will activate the live feed from the camera which in turn will be accessible to the users via a link sent through text. Within the mat are pressure sensors, when the sensors detect pressure, the camera is activated, commencing video recording at its most optimal video mode. The camera which is incredibly small will be installed by the entrance door peephole. Once the camera is activated, an SMS message is sent to the user notifying of a guest or possible intruder at his home location. The SMS message will contain a link that will direct the user to the video in real time with the option of storing the videos as possible evidence as well as for identification purposes.

II. System Components

A. Pressure Sensing Mat

The pressure sensing mat in composed of three layers. The first layer is the Velostat electrically conductive polymeric foil with a grid of copper foil tape on top and bottom, encased in soft foam sheets. The Velostat is used as an antistatic shield for devices sensitive to electrostatic discharges. This material changes resistivity when a force is applied acting like a piezoresistive pressure sensor where the grid of copper foil tape overlaps on top and bottom. The flow of electrons passes through the Velostat material and changes in accordance to the thickness of material when a force is applied. With the grid of copper foil tape connected to a microcontroller the pressure can be sensed when a potential voltage is across the top and bottom layers.

One way to increase accuracy of the pressure sensor, is to connect the pressure sensor to a Wheatstone bridge or originally known as a "Differential Resistance Measurer". A Wheatstone bridge has four resistors, each pair acting like a voltage divider and being configured in parallel. When the ratio of the parallel legs resistance is equal, the output voltage is zero. One leg of the

Wheatstone bridge has a variable resistor and the other leg has the pressure sensor, when the voltage changes on the pressure sensor the variable resistor on the other leg of the bridge is adjusted to zero the output voltage. Configuration of the Wheatstone bridge can differ by having one or two variable resistors, having one variable resistor gives a reading proportional to the force applied changing the resistivity of the pressure sensor, or variable resistor. If the Wheatstone bridge has two variable resistors both of which are acted upon by the outside force changing resistivity, then the output of the Wheatstone bridge is amplified. In a typical pressure sensing circuit one variable resistor is used and the rest are fixed, the Wheatstone bridge is initially balanced having all resistor values equal. Using a Wheatstone bridge provides higher accuracy in reading small measurements such as change in resistance or voltage.

B. Microcontroller

The microcontroller that will handle most of the software implementations of the GuardMat is the Raspberry Pi 3 Model B. The Pi 3 has a Broadcom BCM2837 64bit Quad Core CPU at 1.2GHz, 1GB RAM. Equipped with full-size HDMI Video Output, 40-pin extended GPIO pin, Bluetooth, CSI camera port, 4 USB 2 ports, microSD card slot, a micro USB power input that can handle up to 2.5 Amps and a Wi-Fi capability. The dimension of the Raspberry Pi 3 is 4.8 x 3 x 1.3 inches and weighs 4.8 ounces. The main attribute of the GuardMat is its portability. With this dimension and weight, the GuardMat camera user will easily be able to transfer the product to its desired location in the house.

C. *Camera*

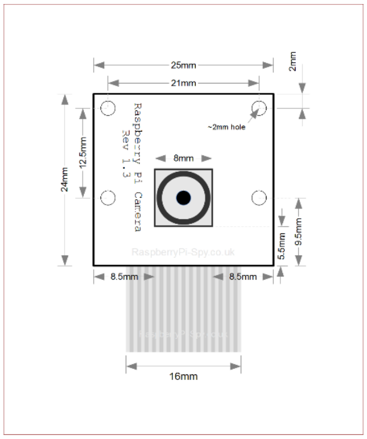

Fig. 1. Raspicam Camera

One of the primary reason as to why the pi camera module V was chosen was simply due to its compatibility with the raspberry pi computer. Having been provided by the same foundation that created the raspberry pi, the v2 camera would have absolutely no issues connecting to or transferring data to and from the camera.

The module V2 was also an affordable option with a base price of $25.00. The dimensions of the camera (25 x 24 x 9 mm) made it an exceptional option considering that the size of the selected camera would have to be small for the purpose of portability. Demanding a minimal amount of power, the module v2 required only 250mA to be fully operational an incredibly low amount of power. Since the camera would be placed in the outdoors, the module would have to have incredible resolution capabilities for video streaming.

The Sony IMX219 sensor provides sharp video quality at 3280 x 2464 pixels. Although the sensor provides a high pixel count, the frames per second (FPS) varies for video mode selected. An inverse relation exists between the pixel count and the frames per second. Higher resolution at 1920 x 1080 provides a disappointing 30FPS while the lowest resolution at 640 x 480 displays at 60 – 90 frames per second with the most optimal resolution and FPS set at 720p displaying 60 FPS. Although the module does not have a full 180-degree view, it does have a horizontal field of view of 62.2 degrees which would suffice considering the placement and purpose of the camera.

A downside in picking the v2 module as the primary camera would be the length of the ribbon cable measuring only at measly 15cm. Due to the fixed size of the ribbon cable, this constraint would require the raspberry pi to be in close proximity to the camera. The disappointing fact of the fixed ribbon cable is not detrimental to overall performance of the camera. As described above, another downside to selecting the v2 module would be the poor FPS at the maximum pixel count of 1920 x 1080. In order to be able to stream videos at the maximum resolution, the FPS would decrease radically up to a 60 – 90 FPS drop from the most optimal video mode of 720p at 60/90 FPS. Although the module does provide FPS capabilities at 1920 x 1080, it would most likely be low quality video streaming which is of high importance considering the v2 module would be streaming in outdoors where light fluctuations occur hourly. As described, the module v2 camera was not chosen specifically due to having no night vision or IR features.

These features are crucial to the overall purpose of the camera. Since the camera will be recording outdoors, it is vital to be able to stream in the full light of day as well as night time. Although the raspberry pi camera module v2 has remarkable features, the most vital and necessary features are not provided which ultimately led to not selecting the module v2 as the primary camera for the security system.

III. System Concepts

In order to understand the overall system of the GuardMat, a flowchart is presented in Fig. 2

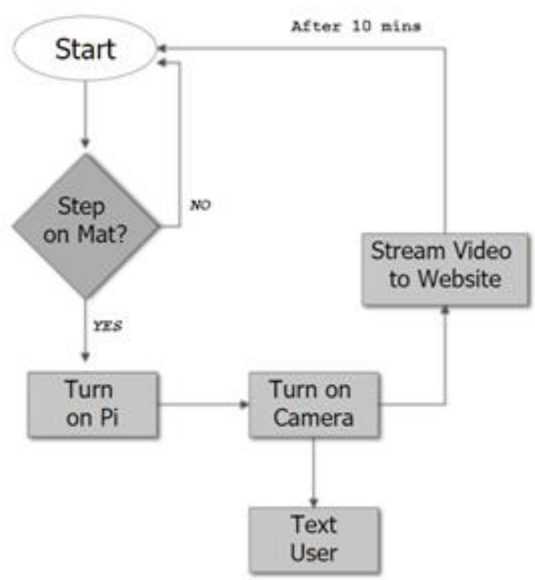

Fig. 2. GuardMat System Concept Flowchart

As shown in the flowchart, the starting point of the overall system of GuardMat is whether the mat is stepped on or not. Once the pressure conductive sheet of the mat has been activated by stepping on the mat, the PCB will then send a signal through the raspberry pi. The pi then wakes from a sleep and turns on and activates the script automatically that will turn on the camera. Once the camera is turned on, it will send a live feed of the video stream and will also send a text to the user along with the link to the website where the camera is streaming the video. In order to conserve battery life, the camera will stream for 10 minutes and then go back to sleep again and wait for the mat to be stepped on and continue the process again.

1) void setup()
2) void loop()

Fig. 3. Main functions handling reading from the Velo stat mat and writing to the microcontroller.

The software that handles the communication between the raspberry pi and that of the MCU is written in C and contains the two function shown below. The setup function (1) in the figure above, commences by initializing the baud rate of the serial communication to 9600 bits per second (bps). The function also handles the necessary configuration for the state of the specified analog pins being set as either the inputs or outputs. The pin mode from which the Velostat is connected is set as an input. The two pins that are connected to the pi, the sleep_pin and the wake_pin from the MCU are the pins that handle setting the voltage to the two pins of the raspberry pi. After the pins mode have been set for the three analog pins, the function also proceeds initializing the wake pin and sleep pins.

The loop function (2) in the figure above, loops infinitely and begins by reading the state of the analog pin which was initialized in the setup function described above. A base value is constantly compared to the value of the analog pin. Since the sensor value of the analog pin fluctuates slightly by a factor of +2, a threshold is created comparing the base value to the new threshold value of the sensor.

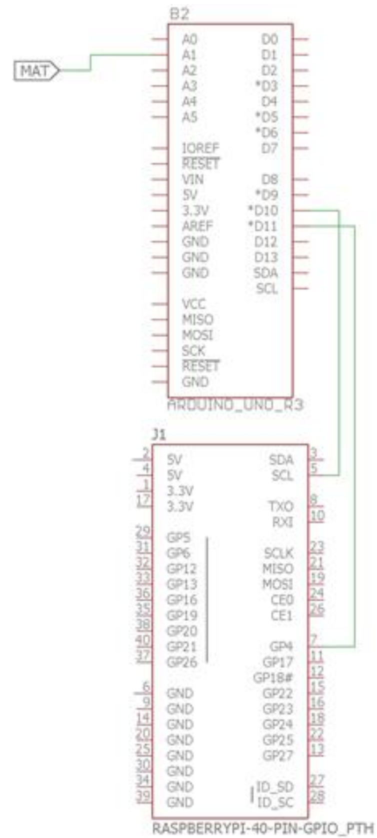

Fig. 4. GuardMat System Concept Flowchart

This threshold is declared, so that the slight fluctuation of the sensor of the analog pin is not interpreted as a pressure detection. For the case when the base value is greater than the threshold value, the wake_pin is set to low, followed by a delay and reset to high. By setting it to low, the receiving pin of the Rpi detected the change from high to low and boots up the pi, thereafter setting it back to high after a small delay to check in the next iteration. After a 5000ms delay, the sleep_pin is set to a low, which in turn will shutdown the pi, afterwards being set back to a high. For the case when base value is equal to or less than the threshold, the wake_pin and the sleep_pin are both set as high as the raspberry pi is only activated when the corresponding pins are changed from a high to a low.

The function also checks if the base value is equivalent to analog digital conversion of 2^10. The MCU has a 10-bit analog to digital converter giving a max 1023 digital levels. If the base value is equivalent to the analog to digital conversion value of 1023 a counter variable is incremented by one. If this counter is equivalent to a count of 5, the case where the mat is disconnected from the MCU, the wake_pin is permanently set to a low and breaks from the loop, no longer reading the sensor value from the analog pin.

For the raspberry pi, there is a python script which handles polling the two GPIO pins of the pi to initiate startup or shutdown. The python script constantly listens for an interrupt which in turn will execute a startup script to boot up the Rpi. In order to detect the edge change, the Rpi. GPio library is utilized that will in turn only execute the startup script when an edge change is detected or when the state is changed from high to a low. For the case when the pi is shutting down, the shutdown script is executed with a 10 minute delay before fully shutting down. The 10 minutes are set so that from the moment the python script is executed to the time the 10 minutes are up, the video streaming will be happening for 10 minutes. The program has been configured for 10 minutes but is determined by the user of the security system.

NETWORKING

Since the security device is independent of a monitor, mouse, and keyboard it is important to automate the network connection in order to stream the live video feed to the website as well as being able to sent the URL to the user's mobile device via a SMS. In order to execute the automation, the configuration file, wpa_supplicant had to be modified to include the name of the network the pi will be connecting to as well as the security key if any for the network. After the configuration file has been modified to include the designated network, the networking interface needs to be enables to automatically connect to any wide area network (WAN). Modification to the configuration file, wpa_supplicant can be altered to connect to any network the system would need to connect to. All changes made on behalf of the team was made utilizing2 the nano text editor due to its simplistic nature and quick accessibility via the command line of the raspberry pi's operating system.

IV. HARDWARE DETAILS

A. MCU

The choice in microprocessor was decided to be the best option based on price/availability and ease of implementation. ATMEGA328PU is what will be used by Guard Mat. Processing the input and giving an output is taken care of during the Analog to Digital conversion process. When using input from the piezoresistive mat, components to perform this task lie inside the microprocessing unit that houses an ADC and DAC (Analog to Digital converter and Digital to Analog converter). The analog digital converter takes any analog signal, whether it come from an ambient sound, a person's voice, or from light waves. Converting these analog signals allows the microprocessor to decode the input signal into ones and zeros so that the rest of the system can understand. In the other direction, digital to analog conversion takes digital output message from the microprocessor to be sent thru a continuous analog signal. This allows communication between two devices thru a wireless medium to exist if needed.

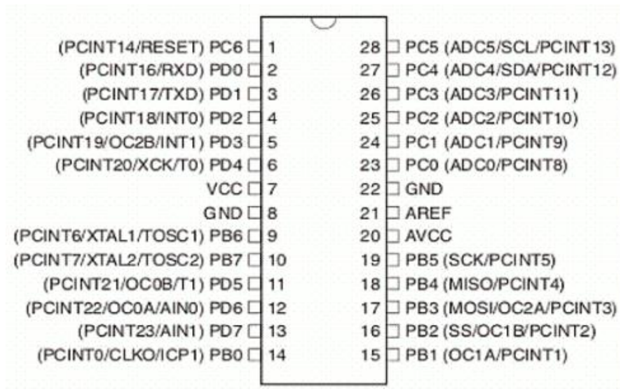

Fig. 5. ATMEGA328PU Schematics

The signal from the pressure sensor will be sent as an analog signal which will need to be converted to a digital signal. An analog signal is a varying value that can range theoretically over an infinite number of values. The need for analog to digital conversion is for electric circuitry to interpret the signal easier. Analog signals are susceptible to noise where digital signals are more defined. An analog signal can have a theoretical infinite range, by converting to digital the range is broken down into segments to find the closest approximation. Typical analog to digital converters use 8, 10, or 12 bits to quantize each level. The accuracy between the 8, 10, and 12 bit converters is 256 levels, 1024 levels and 4096 levels. Each segment is then quantized as a string of ones or zeros depending on where the voltage falls in the range. These strings of ones and zeros are the digital signal to be transmitted.

Describing AVR ATMEGA328PU microprocessor

- 28 pin AVR microcontroller
- Flash memory size of 32KB
- EEPROM data size of 1KB
- SRAM size of 2KB
- GND: Ground node
- Port B: Port B is an 8-bit I/O port. The Port B pins can be activated even under no clock conditions

- Port C: Port C is a 7-bit bi-directional I/O port with internal pull-up resistors. PC6 can also be configured as RESET.
- Port D: It is an 8-bit bi-directional I/O port with internal pull-up resistors.
- AVcc: Supply voltage pin for the ADC.
- AREF: Analog reference pin for the ADC.

B. Velostat Mat

The Velostat material is 11” x 11” and 4 mil thick (0.1mm) with seven strips of 1” wide copper foil tape on top and bottom to create the pressure sensor. The copper foil tape is a dual conductivity adhesive meaning the conductivity properties are on both sides of the tape. The areas where the copper foil overlap from top and bottom area the areas that the electrons will pass through in turn creating a piezoresistive pressure sensor.

C. Camera

The Camera Module (Raspberry Pi) and MCU must both have at least 3.3V to operate. With all systems running at once, datasheet estimated power consumption shouldn’t exceed 500mA @ 5V or 2.5W. This should allow for a few hours of runtime. This capacity can be extended with a larger battery capacity.

D. PCB

This PCB will control the decisions of the system, modulate inputs and outputs correctly, and manage power consumption and signal distribution. Input to the PCB would only be 1 form but can be expanded to 4-12 inputs. Outputs from this PCB would be saved for comparison linked to a particular functionally. Power supply is a major concern for this design or any for that matter. Seeing as most low power development boards use DC sources for turn on initialization. Examining datasheets for a few companies, operating voltages range from 1.8V to 5.5V while the input source voltage is between 7V-12V for recommended usage. This supply voltage is regulated to about 4.2V. This allows for the use of a 3.7V 1500mAh Li-Po battery without much overall power loss. Initially an High lumen LED was to be used for night use, due to the low light activation capabilities of the camera module, this feature was no longer needed.

E. Piezoresistive Pressure Sensor

$$\rho_\sigma = \frac{\left(\frac{\delta\rho}{\rho}\right)}{\varepsilon}$$

$\delta\rho$ = Change in Resistivity

ρ = Original Resistivity

ε = Strain

FIG. 6. PIEZORESISTIVE PRESSURE SENSOR EQUATION

Piezoresistivity works by the change in interatomic spacing from forces applied restricting the flow of electrons, changing resistivity. Piezoresistive devices have a linear change, within a certain range of amount of pressure being applied. The piezoresistive coefficient is the change in electrical resistivity due to strain. The piezoresistive coefficient can be found with the following formula.

V. SOFTWARE DETAILS

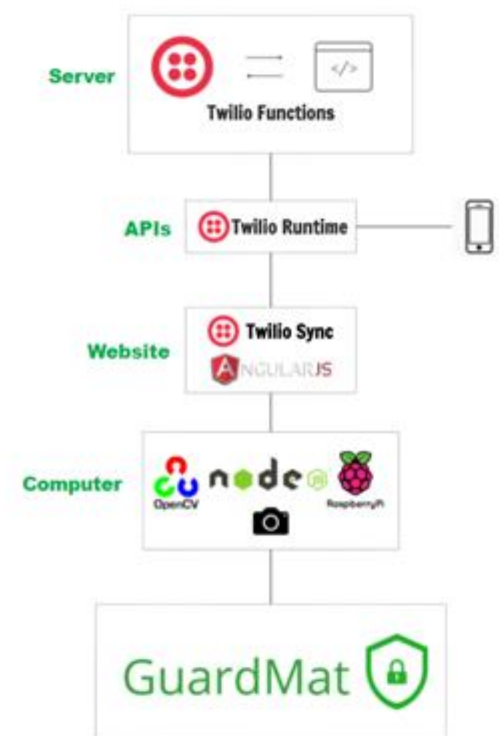

FIG. 7. SOFTWARE OVERALL DIAGRAM

A diagram is shown in Fig. 7 to fully understand the whole system of the GuardMat and how every software components are connected. Before explaining in full detail the software section of the GuardMat system, we will take a look at the overview system of the software. As shown in Fig. 6, we can see the software overall diagram of the system.

Twilio is a developer platform for cloud communication. It is used by over forty thousand businesses such as Uber and Netflix. Using Twilio's APIs it handles all type of communications such as SMS, Fax, Voice, Videos and many more.

Twilio Functions is a server less development environment that hosts the code and the website required to communicate with the Raspberry Pi. Because of Twilio's server less environment we eliminated the need for separate web hosting. All the images and videos are being stored in Twilio's cloud. We can iterate on our application rapidly and our infrastructure automatically scales when needed.

Twilio Runtime is a suite of value-added tools which help you build, scale and operate your application, including helper libraries, application programming interface (API) keys, asset storage, debugging tools, as well as a complete Node.js based server less hosting environment Twilio Functions. APIs helps us to communicate between various software components and with the database. One of the APIs communication protocol is sending the SMS to the user with the URL link of the website.

Twilio Sync is Twilio's state synchronization service, offering two-way real-time communication between browsers, mobiles, and the cloud. Sync terminates and authenticates the web socket connections, manages permissions and access, and propagates data updates to app and device endpoints. It hosts the front-end website of the application written using AngularJS framework and compiled as a single page application that dynamically rewrites the current page rather than loading entire new pages from a server

Raspberry Pi will be the main component that will handle the communication protocol and camera of the GuardMat. The pi is using the Raspbian operating system. It is the recommended operating system with Raspberry Pi users and the one we will use for designing our project. Raspbian has a lot of built-in software that is compatible with this operating system. It is specifically design by using Raspberry Pi as a Linux distribution that works fast and does not need a lot of processing power, you can use it as a regular desktop.

The main system packages that Security Camera depends on are nodejs and libopencv-dev. *Node.js* is an open-source, cross-platform Javascript run-time environment that executes JavaScript code server-side. Node.js uses an event-driven, non-blocking I/O model that makes it lightweight and efficient. Node.js' package ecosystem, npm, is the largest ecosystem of open source libraries in the world. The main Node.js packages our application depends on are raspicam, twilio sync and opencv.

OpenCV is an open source library of programming functions aimed at real-time computer vision. The GuardMat uses OpenCV to detect people and object in the video feed. The OpenCV has a motion activated sensor that triggers the alarm and alert the user. Constantly monitoring the video the device notifies stakeholders of intrusion that threatens assets or safety. The raspicam captures images in regular interval and pushes it through Twilio's pipeline.

Overall software of the GuardMat system will be on the two microcontroller running on Python, JavaScript and C programming language. All implementation of the software design of the system will be done internally and user does not have to program anything.

VI. Standards

Nobody really think about standards but it is fundamental on how we build, create and do things. "Standards provide people and organizations with a basis for mutual understanding and are used as tools to facilitate communication, measurement, commerce and manufacturing. Standards form the basis for the introduction of new technologies and innovations, and ensure that products, components and services supplied by different companies will be mutually compatible." [3]

A. Wireless Communication Standards (802.11n)

802.11n sometimes also called "Wireless N" was an improvement upon its predecessor 802.11g by increasing the amount of bandwidth supported by utilizing multiple wireless signals and antennas (called MIMO technology) instead of one. It provides up to 600 Mbps of maximum data rate, offers a better range over 802.11g and Wi-Fi standards before that and has backward compatibility with 802.11b/g devices. Although the newest standard is the 802.11ac which utilizes dual-band wireless technology. The microcontroller that we are going to use, which is the Raspberry Pi 3 Model B id using the 802.11n which is sufficient enough to implement what we need in this project.

B. *Power Supply Standards*

The International Electrotechnical Commission (IEC) are one of the many agencies that are responsible for electrical safety standards. Its intent is to prevent injury and damage to person and property from such hazards as electric shock. Assessment of electronic and electrical equipment related to human exposure restrictions for electromagnetic fields (0 Hz - 300 GHz): "This standard applies to electronic and electrical equipment for which no dedicated product or product family standard regarding human exposure to electromagnetic fields applies basic restrictions or reference levels on exposure of the general public related to electric, magnetic and electromagnetic fields and induced and contact current." [4] Raspberry Pi 3 Model B is powered by a +5.1 V micro USB supply. The current amount on the Raspberry Pi current (mA) depends on what you connect to it. Tests show that inserting a 2.5A power supply is sufficient to run the Raspberry Pi 3 but typically the Raspberry Pi 3 Model B uses between 700-1000mA.

C. *IP Video Standards*

IP video standards that has video surveillance and other physical security areas that can communicate with one another are implemented by, ONVIF stands for Open Network Video Interface Forum and was founded in 2008 by Axis Communications, Bosch Security Systems, and Sony Corporation. The Raspberry Pi 3 model B camera support video resolutions 1920×1080, 1280×720, and 640×480. It supports G.711 and AAC-LC audio encoding that also supports audio source with 1 kHz waveform. The camera passed Profile S that is a standard for IP video. All selected cameras and recorders should support ONVIF Profile S, which is the dominant open standard for IP video.

VII. Conclusion

The GuardMat systems alerts the user whenever someone steps into the Mat by sending an SMS to the user. When the SMS is received, there is a direct link through the live streaming device of the security camera that the user can go to and watch the live stream wherever the user is. We can do this by applying the Twilio function's API. Choosing the system took a lot of research but we wanted to have a solid choice for the components as well as our PCB design. We researched each individual components of the system, compared the attributes to one another and by doing this we had an inform decision on what component to choose. Portability is one of our goals and objectives. The camera is small enough that you can pretty much place it anywhere. We also did some performance to the microcontrollers and used that information to identify how to cool the housing of the system. Some issues and constraints were faced when creating this project. When creating the system, we had to take account the prices and the performance of every component and if it is compatible with our system. We had to make sure that to comply with the industry standards of the system. Researching about the standards and constraints took a lot of time but luckily this was mostly covered in class and we were able to apply what we learned in creating the GuardMat system. Constraints and issues often occur but overall, we think that we have a clear understanding on how to implement the project and because of careful planning and scheduling we are on track in our milestones

Acknowledgement

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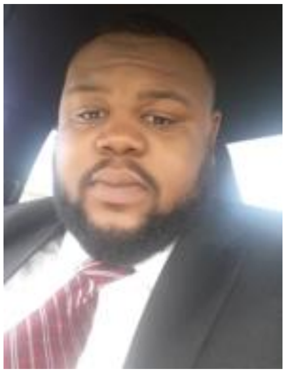
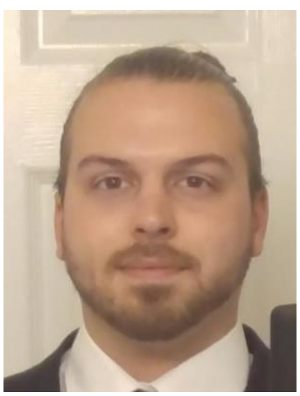
Biography



Landon James Davis was born July 13, 1992 and raised in St. Petersburg FL. Attended Lakewood High School's Center for Advanced Technologies until graduation in 2010. Hobbies include Sports, Automobiles/Motorsports, and Stock Market Analysis. Upon graduation from UCF in Spring 2018 as an Electrical Engineer, will be seeking employment in Power system and FPGA design.

Michael Mosquera is pursuing a Bachelors of Science in Computer Engineering and will be graduating in May of 2018. Currently an intern at Barknock where he works developing an iOS application. After graduating, he plans continuing working at Barknock. Also has an interest in security, mobile development, and backend development.



Zack Foster was born April 18, 1993 and raised in Bradenton, FL. Enrolled into the University of Central Florida to pursue a bachelor's degree in electrical engineering. Zack will graduate in May 2018 and plans to work in the power transmission field or wireless communications.

Christopher John Ison is currently a senior at the University of Central Florida and will receive his Bachelors of Science in Computer Engineering in May of 2018. He is currently working, as a software developer, for BarKnock LLC. Christopher hopes to continue his career in Computer Engineering.

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