The Dibs LightLinks Portable Lighted Pathway System

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***Abstract* — The objective of this project was to design a lighted pathway system that could be used in a wide variety of places, both public and private. The resulting device was to be lightweight, portable, stable, waterproof, and provide light. The group opted to construct this project for senior design because it provided utility and versatility while not being overly complex.**

***Index Terms* — Application Software, Bluetooth, Cellular Phone, Circuits, Master-slave, Microcontrollers**

I. Introduction

When children are frightened of the dark, they sometimes need to sleep with a nightlight. A night light soothes and grants comfort as it permits them to partially see in the darkness. As people grow older, this fear often goes away, but usually their inability to see in the dark does not. People accept that they cannot see and the need for a night light diminishes. Yet, they still have nighttime activities for which they need light: waking up in the middle of the night with need to use the restroom; turning off the lights before crossing a room or going upstairs; getting prepared for early morning work hours. Often people need a light to pave their way through the darkness. Providing a method of simplistic low level lighting would greatly assist nighttime activity.

To address the problems, a low-level lighting system is proposed that can be used for direction in the dark. The Dibs LightLink System is a series of blocks with interconnected capabilities. The system is designed to output low level lighting across all connected units with intent to provide a pathway for the user to follow. Additionally, integrated PIR sensors and RGB LEDs grant multiple modes of operation and utility to the system.

The Dibs LightLink System is composed of three flavors of links. The three flavors are Door Links, Interface Links, and Standard Links. Standard Links are the most prominent. They contain LEDs and sensors. Door Links are constructed to inform the user whether or not a door is open or closed by the path. They are different from other links in that they are a connector linked to a small device that contains a proximity infrared sensor. Lastly, Interface Links are designed to receive the inputs from the user and inform the rest of the system of what actions to take. They contain the components of the Standard Links in addition to Bluetooth compatibility.

Ultimately, the device will offer a wide variety of commercial use and the customizability for the user to make it perform as they need. If the user so requires it, the device could be used solely for its original purpose, to light up and provide a path at night. However, the system can easily be used in other modes. The user can use a security mode option which can alert should there be any motion in the room. It can also be used to provide ambience, by using an option to override the motion sensors and use it to provide constant low-level light in the room, and even alternate the lights. These two additional features recognize the full potential of the device.

II. Operation

The Dibs LightLinks system operates like many electronic devices out in the industry today. It connects to an Android device via Bluetooth to allow the user to control the system. There will be 6 modes of operation for the Dibs LightLinks system which are: Standard Pathway Mode, Power Saving Pathway Mode, Party Mode, Crowd Mode, Security Mode, and Sleep Mode. Initially there were two different security modes, one of which would alert the user if they were not home and someone was detected in their LightLink path. This type of notification system required accessing the internet to send the alert which is no longer possible due to switching from Wifi to Bluetooth as the main communication between the system and the Android application. The Dibs LightLinks system and the Android device will have bidirectional communication. For instance, if the door sensor is tripped by someone, the Dibs LightLinks system will send a signal to the Android device which will show a dialog on the screen informing the user of this happening. The device, on the other hand, will send the system signals to change into a different mode of operation or change the color of the LightLinks.

A. Standard Pathway Mode

This mode of operation is the default mode that is entered the first time you connect to the Dibs LightLinks system. It allows basic functionality, turning on the lights. This was the initial idea for the project but more modes of operation came about as the development process continued. The only thing customizable for this mode is the color of the LEDs.

B. Power Saving Pathway Mode

This mode is a spinoff of the default mode and comes with a bit more customization capabilities. When a user passes a link in this mode, the LEDs will cut off once the user passes them to conserve energy consumption. The user can change the color of the lights, set a custom time for the system to enter this mode, and set a timer to enter sleep mode after the timer has ran out.

C. Party Mode

This mode of operation is the most complex of the operating modes. It is the entertainment mode for the system and allows the user to select a set of colors in which the system will then alternate between based off a timer. The things that can be customized in this mode are the light color set, the timer to switch between colors, the type of pattern the lights are to blink at, and the timer to end the mode and enter into another mode.

D. Crowd Mode

This mode of operation was designed to help when there is a large crowd. The lights of the system are to simulate the movement of the crowd to give a semblance of direction. The lights will go change from three levels of illumination, from dimmest to brightest, replicating the path to be taken by the person. This could be great for large events in which directing the flow of a crowd could be otherwise more task extensive. The customization features for this mode are light color, speed of pattern blinking, timer for switching to a different mode, and setting a time for the system to enter into this mode.

E. Security Mode

This mode of operation is a basic security mode that will allow users to be alerted whenever someone is detected in the Dibs LightLinks system pathway. When this mode is active, the user will be alerted if a door link is tripped, or a PIR sensor detects motion. The user has the option to have the lights activated or deactivated while in this mode. Other customizable features include a timer to default to another mode afterwards, a time set feature to allow the security mode to come on at a preselected time each day, and the ability to change the color of the lights if they are active.

F. Sleep Mode

This mode of operation is the simplest of all the modes. It is exactly what it sounds like. When this mode is active, the Dibs LightLinks system is in a sleeping state. No lights or sensors are active and the system will not respond to any kind of movement. The user will be able to set a timer for sleep mode to enter into another mode of operation whenever the time runs out. Also there is a time set that allows the system to enter into Sleep Mode at a predefined time.

III. Requirements Specifications

In the final production of the devices, certain requirements have been altered. Originally, we were interested in a device of dimensions not exceeding 300 cm by 4 cm by 4 cm, (l, w, h). However, the final device ended up having slightly different dimensions in order to have a more eye-catching shape, sacrificing a thin width for a low height, which was a more desirable quality. Additionally, the shift from having outdoor functions to mainly indoor use meant that water resistance and batteries were no longer needed, obviating the specifications relevant to those applications.

Moreover, the move from WiFi to Bluetooth communications means that the links no longer connect to the Internet. Instead, they connect directly to the smartphone through a Bluetooth-application interface, meaning that WiFi standards no longer are relevant.

IV. Components

Figure 1, Specifications Table

Specification	Original	Actual	Passed?
Turn-on delay per link	<5 ms due to detection delay	3.1 ms	Yes
Signal propagation delay	<20 ns	~5 ns	Yes
Mobile interface delay	<2 s	~0.3 s	Yes
Maximum mass	<0.23 kg	0.20 kg	Yes
Power	<2 W	0.39 W	Yes
Motion sensing range	>2 m	5 m	Yes
Door sensor height	<2.54 cm	1.9 cm	Yes
Door sensor triggering	Open vs closed	Open vs closed	Yes
Signal conversion	Parallel to serial	Parallel to serial	Yes

A. Sensors

In the Dibs LightLinks system, there are two sensors: the door sensor, and the human presence sensor.

The Human Presence Sensor is located on each Link, save for the Battery Link. Its function is to detect the presence of humans, which will be discussed in greater depth below. It relays this information to the MCU, which then can make certain decisions given the data it receives, and the instructions it gets.

Because of their mostly non-directional nature, low sensitivity to environmental shifts, low cost, and the fact that they are the standard non-computer vision method for detecting humans, viz. their use in supermarket door openers, the PIR detector has been chosen. PIR detectors detect a difference in infrared output between spatial points. More precisely, modern PIR detectors detect a change in the difference. This distinction means that there is a short calibration period at the beginning of a PIR sensor's startup process during which all readings must be discarded.

Additionally, PIR sensors which may be bought commercially have certain undesirable qualities which must be corrected for. These qualities are the inability to be re-triggered for a given amount of time, and the long delay a sensor considers itself to have been triggered for. Because of this, the sensors needed to be reverse-engineered and altered in order to bring these values maximally low. The figure above (Fig. 2) shows the replaced components on the PIR's board.

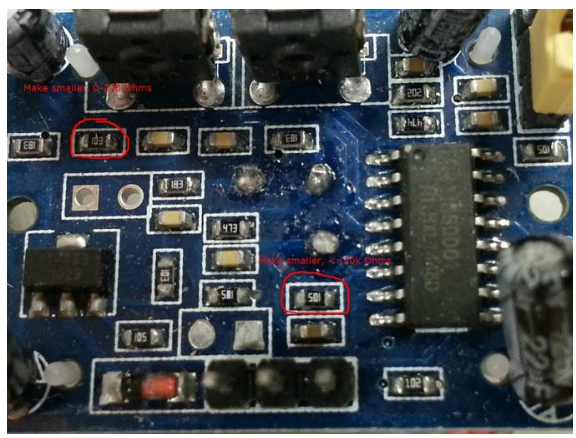

Figure 2, PIR alterations

The PIR sensors also have a built-in directionality, which is set by the configuration of the external Fresnel lens [1]. Since the sensors are mounted on the top, there is a cone which extends upwards from the main Link body. This cone shape creates an exclusion zone low to the ground which rejects excitation by animals less vertically endowed than humans, which is particularly useful in the American, pet-filled home environment.

There is another sensor, which is the Door Sensor. Much like the proximity/PIR sensor, it utilizes infrared light to detect the presence or absence of something. However, it uses a non-passive, reflective system. Essentially, it uses an infrared LED as well as an infrared phototransistor to bounce infrared light off of the bottom of the door which it is below.

The circuit (following page, *Fig. 3*) is fairly simple, composed of only four components, and is housed within the Door Dongle, which may be attached to the Door Link with a detachable cable.

The output voltage is controlled by the IR phototransistor, which varies its resistance with a varying incident infrared light intensity. This output voltage is interpreted by the Atmega328, and is quantized to a 1 or a 0, for open vs. closed.

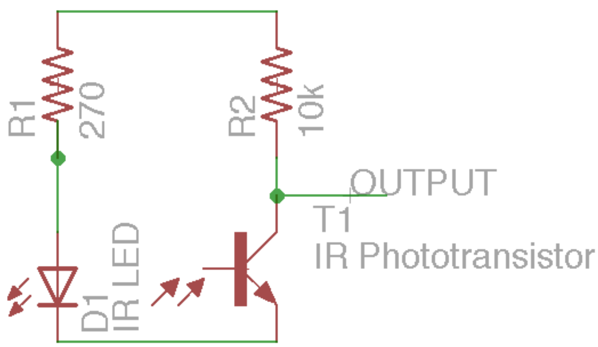

Figure 3, Door Dongle circuit

B. Microcontrollers

For this system, two different microcontrollers will be necessary: one for Bluetooth connection and one to control the lighting systems and sensors.

B.a. Atmel ATmega328p-PU

The microcontroller that shall control the system doesn't require too much processing power, so 8-bits shall be fine, if not optimal for the low power consumption. The Microcontroller needs to be able to connect to another microcontroller, control two RGB LEDs, receive signals from sensors, and relay signals to other Links and microcontrollers. More and more specifics can be added to the microcontroller, but there will still be hundreds of options to choose from, so the Atmega328P-PU microcontroller was decided upon because it satisfied all conditions and is familiar to use.

B.b. HC-05 Bluetooth Module

With the generic microcontroller decided on, only a Bluetooth microcontroller must be determined. This microcontroller doesn't have as many constraints as the Atmega328P-PU, and is therefore more focused on discretion. The microcontroller must be cost efficient, small enough to not take much board space, and most importantly, must be able to connect the Dibs LightLink System to the mobile application via Bluetooth. Obviously this would leave a lot of choices, so, like with the Atmega328P-PU, what was decided on was a popular microcontroller that had a multitude of documentation, the HC-05 Bluetooth module. This microcontroller is cheap, connects other microcontrollers to Bluetooth, and is small enough to not cause strain on the board size.

C. LEDs

As a system designed to provide light, LEDs are included almost without saying. For this device, we use RGB LEDs in order to provide the user with multiple colors to choose from. Additionally, the multiple colors are what make the party mode possible.

The LEDs work very simplistically with the circuit. Upon the microcontrollers receiving an input, they will provide a voltage to a different pin depending on the color of the lighting.

D. Outer Casing

Due to the Dibs LightLinks system's utility in multiple environments, the design for the casing needs to be carefully planned. The expected environments for the device would be various floor types, various humidities, various brightnesses, and potential dampness or wetness. As such, the casing of each device shall be waterproof, have a high friction with any surface, be easily noticeable to any passerby, and not be a nuisance to its users.

In order to satisfy these constraints, PVC is to be used for the device casing and a rubber silicone sheet is to be used for the floor contact. Additionally, in order to mount all the components within the device, a sheet of hard plastic will act as the internal base. Rejected materials include aluminum, due to its high reflectivity both being a potential nuisance to users and possibly hindering PIR sensor tests, and wood, due to its high price and potential to crack when subjected to changing environments.

F. Board Design

Given the modular nature of the Dibs LightLinks system, as well as the general principle of cost savings through high-volume production, only one main board was designed. This is to say that each board has excess connections and traces designed so as to make it possible to convert into any board. This pluripotency is very useful, and is not seen directly in the board below (Fig. 4), but note the lack of stabilizing capacitor on the voltage regulator. This is because each and every board has at least the ground and vcc connections of either the door link sensor (IRVCC, IRGND; left), or the Bluetooth module (VCC, GND; right) free, which saves space.

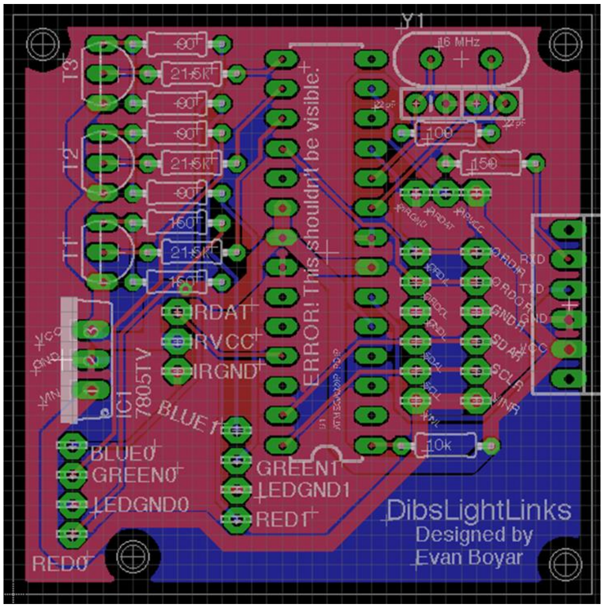

Figure 4, Board

Also note the presence of the Bluetooth module connections even on the Links which do not have a Bluetooth connection--which is to say all Links save the Interface Link. Each Link is connected to all other Links in the chain via the Link Extenders (LEs). The connections to those Les are soldered directly to the board. Those solder points are the two rows of six through holes which may be seen to the right of the Atmega328.

V. Communications

The Dibs LightLinks System utilizes both Wireless Communications and Wired Communications to send different data an instructions to the different components in the system.

A. Wireless Communications

All wireless communications will be directly between the mobile app and the Interface Link over Bluetooth, The mobile app sends different commands to the HC-05 Bluetooth module on the Interface Link, and then the Interface Link tells the rest of the system how to function. The mobile app will also get alerts from the system when the system is in Security Mode.

B. Wired Communications

The Dibs LightLinks will be using wired communication to relay information between the Atmega328-PU microcontrollers. This will be done using the I^2C protocol which is the main wired communication of interest in respect to the project. The way I^2C works is by having a single chip (Master) control all other chips (Slaves). This method of communication seemed the best route to go because the Interface Link will be the Link to receive data from the mobile application wirelessly, and then command all the other Links to do whatever the command was given in the packet of data sent. Another reason I^2C will be used is because it is fairly simple, needing only two wires to communicate with up to 1008 slaves.

VI. Mobile Application

The mobile application will be available on Android devices running Android 3.0 and higher. It was developed using Android Studio and the code was written in the Java programming language. The mobile application creates an interface for the user to interact with the LightLink System. The application allows the user to connect to the system via bluetooth, which then allows them switch between the modes of operation and also customize each mode to their personal preference. Some of the modes have more customizable features than others, due to the complexity of each mode. Some of the main features of customization include changing the colors of the LEDs and setting custom times for modes to come on/off.

The user interface of the application is simple, and easy to use. It follows the basic structure of most Android applications. A toolbar is used for navigating between different screens and also allowing the user to quickly access different functionalities of the application. The toolbar has clickable icons to allow for connecting to a Dibs LightLinks system, changing the color of the system, configuring modes of operation, and going to the settings page. The main screen (next page, Figure 5) displays the six modes of operation, each one as a clickable button that allows for easy switching between modes. With the click of a button the user can switch modes just like that. If the user would like to configure a mode, they can click the configure icon on the toolbar which will take them to a screen that looks very similar to the main screen. The only difference being that there is a prompt at the top of the screen telling the user to select a mode to configure. Now when a mode button is clicked, instead of entering into this mode of operation, the user will be taken to that modes customization page where they can make changes to the mode to fit their own liking.

Initially there was a login page to create an account for being able to receive information over the internet about the user-unique Dibs LightLinks system. With the switch from Wifi to Bluetooth though, the account creation was unnecessary and taken away. Now instead of having to login to connect to the Dibs LightLinks system, anyone who is in range with a Bluetooth connection can connect to the system. This is one of the drawbacks of switching from Wifi to Bluetooth.

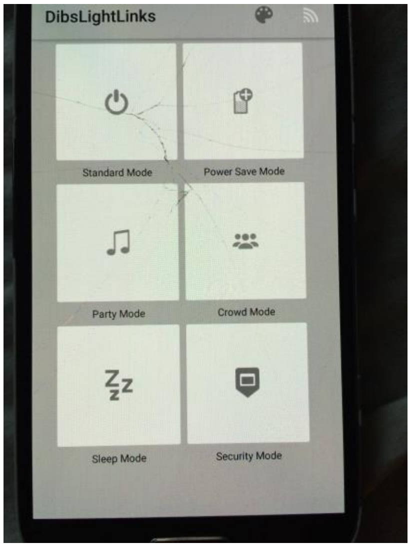

Figure 5, the app interface

VII. Flavors of Links

The Dibs LightLinks system is composed of three different types, or flavors, of links. Each one has its own specifications and role to play in the entire system.

A. Standard Link

The Standard Link is the most prominent link in the system. This link has the simplest design and merely receives commands from previous links and outputs them to both the rest of the system and the circuit it is a part of.

The requirements of the Standard Link are that it has under a 20 ns propagation delay for signals, has a casing that fulfills all the casing requirements, and has low power consumption. The materials used in the Standard Link are PVC, a PIR sensor, RGB LEDs, various resistors, transistors, and other small electrical components, and an Atmega-328 Microcontroller.

B. Interface Link

The Interface Link is the brain of the entire system. It receives inputs from the user and outputs commands to the rest of the system. It is similar to Standard Links in design and most of its functionality. However, unlike the Standard Link, the Interface Link has Bluetooth communications.

The requirements of the Interface Link are that it has under a 20 ns propagation delay for signals, has under a 2 second latency for wireless communication receiving/transmitting, has a casing that fulfills all the casing requirements, and has low power consumption. The materials used in the Interface Link are PVC, a PIR sensor, RGB LEDs, various resistors, transistors, and other small electrical components, the Bluetooth Module, and an Atmega-328 Microcontroller.

C. Door Link

The Door Link is designed for placement in doorways or in locations where a door may be opened. So as to avoid conflict with the door's movement, the Door Link is to be small enough to fit under the door without compromising the system or providing a potential hazard. Rather than utilizing a different case than the rest of the circuit, the door link has a small device attached to it that connects to a dongle that fits under the door.

The requirements of the Door Link are that it has under a 20 ns propagation delay for signals, has a casing that fulfills all the casing requirements, has a dongle that can fit under the average American door, and has low power consumption. The materials used in the Standard Link are PVC, wood (for the dongle), infrared sensors (within the dongle), a PIR sensor, RGB LEDs, various resistors, transistors, and other small electrical components, and an Atmega-328 Microcontroller.

VIII. Future Applications

The Dibs LightLinks technology has many applications currently. From lighting to crowd control to security applications, anyone can find a use for these devices. Despite the versatility it offers, however, the Dibs LightLinks system has many further uses, for both technologies currently available and technologies the future may provide.

An up and coming network focused technology is li-fi, or light fidelity. Li-fi works by using led based technology to alter the brightness of the light rapidly in order to send signals similarly to wifi. Li-fi has many advantages over li-fi, including speed of information transfer, however it also has disadvantages. Li-fi requires direct line of sight for information transfer. This may prove problematic in many different circumstances, however the Dibs LightLinks system may alleviate the issue by providing floor lighting that can transfer li-fi signals wherever the user wishes.

As a versatile system that can be placed anywhere on the ground, the Dibs LightLinks system can have applications dealing with solar energy. Both indoors and outdoors, it's highly likely the links will receive light from external sources, so implementing solar panels into them seems to be a logical step towards energy efficiency. As solar technology improves, it's possible that solar panels will be able to provide enough power to each individual link such that a battery link or external source of power is unnecessary. Alternatively, the battery link could be specialized to implement solar panels more effectively than other links, granting them the capability to power the whole system off solar power alone.

The security the system currently provides is meager in comparison to specialized automated home security systems. Rather than being a focused security system, the Dibs LightLinks system offers some security in addition to its primary function. In the future, however, this could change. With advances in home automation technology and sensor technology, the Dibs LightLinks system could change to be an easily movable security system.

The Dibs LightLinks system is designed especially for ground usage, both indoors and out. This may change. As new needs arise and technologies improve, so might the Dibs. The device may be placed on walls in the future, either through adhesives or through more permanent implants. In a more distant future, the links may even hover slightly above the ground, leading to even more potential applications and usages.

As a device that can be easily picked up and moved to a more convenient location, it only makes sense that people make robots to do that for them. This is a technology that is available now, but still in a more primitive stage. As the technology improves, however, it won't be long before the Dibs LightLinks system is outfitted with small legs of other movement-focused device in order to automate the relocation aspect.

The Dibs LightLinks system is currently still primitive. Its algorithms and designs focused towards the simple security aspects and basic modes that have been implemented. Future engineers working on the device may expand drastically, writing more advanced algorithms for other implementations. These algorithms may permit the system to be able to distinguish between different individuals, and light up differently depending on how each individual requests.

Voice automation has been improving drastically in the past years. With modern smartphones being able to distinguish human words to respond to various commands, so too might the Dibs LightLinks system. If voice commands are implemented, it could also open up a fusion of technologies with household automation.

Overall, the future looks bright for the Dibs LightLinks system. From technologies people already have access to, to technologies that are on the verge of commercial use, the system offers versatility and promise. With so many up and coming technologies that can improve on what we've designed, this technology can evolve with the future.

IX. Conclusion

Throughout all of history, humanity has sought light. From the discovery of fire to the creation of the light bulb, some of humanity's greatest inventions have dealt with light generation. This is because humans need light to see. People sleep at night because they cannot see, but sometimes they need to traverse the darkness. Sometimes, people need a guiding light.

The Dibs LightLinks System offers a safe and power efficient source of light. By providing ease of use and portability with a wide variety of lighting modes and customizable option, this system can be utilized in any environment, both public and private. The Dibs LightLinks System is composed of multiple Links of three different flavors. The different flavors of Links are Door, Interface, and Standard. The system is designed to be set up by connecting numerous Links on two different Chains. Each Chain must contain at least one Interface Link, but will almost certainly contain several Standard Links, too.

Overall, the Dibs LightLink System is a versatile and customizable system that has uses in every household and workspace. It can provide security, safety, and entertainment; or simply offer ambient lighting. The user can use the system to fit whatever their needs may be, and in the future, the system can offer so much more. As technology improves, so can the Dibs LightLink System, as it adapts with the future.

Acknowledgement

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References

[1] https://learn.adafruit.com/pir-passive-infrared-proximity-motion-sensor/how-pirs-work

Evan Boyar is an Electrical Engineering student at the University of Central Florida. He will be graduating with a Bachelor's of Science in Electrical Engineering in May 2016. His interests include embedded system design, digital and analog communications, and more generally, device design. Evan intends to pursue a career focusing on these areas of interest following graduation.

Matthew Bolan is a Senior at the University of Central Florida. He will graduate with a Bachelors in Electrical Engineering and a minor in Physics in Winter 2016. Following the footsteps of his father, Matthew has grown a passion for understand how things work and building useful devices. He intends to get a job that compliments his interests and has a Summer job

Ronauldus Woods is currently a senior Computer Engineering student at the University of Central Florida. He plans to graduate with his Bachelors of Science degree in Computer Engineering in May of 2016. He is a member of the National Society of Black Engineers, the Robotics Club, and Contemporary A Cappella (CAC) at UCF. He has been a performing member within CAC as a part of the Crescendudes as well as Voicebox and is currently working as a professional Vocal Percussionist at Disney Springs with the group Right On Key. He plans to attend graduate school at the UCF Florida Interactive Entertainment Academy to pursue a Master's degree in Interactive Entertainment. He also intends to pursue a career in the field of Embedded Software Development as well as Game Design.

Nicholas Cain is a Senior at the University of Central Florida. He will graduate with his Bachelors of Science in Computer Engineering at the end of Summer 2016. While completing his degree, Nicholas acquired a passion for programming and continues to pursue more knowledge in the computer programming field. He plans to get a job working in software development somewhere after graduation.