Automated Honey Extractor

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***Abstract* — The honeybee population is vastly decreasing due to many reasons and has created a global concern due to their high importance [1]. The Automated Honey Extractor is meant to increase the number of hobbyist beekeepers and small beekeeping businesses and as a result stimulate the globally decreasing population of honeybees which play an indispensable role in agriculture (honeybees play a major role in pollinating crops) and more. Beekeeping can be troublesome for hobbyist beekeepers, but with an introduction of an inexpensive, and yet full of useful features and ease of operation automated honey extractor, beekeeping practice becomes less difficult as honey extraction itself is usually the main reason why hobbyists practice beekeeping.**

***Index Terms* — Android, Bluetooth, Electric Motor, Temperature Sensor, Humidity Measurement.**

I. Introduction

Automated honey extractors along with many other automated equipment necessary for the honey extraction processes are popular among big honey extraction industries. In fact, no big industry will be able to exist without automated equipment in order to extract big amounts of honey in a short period of time. Among beekeepers who do not own big businesses or industries, automated honey extraction equipment is not so popular due to high costs.

The main idea of this honey extractor was to make the extraction process as automated and easy as possible and to be available in terms of cost to the beekeepers that practice beekeeping not necessary for business purposes but as a hobby as well.

Once the beekeeper gets the honeycomb frames prepared for the extraction by uncapping them, they are ready to be loaded into the automated honey extractor. Once the frames are loaded into the apparatus, the beekeeper or the operator of the machine is presented with two ways of controlling the machine. The first option is the onboard analog buttons and LCD screen, the second option is to control it wirelessly using an android device such as a phone or a tablet that has Bluetooth connectivity.

The main feature of the automated honey extractor is that it has a controllable electric motor which spins the honeycomb frames with honey at a certain speed inside of a container and extracts the honey to the walls of the cylindrical vat (the same principle is used in a centrifuge). The honey then flows down the walls to the bottom of the vat, where a valve is located, through which the honey is collected.

However that is not the only feature that the extractor has, it also has a heating system that speeds up the extraction process by slightly heating the honey (up to forty degrees Celsius, in order to avoid damaging the honey) to make it less viscous and thus flow down the walls of the vat quicker.

All in all, all of the systems and subsystems of the honey extractor are designed to aid the extraction process in one way or another. The honey extractor has systems to speed up the extraction, monitor it and control it.

II. System Overview

A. Power Distribution:

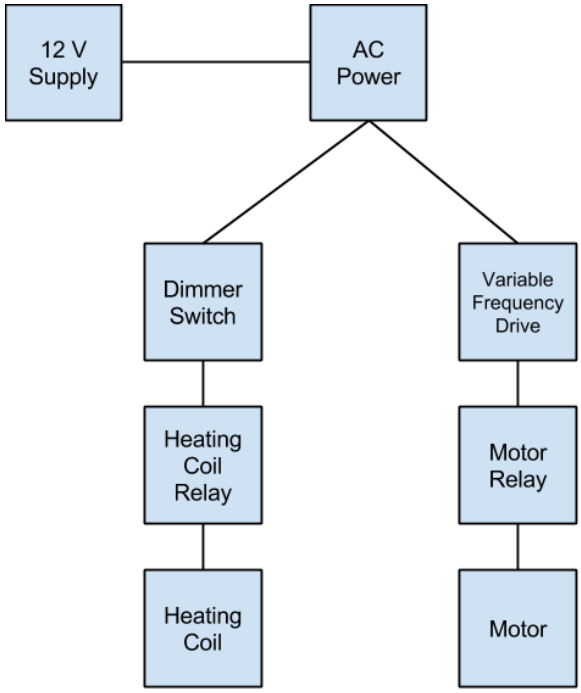

Fig. 1: high level power distribution

All high power components are operating at 110 volt alternating current (AC). This power device is used to

limit the current flowing through the system. 110 volt AC allows for the unit to simply plug into a standard wall outlet. The subsystems fed by the 110V system are the 12 volt power supply, the Variable frequency drive and the Dimmer Switch. These systems are shown in figure 1.

The 12 volt Power supply is a modified 12 volt wall wart. It is a self-contained unit that takes in 110 volt alternating current and rectifies and steps it down to produce 12 volts DC source. This 12 volt source is used to power the relays, lights and the microcontroller board.

The Dimmer switch uses the 110 volt AC and attenuates to step down the power. This value is set by a potentiometer built onto the unit. It is used to set the max heating speed for the heating coil. After the dimmer switch is the heating coil relay. This relay allows the microcontroller to turn on and turn off the heating coil.

The Variable Frequency Drive is used to control the main spinning motor. It takes in the 110 volt AC power and rectifies it to a DC supply. The DC supply is the fed through a three phase H-Bridge and produces a three phase AC supply. This supply is used to power the motor. Because this supply is fed through the H-Bridge, it allows for frequency control. This frequency control allows for control of the motor's speed. A four pole double throw relay is placed between the variable frequency drive, and allows for emergency stop.

B. Emergency Stop

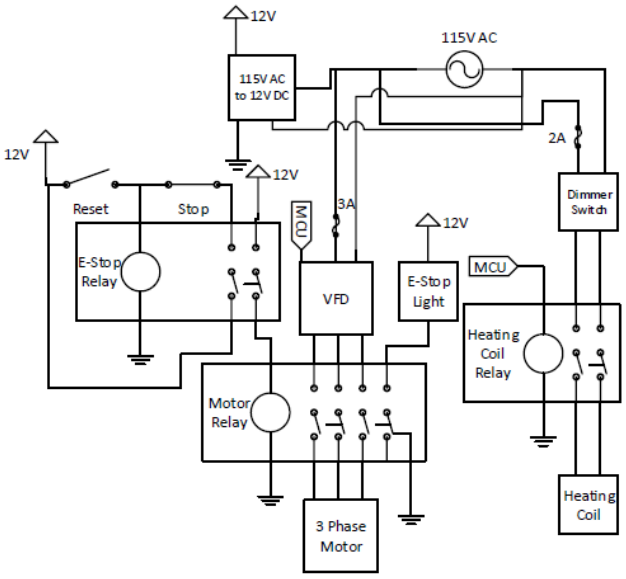

Fig. 2: Emergency Stop Circuit

One of the greatest concerns taking place during the design of the Honey Extractor was safety. The centrifugal drum may hold up to 70 lbs when fully loaded. At maximum+ RPM, this creates an extremely large amount of rotational inertia, enough to cause serious bodily injury. There are several ways to cut power to the motor, as illustrated in figure 2. The most obvious way is the large red button in front of the control box (which can be seen in figure 3 which is a picture of the control box of the honey extractor. The picture also shows the LCD screen that displays the sensor data and operation options as well as the buttons that are used to navigate through the operation menu, such as the on/off switch and the five navigation buttons). This button will cut power to the coil on the emergency stop relay, severing the connection from the variable frequency drive to the motor. The only way to restore power to the relay is to use the reset switch.

Fig. 3: Control Box

Another way to stop the extractor is to use a "soft" reset. This can be done in a couple of ways. When the Bluetooth interface is used, the "stop extractor" button will send a kill command to the motor. In the motor control menu, if the center button is pressed, a kill command will be sent to the motor. Finally, if the command module is in any menu except for the motor control menu or the Bluetooth menu, a kill command will be sent to the motor. All in all, if the user wants to or needs to stop the motor from spinning immediately, there are numerable ways provided for that purpose

Mechanical safety features are also incorporated into the project. These include markings on the system to warn users of dangerous features of the project such as the "danger moving parts" on the spinning centrifuge and the "warning hot" label on the heating element. Other features will include a cover over the frame holder to keep the honey in and foreign objects out. Foreign objects in the frame holder will spoil the honey and may unbalance the centrifuge.

C. Micro Controller

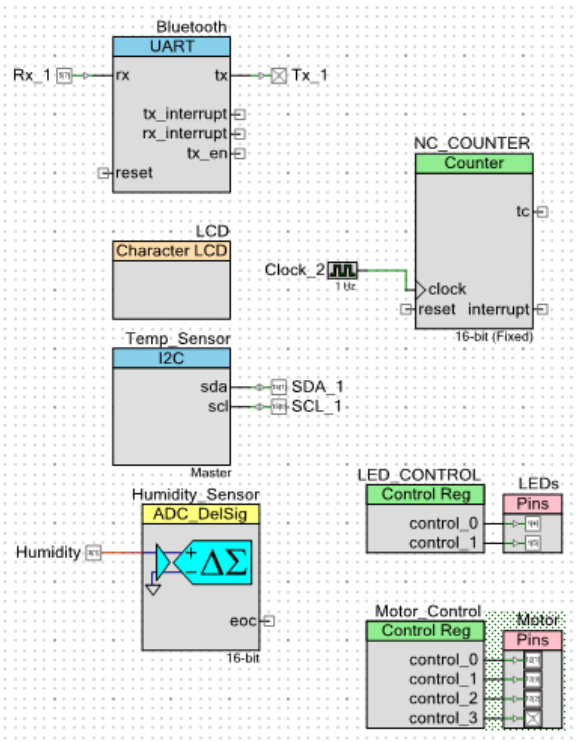

Fig. 4 Microcontroller functionality

The microcontroller (MCU) takes care of all of interfacing to the sensors and outputs. It is placed on a custom made printed circuit board that also houses a high efficiency 5v power supply used to power various components. Two status LEDs are integrated on the board for diagnostic. The functionality of the microcontroller includes the Bluetooth connection, the LCD display, the temperature sensor interface, the ADC for the humidity sensor, the connection timer, on board LED control, the motor controller interface, and the push button interface.

Serial communication to and from the device include the Bluetooth universal asynchronous receiver transmitter (UART) and the temperature sensor's I2C interface. A simple UART at 9600 baud is used to communicate to the HCO6 Bluetooth module. The commands received use ASCII coded strings to talk to the microcontroller. Data from the sensors are converted to 8-Bit integers and sent over the UART in the form of (Humidity – 0 – Temperature). The temperature sensor communicates to the microcontroller using the I2C interface. This interface is used so that multiple sensors can communicate on the same bus. The sensor's data register is selected and the read and converted into degrees Celsius.

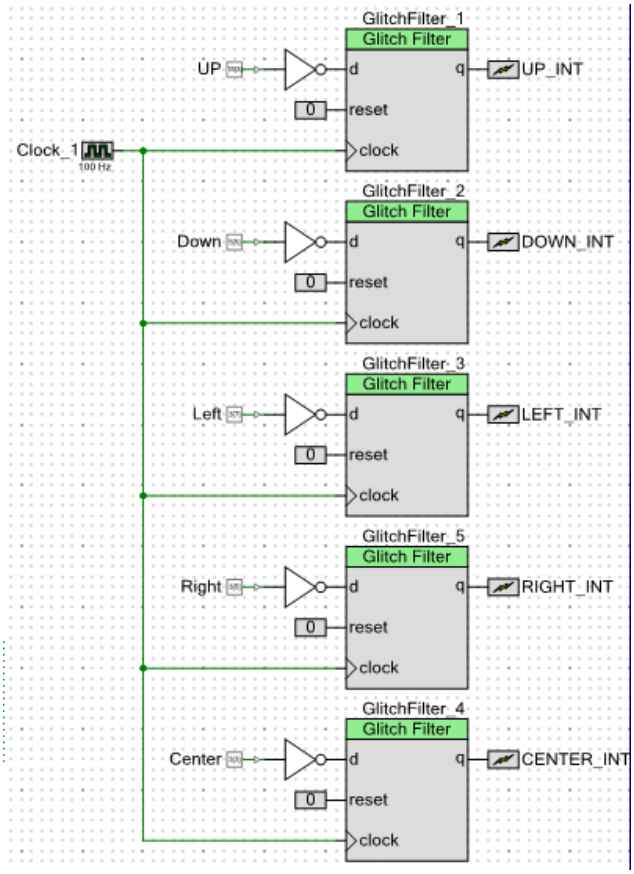

Fig. 5 Switch Debouncing

A 2 x 16 Liquid Crystal Display (LCD) is used to view data in the micro controller. This display uses the standard HD44780 interface. A control menu is used to debug and test various components on the System. The menus include Bluetooth interface, temperature control, motor control and humidity read. Cycling and selecting different items is achieved through 5 pushbutton switches. These switches short ground to the microcontroller pins and have in internal pull up resister. The pins are passed through a glitch filer in the microcontroller to implement debouncing. Figure 5 lustrates switch debouncing schematic.

Control to the variable frequency drive compromises of 4 pins. Each pin drives to ground and sinks 11mA. Because of this, high current pins must be used. The four control lines are enable, forward / backwards and two data lines. The data lines select between 4 preprogramed speeds. The first enable pin is used as the soft emergency stop.

D. *The Heating System*

The heating system includes a one hunded feet long gauge twelve copper wire that is used as a heating element, a power supply and a temperature sensor. The temperature sensor constantly reads the temperature of the extracted honey and feeds the data to the MCU, which in turn transfers the data to the android enabled device and the onboard LCD screen for viewing, The MCU makes decisions to either increase the temperature of the vat or decrese the temperature based on the readings as well. If the temperature of the honey is below forty degrees Celsius, the MCU turns on a relay which is connected to the heating coil and the power supply, likewise if the temperature is above forty degrees Celsius, the MCU turns of the relay and lets the temperature drop slowly. Figure 6, located below shows the control loop of the heating system.

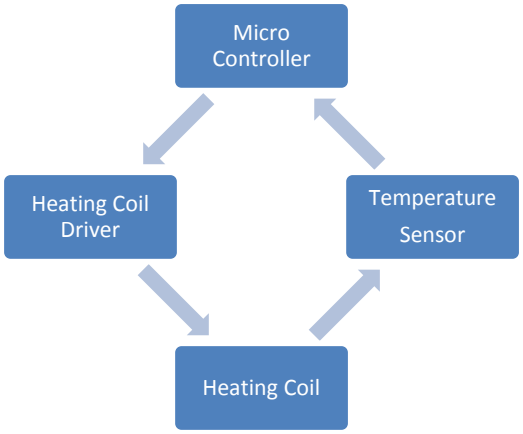

Fig. 6 Heating System Control Loop

E. *Temperature Sensor*

The extractor is equipped with an infrared temperature sensor. An infrared temperature sensor was chosen because of implementation simplicity. Since the honey extractor is equipped with a heating system, monitoring the temperature inside of the vat is essential since it will be higher from the surrounding environment temperature. Implementing a regular temperature sensor on the spinning drum would require a wireless communication of the sensor and the microcontroller which brings redundancy, ineffective and costly decision to the project. Implementing a regular contact sensor on the walls of the container where it will get in contact with the honey itself is more practical to do but is not the best solution. Therefore the infrared temperature sensor is mounted on the top of the apparatus and is pointed on the side of the interior part of the vat. Once again, monitoring the temperature is essential since the honey extractor is equipped with a heating system and the honey should not be overheated (enzyme destruction occurs when honey is overheated) in order to maintain many of its beneficial health properties and overall quality. The decision to use an infrared thermometer was clear to the team from early stages of the project development. The MLX90614 sensor was chosen due to low cost, small size, ease of integration with the microcontroller, high accuracy and resolution, wide range, factory calibration, and other useful features. It comes with a customizable 10-bit PWM digital output for continuous reading as well as a SMBus compatible digital interface for fast temperature readings. As a standard, the 10-bit PWM is configured to continuously transmit the measured temperature of a range from -20 to 120 °C, with an output resolution of 0.14 degrees, which is satisfactory for the purposes of the heating system on the honey extractor.

F. *Humidity Sensor*

The purpose of the humidity sensor in the extractor is mainly for user's convenience. Water content in honey highly depends on the humidity levels during the extraction, and high water content negatively affects honey's quality. If the humidity level is above normal during the extraction process, the user is warned of honey quality loss, besides that, the user can monitor the humidity level of the surrounding environment at any time. Comparing to the temperature sensor, the humidity sensor does not have to be implemented inside of the vat. The HIH-4030-003 sensor was chosen and is implemented along with other electronics on top of the extractor. This humidity sensor is widely used because of its cost and ease of integration. It outputs a linear voltage which makes it easy to communicate with the microcontroller, the voltage supply needed is variable anywhere between 4 and 5.8 volts, operates at wide temperature range from -45°C to 85°C, has a 0 to 100 % humidity range and a satisfactory accuracy (for the purpose of the extractor's use) of +-3.5% with a response time of 5 seconds..

III. MECHANICAL DESIGN

The main mechanical parts of the Automated Honey Extractor are the vat, the frame holder, the valve and the three phase electric motor. The entire apparatus looks and operates similarly to a washer or a dryer machine. The three phase motor is mounted on the top side of the apparatus and is connected to the frame holder or the drum through a pulley system with a v-shaped belt.

A. Frame Holder

The frame holder can hold up to eight honeycomb frames. As long as the frame holder is balanced, a fewer number of frames can be inserted. In order for the holder to be balanced for every frame there should be another frame inserted on the opposite side. Once the honeycomb frames are inserted into the frame holder, the motor spins the drum and creates a centrifugal by which the honey is being extracted from the frames. The frame holder is designed in a way that with a little welding it can be upgraded to hold up to twelve frames at a time. The frame holder is made with Grade 304 (food grade) stainless steel.

B. Vat

The vat serves as a temporary container for the honey which is extracted from the honeycomb frames through a centrifugal force during operation. The honey then flows from the sides to the bottom of the container. A valve is mounted on the bottom of the vat from which the honey flows into other containers. The vat has metal hooks welded on to it that are used to hold the stainless steel shield that protects the operator from the heating coils.

The vat is made of Gauge 16 (1/16" width) Grade 304 (food grade) stainless steel. The bottom of the vat is made of Gauge 13 (3/32inch width) Grade 304 stainless steel. The vat's dimensions are:

- Diameter: 32 inches (100.531" circumference)
- Height: 31inches
- Total Volume: 24931.68 Cubic Inches

The protective shield is made of Gauge 24 (1/40 inch width) Grade 304 Stainless steel.

Figure 7 shows roughly how the motor is placed above the vat.

Fig. 7 Physical layout of vat and motor

C. Valve

A Homewerks Worldwide 1-1/4". Packing Gland Lead Free Brass FPT x FPT Full Port Ball Valve is placed below the vat. Through this valve the extracted honey flows into the container placed under it (such as a bottle or pot).

Figure 8 shows valve that is installed below the vat, as it can be seen, the valve is hand operated. It will be opened during the operation of the extractor and closed when the container below is being switched or the extractor is not operating.

Fig. 8 Valve

Figure 9 displays the motor spinning the frame holder using the pulley system. The size of the pulley wheel installed on the the frame holder is 7 inches in diameter while the size of the pulley wheel installed on the motor is one inch and a half. The length of the v-shaped belt is 30 inches.

Fig. 9 Motor spinning frame holder

IV. Remote Control

A. Remote Control Design

The Automated Honey Extractor can be controlled either manually or by Android device. The remote control consists of a cell phone running Android's operating system level 4.0 or later. For the purpose of this project a customized Android application was developed to control the Automated Honey Extractor and display sensors' data. Communication between the Android device and the microcontroller will be accomplished via the Bluetooth module. The microcontroller will report data collected from sensors via the Bluetooth module to the Android device and then the data will be displayed on the graphical user interface (GUI) of the mobile application in real time. The user will be able wirelessly monitor the inside temperature and humidity of the Automated Honey Extractor in real time. Simultaneously, the user will be able to control the speed of the motor utilizing a slider interface on the Android device.

B. Communication Choice

For this project the Bluetooth module appeared to be the most efficient method of communication between the Android phone and the microcontroller. It was selected for several reasons: low cost, communication range, not a line of sight technology, ease of implementation, and the ability to connect to other Bluetooth devices.

C. Android Application

The application will be accessible through an icon on the Android device that has Honey Extractor application installed onto it. Upon launching the application the user will be prompted to turn on the local Bluetooth, if it has not been previously turned on manually by the user. Figure 10. depicts the Bluetooth permission request dialog.

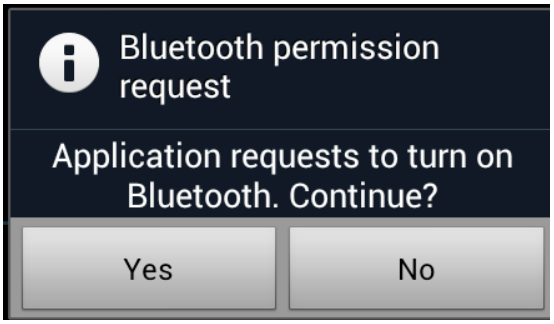

Fig. 10 The Enabling Bluetooth Dialog

If the user chooses not to enable the Bluetooth, no communication will be possible between the Honey Extractor and the Android device. If the user chooses to enable the Bluetooth by pressing the 'Yes' then the local Bluetooth will be activated. This feature will allow the user automatically to turn on the local Bluetooth without the need of exiting the application.

The menu option 'Connect a device' will be accessible through the basic operating system interface on the Android device. By selecting 'Connect a device' option and having local Bluetooth activated the user will be able to scan, connect, and pair with available Bluetooth devices in the vicinity of the phone. If the two devices have been previously paired the user will be able to select from the list of previously paired devices and connect without additional scanning. Figure 11 depicts the paired devices dialog.

Fig. 11 Paired Devices Dialog

Once the local Bluetooth connects to the selected device a confirmation message will be displayed with the name of the Bluetooth device indicating successful connection. If the two devices fail to connect then 'Unable to connect device' notification will be displayed on the screen informing the user about the connection failure. When the user exits the application or loses the connection with the Bluetooth module the notification 'Device connection was lost' will be displayed on the screen.

Figure 12 illustrates a successful connection to Linvor Bluetooth module, can be seen above the yellow slider.

Fig. 12 Graphical User Interface

The graphical user interface will include Forward, Reverse, and Stop buttons. The Forward button will allow for the Honey Extractor to spin clockwise, whereas the Reverse button will spin in the counterclockwise direction. Spinning the device in both directions will result in more complete honey extraction.

To remind the user which button was activated, the previously selected button will remain highlighted in red. As a precaution, the user will not be able to rotate the device in the opposite direction unless the Stop button is pressed. This feature will prevent excessive wear and tear on the motor. For example, if the Forward button was pressed and the device is currently rotating in clockwise direction, the Reverse button will be disabled until the Stop button is pressed. The Stop button will halt the motor of the Honey Extractor. The buttons will be aligned in one row and located across the top of the GUI.

In the center of the GUI current humidity and temperature data will be displayed. The data will be collected from sensors located inside of the drum of the Honey Extractor. The humidity is expressed as a percent and the temperature is expressed in degrees Fahrenheit or Celsius. The user will be able to toggle the temperature between Celsius and Fahrenheit by utilizing two radio buttons.

On the bottom of the GUI a manual speed controller is available to the user. With the help of an interactive slider the user will be able to vary the speed of the motor manually. Interactive slider makes it possible to select a value from discrete range of values by moving the slider thumb. The slider will not only provide a variable speed, but also will allow for the rotation of a motor in both forward and revise directions.

The user can minimize the application by pressing the Back button, while staying connected to the device. To maximize the application the user may simply click on the application icon. To exit the application the user should press the Home button. Both buttons are accessible through the basic operating system interface on the Android device.

V. Specifications

- Up to 8 frames can be extracted at once.
- The vat can temporarily hold up to 12 gallons of honey.
- The vat is made of food grade stainless steel
- A mechanical valve is mounted on the bottom of the extractor.
- The extractor is equipped with a heating system for speeding up the process.
- The heating system automatically keeps the temperature at ~40 °C.
- The motor adjusts speed automatically as needed.
- Motor's speed can be controlled manually.
- The extractor is equipped with an emergency stop button.
- The extractor can be operated wirelessly through Bluetooth from a distance of at least ten feet.
- The extractor is powered by a single wall outlet of 115 volts.
- The extractor is equipped with a humidity sensor.
- The extractor is equipped with an onboard LCD screen
- Sensor data is displayed on both the android device and the LCD screen.

VI. Conclusion

From the beginning, the team's goal was to design and implement a system that would help apiculturist (beekeepers) to extract honey more easily from the wax frames taken from beehives. This project has served to provide technical challenges and experiences for each group member. Every aspect of the project has motivated each member to explore new innovations in technology, learn new skills, and bring advancements to the apiculturists' society. With the teams innovative approach to solving a labor intensive honey extraction process this improvement has been made in harvesting the honey. This new innovation will enable the apiculturists to harvest the honey more efficiently, resulting in being able to bring the honey to market more quickly and, as a consequence, realizing a potential savings to the consumer.

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Biographies

Kira Farney received her Computer Engineering degree from Tashkent college of Information Technology in 2000. Kira will be graduating from the University of Central Florida with a Bachelor's of Science in Computer Engineering in December 2013. She plans to continue her education and pursue a master's degree in the future. Upon graduation, Kira will continue her employment with Northrop Grumman as a Software Engineer.

Dmytro Boichev is an Electrical Engineering student at UCF graduating in December 2013. Dmytro has an interest in communications as well as hardware and software development for smartphone industry. He plans to attend a graduate school while working for a local engineering firm.

Brandon Parmeter is an Electrical Engineering student at UCF graduating in December 2013. He is the president of the UCF Robotics Club. He has an interest in designing hardware for robotic systems. He has experience in mechanical CAD, electrical CAD and embedded programming. He is currently employed as an intern at Primal Innovations in Sanford Florida. He plans on working there when he graduates.

Petr Boychev is an Electrical Engineering student at UCF graduating in December 2013. Upon graduation Petr is planning on attending the Slavic Missionary Bible School for half a year, after which he plans on finding a job in the Electrical Engineering field.