

Original Research Article

**Building an Automatic Controlled Smart Feral Cat Shelter Using a Microcontroller
Arduino Mega**

ABSTRACT

Millions of stray cats, also known as feral cats, live in the United States, and many are left to die each year. They usually roam around our neighborhoods, struggling to survive because they fear interactions with people. These cats are the same animals many people care for at home as pets, but those who are on the streets are often neglected. Because of social hatred and their notorious reputation, the abandoned felines still suffer without basic survival necessities like food and a warm place to stay throughout the winter. In this paper, an IOT-based smart feral cat shelter has been assembled and tested. The functions of the smart system included automatic control of room temperature with electric fans and a heating pad, food and water supply using sensors, and email reports to the user. In addition, an advanced type of webcam functionality has been added to track outside movement. The system proves effective and offers advanced functions to the feral cat. This research displays the positive influence that the shelter will have towards the public perception of stray felines.

Keywords: Arduino Mega Microcontroller, Automatic Controlled System, Feral Cat Shelter Design, IoT System

1. INTRODUCTION

The feral cat population in the United States is between 50 and 70 million. In New Jersey, that amount is around 147,000 and is constantly growing [1, 2]. Because of their hostility, people often forget that feral cats are the same as many house cats that people have as their own pets [3, 6]. This is why that number is always increasing. It is also important to note that the increasing number of feral cats also means more fatalities for these feral cats.

Due to the lack of documentation or care for these feral cats, finding an accurate estimate at the rate of which they increase is extremely difficult. Because of this lack of knowledge, ensuring to reduce that number is extremely important because of the many downsides that feral cats bring to the surrounding ecology. Stray cats can drastically lower populations of native animals, such as birds, small mammals, reptiles, and amphibians, because they are voracious hunters. Native species may experience decreases or possibly become extinct as a result of this predation, particularly on islands where the species have evolved to live without such predators.

Additionally, feral cats compete with natural predators for food, which frequently leads to a decline in the numbers of these natural animals. They also disperse illnesses including feline immunodeficiency virus, toxoplasmosis, and feline leukemia, which can infect domestic animals, local wildlife, and even people [6]. The conservation of wild cat species is threatened by interbreeding, which dilutes their genetic makeup in locations where wild cat species coexist. Furthermore, tiny animals that are essential to soil health and seed dissemination are severely preyed upon by feral cats, which upsets the balance of the environment.

Even looking beyond the issues, these cats are in a very constant and quick cycle of reproducing and dying. The issue with feral cats is that too many of them die early on. Around 75% of feral kittens die in their first few weeks [15]. Having a place to grow comfortably will allow more kittens to grow in shelters and even become pets. Fertile cats struggle to survive, especially when they do not have a home during winter. Because of their fear of humans, they have little food sources and no form of warmth throughout the lower temperatures.

Compared to domesticated cats, feral cats live between 2-5 years [15]. They aren't provided any food and have experience dealing with many predators such as dogs or people. Having poor encounters with people, these feral cats often have difficulty placing their trust in humans who are willing to actually help them.

These cats are constantly reproducing as well. The average cat has the ability to produce a litter 5 times a year. Each litter typically consists of between 4 to 6 kittens [20]. Although 75% of feral

kittens die in their first few weeks, the rate at which they reproduce causes the population to continue to consistently increase.

Because of the reproductive rate, millions of feral cats are killed. Even those that are sent back to shelters after being rescued are rarely returned to their owners. Only 2% of stray felines that are discovered are sent back [19]. This means that those that are sent back are hardly ever returned which increases the concern for these cats.

The kittens entering this constant cycle of death while also bringing unprecedented amounts of damage to the environment make this an urgent issue to be taken care of.

With this in mind, the plan was to create a cost-effective feral cat shelter that can keep the cats in a safe and open area while also creating the possibility of domesticating the cats. By providing these opportunities to cats, they can be adopted at much faster rates and drastically reduce the amounts of environmental issues that they create.

While addressing this issue, multiple examples were used to inspire this feral cat shelter. Some examples include heated houses for cats that have good insulation or cooler shelters. However, the functionalities of these shelters are limited to almost one or two things. They lack the ability to thrive during all the seasons and offer very minimal amounts of applications.

Creating a feral cat shelter with multiple functionalities while keeping costs low could significantly contribute to reducing the number of cats on the streets. These shelters could offer essential services such as vaccination and basic veterinary care. Additionally, they could provide safe living spaces for cats in extreme weather and facilitate adoption programs to place socialized cats into homes.

By incorporating sustainable materials and designs, these shelters can remain affordable while being effective. Such an initiative could create a lasting impact on controlling feral cat populations and improving the overall health and well-being of these animals, while also reducing their negative effects on local ecosystems.

In this way, the cats can either remain safe while also giving them the possibility of being able to find a new home.

Avoiding direct contact with feral cats is the best method to start caring for feral cats. This can be done through sensors that are connected to an Arduino. Both food and water sensors are implemented to notify the owner of the status regarding the amount of water and food in each container, so the shelter can always be available as a method of food for stray cats. Even if the cats are apprehensive towards humans, they would be willing to make use of the shelter to eat.

Another functionality that can be implemented is through the relay switches that activate the heating pad and fans based on temperature readings [17]. Throughout different seasons of the year, these cats often die due to the harsh conditions of the wild. Especially in the winter, a heating pad that turns on based on the surrounding temperature can help improve energy efficiency while also ensuring that the shelter remains warm enough for the feral cat to survive. This would work by connecting the temperature sensors to the heating pad and the fans through the relay modules.

Although being completely automated and away from humans, these functions can help the cats to place more trust in humans and provide an opportunity for the shelter owner to slowly approach and interact with the cats inside. By offering a safe and comfortable environment, automated shelters can reduce the stress and fear that feral cats often experience. Over time, as the cats become accustomed to the shelter's consistent care, they may begin to associate humans with positive experiences, making it easier for the owner of the shelter to build trust and potentially socialize these cats for future adoption.

The feral cat shelter started initially through a black container. Before drilling into the container, all the different sensors were assembled, as well as the recordings of the proper measurements of each sensor. The shelter was mainly to serve as multi-functioning: to provide food and warmth. To provide that warmth, a DHT22 was used to measure temperature and humidity, an HC-SR04 that measure food, and a Gikfun liquid sensor that measured water. More improved features

were installed that monitored the feral cat's condition. From readings from the temperatures, the fans and the heating pad turned on through the relay modules were all effective.

The initial plan was to have a fully functioning automated cat shelter that notifies the owner of the shelter whenever the shelter needs to be taken care of. To make this viable in fixing the issue of feral cats on the streets, the shelter was made as affordable as possible to help in potential domestication. When being more accustomed to receiving help from external sources, the vision of this shelter was to help the cats to open up to the help from actual humans.

2. EXPERIMENTAL METHODS

2.1 Experimental Materials

To start, the following parts were collected and assembled accordingly. The Arduino Mega microprocessor was purchased from Jamesco.com. 2 Electric Fans, Heating Pad, Wyze Camera were obtained through local stores. The distance sensor, HC-SR04, and the temperature and humidity sensor, the DHT-22, were bought from Digiky.com. The Gikfun Liquid Sensor, ESP8266, Relay Module, LCD were bought through Amazon purchases.

2.2 Assembly of Smart Feral Cat Shelter

The assembly of the smart system for the feral cat shelter is shown below in diagram 1. Considering the Arduino Mega as the core central microcontroller, the other sensors were connected to it. The LCD was used for monitoring the working condition and was connected to I2C, SCL and SDA pins. The Fans and heating pad were also connected through the relay modules which connected to the 5V and GND pins. The DHT22, HC-SR04, ESP8266, and Gikfun Liquid sensors were all connected to different analog and digital pins. The Wyze Camera was connected outside of the Arduino through a power outlet.

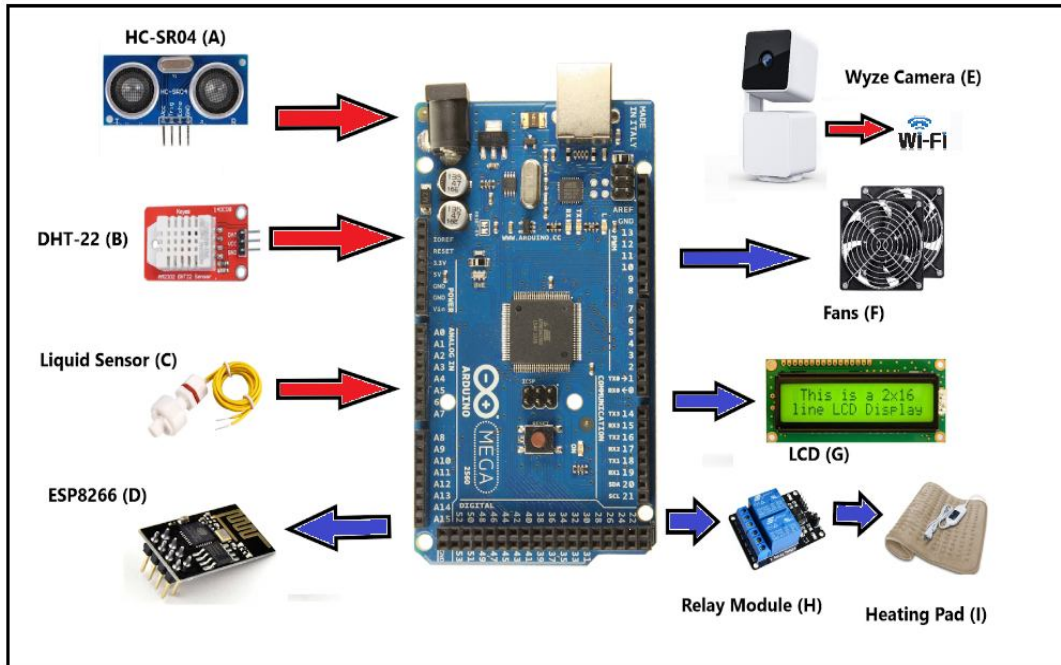


Diagram 1 illustrates the connections of sensors and actuators used in the study.

2.3.1 Temperature and Humidity Sensor

The feral cat shelter used two different temperature and humidity sensors. One of them was a very affordable option that had an I2C interface. The AM2320, the sensor that was used, is not documented well and is not as efficient, but it was used as a backup in case the DHT22 failed. Although it was not as effective as other costly models, the AM2320 served its purpose and for an affordable price. The other temperature and humidity sensor was the DHT22. Being an affordable and reliable option, this sensor had a temperature accuracy of $\pm 2^{\circ}\text{C}$ and a humidity accuracy of $\pm 5\% \text{RH}$. This was the main sensor for temperature and humidity readings, and its readings were the ones that were displayed on the LCD.

2.3.2 Food Sensor Application with Distance Sensor

A food sensor was used with a distance sensor, HC-SR04. The initial distance for the sensor to detect was in the range of 10 millimeters. The distance center was placed at the bottom of the food container to see if any food was left at the bottom. It was installed at a 20% lower position to detect the existence of foods. Multiple trials were carried out for the accuracy of the performances. If there were no food left, this sensor would notify the carer. This sensor is

attached to Arduino Mega and would work with other modules to ensure that the shelter owner would be notified of the minimal amount of food left in the container.

2.3.3 Water Level Sensor

The water level sensor was attached with a 2/8" bolt at the left front of the assembly box. The sensor is a Gikfun M8 Liquid Level Sensor and detects if there is water by the level of the switch. If the switch is floating, the code knows that there is water, but if the switch is down, that alerts the owner that there is no water left in the container. The sensor is attached to the Arduino Mega and worked with other modules to ensure that the owner would be notified of the necessary refill of water in the container.

2.3.5 Our Webcamera Streaming, Remote Observation



Fig. 1 presents a Webcam view.

This camera as in Fig.1 is attached to the feral cat shelter and monitors its ambient activity. The camera automatically tracks any movement near the outside and the food and water containers using its smart AI detection. Using an application on a digital device, the owner of the shelter can monitor the activity of the feral cat shelter to ensure enough resources are available for the feral cats. This camera is attached to the

outside of the box and measures 2"x2"x5". The specs on the camera allow the user to view almost anything within a 20-meter radius. This can help to monitor the cat and to pick up on certain issues if the sensor may be dealing with certain malfunctions/defects.

2.3.6 Fan and Heating Blanket Control

There are two fans added to both ends of the shelter. After cutting two holes (9" diameter) into the two ends, the two fans were hot glued onto the shelter ensuring that there was enough space. During typically warmer temperatures throughout the year, the fans help dry and keep the cats cool.

Inside the shelter, there is a heating pad on the floor. This heating pad will help in keeping the cat inside of the shelter to be warm. It can also assist in helping the cat dry off if the weather

outside is rainy. This is an effective method to ensure the cat can thrive in warm and cold weather. Even if the conditions are ideal, a small amount of heat from the soft pad can help the cat get the necessary rest.

2.3.7 Flow Chart Plan for Sensor Calibration

After all the sensors and actuators were connected and wired, there was a common formula that happened with sensor calibration. As illustrated in diagram 2 below, the sensor started with being attached to the designated Arduino (a). Upon proper attachment to the Arduino (b), the sensor was put through calibration (c), usually through comparison to an advanced sensor of the same type (d). If the readings of both sensors were not aligned (e), the sensor would be recalibrated and checked for any dysfunctions. If the readings were either very close or the same (f), this process would be repeated through moving on to the next sensor (g).

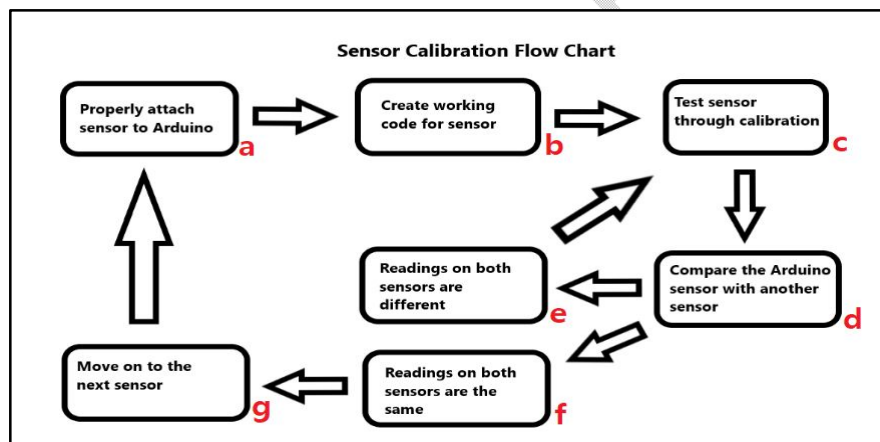


Diagram 2 presents the flow chart of the sensor calibration procedures.

2.3.8 Data Analysis

All the calibration data was summarized as mean and standard deviation. And, the regression analysis has been performed with the trendline functionality in Microsoft Excel. The regression equation and regression coefficient were acquired after finding the magnitude of the R squared.

3. RESULTS AND DISCUSSIONS

The system has been completed and tested to examine if they were working properly.

3.1 Temperature Control Sensitivity Calibration

The DHT22 is the main temperature and humidity measurement source throughout the cat shelter. This sensor measures 1.5"x1" and is an accurate sensor connected to the Arduino Mega Board with the absolute accuracy being $\pm 2\%$. Attached to Pin2, 5V, and GND, this sensor works by containing a thermistor, capturing the surrounding air, and sending the resulting info into the computer. This sensor comes with a resistor and is more precise than other temperature sensors.

The LM35 is another temperature sensor that works to help measure the conditions inside of the cat shelter. This sensor can be used as an alternative to the DHT 22 sensor, and once calibrated, linear regression can be utilized to determine the accuracy and ideal conditions of the shelter.

The AM2320 is another temperature sensor that was compared with the DHT22. It measures both temperature and humidity. The temperature sensor has an accuracy of ± 0.5 degrees Celsius.

Upon comparison of the temperatures to the Cal meter thermometer, the DHT22 was the most accurate. The readings of the AM2320 were also close to the ones from the Cal meter thermometer, and both were attached to the main shelter.

Fig. 2 below shows the change of DHT22 temperature with respect to the temperature value from the calibration thermometer that was considered an actual temperature. The regression relationship between the two calibration curves was offset in the actuator algorithm.

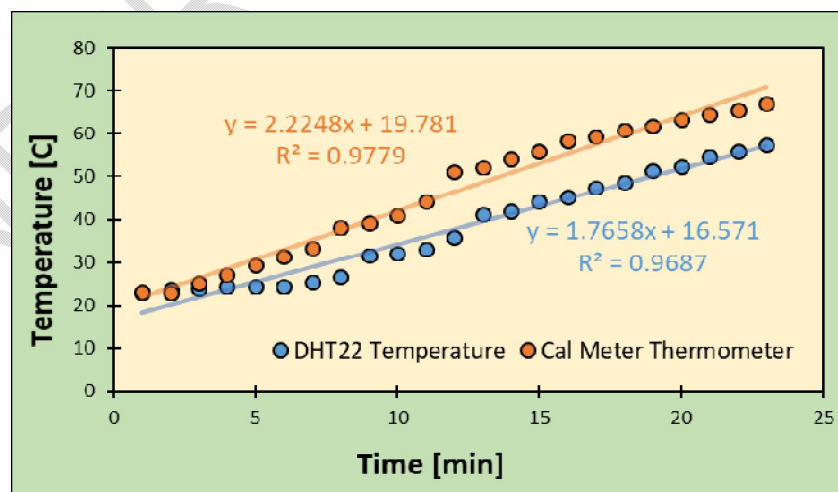


Fig. 2 presents the relationship of the temperature from DHT22 and the Calibration Thermometer.

3.2 Humidity Control Sensitivity

The humidity sensor is the DHT22. The DHT22 measures both temperature and humidity and is used inside the shelter to measure both. The way the DHT22 measures humidity is through the humidity sensor installed inside the sensor. This sensor does this by measuring the change of moisture in a substrate material that is sensitive to humidity. Another humidity sensor that was used is from the AM2320. It has an accuracy of $\pm 3\%$ and requires the Adafruit library to work. It uses an I2C interface to connect the sensor and transmit the information to the computer.

To start humidity calibration, the DHT22 sensor was used first. To compare with the sensor, a trustworthy humidity and temperature sensor that accurately relayed the temperature and sensor of the surroundings was used. To start, a jar was filled with cold water. Both sensors were placed towards the top of the jar, not touching the water. After letting both sensors stabilize, the temperature and humidity of both sensors were measured.

3.3 Calibration for humidity and temperature sensors

As for our data, Fig. 3 gives a glimpse of the mutual relationship of DHT22 humidity and calibration meter humidity. As examined closely, it reached a plateau at 7.5 min to 100% relative humidity. The humidity should never be higher than 100 for actual ambient weather conditions. So, two linear regression equations that should be reflected in digital codes in our algorithm were created.

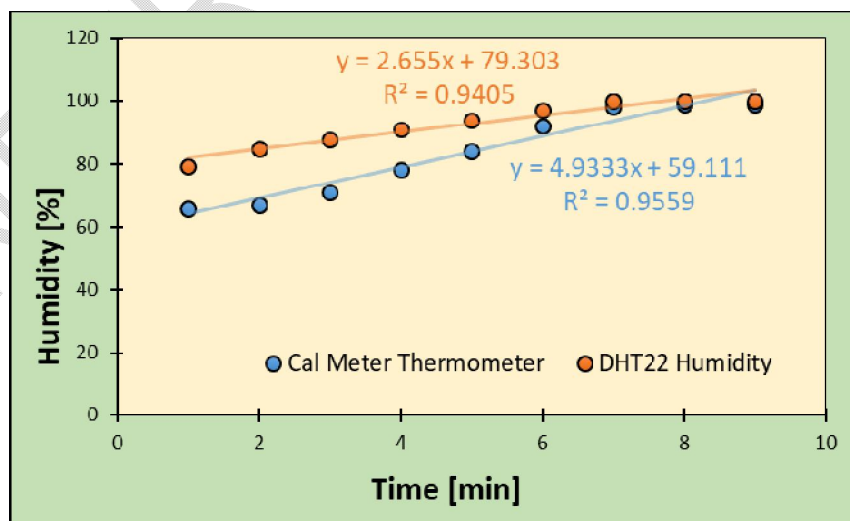


Fig. 3 presents the relative humidity measured from the DHT22 humidity sensor and calibration humidity meter.

3.4 Floor Condition Control Calibration Output

The floor condition was monitored through the internal temperature and humidity. If the shelter was too cold, the heating pad was turned on to ensure that the feral cat inside remained warm. The heating pad is connected to the relay module, so when the Arduino picks up the temperature and humidity from the DHT22 sensor, the heating pad will be turned on after a certain threshold.

3.3.1 Fan Control Operating Checkpoints

The temperature control inside of the container was monitored through the internal temperature. If the temperature were too hot, the fan would be turned on through a relay module connected to the main Arduino. The main Arduino was connected to the temperature sensor, so if the temperature sensor reading is higher than average, the fan will turn on. These two fans were calibrated using a temperature sensor and an enclosed space. If the temperature were too high, the fan would turn on.

3.4 Food Sensor Sensitivity Calibration

The food sensor is operated through a distance sensor placed at the bottom of the food container. If the distance sensor dictates that there is an object a certain amount of distance away, that indicates that there is food present inside the container. If there is no food present inside of the container, there will be a larger distance in front of the distance sensor, which is an indication that there is no food present. To calibrate the food sensor, a small container was filled with food and viewed if the distance would properly correlate with the amount of food present as in Fig.4.

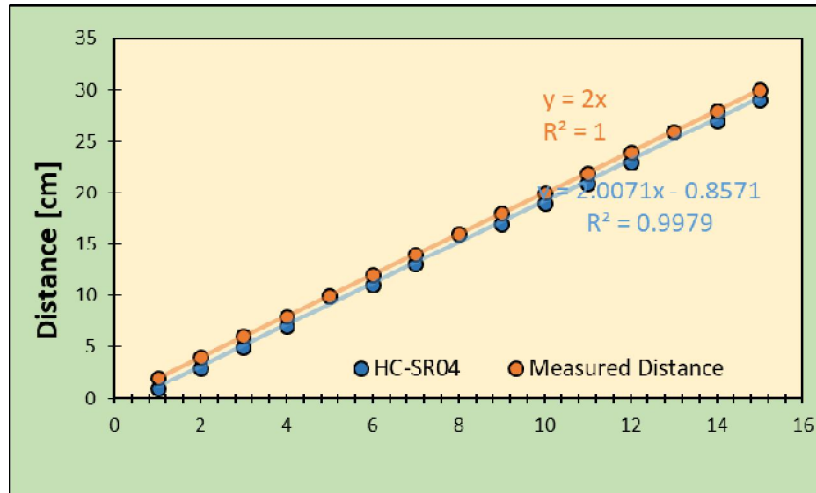


Fig. 4 illustrates the relation of distance sensor output with a metric ruler measurement.

3.5 Water Level Sensitivity Calibration

The principle of the water level sensor is to determine the amount of water inside the water container at all times. Because this is a feral cat shelter, it was important to add other necessities to help the cat survive. With this sensor, the container of water attached to the outside of the shelter can be monitored at every second. To determine when that container should be refilled, the sensor was used to figure out the water level using a lever. This sensor was connected to the Pin5 Arduino Mega. Depending on the position of the lever, it generates a digital number. From that number, it sends to the main computer a message about whether the water levels are either high or low. This sensor was tested 20 times under different situations. For 10 of the tests, the lever was pushed up by the water, and it accurately indicated that there was sufficient water present inside the container, as seen in Fig.5 below. The level was dropped for the remaining 10 of the tests, and water was absent in the container. Again, for each trial, the lever accurately notified the computer that the levels were low and a refill was needed. For the 20 trials, each one was accurate. The sensor works through the indicator bar, which when touched 2 cm from the bottom, sends out the alert to the LCD display and light. It ensured that the container had 30 ml of water at all times.

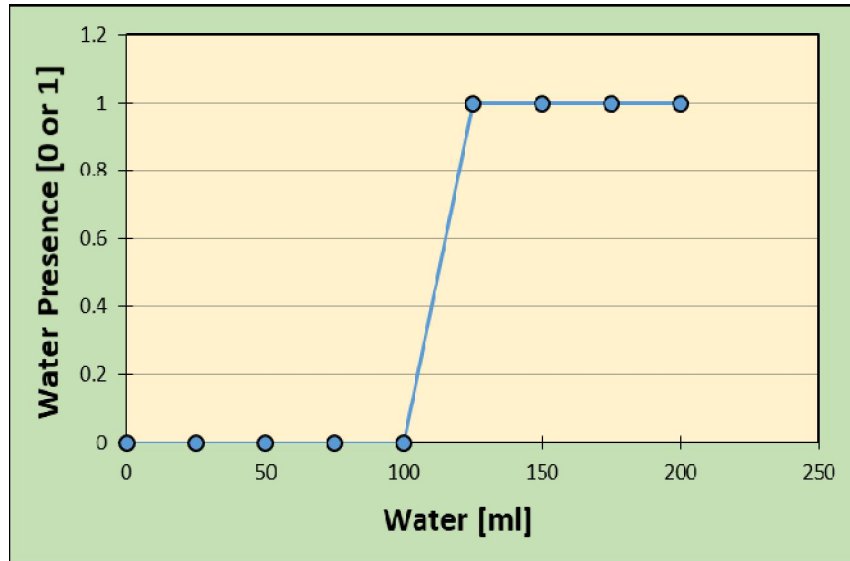


Fig. 5 illustrates the digital potential output from Arduino while changing the water level in the water supply container.

3.6 Floor mat and Fan Coordination with Temp Sensor

It must be very important to make the floor conditions healthy and enjoyable to the feral cats. The calibration of the heating mat was done in conjunction with the fans. Varying temperatures were tested to view the activity of the heating pad. As illustrated in diagram 3, when the temperature was normal, both the fan and heating pad were turned off. The fan should be turned on (point a') when the temperature goes up (point a), while the fan turned off (b'), and the heating pad turned on (b'') when the temperature goes down (b), as the system was automatically operated as a feedback mode.

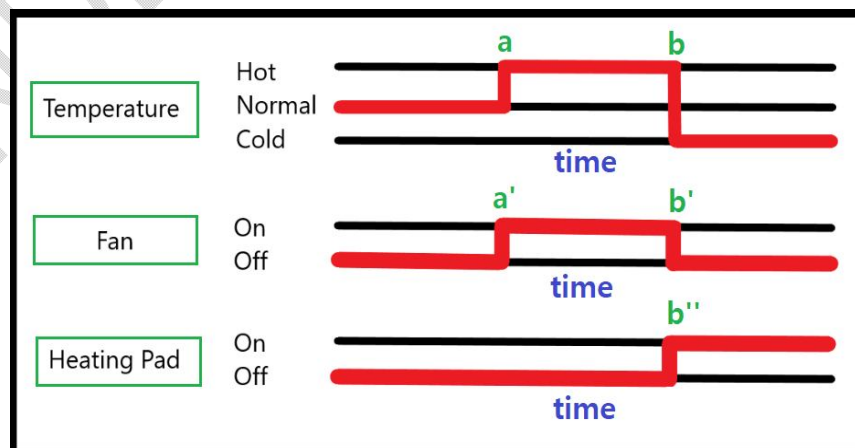


Diagram 3 presents the response of the fan and heating pad to the temperature in the cat shelter.

3.7 Webcam Observation

The function of this webcam was very good, and its image quality was excellent at 1080p. Since the camera tracks moving objects, it could monitor different interferences, even in the darkness of 50 lumens using the 4 IR LEDs. Because of the extra distance sensor that could detect objects from 20m away, any abnormal activities near the shelter should be exposed to another lighting system. For daylight monitoring, the camera records at 20 fps, and for nighttime, it is 15 fps which is standard for cameras. The view range for the cameras is also 360 degrees horizontally, allowing them to monitor anything that is moving; it can also view things 180 degrees vertically. For the long viewing range function, the camera can also zoom in 8x.

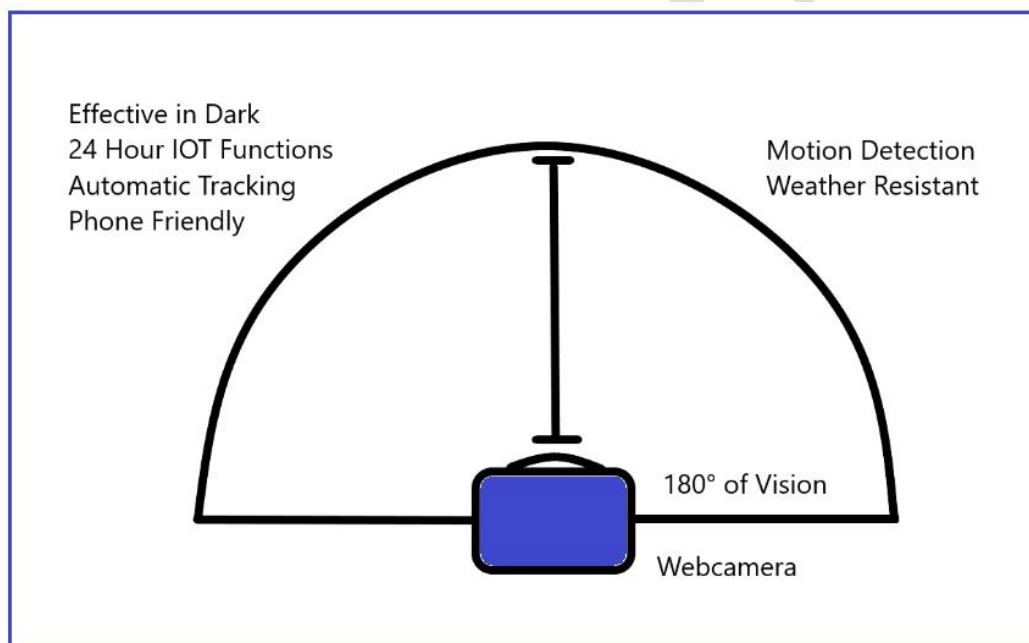


Diagram 4 illustrates the view range of 180-degree angles.

3.8 ESP8266 Observation

The ESP8266 was made to utilize a local WiFi network to send emails. The ESP was used to send alerts to the owner's email regarding the conditions of the cat shelter. If the shelter were lacking food (indicated by the food sensor), the ESP would send an email to the designated user

to fill up the container. The same is done with water or if the camera picks up motion. These emails are conveniently sent to the user's inbox and the conditions need to be improved. For the calibration aspect of the ESP, the food sensor was tested by viewing when it detected no food and how many times out of 10 trials the ESP would accurately send emails to the owner. From the results, this is accurately done and shows the effectiveness of the ESP in sending emails when necessary.

4. CONCLUSIONS

In summary, all the electric parts and sensors were confirmed to operate as intended. The feral cat shelter successfully managed to take in proper information regarding food and water amounts. With a total cost coming under 100 dollars, this feral cat shelter welcomes strays and can ultimately work towards reducing the number of felines that are left to die. This affordable price is more than half of the price of shelters being sold online and provides so much more functionality than them. After placing this in an open environment, the main purpose of catering towards the cat was fulfilled. Whether it be to just simply eat or drink water, stray cats came to this shelter and proved that the shelter worked as intended. The progression and activity of the shelter were monitored using the camera and the emails that were sent towards the mobile device regarding the amounts of food and water in the containers.

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