Journal of Basic and Applied Research International

Volume 30, Issue 4, Page 1-12, 2024; Article no.JOBARI.12277
ISSN: 2395-3438 (P), ISSN: 2395-3446 (O)

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

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Author's contribution

The sole author designed, analysed, interpreted and prepared the manuscript.

Article Information

DOI: https://doi.org/10.56557/jobari/2024/v30i48813

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://prh.ikprress.org/review-history/12277

Original Research Article

Received: 03/06/2024
Accepted: 06/08/2024
Published: 09/08/2024

ABSTRACT

Millions of stray cats, also known as feral cats, live in the United States, and many are left to die each year. These cats are the same animals as the domesticated felines that people care for in their homes. Because of their notorious reputation of being resistant towards humans, the abandoned felines still suffer without basic survival necessities like food and a warm place to stay throughout the winter. Along with the suffering that these cats go through, it is also crucial to acknowledge that the growing number of these stray cats is a threat to the environment: the spread of disease and competition. In this paper, an IoT-based smart feral cat shelter has been assembled and tested to effectively minimize the stray cats on the streets. The shelter will be used as a method to get the cats to become more dependent on the help of humans which can lead them through the process of domestication. The functions of the smart system include temperature monitoring that is directly connected to sensors that control electric fans and a heating pad. It also includes containers with food and water that were controlled by sensors along with a system that

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Cite as: *Hong, Jonathan. 2024. "Building an Automatic Controlled Smart Feral Cat Shelter Using a Microcontroller Arduino Mega". Journal of Basic and Applied Research International 30 (4):1-12. https://doi.org/10.56557/jobari/2024/v30i48813.*

sends emails and text reports to the user. In addition, an advanced type of webcam functionality is added to track outside movement and ensure everything is working as intended. Through individually testing all the components, the system proves effective and offers advanced functions to the feral cat. With everything working as intended, creating and using more of these shelters across different communities can leave a permanent change in the total feral cat population. Though everything works well, there is always room for future modifications to help ensure that the shelter is used as intended and other security measures.

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 pets [3,4]. 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 of the rate at which they increase is extremely difficult. Because of this lack of knowledge, ensuring the reduction of that number is extremely important because of the many downsides that feral cats bring to the surrounding ecology [5,6]. 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. Stray cats can be considered invasive species because their constantly increasing amount leads to them infiltrating new environments which leads to an increase in competition [7,8].

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 [9-12]. The conservation of wild cat species is threatened by interbreeding, which dilutes their genetic makeup in locations where wild cat species coexist. Furthermore, smaller animals that are essential to soil health and seed dissemination are severely preyed upon by feral cats, which further ruins the nature of that ecosystem [5-13].

Even looking beyond the environmental 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 [14]. 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 colder seasons [15,16].

Compared to domesticated cats, feral cats live between 2-5 years [14]. They aren’t provided any food and have experience dealing with many predators such as dogs or people.

Although the rate at which these feral cats pass away is alarmingly high, these cats are constantly reproducing as well. The average cat can produce a litter 5 times a year. Each litter typically consists of between 4 to 6 kittens [17]. With this rate of reproduction, the number of stray felines is only continuing to grow throughout the country.

Cats 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 [18,14]. This means that those that are sent back are hardly ever returned which increases the concern for these cats and their previous owners. With such a high chance of fatality, something needs to be done to ensure that lost felines are safely returned to their owners.

As IoT is becoming more common within livestock management, utilizing IoT to help gather and utilize information was an innovative way to help cats [19]. People make automatic food-feeders for their pets using IoT [20]. To make a fully automatic smart shelter using IoT seemed feasible and cost-effective. With how common IoT is being implemented within animal preservation like monitoring animal behavior and early disease detection, technology being implemented in nature has allowed new advancements to be made [21,22]. With this in mind, the plan was to create a cost-effective and smart feral cat shelter that can help provide the cats with a safe 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 amount of environmental issues that they create [23,24].

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 cannot thrive during all seasons and offer very minimal amounts of applications.

These shelters could offer essential services such as vaccination and basic veterinary care. Additionally, because all of the functions are man-made, cats using this shelter can become more accustomed to aid from external sources. This could allow the cats to re-establish relationships with people and be willing to trust their care.

By helping to provide them with medical care, these cats can reduce the risk of harming other environments with diseases. 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.

To start this process, 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 will be implemented is through the relay switches that activate the heating pad and fans based on temperature readings [25]. 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 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 measured 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, we succeeded in our vision of this shelter which was to help the cats to open up to the help from actual humans.

However, several issues were encountered throughout the creation of the shelter.

First, the deployment of the shelter turned out to be difficult. Many different influences prevent the shelter from being used properly. For example, in some neighborhoods, the existence of rabbits or street dogs could make it difficult for feral cats to make use of the shelter. The design of the shelter supplied all the necessities for the cats but can be improved in this aspect. Different environments require different things which is why there are many different future applications and modifications of the original model that could help the shelter fulfill its designated purpose.

Second, there was little security regarding the shelter other than the web camera. Although the camera would record external sources, the camera could easily be disarmed and the shelter could be taken. A future implementation that would prove to be beneficial would be the implementation of a lock to the ground or an alarm system.

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 Fig. 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, SDL 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.

2.2.1 Conceptual model

The assembly of the model starts with a black container. A black container is flipped over and attached to a wooden panel. Three holes are drilled on three sides of the container; one is used as an entryway for the cats while the other two on the sides are used to attach the fans to the shelter. A heating pad is placed inside of the container. The top of the container is used to place the Arduino Mega and the sensors. Smaller holes are drilled throughout the container which connect the Arduino to the fans and the pad. The food and water containers are both attached next to the entrance of the shelter along with their designated sensors. The camera is finally attached towards the top which monitors the nearby surroundings.

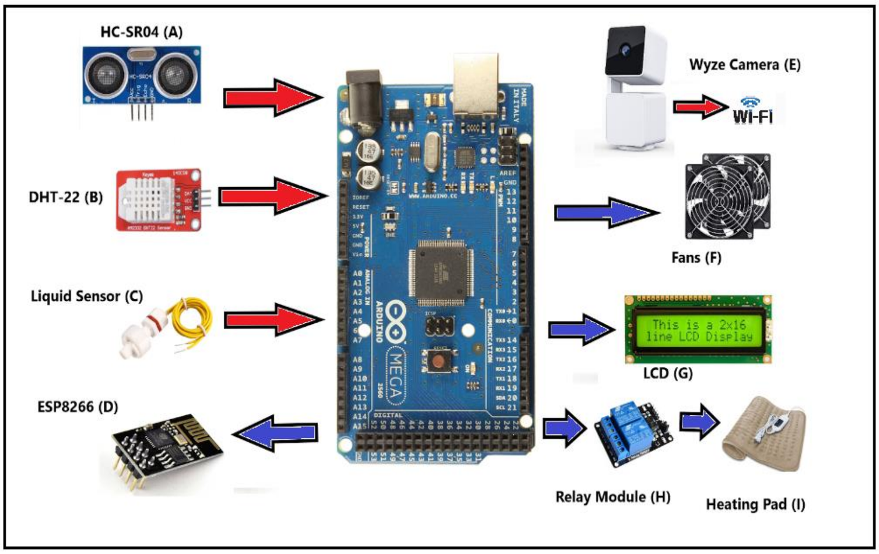

Fig. 1. Diagram illustrates the connections of sensors and actuators used in the study

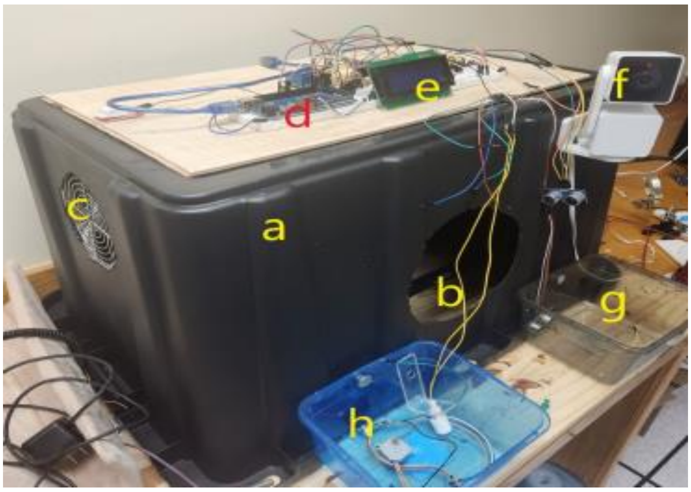

Fig. 2. Assembly of the model starts with a black container

2.2.2 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 ±2°C and a humidity accuracy of ±5%RH. This was the main sensor for temperature and humidity readings, and its readings were the ones that were displayed on the LCD.

2.2.3 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.

2.2.4 Water level sensor

Next to the entry of the shelter, there is a container that contains water. The water level sensor was attached with a 2/8” bolt towards the bottom of the container. 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. Naturally, if there is water present, the switch floats to the top, but if there is no water present, the switch naturally reverts back to its original position. 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.

2.2.5 Our webcamera streaming, remote observation

This camera as in Fig. 3 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.

Fig. 3. A webcam view

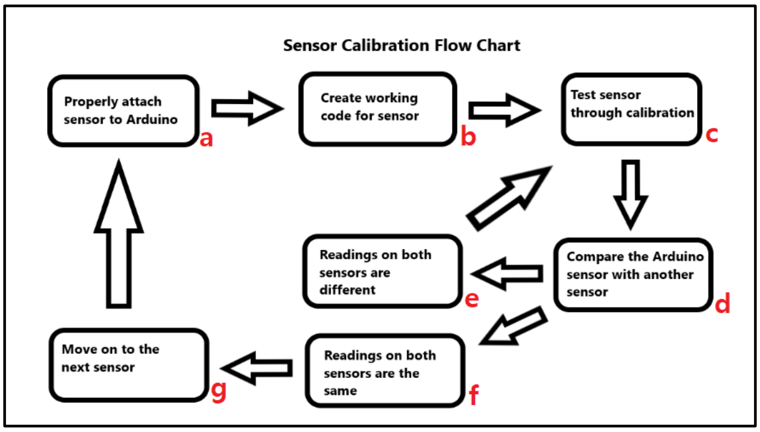

Fig. 4. Diagram presents the flow chart of the sensor calibration procedures

2.2.6 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.

2.2.7 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 Fig. 4, 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 dysfunctionalities. If the readings were either very close or the same (f), this process would be repeated through moving on to the next sensor (g).

2.2.8 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 DISCUSSION

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 ±2%. Attached to Pin2, 5V, and GCC, 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. 5 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.

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 ±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. 6 gives a glimpse of the mutual relationship of DHT22 humidity and calibration meter humidity. The humidity sensor compares with the Cal Meter Thermometer and starts off with different humidity readings. However, as time passed, the humidity readings became closer to one another and displayed an accurate reading which proves the effectivity of the sensor used in the model. 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. Using this information, two linear regression equations that should be reflected in digital codes in our algorithm were created.

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.

3.4.1 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.

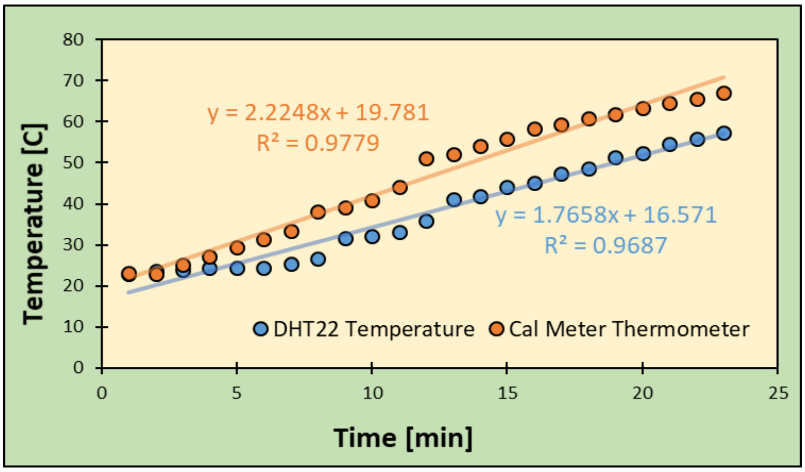

Fig. 5. Presents the relationship of the temperature from DHT22 and the Calibration Thermometer

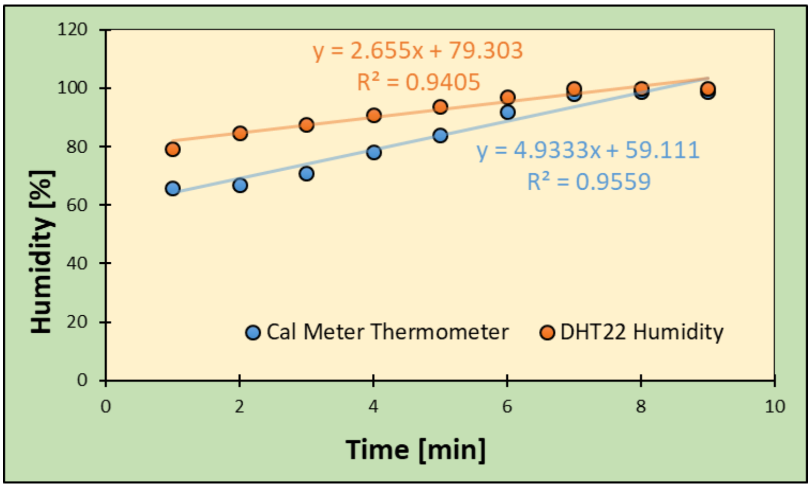

Fig. 6. Presents the relative humidity measured from the DHT22 humidity sensor and calibration humidity meter

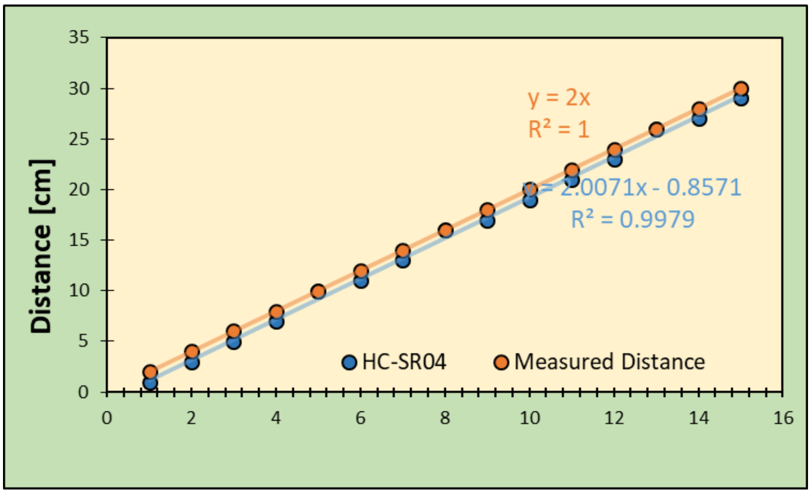

Fig. 7. Illustrates the relation of distance sensor output with a metric ruler measurement

3.5 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. 7.

3.6 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. 8. 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.

3.7 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 Fig. 9, 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.

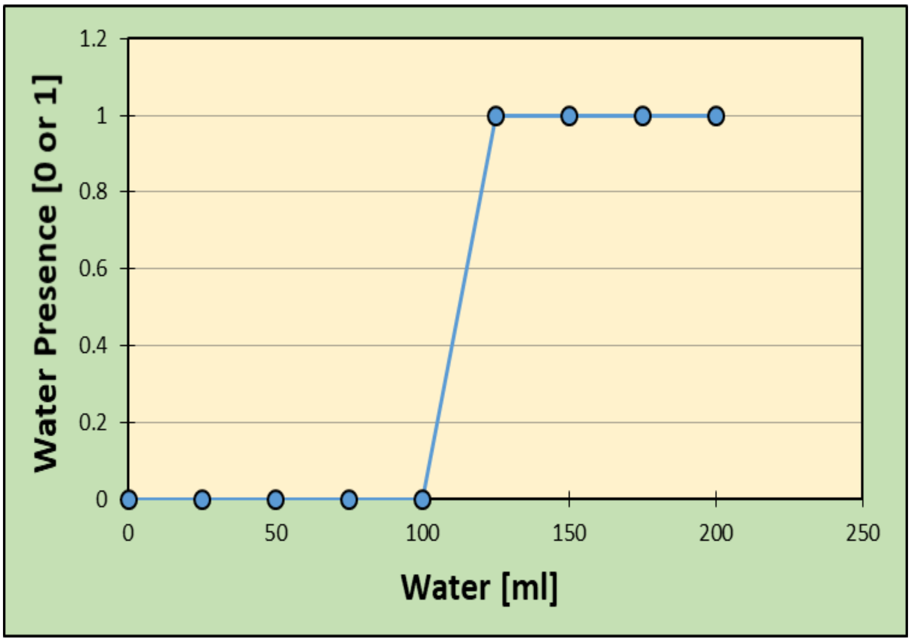

Fig. 8. Illustrates the digital potential output from Arduino while changing the water level in the water supply container

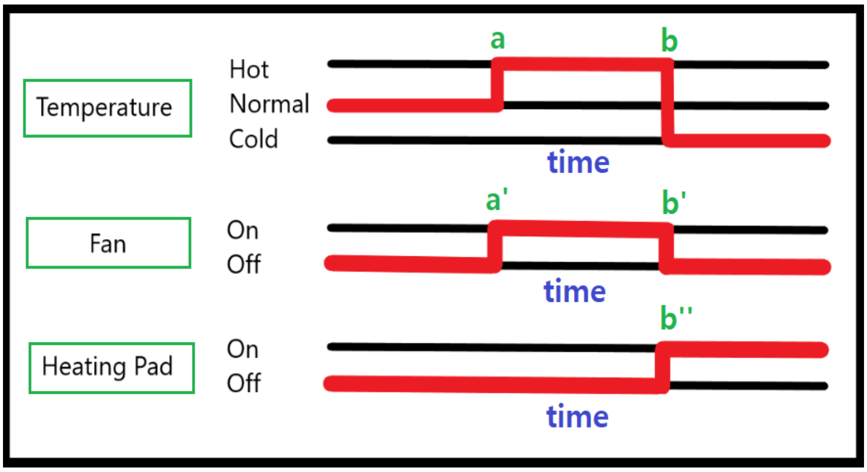

Fig. 9. Diagram presents the response of the fan and heating pad to the temperature in the cat shelter

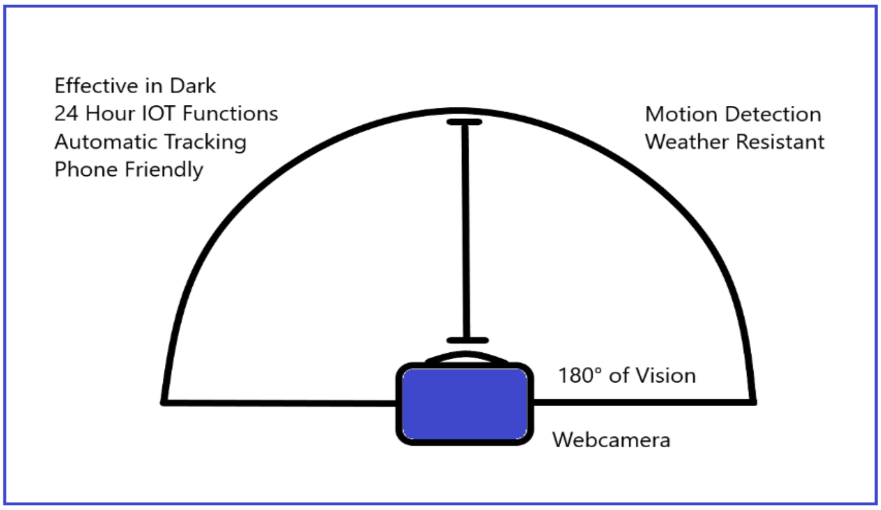

Fig. 10. Diagram illustrates the view range of 180-degree angles

3.8 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.

3.9 ESP8266 Observation

The ESP8266 was made to utilize a local WiFi network to send emails and text messages. The ESP was used to send alerts to the owner's email and phone regarding the conditions of the cat shelter. If the shelter were lacking food (indicated by the food sensor), the ESP would send an email and a text message to the designated user to fill up the container. The same is done with water or if the camera picks up motion. These emails and messages are conveniently sent to both the user's inbox and phone. 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 and messages to the owner. From the results, this is accurately done and shows the effectiveness of the ESP in sending notifications 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 to 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 notifications that were sent to the mobile device regarding the amounts of food and water in the containers. Based on the current results, some adjustments could be implemented. To ensure smoother operation of the shelter, a sensor could be implemented in the future that could detect any movement and report back to the owner along with modifications to the placement of the webcam to be able to monitor both the outside and the inside of the shelter. Another possible implementation could be security measures like locks or an alarm system to ensure that the shelter does not get stolen. The current model is rudimentary as it fulfills all the necessities which is why certain implementations in the future could be made to improve the quality and safety of the model.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Author has declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://prh.ikprress.org/review-history/12277