ECE 445
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Project #84
Mobile Stray Cat Rescue Station

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1. Introduction

1.1. Problem

For now, because of the kind people from all walks of life and the existence of many adoption agencies, it is difficult for us to see stray animals on the street without a fixed place to live, but this is not absolute! Because in my community, I always see a lot of stray cats, regardless of age and species. When I meet them, they are not necessarily alive. The cold and food shortage will threaten their lives. And every time I want to help them, I can't just happen to be able to provide them with food. Even if I can give them food, the stray cat population and its offspring will continue to wander. So my idea is how to help them live better. I plan to build a portable stray cat rescue station that can be placed in areas where stray cats are present to provide them with warmth and food.

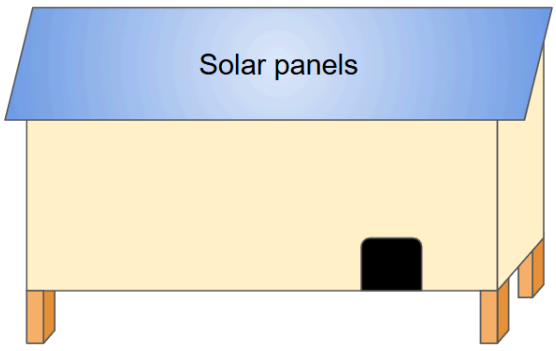
1.2. Solution

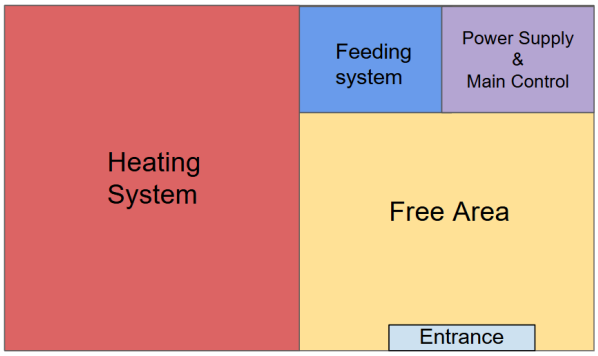
Our solution is to design a wireless constant temperature device that can detect the temperature in the cat's nest at all times to determine whether the heating device is turned on and off. Then equip it with feeding equipment, and detect whether there is enough food in the cat's food bin. Through wireless data transmission, maintenance personnel can decide whether to add food to the equipment according to the data.

This device includes the following modules:

- Power supply module: as the power source of the entire device and other subsystems.
- Heating module: to control the device temperature.
- Main control module: transmit real-time data of the device Casing and heating layer: enhance the warmth of the device at the physical level.

1.3. Visual Aid



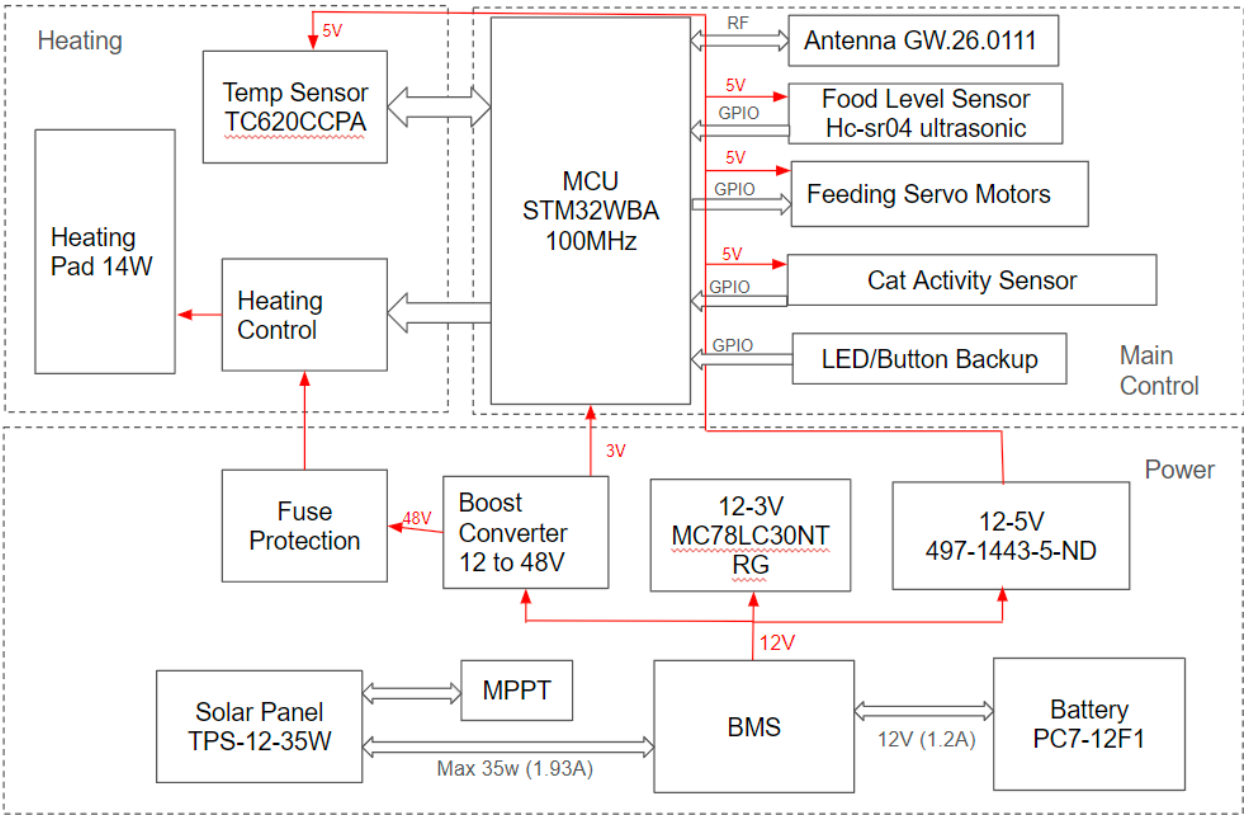


1.4. High Level Requirements List

- The heater will automatically turn on and off when the temperature is within the set value range. It would take no more than 10 sec for the heater to respond.
- Everytime that the food is dispensed, the dispense error of the total amount of food dispensed would be less than 10 percent.
- Camera can detect whether it is a cat inside the station. It would take up to 10 seconds for the system to detect whether it is a cat or not.

2. Design

2.1. Block Diagram



2.2. Subsystem Overview

Subsystem 1: Power supply module

Overview: This subsystem uses solar panels and lithium batteries to realize the device power supply system. While avoiding the trouble of replacing batteries, it can also realize the convenience of this device and can be installed outdoors. It is also conducive to the operation of subsystem 2 (heating module) at night.

Design:

a. Power Generation
    i. Solar Panel: a reasonable size of solar panel usually provides 20 ~ 50w power to maximize efficiency in limited sunlight conditions. (https://www.digikey.com/en/products/detail/tycon-systems-inc/TPS-12-35W/11480036)
    ii. Charge/Discharge Control: BMS to improve charging efficiency and prevent overcharging.
b. Power Storage: Secondary Lithium Battery Pack
    i. Battery Type: Rechargeable for long lifespan (12~48V, 1~2A? Need to determined for heating) (https://digikey.com/en/products/detail/b-b-battery/BP1-2-12-T1/653328)
    ii. Protection Circuit: Battery Management System to monitor battery health.
c. Voltage Regulation
    i. Buck-Boost converters to regulate voltage for different subsystems (3~5v for mcu and operation, 12V for heating, etc.)
    ii. Fuse Protection?

Subsystem 2: Heating module

Overview: This subsystem automatically controls the temperature in the device through heating equipment and temperature and humidity sensors

Design:

a. Heating Method:
    i. Material: Carbon fiber heating wires or heating pads placed along the floor and walls. https://www.walmart.com/ip/Walbest-Reptile-Heating-Pad-20W-Waterproof-Heat-Pad-Under-Tank-Terrarium-Temperature-Control-Safety-Adjustable-Mat-Turtle-Tortoise-Snakes-Lizard-Geck/572066967?sid=972434b3-daa3-42b1-8816-927c844532d5
    ii. Power Consumption: ~15W (to balance efficiency and power availability).
    iii. Safety Features: Fire-resistant insulation and thermal cutoff switch to prevent overheating.
b. Temperature Control:
    i. Temperature Sensor: to monitor internal temperature.
    ii. Smart Controlling System for improving heating efficiency.
c. Control Mechanism:
    i. Heating activates when temperature falls below 10°C (50°F).
    ii. Heating turns off when temperature exceeds 25°C (77°F).
    iii. Real-time monitoring through the main control unit.

Subsystem 3: Main control module

Overview: Collects data from various sensors and transmits it to a remote monitoring station via **WiFi**. It also controls the **feeding system**, battery monitoring, and heating regulation.

Design:

a. Microcontroller
    i. STM32/ESP32 with WIFI module for efficient remote data transmission and local processing.
    ii. Sensors can be used to trigger the active mode of the MCU, which can usually be in low-power mode.
b. Transmission method: Use WIFI devices for transmission to ensure that various data can be effectively transmitted.
c. Feeding System:
    i. Ultrasonic sensor for detecting remaining cat food.
    ii. Feeder controls: The motor responsible for dispensing food will only be activated when the food in the food bowl is below the set value.
d. Power monitoring: Real-time recording of battery remaining power
e. Cat Activity Monitoring:
    i. A camera used to monitor cat activities and transmit images to the cloud to perform AI detection to see if the target is a cat.

Subsystem 4: Shell and heating layer

Overview: Use physical methods to assist and strengthen the role of subsystem 2 (temperature control module), and reduce power consumption.

Design:
Shell: Waterproof plastic board, aluminum plate or 3D printing material, and a metal frame about 10 cm above the ground to prevent rainy weather
Inner layer: Warm and fireproof foam board or other insulation material

2.3. Subsystem Requirements

2.3.1. Subsystem 1 Requirement

2.3.1.1. The subsystem should be able to obtain solar energy using a solar panel rated between 20W and 50W, and i should provide a nominal operating voltage range of 15-22VDC.

2.3.1.2. Should include an MPPT(Maximum Power Point Tracking) charge controller to optimize the solar power conversion to achieve a minimum of 90% tracking efficiency under varying sunlight. IT

should also handle an input voltage up to 30VDC, and charge the lithium battery correctly.

2.3.1.3. Should store energy in a secondary lithium battery pack capable of supporting nighttime/low-light operation for subsystem 2. It should have a nominal voltage in the 12-14.8 V range, for at least 4 hours under low/no sunlight conditions.

2.3.1.4. Include a BMS(Battery Management System) to monitor the battery voltage, current and state of charge, as well as the temperature, making sure that there is no overheating. It would make sure that the battery temperature is within a safe operating range of 0 degree Celsius to 45 degree Celsius during chagrin state, and -10 - 50 degree Celsius during discharging, with an accuracy plus or minus 3 degree Celsius.

2.3.1.5. Regulate output voltages using buck-boost converters to provide stable power at 3-5V for MCU and control circuit, and then 12V for heating module.

2.3.2. Subsystem 2 Requirement

2.3.2.1. The interior of the rescue station would have a heating pad that's able to function with the power generated from the solar panel.

2.3.2.2. The walls of the interior would have a thermal insulation that's able to maintain the temperature, with at least 50% thermal insulation.

2.3.2.3. Be able to control the temperature within the set range of 10°C - 25°C. Making sure that the temperature never drops below 10°C, and then the temperature would increase up to the limit of 25°C when there is a cat ent ering the rescue station.

2.3.3. Subsystem 3 Requirement

2.3.3.1. The microcontroller should be able to support low-power modes, reduce power consumption when idle, and only activate when needed.

2.3.3.2. The transmission device should be able to work over long distances (covering at least 1 km in open space).

2.3.3.3. The system should be able to monitor the battery level within ±5% accuracy.

2.3.3.4. Data updates should be able to transmit real-time data within 10 seconds.

2.3.3.5. The system's camera module should be able to capture relatively clear images and be able to distinguish the correct target to assign the correct instructions to other modules.

2.3.3.6. The system should only dispense food when a cat is detected and respond with a feeding system within 10 seconds of detection.

2.3.4. Subsystem 4 Requirement

2.3.4.1. Ability to maintain the internal temperature of the device when the heater is off, and be able to ensure that the room temperature does not drop by more than 5 degrees Celsius within 30 minutes.

2.4. Tolerance Analysis

Overall Power Demand

The power system of the mobile stray cat rescue station relies on a solar panel and a rechargeable battery pack to ensure continuous operation. The critical aspect is to ensure the system has sufficient power generation and storage to sustain functionality.

For a simple power consumption calculator:

Subsystem	Estimated Power
Heating	15W (intermittent)
MCU/Sensors	2W (intermittent)
Camera Module	3W
Food dispensing	5W (intermittent)
WiFi	2W
Total Estimated	**~ 20W for heating**

Solar Panel Generation: The efficiency of solar panels depends on multiple factors, but assuming a 35W solar panel with an efficiency of 20%, a 5 hour charging will generate 31.5Wh energy everyday.
Battery Storage and Capacity: For a 12V, 10Ah battery, it can support around 5.5 hours heating.

Tolerance Considerations

- Solar Panel Output Variability:
    - Under cloudy conditions, solar power generation may drop by 50% or more. This means the daily power generation could fall to 15Wh/day.
    - A larger panel (50W) or multiple panels would mitigate this risk.
- Battery Efficiency and Degradation:
    - Lithium batteries degrade over time. Typically, their capacity reduces by 20% after 500 charge cycles.

    - To compensate, a larger battery pack (e.g., 15Ah instead of 10Ah) may be required.
- Power Consumption Variation:
    - Peak power draw (e.g., when heating and food dispensing occur simultaneously) could exceed 25W.
    - A higher capacity battery or power management techniques (e.g., prioritizing heating over feeding when battery is low) can help maintain efficiency.
- Temperature Effects:
    - Lithium-ion batteries lose efficiency in cold conditions. At -10°C, efficiency can drop by 30%.
    - Insulation and heating elements powered by excess solar energy can help mitigate this issue.

So this means we need to actively design a heating system to open/close the heating pad and save energy.

3. Ethics and Safety

3.1. Usage of Solar Panel

3.1.1. Since we are using a solar panel for the main purpose of power supply, we should keep in mind the precautions of a solar panel, such as electrical safety, mounting and structural precautions, positioning and shading, and cleaning and maintenance.

3.1.1.1. Electrical Safety

3.1.1.1.1. Making sure that power is turned off before maintenance, since solar panels can generate significant voltage in sunlight.

3.1.1.1.2. Usage of gloves that isolates electricity, insulated tools, and safety glasses

3.1.1.1.3. Making sure all wiring connections are secure and that hot components are taken care of before repairing.

3.1.1.2. Mounting and Structural Precautions

3.1.1.2.1. Making sure the ground mount is strong enough to handle the weight of solar panels, and that it doesn't get destroyed with by the local wind and weather conditions.

3.1.1.2.2. Avoiding dangerous contact with the solar panel, such as steeping and cracking it.

3.1.1.3. Positioning and Shading

3.1.1.3.1. Properly positioning the solar panel, and making sure the tilt angle is orientated correctly to obtain sunlight and transform that into power.

3.1.1.3.2. Minimize shading to obtain the most amount of sunlight as possible, since even a small shaded area can cause significant reduction of the panels power output.

3.1.1.4. Cleaning and Maintenance

3.1.1.4.1. Scheduling regular maintenance to make sure that the solar panel doesn't get affected by dust, dirt, or other objects/cracks that would affect regular usage.

3.2. Fuse Protection

3.2.1. When the current exceed 0.5 A, the fuse would automatically disconnect, due to danger of overheating

4. Reference

1. **Power Generation**
   Tycon Systems 35W Solar Panel TPS-12-35W
   Available at Digi-Key
2. **Battery Type**
   B.B. Battery BP1.2-12-T1 12V Rechargeable Battery
   Available at Digi-Key
3. **Heating Module**
   Walbest 20W Reptile Heating Pad (Waterproof, Adjustable)
   Available at Walmart
4. **Microcontroller & Communication**
   ESP32 WiFi+Bluetooth Development Board
   Available at Adafruit
5. **Temperature Sensor**
   DHT22 Temperature & Humidity Sensor
   Available at SparkFun
6. **Solar Charge Controller**
   EPEVER MPPT 20A Solar Charge Controller
   Available at Renogy
7. **Voltage Regulation**
   LM2596 Buck Converter (12V to 5V)
   Available at Digi-Key
8. **Food Dispensing Motor**
   NEMA 17 Stepper Motor (for controlled food dispensing)
   Available at Pololu