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Thermal Imaging for Landmine Detection

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Introduction:

In our study of which sensor to use in the UAV for landmine detection, we concluded that thermal imaging is best suited. Therefore, we tested the MLX90640 sensor. We conducted experiments that included testing the camera in the open air and then burying the object in sand to recreate real-life scenarios.

Testing Apparatus:

- Raspberry Pi
- MLX90640 thermal sensor
- Memory Chip
- Raspberry Power adapter

Setup:

1. Put the Raspberry Pi operating system on a memory card:
We get a memory card that works with our Raspberry Pi.
Save the Raspberry Pi OS image to our computer by downloading it from the official website.

2. Use the Memory Card to flash the operating system: Flash the downloaded OS image onto the memory card using an application such as Rpi Imager.
We entered our password and selected SSID (Wi-Fi network name) during the flashing procedure. When the Raspberry Pi is turned on, it will connect to our Wi-Fi network.

3. Integrate the Memory Card with the Raspberry Pi: - Then we placed the memory card flashed into the card port on the Raspberry Pi.

4. Connect Raspberry Pi and Laptop to the Same Wi-Fi Hotspot: - We will verify that the Raspberry Pi and our laptop are connected to the same Wi-Fi hotspot using the previously given SSID and password.

5. Create an SSH connection to the Raspberry Pi: - Then we installed PuTTY or another SSH client on our laptop.
Turn on the Raspberry Pi.
Locate its IP address on our network when it has booted up and established a Wi-Fi connection.
To establish an SSH connection, we open PuTTY and enter the Raspberry Pi's IP address.

6. Configure the Raspberry Pi for VNC by running `sudo raspi-config` when logged in via SSH.
To enable VNC, we navigated to {Interfacing Options} > `VNC}.

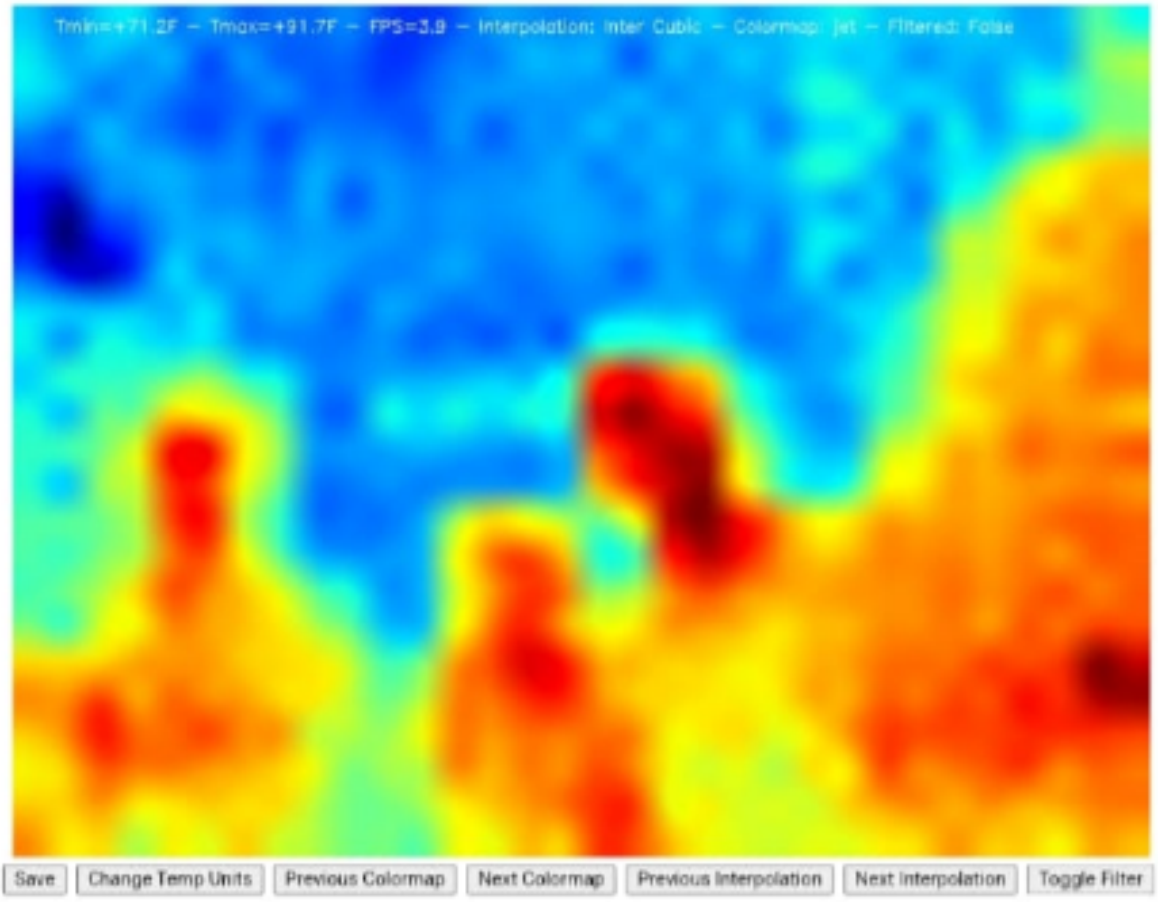
7. Use VNC to Access the Raspberry Pi's Desktop:
Then, we downloaded and installed a VNC viewer like RealVNC on our laptop.
Then, we established a VNC connection, launched RealVNC and entered the Raspberry Pi's IP address.

8. Connected thermal sensor to Raspberry: Then we made connections of the thermal sensor with Raspberry Pi.

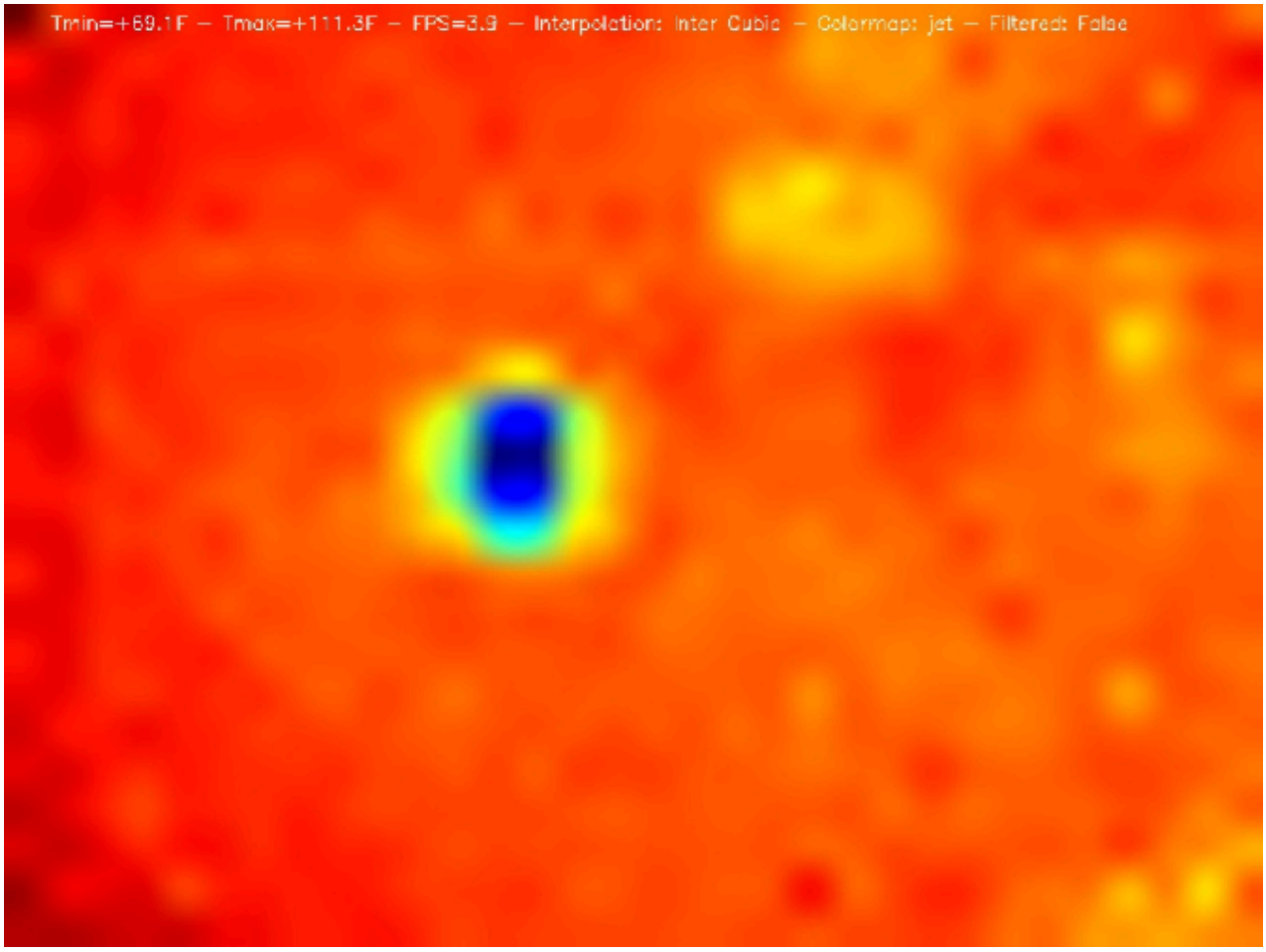
9. After that, we installed Python on Raspberry Pi and coded the connection of the thermal sensor. We even coded the part where we can generate a web server that we can open on any device connected to the same network and access the output anytime.

Results:
The following are the images produced by the thermal camera.

Pi Thermal Video



This is the test image where we can see three subjects in the frame and the thermal camera detecting their heat signature. In this picture, the colour grading we used is such that the higher temperature area is red.



This image is of a coin buried 2cm under sand in the evening, clearly showing the camera's detection capabilities and proving that the concept of detecting the mines works. The colour-grading we are using here is where the blue part shows a higher temperature area, different from the first picture. We can see that the plate is hotter than the soil. The distance between the camera and the soil surface is around 30cm.

The thermal signature of a landmine compared to the surrounding sand depends on various factors, including the time of day, the properties of the landmine materials, and environmental conditions. However, generally speaking, the landmine and the surrounding sand will have different thermal behaviours:

During Daytime Heating:

Surrounding Sand: Sand heats up relatively quickly during the day due to its low thermal inertia.

Landmine: The landmine, usually made of metal, plastic, or composite materials, might heat up more slowly. However, it can retain heat longer than the surrounding sand once it heats up.

During Night time Cooling:

Surrounding Sand: Sand cools down quickly at night because it loses heat rapidly.
Landmine: The landmine, especially with metal components, will retain heat longer and cool down more slowly than the surrounding sand.

Thermal Inertia Differences:

Landmine Materials: Metals have high thermal inertia, meaning they take longer to heat up and cool down than sand. Plastic and composite materials also have different thermal properties compared to sand.
Air Cavities: Many landmines have air cavities that affect how they absorb and release heat. These cavities can lead to different thermal behaviours compared to solid sand.

Practical Observation:

Early Morning: During early morning, the sand, having cooled down quickly overnight, will likely be more relaxed than the landmine, which might still retain some heat.
Late Evening: In the late evening, after a day of heating, the sand will cool down quickly, while the landmine might still retain more heat.

Detection Strategy:

Observing the temperature differences when the thermal contrast is most pronounced is essential to detect landmines using thermal cameras effectively. Typically, the optimal times are:
Early Morning: The landmine might be warmer than the surrounding sand.
Late Evening: The landmine might be more relaxed than the surrounding sand after a day of heating.

Summary:

Landmine vs. Sand: During periods of rapid temperature change (dawn and dusk), the landmine may exhibit a different thermal signature (either warmer or cooler) than the surrounding sand.

Optimal Detection Times: Focus on early morning and late evening for better thermal contrast.

This is the setup that we used to detect the coin under sand.