INTERNSHIP PRESENTATION

Fire Identification in Coal Mines Using Thermal Imaging and Drones

Guided by

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INTRODUCTION

- Spontaneous coal oxidation can cause fires, risking lives, infrastructure, and the environment.
- Traditional sensors detect fires only after ignition, delaying response.
- This project aims at using drone-mounted thermal cameras for early fire risk detection and real-time alerts.

OBJECTIVE

- To identify fires before they occur in a coal power plant by detecting hotspots present there.
- To map the area into a grid comprising of thermal images for determining the possible areas where fire could be ignited.

MOTIVATION

- Coal can easily catch fire when exposed to air and heat, as seen in India's Jharia coalfield, which has been burning for over a century due to underground coal seam fires triggered by mining activities.

Fig 1. Jharia coalfield [1]

PROBLEM STATEMENT

- Coal fields are highly susceptible to spontaneous combustion due to the oxidation of coal, leading to sudden fires that endanger human lives, damage equipment, and cause environmental harm. Traditional fire detection systems often detect fires only after ignition, making timely prevention nearly impossible. There is a critical need for an advanced, real-time monitoring system that can detect early signs of combustion to prevent fire outbreaks in coal mining operations.

PROPOSED METHODOLOGY

- System Integration:
  Connect a thermal camera to raspberry pi 5 for real-time thermal imaging and data collection.

- Data Processing & Communication:
  Create a log file from the snapshots taken, which has the image number and its temperature.
  Analyze collected thermal data to distinguish between normal and hazardous heat patterns. Transmit data to a central monitoring station for risk assessment.

SYSTEM ARCHITECTURE

steag

Topdon TC001 camera

raspberry pi 5

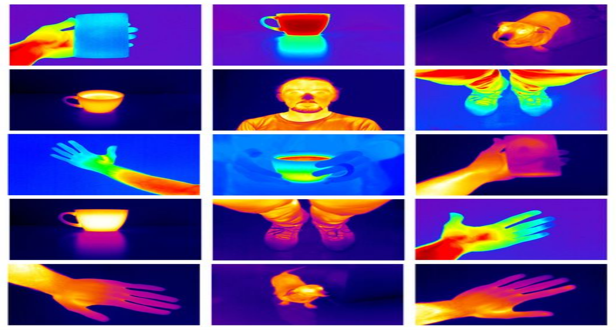
Program that takes raw feed from camera every 5 seconds

Thermal image

Processing

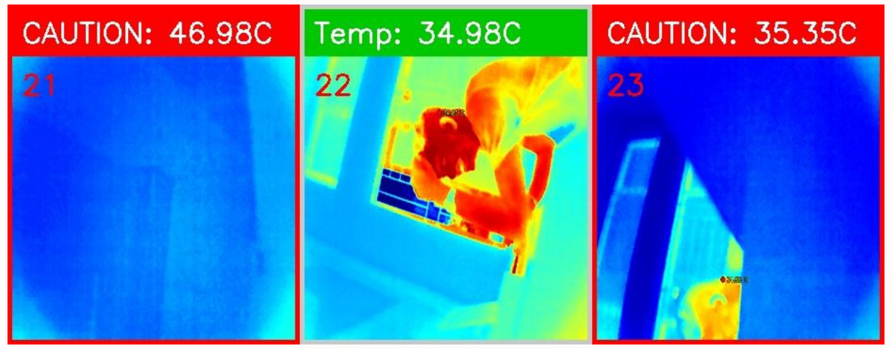
OpenCV

Combining the image to form a grid



Processing

highlights the image with temperature above set threshold



WEEK WISE WORK DONE

WEEK 1: (07/01/25)

Had a discussion session with the supervisors at STEAG, got an overview of the project and how to segment it into different phases.

Researched about thermal sensors in google, some of the ones we looked into are:

1. **MLX90614** ESF Non-Contact Human Body Infrared Temperature Measurement Module
2. **MLX90641** IR array thermal

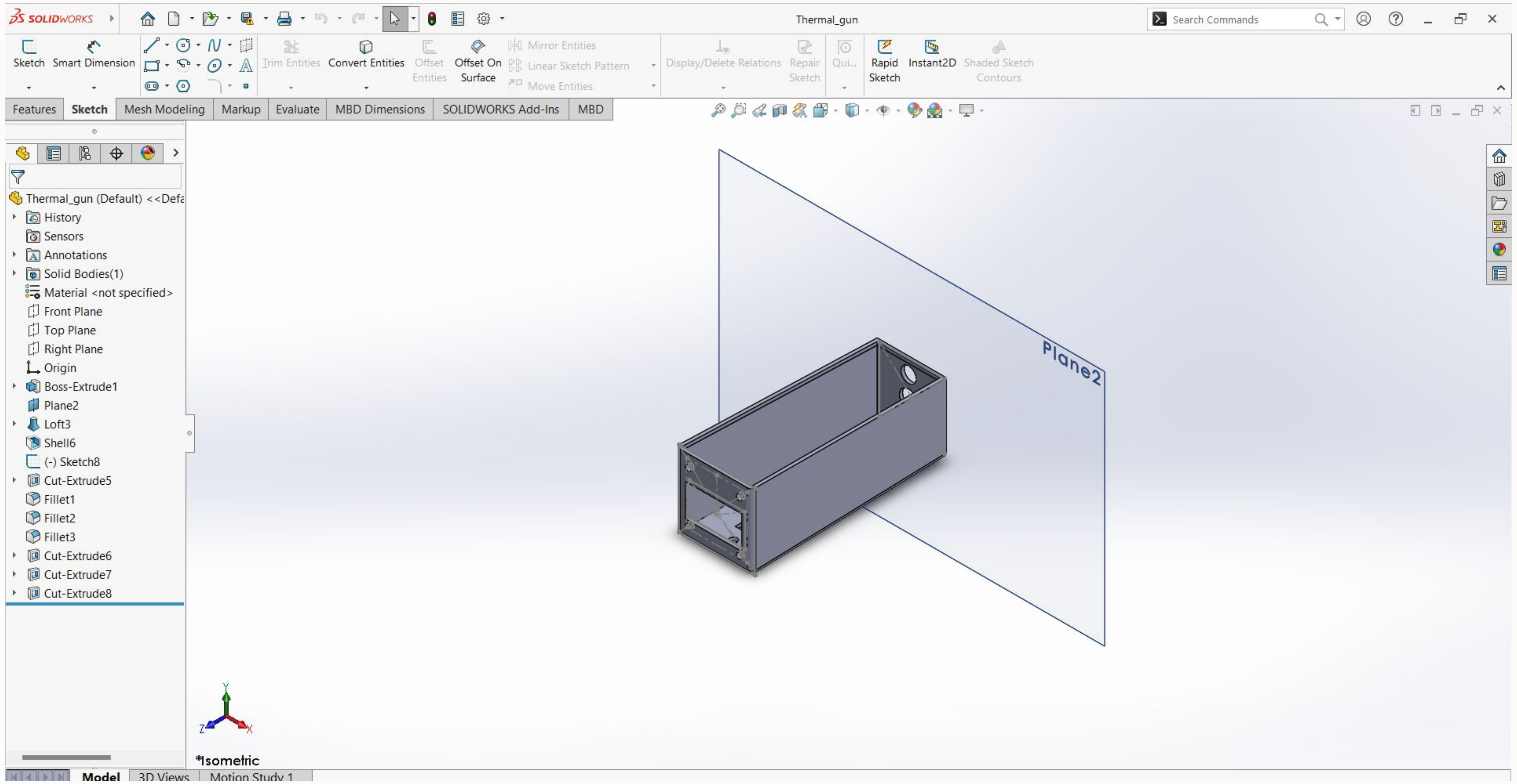
Also considered using the sensor from the widely available forehead temperature gun, which was later found to be **MLX90614**

WEEK WISE WORK DONE

WEEK 2: (13/01/25)

AIM: To use an infrared sensor to find the temperature of an area/object 1-3 cm away from it.

CAD MODEL OF TOP PORTION OF THERMAL GUN

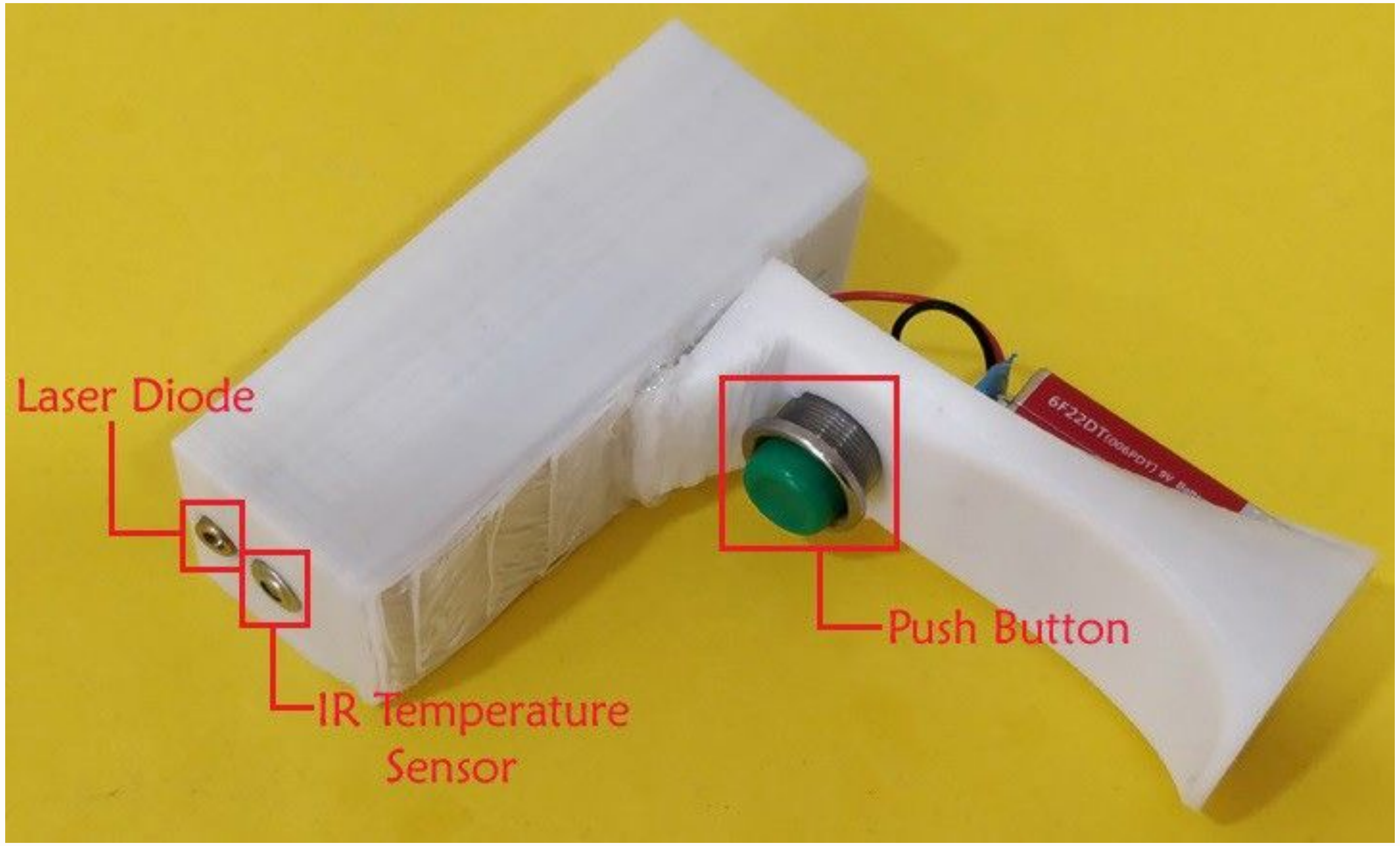


WEEK WISE WORK DONE

WEEK 2: (13/01/25)

3D PRINTED PART

EXPECTED OUTCOME

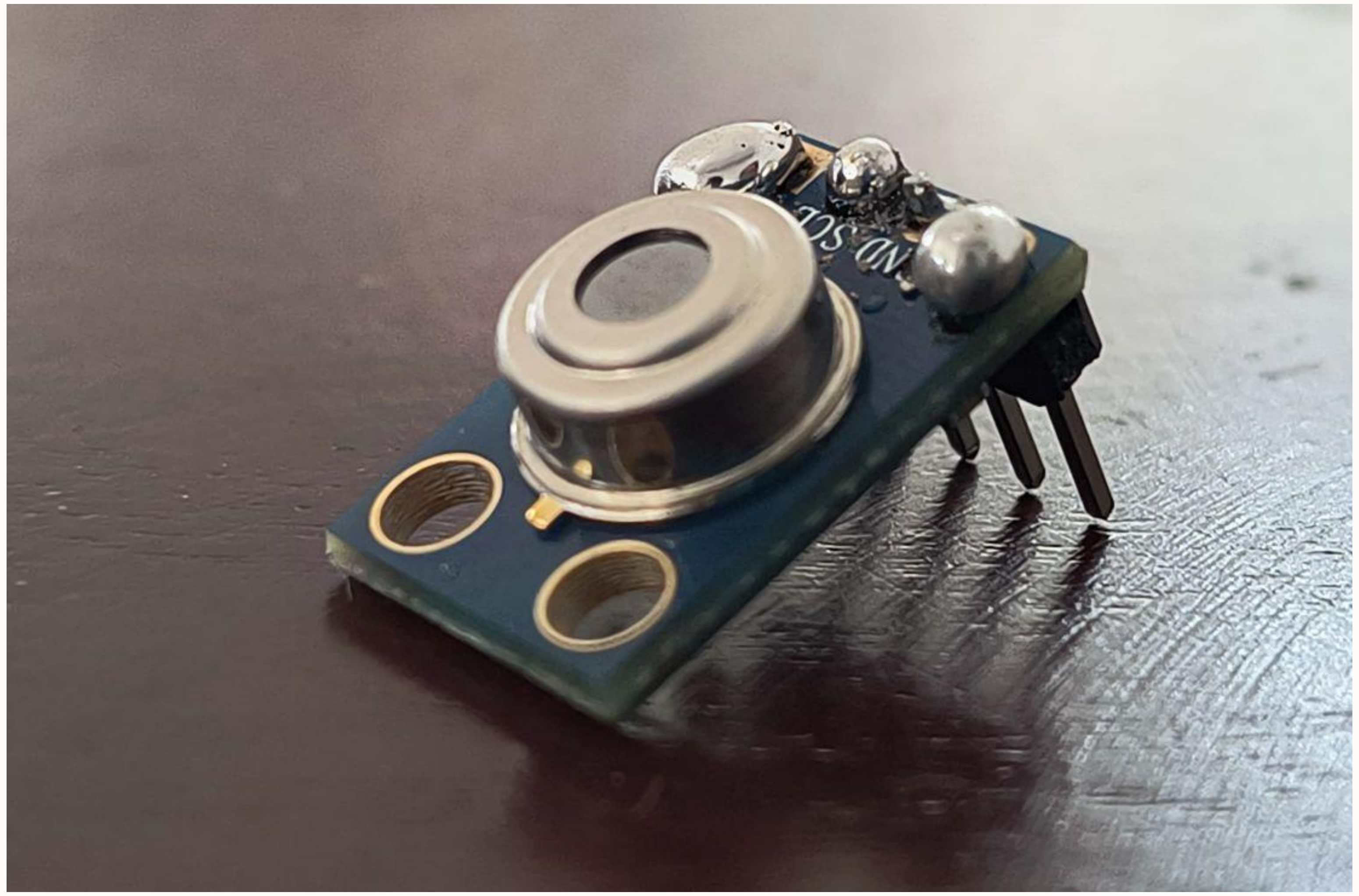


WEEK WISE WORK DONE

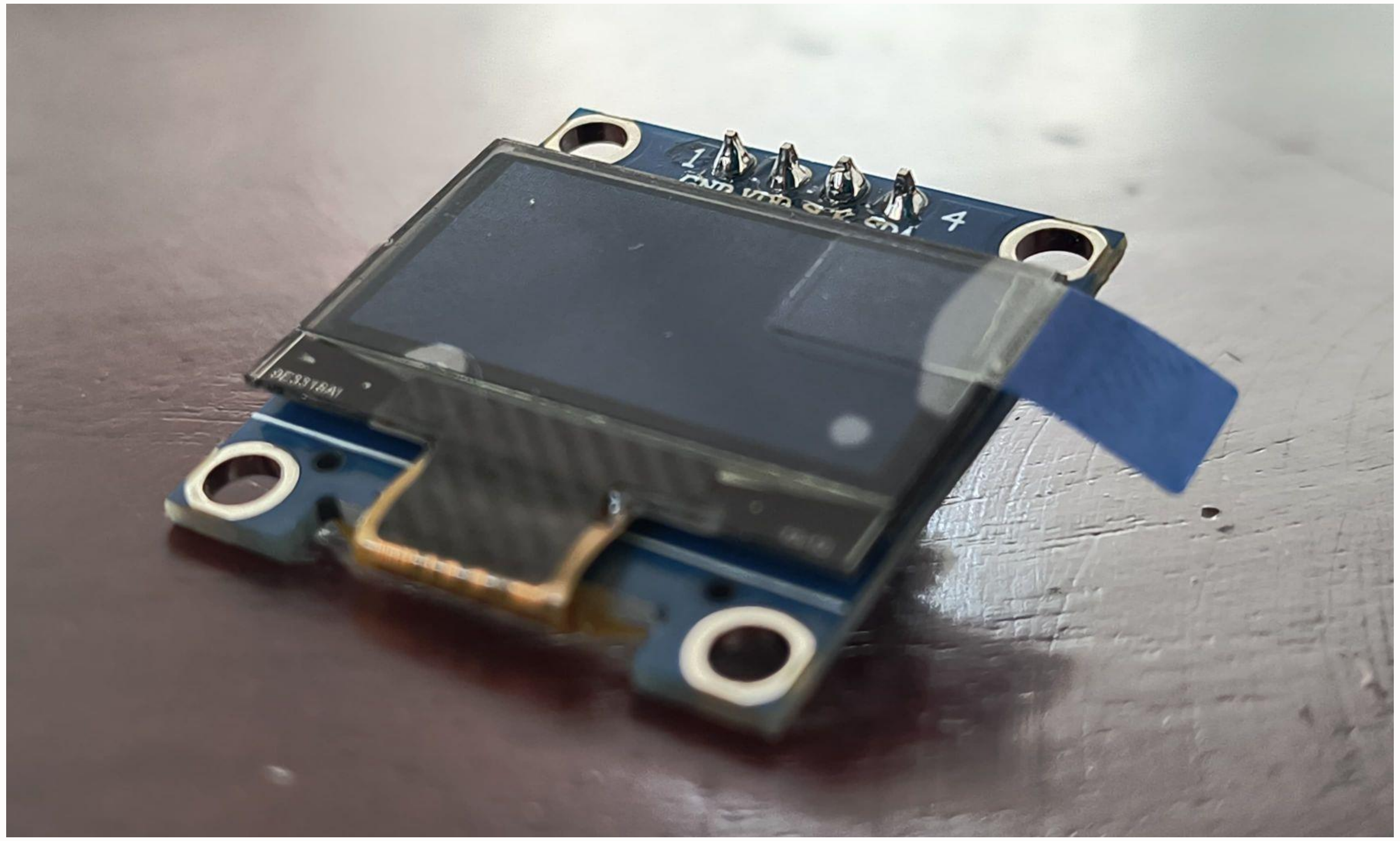
WEEK 3: (24/01/25)

AIM: Testing the sensor and uploading the code to arduino nano.

TEMPERATURE SENSOR: MLX90614



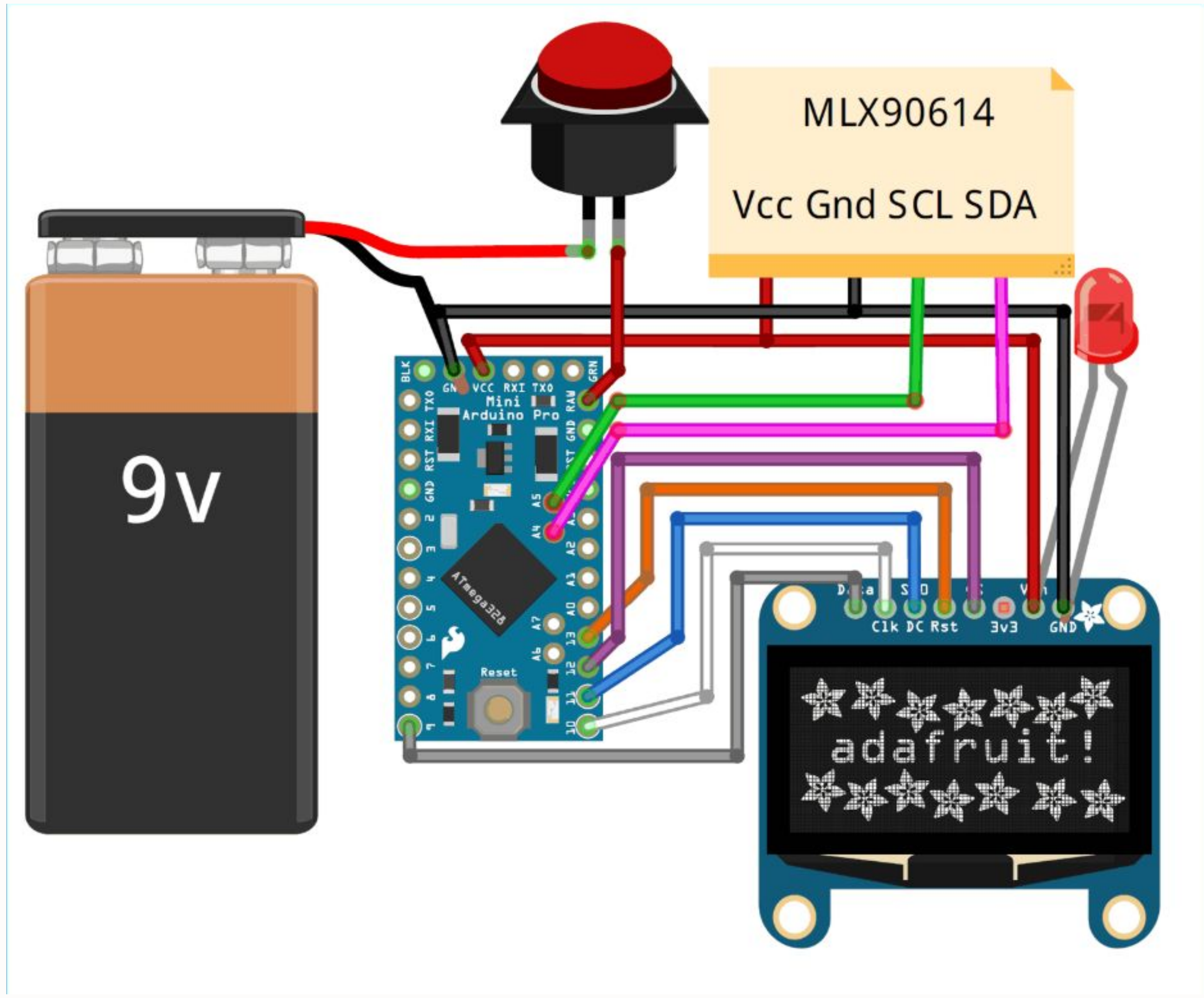
OLED DISPLAY: SSD1306



WEEK WISE WORK DONE

WEEK 3: (24/01/25)

CIRCUIT DIAGRAM:



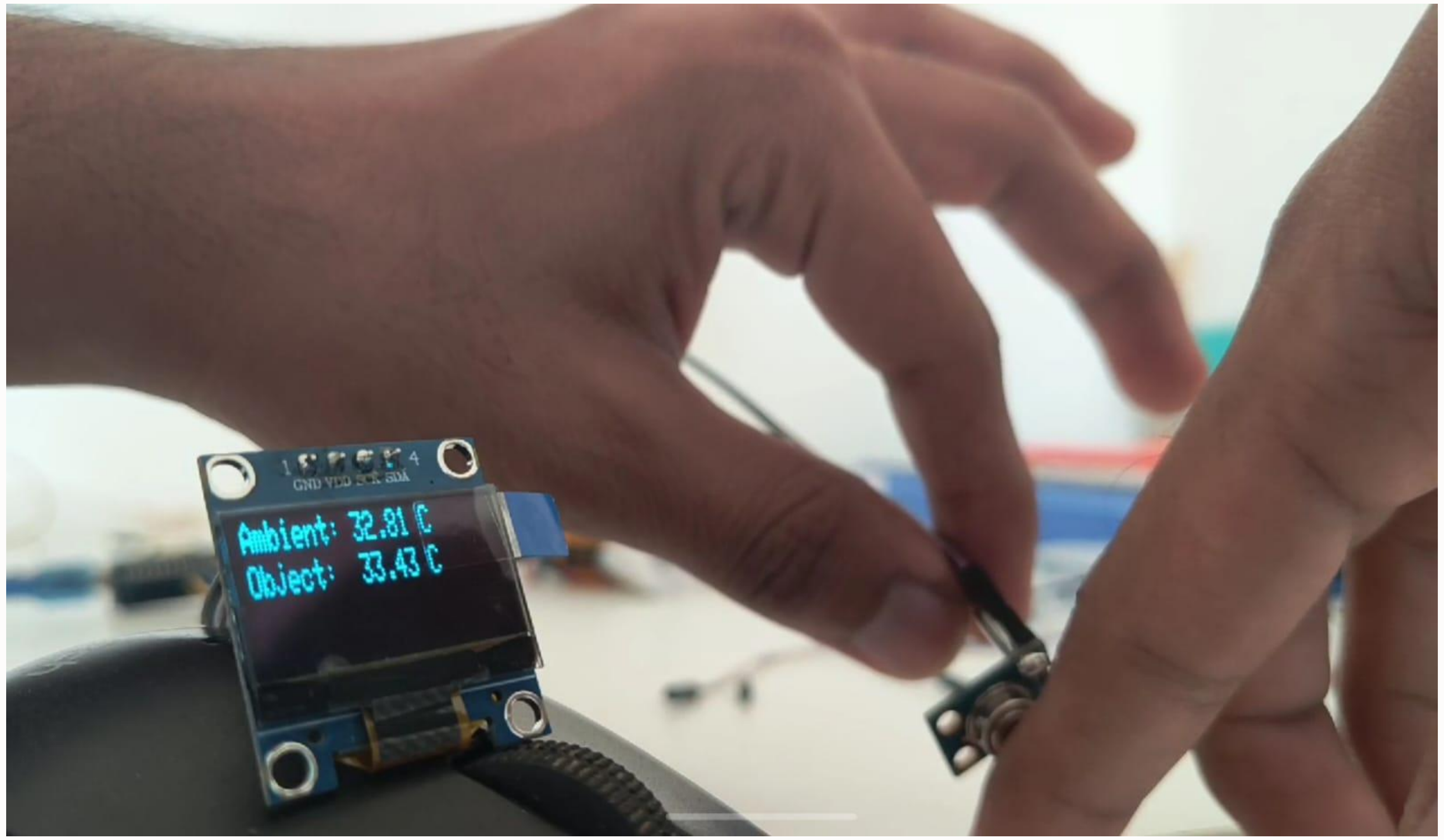
3D PRINTED BOTTOM PART OF GUN:

WEEK WISE WORK DONE

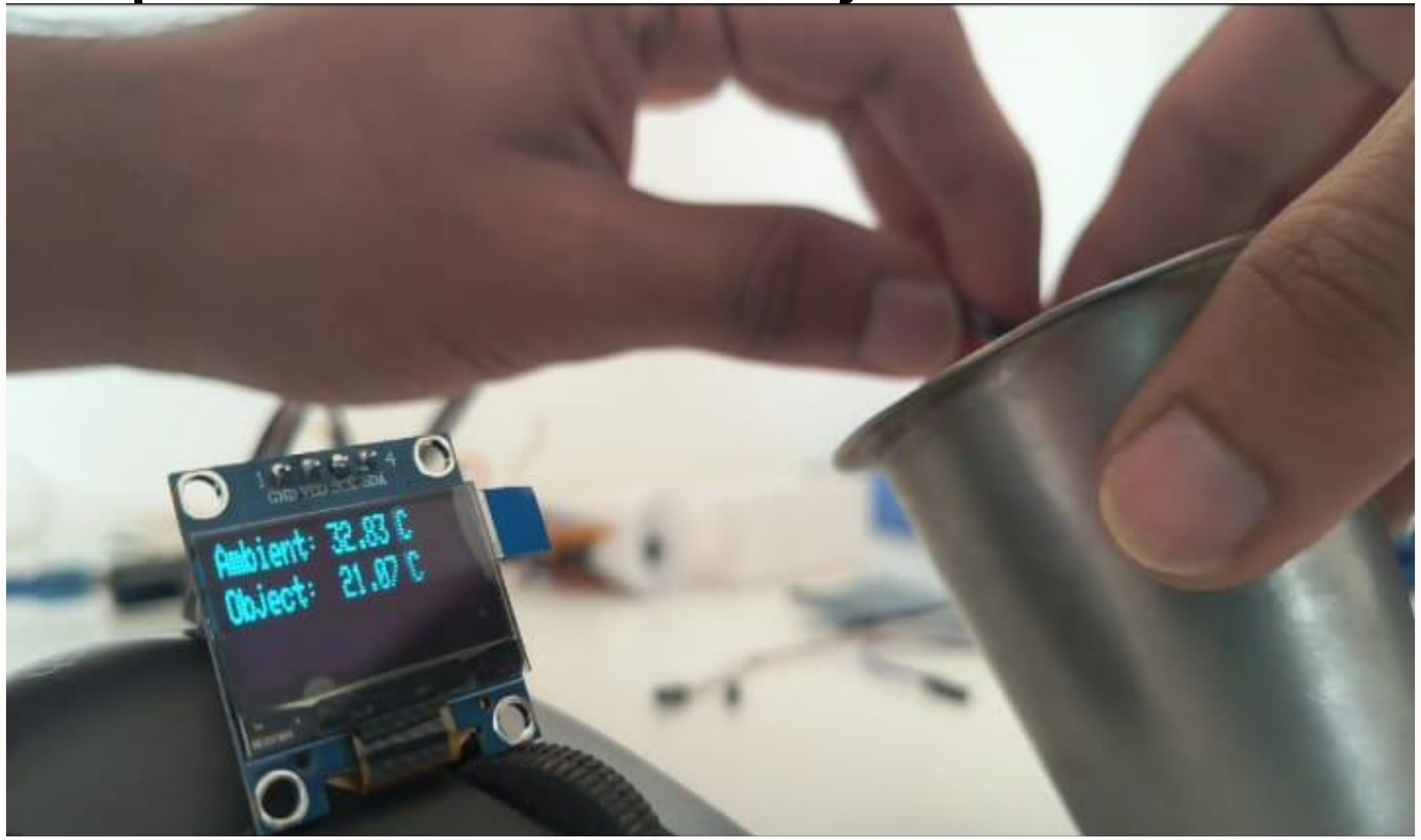
WEEK 3: (24/01/25)

VIDEO FOOTAGE OF TESTING THE TEMPERATURE SENSOR

Temperature sensed : Hot Object



Temperature sensed: Cold Object



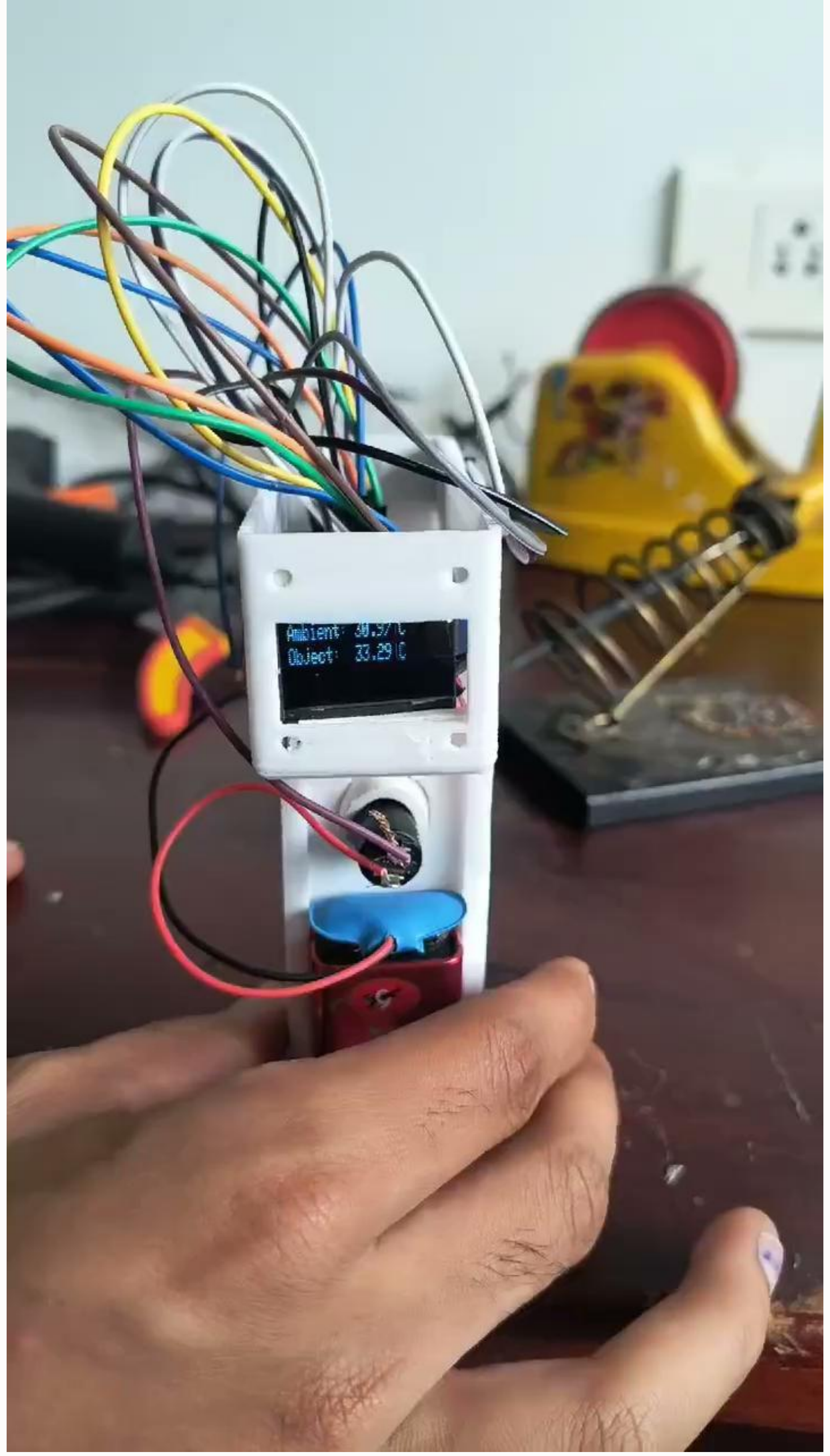
WEEK WISE WORK DONE

WEEK 4: (29/01/25)

AIM: Complete assembly of the thermal gun

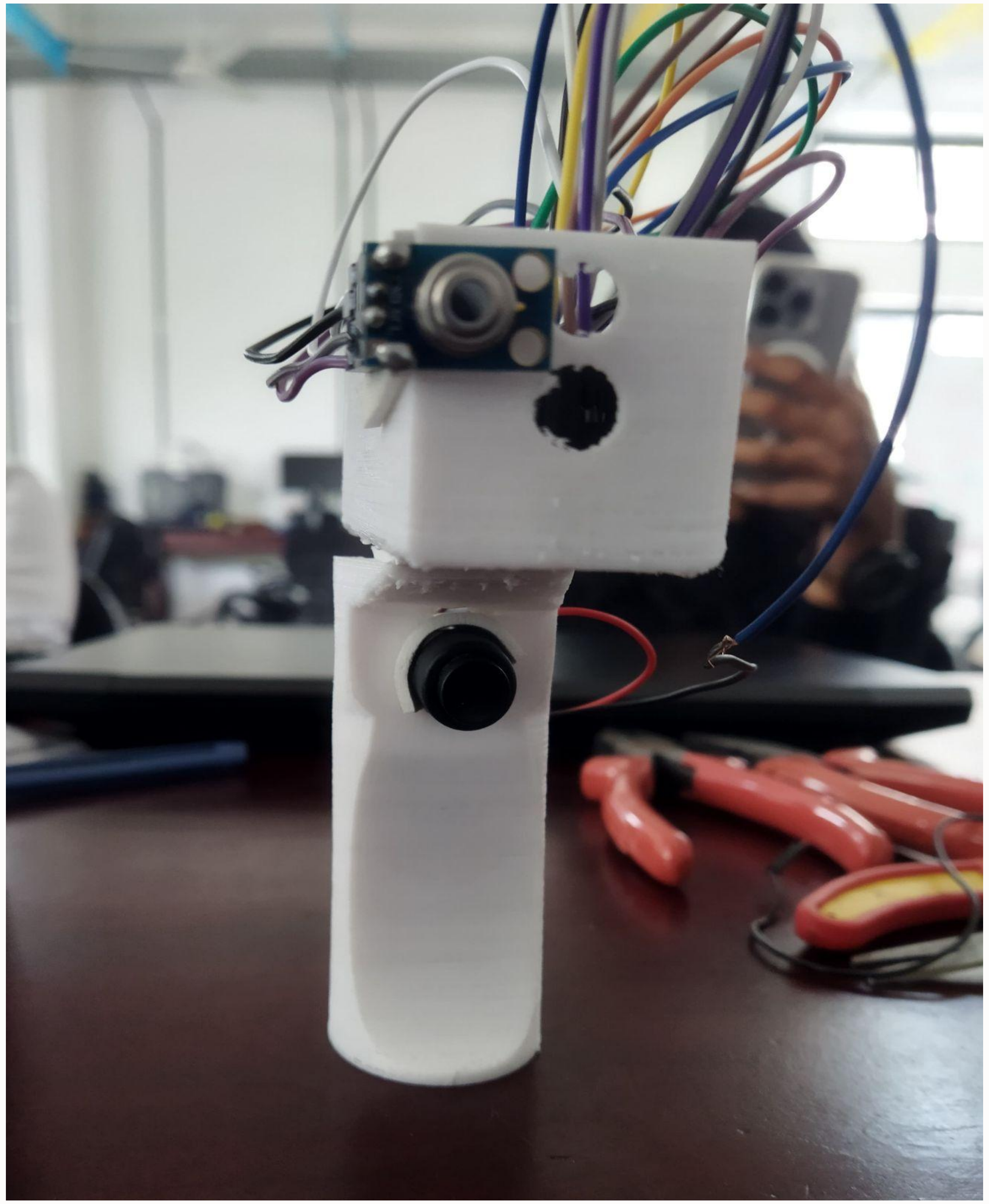
VIDEO OF THE WORKING APPARATUS

- The sensor detects the temperature and data is sent to the arduino nano, which is displayed by the OLED display. The battery powers up the apparatus and there’s a switch to on and off the working of the apparatus.



WEEK WISE WORK DONE

WEEK 4: (29/01/25)



WEEK WISE WORK DONE

WEEK 5: (07/02/25)

- Using Neo 7M (GPS Module) to get absolute position value.

- Using MPU6050 (IMU), an accelerometer measures linear acceleration which can be integrated over time to estimate displacement and the gyroscope tracks rotation which gives us the orientation of that displacement. We can use that data to estimate movement in space and plot a map.

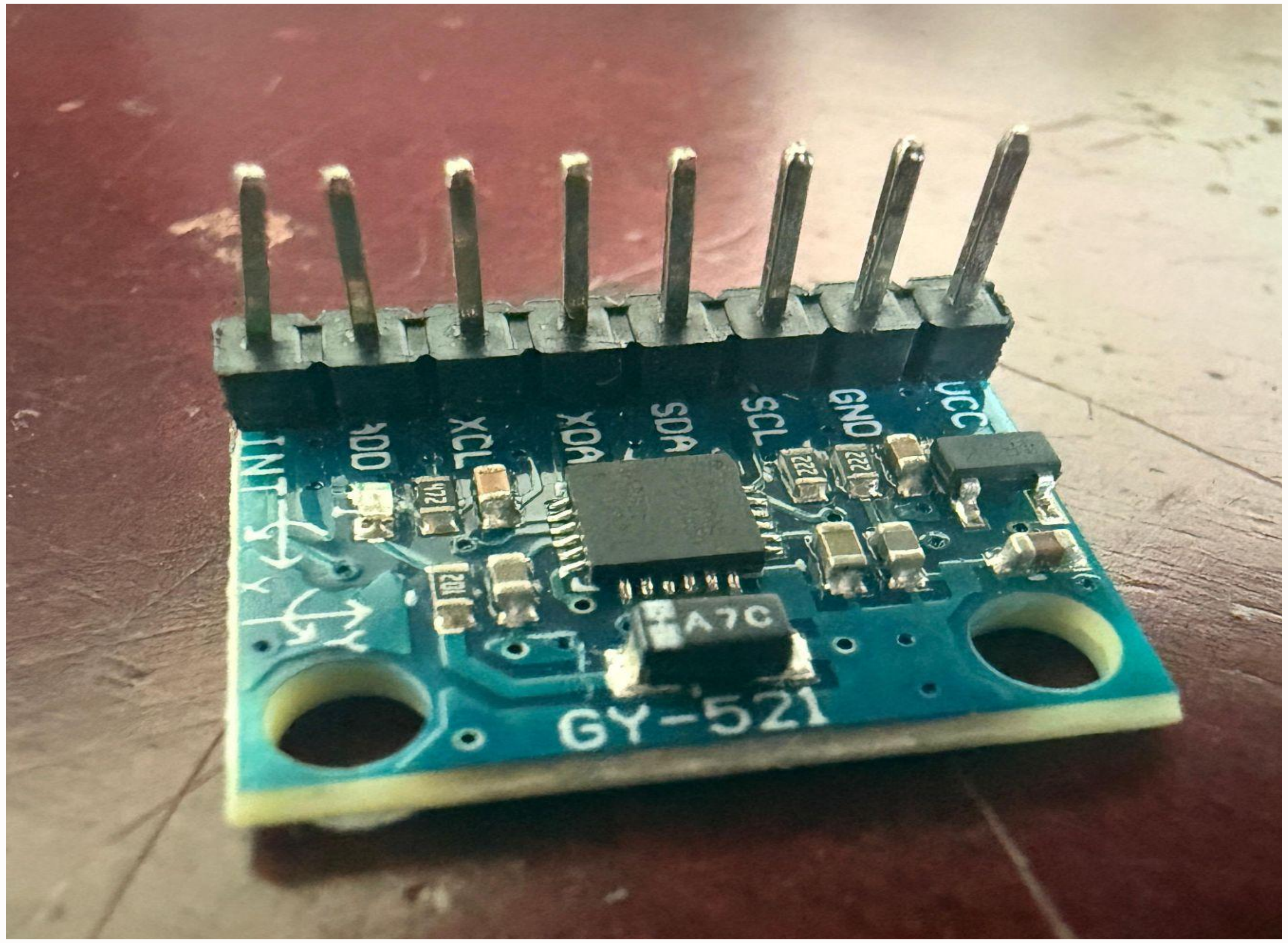
- Learn about final thermal sensor to be used -TOPDON TC001 256x192 IR High Resolution, Thermal Imaging Camera

WEEK WISE WORK DONE

WEEK 6: (14/02/25)

AIM: To experiment with the MPU6050 to track movement in space and visualize the displacement over time.

MPU6050:



WEEK WISE WORK DONE

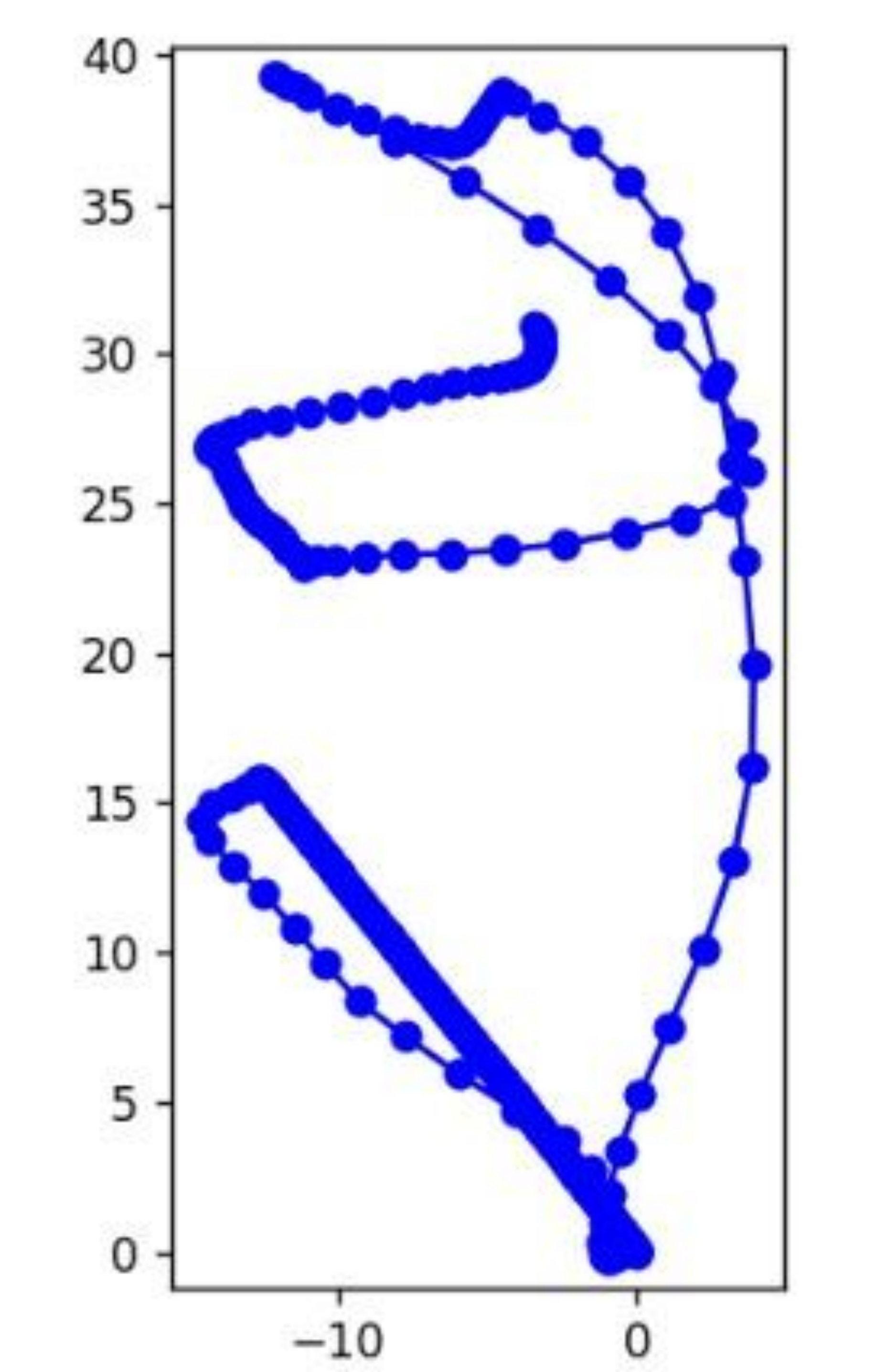
WEEK 6: (14/02/25)

We attempted to use IMU data to plot movement from an initial position. However, several issues emerged:

- Even the smallest inaccuracies in acceleration readings led to exponential errors when computing displacement.
- The plotted path was unreliable due to sensor noise, leading to deviations that got added over time.
- Since the IMU provides relative measurements, any bias in the sensor readings can cause significant deviations from the actual movement.

Hence the graph plotting ended up being inaccurate.

This is one of the graphs that we came up with:



WEEK WISE WORK DONE

WEEK 7: (19/02/25)

AIM: To explore TOPDON TC001 thermal imaging camera and retry graphing.

A little about the camera:

The TOPDON TC001 is a compact thermal imaging camera which is compatible with Android and Windows PCs using USB-C connection (cable comes along with the camera).

WEEK WISE WORK DONE

WEEK 7: (19/02/25)

Prior to using the device, we had to download an app which was mentioned in the user manual called TCView/TC001:

Developed for TC001.

Download, connect, hassle-free. Quickly start your device with TOPDON's ultra-intuitive and friendly interfaces.

We explored many of its functionalities, and some of them are shown here:

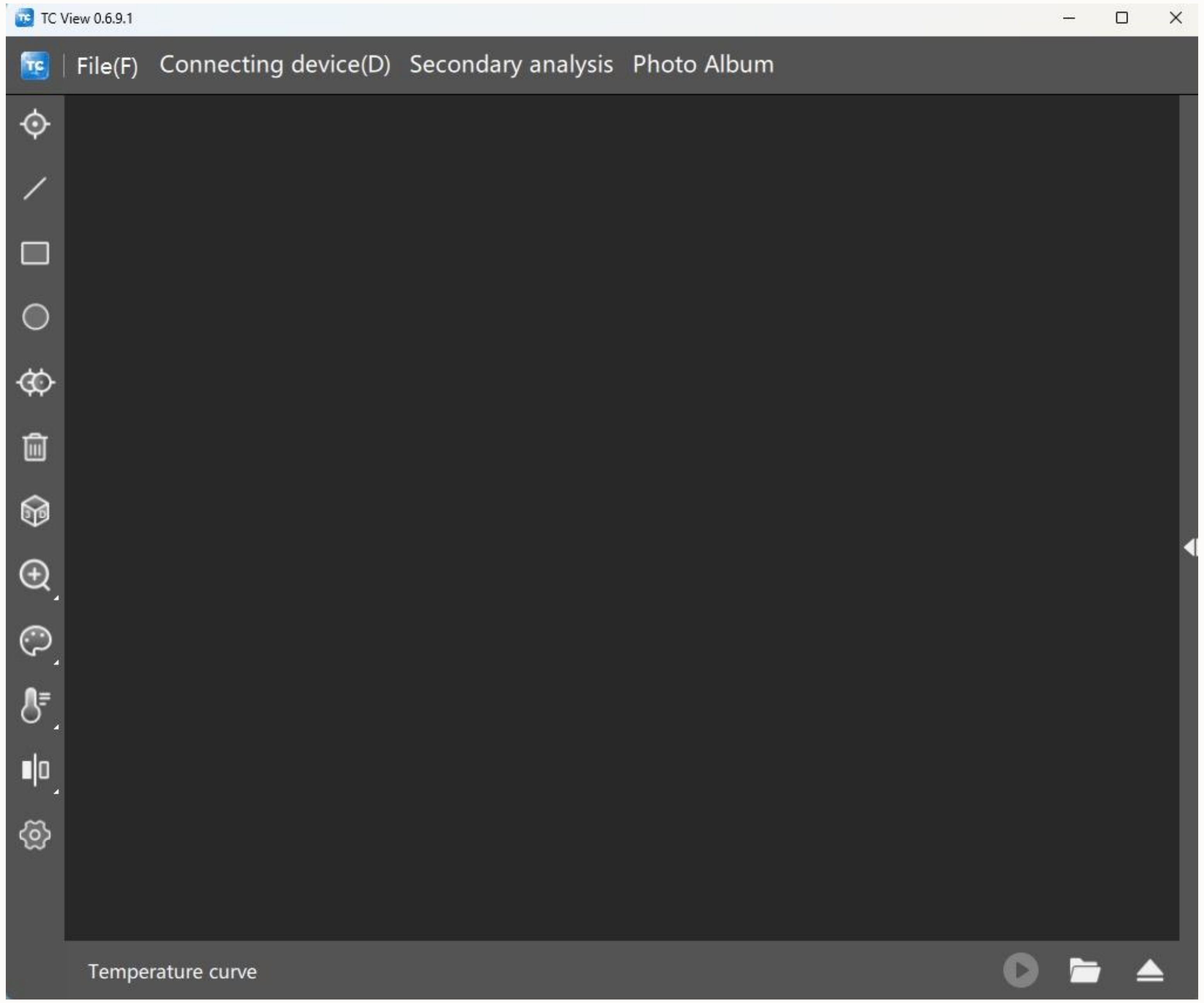
WEEK WISE WORK DONE

WEEK 7: (19/02/25)

We have to connect the device to the PC. Since we were using our laptops, we connected the camera to the PC using the USB-C connection cable which came along with the packaging. Then we had to choose the device connection in the app as well.

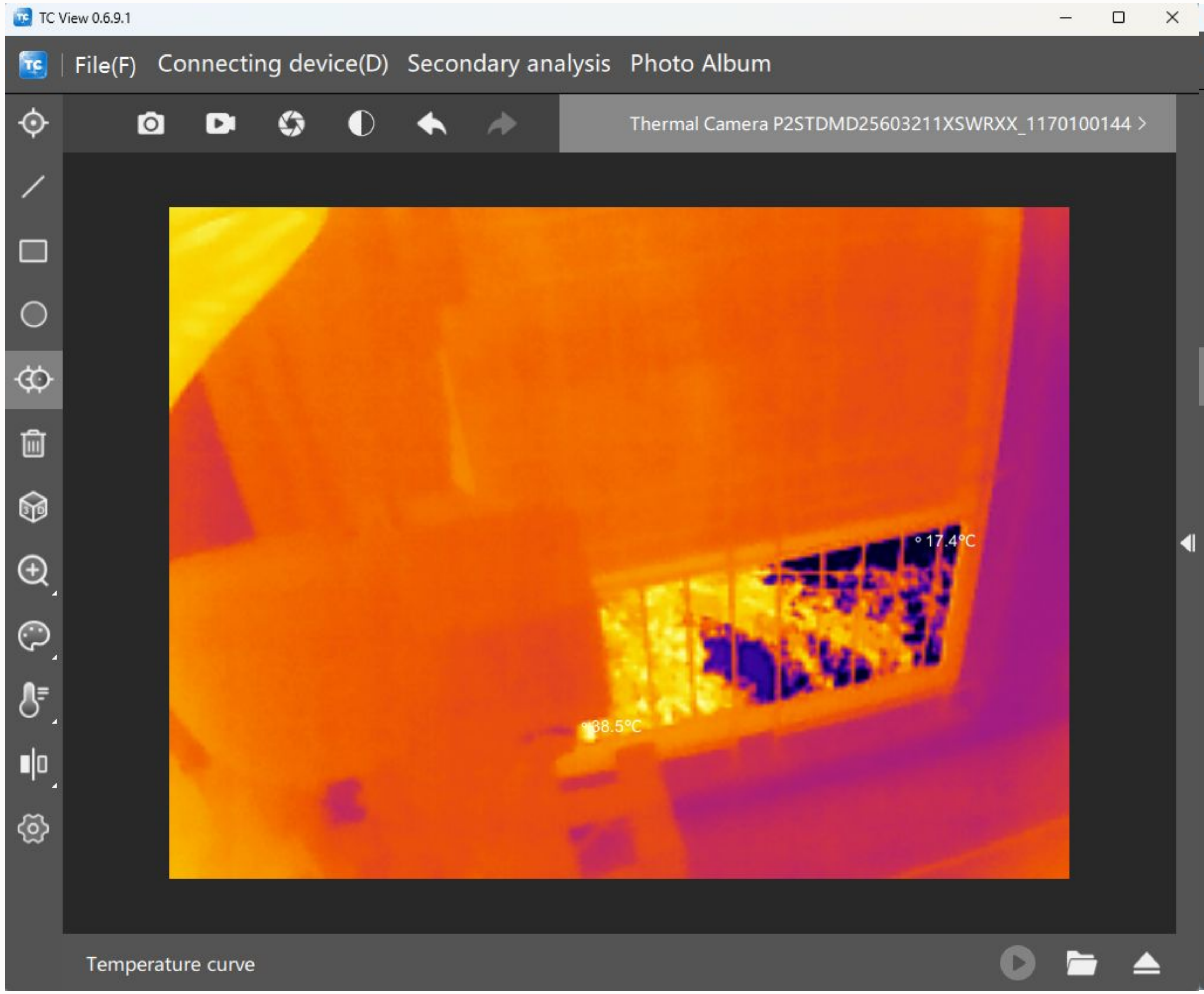
Following this, after that we have to click on “connecting device” and choose the thermal camera to connect.

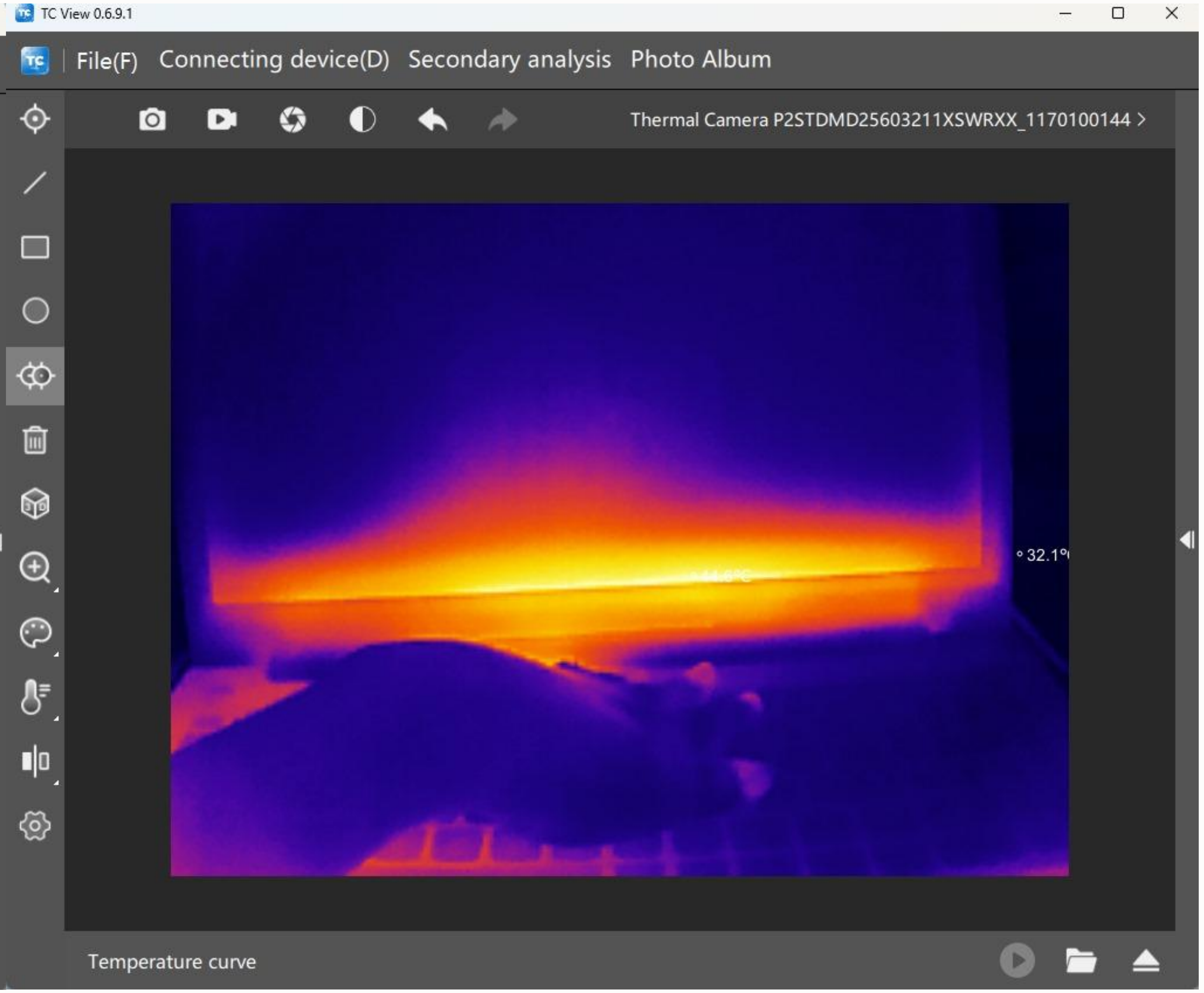
Then the thermal imaging begins.



WEEK WISE WORK DONE

WEEK 7: (19/02/25)





This is the thermal image which was captured by the camera. The temperature is mentioned in celsius by default.

WEEK WISE WORK DONE

WEEK 7: (19/02/25)

REPEATED ATTEMPT ON GRAPHS:

- Tested a GPS module to enhance motion tracking accuracy using it's reliable initial position data.
- Addressed drift errors in IMU-based tracking by introducing thresholds to filter out minor fluctuations and reduce integration errors.
- Despite these efforts, significant inaccuracies persisted, and graphical outputs failed to produce meaningful results.

WEEK WISE WORK DONE

WEEK 8: (06/03/25)

- Forked and refactored version of Les Wright's PyThermalCam script.
  Designed for TS001 thermal sensor on Windows 11 using Python 3.12.4 and OpenCV.
  Developed as an open-source contribution by an undergraduate student.
  Aimed to resolve compatibility issues present in the original script.

- We attempted to use this version but faced data inaccuracies, likely due to unresolved Windows-specific issues.

WEEK WISE WORK DONE

WEEK 8: (06/03/25)

- Faced multiple issues with the Windows version of PyThermalCamera.

- Explored migrating to Linux for better hardware and library compatibility.

- Began developing a custom Python script to:

  Capture raw thermal data from the sensor.

  Generate heat maps from the data.

  Stitch multiple frames into comprehensive visualizations.

- This approach aimed to create a simpler and more effective thermal imaging workflow.

WEEK WISE WORK DONE

WEEK 9: (13/03/25)

- Faced repeated issues on Windows, explored Linux migration for better support.
- Considered to fallback to manufacturer's app (TC001 Viewer).
- Developed a streamlined Python script to capture raw thermal data and process it into heat maps. It also helped us to stitch frames into comprehensive visulizations
- This new approach offers a simpler and more efficient solution for handling thermal imaging data.

WEEK WISE WORK DONE

WEEK 10: (19/03/25)

- After running the PyThermalCamera script on Linux, it connected to the camera successfully.
- But the temperature readings were wrong because the values looked unrealistic.
- We checked the part of the code that converts sensor data into temperature.
- By trying different calibration values, we improved the results.
- The output was more stable and closer to real temperatures, but not perfect.
- We realized that we need more accurate calibration, maybe using known heat sources to compare.

WEEK WISE WORK DONE

WEEK 11: (04/04/25)

- By trial and error, we improved the results.
- The output was more stable and closer to real temperatures, but not perfect.
- Got the most realistic result on Linux, but more tuning is still needed for perfect results.
- Realised maybe the value error is due to compatibility or software, so we decided to go all in on Linux.

WEEK WISE WORK DONE

WEEK 12: (11/04/25)

- Re-tested original code and found it gave accurate & consistent thermal readings.
- Added an automated snapshot feature to capture frames at regular intervals.
- Each snapshot is analyzed to log the maximum temperature in a structured log file.
- Implemented a grid layout stitching tool to display snapshots as a visual heat map.
- These updates support easier monitoring, analysis, and visualization of thermal data.

WEEK WISE WORK DONE

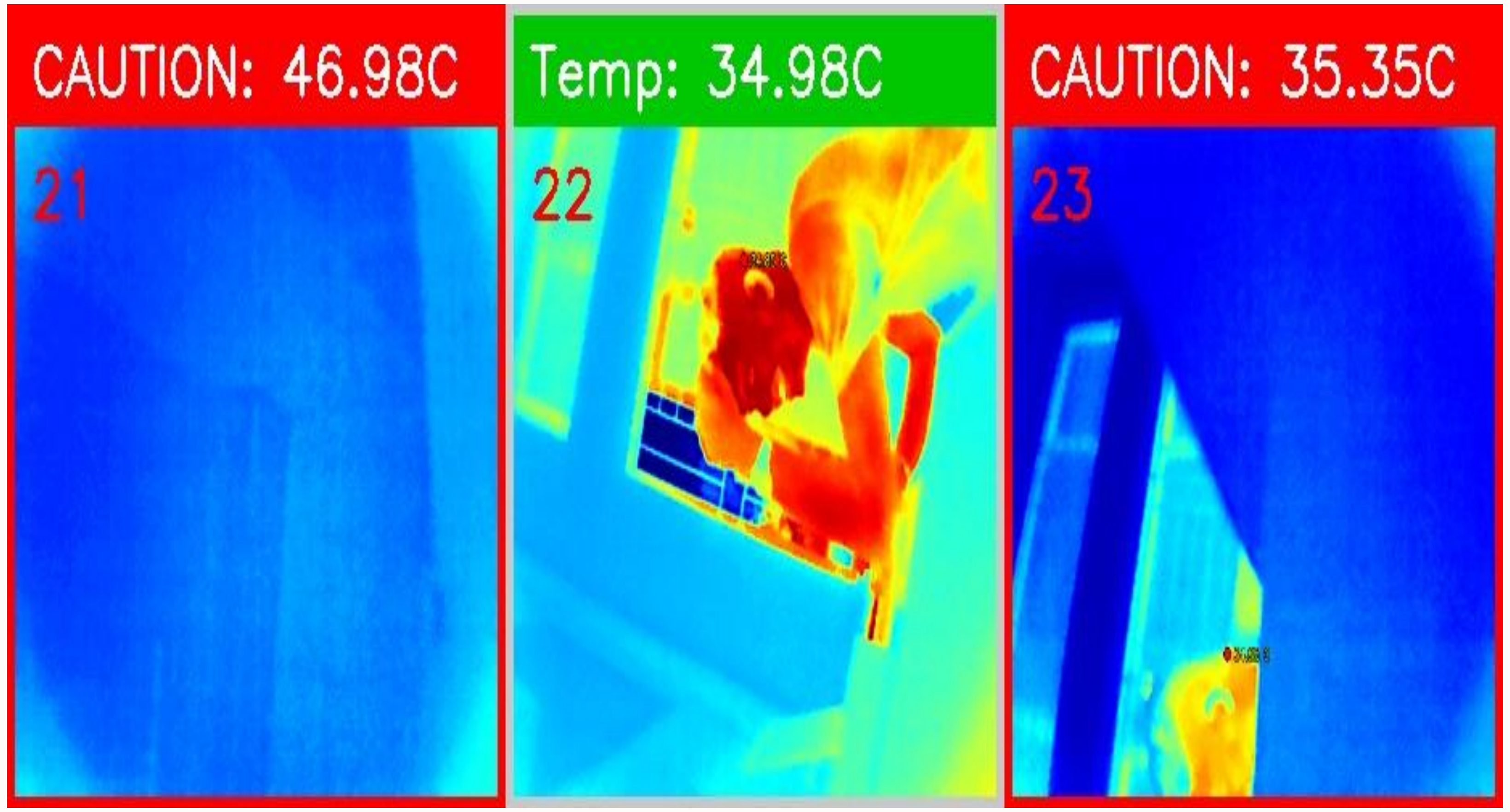
WEEK 13: (15/04/25-16/04/25)

- Polished the original code
- Made the entire process wireless by using Raspberry pi and VNC viewer
- Tried working on drone

EXPERIMENTS AND RESULTS

- Thermal images with their respective max temperature values are stitched into a grid to form a thermal map.

- Frame having a temperature exceeding the limit set is highlighted.



CONCLUSION

- Spontaneous combustion in coal mines is a major concern, causing fires that risk lives, equipment, and the environment.
- Current detection systems are slow, as they rely on smoke or gas sensors that activate only after a fire has started.
- Our drone-based thermal sensing system offers a proactive solution, that is a mapping system which shows an image in the grid with a temperature greater than threshold.

REFERENCES

1. https://www.cnbc.com/2015/12/02/indias-jharia-coal-field-has-been-burning-for-100-years.html
2. https://github.com/m-riley04/PyThermalCamera-Windows
3. https://www.eevblog.com/forum/thermal-imaging/infiray-and-their-p2-pro-discussion/msg5787923/#msg5787923
4. https://github.com/leswright1977/PyThermalCamera

THANK YOU!