RP TU Rheinland-Pfälzische Technische Universität Kaiserslautern Landau

Task 02: Analysis of Temperature Distribution within a Printed Wall

Yating Wei
Hakim Dalim
Yahya Badine

Agenda

Task	Subtask	
Camera Mount Design	Design Description	H hakimdalim
	Thermal Camera Calibration	YaHya BaDine
	Camera Setup Procedure	YaHya BaDine
Temperature Measurement		
	Printing Speed Affect the Temperature Distribution	H hakimdalim
	Temperature Difference on Printing Wall Size	H hakimdalim
Simulation	Simulation Model and Method	W Wei
	Printing Speed on Temperature Distribution	W Wei
	Results and Analysis	W Wei

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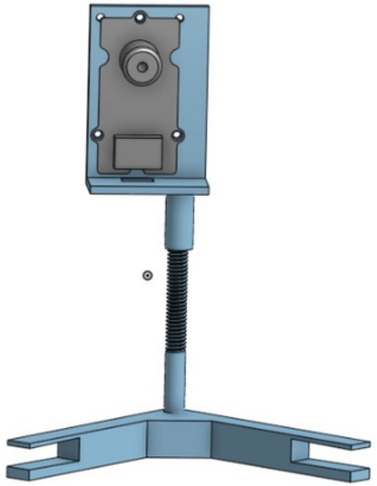
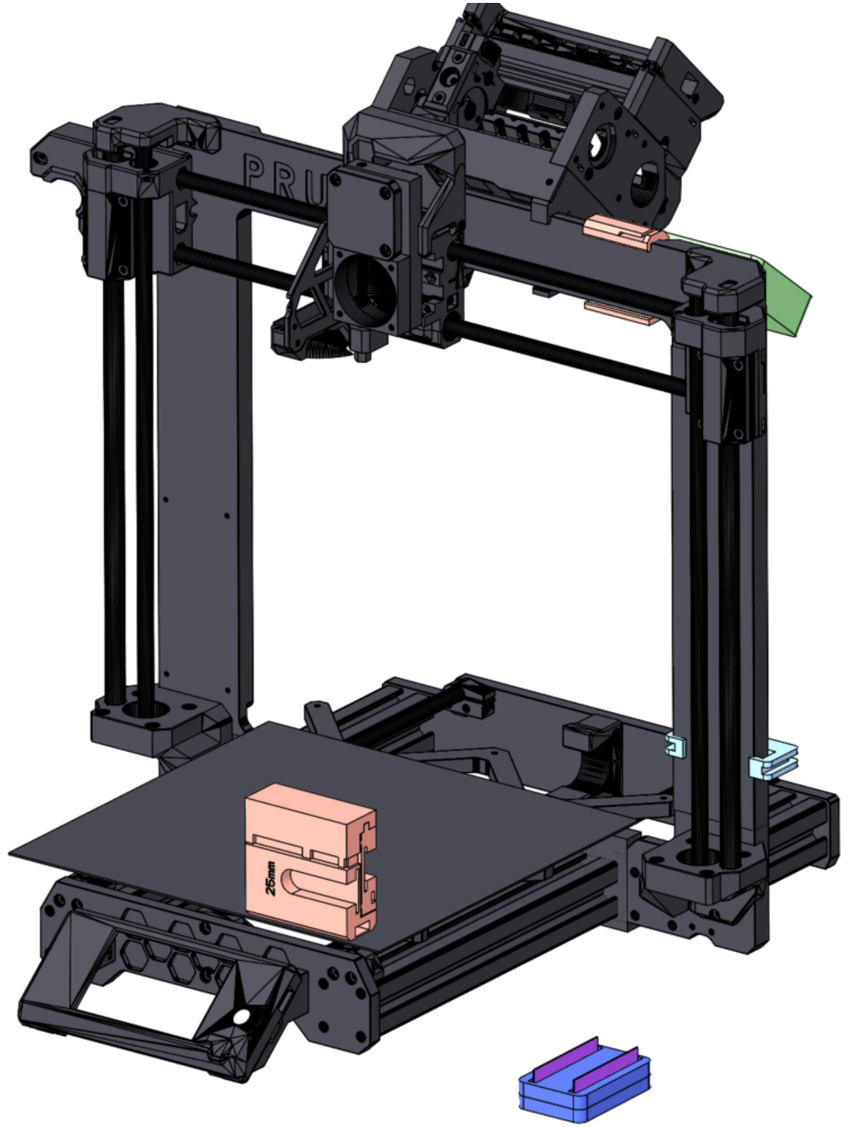
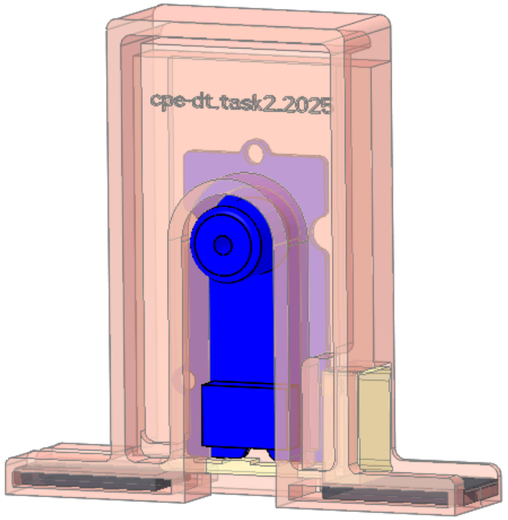
Camera Mount Design

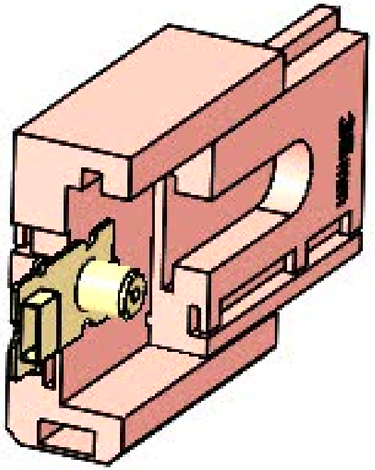
- Requirements and Constraints
  - Easy attachment and detachment
  - Full field of view
  - Stable

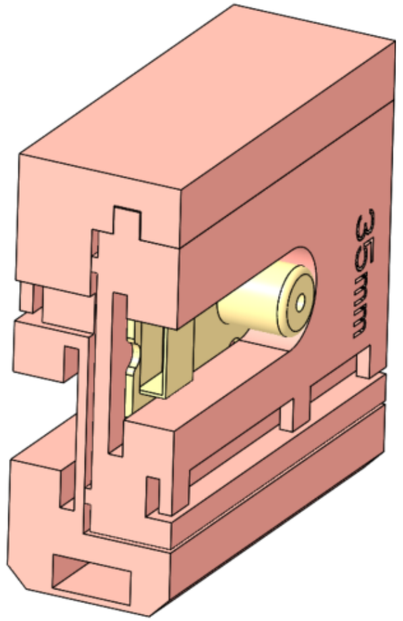


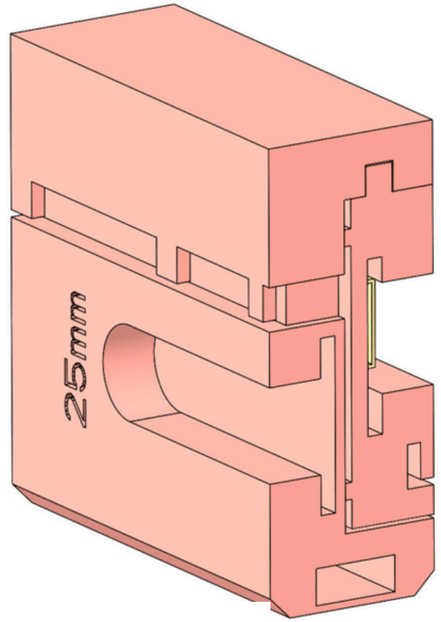


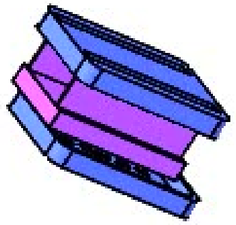
Camera Mount Design: ESP32 Wroom



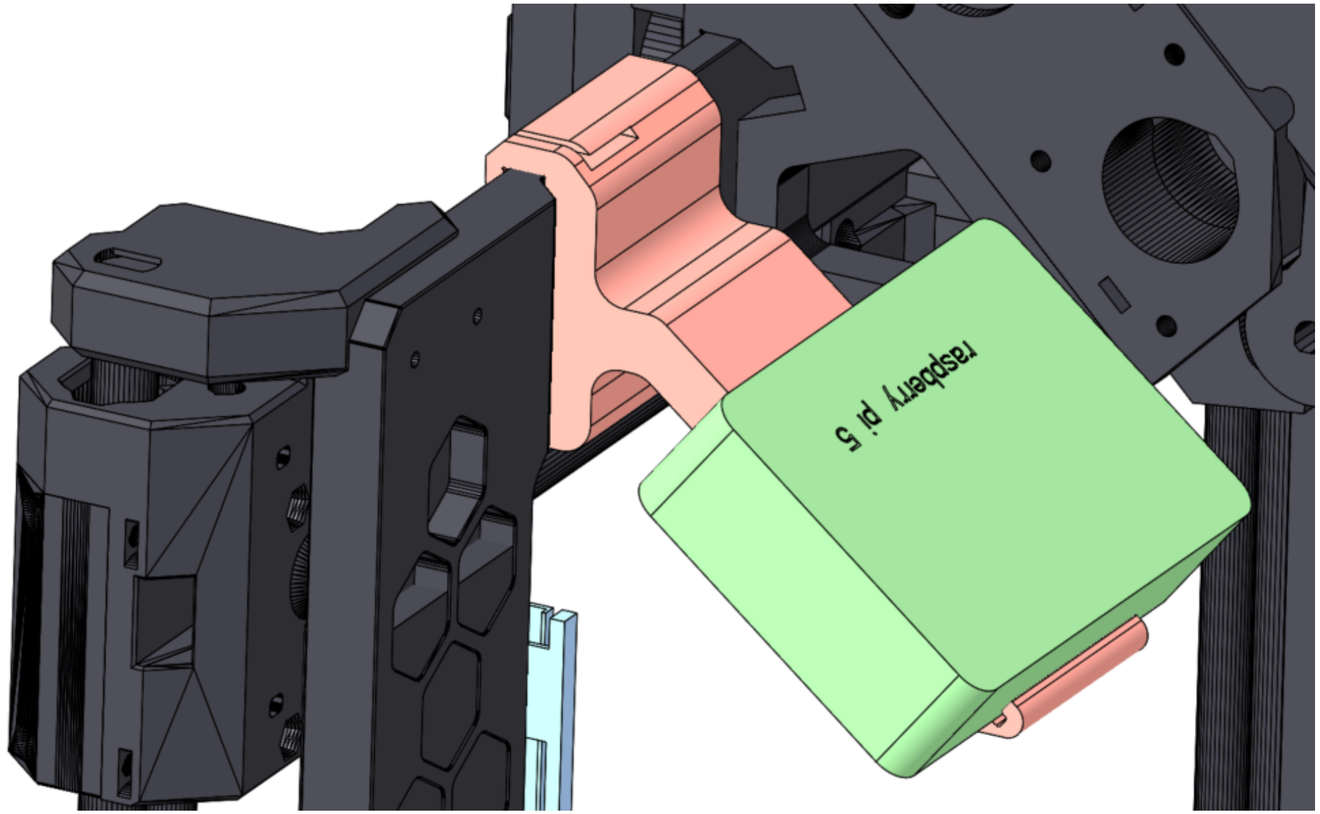


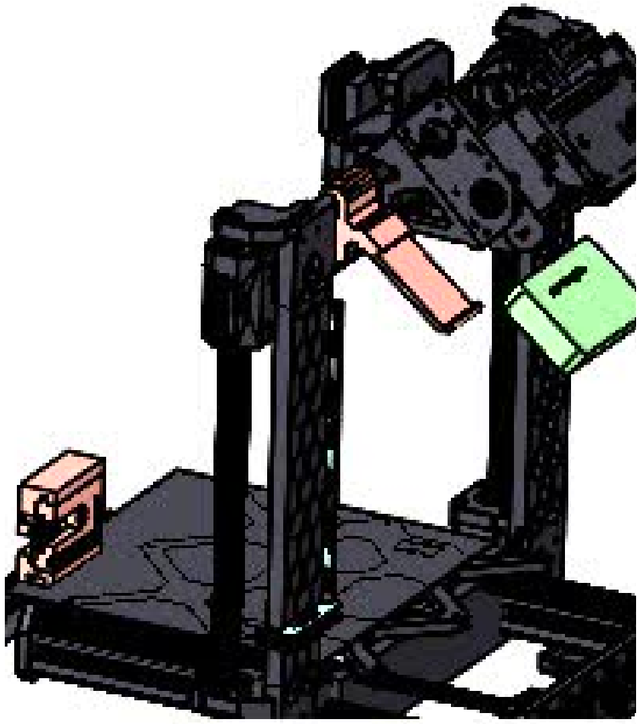






Camera Mount Design: Raspberry Pi 5





[2] PRUSA M4 printer

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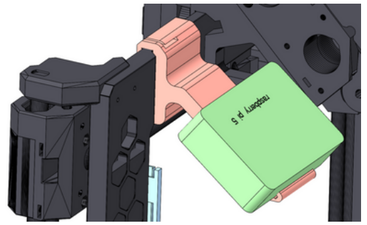

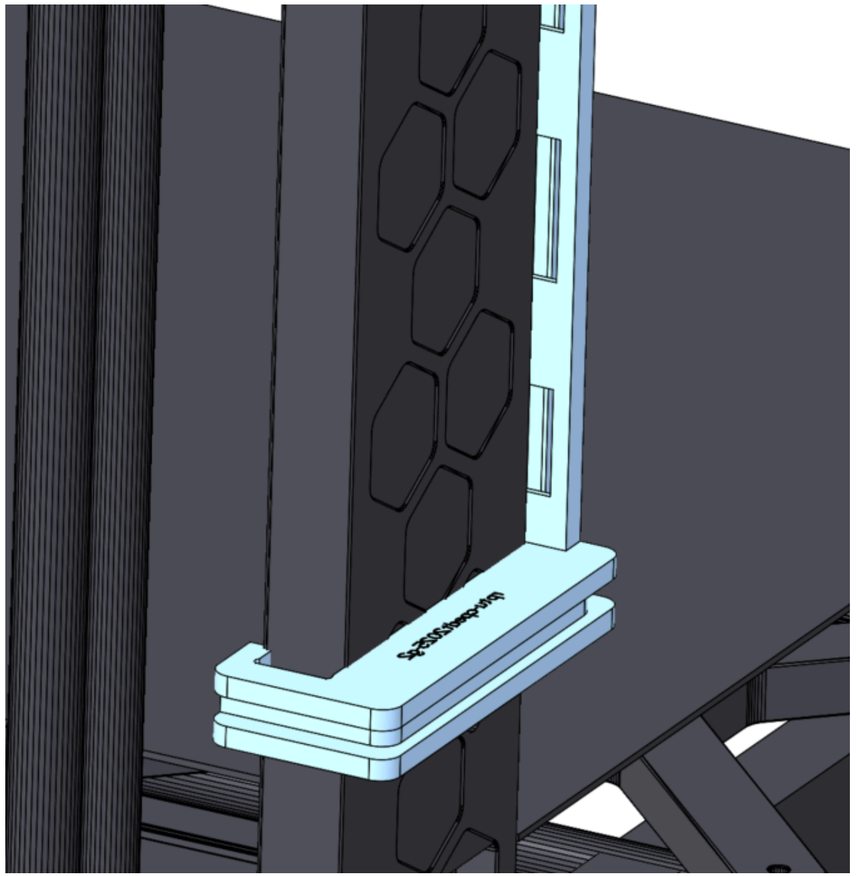

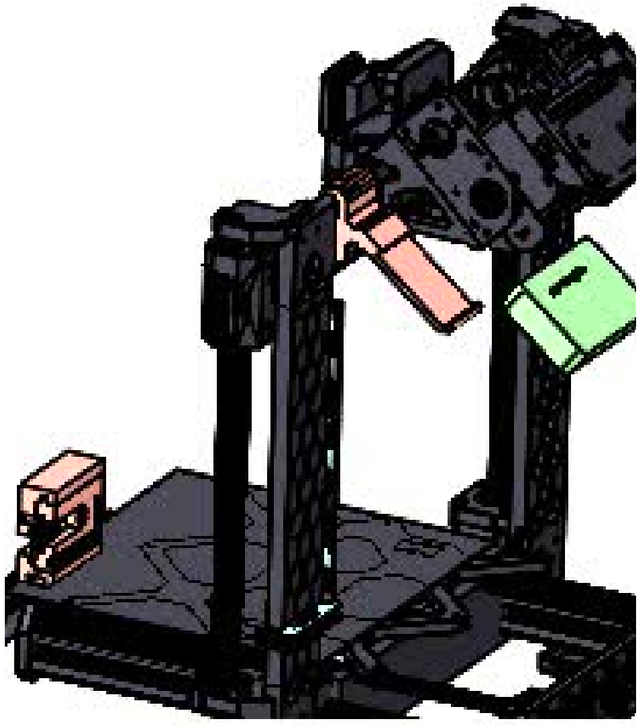

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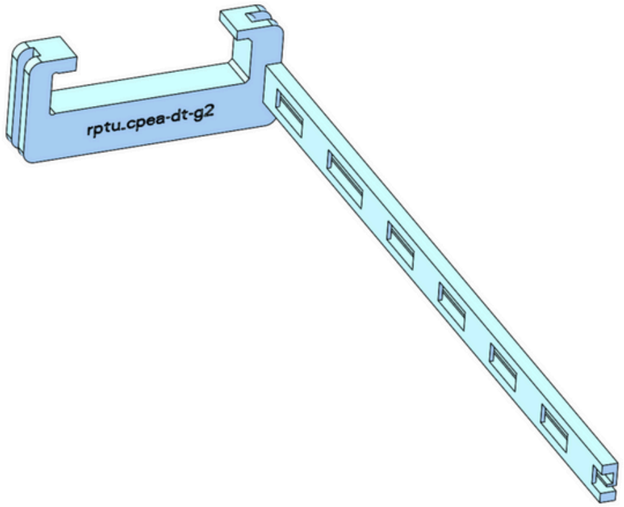

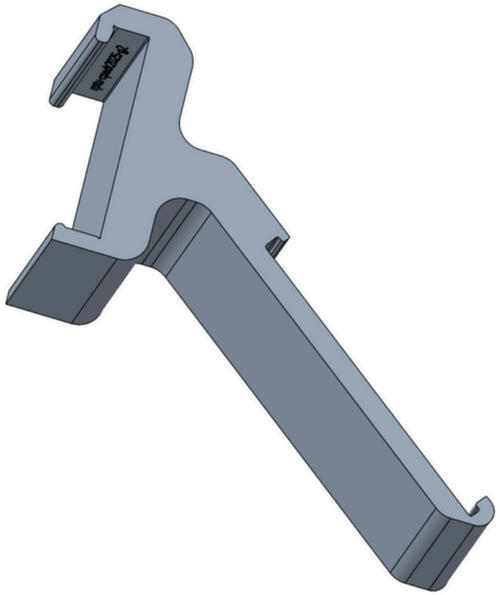

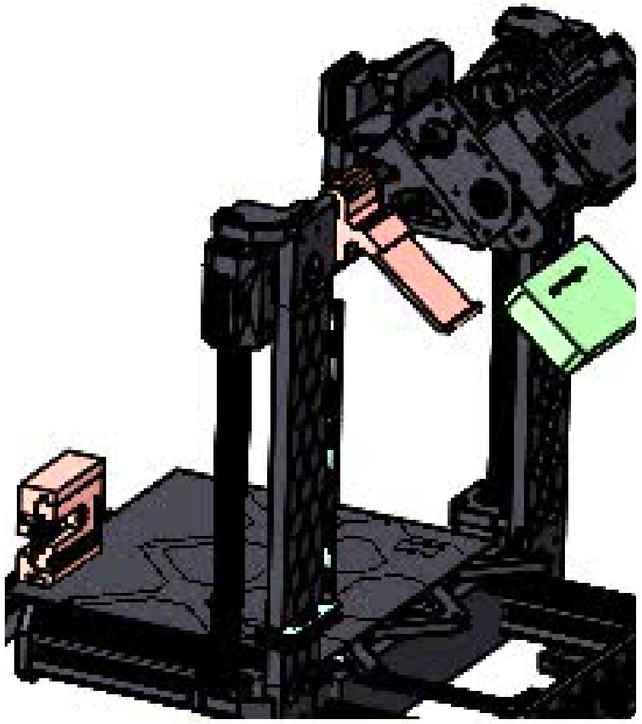

Camera Mount Design

Mount aspect				
Task		**Status**	**Priority**	**Notes**
cable management		✅ Completed	🟢 High	
cable protection		✅ Completed	🟢 High	hot nozzle
vibration isolation		✅ Completed	🟠 Medium	magnet; zero interference between bed and nozzle motor
distance-adaptive		✅ Completed	🟠 Medium	range between obj and cam

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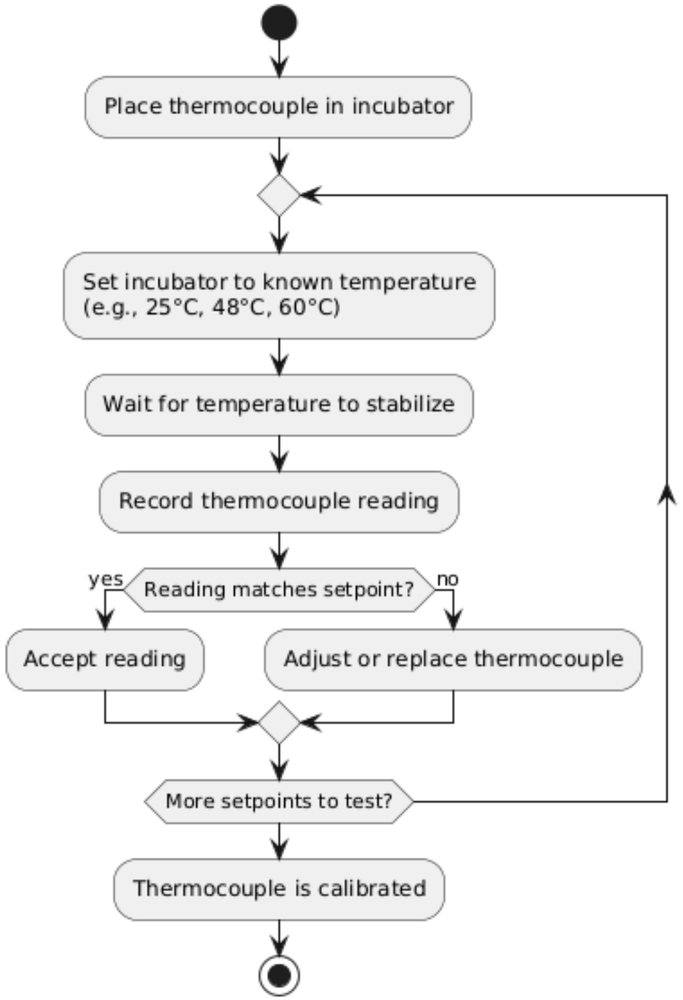
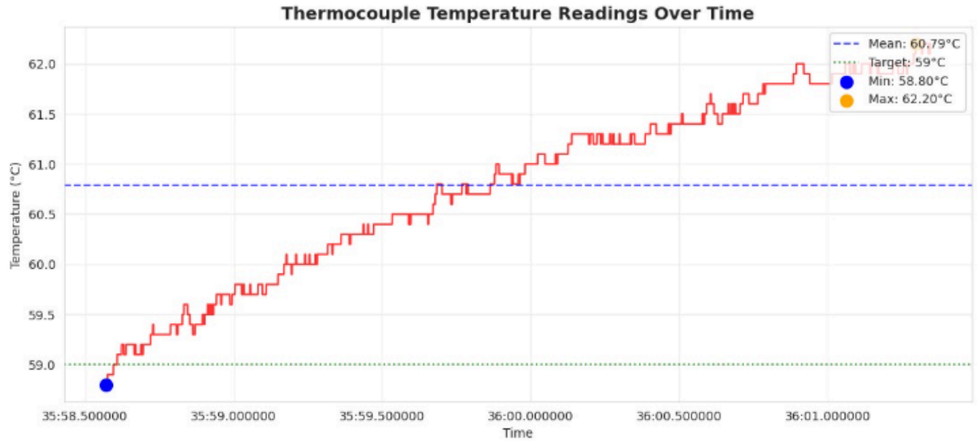
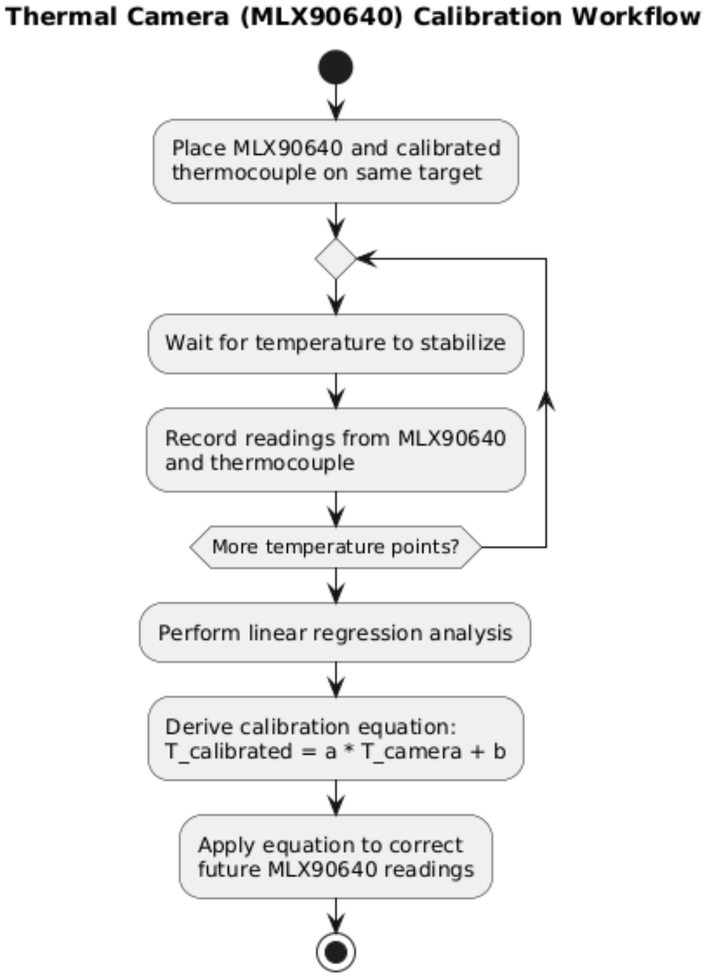
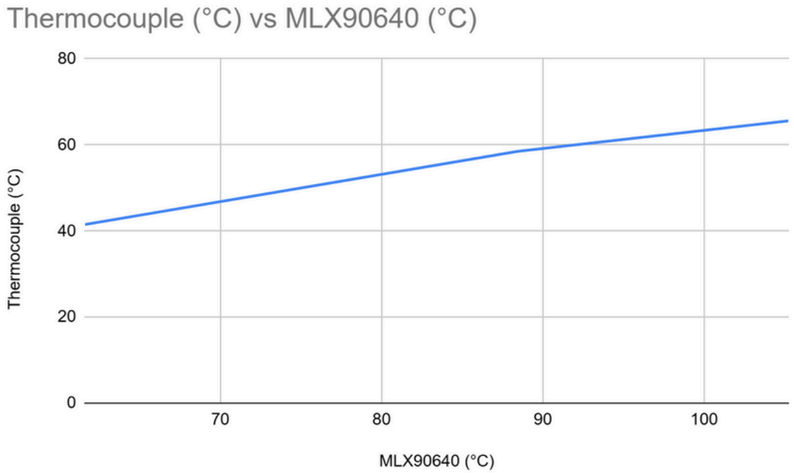
Thermalcouple Calibration





Thermal Camera Calibration





MLX90640 (°C)	Thermocouple (°C)
61.58	41.5
88.46	58.53
105.26	65.6

$$T_{\text{calibrated}} = 0.559 \cdot T_{\text{camera}} + 7.61$$

Thermal Camera Calibration

Solution : Piecewise Linear Calibration

- Why?

The relationship between thermal camera and actual temperature is nonlinear.

- Approach:

Split the data into two temperature ranges and apply a separate linear fit to each.

- Benefits:

Simple to implement
More accurate than one global linear model
Works well for small dataset

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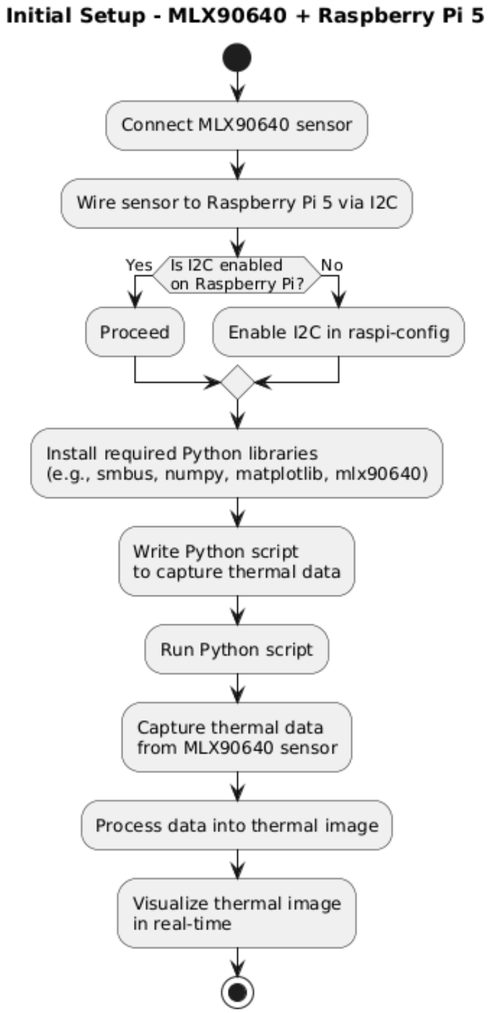
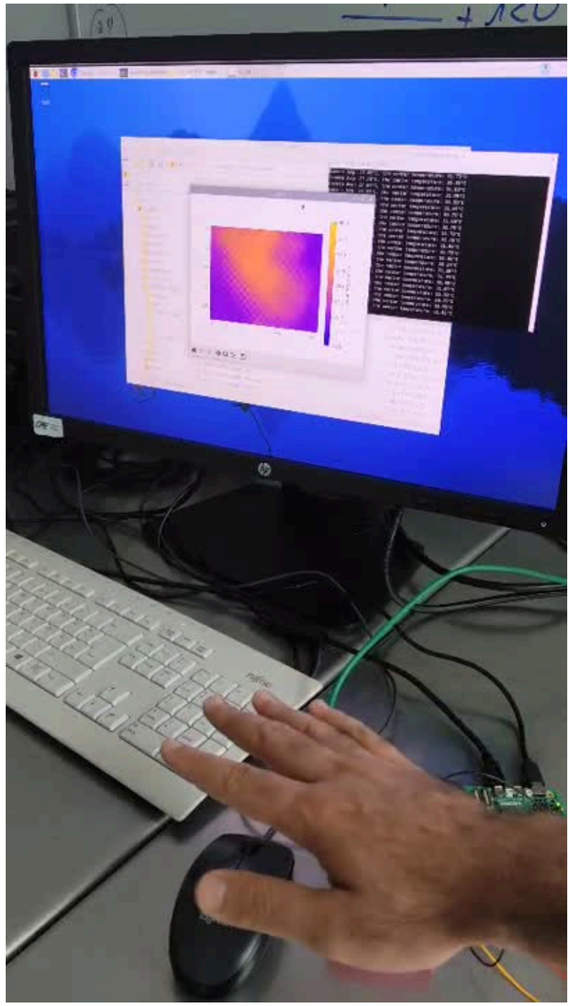
Camera Setup Procedure





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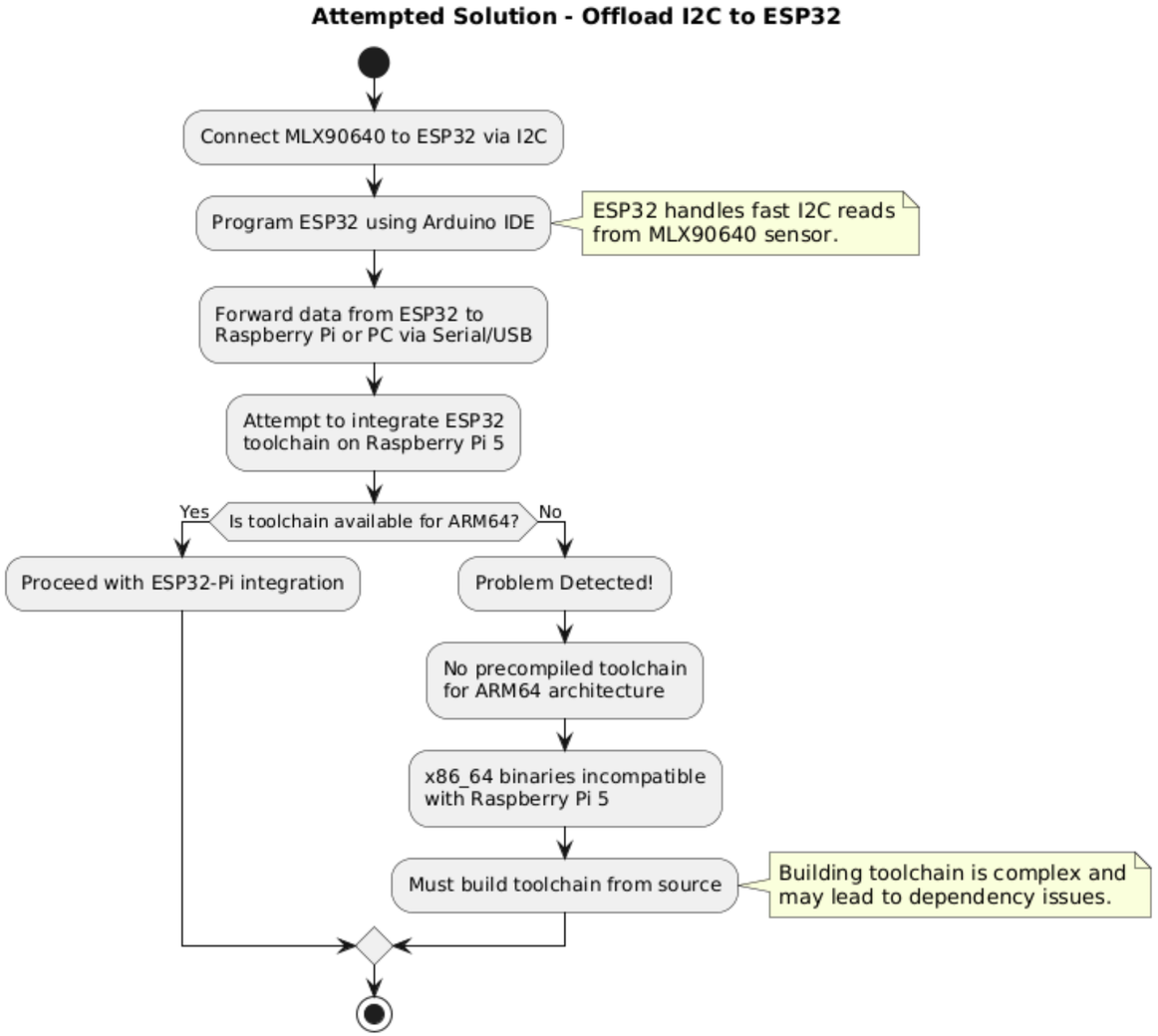

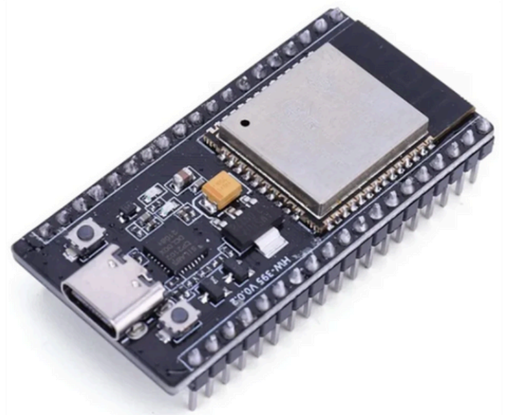

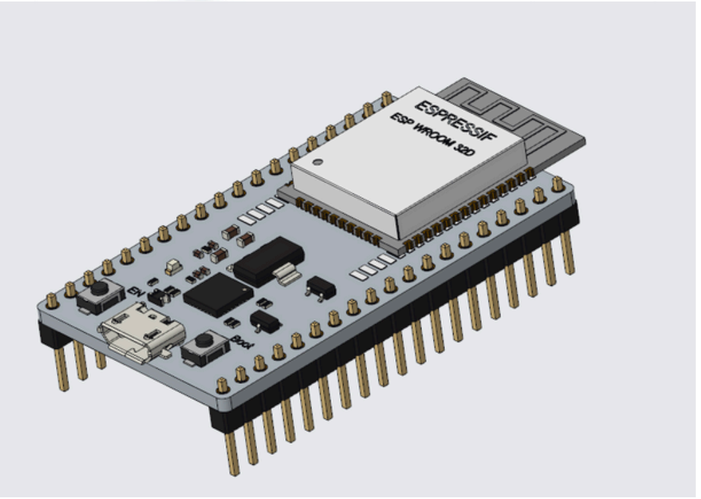

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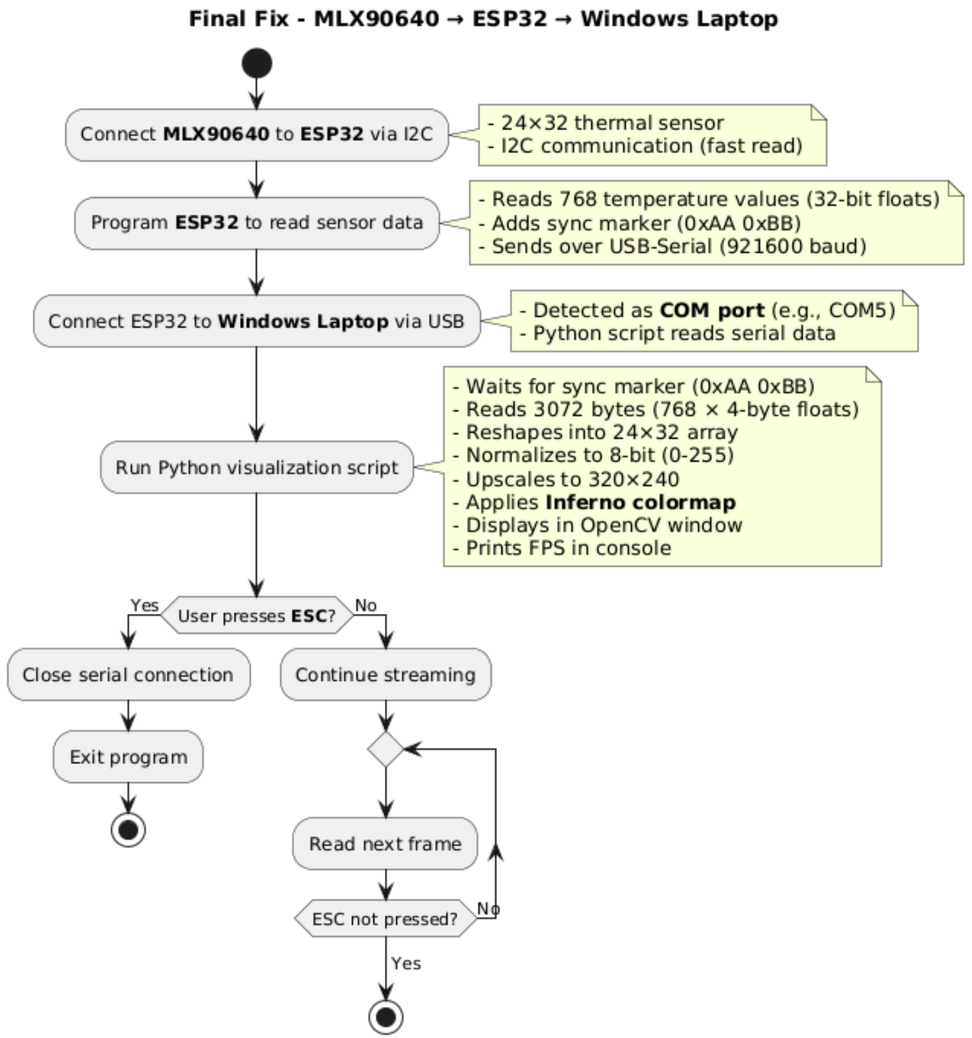

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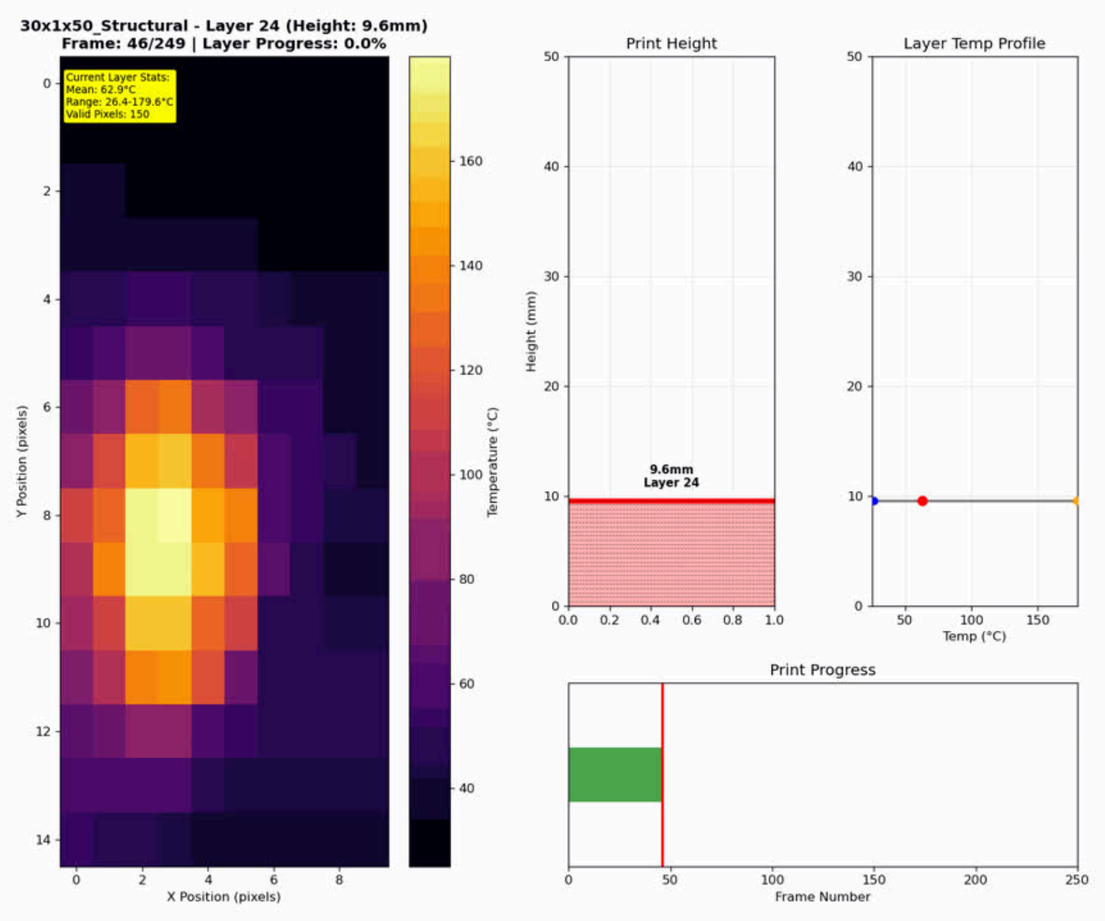
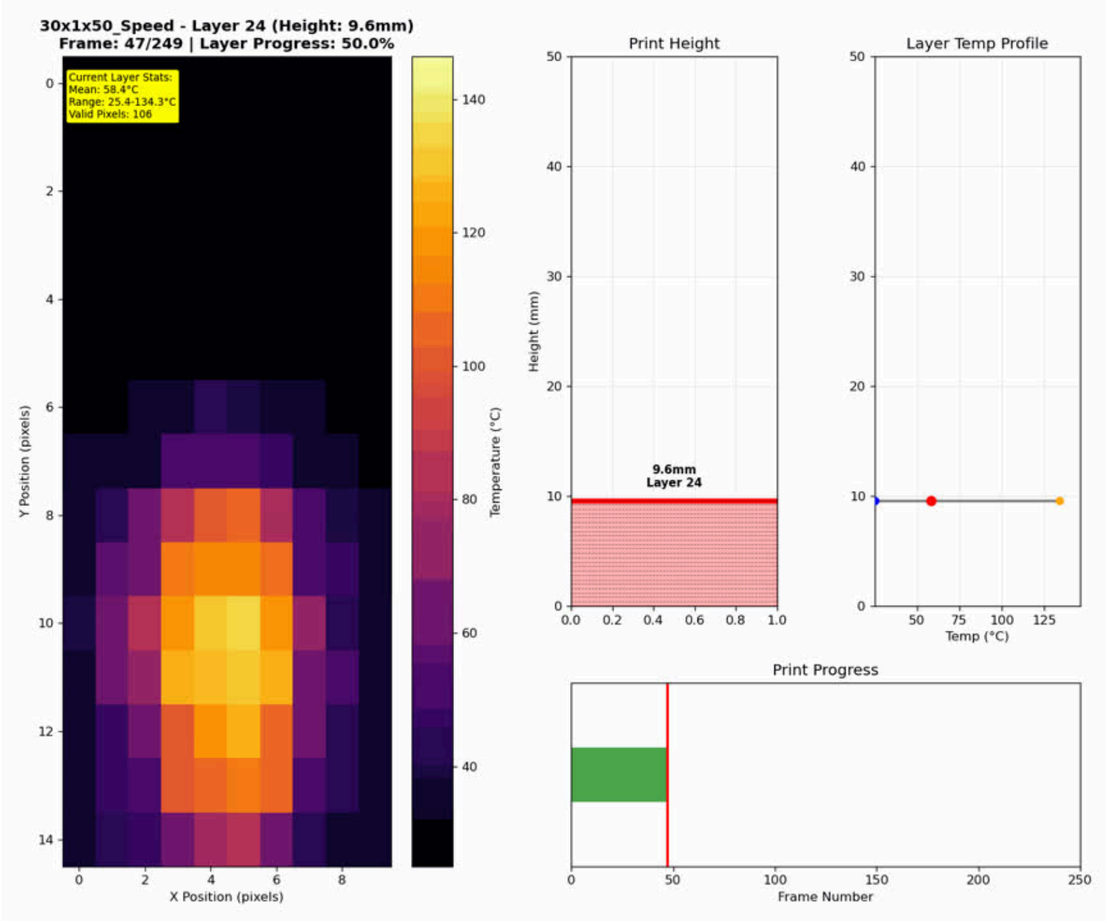
Printing Height Speed





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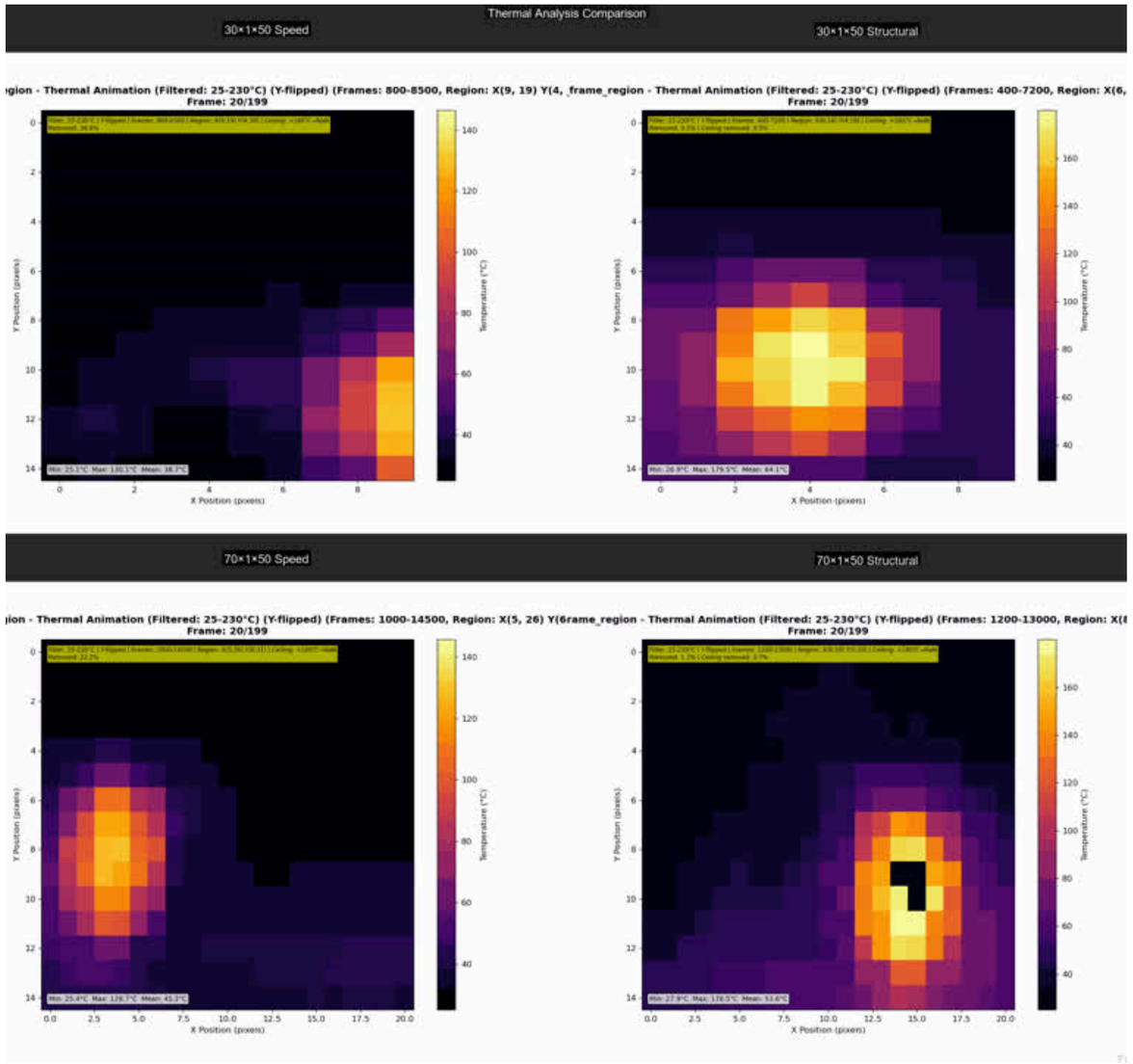
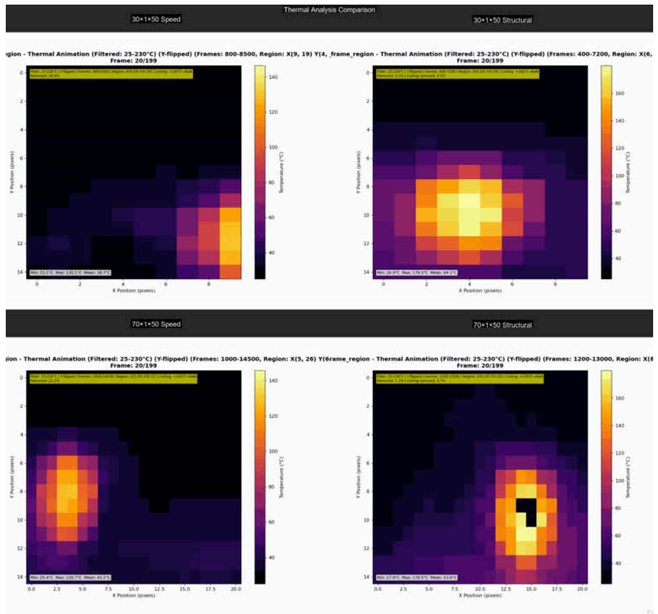
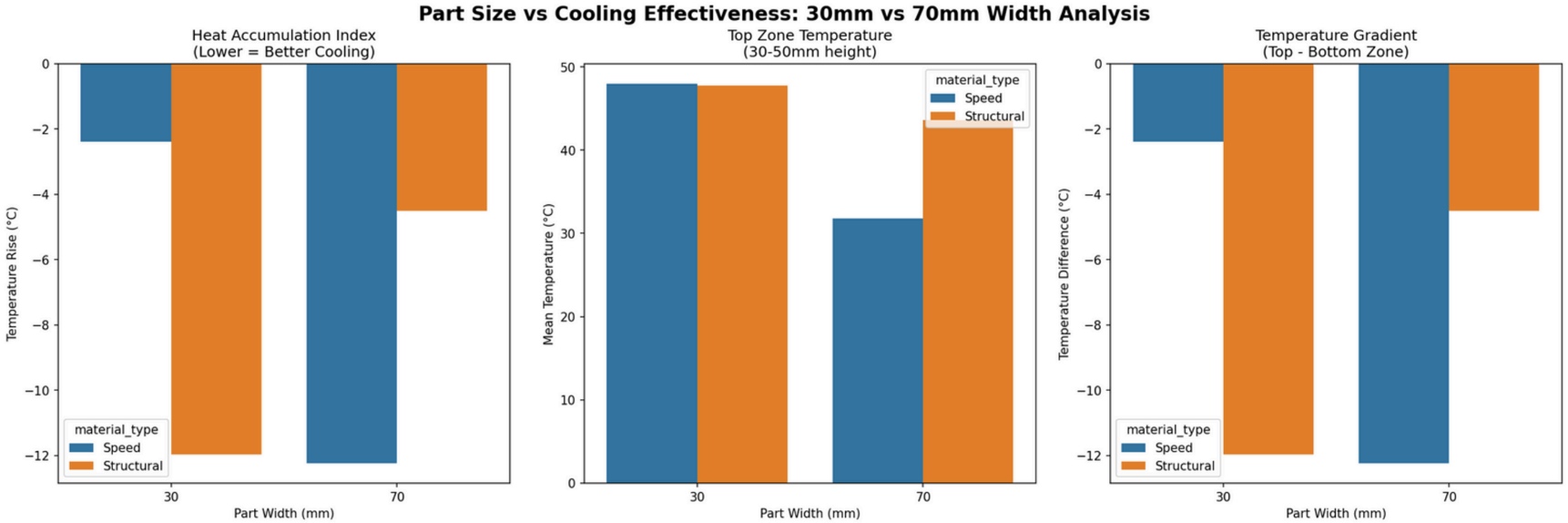
Temperature Difference Detection on Difference Wall Size



Temperature Measurement

Temperature Difference Detection on Difference Wall Size





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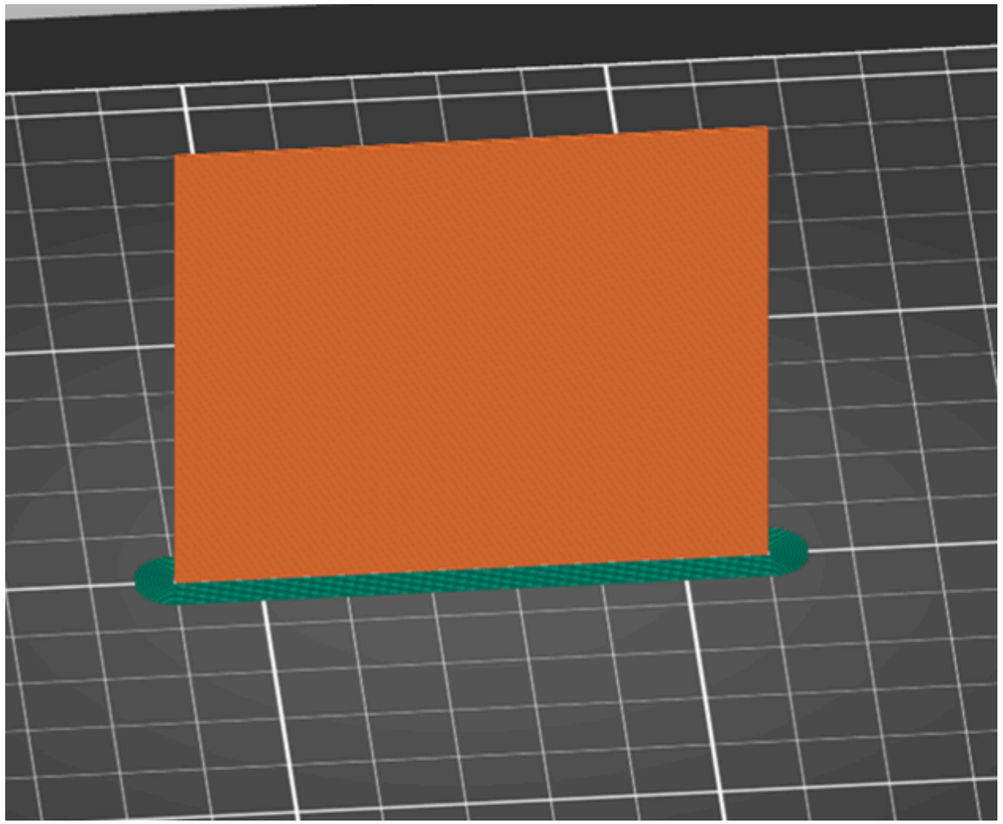
Task 3 : Simulation of the temperature distribution in the wall



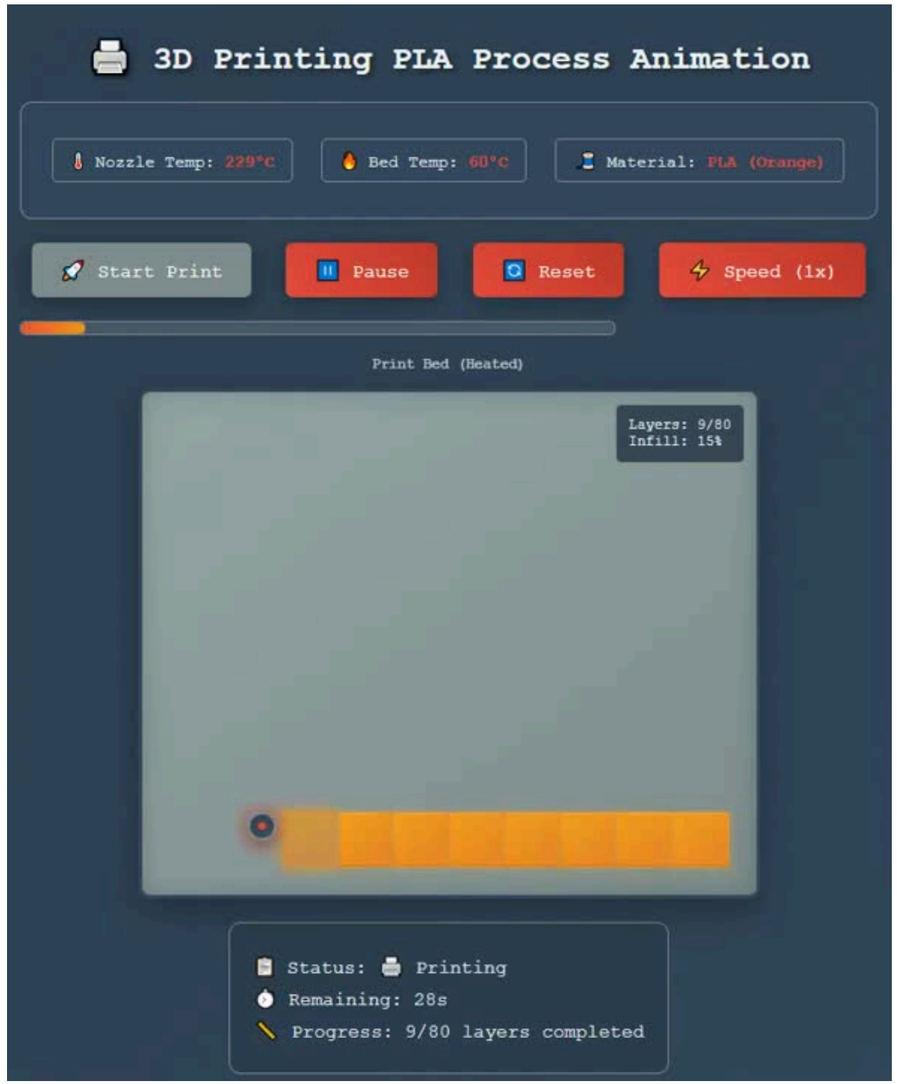
Printing Parameter:

layer height:	0.2 mm
speed for print move:	45/170 mm/s
size: length	30/70 mm
thickness	1 mm
height	50 mm

PLA material properties:

density ρ:	1250 kg/m^3
specific heat capacity c_p:	1800 J/ (kg K)
thermal conductivity K_0:	0.13 W/(m K)

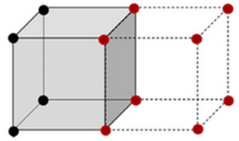
Simulation Setting: Model + Method



Problem: transient 2D Heat transfer [Ramos et al.]

$$\rho c_p \frac{\partial T(\mathbf{x},t)}{\partial t} = \nabla\cdot(K_0 \nabla T(\mathbf{x},t)) + Q$$

$$\boldsymbol{q} = K_0 \nabla T(\mathbf{x},t)$$



Boundary Conditions:

$$K_0 \nabla T(\mathbf{x},t)\cdot\mathbf{n} + h(T - T_\infty) = 0 \quad \mathbf{x} \in \Gamma_c$$

$$T(\mathbf{x},t) = T_b \quad \mathbf{x} \in \Gamma_b$$

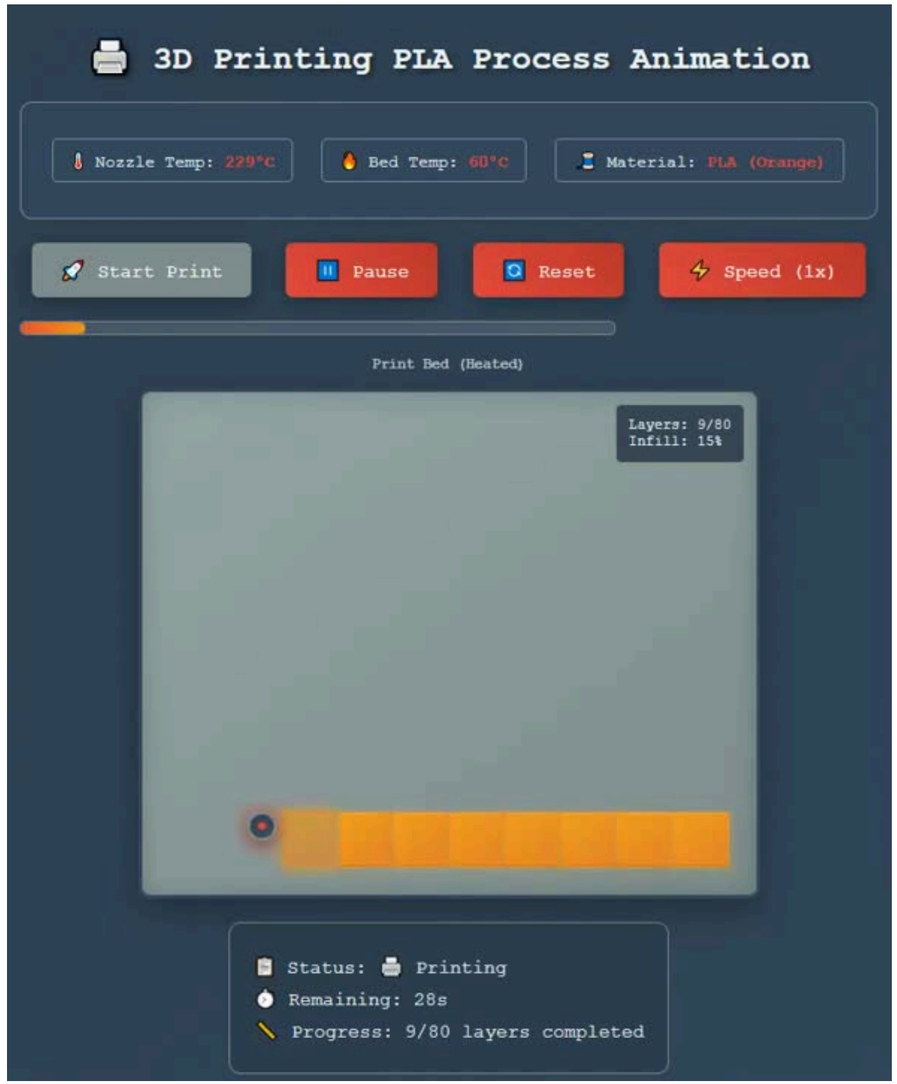
Initial Condition:

$$T(\mathbf{x},0) = T_a \quad \mathbf{x} \in \Omega_q$$

$$T^i(\mathbf{x},0) = T^{i\text{-}1}(\mathbf{x},t_e) \quad \mathbf{x} \in \Omega_q$$

Q: heat source [W/m^3]
$\boldsymbol{q}$: heat flux vector [W/m^2]
h: heat transfer coefficient = 25 W/(m^2 K)
T_b: bed temperature = 60 ℃
T_a: ambient temperature = 25 ℃

Simulation Setting: Model + Method



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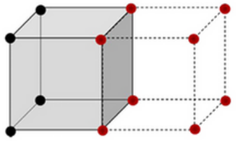

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T_a: ambient temperature = 25 ℃

Method:

Numerical:

Time discretization: θ – method

$$\frac{T^{n+1}-T^n}{\Delta t} = \theta\cdot f(T^{n+1}) + (1-\theta)\cdot f(T^n)$$

θ = 0 -> explicit

θ = 1 -> implicit

θ = 0.5 -> Crank-Nicolson

Space discretization: FDM

Analytical: Q -> moving heat source -> complex

Agenda

Task	Subtask	
Camera Mount Design	Design Description	hakimdalim
	Thermal Camera Calibration	YaHya BaDine
	Camera Setup Procedure	YaHya BaDine
Temperature Measurement	Temperature Change against Print Height	YaHya BaDine
	Printing Speed Affect the Temperature Distribution	hakimdalim
	Temperature Difference on Printing Wall Size	hakimdalim
Simulation	Simulation Model and Method	Wei
	Printing Speed on Temperature Distribution	Wei
	Results and Analysis	Wei

Printing Speed on Temperature Distribution [Tomáš et la.]

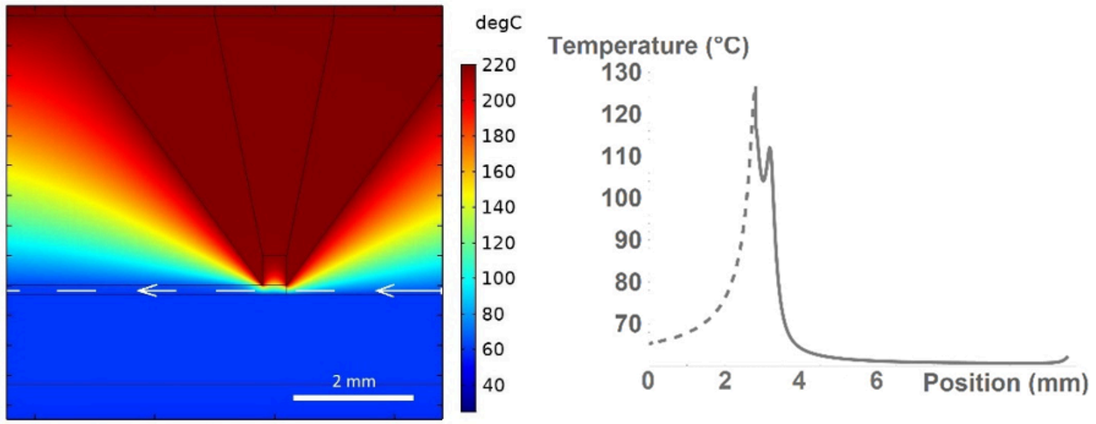


Figure 5. Detail of the printer nozzle/bed interface (left). Temperature distribution along the white line, where the white arrow denotes the direction of the x-axis (right). Printhead moves in the right direction.

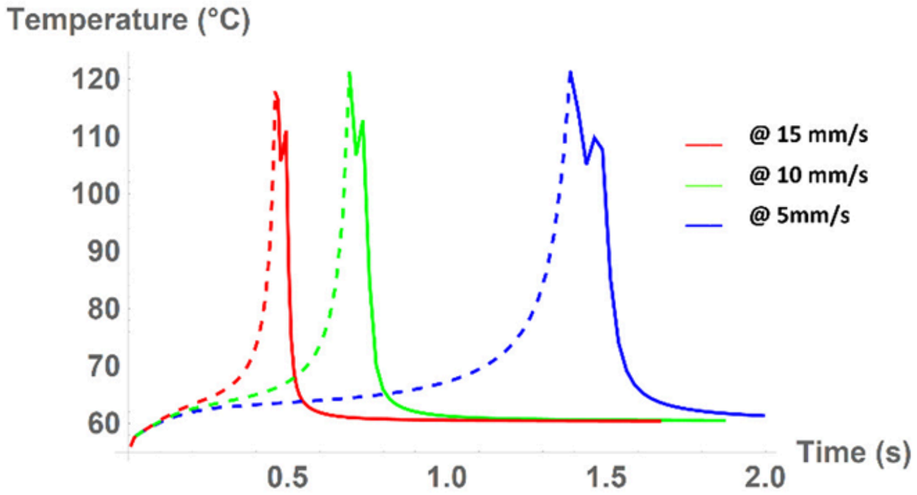
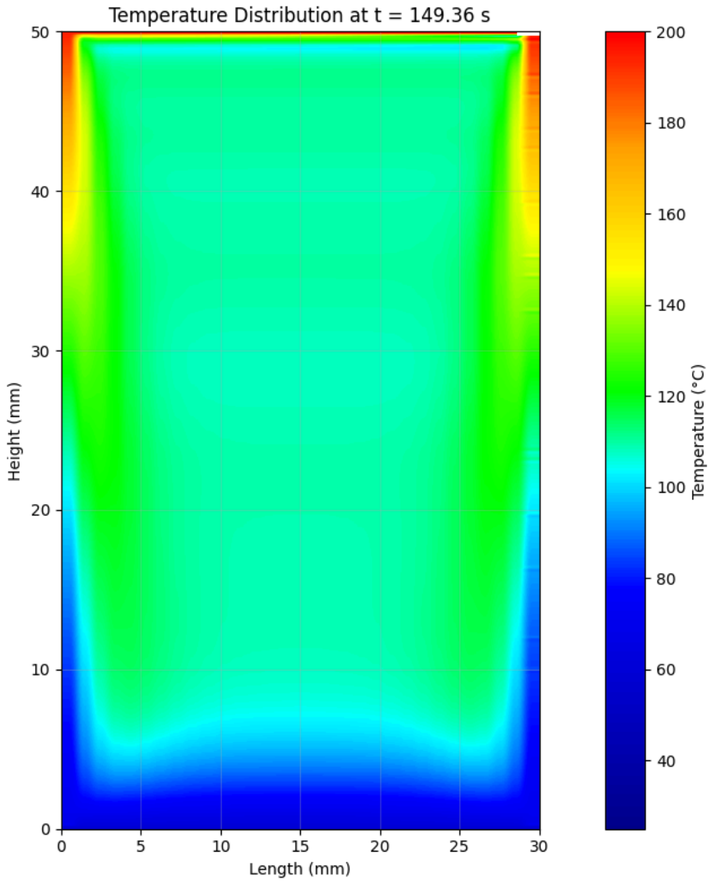


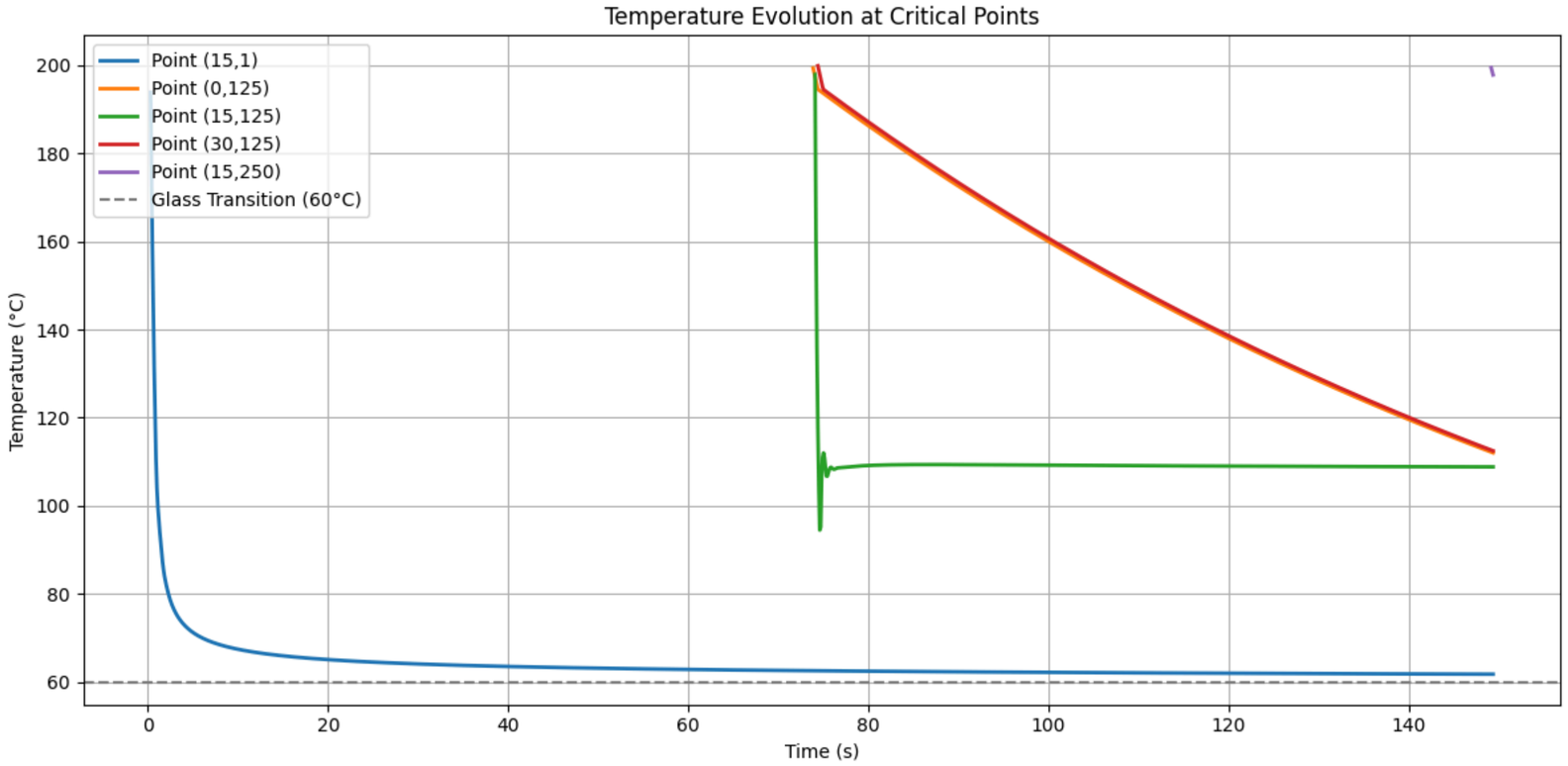
Figure 8. Temperature of the fixed-point during printing.

Agenda

Task	Subtask	
Camera Mount Design	Design Description	hakimdalim
	Thermal Camera Calibration	YaHya BaDine
	Camera Setup Procedure	YaHya BaDine
Temperature Measurement	Temperature Change against Print Height	YaHya BaDine
	Printing Speed Affect the Temperature Distribution	hakimdalim
	Temperature Difference on Printing Wall Size	hakimdalim
Simulation	Simulation Model and Method	Wei
	Printing Speed on Temperature Distribution	Wei
	Results and Analysis	Wei

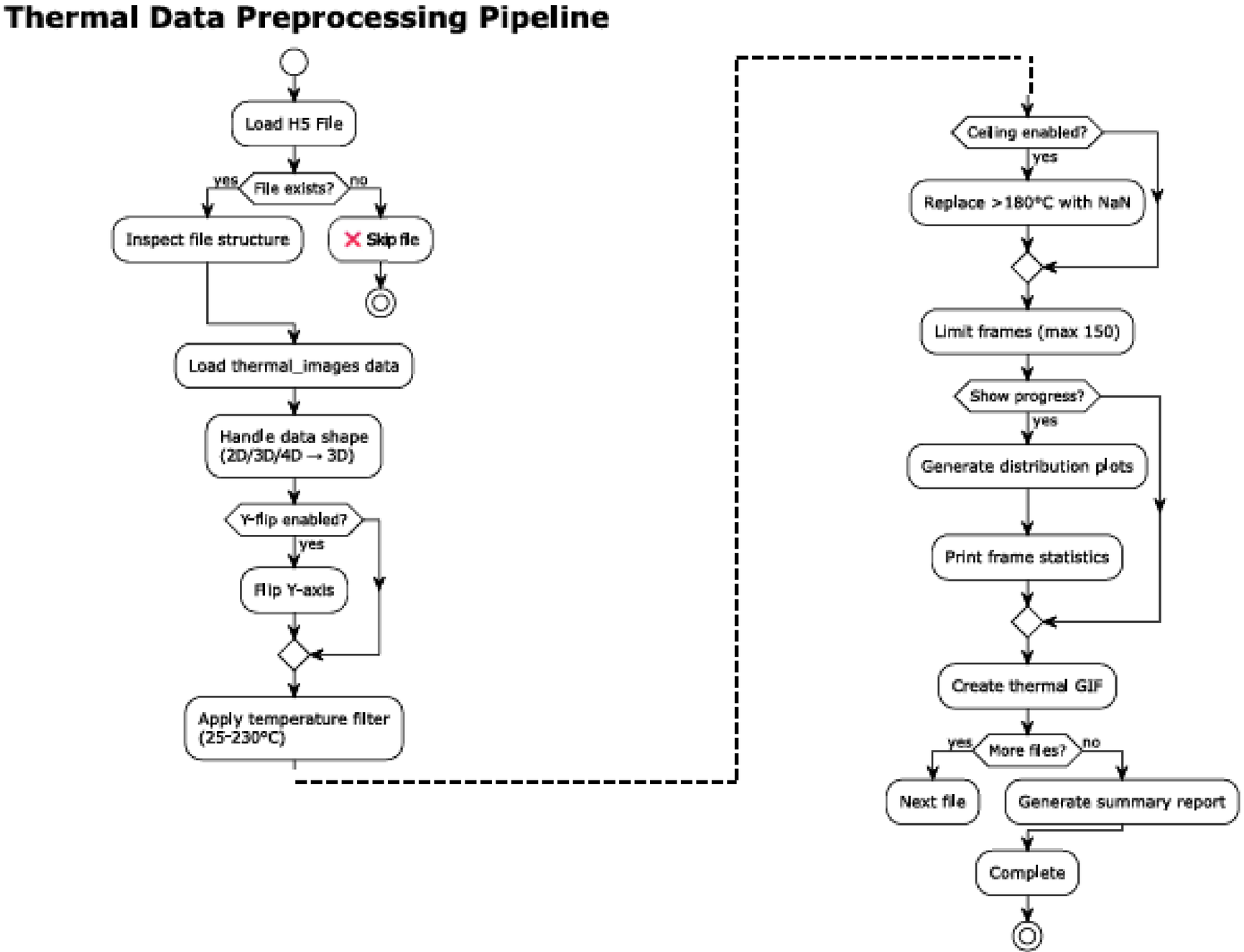
Result


Temperature Distribution at t = 149.36 s
Height (mm)
Length (mm)
Temperature (°C)
0
10
20
30
40
50
0
5
10
15
20
25
30
40
60
80
100
120
140
160
180
200

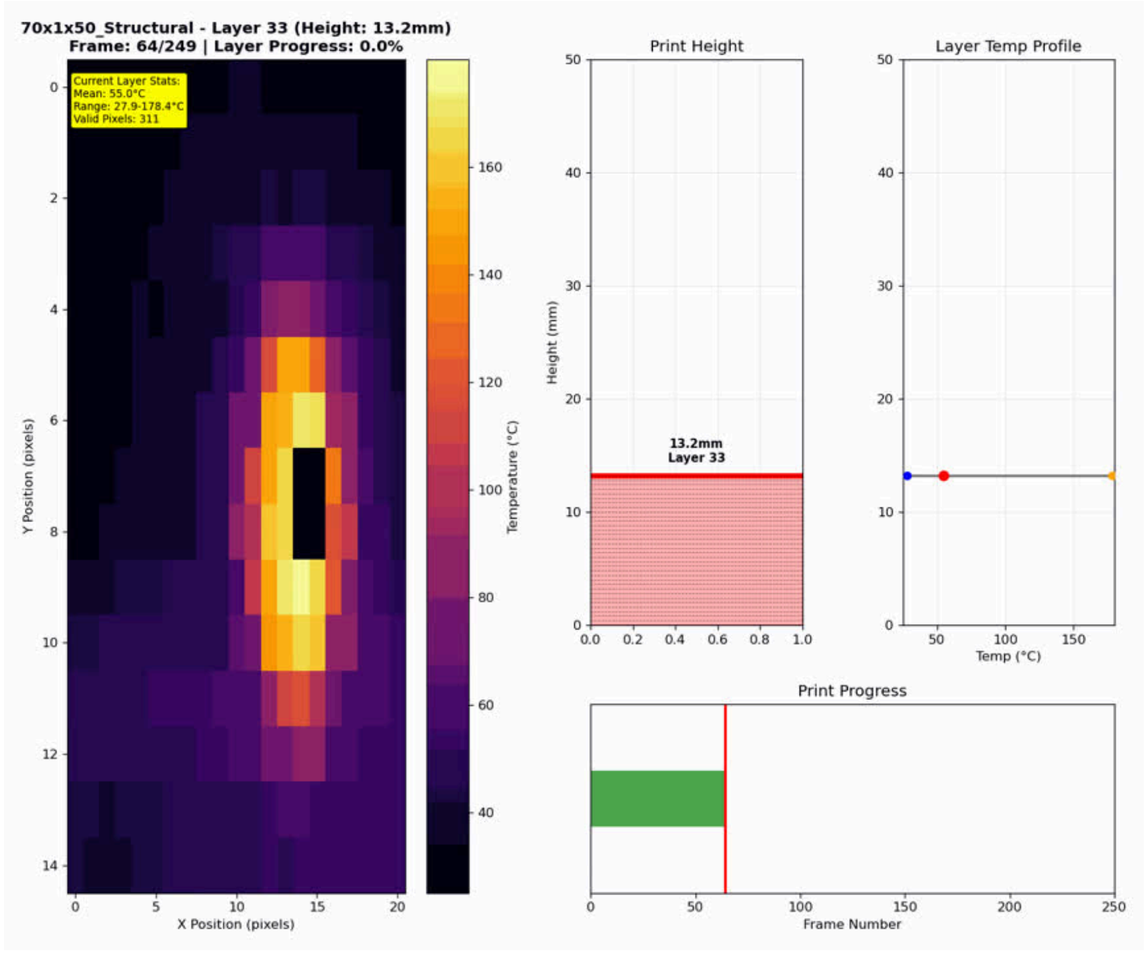

Temperature Evolution at Critical Points
Point (15,1)
Point (0,125)
Point (15,125)
Point (30,125)
Point (15,250)
Glass Transition (60°C)
Temperature (°C)
Time (s)
60
80
100
120
140
160
180
200
0
20
40
60
80
100
120
140

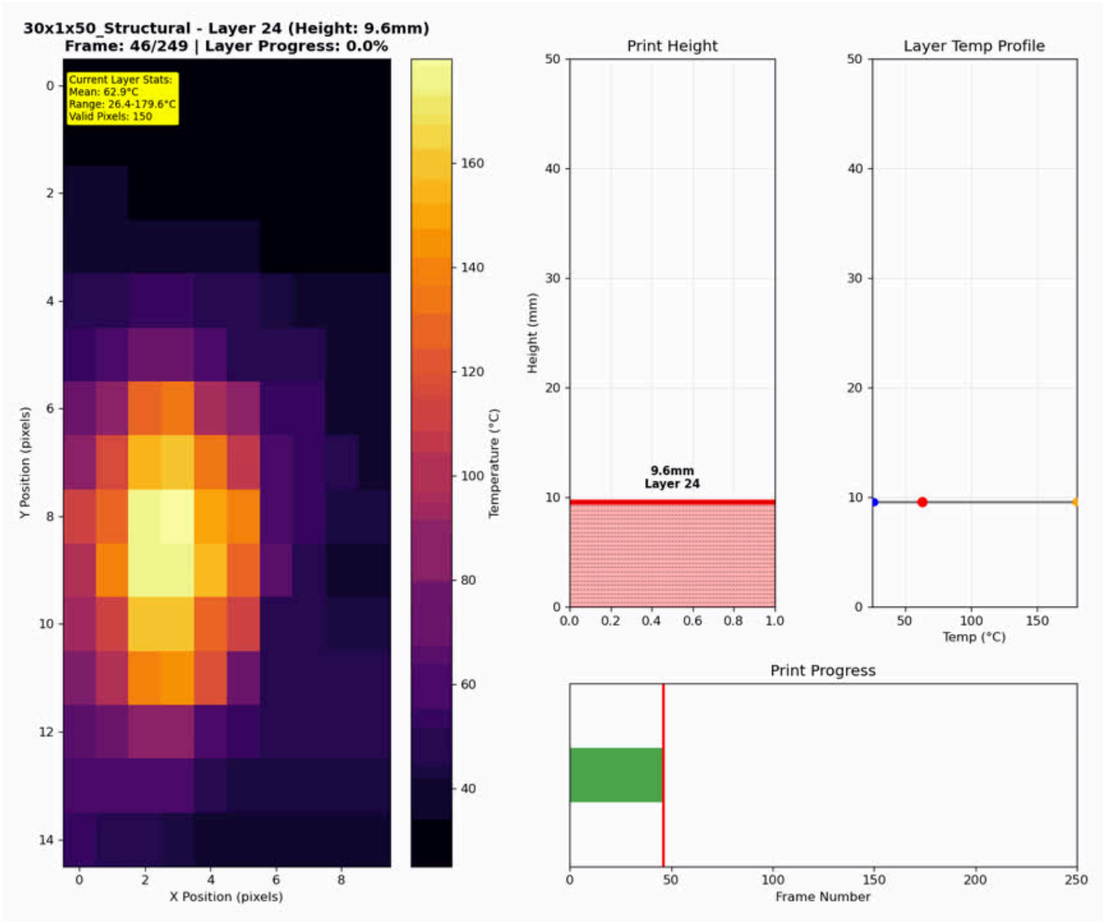
Danke

Appendix


Thermal Data Preprocessing Pipeline
Load H5 File
File exists?
yes
no
Inspect file structure
Skip file
Load thermal_images data
Handle data shape (2D/3D/4D → 3D)
Y-flip enabled?
yes
Flip Y-axis
Apply temperature filter (25-230°C)
Ceiling enabled?
yes
Replace >180°C with NaN
Limit frames (max 150)
Show progress?
yes
Generate distribution plots
Print frame statistics
Create thermal GIF
More files?
yes
no
Next file
Generate summary report
Complete

Appendix


70x1x50_Structural - Layer 33 (Height: 13.2mm)
Frame: 64/249 | Layer Progress: 0.0%
Current Layer Stats:
Mean: 55.0°C
Range: 27.9-178.4°C
Valid Pixels: 311
Y Position (pixels)
X Position (pixels)
Temperature (°C)
Print Height
Height (mm)
13.2mm
Layer 33
Layer Temp Profile
Temp (°C)
Print Progress
Frame Number


30x1x50_Structural - Layer 24 (Height: 9.6mm)
Frame: 46/249 | Layer Progress: 0.0%
Current Layer Stats:
Mean: 62.9°C
Range: 26.4-179.6°C
Valid Pixels: 150
Y Position (pixels)
X Position (pixels)
Temperature (°C)
Print Height
Height (mm)
9.6mm
Layer 24
Layer Temp Profile
Temp (°C)
Print Progress
Frame Number