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3D Printing Filament Monitoring System Based on ESP32-CAM and Raspberry Pi

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INTRODUCTION & AIM

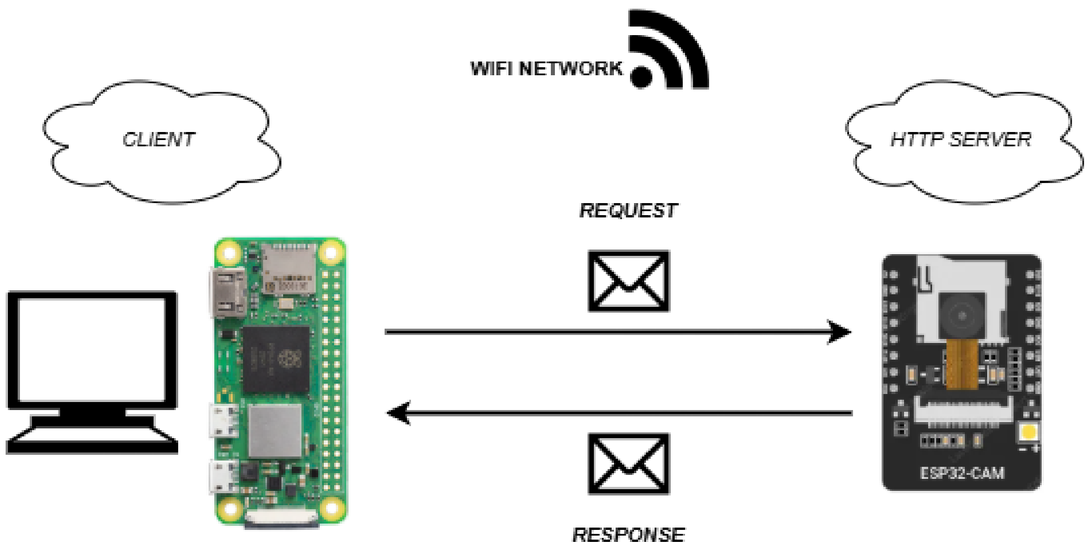
- 3D printing has expanded personal and educational manufacturing, encouraging the development of home extruders capable of producing filament from pellets or recycled material. However, ensuring constant filament diameter is essential [1].

- This work presents a low-cost, open-source system using an ESP32-CAM and a Raspberry Pi Zero W2 to measure filament diameter through computer vision and enable real-time extrusion control.

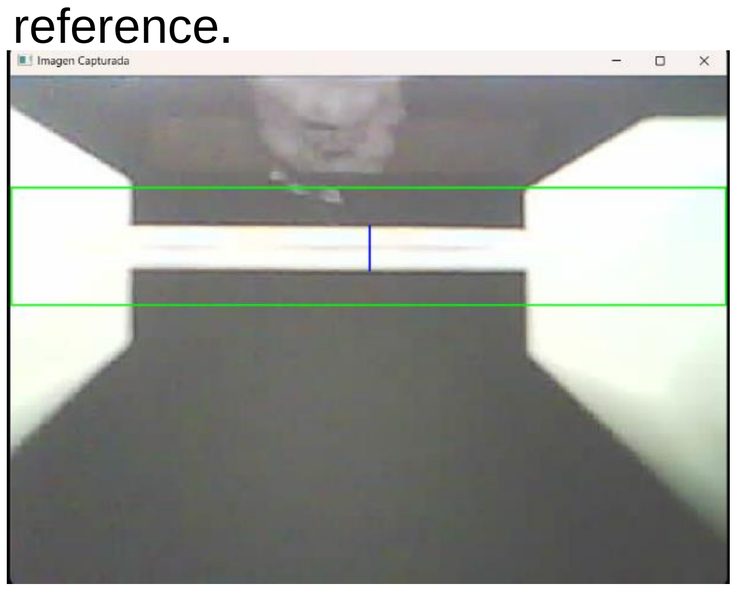
METHOD

1. **Physical configuration:** The filament passes through 3D-printed pulleys to stay aligned with the camera inside an opaque enclosure. Controlled LED lighting ensures consistent illumination and avoids external reflections.

2. **Hardware and comunications:**



3. **Image processing:** Using OpenCV, the system detects filament edges through gradient analysis, applies subpixel interpolation for higher precision [2], and converts pixel data to millimeters using a 1.75 mm calibration reference.

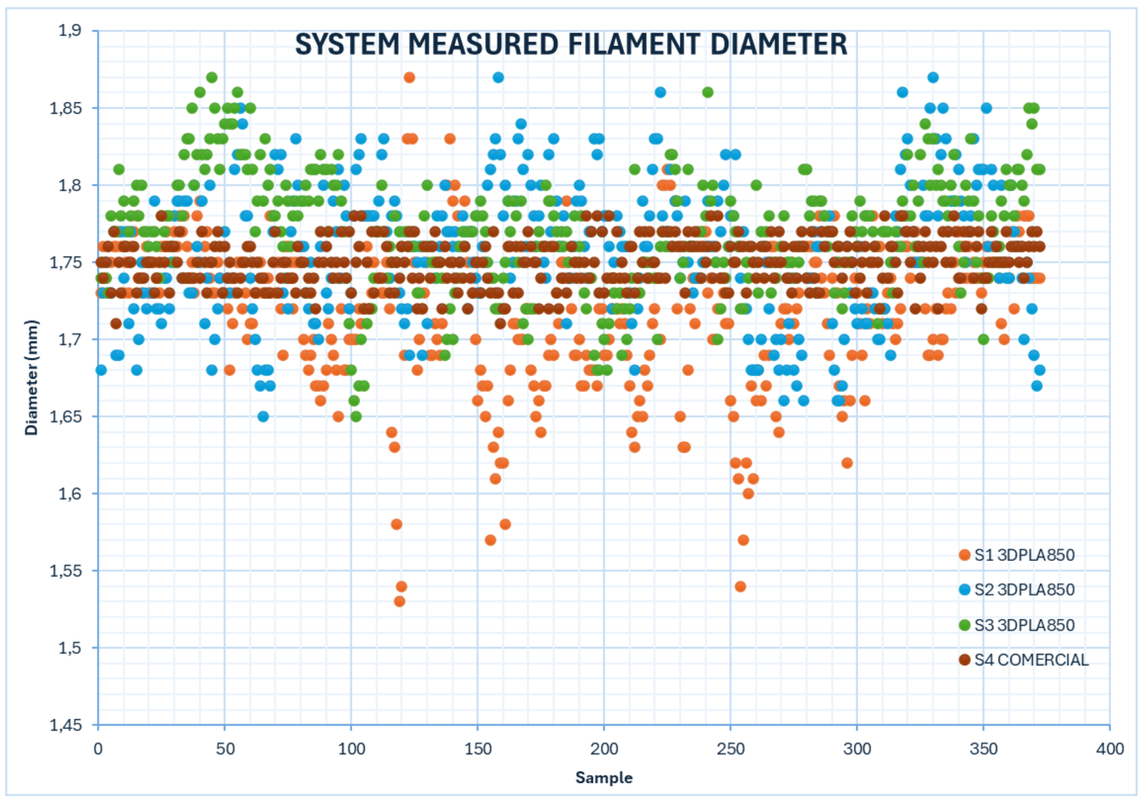


4. **Viewing and recording:** Measured diameters are shown on a 1602 LCD and stored in a .csv file.

RESULTS & DISCUSSION

- To assess the system performance, three tests were carried out on lab-extruded PLA filament and one on commercial filament.

Serie	Median Camera (mm)	Median Caliber (mm)	Standard Desv. Camera (mm)	Standard Desv. Caliber (mm)
1	1.725	1.735	0.048	0.030
2	1.760	1.770	0.044	0.023
3	1.770	1.800	0.038	0.054
Comercial	1.750	1.750	0.016	0.008



- The results indicate a close match between the vision system's measurements and those from a digital calibrator, validating the system's accuracy and reliability for continuous diameter monitoring and real-time quality control in filament production.

CONCLUSION

- A reliable and low-cost system was developed to measure filament diameter using machine vision.
- The system achieves accuracy comparable to that of conventional instruments.

FUTURE WORK / REFERENCES

- Integrate the system with the extruder for automatic temperature and speed adjustment and implement machine learning algorithms to improve edge detection.

- References:

[1] S. Kumar, A. M. A. Zaidi, R. D. Sahu, D. Pathak, y H. Kaur, "Additive Manufacturing: State-of-the-Art, Challenges and Applications," *Materials Today: Proceedings*, vol. 80, pp. 2580–2585, 2023, doi: 10.1016/j.matpr.2023.03.436.

[2] Mikulastik, Patrick & HÖver, Raphael & Urfalioglu, Onay. (2008). Error analysis of subpixel edge localisation, doi: 10.1007/978-0-387-72500-0_10.