

**TINY-MACHINE LEARNING BASED GESTURE CLASSIFICATION FOR
6-DEGREE OF FREEDOM ROBOTIC ARM CONTROL USING ESP32 WITH
ACCELEROMETER AND GYROSCOPE SENSOR DATA**

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Revision after the Thesis Defense on February 6, 2026

STATEMENT BY THE AUTHOR

I hereby declare that this submission is my own work and to the best of my knowledge, it contains no material previously published or written by another person, nor material which to a substantial extent has been accepted for the award of any other degree or diploma at any educational institution, except where due acknowledgement is made in the thesis.



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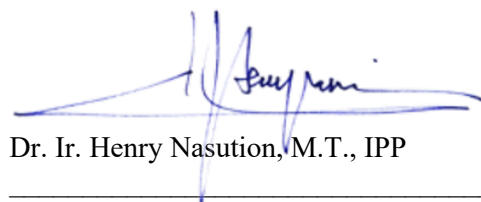


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ABSTRACT

TINY-MACHINE LEARNING BASED GESTURE CLASSIFICATION FOR 6-DEGREE OF FREEDOM ROBOTIC ARM CONTROL USING ESP32 WITH ACCELEROMETER AND GYROSCOPE SENSOR DATA

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This research addresses critical operational limitations in educational robotics where cable damage incurs 20% downtime and potentiometer interfaces require 12.5% of semester time for orientation. The study developed a wireless gesture-based control system using MPU6050 inertial measurement unit sensors and ESP32 microcontroller for 10-gesture recognition. The methodology integrated systematic root cause analysis and field validation across 10 diverse users. The gesture recognition system achieved 95.19% classification accuracy with 10,000 sensor samples, demonstrating excellent cross-user generalization ($\pm 0.67\%$ standard deviation). Robot arm integration confirmed 100% successful gesture-to-servo mapping. Practical evaluation revealed 76.2% task completion time improvement ($4.20\times$ faster) compared to potentiometer control. The system demonstrated production readiness through real-world deployment validation, eliminating physical control cable constraints while maintaining reliability. Threshold-based gesture recognition achieved accuracy competitive with machine learning approaches while maintaining interpretability for educational contexts. The system is immediately deployable in educational robotics laboratories, providing intuitive wireless control with superior usability and operational efficiency.

Keywords: Gesture Recognition, ESP32 Microcontroller, 6-DOF Robotic Arm, IMU Sensor Fusion, Threshold-Based Classification



DEDICATION

I dedicate this works for my family.



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I gratefully acknowledge Swiss German University for providing equipment access and the educational environment necessary to develop and test the gesture recognition system on the 6-DOF robotic arm.

Finally, I dedicate this work to my family, whose encouragement, patience, and unwavering support throughout my graduate studies have been my greatest source of motivation.

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