**Abstract**

In this thesis, we develop, evaluate and deploy a real-time human presence detection (HPD) system using low-resolution thermal sensing that address the limitations of traditional passive infrared (PIR) sensors, while maintaining the privacy. The system integrates the Omron D6T-32L-01A MEMS thermal array (32×32 pixels) with a Temporal Convolutional Neural Network (T-CNN), optimized for embedded edge platforms. The research focuses on enhancing classification accuracy in both dynamic and static occupancy scenarios while maintaining feasibility for low-power deployment.

A key innovation introduced in this study is the implementation of an Exponential Moving Average (EMA)-based adaptive background subtraction mechanism, enabling the system to dynamically suppress static heat sources (e.g., radiators, electronics). Empirical testing showed that the background model required approximately 12 seconds (60 frames at 5 FPS) to converge in human-free environments. Detection performance was evaluated across three controlled environments and ten test trials, achieving a mean F1-score of 0.90 and 100% precision during real-time operation on a Raspberry Pi 4. Comparative analysis against PIR sensors revealed a 1.73-second average lag in initial response but a 3.5× improvement in detection persistence during static occupancy.

Furthermore, a quantized CNN variant (INT8) was deployed on an ESP32-S3 microcontroller. The model, reduced to ~600 kB flash size and under 20% IRAM usage, maintained 94% live inference accuracy despite omitting background subtraction due to hardware limitations. This confirms the model’s robustness under constrained memory and compute resources.

The study concludes that thermal-based ML models significantly outperform PIR-based systems in reliability and static presence detection, with scalable deployment potential in smart homes, energy automation, and privacy-sensitive environments. The dual-platform implementation, combined with real-time adaptive learning and rigorous metric validation, offers a deployable, low-cost, and privacy-conscious solution for next-generation occupancy detection.