A Novel Framework for Object Detection in UAV-Aided Smart Surveillance Using Edge AI

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Certificate

This is to certify that the thesis entitled **"A Novel Framework for Object Detection in UAV-Aided Smart Surveillance Using Edge AI"** is an authentic record of the work done by **Mr. Vivek Patel** for partial fulfilment of the degree of Master of Technology (M. Tech.) in Information Technology(Session 2024-25), Department of Information Technology, Guru Ghasidas Vishwavidyalaya, a central university, Bilaspur (C.G.).

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Abstract

In the rapidly evolving domain of UAV-aided smart surveillance, the demand for real-time object detection has become increasingly critical, particularly in applications requiring immediate situational awareness. However, traditional centralized approaches to object detection often introduce significant privacy risks, as sensitive data must be transmitted to a central server, alongside latency issues that hinder real-time performance. This thesis proposes an innovative framework designed to overcome these limitations by harnessing the power of edge AI and federated learning, delivering an efficient and privacy-preserving solution for object detection in aerial surveillance systems. The proposed framework utilizes the YOLOv5s model, renowned for its balance of speed and accuracy, to perform real-time object detection on aerial imagery sourced from the VisDrone dataset. To enable collaborative training across distributed edge devices, the framework integrates the FedProx algorithm within a federated learning architecture, allowing multiple UAVs to contribute to model improvement without ever sharing raw data, thereby safeguarding privacy. A key challenge in this distributed setup is the heterogeneity of data captured by different UAVs, often resulting in non-IID (non-independent and identically distributed) data distributions. The FedProx algorithm addresses this by introducing proximal terms that stabilize training and ensure robust model convergence across diverse edge devices. Furthermore, to tackle the communication overhead typical of federated learning in bandwidth-constrained environments, the framework employs 8-bit quantization of model updates. This optimization reduces the data transmission size by an impressive 75%, maintaining detection accuracy while making the system viable for resource-limited settings. Experimental results highlight the framework's effectiveness, achieving a mean Average Precision (mAP@0.5) of 20-30% in federated settings—a performance that closely rivals centralized models, which typically reach 30-40% mAP but compromise on privacy. Importantly, the privacy-by-design approach ensures that sensitive aerial imagery remains localized on the edge devices, never requiring centralized aggregation.

Keywords: federated learning, edge AI, object detection, UAV, smart surveillance, privacy-preserving, YOLOv5s, FedProx, 8-bit quantization, VisDrone dataset, non-IID data, real-time processing, smart cities, disaster response, aerial monitoring, distributed learning, bandwidth optimization.