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SICK
Sensor Intelligence.

Master Thesis Proposal

Federated Learning for Object Detection Using 3D Depth Images

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1 Introduction

1.1 Topic of This Thesis

- Provide reasonably detailed description of what you intent to do in your R&D project.
- You may also discuss the challenges that you have to address.
- Reflect on the profile of the reader and PLEAAAASE, tell a story here and refrain from bombarding the readers with details which they may not be able to appreciate.
- TODO: Put a story or a very basic scenario here to make the reader understand the problem.
- Keep it in industrial context
- Start with privacy issue with the centralized training especially in the consumer AI context
- Issue with scaling DL models
- Then how FL solves that problem, put a FL workflow diagram
- FL settings, what is our focus in that
- Industrial context
- Applicable to broader fields, medical, finance, surveillance
- Laws enforcing FL, put those papers
  - [1]

1.2 Relevance of This R&D Project

- Who will benefit from the results of this R&D project?
- What are the benefits? Quantify the benefits with concrete numbers.

2 Related Work

2.1 Survey of Related Work

- What have other people done to solve the problem?
- You should reference and briefly discuss at least the "top twelve" related works
- Rising research trend for FL, put that fig with papers over years
- But mostly theoretical aspect on benefits of FL and its comparison with some toy datasets
- FL+CV, only classification is covered in most of the papers, show that paper published graphs
- A very few FL+OD papers, that to even in practical and application oriented are close to none

2.2 Limitation and Deficits in the State of the Art

- List the deficits that you have discovered in the related work and explain them such that a person who is not deep into the technical details can still understand them. For each deficit, provide at least two references
- You should reference and briefly discuss at least the "top twelve" related works
- None in the 3D depth image domain or intensity images
- Here, input data itself prioritize privacy especially when it comes to person recognition

3 Problem Statement

- Which of the deficits are you going to solve?

- What is your intended approach?
- How will you compare you approach with existing approaches?
- FL+OD working pipeline, on a real world dataset
- A non-RGB based dataset
- Implementation on edge-devices
- Compare FL frameworks and choose 1 or 2
- Check FL aggregation methods
- Analyze compute resource constrained OD models
- As seen in the Figure (TODO: add a figure with computer vision task papers), most of the literature work is done in federated learning (FL) for computer vision is for classification. FL with object detection is not yet well explored with the new edge hardware and the state-of-the-art models.

4 Project Plan

4.1 Work Packages

WP1 Literature Study

WP1.1 Conduct a comprehensive literature review on state-of-the-art FL-based object detection methods

WP1.2 Analyze existing centralized and FL-based object detection frameworks, focusing on their architectures and performance metrics

WP1.3 Identify key models and techniques to replicate and compare, and document best practices for FL in the context of object detection on 3D depth images

WP2 Data Collection and Preparation

- WP2.1 Generate a custom dataset consisting of 3D depth images suitable for training and testing object detection models
- WP2.2 Preprocess the dataset, including data cleaning, augmentation, and handling any data imbalance issues
- WP2.3 Develop tools for managing and preparing the dataset for Federated Learning experiments (e.g., partitioning the dataset across simulated nodes)

WP3 Model Development and Initial Testing

- WP3.1 Replicate and test existing models from the literature to establish a baseline performance on the custom dataset
- WP3.2 Implement the FL-based object detection pipeline, starting with a centralized approach for comparison
- WP3.3 Test and evaluate initial models to ensure functionality and establish initial performance benchmarks

WP4 Comparative Analysis and Performance Evaluation

- WP4.1 Perform a comparative analysis between centralized and FL-based object detection methods, focusing on performance metrics such as accuracy, inference time, and system profile
- WP4.2 Evaluate models on the custom dataset and analyze the strengths and weaknesses of each approach
- WP4.3 Optimize model performance by tuning hyperparameters, modifying architecture, or adjusting the dataset for improved FL-based results

WP5 Implementation on Edge Devices

- WP5.1 Implement the FL-based object detection model on edge devices, ensuring it runs efficiently under resource constraints (e.g., limited computation, bandwidth)
- WP5.2 Test and evaluate the performance of the model on edge devices, measuring factors such as accuracy, inference time, and system profile

WP5.3 Integrate any necessary optimizations for FL-based object detection specifically tailored to edge deployment scenarios

WP6 Advanced Development and Optional Extensions

WP6.1 Develop a containerized workflow to facilitate easy deployment of the FL-based object detection pipeline across different environments

WP6.2 If time permits, extend the project by integrating object tracking with FL-based object detection or adding uncertainty estimation capabilities to the models

WP7 Project Report and Finalization

WP7.1 Write a comprehensive project report detailing the research objectives, methodology, results, and findings

WP7.2 Present a critical analysis of the performance comparison between centralized and FL-based approaches, highlighting contributions, limitations, and future research directions

WP7.3 Prepare the final thesis draft, ensuring clarity and coherence in presenting the experimental outcomes and their implications for FL-based object detection

4.2 Milestones

M1 Comprehensive literature review on state-of-the-art FL-based object detection methods completed, with key models and techniques identified for replication

M2 Replication of existing models from relevant literature completed

M3 Custom 3D depth image dataset generated and preprocessed (e.g., cleaning, augmentation)

M4 Comparative analysis of at least two object detection methods on the custom dataset completed, with detailed performance metrics recorded

M5 Development of a working pipeline for FL-based object detection (simulated) on 3D depth images completed

M6 Implementation of FL-based object detection on edge devices completed

M7 Comparative analysis of centralized vs. FL-based object detection completed, with performance results and key findings documented

M8 Final model development and testing completed, including optimization and an in-depth evaluation of strengths and weaknesses

M9 Extension of the project with the development of a containerized workflow for easy deployment completed

M10 Final project report completed, covering methodology, experimental setup, results, and thorough analysis.

4.3 Project Schedule

WP ID	Task Description	Duration (Weeks)	Start Date	End Date	September	October	November	December	January	February
1	Literature Study	8	01.09.2024	31.10.2024						
2	Data Collection and Preparation	6	01.10.2024	15.11.2024						
3	Model Development and Initial Testing	8	15.10.2024	15.12.2024						
4	Comparative Analysis and Performance Evaluation	6	01.12.2024	17.01.2025						
5	Implementation on Edge Devices	6	15.12.2025	31.01.2025						
6	Advanced Development and Optional Extensions	4	01.02.2025	28.02.2025						
7	Project Report and Finalization	10	20.12.2024	03.03.2025						

Figure 1: Gantt chart of the project schedule

4.4 Deliverables

Minimum Viable

- Conduct a comprehensive literature review on state-of-the-art Federated Learning (FL)-based object detection methods
- Develop and test existing models to reproduce results from relevant literature
- Generation of a custom dataset consisting of 3D depth images
- Perform a comparative analysis of at least two methods on a custom dataset
- Produce a detailed project report that summarizes the work done and the obtained results

Expected

- Fulfill all minimum viable deliverables
- Perform a comparison of centralized versus FL-based object detection, focusing on performance analysis
- Complete the final development and testing of the model, and a detailed analysis of the strengths and weaknesses of each approach
- Develop a working pipeline for FL-based object detection on 3D depth images (simulated)
- Produce a more extensive project report detailing the methodology, experimental setup, results, and in-depth analysis

Desired

- Fulfill all expected deliverables
- Implement FL-based object detection on edge devices
- Develop a containerized workflow for easy deployment

- Additional objectives (if time permits):
  - Integrate object tracking with FL-based object detection
  - Implement FL-based object detection with uncertainty estimation

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