Hochschule
Bonn-Rhein-Sieg
University of Applied Sciences

b-it Bonn-Aachen International Center for Information Technology

SICK
Sensor Intelligence.

Master Thesis Proposal

Federated Learning for Object Detection Using 3D Depth Images

Kevin Patel

Supervised by

Prof. Dr.-Ing. Sebastian Houben
Prof. Dr. Robert Lange
Dr. Markus Hammes
Dr. Nikolaus Mayer

September 2024

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.

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

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

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?

4 Project Plan

4.1 Work Packages

WP1 Literature Study

WP1.1 Conduct a comprehensive literature review of state-of-the-art methods for object detection under adverse weather conditions using multiple modalities

WP1.2 Analyze and compare various fusion strategies for exploiting the complementary characteristics of different sensors

WP1.3 Search for suitable public datasets with adverse weather conditions and multimodal sensors data

WP2 Data Collection and Preparation

WP2.1 Acquire the necessary datasets for multimodal object detection under adverse weather conditions, such as K-radar, DENSE, and aiMotive

WP2.2 Develop tools for pre-processing and augmenting the datasets to enhance the performance of the models

WP2.3 Perform statistical analysis to identify the main characteristics and challenges of the datasets, including data imbalance and class imbalance

WP3 Model Design and Implementation

WP3.1 Design and implement an existing multimodal object detection architectures that integrates camera, LiDAR, and radar data

WP3.2 Investigate various fusion strategies, such as concatenation, mixture of experts, attention-based fusion etc, to determine the most effective approach

WP3.3 Explore deep learning architectures, such as CNNs, RNNs, and Transformers, to improve the performance of the multimodal model

WP3.4 Optimize the model's hyperparameters and train the model on the acquired datasets

WP4 Model Evaluation and Validation

WP4.1 Evaluate the performance of the developed multimodal object detection model on the acquired datasets under adverse weather conditions

WP4.3 Compare the proposed model's results to existing state-of-the-art or baseline methods and analyze the strengths and weaknesses of each approach

WP4.4 Identify the limitations of the proposed model and suggest possible future improvements

WP5 Project Report

WP5.1 Write a detailed report that includes the research problem, objectives, methodology, results, and conclusion

WP5.2 Present the research findings in a clear and concise manner, highlighting the contributions and limitations of the proposed multimodal object detection model

WP5.3 Discuss possible future research directions based on the outcomes of the study

4.2 Milestones

M1 Literature review completed and best practice identified

M2 Data collection and preprocessing completed, including cleaning and augmentation

M3 Initial model development and testing completed

M4 Evaluation and optimization of the model completed

M5 Final model development and testing completed, including comparison with existing state-of-the-art methods and analysis of strengths and weaknesses of each approach.

M6 Project report completed

4.3 Project Schedule

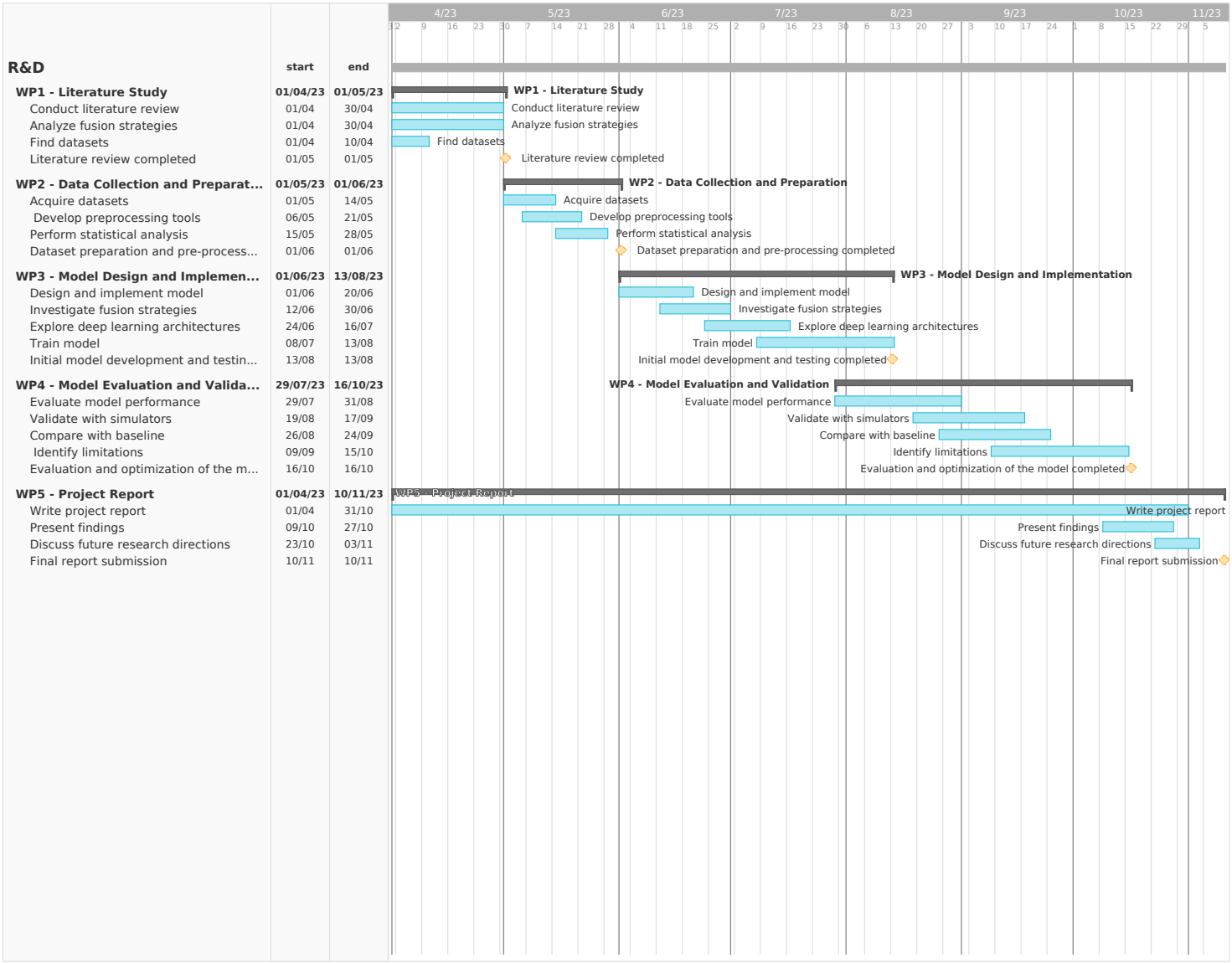

Figure 1: Gantt chart of the project schedule

4.4 Deliverables

Minimum Viable

- Conduct a comprehensive literature review on state-of-the-art multimodal object detection methods and their fusion strategies
- Develop and test existing models for object detection
- Perform a comparative analysis of at least two methods on one dataset
- Produce a project report that summarizes the work done and the results obtained

Expected

- Compare the performance of more advanced methods with the baseline methods
- Complete the final development and testing of the model, including comparison with existing state-of-the-art methods and analysis of the strengths and weaknesses of each approach.
- Produce a more extensive project report that details the methodology, experimental setup, results, and analysis.

Desired

- Compare the developed models' performance on one or more additional datasets.
- Propose improvements to the baseline fusion methods.

References

[1] Author Name. Book title. *Lecture Notes in Autonomous System*, 1001:900–921, 2003.

[2] Paul Voigt and Axel Von dem Bussche. The eu general data protection regulation (gdpr). *A Practical Guide, 1st Ed., Cham: Springer International Publishing*, 10(3152676):10–5555, 2017.

[3] Donald Shenaj, Giulia Rizzoli, and Pietro Zanuttigh. Federated learning in computer vision. *IEEE Access*, 2023.

[4] Brendan McMahan, Eider Moore, Daniel Ramage, Seth Hampson, and Blaise Aguera y Arcas. Communication-efficient learning of deep networks from decentralized data. In *Artificial intelligence and statistics*, pages 1273–1282. PMLR, 2017.

[5] Bingyan Liu, Nuoyan Lv, Yuanchun Guo, and Yawen Li. Recent advances on federated learning: A systematic survey. *Neurocomputing*, page 128019, 2024.

[6] Deepthi Jallepalli, Navya Chennagiri Ravikumar, Poojitha Vurtur Badarinath, Shravya Uchil, and Mahima Agumbe Suresh. Federated learning for object detection in autonomous vehicles. In *2021 IEEE Seventh International Conference on Big Data Computing Service and Applications (BigDataService)*, pages 107–114. IEEE, 2021.

[7] Vinit Hegiste, Tatjana Legler, and Martin Ruskowski. Federated ensemble yolov5–a better generalized object detection algorithm. In *2023 Eighth International Conference on Fog and Mobile Edge Computing (FMEC)*, pages 7–14. IEEE, 2023.

[8] Hao Guan, Pew-Thian Yap, Andrea Bozoki, and Mingxia Liu. Federated learning for medical image analysis: A survey. *Pattern Recognition*, page 110424, 2024.

[9] Keval Doshi and Yasin Yilmaz. Federated learning-based driver activity recognition for edge devices. In *Proceedings of the IEEE/CVF Conference on computer Vision and Pattern Recognition*, pages 3338–3346, 2022.

[10] Cristian Tangemann. Sensor fusion, 2022. Accessed on 29.09.2022.

[11] Markus Willems. A dsp for implementing high-performance sensor fusion on an embedded budget, Nov 2021.

[12] robert laganière. Sensor fusion for autonomous vehicles: Strategies, methods, and tradeoffs, 2022. Accessed on 18.12.2022.

[13] Dan Leibholz. Real-time sensor fusion challenge, 2022. Accessed on 29.09.2022.

[14] Ann Steffora Mutschler. Sensor fusion challenges, 2022. Accessed on 29.09.2022.