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Federated Learning for Assisting the Visually-Impaired Using Augmented Reality

A Goal Document for a Master’s Thesis Work

By

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2025

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Project start: 2025-02-10

Project end: 2025-06-10

Course Code: EITM02

1. Introduction

This thesis focuses on implementing a federated learning system to train machine learning models while ensuring data privacy. Instead of collecting data in one central location, client devices with compact GPU modules train models locally and share only updates with a central server. The server combines these updates to improve the global model, which is then sent back to the clients for further training. This process continues until the model reaches the desired performance. The system will be implemented using a cloud platform or a standalone server.

In addition to ensuring data privacy, this research explores the application of federated learning for assisting visually-impaired individuals using augmented reality. By leveraging a decentralized model training approach, the system can process real-time sensory data on local devices, enhancing accessibility tools without compromising user privacy. The goal is to improve navigation and interaction capabilities for visually-impaired users by integrating federated learning with augmented reality interfaces. This research aims to demonstrate how federated learning enables secure, decentralized model training while facilitating innovative assistive technologies.

1. Background and Motivation

This research explores federated learning as a privacy-preserving method for training models while enhancing assistive technologies for visually-impaired individuals using augmented reality. Traditional centralized data collection poses ethical and security risks, particularly in sensitive domains like healthcare and accessibility solutions. By keeping data on local devices, federated learning ensures privacy while enabling continuous improvement of AI-driven assistive tools. Integrating this approach with augmented reality allows for real-time enhancements in navigation and object recognition, improving independence and safety for visually-impaired users.

1. Project Aims and Main Challenges

The primary goal of this project is to design and implement a federated learning network that enables real-time assistance for visually-impaired individuals using augmented reality. By deploying federated learning, we aim to enhance AI-driven assistive tools while maintaining user privacy.

This research will focus on:

* Developing a decentralized system where multiple clients (nodes) train machine learning models locally and share updates with a central server.
* Ensuring privacy-preserving model training while improving real-time object recognition and navigation assistance.
* Evaluating the effectiveness of federated learning in assistive technology compared to traditional centralized training approaches.

Key challenges include optimizing communication between devices, ensuring efficient model aggregation, and integrating augmented reality interfaces with federated learning.

1. Approach and Methodology

The project will follow a structured step-by-step approach:

1. Develop a CNN model using the MNIST dataset in Python.
2. Learn to work with Jetson Nano and configure it for machine learning applications. Deploy and run the CNN model on the Jetson Nano.
3. Develop a federated learning program that enables communication between the devices and a central server.
4. Establish a communication network between the Jetson Nano devices and the PC.
5. Run the federated learning program with multiple clients (Jetson Nano devices) and a central PC to train a model collaboratively.
6. Assess potential improvements such as adding more clients, increasing dataset complexity, and improving overall scalability.
7. Test the scalability of the federated learning system by adding more clients and increasing dataset complexity to improve real-world applicability.
8. Integrate the system with augmented reality to enhance real-time assistance for visually-impaired individuals, optimizing navigation and object recognition.
9. Previous work

Several studies have explored federated learning in various domains, focusing on privacy preservation, communication efficiency, and real-world applications. Fundamental concepts and methodologies in this field are discussed in [1][2], while more recent developments and challenges are addressed in [3][4][5]. These works provide a solid foundation for understanding federated learning and its implementation in decentralized machine learning systems.

Recent research [6][7][8] has also explored the integration of federated learning with assistive technologies, demonstrating its potential for privacy-preserving AI-driven applications. In the context of visually-impaired individuals, federated learning can enable real-time adaptation of augmented reality systems by continuously improving recognition models without exposing sensitive user data. This approach enhances personalized assistance while maintaining strict privacy standards.

References:

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[8] S. Baghersalimi, T. Teijeiro, A. Aminifar, and D. Atienza, “Decentralized federated learning for epileptic seizures detection in low-power wearable systems,” *IEEE Transactions on Mobile Computing*, vol. 23, no. 5, pp. 6392–6406, May 2024, doi: 10.1109/TMC.2023.3320862.

1. Advancements and Outcome

The theoretical foundations of this research will be validated through real-world experiments, demonstrating the practical feasibility of federated learning in a controlled environment. The findings will contribute to the academic discourse on decentralized machine learning and may serve as a basis for further developments in the field.

In addition, the system will be tested in the context of assisting visually-impaired individuals using augmented reality. By evaluating the performance of real-time object recognition and navigation support, we aim to assess how federated learning enhances assistive technologies while preserving user privacy. These tests will help refine the system and ensure its effectiveness in practical applications.

1. Resources

To complete the project successfully, the following resources are required:

* High-performance computing resources (PC with sufficient computational power for server-side processing).
* Jetson Nano devices with network communication capabilities.
* Python and relevant machine learning frameworks (TensorFlow, PyTorch, or TensorFlow Federated).
* Networking setup to enable communication between multiple devices.

The project will initially be conducted at the university, with plans to expand to a larger-scale environment if successful.

This goal document is approved by:

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| Main Supervisor  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  Amir Aminafar |  | Examiner  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  Christian Nyberg |

Project Plan

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| Task 1: 10th Feb – 14th Feb:   * Goal Document   Task 2: 17th Feb – 23th Feb:   * Basic CNN with MNIST in python * On PC   Task 3: 24st Feb – 10th March   * Get to know the Jetson Nano * Search for all the components necessary for network communication * Install an OS on the Jetson * Run the CNN on the Jetson Nano   Task 4: 3st March – 24th March   * Make a python Federated Learning code combined with the CNN * Using 2 clients * On the PC   Task 5: 17st March – 14th April   * Make an network connection between the Jetson Nano and PC * Set up communication * Set up and try Federated Learning Network   Task 6: 14th April– 28th April   * Set up and try Federated Learning Network * Add other client(s)   Task 7: 28th April– 9th May   * Test the scalability * Add more clients   Task 8: 9th May - 21th May   * Add the Visually-impaired application * Test the Visually-impaired application in combination with the Federated learning model   Task 9: 14th April – 1st June   * Write the report * Make the PowerPoint for the presentation |

1. A graph with black rectangular shapes

   AI-generated content may be incorrect.The project plan for the thesis work.
2. A Gantt chart over the project plan from Fig. 1.

This project plan is approved by:

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| Main Supervisor  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  Amir Aminafar |  | Examiner  \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_  Christian Nyberg |