Degree project 30 credits in Biomedical Engineering

Medical Image-to-Image translation in federated learning

Biomedical Engineering R&D (MT-FoU) is a research and development department at the Center for Information Technology and Biomedical Engineering at Norrland University Hospital, Region Västerbotten. The department conducts international research, development and education in the field of biomedical engineering, with expertise in, for example, sensors and measurement systems, image and signal analysis and biomechanical models. MT-FoU is also a part of the competence center AI for Medicine in Northern Sweden, AIM North, which supports clinical research projects with technical method expertise in machine learning and AI.

Background

Image-to-image translation is a technique that transforms images from one domain to another, offering significant potential in the medical imaging field. However, these methods still rely on centrally collected records which raises significant privacy and security concerns, especially in healthcare. Federated Learning (FL) offers a decentralized solution by allowing institutions to train models locally on their data without sharing sensitive information. Instead of sending raw data to a central server, only model updates are aggregated, preserving privacy and complying with regulations (e.g., GDPR). Integrating image-to-image translation within the federated learning framework presents its own set of technical challenges. Medical imaging data from different institutions comes from various scanners, acquisition protocols, and patient demographics, creating heterogeneity that complicates model convergence. Furthermore, ensuring consistency and high performance across all local models while maintaining privacy is not trivial. Despite these challenges, the combination of image-to-image translation and FL has the potential to advance medical image analysis. By enabling collaborative learning across healthcare institutions without compromising data privacy, FL can pave the way for more inclusive, generalizable, and safe medical imaging models. This approach could accelerate advancements in clinical applications such as disease diagnosis, image enhancement, and cross-modality image synthesis.

Aim of the project

The aim of this project is to develop a secure and privacy-preserving framework for medical image-to-image translation using Federated Learning (FL). By leveraging FL, the project seeks to enable decentralized model training across multiple (simulated) institutions, ensuring that sensitive medical data remains local while collaboratively improving image translation models.

Work description

The key objectives and tasks for this project include:

1. **Literature review**: research existing image translation techniques with possible intersection with FL strategies. The focus will be on identifying methods relevant to medical imaging and understanding current challenges in decentralized learning.
2. **Data preprocessing and model implementation:** we plan to use publicly available datasets as well as in-house data. The dataset will be divided into simulated "centers" according to specific criteria, such as imaging modality, patient demographics, or geographical regions, to mimic an FL environment. This division will ensure that each simulated centre holds its localized data. Preprocessing will be facilitated by ongoing research and existing scripts. For model implementation, existing implementations developed by the lab about image-to-image translation models will be leveraged, allowing the project to focus on FL.
3. **Comparison of Federated Learning Strategies**: Evaluate different FL strategies (e.g., FedAvg, FedProx, and FedMA) within the image-to-image translation framework. The comparison will focus on the trade-offs in convergence speed, accuracy, and robustness across diverse client datasets.
4. **Validation and Testing**: Validate the performance of the image-to-image translation models trained using FL strategies on unseen medical data. Both quantitative metrics and qualitative evaluations will be used to assess the fidelity of the translated images.
5. **Reporting and Documentation:** document all stages of the project, including methods, results, and insights gained, producing a final report.

If your program has 15 credits rather than 30, we will adapt the scope of the thesis to fit within the credits.

Supervisor at MT-FoU
Paolo Soda and Francesco Di Feola
CIMT, Medicinsk teknik – FoU
Region Västerbotten
E-post: paolo.soda@umu.se, francesco.feola@umu.se
Web: https://www.regionvasterbotten.se/medicinsk-teknik-forskning-och-utveckling, https://www.umu.se/en/staff/paolo-soda/