ECG Monitoring Healthcare System with Federated Transfer Learning and Explainable AI

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Abstract

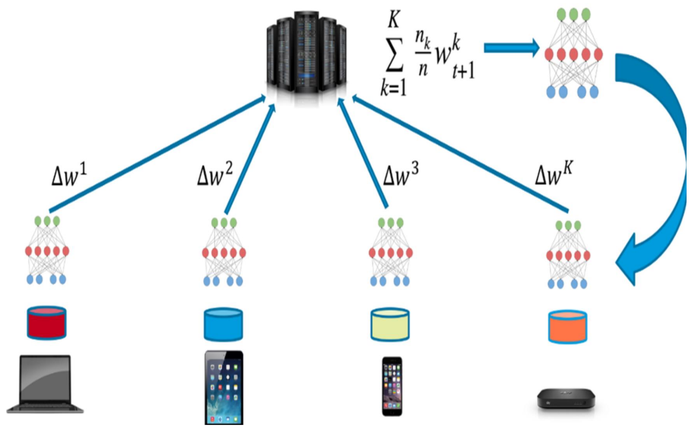
Deep learning plays a vital role in digital healthcare. However, it generally requires large datasets to train a robust model. Collecting such large datasets have certain limitations: not easily available from a single silo, and collecting them in a central repository has data privacy concerns. Moreover, due to complex nature of deep models, its hard to interpret the reasons and causes of results of such models. Hence, we propose a framework in federated setting for enhanced privacy, where globally distributed silos (hospitals and organizations) can jointly train agreed robust model(s). Additionally, we proposed an explainable AI based model to interpret the results of proposed framework. We show applicability of the proposed framework using Electrocardiograph (ECG) classification as an example application.

Objectives

- Designing an explainable artificial intelligence (XAI) based deep learning framework in a federated setting for healthcare applications.
- Use federated learning to solve issues such as data availability and privacy concerns.
- Framework to effectively classify arrhythmia's using an autoencoder and a classifier based on deep learning (Convolutional Neural Networks)
- Design of interpretable-AI based module to help interpret the predictions of proposed framework.

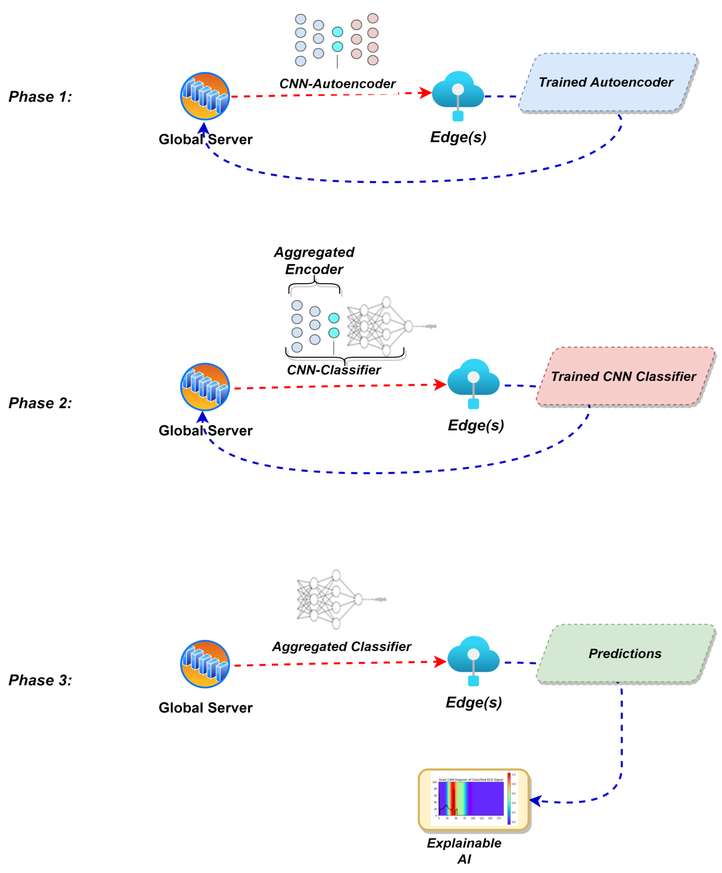
Federated Learning

- Federated learning (FL) can be used to train a robust model collaboratively, without sharing the data.
- Instead of sharing data, participating peers/edge(s) in FL share parameters of locally trained models.
- A global server or aggregator aggregates the shared parameters according to a given aggregation algorithm .
- Peers/edge(s) download the global model from the global server.
- This process repeats until a desired performance of global model is achieved.

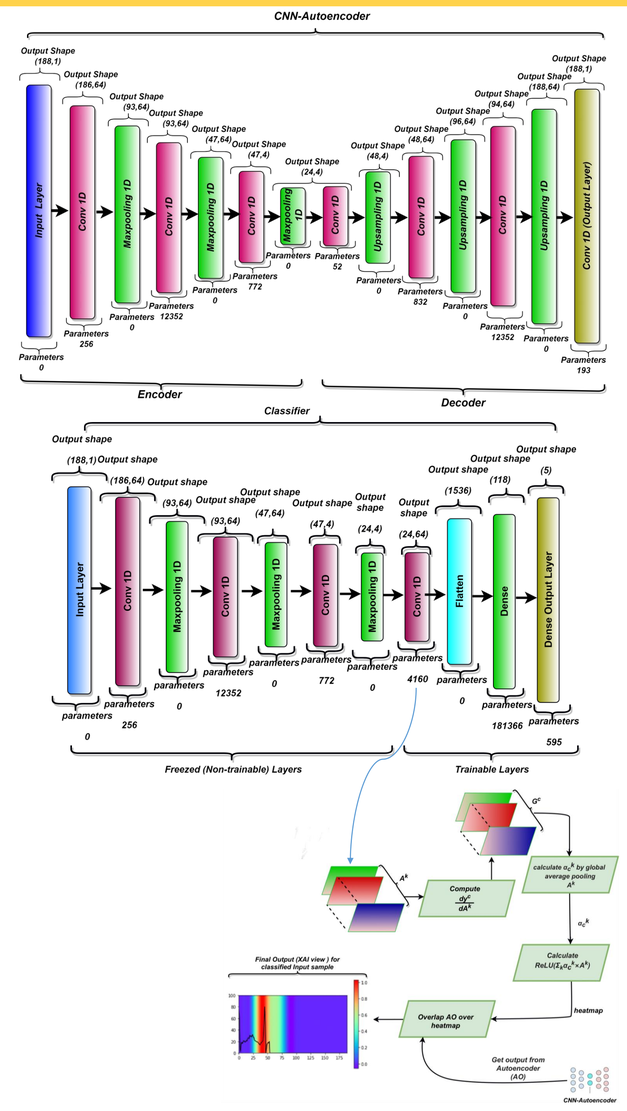


Federated Learning architecture

Overview

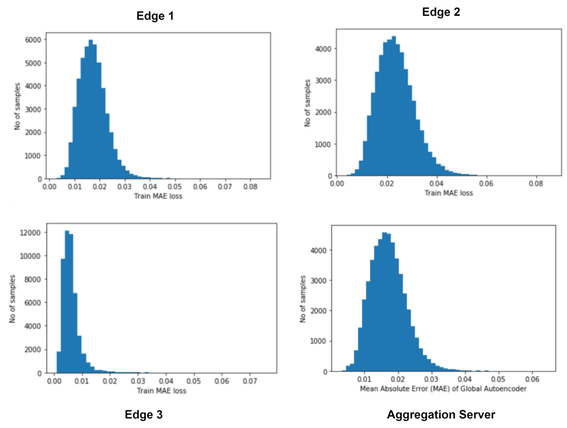


Proposed Framework



Results

Reconstruction MAE



Classification Performance

Class	Precision	Recall	F1-Score	Overall Accuracy
N	89	91	90	94.9%
S	94	89	92	
V	93	96	94	
F	95	94	95	
Q	99	99	99	

Edge 1 (20% noise)

Class	Precision	Recall	F1-Score	Overall Accuracy
N	85	87	86	91.9%
S	91	87	88	
V	91	94	92	
F	93	93	93	
Q	98	98	98	

Edge 2 (30% noise)

Class	Precision	Recall	F1-Score	Overall Accuracy
N	94	98	96	97.9%
S	98	92	95	
V	95	99	97	
F	99	94	96	
Q	97	100	98	

Edge 3 (10% noise)

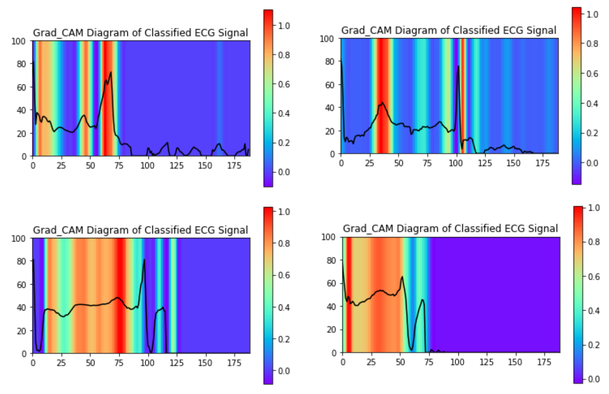
Class	Precision	Recall	F1-Score	Overall Accuracy
N	95	99	97	98.9%
S	98	97	98	
V	97	99	98	
F	99	93	96	
Q	100	100	100	

Global/Aggregation server (clean data)

Class	Precision	Recall	F1-Score	Overall Accuracy
N	90	92	91	94.5%
S	94	89	91	
V	93	96	94	
F	95	96	95	
Q	99	99	99	

Global/Aggregation server (noisy data)

XAI Results



Conclusions

- AI-based framework was proposed to collaboratively train a model with enhance privacy of deep learning-based healthcare applications, e.g., ECG signal classification.
- We extended the usability of the proposed framework by providing an interpretable module on top of the classifier, which can be used to interpret the classification results.

See the following paper for more details:

Raza, A., Tran, K. P., Koehl, L., & Li, S. (2022). Designing ECG monitoring healthcare system with federated transfer learning and explainable AI. Knowledge-Based Systems, 236, 107763.