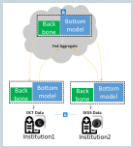

Privacy preserving federated learning for multi-modality multi-institution image segmentation

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HAMLYN SYMPOSIUM ON MEDICAL ROBOTICS

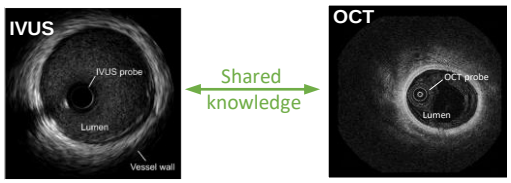
Introduction

Clinical background: Side-viewing catheter-based medical imaging modalities are used to produce cross-sectional images underneath tissue surfaces. Mainstream side-viewing catheters are based on Optical Coherence Tomography (OCT) or Intravascular Ultrasound (IVUS), and they are often applied to the endoluminal environment. Real-time automatic lumen segmentation is a crucial task, which can be used to provide geometry information for applications like real-time lumen assessment and diagnosis or robotic control.

Objective: OCT and IVUS images share certain similarities and the same deep learning architecture can be applied to both of them. We seek to maximize the learning of common knowledge shared within two image modalities (e.g., the geometry), while allowing the networks to handle the domain gap (e.g., the signal intensity and attenuation).

Contributions:

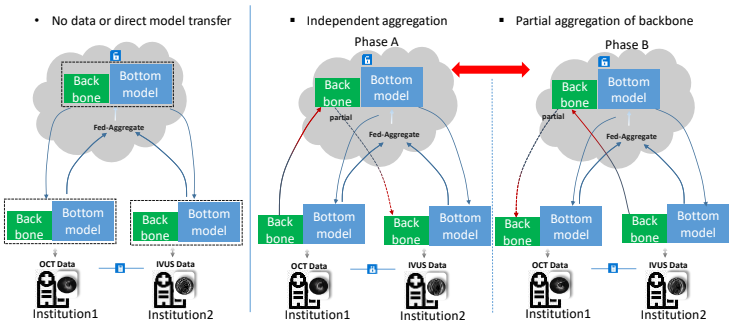
- A cross-domain federated learning pipeline is proposed to train models for processing OCT and IVUS images together, without sharing data between different institutions that hold private medical data.
- Relying on a previously proposed coordinates encoding network for side-viewing image segmentation, the proposed federated learning method addresses the weight update for the backbone feature extractor and coordinates.
- The federated trained networks achieved better performance (on OCT images and IVUS images) in comparison to a network that is only trained on IVUS or OCT images.



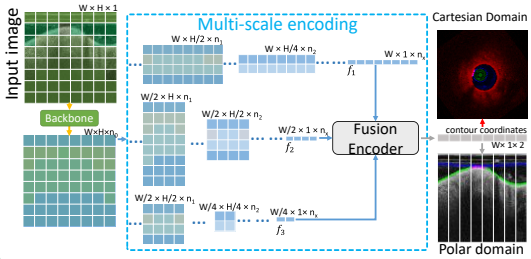
Method

IVUS-OCT cross domain federated learning

No data sharing agreement is needed, while learning from each other



Deep neural network architecture [1]



- Dense domain information from backbone module
- Geometry information from A-line encoding
- Suited for rotational scanning system (i.e., IVUS or OCT)

Results

Shared knowledge enhanced from cross domain fed-learning

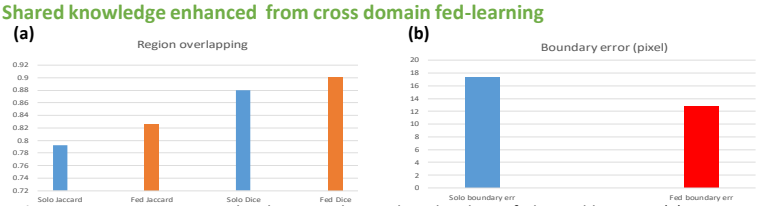


Figure 1 - Accuracy test on local unseen data with and with out federated learning. (a) Region overlapping score evaluated with Jaccard Index and Dice Coefficient (b) Average boundary error calculated with A-line coordinates in polar domain

Federated learning loss on statistical heterogeneity distribution

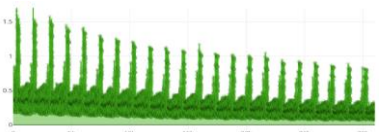
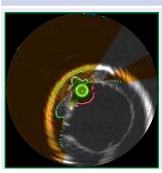
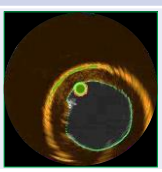
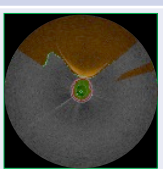
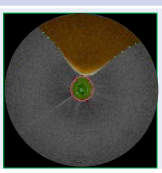


Figure 2 – Fed-learning loss of backbone

Figure 3 – Fed-learning loss of bottom model

Statistical heterogeneity distribution fed-learning

	Site A –W/O Fed	Site A – Fed learning	Site B –W/O Fed	Site B– Fed-learning
IoU	62.33 ± 14.16%	93.93 ± 4.66%	90.66 ± 10.40%	95.75 ± 2.21%
Exemp-lar Image				

Discussion

- Improved the generalization of networks by learning data from different institutions without any data center to collect all the images;
- Resolved the problem of statistical heterogeneity among institutions' datasets, and improved the network performance when institutions holding multi-domain data join the collaborative training pipeline;
- No data sharing between different medical centers, by safely aggregating models using protected cloud.

Future work

- Include more data centers in the federated training pipeline;
- Implement layer-wise partial aggregation, allowing each client to weigh each layer differently;
- Accelerate the federated update pipeline by increasing the communication between different medical centers.

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