Advancing Brain Vessel Analysis: From Annotation-Efficient Selection to Population-Scale Insights

MICCAI 2025 Doctoral Consortium

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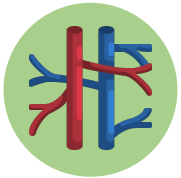
25 SEPTEMBER 2025

01 Research Context & Motivation

The Annotation Bottleneck Problem

Clinical Importance

Vessel segmentation is crucial in neurovascular imaging applications



Current Challenge

Deep learning models: extensive expert annotations requirements

Key Problems

- **Manual annotation** is time-consuming and **expensive**
- **Inconsistent annotation protocols** across experts and institutions
- **Important Gap** between research and real-world **clinical deployment**

02 Thesis Structure: Three Contributions

1) V-DiSNet - Smart Selection from Limited Data

"How to choose the right data to annotate"

2) VesselVerse - Collaborative Annotation Improvement

"How to scale annotation efforts through collaboration"

3) Clinical Translation - Proven Healthcare Impact

"How to bridge the gap between research and real-world deployment"

03

Contribution 1: V-DiSNet

Early Accepted - MICCAI 2025

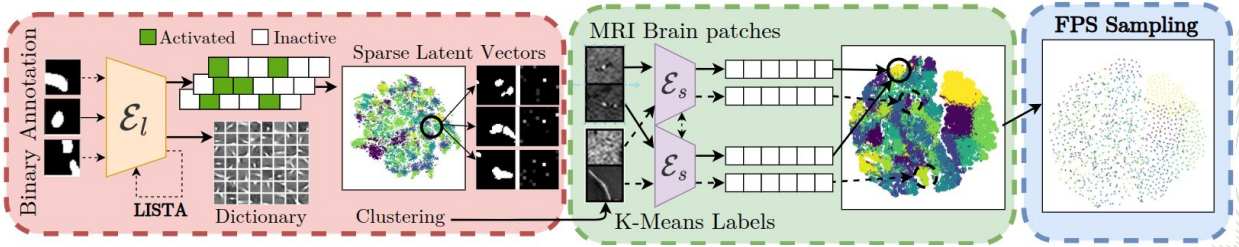
One-shot active learning for vessel segmentation

Daniele Falcetta, Hava Chaptoukaev, Francesco Galati, **Maria A. Zuluaga**

1) V-DiSNet - Framework & Results

Scientific Approach

Main Idea: Brain Vessel Tree exhibit recurring branching patterns



Identify Patterns: Elementary Atoms of a Learned Dictionary

+

Pattern Similarity Discovery through **K-Means Clustering**

+

Informative Patterns Selection with stratified further sampling

Key Results

Consistently outperform baselines across 3 Public Datasets (**low sample %**)

Breakthrough

Reach Interpretability and Data Efficiency by exploiting Vessel Pattern Similarity

04

Contribution 2: VesselVerse

Early Accepted & Spotlight Presentation - MICCAI 2025

VesselVerse: A Dataset and Collaborative Framework for Vessel Annotation

Daniele Falcetta, Vincenzo Marciano, Kaiyuan Yang,
Jon Cleary, Loic Legris, Massimiliano D. Rizzaro,
Ioannis Pitsiorlas, Hava Chaptoukaev,
Benjamin Lemasson, Bjoern Menze, **Maria A. Zuluaga**

2) VesselVerse: Dataset & Framework

Scientific Approach

Brain **Vessel Dataset** are **imperfect** due to annotation errors and subjective inconsistency

Dataset	#Images	#Annotations	Method Coverage	Modality
IXI	600	4,822	9/9 methods	TOF-MRA
TubeTK	100	800	8/9 methods	T1-MRA
TopCoW MRA	125	1,000	8/9 methods	MRA
TopCoW CTA	125	635	6/9 methods	CTA
Total VesselVerse	**950**	**7,257**	—	

Breakthrough:

A **Collaborative** Framework to incrementally improve **ANY type of Annotation** , beyond just brain vessels segmentation

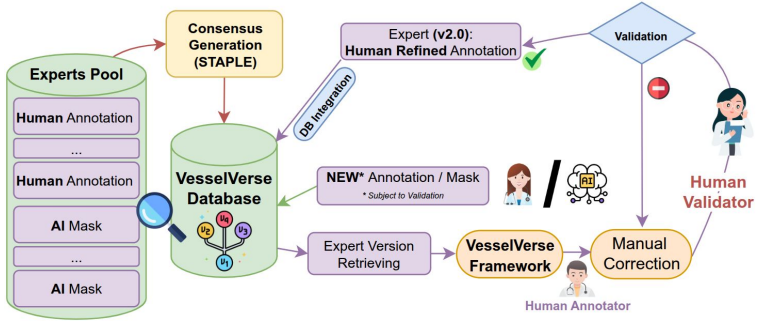
Largest *Imperfect* Dataset of Vessel Annotations

+

Annotations Tracking via **Data Versioning**

Key Results

- **7,200+ Annotations (950 Images)** in 3 datasets
- Up to **9 Annotators** between **Experts** and **AI Model**
- **Quality Validation** from 4 International Expert



05

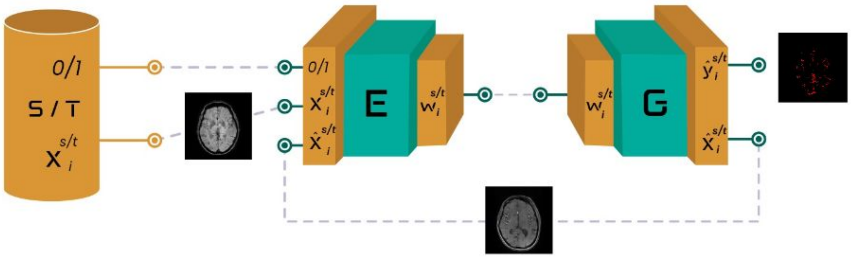
Contribution 3: Clinical Translation

Machine Learning for Biomedical Imaging, MELBA

Multi-domain Brain-Vessel Segmentation Through Feature Disentanglement

Francesco Galati*, **Daniele Falcetta***,
Rosa Cortese, Ferran Prados, Ninon Burgos, **Maria A. Zuluaga**

3) Clinical Translation in Three Real-World Healthcare Scenarios



MultiVesSeg: a cross-modality framework for Brain Vessel Segmentation

Built on a subset of **VesselVerse Dataset**

Easy to deploy across clinical applications

Grenoble Institut Neurosciences

1. AVA-Stroke: Automated Stroke Diagnosis

Large Vessel **Occlusions Detection** achieving **high accuracy and recall**.

King's College London

2. Genetic Vascular Analysis in TwinsUK Dataset

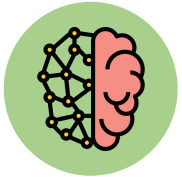
Smaller **vascular differences** in identical compared to fraternal twins.

CHU Grenoble Alpes · Inria · chu de Nice

3. Federated Vessel Segmentation Deployment

Privacy-preserving knowledge sharing across centers with diverse infrastructures.

06 Future Work & Conclusion



Develop Practical AI Systems

Focus on building Real-World applicable AI solutions.

Neurovascular Imaging Advancing

"From GPU to Bedside"
Transition improving patient outcomes

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Thank you for the attention!

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