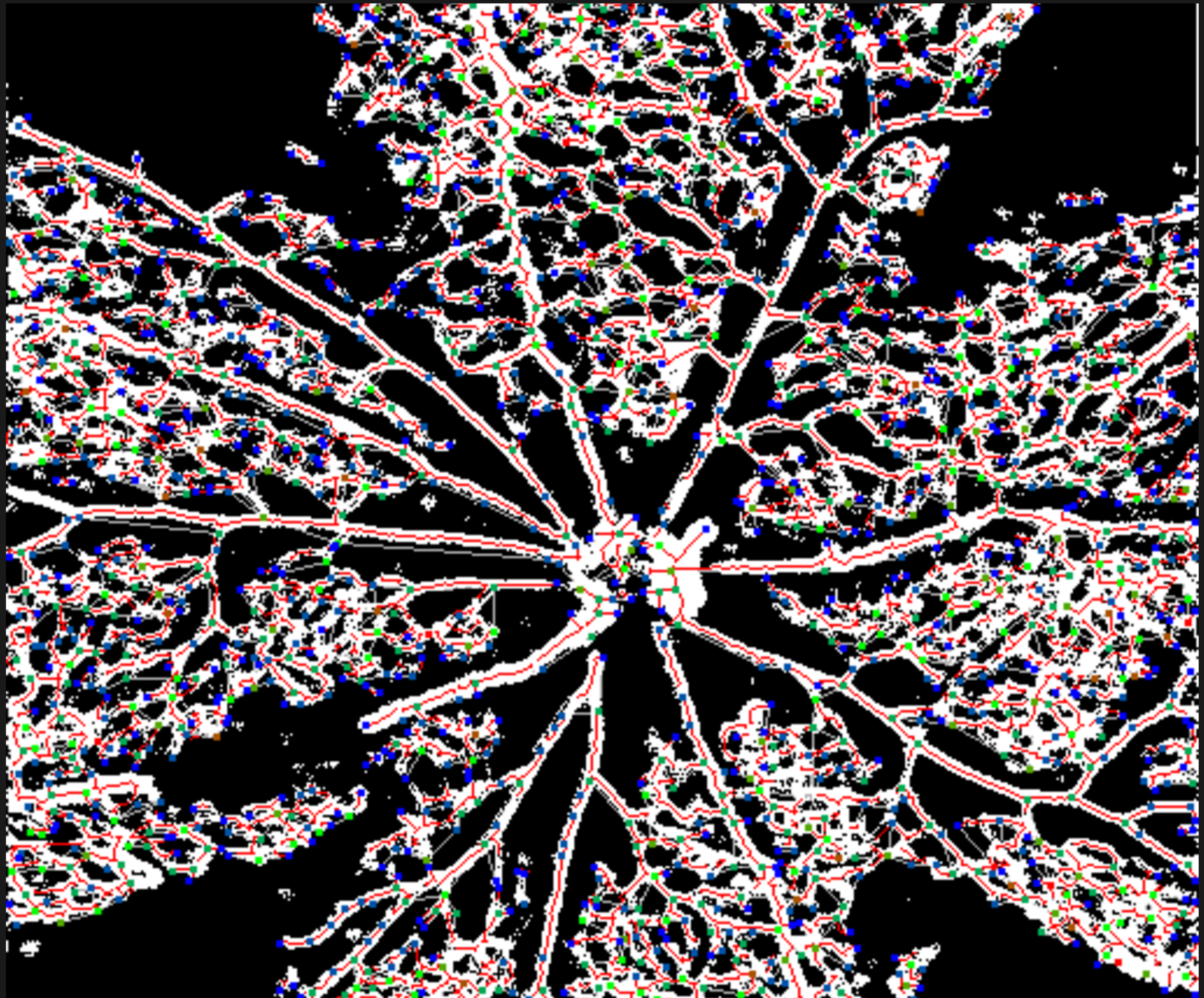
AngioNet



YASHAS H MAJMUDAR

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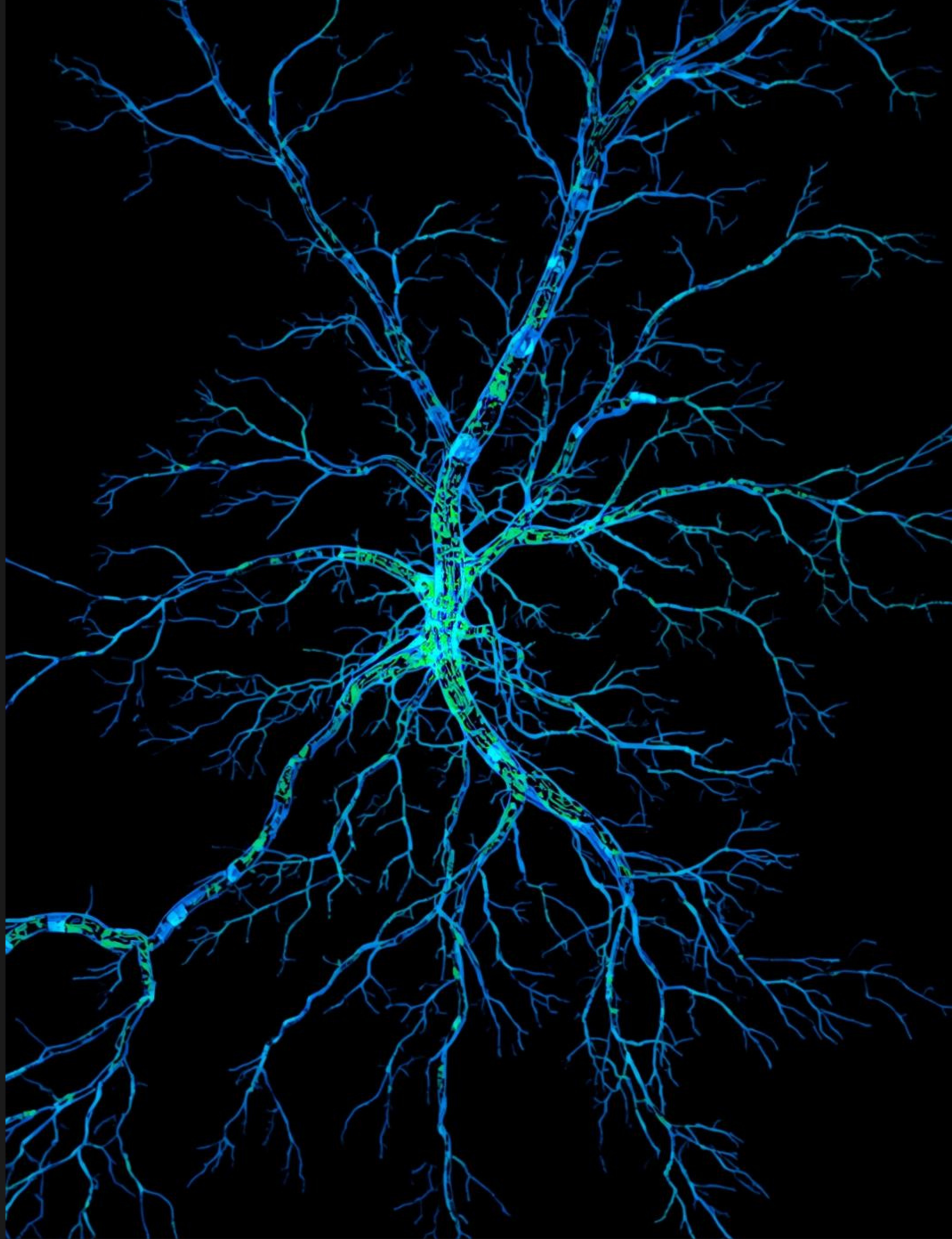
Importance of Retinal Vasculature

Understanding early vascular development as a critical angiogenesis model for research

The study of early retinal vasculature development is crucial as it serves as a **gold-standard model** for angiogenesis. The morphology of these vessels provides insights into various diseases and the **efficacy of treatments**. By automating our computational pipeline, we aim to enhance reproducibility and advance our understanding of vascular development.



Overview of Contributions

Segmentation

Deep learning-based segmentation technique

Feature Extraction

Graph-based morphological feature analysis

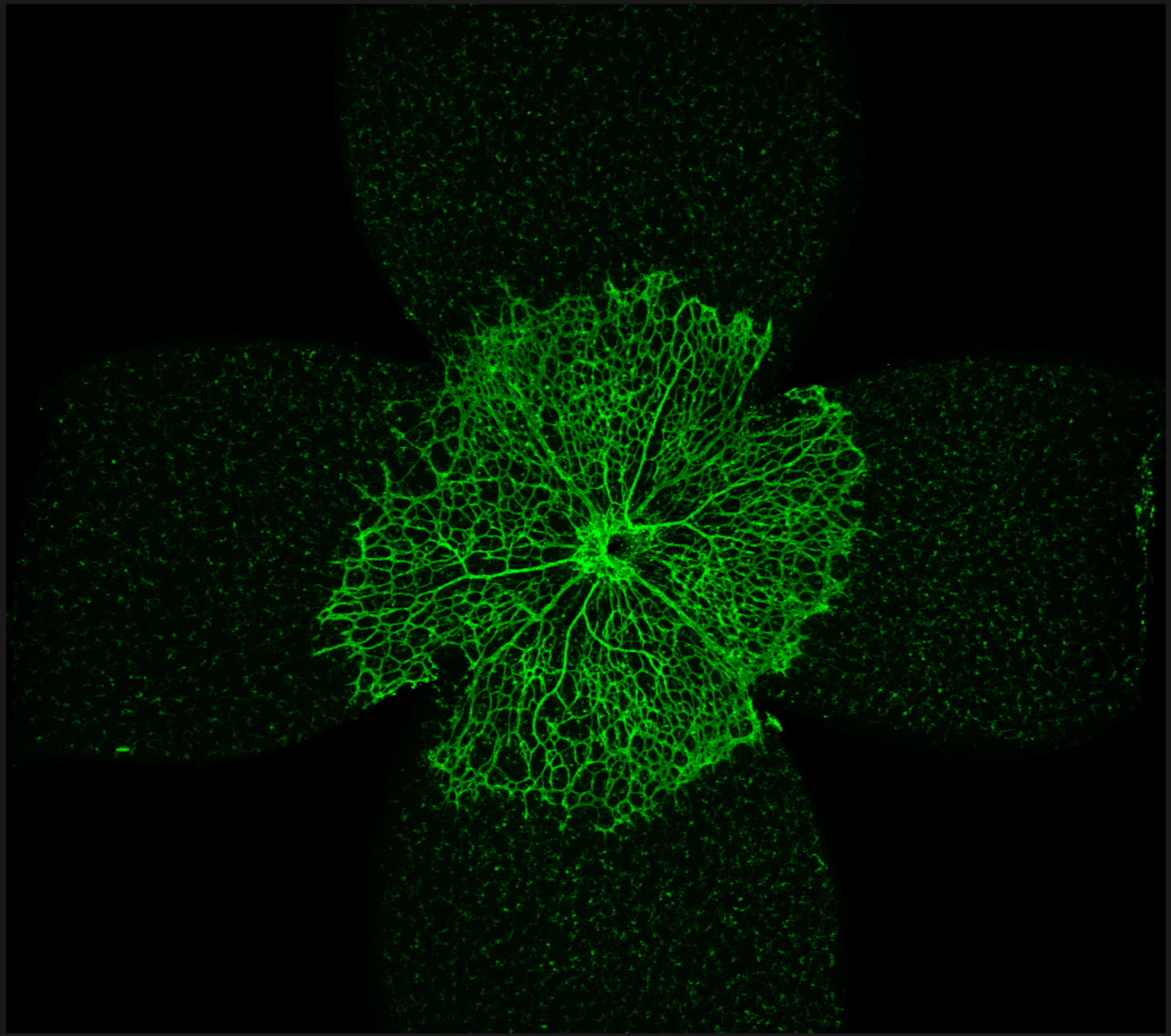
Exploratory Data Analysis

Comprehensive data exploration and insights

Reproducibility

Framework for consistent result replication

Data Overview: High-Resolution Imaging



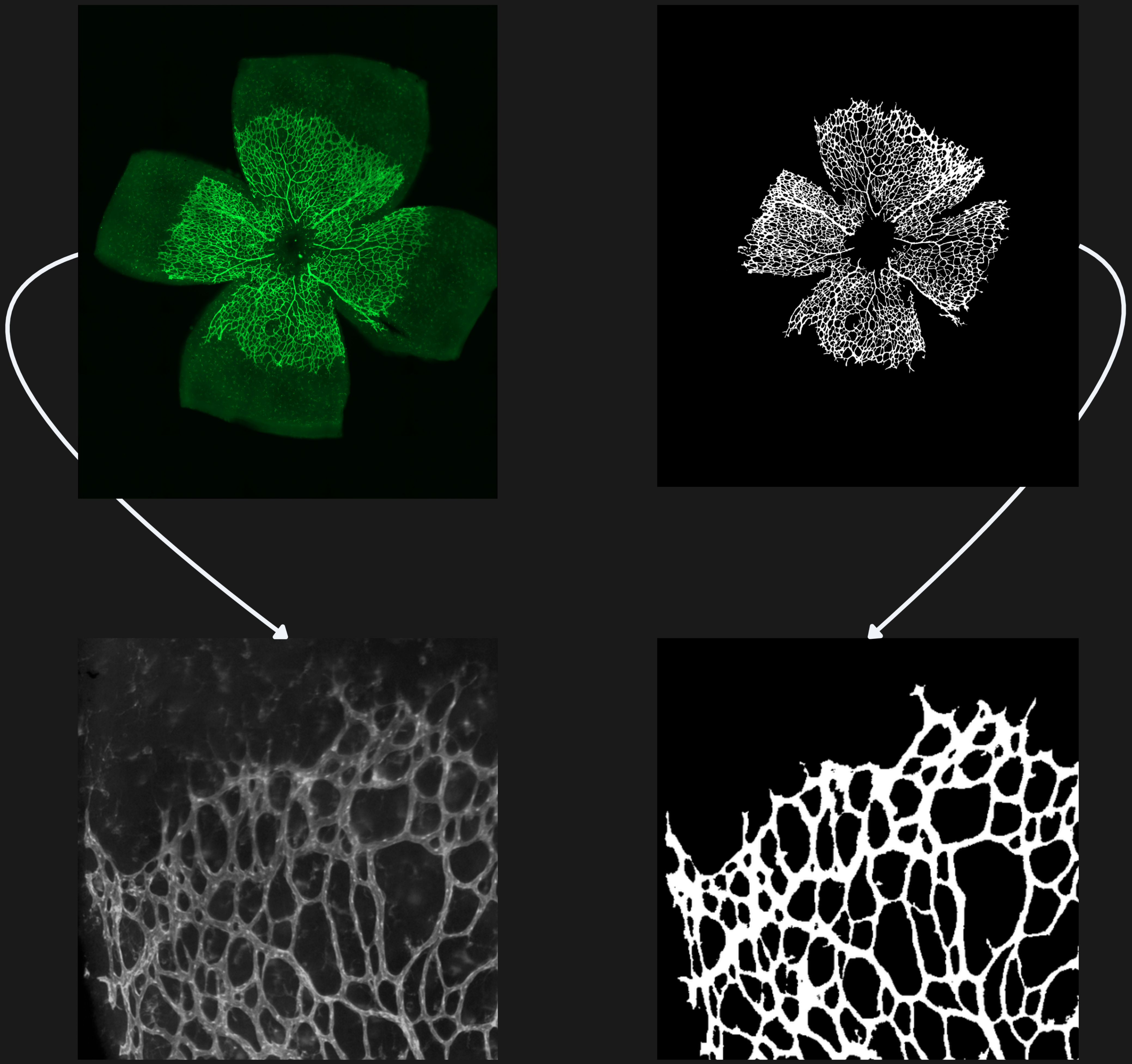
Retinal Vasculature

This image illustrates the complexities of retinal vessels.

Preprocessing Pipeline

Steps for Preparing High-Resolution Retinal Image Data for Analysis

The preprocessing pipeline is crucial for ensuring data quality and consistency. It involves converting RGB images to grayscale, extracting overlapping patches, and removing any patches with insufficient vessel pixels. This systematic approach guarantees the creation of a robust dataset that enhances the reliability of subsequent analyses and deep learning processes.



U-Net Architecture

Deep Learning

Utilizes advanced convolutional neural networks for precision

UNet

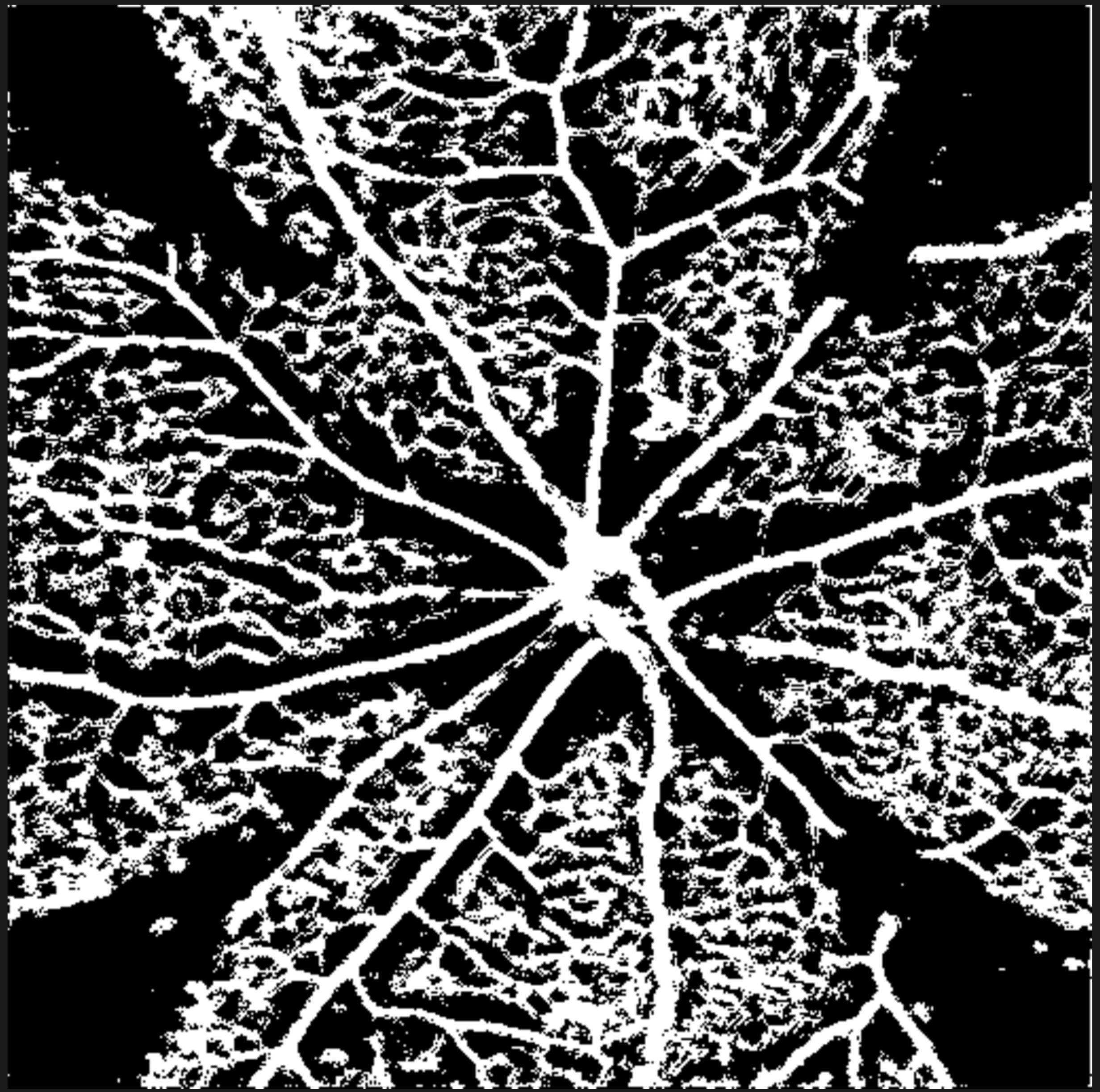
Encoder-decoder structure with skip connections that preserve fine-grained spatial information.

Model Efficiency

Optimized for fast and accurate segmentation

Training the Model

The model was trained by Adam optimizer with a learning rate of 1×10^{-5} and a batch size of eight patches. Binary cross-entropy with logits loss was employed, combining sigmoid activation with cross-entropy. Training was performed for seven epochs.



Prediction

Each patch was processed independently, followed by recombination to reconstruct the full-size segmentation mask.

Dice Score: 0.936

Indicates high segmentation accuracy

Pixel Accuracy: 91.85%

Effective vessel segmentation performance

Robust Generalization

Across vessel widths and patterns

Feature Extraction

Morphological Analysis

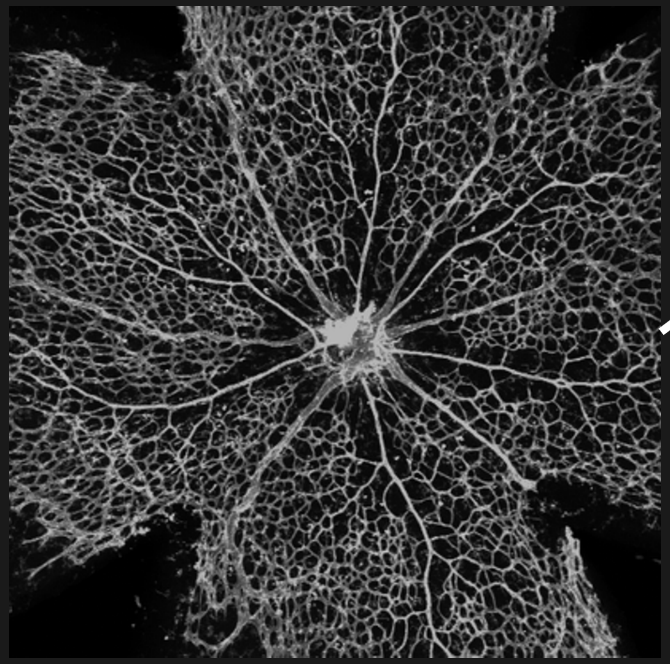
Analyzing vessel shapes and structures efficiently

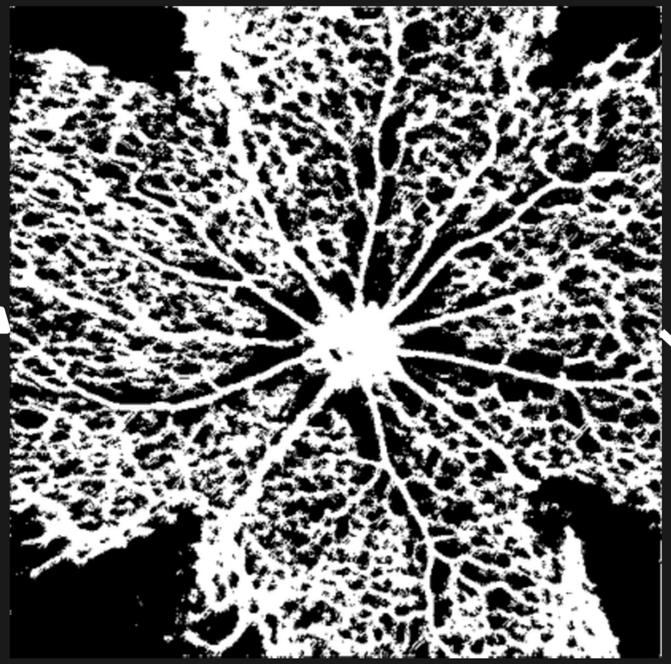
Graph Representation

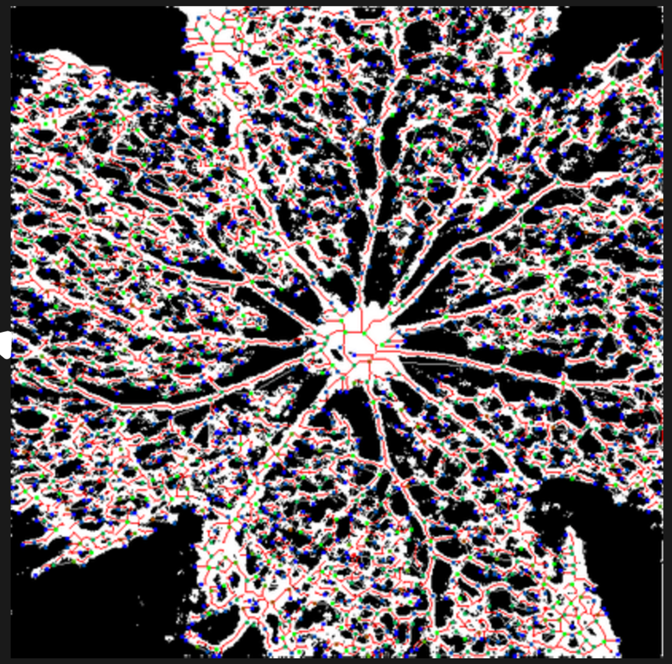
Utilizing NetworkX for advanced feature extraction

Node Characterization

Identifying key characteristics of vascular nodes



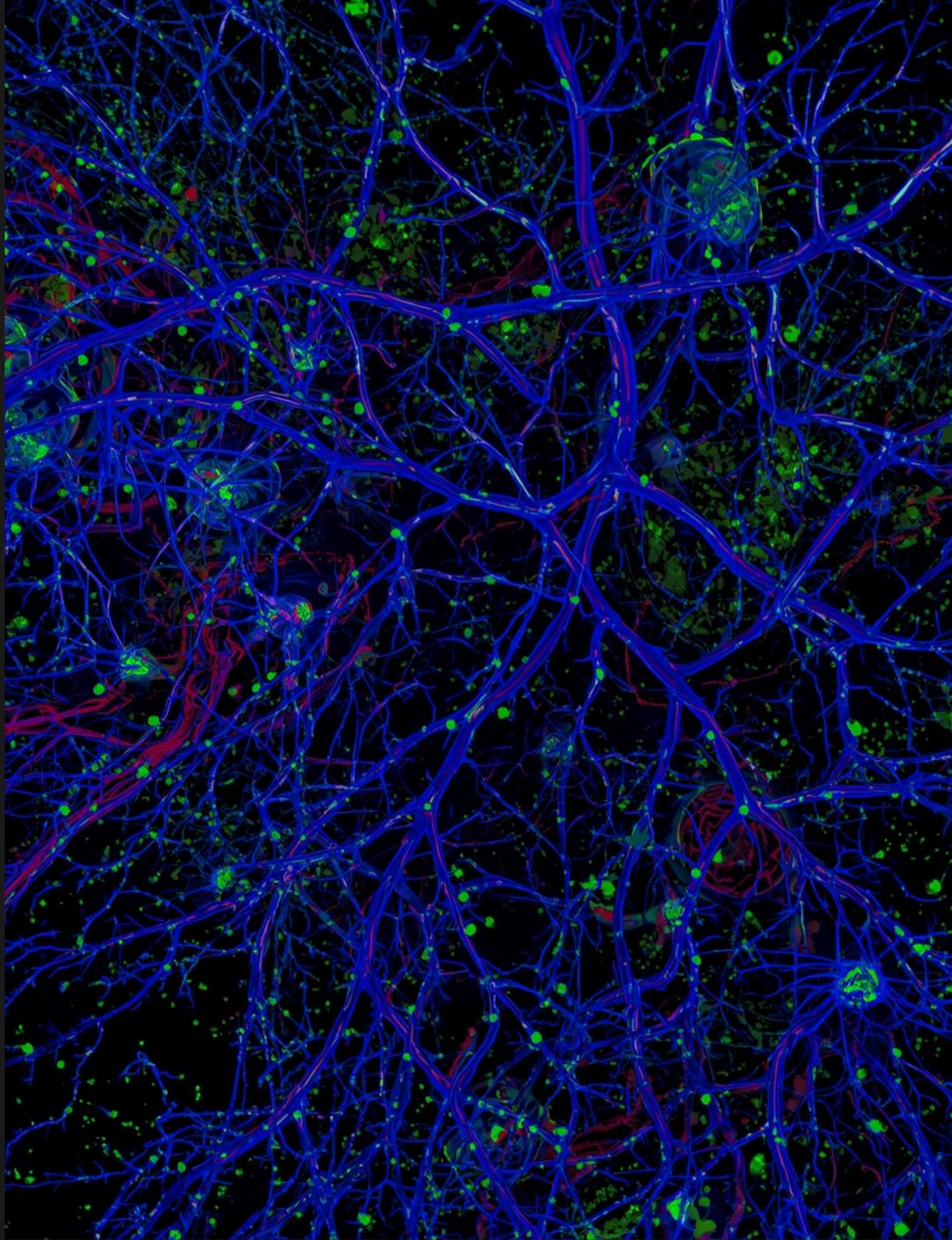




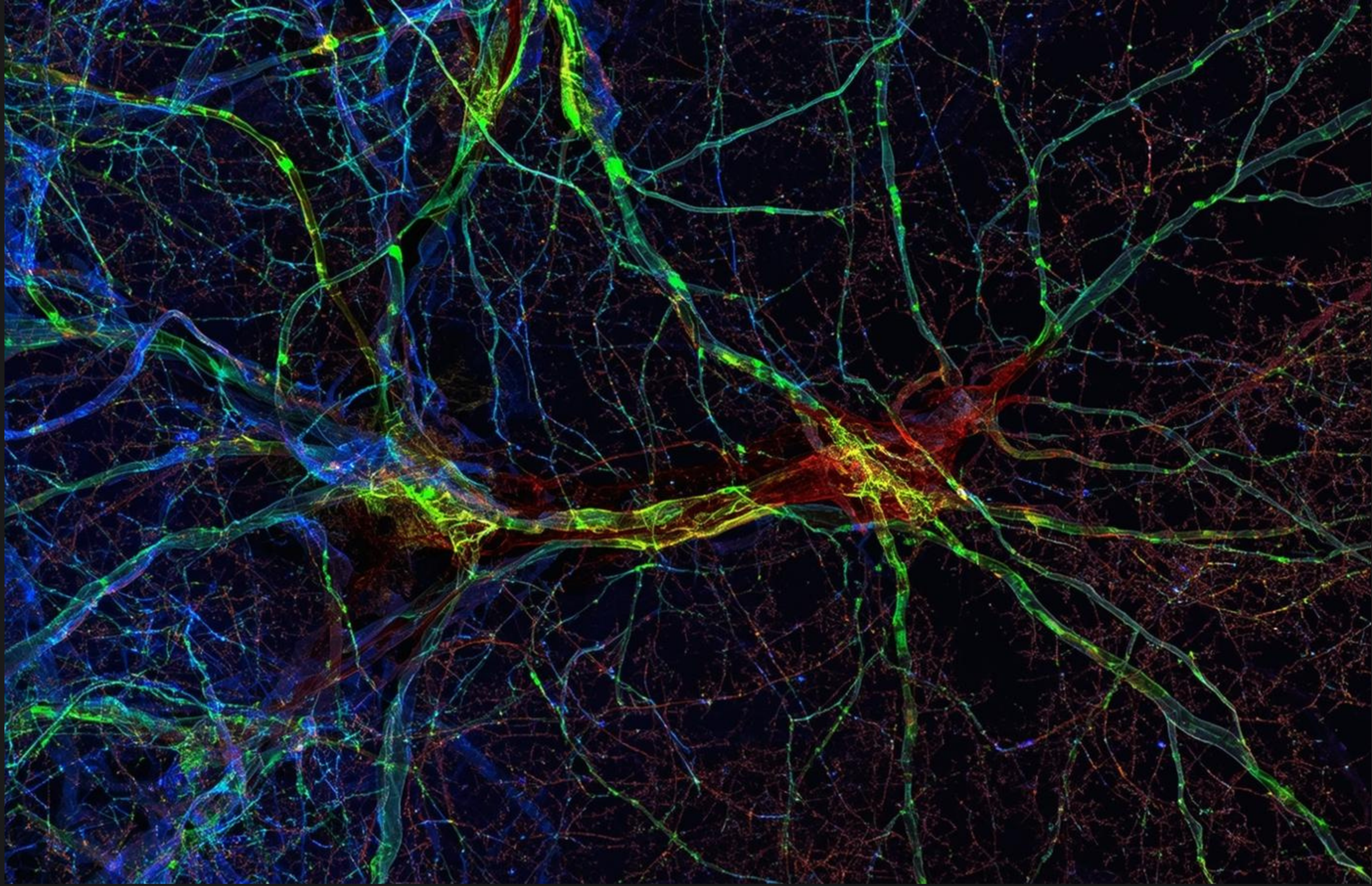
EDA Goals

Characterizing Vascular Structure and Network Properties Over Developmental Stages

The primary goals of the exploratory data analysis (EDA) are to characterize the **vascular structure** at both patch and developmental levels, identify morphological trends across stages P2 to P7, and quantify branching and network complexity, ensuring the validation of segmentation quality and detection of any anomalies or artifacts present.



Vessel Segment Statistics Overview



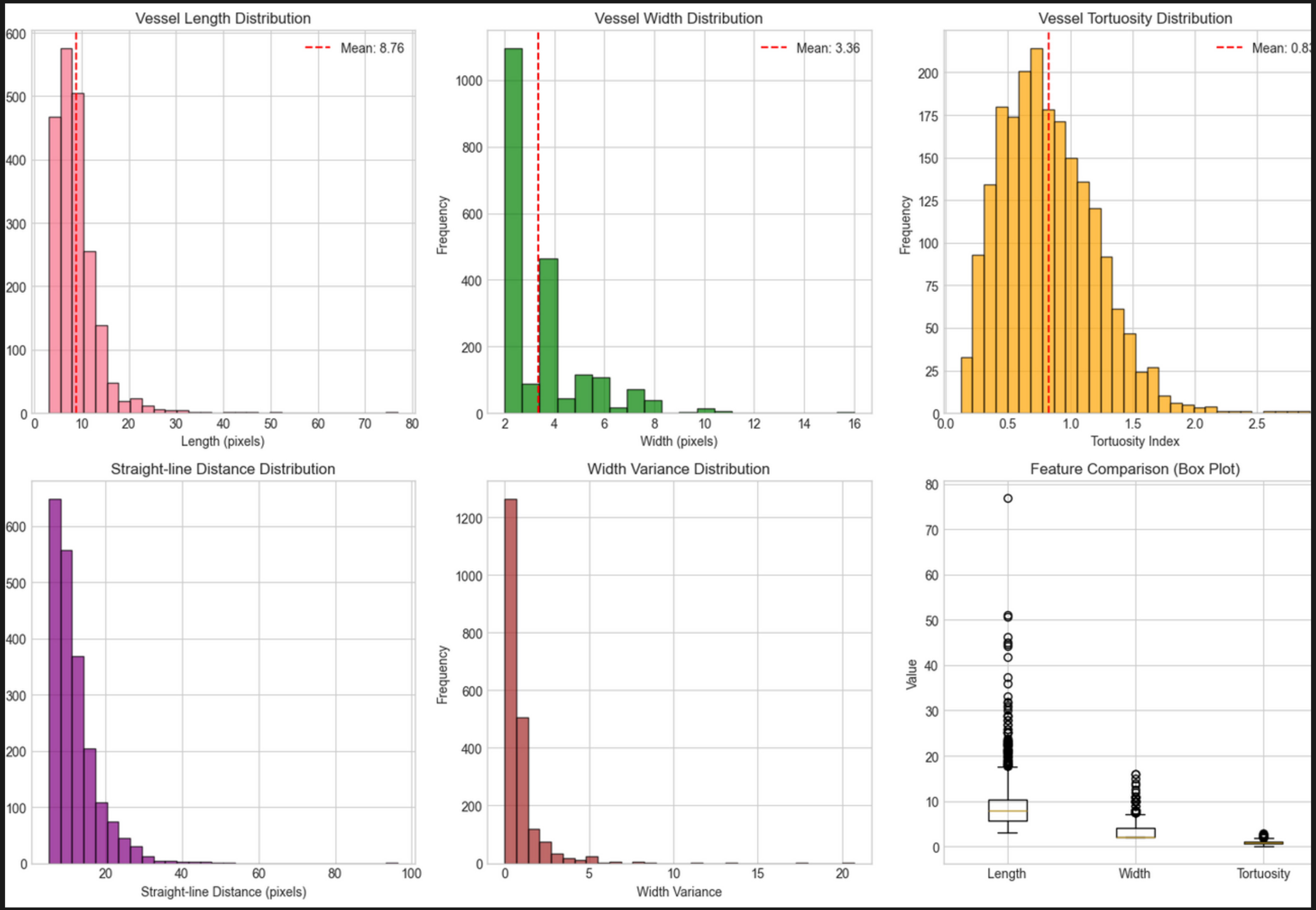
Vessel Feature Distributions

Length

Average segment length trends observed

Width

The average thickness of the segment.



Tortuosity

Changes in vessel curvature patterns

Variance

Width variance indicating stability changes

Node Degree Analysis

Degree 1
Endpoints represent **vessel endings** or sprouting fronts

Degree 2
Continuations indicate **straight sections** of vessels

Degree 3
Bifurcations show **branching points** in networks

Degree ⩾4
Complex junctions signify **network interconnections**

Node Type	Degree	Percentage	Biological Interpretation
Endpoint	1	15-25%	Vessel tips, sprouting fronts
Continuation	2	40-60%	Vessels pass through
Bifurcation	3	20-35%	Vessel splits into two
Higher-order	4+	5-15%	Complex junctions

Vessel Characteristics Correlations

Length

Strong correlation with straight-line distance

Width

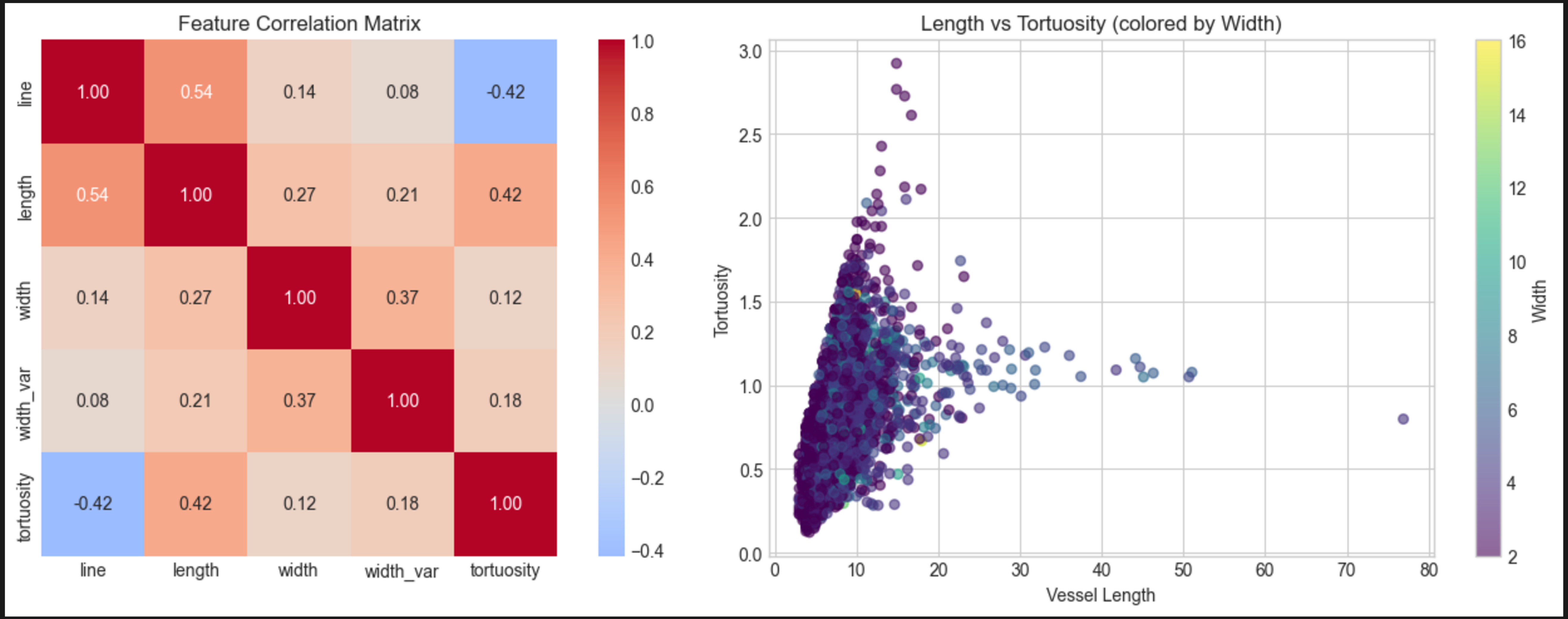
Moderate correlation with width variability

Tortuosity

Weak correlation with vessel length

Insights

Supports biological expectations and segmentation fidelity



Developmental Trends

Analyzing the evolution of vessel characteristics from P2 to P7 stages

The **developmental trends** observed across P2 to P7 illustrate significant changes in retinal vasculature. As the vessels mature, we see an **increase in length** and variability in width, while tortuosity decreases, indicating a more organized network. This progression is crucial for understanding angiogenesis and its implications in retinal health.

Day	Vessel Segments	Network Nodes	Mean Length	Mean Width
P2	635	545	8.61 ± 3.52	4.36 ± 3.14
P3	1180	947	8.74 ± 3.38	4.64 ± 2.88
P4	1736	1530	8.48 ± 3.81	3.96 ± 2.59
P5	2638	2132	9.04 ± 4.16	4.39 ± 2.83
P6	2425	2009	8.89 ± 4.38	4.13 ± 2.41
P7	4303	3705	8.88 ± 5.13	3.57 ± 1.88

Day	Mean Tortuosity	Bifurcation %	Endpoint %	Mean Distance
P2	0.823 ± 0.365	19.4%	39.4%	100.3
P3	0.846 ± 0.362	21.1%	32.6%	120.2
P4	0.818 ± 0.385	16.6%	40.7%	157.3
P5	0.858 ± 0.369	23.0%	32.1%	190.1
P6	0.836 ± 0.374	20.4%	36.2%	193.0
P7	0.833 ± 0.373	21.5%	34.8%	191.6

Analysis of Network Statistics

- Vessel length exhibited a right-skewed distribution, with most vessels being short to medium in length.
- Mean vessel length increased progressively from P2 to P7, reflecting network maturation.
- Vessel width distributions were often bimodal, indicating the presence of both capillaries and larger vessels.
- Width variability decreased slightly over development as vessel types differentiated.
- Tortuosity, defined as the ratio of actual vessel length to straight-line distance, showed a predominance of vessels in the normal range.
- Tortuosity decreased over time, consistent with optimization of vascular paths during maturation.
- Across development, the bifurcation ratio increased while the endpoint ratio decreased, indicating reduced sprouting and enhanced network complexity.
- Spatial distribution, measured as distance from the optic nerve head, expanded radially with development, confirming expected patterns of vascular growth.

Reproducibility

Demo

Questions?