Vessel segmentation of the retina

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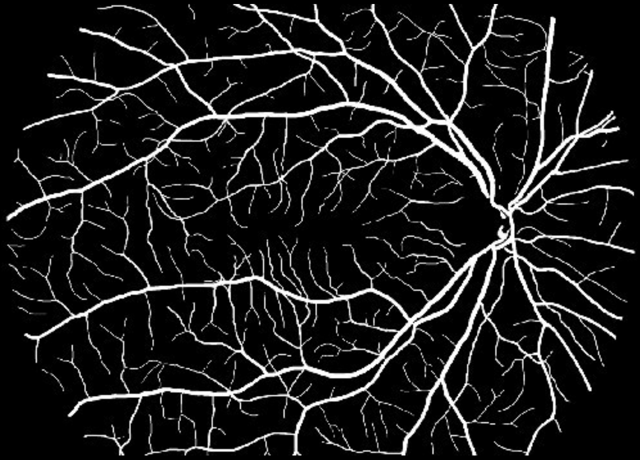
Motivation

- SSIP 2012
- Diagnostics
  - Measurements
  - Abnormalities
  - Laser surgery
- Registration
  - Different modalities

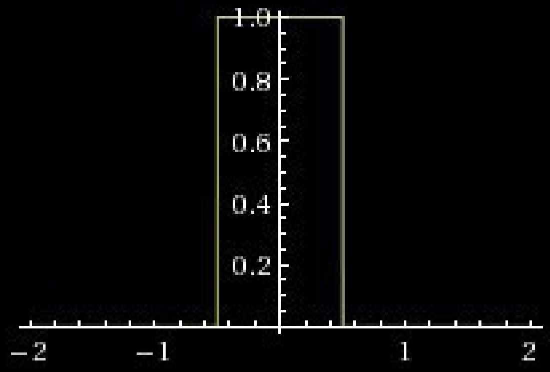


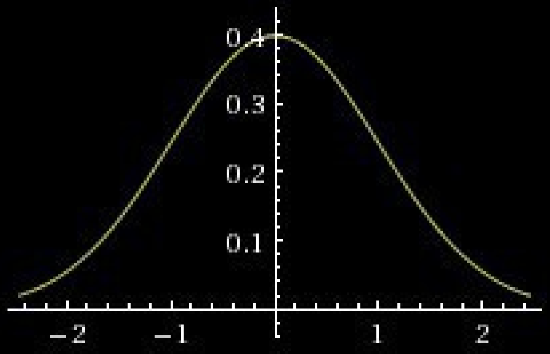
Difficulties of segmentation

- No universal solution
- Methods depend on:
    - Modality
    - Approach
    - Automatic / Manual
- Complex problem
    - Combination of different approaches
    - Specific detectors for all situations

Vessel properties

- Tubular structure
- Linear segments
- Similarity to one another
- Cross-section can be approximated by box or Gaussian functions

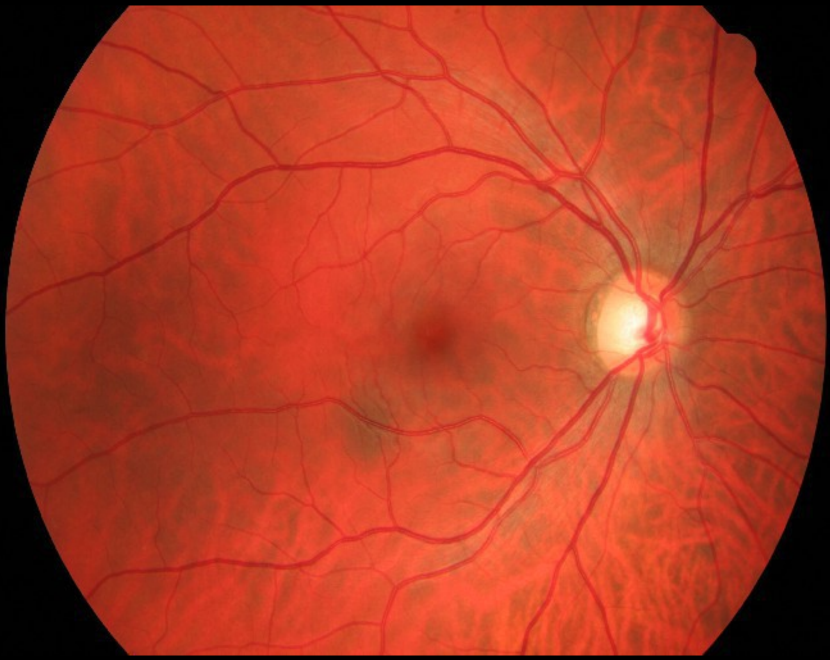




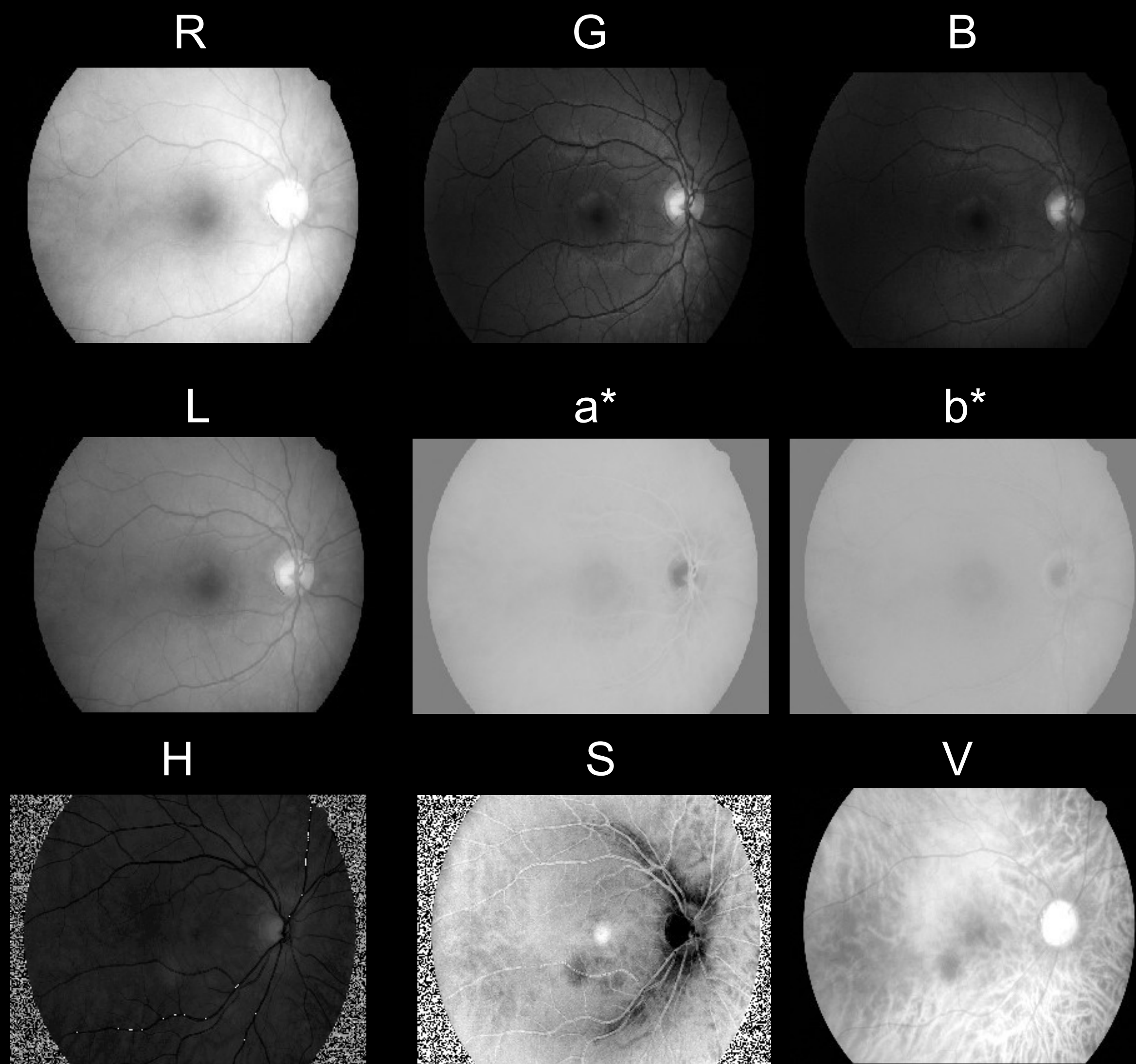
Possible approaches

- Pattern recognition
  - ridge-based (local peaks in max surface gradient)
  - skeleton-based (centerlines)
  - region growing (postprocessing, cavities, smoothing)
  - matching filters (+ centerline detection/thresholding)
  - morphology-based (nonlinear filtering)
- Model-based
  - explicit models
  - active contours (requires good initial state)
  - deformable models

Original image



Channel selection

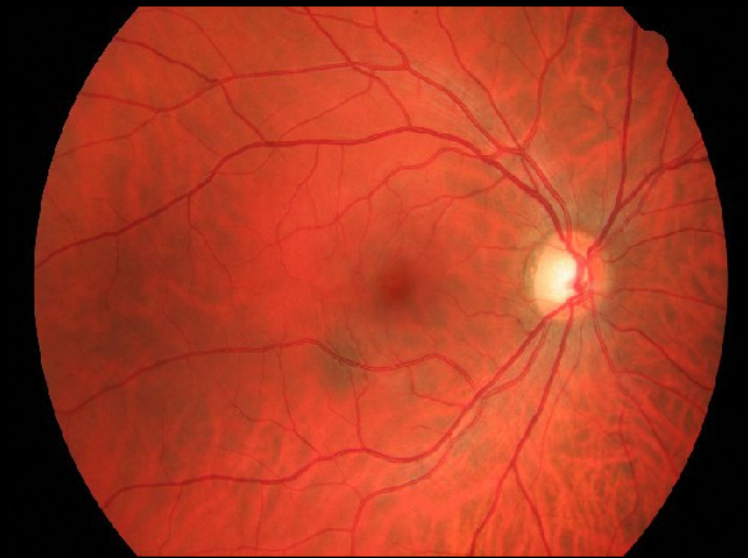


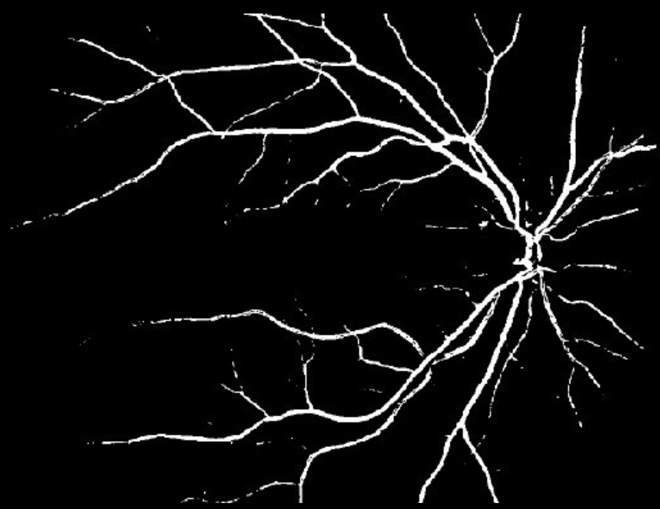
Channel selection - Green

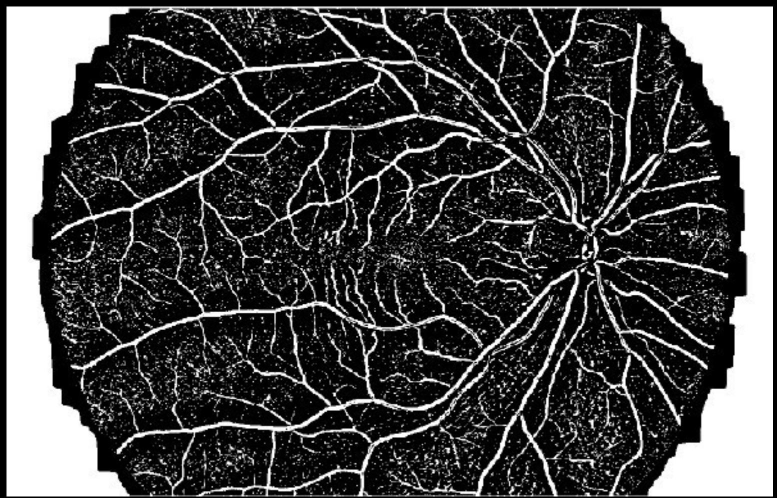
Proposed method

- Core of the algorithm: morphological reconstruction by dilation
- Mask and marker images are prepared in a similar way:
    - Morphological opening to fill the interior of wider vessels
    - Black top-hat to isolate small dark structures (vessels)
    - Coherence enhancing diffusion so that the thresholding doesn’t break the vessels (used only for the mask)
    - Thresholding – global for the marker, adaptive for the mask
    - Median filtering of the marker (removes most noise)
- Removal of very small components by area opening
- Removal of larger (but still small) components that are far enough from other components by using a sliding window
(removal of the spots in retinopathy images)

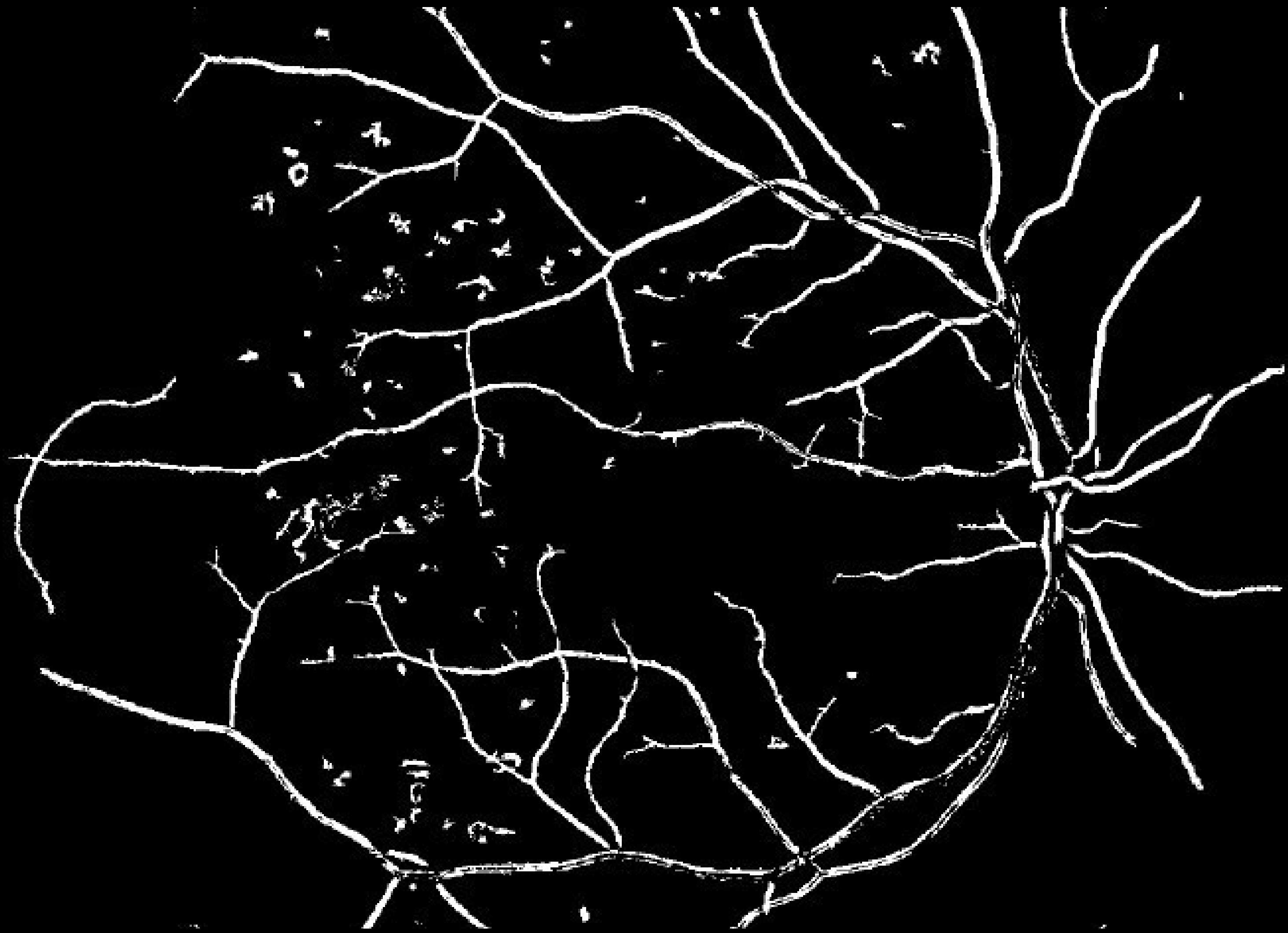
Marker and Mask







Clutter removal



Clutter removal

Comparison to the state of the art

- Segmentation by thresholding
  - Thitiporn Chanwimaluang, PhD thesis
- Hessian-based “vesselness” filter
  - Dirk-Jan Kroon

Results

healthy	Adaptive thresholding	Vesselness filter	Proposed method
recall	0.629	0.400	0.713
precision	0.734	0.965	0.816
F1 score	0.677	0.566	0.761
connectivity	0.999	0.995	0.999
area	0.744	0.590	0.791
length	0.730	0.589	0.789

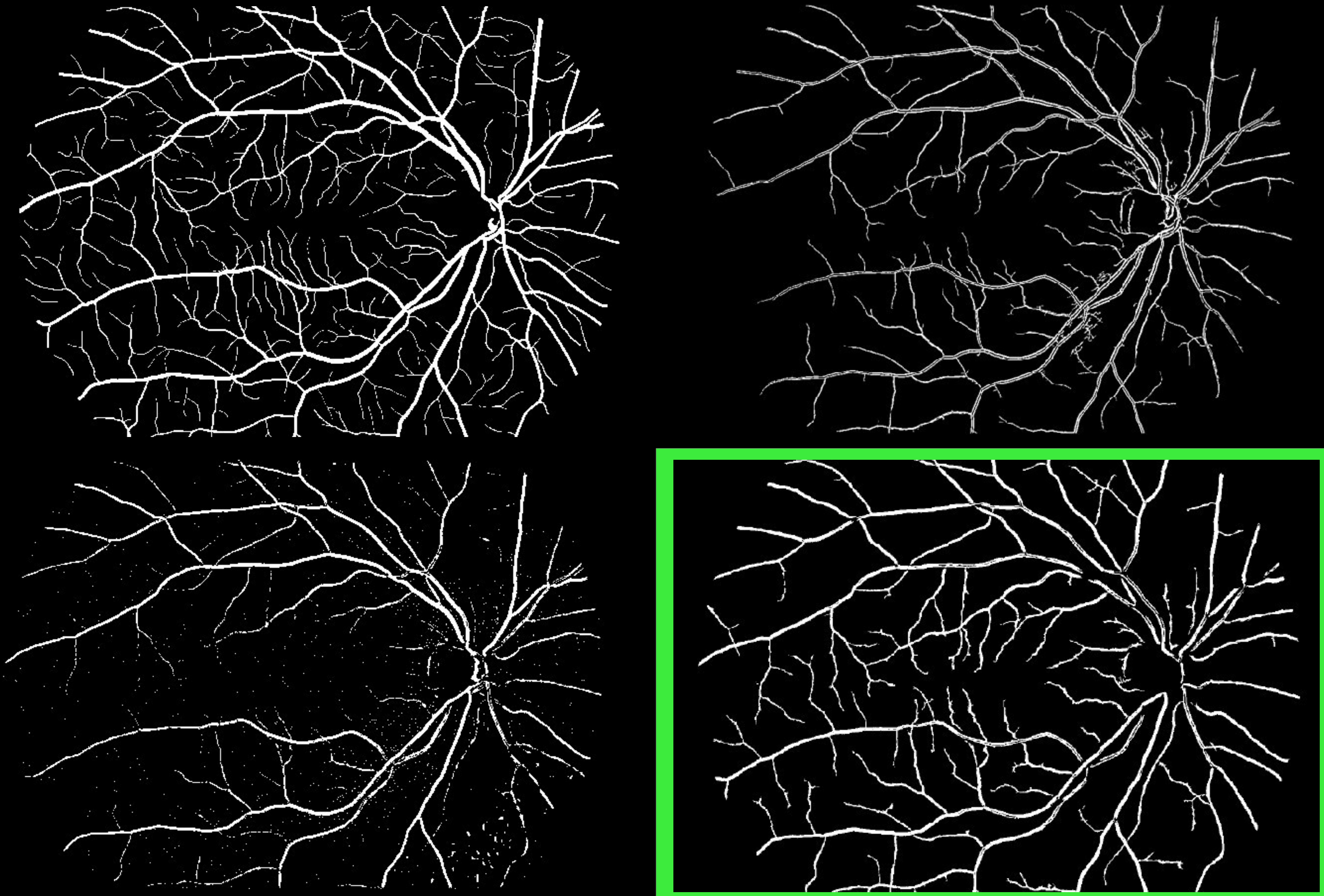
Results

glaucoma	Adaptive thresholding	Vesselness filter	Proposed method
recall	0.604	0.331	0.708
precision	0.664	0.934	0.668
F1 score	0.633	0.489	0.687
connectivity	0.999	0.997	0.999
area	0.740	0.485	0.745
length	0.725	0.446	0.720

Results

retinopathy	Adaptive thresholding	Vesselness filter	Proposed method
recall	0.566	0.339	0.607
precision	0.553	0.775	0.650
F1 score	0.559	0.472	0.628
connectivity	0.999	0.976	0.999
area	0.643	0.520	0.671
length	0.651	0.448	0.690

Visual comparison



Conclusion

- No general solution for unhealthy cases
- Many different approaches
- Selection of color space
- Pre- and post-processing are important

Thank you for your attention