

Retinal Blood Vessel Segmentation Using Contrast Enhancement and Light Attention U-Net

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1. Problem

Diabetic retinopathy is a leading cause of preventable blindness; retinal vessels are key biomarkers for screening.

Automating vessel segmentation is hard because of:

- **Low contrast** between thin capillaries and the background.
- **Pathologies** (exudates, hemorrhages) obscuring vessel boundaries.
- **Illumination & device variation** across acquisitions.
- **Severe class imbalance** — vessel pixels are only 8–12% of the image.

Gap

Classical hand-crafted methods (matched filtering, vessel tracking, morphology) fail to generalize across datasets and imaging conditions.

2. Proposed Solution

A complete deep-learning pipeline pairing **contrast-enhancement preprocessing** with a **Light Attention U-Net**.

Key Contributions

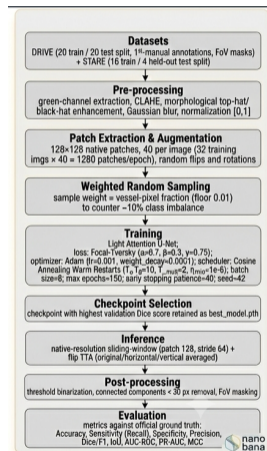
- Preprocessing combining **CLAHE** with morphological top-hat / black-hat enhancement.
- **Light Attention U-Net** ($\approx 7.85\text{M}$ params vs. 31M for standard Attention U-Net) — suited to small datasets.
- **Native-resolution patch training** that preserves thin vessels instead of downsampling.
- **Focal Tversky loss** ($\alpha=0.7$) biased toward false-negative reduction \rightarrow **+13%** sensitivity over the balanced baseline.

3. Methodology

Five-stage pipeline, raw fundus image → binary mask:

- 1 **Preprocessing** — CLAHE + morphology.
- 2 **Patch extraction** — 128×128 , native resolution.
- 3 **Training** — Light Attention U-Net, weighted sampling, Focal Tversky loss.
- 4 **Inference** — sliding window (stride 64) + TTA.
- 5 **Post-processing** — threshold + component filtering + FoV masking.

Data: 16 DRIVE + 16 STARE train; test on 20 DRIVE + 4 STARE.



4. Component & Step Description

Preprocessing

- Green-channel extraction (best contrast).
- CLAHE: clip 2.0, 8×8 tiles.
- Morphology: $I_{enh} = I_{clahc} + I_{tophat} - I_{bht}$.
- Gaussian blur + normalize to $[0, 1]$.

Light Attention U-Net

- Encoder: 4 DoubleConv, channels $[32, 64, 128, 256]$.
- Bottleneck: 512 ch + Dropout ($p=0.3$).
- Decoder: transposed conv + attention-gated skips.
- Gate: $\hat{x} = x \odot \sigma_2(q_{att})$; output 1×1 conv + sigmoid.

Loss: Focal Tversky FTL = $(1 - TL)^\gamma$,
 $\alpha=0.7, \beta=0.3, \gamma=0.75$.

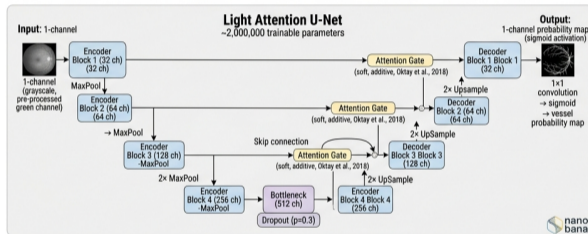


Figure 2: 02_architecture_diagram

Light Attention U-Net

5. Results

DRIVE official test (FoV-masked)

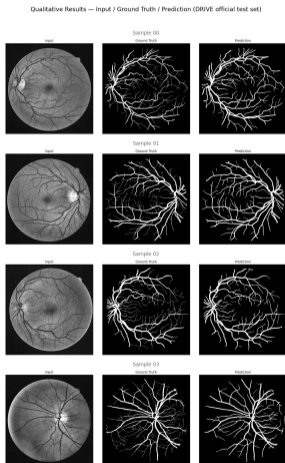
Metric	Value ($\tau=0.5$)
Accuracy	0.9496
Sensitivity	0.8574
Specificity	0.9630
Dice / F1	0.8123
AUC-ROC	0.9529

STARE hold-out (unseen)

Metric	Value
Sensitivity	0.8533
Specificity	0.9815
Dice / F1	0.8010
AUC-ROC	0.9629

- Re-weighted loss ($\alpha=0.7$) lifted sensitivity **0.7588** \rightarrow **0.8574** (+13%).
- Comparable sensitivity across datasets confirms strong **generalization**.

5. Results — Qualitative



Input fundus image / ground-truth mask / predicted segmentation

6. Limitations of the Implementation

- **Sensitivity–precision trade-off:** higher sensitivity lowers precision (0.7717 vs. 0.8603) — more false positives at boundaries and around pathologies.
- **Small training set:** only 32 images (DRIVE + STARE) limits learning of diverse pathologies.
- **Single green channel:** discards red/blue information such as optic-disc boundary and hemorrhage cues.
- **Hardware-constrained:** trained on a 2 GB MX450 GPU, bounding batch size and patch throughput.

7. Conclusion & Future Work

Conclusion

A Light Attention U-Net with contrast-enhancement preprocessing and Focal Tversky loss achieves competitive DRIVE results (Dice 0.8123, Sens. 0.8574, AUC 0.9529) and strong STARE cross-dataset generalization (Dice 0.8010, AUC 0.9629) — with only $\approx 7.85\text{M}$ parameters.

Future directions:

- Larger, more diverse datasets (CHASE-DB1, HRF).
- Multi-scale feature fusion for thick & thin vessels.
- Self-supervised pretraining on unlabeled fundus images.
- Transformer-based architectures (TransUNet, SwinUNet).

Thank You!

Questions?