Tensorflow-Tiled-Image-Segmentation-Pre-Augmented-STARE-Retinal-Vessel (2025/02/02)

This is the first experiment of Tiled Image Segmentation for **STARE Retinal Vessel** based on the latest Tensorflow-Image-Segmentation-API, and a **pre-augmented tiled dataset** Augmented-Tiled-STARE-ImageMask-Dataset.zip, which was derived by us from the following images and labels:

Twenty images used for experiments
Hand labeled vessel network provided by Adam Hoover

On detail of **STARE(STructured Analysis of the Retina)**, please refer to the official site:
STructured Analysis of the Retina , and github repository STARE

Please see also our experiment Tensorflow-Image-Segmentation-Retinal-Vessel based on CHASE_DB1 dataset.

Experiment Strategies
As demonstrated in our experiments Tensorflow-Tiled-Image-Segmentation-IDRiD-HardExudates , and Tensorflow-Tiled-Image-Segmentation-Augmented-Skin-Cancer , the Tiled Image Segmentation based on a simple UNet model trained by a tiledly-splitted images and masks dataset, is an effective method for the large image segmentation over 4K pixels.

It is difficult to precisely segment Retinal Blood Vessels in small images using a simple UNet model because these vessels are typically very thin and difficult to detect. Therefore, we generate a high-resolution retinal image dataset by upscaling the original images and use it to train the UNet model to improve segmentation performance.

In this experiment, we employed the following strategies to apply the Tiled Image Segmentation method to STARE Retinal Vessel.

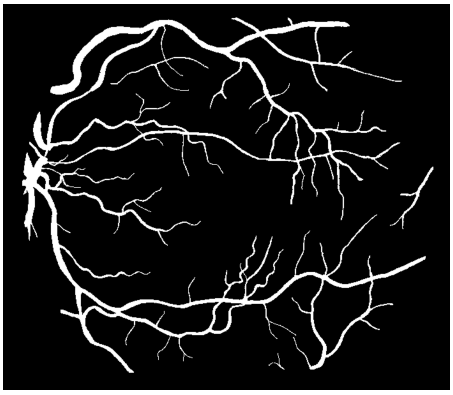
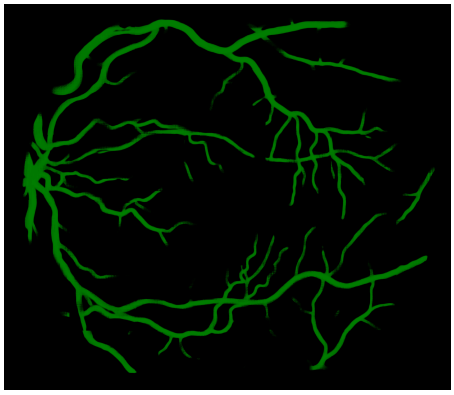
1. Enlarged Dataset
We generated a 5x enlarged dataset of 19 JPG images and masks, each with 3500x3025 pixels, from the original STARE 700x605 pixels PPM.GZ image and label files using bicubic interpolation.

2. Pre Augemtned Tiled STARE ImageMask Dataset
We generated a pre-augmented image mask dataset from the enlarged dataset, which was tiledly-splitted to 512x512 pixels and reduced to 512x512 pixels image and mask dataset.

3. Train Segmention Model
We trained and validated a TensorFlow UNet model by using the **Pre Augmented Tiled STARE ImageMask Dataset**

4. Tiled Image Segmentation
We applied our Tiled-Image Segmentation inference method to predict the STARE Retinal Vessel for the mini_test images with a resolution of 3500x3025 pixels of the Enlarged Dataset.

Actual Tiled Image Segmentation for Images of 3500x3025 pixels
As shown below, the inferred masks look similar to the ground truth masks.

Input: image	Mask (ground_truth)	Prediction: inferred_mask
		

In this experiment, we used the simple UNet Model TensorflowSlightlyFlexibleUNet for this STARESegmentation Model.
As shown in Tensorflow-Image-Segmentation-API. you may try other Tensorflow UNet Models:

- TensorflowSwinUNet.py
- TensorflowMultiResUNet.py
- TensorflowAttentionUNet.py
- TensorflowEfficientUNet.py
- TensorflowUNet3Plus.py
- TensorflowDeepLabV3Plus.py

1. Dataset Citation

The dataset used here has been take from from the following images and labels in STructured Analysis of the Retina :

Twenty images used for experiments
Hand labeled vessel network provided by Adam Hoover

Please see also STARE

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Citation
@ARTICLE{845178,
author={Hoover, A.D. and Kouznetsova, V. and Goldbaum, M.},
journal={IEEE Transactions on Medical Imaging},
title={Locating blood vessels in retinal images by piecewise threshold probing of a matched filter response},
year={2000},
volume={19},
number={3},
pages={203-210},
doi={10.1109/42.845178}}

2 Augmented-Tiled-STARE ImageMask Dataset

If you would like to train this STARE Segmentation model by yourself, please download the pre-augmented dataset from the google drive Augmented-Tiled-STARE-ImageMask-Dataset.zip, expand the downloaded ImageMaskDataset and put it under **./dataset** folder to be

```
./dataset
└─Augmented-Tiled-STARE
    ├─test
    │  ├─images
    │  └─masks
    ├─train
    │  ├─images
    │  └─masks
    └─valid
       ├─images
       └─masks
```

This is a 512x512 pixels pre augmented tiles dataset generated from 3500x3025 pixels 19 **Enlarged-images** and their corresponding **Enlarged-masks**.

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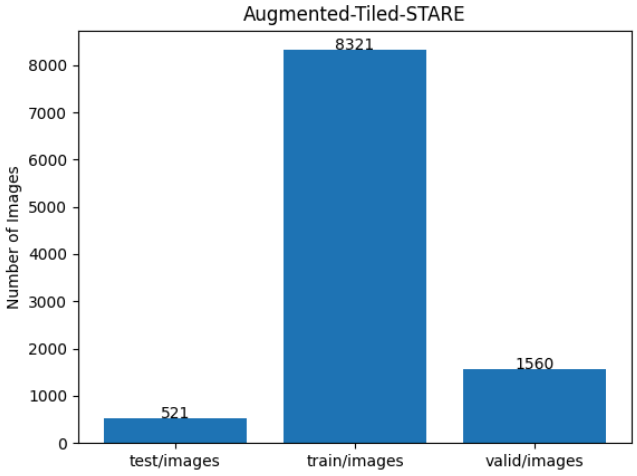
We excluded all black (empty) masks and their corresponding images to generate our dataset from the original one.
The folder structure of the original stare-images and labels-ah data is the following.

```
./STARE
    ├─stare-images
    │  ├─im0001.ppm.gz
    │  ├─im0002.ppm.gz
    │  ├─...
    │  └─im0319.ppm.gz
    └─labels-ah
       ├─im0001.ah.ppm.gz
       ├─im0002.ah.ppm.gz
       ├─...
       └─im0319.ah.ppm.gz
```

We excluded im0324.ah.ppm.gz file in the original labels-ah folder, because no corresponding im0324.ppm.gz was in stare-images folder.
On the derivation of this tiled dataset, please refer to the following Python scripts.

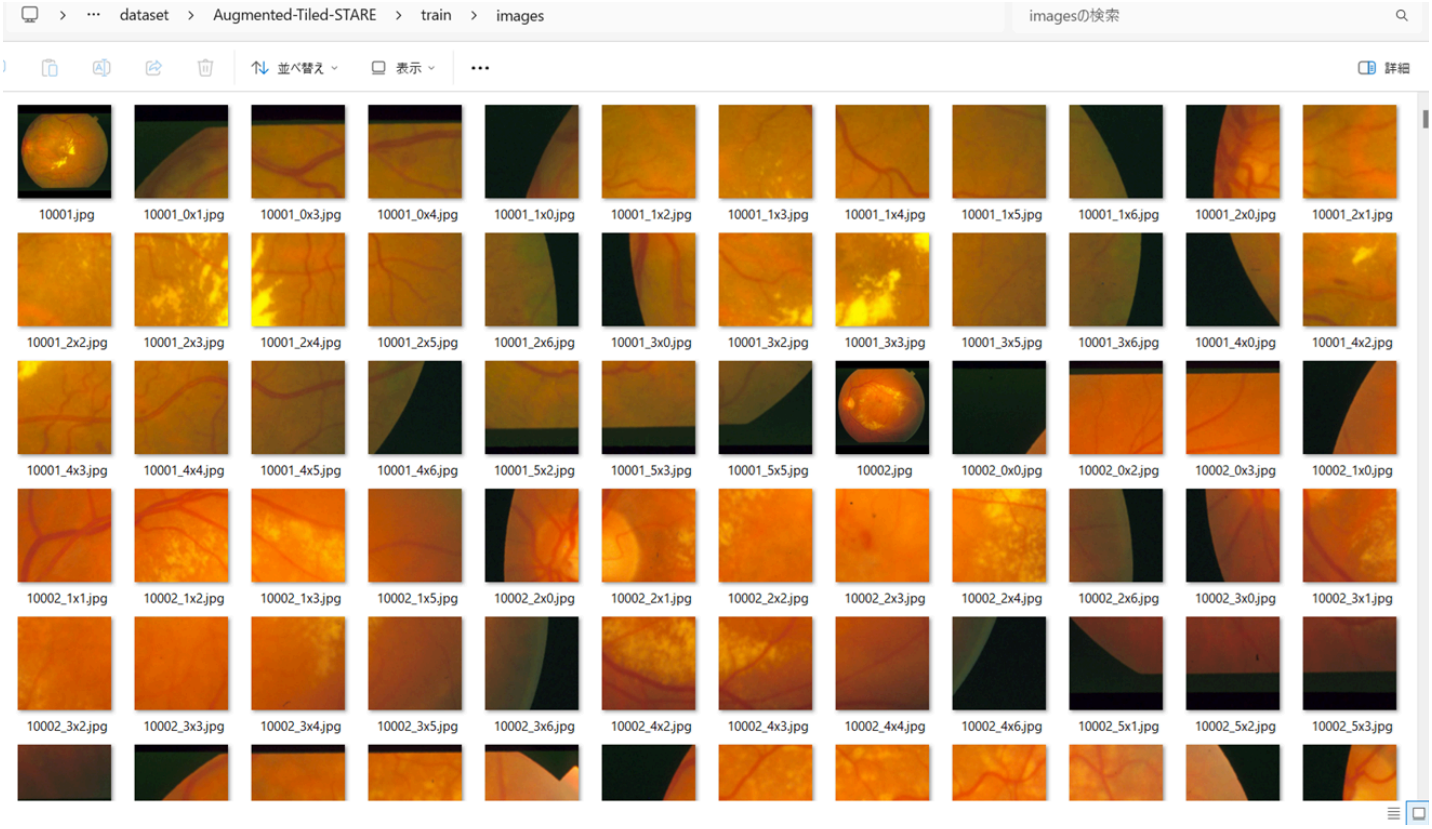
- Preprocessor.py
- TiledImageMaskDatasetGenerator.py
- split_tiled_master.py

Augmented-Tiled-STARE Statistics

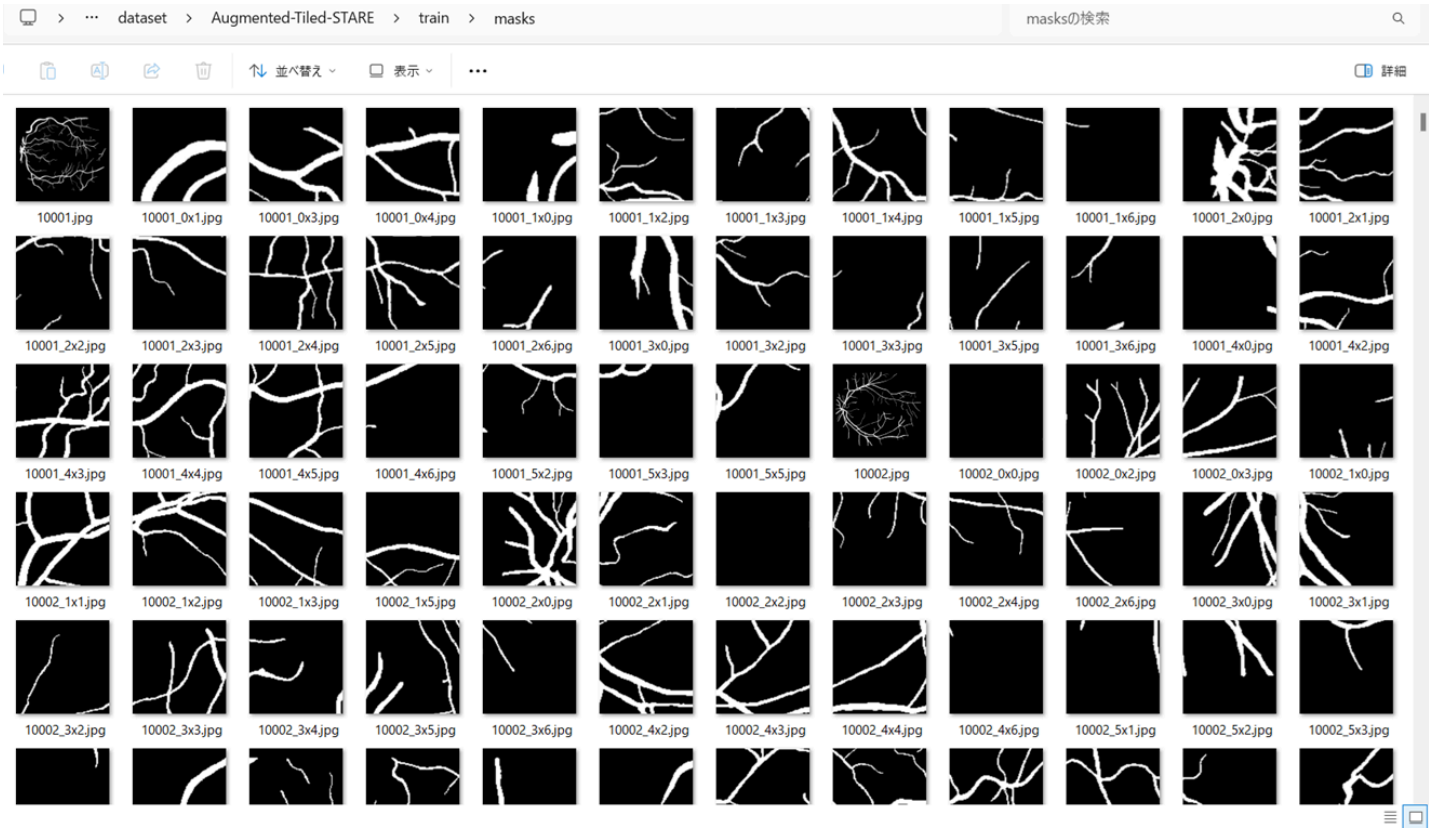


As shown above, the number of images of train and valid datasets is enough to use for a training set of our segmentation model.

Train_images_sample



Train_masks_sample



3 Train TensorflowUNet Model

We have trained STARE TensorflowUNet Model by using the following **train_eval_infer.config** file.
Please move to ./projects/TensorflowSlightlyFlexibleUNet/Augmented-Tiled-STARE and run the following bat file.

```
>1.train.bat
```

, which simply runs the following command.

```
>python ../../../src/TensorflowUNetTrainer.py ./train_eval_infer.config
```

Model parameters
Enabled Batch Normalization.

Defined a small **base_filters=16** and large **base_kernels=(9,9)** for the first Conv Layer of Encoder Block of TensorflowUNet.py and a large num_layers (including a bridge between Encoder and Decoder Blocks).

```
[model]
base_filters   = 16
base_kernels   = (9,9)
num_layers     = 8
dilation       = (3,3)
```

Learning rate

Defined a small learning rate.

```
[model]
learning_rate  = 0.00007
```

Online augmentation

Disabled our online augmentation tool.

```
[model]
model         = "TensorflowUNet"
generator     = False
```

Loss and metrics functions

Specified "bce_dice_loss" and "dice_coef".

```
[model]
loss          = "bce_dice_loss"
metrics       = ["dice_coef"]
```

Learning rate reducer callback

Enabled learing_rate_reducer callback, and a small reducer_patience.

```
[train]
learning_rate_reducer = True
reducer_factor     = 0.4
reducer_patience   = 4
```

Dataset class

Specified ImageMaskDataset class.

```
[dataset]
datasetclass  = "ImageMaskDataset"
resize_interpolation = "cv2.INTER_LINEAR"
```

Early stopping callback

Enabled early stopping callback with patience parameter.

```
[train]
patience      = 20
```

Tiled inference

We used 3500x3025 pixels enlarged images and masks generated by Preprocessor.py as a mini_test dataset for our TiledInference.

```
[tiledinfer]
overlapping   = 64
images_dir    = "./mini_test/images"
output_dir    = "./mini_test_output_tiled"
```

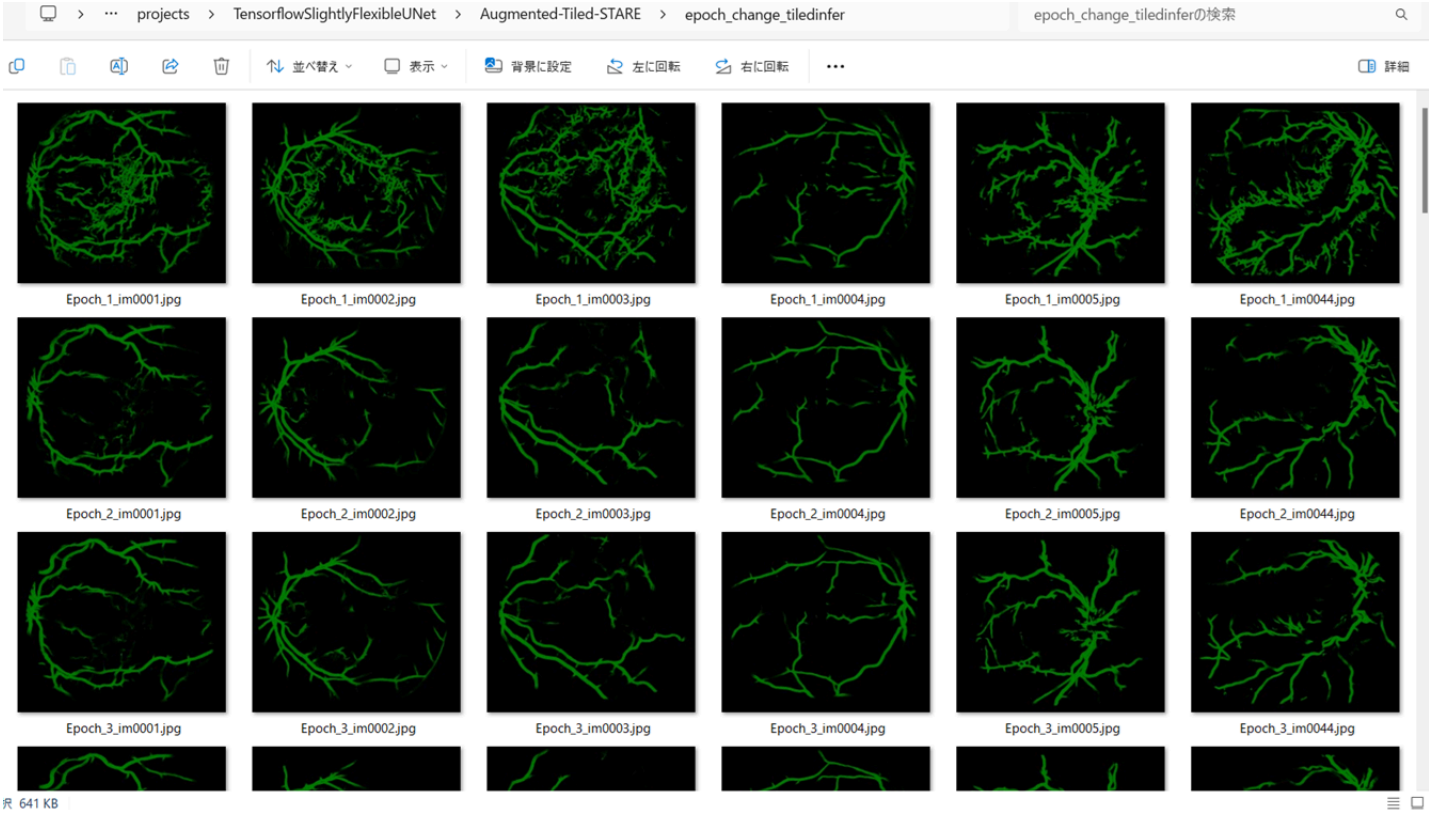
Epoch change inference callbacks

Enabled epoch_change_infer callback.

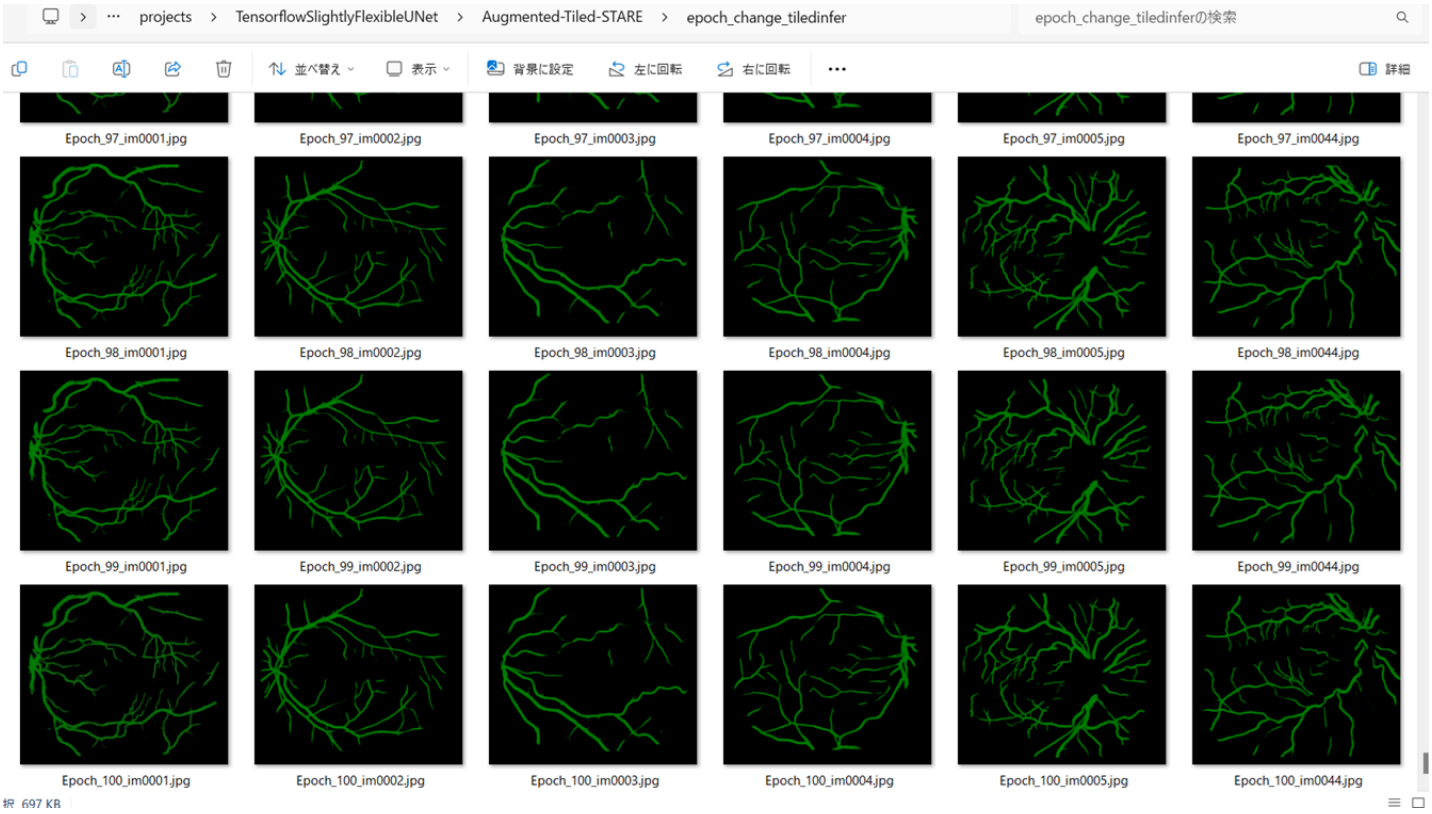
```
[train]
epoch_change_infer      = False
epoch_change_infer_dir  = "./epoch_change_infer"
epoch_change_tiledinfer = True
epoch_change_tiledinfer_dir = "./epoch_change_tiledinfer"
num_infer_images       = 6
```

By using this callback, on every epoch_change, the epoch change tiledinfer procedure can be called for 6 images in **mini_test** folder. This will help you confirm how the predicted mask changes at each epoch during your training process.

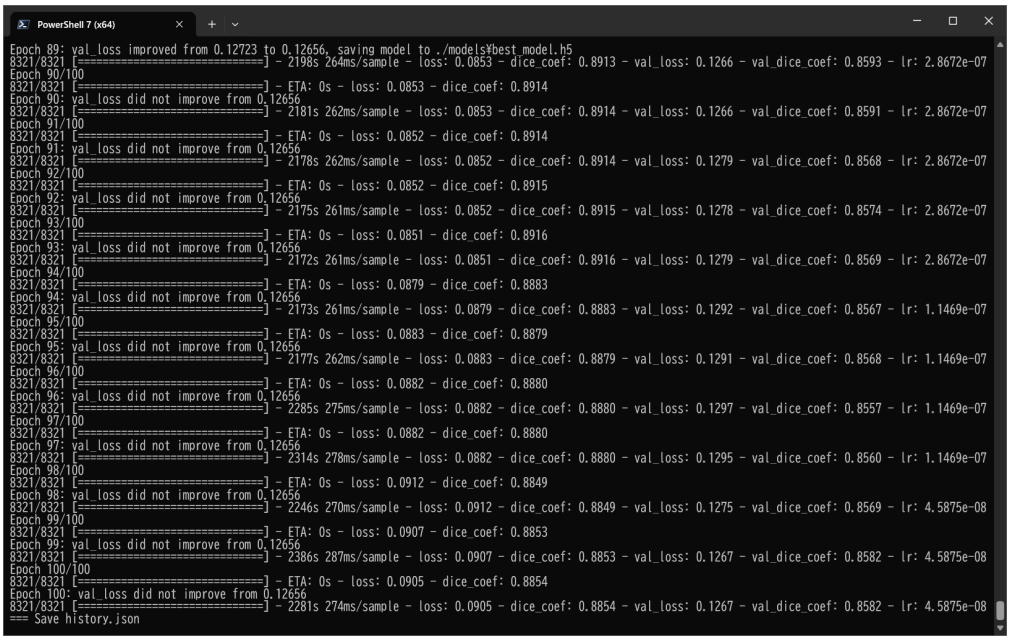
Epoch_change_inference output at starting (1,2,3)



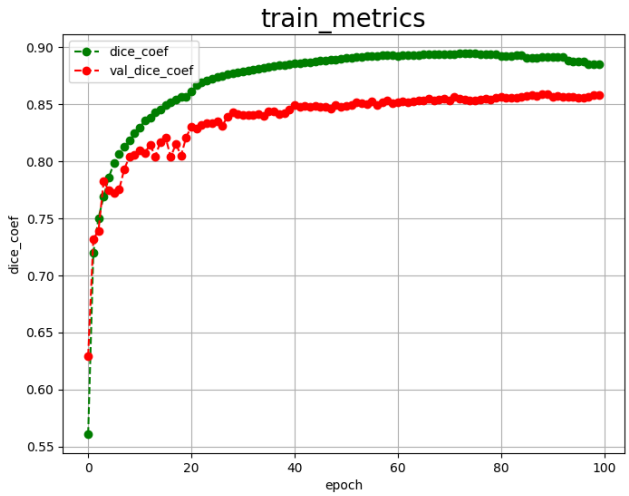
Epoch_change_inference output at ending (98,99,100)



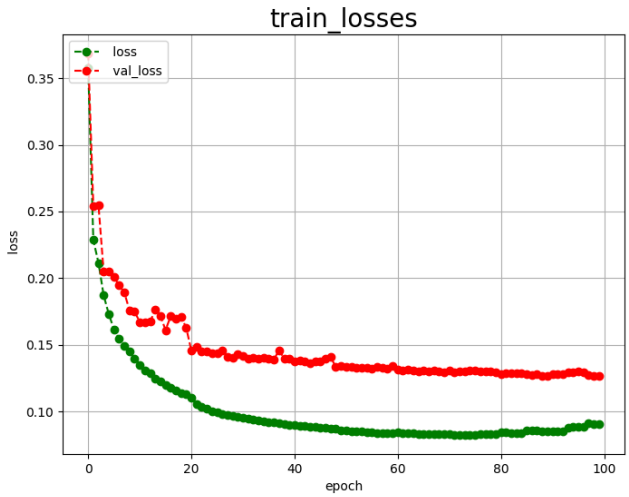
In this experiment, the training process was terminated at epoch 100.



[train_metrics.csv](#)



[train_losses.csv](#)



4 Evaluation

Please move to a **./projects/TensorflowSlightlyFlexibleUNet/Augmented-Tiled-STARE** folder,
and run the following bat file to evaluate TensorflowUNet model for STARE.

```
./2.evaluate.bat
```

This bat file simply runs the following command.

```
python ../../../src/TensorflowUNetEvaluator.py ./train_eval_infer_aug.config
```

Evaluation console output:

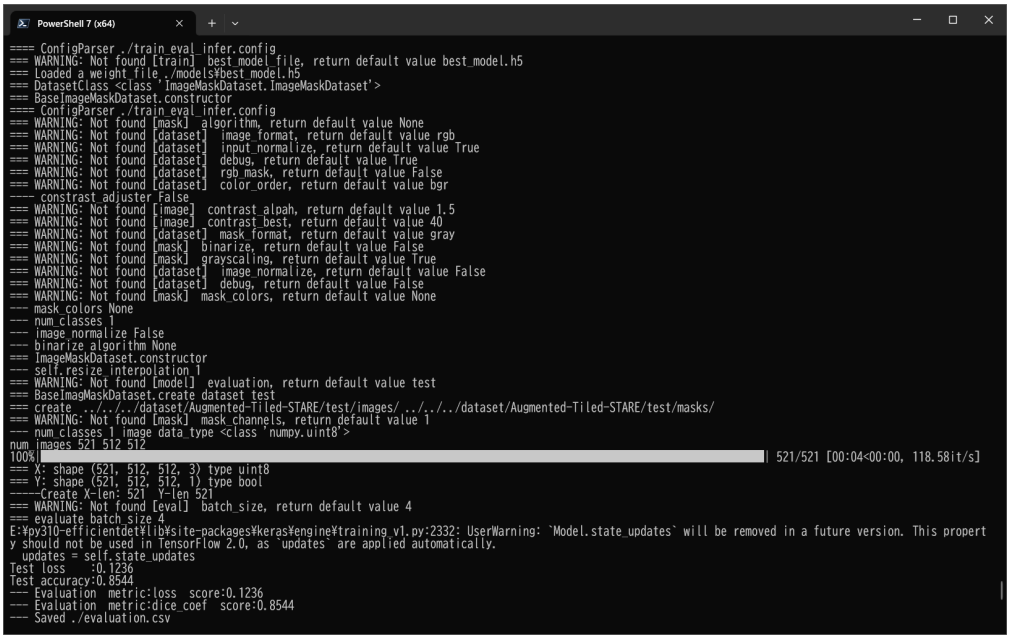


Image-Segmentation-STARE [evaluation.csv](./projects/TensorflowSlightlyFlexibleUNet/Augmented-Tiled-STARE/evaluation.csv)
The loss (bce_dice_loss) to this Augmented-Tiled-STARE/test was low, and dice_coef high as shown below.

```
loss,0.1236
dice_coef,0.8544
```

5 Tiled inference

Please move to a **./projects/TensorflowSlightlyFlexibleUNet/Augmented-Tiled-STARE** folder
,and run the following bat file to infer segmentation regions for images by the Trained-TensorflowUNet model for STARE.

```
./4.tiled_infer.bat
```

This simply runs the following command.

```
python ../../../src/TensorflowUNetTiledInferencer.py ./train_eval_infer.config
```

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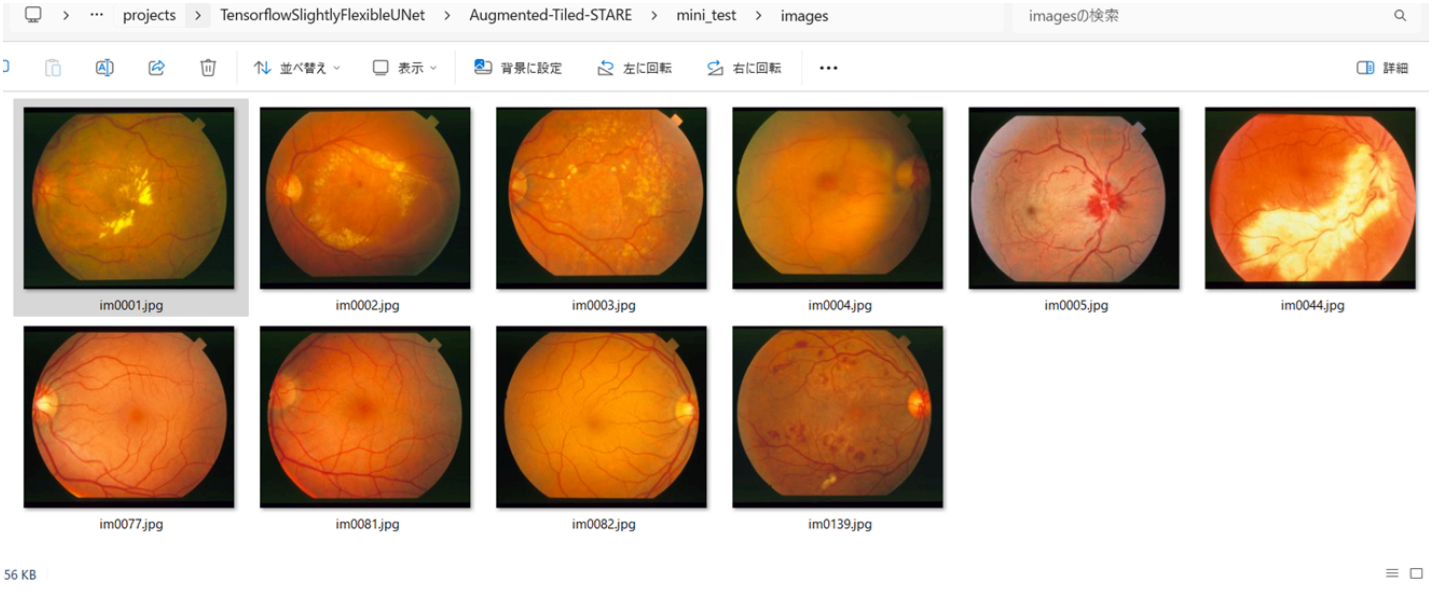
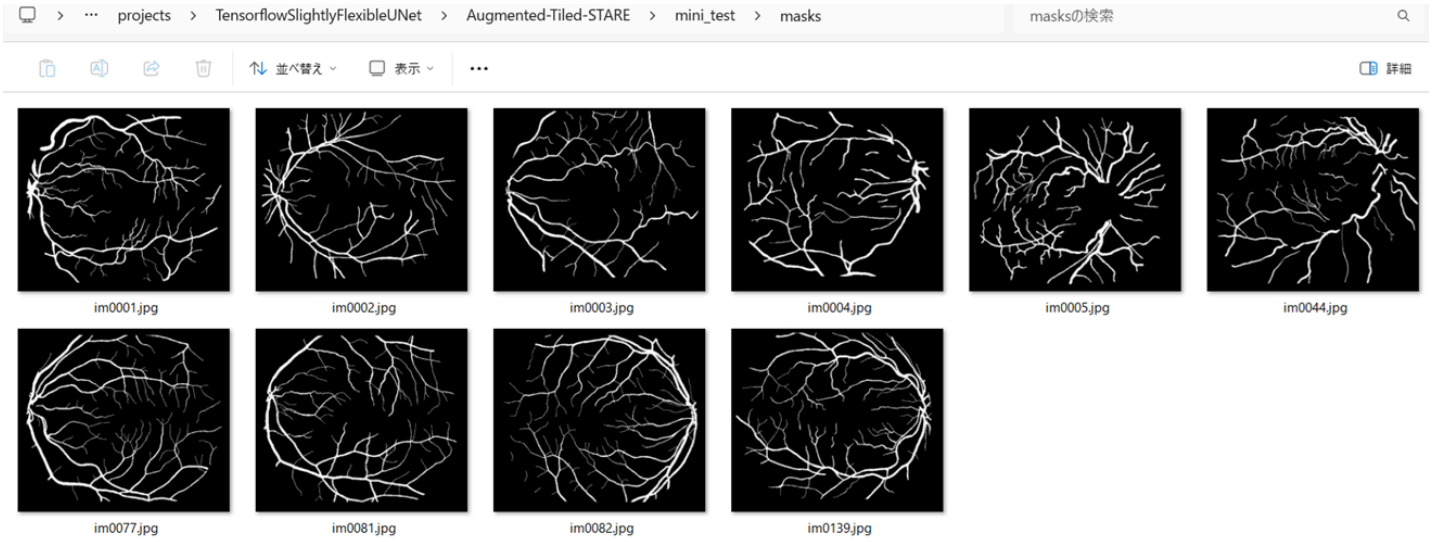
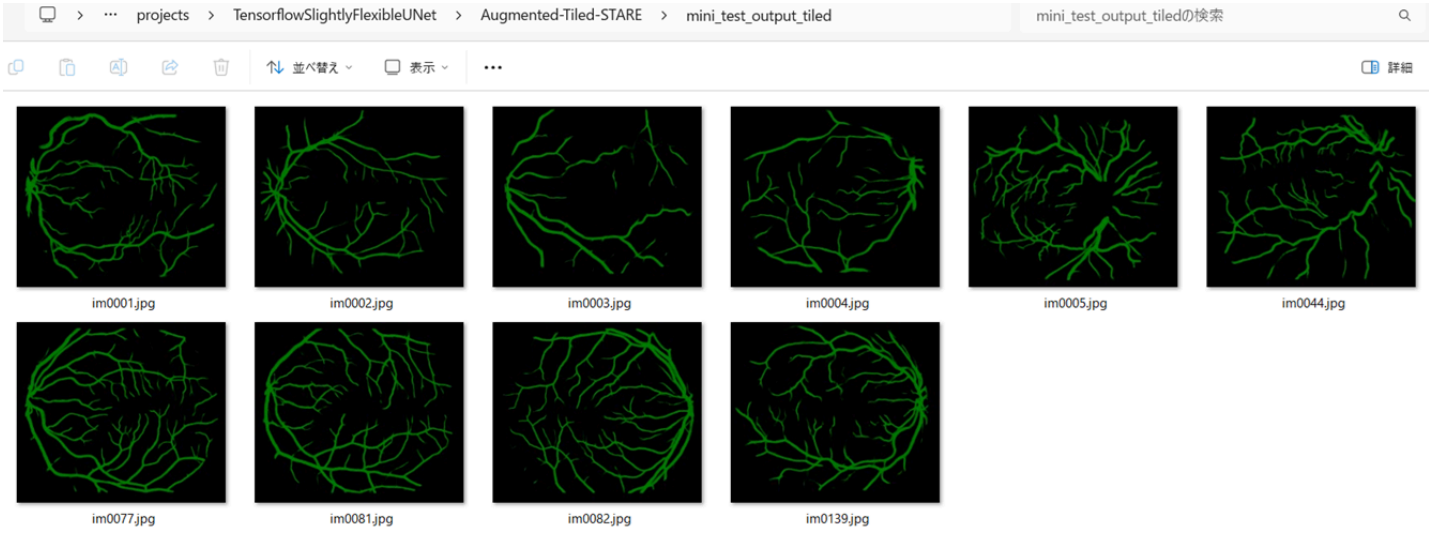
mini_test_images (3500x3025 pixels)



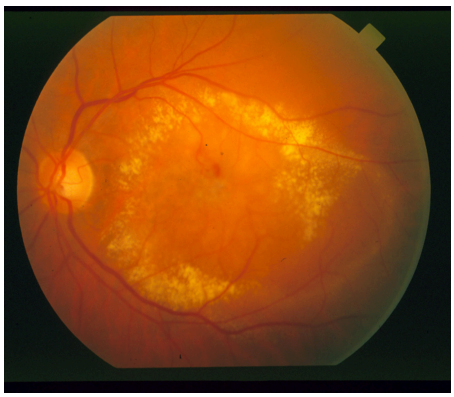
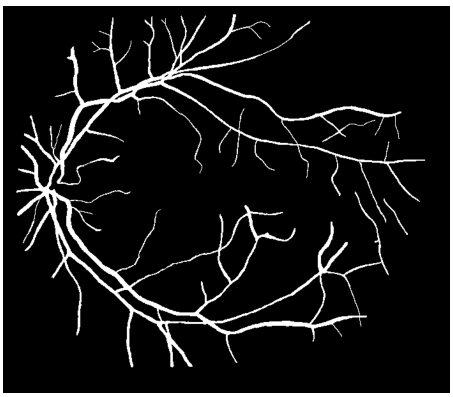
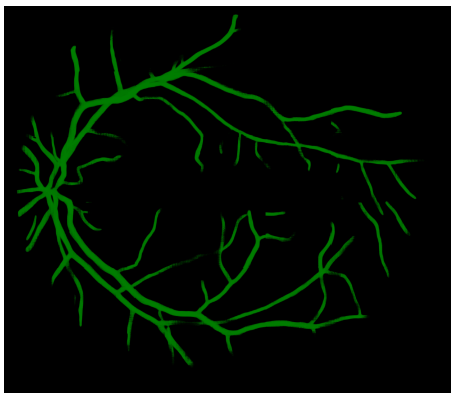
mini_test_mask(ground_truth)

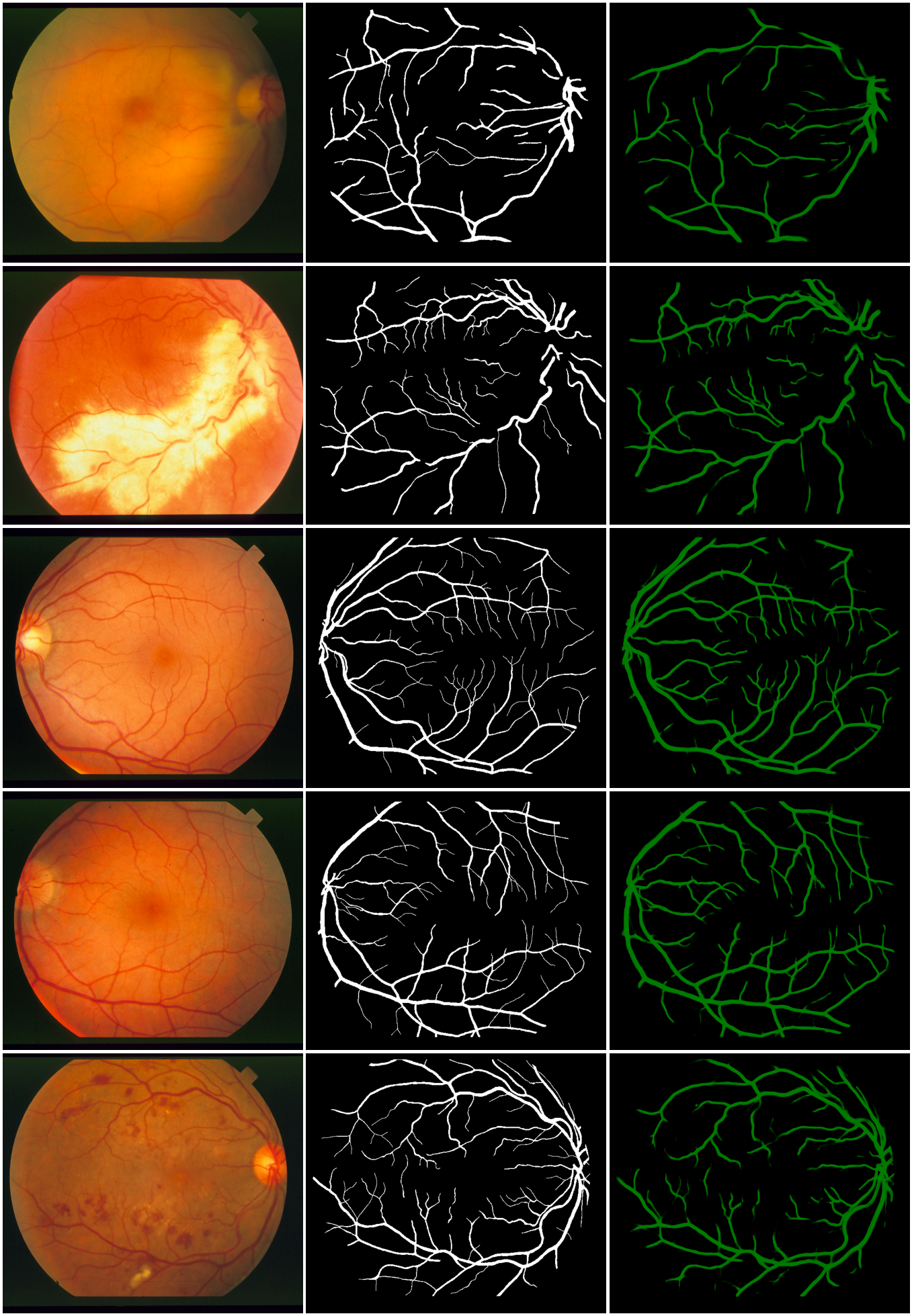


Tiled inferred test masks (3500x3025 pixels)



Enlarged images and masks of 3500x3025 pixels

Image	Mask (ground_truth)	Tiled-inferred-mask
		



References

1. Locating Blood Vessels in Retinal Images
by Piecewise Threshold Probing of a
Matched Filter Response
Adam Hoover, Valentina Kouznetsova, and Michael Goldbaum
https://www.uhu.es/retinopathy/General/000301IEEETransMedImag.pdf

2. STructured Analysis of the Retina
https://cecas.clemson.edu/~ahoover/stare/

3. STARE
https://github.com/openmedlab/Awesome-Medical-Dataset/blob/main/resources/STARE.md

4. State-of-the-art retinal vessel segmentation with minimalistic models
Adrian Galdran, André Anjos, José Dolz, Hadi Chakor, Hervé Lombaert & Ismail Ben Ayed
https://www.nature.com/articles/s41598-022-09675-y

5. Retinal blood vessel segmentation using a deep learning method based on modified U-NET model
Sanjeewani, Arun Kumar Yadav, Mohd Akbar, Mohit Kumar, Divakar Yadav
https://www.semanticscholar.org/reader/f5cb3b1c69a2a7e97d1935be9d706017af8cc1a3

6, Tensorflow-Image-Segmentation-Retinal-Vessel
Toshiyuki Arai @antillia.com
https://github.com/sarah-antillia/Tensorflow-Image-Segmentation-Retinal-Vessel

7. Tensorflow-Tiled-Image-Segmentation-Augmented-Skin-Cancer
Toshiyuki Arai @antillia.com
https://github.com/sarah-antillia/Tensorflow-Tiled-Image-Segmentation-Augmented-Skin-Cancer

8. Tensorflow-Tiled-Image-Segmentation-Augmented-MultipleMyeloma
Toshiyuki Arai @antillia.com
https://github.com/sarah-antillia/Tensorflow-Tiled-Image-Segmentation-Augmented-MultipleMyeloma

9. Tiled-ImageMask-Dataset-Breast-Cancer
Toshiyuki Arai @antillia.com
https://github.com/sarah-antillia/Tiled-ImageMask-Dataset-Breast-Cancer