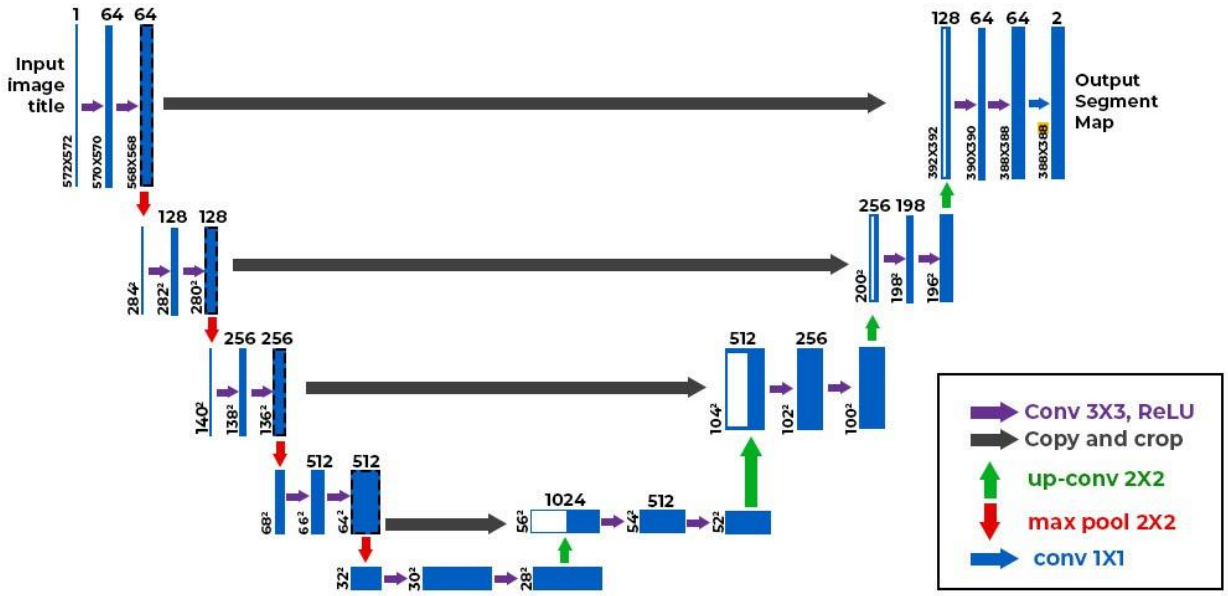
Glaucoma detection in retinal fundus images using U-Net and Supervised/Unsupervised machine learning algorithms

Introduction

Glaucoma is a neuro-degenerative eye disease developed due to an increase in the Intra-ocular Pressure inside the retina. Being the second largest cause of blindness worldwide, it can lead the person towards complete blindness if an early diagnosis does not take place. With respect to this underlying issue, there is an immense need of developing a system that can effectively work in the absence of excessive equipments, skilled medical practitioners and also is less time consuming.

Step By Step Explanation



Preprocessing:

- Convert the images to same channels and sizes so that our model can fit perfectly.
- Resize the images to (256, 256, 1) format for learning.
- 2 folders are created named as resized and resizeddo which contain the processed/resized images of eye and their respective masks.
- These images will be used for model training and testing

Preparing Data:

- Convert all the images to same channels and sizes so that our model can fit perfectly.
- Resize the images to (256, 256, 1) format for learning.
- Load all the images into a list and convert them to grayscale.
- Load all the masks to list.
- Now to separate the optical cup and optical disk from these masks.
- First we will threshold a mask and store all the values which are 1 or white into another list which is called optical disk list.
- Then we will threshold all values less than 1 or white and store them into another list which is called optical cup list.
- Now we have three lists, images list, optical cup list, optical disk list.
- These lists will be used to train and test.

Model Building Functions:

- We are using U-NET model to achieve our task.
- Functions for building the encoder and decoder blocks of a U-Net architecture.
- `conv_block`: Defines a convolutional block consisting of two convolutional layers followed by batch normalization and ReLU activation.
- `encoder_block`: Combines a convolutional block with max-pooling for down sampling.
- `decoder_block`: Defines a decoder block that includes convolutional transpose (deconvolution) for up sampling followed by concatenation with skip connections from the encoder and convolutional blocks.
- Encoder block encodes the data using 2 convolutional layers

Building the U-Net Model:

- Defines a function `build_unet` to construct the U-Net architecture using the previously defined encoder and decoder blocks.
- The model takes an input shape ` (256, 256, 1) ` and generates a binary segmentation mask.
- The shape is important that is why we resized each image and mask into 256, 256, 1 format for our model to work perfectly.

Model Compilation and Training:

- Fits the models to the training data (`image_array` and corresponding masks) using a batch size of 2 and 30 epochs.
- We are training the images on first 20 images if the dataset.
- We will be using minimum 25 epoch to fit the data.
- Using this value of epoch we will get more perfect results as compared to using less value of epoch.

Model Prediction and Post-processing:

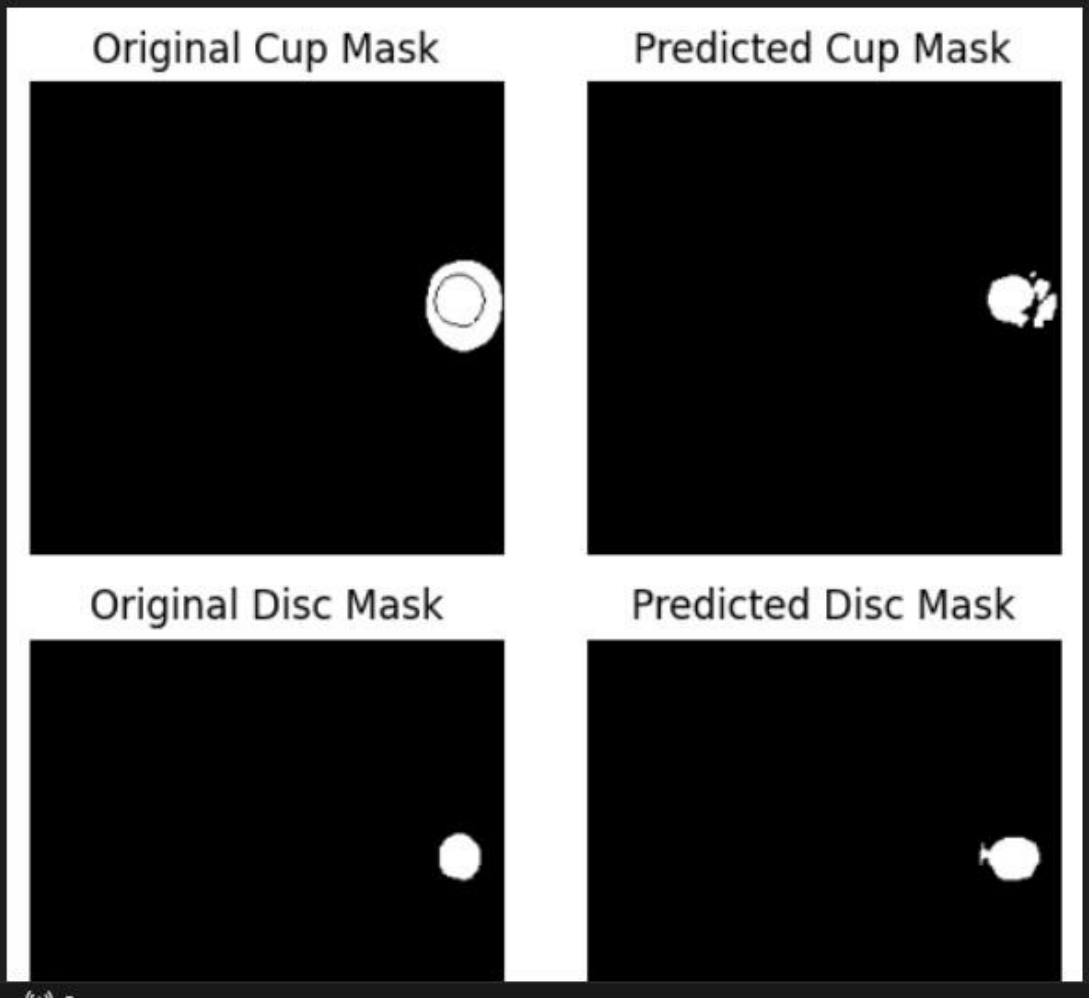
- The model is being trained using the first 20 images.
- When the model has been trained we will give any value of i, which means which image number you want to test the model on.
- When we give value of i, the model tests that image, and provides us with results.

Evaluation Metrics and Diagnosis

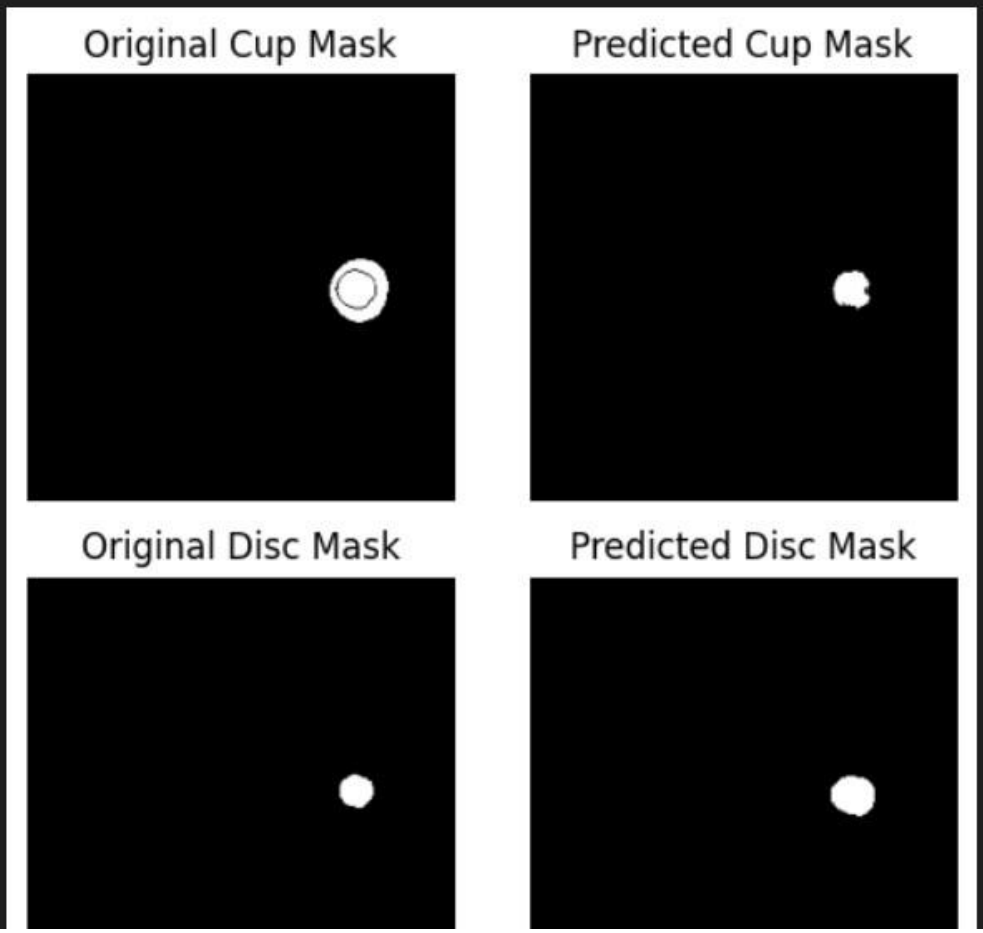
- Calculates Cup-to-Disc Ratio (CDR) based on the areas of segmented optic disc and optic cup.
- Determines diagnosis ("High likelihood of glaucoma" or "Low likelihood of glaucoma") based on the CDR threshold (0.4).
- If CDR is greater than 0.4, then there is High Likelihood, else there is Low Likelihood.
- Calculates evaluation metrics (accuracy, precision, recall, IoU) for both optic disc and optic cup segmentation using the calculated masks and predicted masks.

Supervised Outputs:

Segmentation Task	Metric	Value
Optic Disc Segmentation	Accuracy	0.986261055199756
	Precision	0.9380281690140845
	Recall	0.43729481286933686
	IoU	0.4250159540523293
Optic Cup Segmentation	Accuracy	0.9978067837397383
	Precision	0.7763401109057301
	Recall	0.9480812641083521
	IoU	0.7446808510638298
Diagnosis	CDR	1.3123844731977818
	Diagnosis	High likelihood of glaucoma

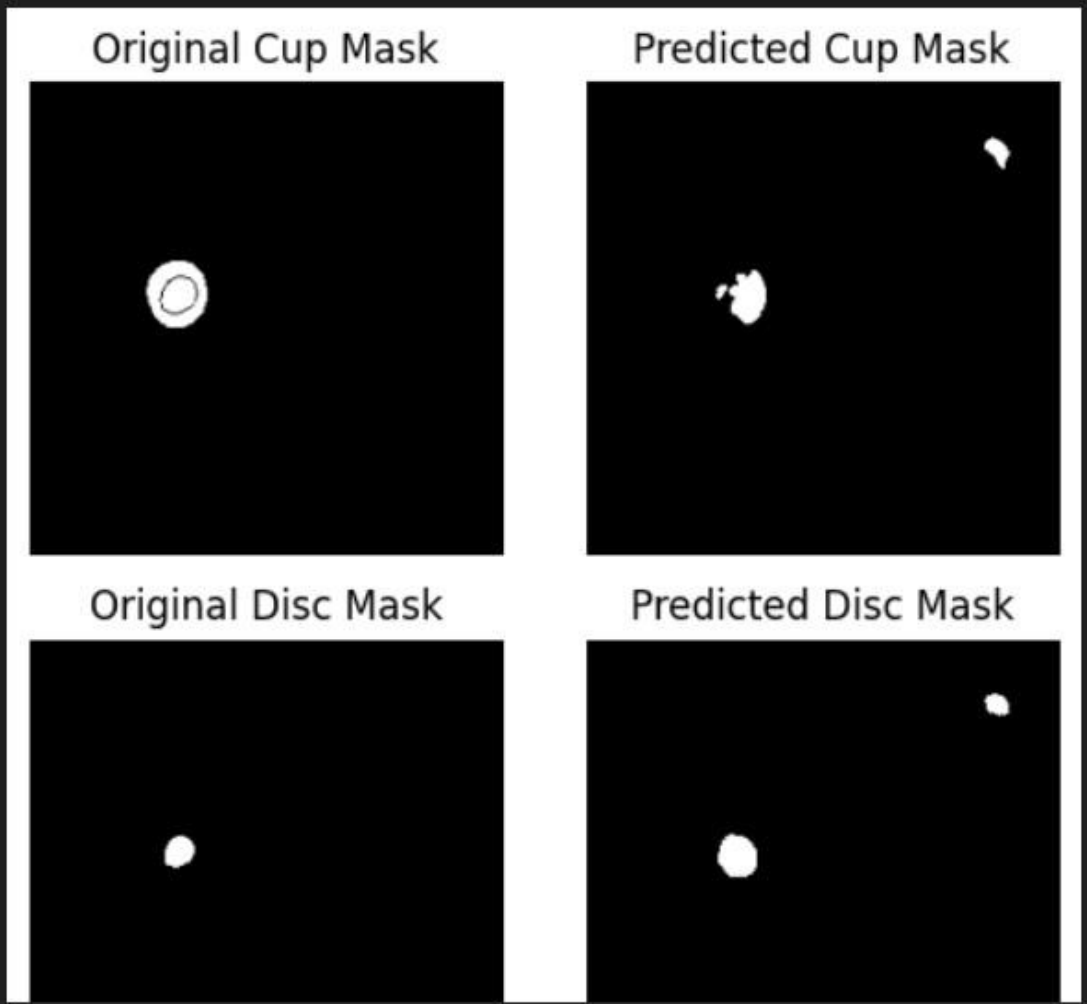


Optic Disc Segmentation	Accuracy	0.9902530545005263
	Precision	0.9381720430107527
	Recall	0.3616580310880829
	IoU	0.3532388663967611
Optic Cup Segmentation	Accuracy	0.9964103734124268
	Precision	0.5752032520325203
	Recall	0.9129032258064517
	IoU	0.5452793834296724
Diagnosis	CDR	0.7560975609756098
	Diagnosis	High likelihood of glaucoma

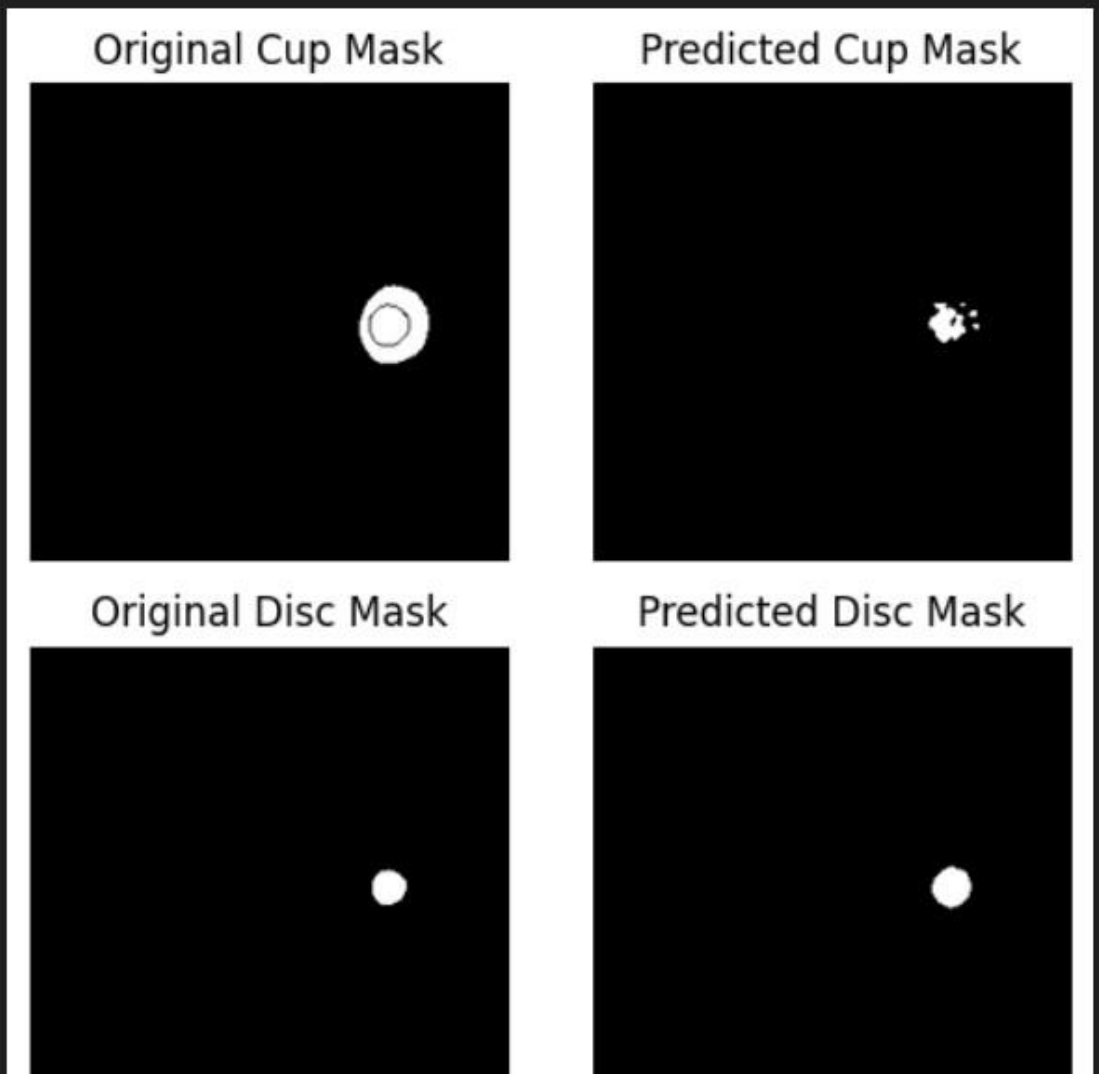


Unsupervised Outputs:

Segmentation Task	Metric	Value
Optic Disc Segmentation	Accuracy	0.9896080579392611
	Precision	0.6713286713286714
	Recall	0.43686006825938567
	IoU	0.3598875351452671
Optic Cup Segmentation	Accuracy	0.995564197605882
	Precision	0.42063492063492064
	Recall	1.0
	IoU	0.42063492063492064
Diagnosis	CDR	1.1349206349206349
	Diagnosis	High likelihood of glaucoma



Optic Disc Segmentation	Accuracy	0.9863916519192042
	Precision	0.9565217391304348
	Recall	0.23076923076923078
	IoU	0.22837370242214533
Optic Cup Segmentation	Accuracy	0.9988112293108178
	Precision	0.7732558139534884
	Recall	1.0
	IoU	0.7732558139534884
Diagnosis	CDR	0.8023255813953488
	Diagnosis	High likelihood of glaucoma



```
...   Segmentation Task        Metric     Value
      ----------------------   ---------  --------------------------
      Optic Disc Segmentation  Accuracy   0.988795731707317
                               Precision  0.8990536277602523
                               Recall     0.45930701047542305
                               IoU        0.4367816091954023
      Optic Cup Segmentation   Accuracy   0.9973518400146105
                               Precision  0.697508896797153
                               Recall     0.98989898989899
                               IoU        0.6925795053003534
      Diagnosis                CDR        1.1281138790035588
                               Diagnosis  High likelihood of glaucoma
```

...