Digital Image Processing Project Report
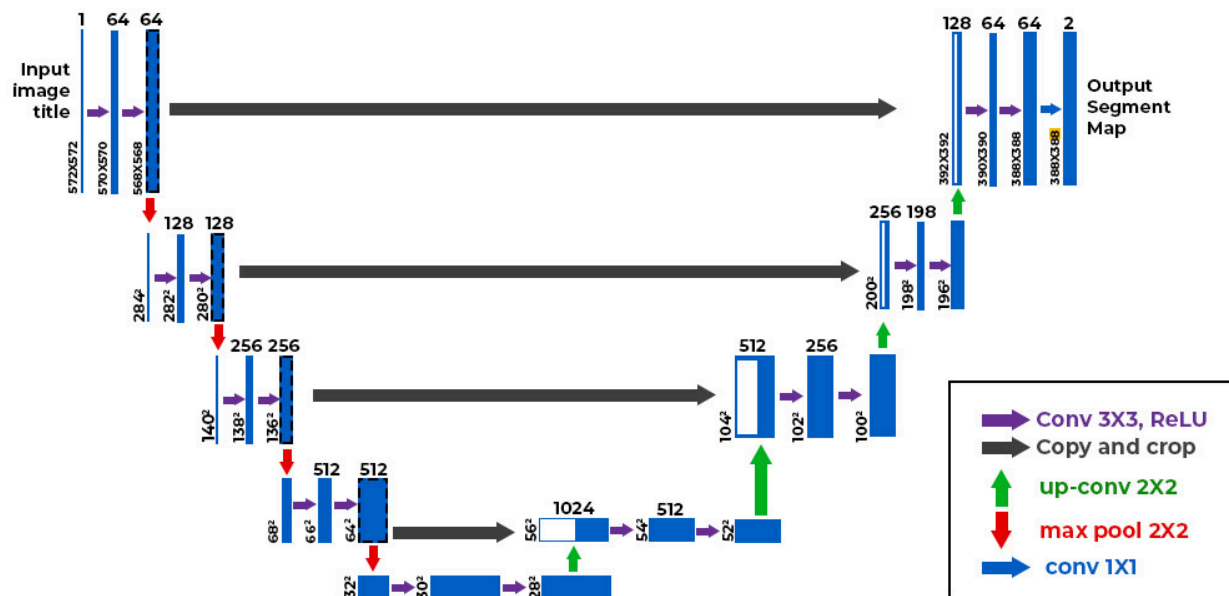
Developed By

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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 ad 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 ad 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 achiever 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 downsampling.
- `decoder_block`: Defines a decoder block that includes convolutional transpose (deconvolution) for upsampling followed by concatenation with skip connections from the encoder and convolutional blocks.
- Encoder block encodes the data using 2 concolutional layes

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.
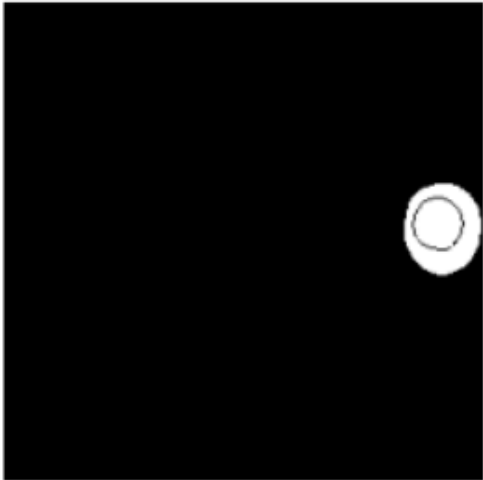
Evaluation Metrics and Diagnosis

- 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.
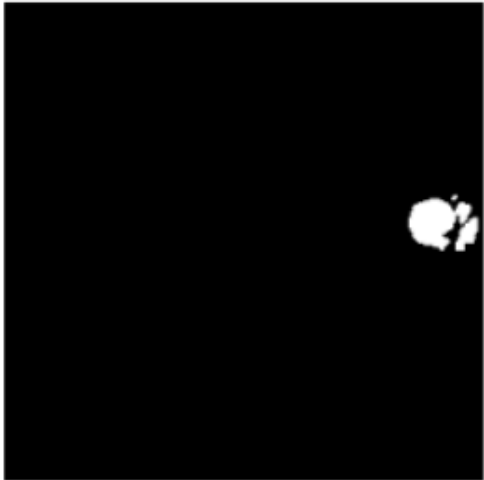
Supervised Outputs:

```
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
```
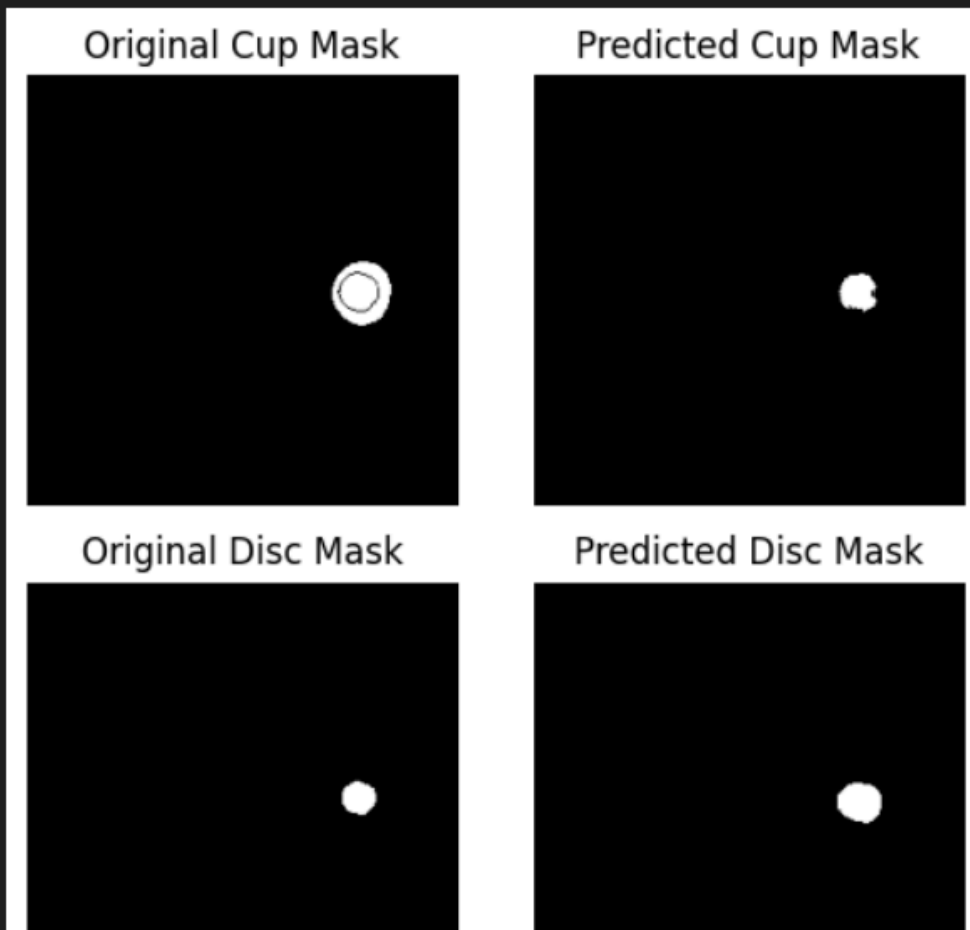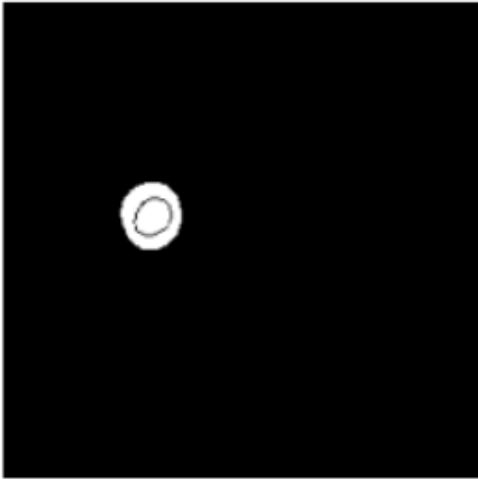

Original Cup Mask | Predicted Cup Mask

Original Disc Mask | Predicted Disc Mask

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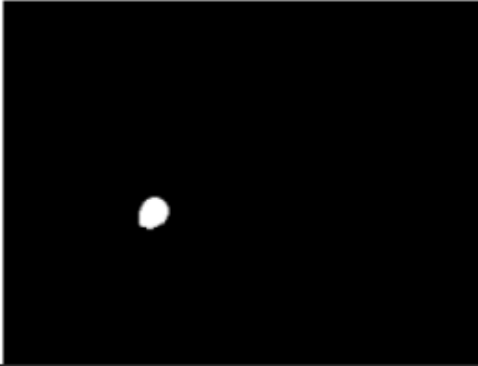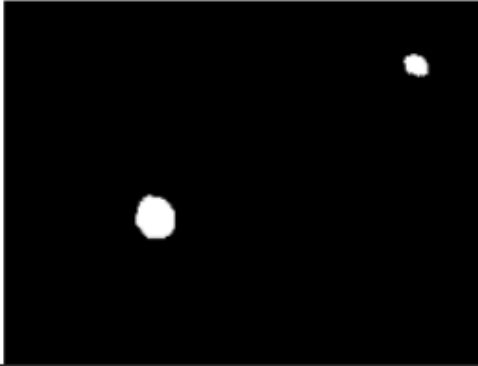
```
Optic Disc Segmentation    Accuracy    0.9863916519192042
                           Precision   0.9565217391304348
                           Recall      0.23076923076923078
                           IoU         0.22837370242214533
Optic Cup Segmentation     Accuracy    0.9988112293108178
    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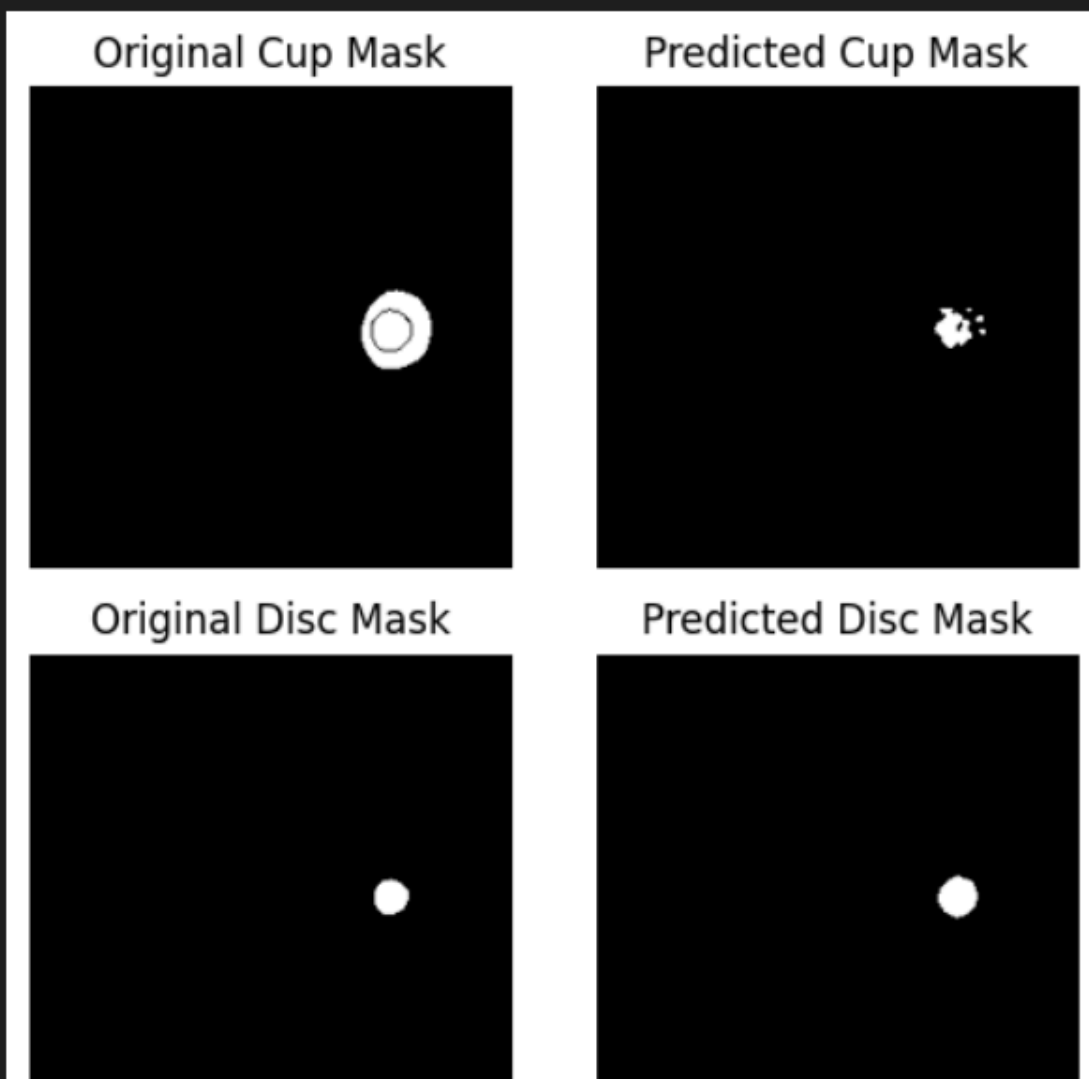

Original Cup Mask   Predicted Cup Mask

Original Disc Mask   Predicted Disc Mask

```
...    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
```