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Capstone Project 2 - Milestone Report 2
Springboard Data Science Career Track
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November 13, 2019

Cancer Detection in Histological Slides

OVERVIEW

Cancer is deadly and early diagnosis will play an important role in treatment and improvement of the patient's survival rate. Cancer can be benign or metastatic. One of the most important early diagnosis is detection in lymph nodes to find out whether the cancer has metastasized. The method to do this is H & E staining of histological slides of lymph nodes taken from biopsies.

GOALS

Currently pathologists manually examine the slides and decide if the patient has metastatic cancer or not. Because human judgement is not consistent and the diagnosis can vary between person to person and even between different days by the same person. Thus by developing deep learning algorithm we can automate the process and give unbiased results.

DATA SOURCE

The data for my project are downloaded from Kaggle website (https://www.kaggle.com/c/histopathologic-cancer-detection/data). Following data are provided:-

1. Sample_submission.csv - a sample submission file in the correct format
2. Train_labels.csv - a file with labels of 0 or 1 (0 for cancer not detected and 1 for cancer detected) for corresponding images in training dataset.

3. Train - a folder with 220,025 images from histopathological slides. These are the images I have to train my model on.
4. Test - a folder with 57,458 images. These are the images I will use to predict cancer detection.

EXPLORATORY DATA ANALYSIS

The training set has 220,025 images. The dataset is imbalanced (number of images in each class is not equal) as seen in figure 1 below:-

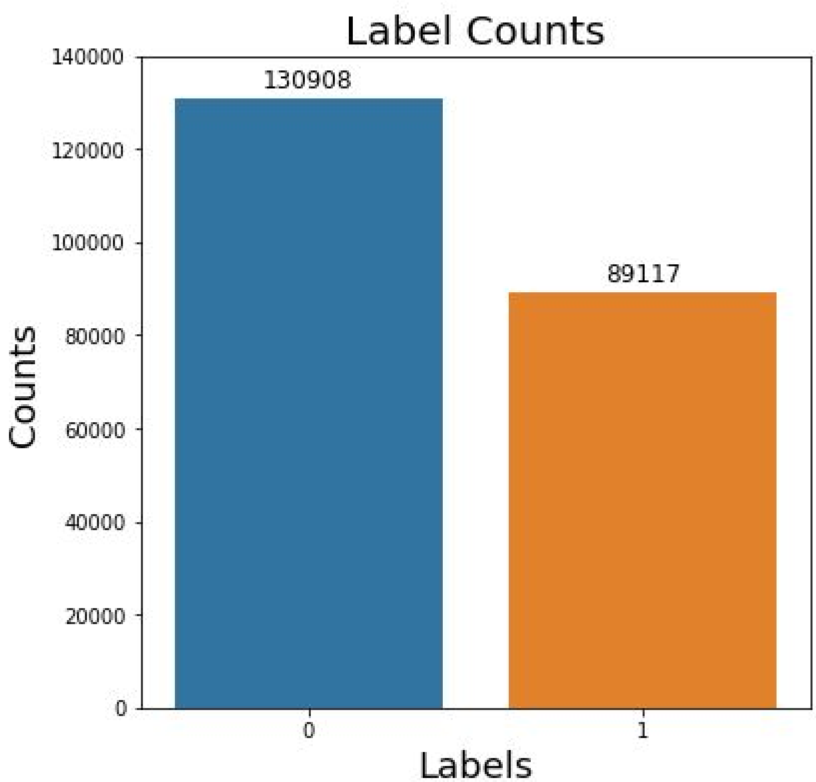

Figure 1: Distribution of images in the datasets

Images of normal tissue comprised of 59.5% and cancerous tissue only 40.5%.

Shown below, in figure 2, are representative images of normal (0) and cancerous (1) tissues.

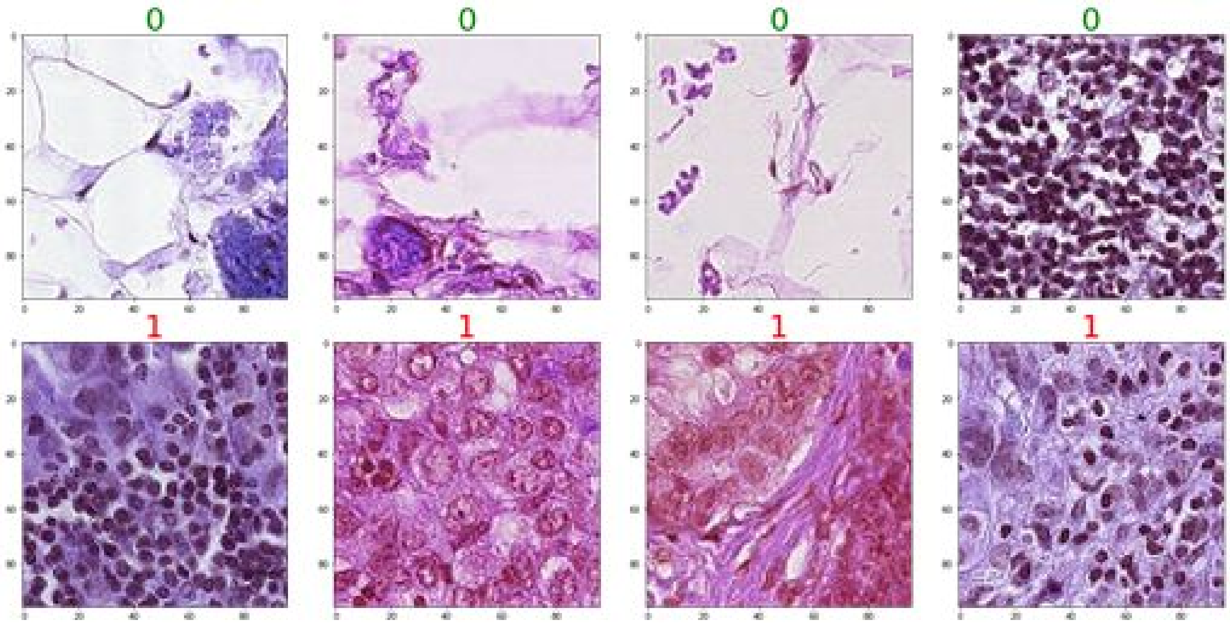

Figure 2: Representative images

DATA WRANGLING / SAMPLING OF IMAGES FOR TRAINING

Since the dataset is imbalanced and very large and neural networks take very long to train on all the datasets, I decided to sample 20,000 images in each class (a total of 40,000 images) to make the dataset balanced and smaller yet containing enough images to train my models. After sampling, I put them into separate folders to be consistent in training different models multiple times. Then I split the data 80/20 into training and validation sets. This will be my training and validation datasets for all the models.

CONVOLUTIONAL NEURAL NETWORK MODELS

I built five CNN models and two pretrained models that were fed features extracted from the image sequences. Machine learning was performed using Python, primarily with Keras with TensorFlow in the backend on MacBookPro with 2.3 GHz Quad-core Intel Core i5 and 16 GB memory.

Model Descriptions:

Model-1: "sequential_1"

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_1 (Conv2D)            (None, 95, 95, 32)        416
_________________________________________________________________
```

```
conv2d_2 (Conv2D)            (None, 94, 94, 32)        4128
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 93, 93, 32)        4128
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 46, 46, 32)        0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 45, 45, 32)        4128
_________________________________________________________________
conv2d_5 (Conv2D)            (None, 44, 44, 32)        4128
_________________________________________________________________
conv2d_6 (Conv2D)            (None, 43, 43, 32)        4128
_________________________________________________________________
max_pooling2d_2 (MaxPooling2 (None, 21, 21, 32)        0
_________________________________________________________________
conv2d_7 (Conv2D)            (None, 20, 20, 64)        8256
_________________________________________________________________
conv2d_8 (Conv2D)            (None, 19, 19, 64)        16448
_________________________________________________________________
conv2d_9 (Conv2D)            (None, 18, 18, 64)        16448
_________________________________________________________________
max_pooling2d_3 (MaxPooling2 (None, 9, 9, 64)          0
_________________________________________________________________
flatten_1 (Flatten)          (None, 5184)              0
_________________________________________________________________
dense_1 (Dense)              (None, 64)                331840
_________________________________________________________________
dropout_1 (Dropout)          (None, 64)                0
_________________________________________________________________
dense_2 (Dense)              (None, 2)                 130
=================================================================
Total params: 394,178
Trainable params: 394,178
Non-trainable params: 0

_________________________________________________________________
```

Model-2: "sequential_2"

```
_________________________________________________________________

Layer (type)                 Output Shape              Param #

=================================================================

conv2d_10 (Conv2D)           (None, 95, 95, 32)        416

_________________________________________________________________

conv2d_11 (Conv2D)           (None, 94, 94, 32)        4128
```

```
_________________________________________________________________
conv2d_12 (Conv2D)           (None, 93, 93, 32)        4128
_________________________________________________________________
max_pooling2d_4 (MaxPooling2 (None, 46, 46, 32)        0
_________________________________________________________________
conv2d_13 (Conv2D)           (None, 45, 45, 32)        4128
_________________________________________________________________
conv2d_14 (Conv2D)           (None, 44, 44, 32)        4128
_________________________________________________________________
conv2d_15 (Conv2D)           (None, 43, 43, 32)        4128
_________________________________________________________________
max_pooling2d_5 (MaxPooling2 (None, 21, 21, 32)        0
_________________________________________________________________
conv2d_16 (Conv2D)           (None, 20, 20, 64)        8256
_________________________________________________________________
conv2d_17 (Conv2D)           (None, 19, 19, 64)        16448
_________________________________________________________________
conv2d_18 (Conv2D)           (None, 18, 18, 64)        16448
_________________________________________________________________
max_pooling2d_6 (MaxPooling2 (None, 9, 9, 64)               0
_________________________________________________________________
conv2d_19 (Conv2D)           (None, 8, 8, 128)         32896
_________________________________________________________________
conv2d_20 (Conv2D)           (None, 7, 7, 128)         65664
_________________________________________________________________
conv2d_21 (Conv2D)           (None, 6, 6, 128)         65664
_________________________________________________________________
max_pooling2d_7 (MaxPooling2 (None, 3, 3, 128)         0
_________________________________________________________________
```

```
flatten_2 (Flatten)          (None, 1152)            0
_________________________________________________________________
dense_3 (Dense)             (None, 64)                73792
_________________________________________________________________
dropout_2 (Dropout)          (None, 64)              0
_________________________________________________________________
dense_4 (Dense)              (None, 2)               130
=================================================================
Total params: 300,354
Trainable params: 300,354
Non-trainable params: 0
_________________________________________________________________
```

Model-3: "sequential_3"

```
_________________________________________________________________
Layer (type)                 Output Shape            Param #
=================================================================
conv2d_22 (Conv2D)           (None, 95, 95, 32)      416
_________________________________________________________________
conv2d_23 (Conv2D)           (None, 94, 94, 32)      4128
_________________________________________________________________
conv2d_24 (Conv2D)           (None, 93, 93, 32)      4128
_________________________________________________________________
max_pooling2d_8 (MaxPooling2 (None, 46, 46, 32)      0
_________________________________________________________________
conv2d_25 (Conv2D)           (None, 45, 45, 32)      4128
_________________________________________________________________
conv2d_26 (Conv2D)           (None, 44, 44, 32)      4128
_________________________________________________________________
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```
conv2d_27 (Conv2D)           (None, 43, 43, 32)     4128
_________________________________________________________________
max_pooling2d_9 (MaxPooling2 (None, 21, 21, 32)     0
_________________________________________________________________
conv2d_28 (Conv2D)           (None, 20, 20, 64)     8256
_________________________________________________________________
conv2d_29 (Conv2D)           (None, 19, 19, 64)     16448
_________________________________________________________________
conv2d_30 (Conv2D)           (None, 18, 18, 64)     16448
_________________________________________________________________
max_pooling2d_10 (MaxPooling (None, 9, 9, 64)       0
_________________________________________________________________
conv2d_31 (Conv2D)           (None, 8, 8, 128)      32896
_________________________________________________________________
conv2d_32 (Conv2D)           (None, 7, 7, 128)      65664
_________________________________________________________________
conv2d_33 (Conv2D)           (None, 6, 6, 128)     65664
_________________________________________________________________
max_pooling2d_11 (MaxPooling (None, 3, 3, 128)      0
_________________________________________________________________
flatten_3 (Flatten)          (None, 1152)               0
_________________________________________________________________
dense_5 (Dense)              (None, 64)             73792
_________________________________________________________________
dropout_3 (Dropout)          (None, 64)             0
_________________________________________________________________
dense_6 (Dense)              (None, 2)              130
=================================================================
Total params: 300,354
```

```
Trainable params: 300,354

Non-trainable params: 0

_________________________________________________________________
```

Model-4: "sequential_4"

```
_________________________________________________________________

Layer (type)                 Output Shape              Param #

=================================================================

conv2d_34 (Conv2D)           (None, 94, 94, 32)        896

_________________________________________________________________

conv2d_35 (Conv2D)           (None, 92, 92, 32)        9248

_________________________________________________________________

conv2d_36 (Conv2D)           (None, 90, 90, 32)        9248

_________________________________________________________________

max_pooling2d_12 (MaxPooling (None, 45, 45, 32)        0

_________________________________________________________________

dropout_4 (Dropout)          (None, 45, 45, 32)           0

_________________________________________________________________

conv2d_37 (Conv2D)           (None, 43, 43, 64)        18496

_________________________________________________________________

conv2d_38 (Conv2D)           (None, 41, 41, 64)        36928

_________________________________________________________________

conv2d_39 (Conv2D)           (None, 39, 39, 64)        36928

_________________________________________________________________

max_pooling2d_13 (MaxPooling (None, 19, 19, 64)        0

_________________________________________________________________

dropout_5 (Dropout)          (None, 19, 19, 64)        0

_________________________________________________________________

conv2d_40 (Conv2D)         (None, 17, 17, 128)         73856
```

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_________________________________________________________________
conv2d_41 (Conv2D)           (None, 15, 15, 128)       147584
_________________________________________________________________
conv2d_42 (Conv2D)           (None, 13, 13, 128)       147584
_________________________________________________________________
max_pooling2d_14 (MaxPooling (None, 6, 6, 128)         0
_________________________________________________________________
dropout_6 (Dropout)          (None, 6, 6, 128)         0
_________________________________________________________________
flatten_4 (Flatten)          (None, 4608)              0
_________________________________________________________________
dense_7 (Dense)              (None, 256)               1179904
_________________________________________________________________
dropout_7 (Dropout)          (None, 256)               0
_________________________________________________________________
dense_8 (Dense)              (None, 2)                 514
=================================================================
Total params: 1,661,186
Trainable params: 1,661,186
Non-trainable params: 0
_________________________________________________________________
```

Model-5: "sequential_5"

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
conv2d_43 (Conv2D)           (None, 95, 95, 32)        416
_________________________________________________________________
```

```
conv2d_44 (Conv2D)           (None, 94, 94, 32)     4128
_________________________________________________________________
conv2d_45 (Conv2D)           (None, 93, 93, 32)     4128
_________________________________________________________________
max_pooling2d_15 (MaxPooling (None, 46, 46, 32)     0
_________________________________________________________________
dropout_8 (Dropout)          (None, 46, 46, 32)     0
_________________________________________________________________
conv2d_46 (Conv2D)           (None, 45, 45, 64)     8256
_________________________________________________________________
conv2d_47 (Conv2D)           (None, 44, 44, 64)     16448
_________________________________________________________________
conv2d_48 (Conv2D)           (None, 43, 43, 64)     16448
_________________________________________________________________
max_pooling2d_16 (MaxPooling (None, 21, 21, 64)     0
_________________________________________________________________
dropout_9 (Dropout)          (None, 21, 21, 64)        0
_________________________________________________________________
conv2d_49 (Conv2D)           (None, 20, 20, 128)    32896
_________________________________________________________________
conv2d_50 (Conv2D)           (None, 19, 19, 128)    65664
_________________________________________________________________
conv2d_51 (Conv2D)           (None, 18, 18, 128)    65664
_________________________________________________________________
max_pooling2d_17 (MaxPooling (None, 9, 9, 128)      0
_________________________________________________________________
dropout_10 (Dropout)         (None, 9, 9, 128)      0
_________________________________________________________________
conv2d_52 (Conv2D)        (None, 8, 8, 128)         65664
```

```
_________________________________________________________________
conv2d_53 (Conv2D)           (None, 7, 7, 128)         65664
_________________________________________________________________
conv2d_54 (Conv2D)           (None, 6, 6, 128)         65664
_________________________________________________________________
max_pooling2d_18 (MaxPooling (None, 3, 3, 128)         0
_________________________________________________________________
dropout_11 (Dropout)         (None, 3, 3, 128)         0
_________________________________________________________________
flatten_5 (Flatten)          (None, 1152)              0
_________________________________________________________________
dense_9 (Dense)              (None, 256)               295168
_________________________________________________________________
dropout_12 (Dropout)         (None, 256)               0
_________________________________________________________________
dense_10 (Dense)             (None, 2)                 514
=================================================================
Total params: 706,722
Trainable params: 706,722
Non-trainable params: 0
_________________________________________________________________
```

Model-6 ResNet50: "model_1"

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         (None, 96, 96, 3)         0
_________________________________________________________________
resnet50 (Model)             (None, 3, 3, 2048)        23587712
_________________________________________________________________
global_average_pooling2d_1 ( (None, 2048)              0
_________________________________________________________________
dropout_1 (Dropout)          (None, 2048)              0
_________________________________________________________________
dense_1 (Dense)              (None, 2)                 4098
=================================================================
Total params: 23,591,810
Trainable params: 23,538,690
Non-trainable params: 53,120
_________________________________________________________________
```

Model-7 NASNet: "model_1"

```
__________________________________________________________________________________________________
Layer (type)                    Output Shape         Param #     Connected to
==================================================================================================
input_2 (InputLayer)            (None, 96, 96, 3)    0
__________________________________________________________________________________________________
NASNet (Model)                  (None, 3, 3, 1056)   4269716 input_2[0][0]
__________________________________________________________________________________________________
global_max_pooling2d_1 (GlobalM (None, 1056)         0           NASNet[1][0]
__________________________________________________________________________________________________
global_average_pooling2d_1 (Glo (None, 1056)             0       NASNet[1][0]
__________________________________________________________________________________________________
```

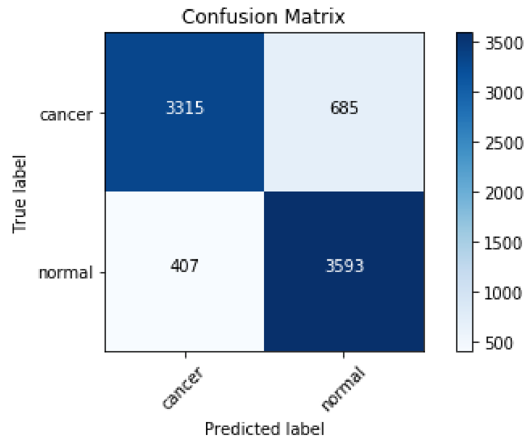
```
flatten_1 (Flatten)           (None, 9504)          0              NASNet[1][0]
_________________________________________________________________________________________
concatenate_5 (Concatenate)   (None, 11616)         0
                                                                global_max_pooling2d_1[0][0]
                                                                   global_average_pooling2d_1[0][0]
                                                                       flatten_1[0][0]
________________________________________________________________________________________
dropout_1 (Dropout)           (None, 11616)         0              concatenate_5[0][0]
_________________________________________________________________________________________
3_ (Dense)                    (None, 2)             23234          dropout_1[0][0]
=========================================================================================
Total params: 4,292,950
Trainable params: 4,256,212
Non-trainable params: 36,738
_________________________________________________________________________________________
```

Model performances:

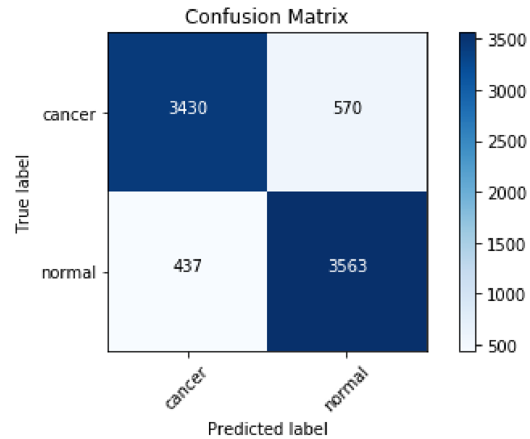
	Val_loss	val_acc	roc_auc_scores
Model1	0.023002	0.865250	0.940067
Model2	0.018761	0.869687	0.945249
Model3	0.014563	0.871375	0.945899
Model4	0.025661	0.838375	0.921132
Model5	0.056837	0.853500	0.925100
Model6	0.008133	0.935375	0.980530
Model7	0.031510	0.840813	0.925162

Based on the above data, it looks like Model6 performed the best.

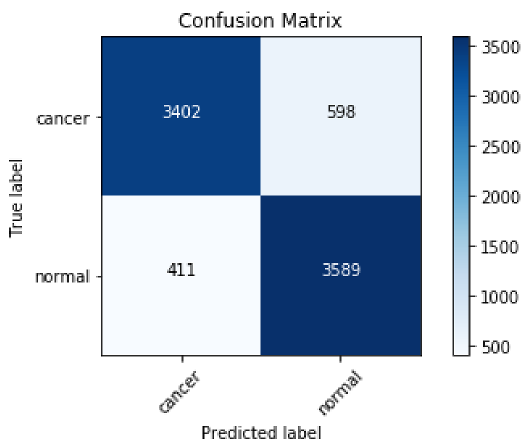
Model 1



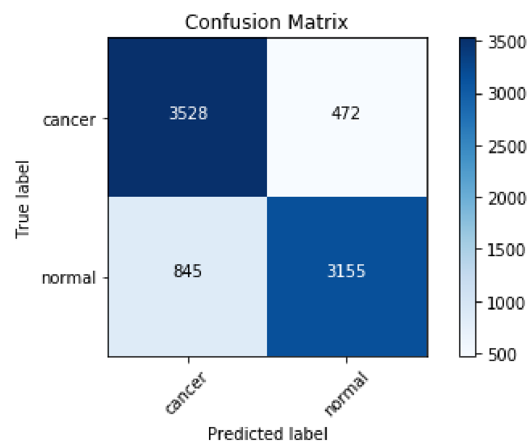
Model 2



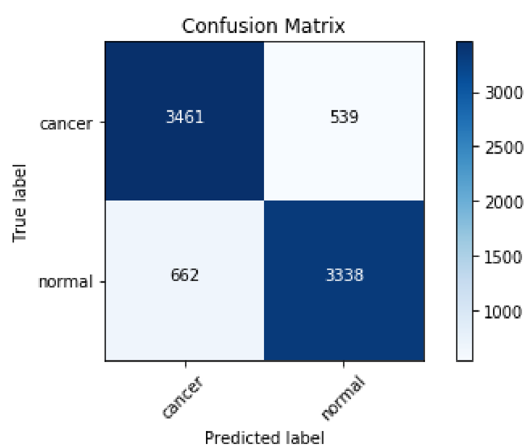
Model 3



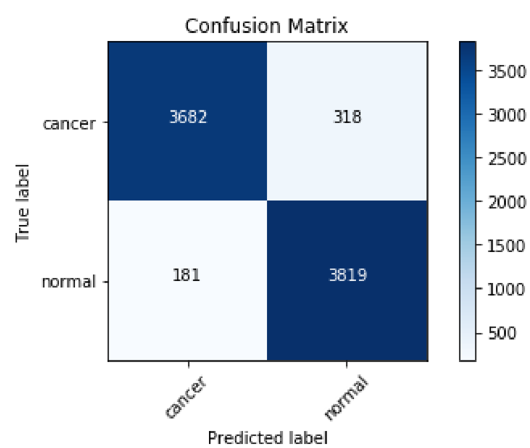
Model 4



Model 5



Model 6



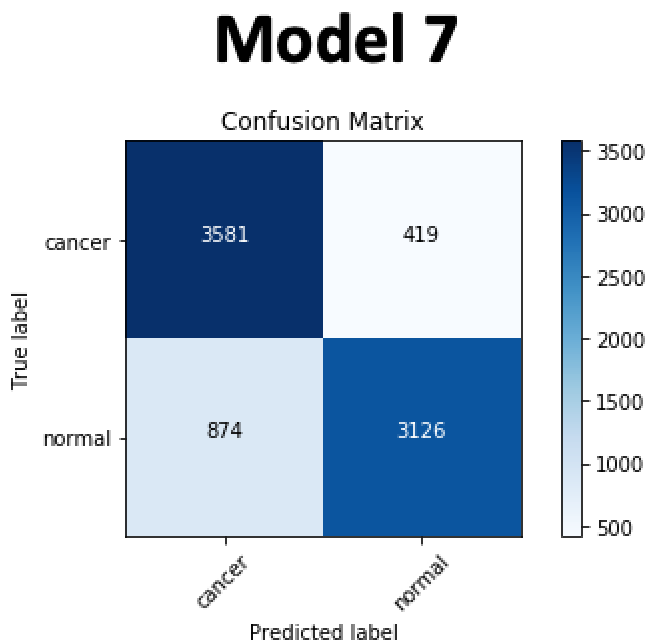


Figure 3: Confusion matrices of the model performances.

Table1: Precision and recall of the models tested.

	precision		recall		f1-score	
	cancer	normal	cancer	normal	cancer	normal
model1	0.89	0.84	0.83	0.9	0.86	0.87
model2	0.89	0.86	0.86	0.89	0.87	0.88
model3	0.89	0.86	0.85	0.9	0.87	0.88
model4	0.81	0.87	0.88	0.79	0.84	0.83
model5	0.84	0.86	0.87	0.83	0.85	0.85
model6	0.95	0.92	0.92	0.95	0.94	0.94
model7	0.8	0.88	0.9	0.78	0.85	0.83

FUTURE DIRECTIONS:

In this project I trained the model using 20,000 images in each class. Based on the computing power the entire dataset with 220,025 could be utilized to train the models.

PROJECT LINK

https://github.com/leukemia/Capstone_Projects/tree/master/Capstone_Project02/Milestone_Report-02