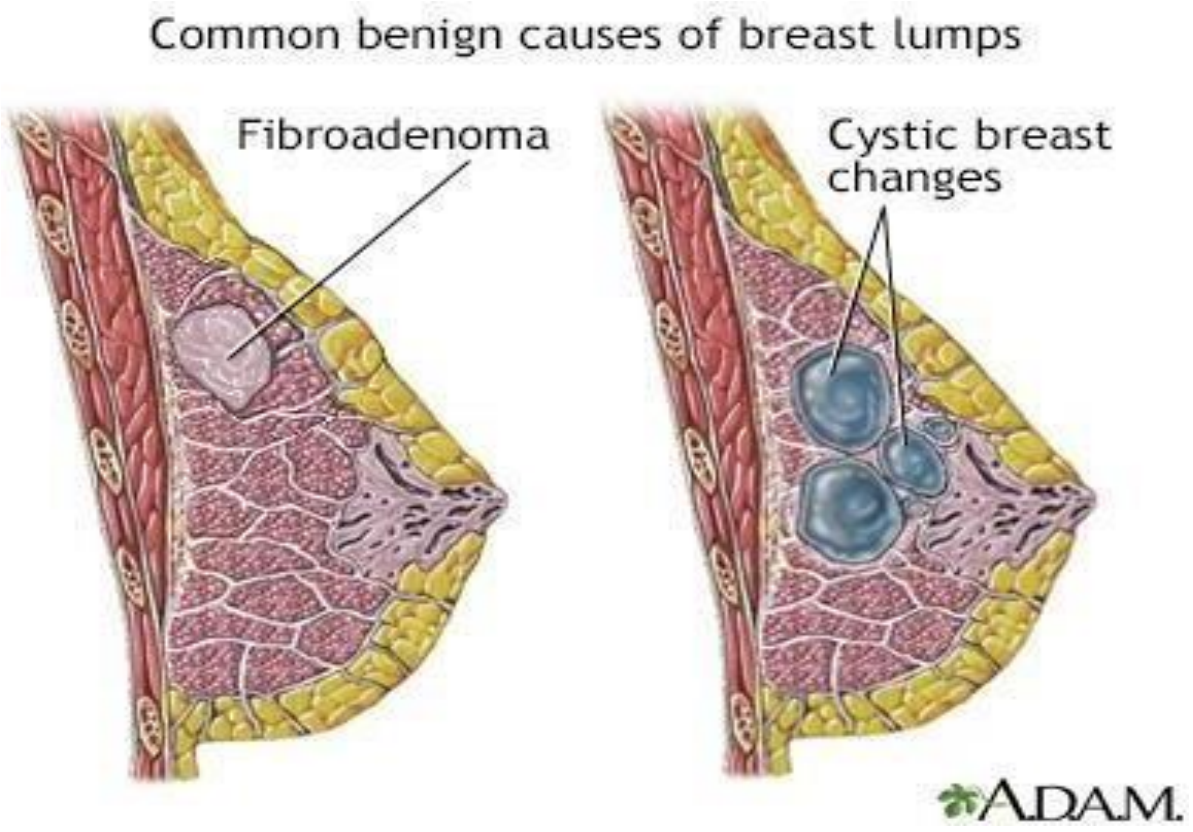
BREAST CANCER PREDICTION USING DEEP LEARNING

- Breast cancer is the second leading cause of cancer deaths among U.S. women, it is a type of cancer that starts when cells begin to grow outof control
- Most breast cancers begin in the ducts that carry milk to the nipple (ductal cancers),
- Breast cancer can spread when the cancer cells get into the blood or lymph system and are carried to other parts of the body.
- Cancerous breast tumors are detected by a special type of examination, which is screening mammogram



Detection of breast cancer on screening mammography is challenging as an image classification task because the tumors themselves occupy only a small portion of the image of the entire breast. For example, a full-field digital mammography (FFDM) image is typically 4000 × 3000 pixels while a potentially cancerous region of interest (ROI) can be as small as 100 × 100 pixels.

This explains the large number that we have in the data, which is more than **a quarter of a million** images!

Key facts

- Breast cancer caused 685 000 deaths globally in 2020.
- Roughly half of all breast cancers occur in women with no specific risk factors other than sex and age.
- Breast cancer occurs in every country in the world.
- Approximately 0.5–1% of breast cancers occur in men.

Overview

- Breast cancer is a disease in which abnormal breast cells grow out of control and form tumours. If left unchecked, the tumours can spread throughout the body and become fatal.
- Breast cancer cells begin inside the milk ducts and/or the milk-producing lobules of the breast. The earliest form (in situ) is not life-threatening. Cancer cells can spread into nearby breast tissue (invasion). This creates tumours that cause lumps or thickening.
- Invasive cancers can spread to nearby lymph nodes or other organs (metastasize). Metastasis can be fatal.
- Treatment is based on the person, the type of cancer and its spread. Treatment combines surgery, radiation therapy and medications.

Scope of the problem

In 2020, there were 2.3 million women diagnosed with breast cancer and 685 000 deaths globally. As of the end of 2020, there were 7.8 million women alive who were diagnosed with breast cancer in the past 5 years, making it the world's most prevalent cancer. Breast cancer occurs in every country of the world in women at any age after puberty but with increasing rates in later life.

Breast cancer mortality changed little from the 1930s through to the 1970s when surgery alone was the primary mode of treatment (radical mastectomy).

Improvements in survival began in the 1990s when countries established breast cancer early detection programmes that were linked to comprehensive treatment programs including effective medical therapies.

Who is at risk?

Female gender is the strongest breast cancer risk factor. Approximately 0.5–1% of breast cancers occur in men. The treatment of breast cancer in men follows the same principles of management as for women.

Certain factors increase the risk of breast cancer including increasing age, obesity, harmful use of alcohol, family history of breast cancer, history of radiation exposure, reproductive history (such as age that menstrual periods began and age at first pregnancy), tobacco use and postmenopausal hormone therapy.

Approximately half of breast cancers develop in women who have no identifiable breast cancer risk factor other than gender (female) and age (over 40 years).

Family history of breast cancer increases the risk of breast cancer, but most women diagnosed with breast cancer do not have a known family history of the disease. Lack of a known family history does not necessarily mean that a woman is at reduced risk.

Certain inherited high penetrance gene mutations greatly increase breast cancer risk, the most dominant being mutations in the genes BRCA1, BRCA2 and PALB-2. Women found to have mutations in these major genes may consider risk reduction strategies such as surgical removal of both breasts.

Signs and symptoms

Breast cancer can have combinations of symptoms, especially when it is more advanced. Most people will not experience any symptoms when the cancer is still early.

Symptoms of breast cancer can include:

- a breast lump or thickening, often without pain
- change in size, shape or appearance of the breast

- dimpling, redness, pitting or other changes in the skin
- change in nipple appearance or the skin surrounding the nipple (areola)
- abnormal or bloody fluid from the nipple.
- People with an abnormal breast lump should seek medical care, even if the lump does not hurt.

Most breast lumps are not cancer. Breast lumps that are cancerous are more likely to be successfully treated when they are small and have not spread to nearby lymph nodes.

Breast cancers may spread to other areas of the body and trigger other symptoms. Often, the most common first detectable site of spread is to the lymph nodes under the arm although it is possible to have cancer-bearing lymph nodes that cannot be felt.

Over time, cancerous cells may spread to other organs including the lungs, liver, brain and bones. Once they reach these sites, new cancer-related symptoms such as bone pain or headaches may appear.

Treatment

Treatment for breast cancer depends on the subtype of cancer and how much it has spread outside of the breast to lymph nodes (stages II or III) or to other parts of the body (stage IV).

Doctors combine treatments to minimize the chances of the cancer coming back (recurrence). These include:

Surgery to remove the breast tumour :

Radiation therapy to reduce recurrence risk in the breast and surrounding tissues medications to kill cancer cells and prevent spread, including hormonal therapies, chemotherapy or targeted biological therapies.

Treatments for breast cancer are more effective and are better tolerated when started early and taken to completion.

Surgery may remove just the cancerous tissue (called a lumpectomy) or the whole

breast (mastectomy). Surgery may also remove lymph nodes to assess the cancer's ability to spread.

Radiation therapy treats residual microscopic cancers left behind in the breast tissue and/or lymph nodes and minimizes the chances of cancer recurring on the chest wall.

Advanced cancers can erode through the skin to cause open sores (ulceration) but are not necessarily painful. Women with breast wounds that do not heal should seek medical care to have a biopsy performed.

Medicines to treat breast cancers are selected based on the biological properties of the cancer as determined by special tests (tumour marker determination). The great majority of drugs used for breast cancer are already on the WHO Essential Medicines List (EML).

Lymph nodes are removed at the time of cancer surgery for invasive cancers. Complete removal of the lymph node bed under the arm (complete axillary dissection) in the past was thought to be necessary to prevent the spread of cancer. A smaller lymph node procedure called "sentinel node biopsy" is now preferred as it has fewer complications.

Medical treatments for breast cancers, which may be given before ("neoadjuvant") or after ("adjuvant") surgery, is based on the biological subtyping of the cancers. Cancer that express the estrogen receptor (ER) and/or progesterone receptor (PR) are likely to respond to endocrine (hormone) therapies such as tamoxifen or aromatase inhibitors. These medicines are taken orally for 5–10 years and reduce the chance of recurrence of these "hormone-positive" cancers by nearly half. Endocrine therapies can cause symptoms of menopause but are generally well tolerated.

Cancers that do not express ER or PR are "hormone receptor negative" and need to be treated with chemotherapy unless the cancer is very small. The chemotherapy regimens available today are very effective in reducing the chances of cancer spread or recurrence and are generally given as outpatient therapy.

Chemotherapy for breast cancer generally does not require hospital admission in the absence of complications.

Breast cancers may independently overexpress a molecule called the HER-2/neu oncogene. These “HER-2 positive” cancers are amenable to treatment with targeted biological agents such as trastuzumab. These biological agents are very effective but also very expensive, because they are antibodies rather than chemicals. When targeted biological therapies are given, they are combined with chemotherapy to make them effective at killing cancer cells.

Radiotherapy plays a very important role in treating breast cancer. With early-stage breast cancers, radiation can prevent a woman having to undergo a mastectomy. With later stage cancers, radiotherapy can reduce cancer recurrence risk even when a mastectomy has been performed. For advanced stage of breast cancer, in some circumstances, radiation therapy may reduce the likelihood of dying of the disease.

The effectiveness of breast cancer therapies depends on the full course of treatment. Partial treatment is less likely to lead to a positive outcome.

Global impact

Age-standardized breast cancer mortality in high-income countries dropped by 40% between the 1980s and 2020. Countries that have succeeded in reducing breast cancer mortality have been able to achieve an annual breast cancer mortality reduction of 2–4% per year.

The strategies for improving breast cancer outcomes depend on fundamental health system strengthening to deliver the treatments that are already known to work. These are also important for the management of other cancers and other non-malignant noncommunicable diseases (NCDs). For example, having reliable referral pathways from primary care facilities to district hospitals to dedicated cancer centres.

The establishment of reliable referral pathways from primary care facilities to district hospitals to dedicated cancer centres is the same approach as is required

for the management of cervical cancer, lung cancer, colorectal cancer and prostate cancer. To that end, breast cancer is an “index” disease whereby pathways are created that can be followed for the management of other diseases.

WHO response

The objective of the WHO Global Breast Cancer Initiative (GBCI) is to reduce global breast cancer mortality by 2.5% per year, thereby averting 2.5 million breast cancer deaths globally between 2020 and 2040. Reducing global breast cancer mortality by 2.5% per year would avert 25% of breast cancer deaths by 2030 and 40% by 2040 among women under 70 years of age. The three pillars toward achieving these objectives are: health promotion for early detection; timely diagnosis; and comprehensive breast cancer management.

By providing public health education to improve awareness among women of the signs and symptoms of breast cancer and, together with their families, understand the importance of early detection and treatment, more women would consult medical practitioners when breast cancer is first suspected, and before any cancer present is advanced. This is possible even in the absence of ammographic screening that is impractical in many countries at the present time.

Public education needs to be combined with health worker education about the signs and symptoms of early breast cancer so that women are referred to diagnostic services when appropriate.

Rapid diagnosis needs to be linked to effective cancer treatment that in many settings requires some level of specialized cancer care. By establishing centralized services in a cancer facility or hospital, using breast cancer as a model, treatment for breast cancer may be optimized while improving management of other cancers.

Convolutional Neural Network for Breast Cancer Classification

Deep Learning for solving the most commonly diagnosed **cancer** in women

Breast cancer is the second most common cancer in women and men worldwide. In 2012, it represented about 12 percent of all new cancer cases and 25 percent of all cancers in women.

Breast cancer starts when cells in the breast begin to grow out of control. These cells usually form a tumor that can often be seen on an x-ray or felt as a lump. The tumor is malignant (cancer) if the cells can grow into (invade) surrounding tissues or spread (metastasize) to distant areas of the body.

The Challenge

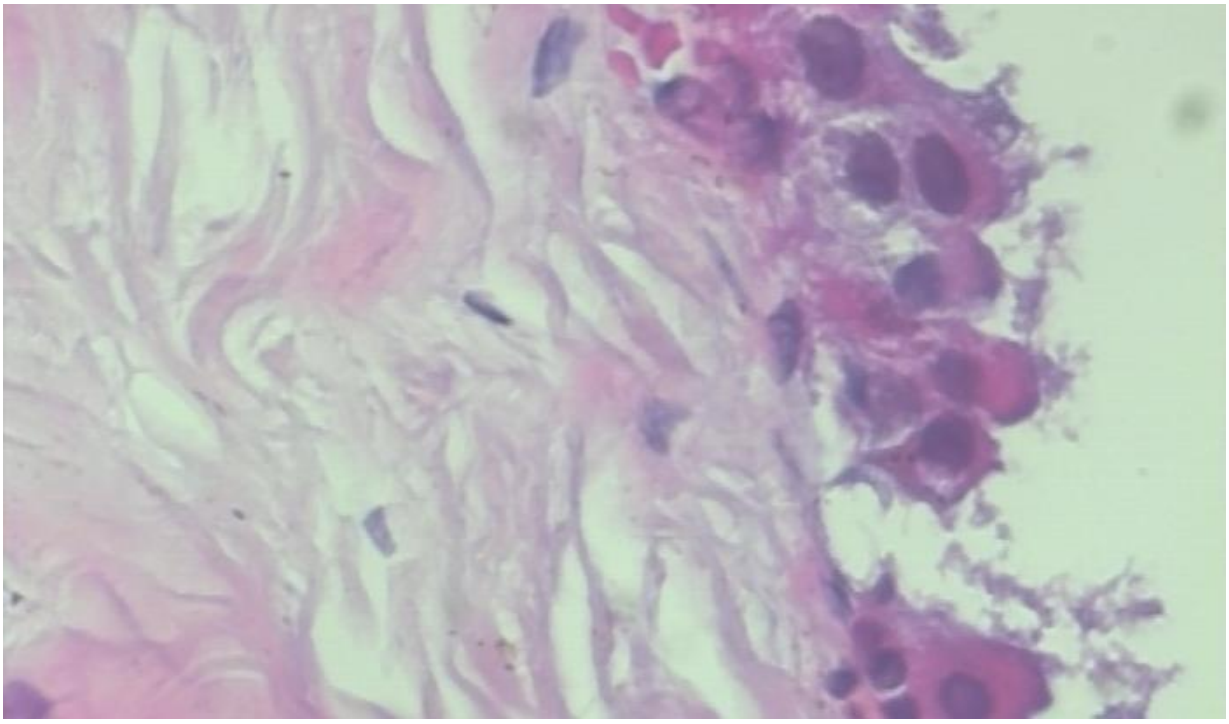
Build an algorithm to automatically identify whether a patient is suffering from breast cancer or not by looking at biopsy images. The algorithm had to be extremely accurate because lives of people is at stake.

Data

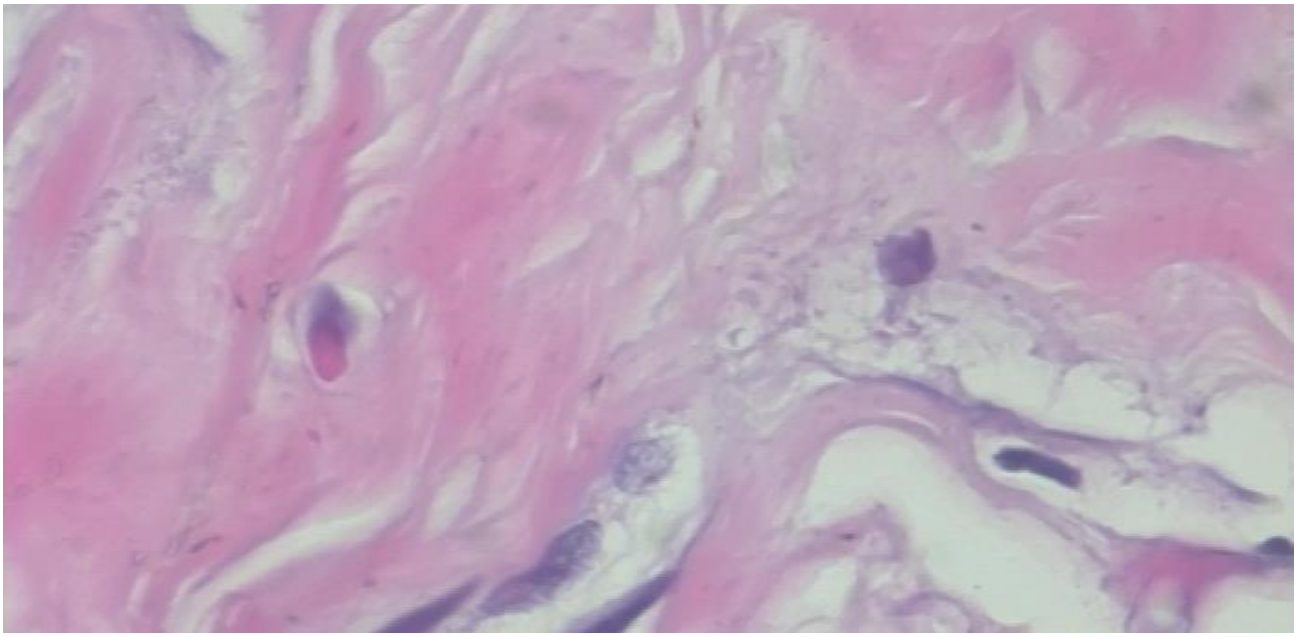
```
dataset train benign
      b1.jpg
      b2.jpg
      //
    malignant
      m1.jpg
      m2.jpg
      // validation
      benign
        b1.jpg
        b2.jpg
        //
      malignant
        m1.jpg
```

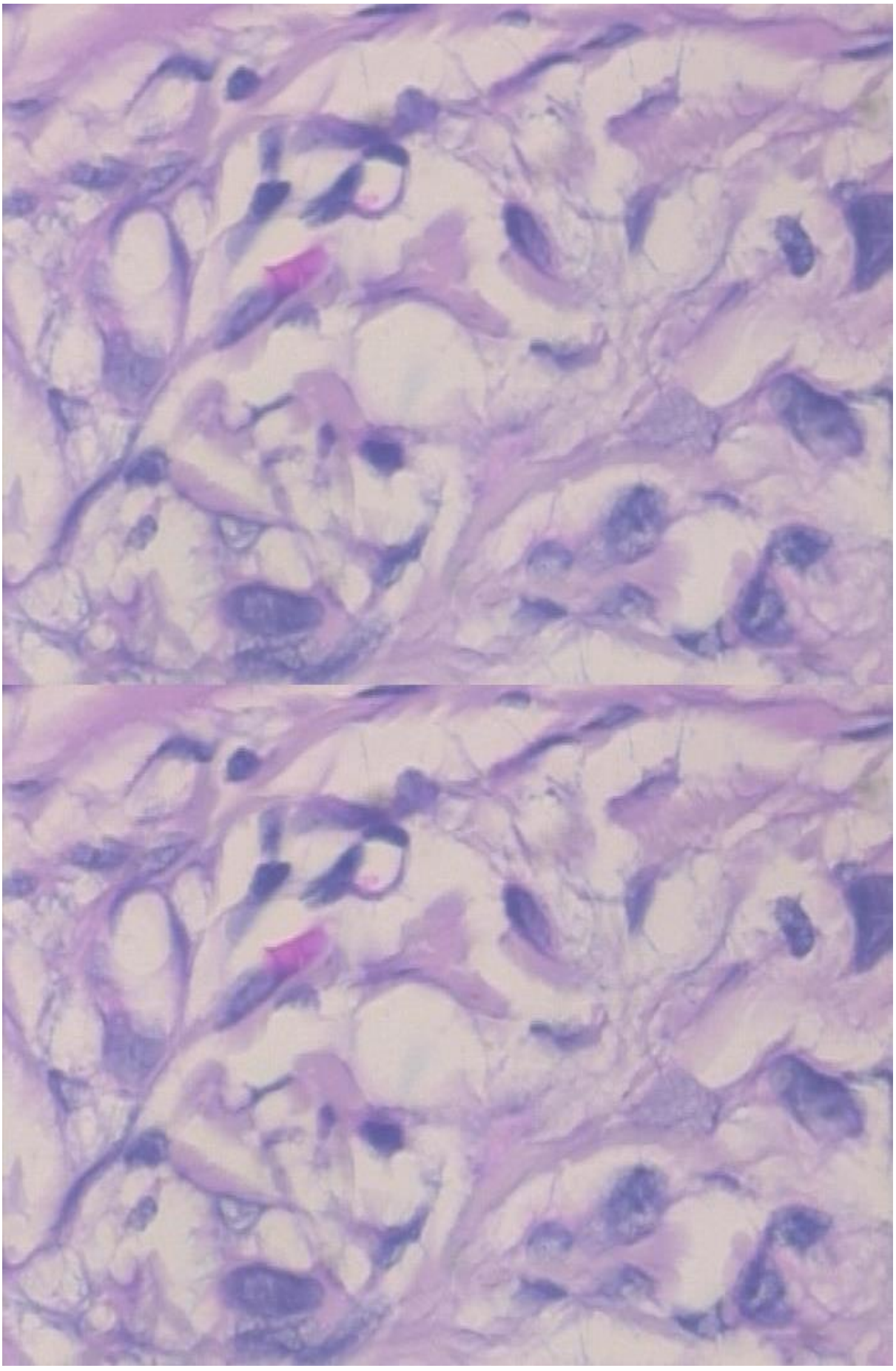
The training folder has 1000 images in each category while the validation folder

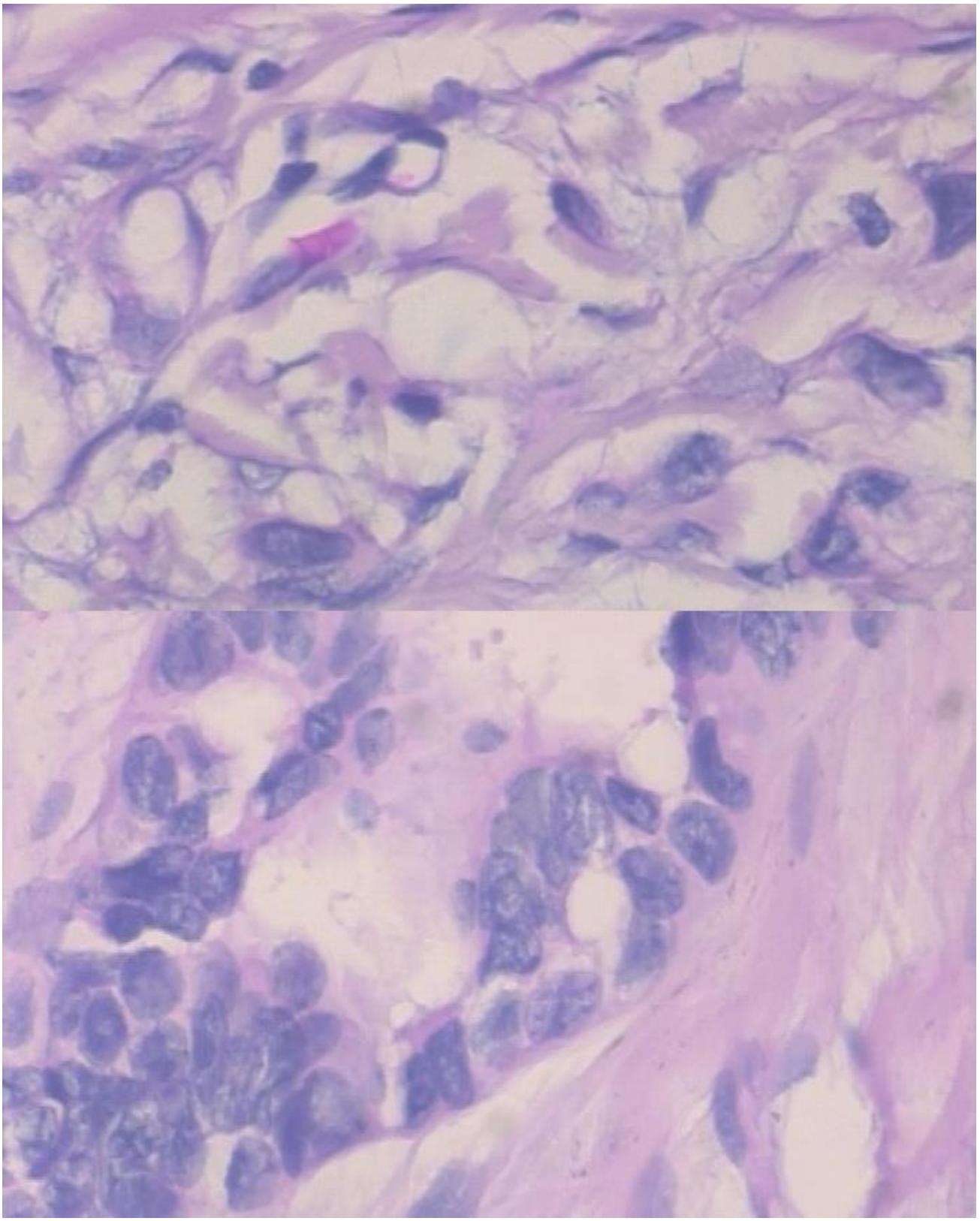
has 250 images in each category.



Benign sample







Malignant sample

CNN Architecture

Let’s go step by step and analyze each layer in the Convolutional

Neural Network.

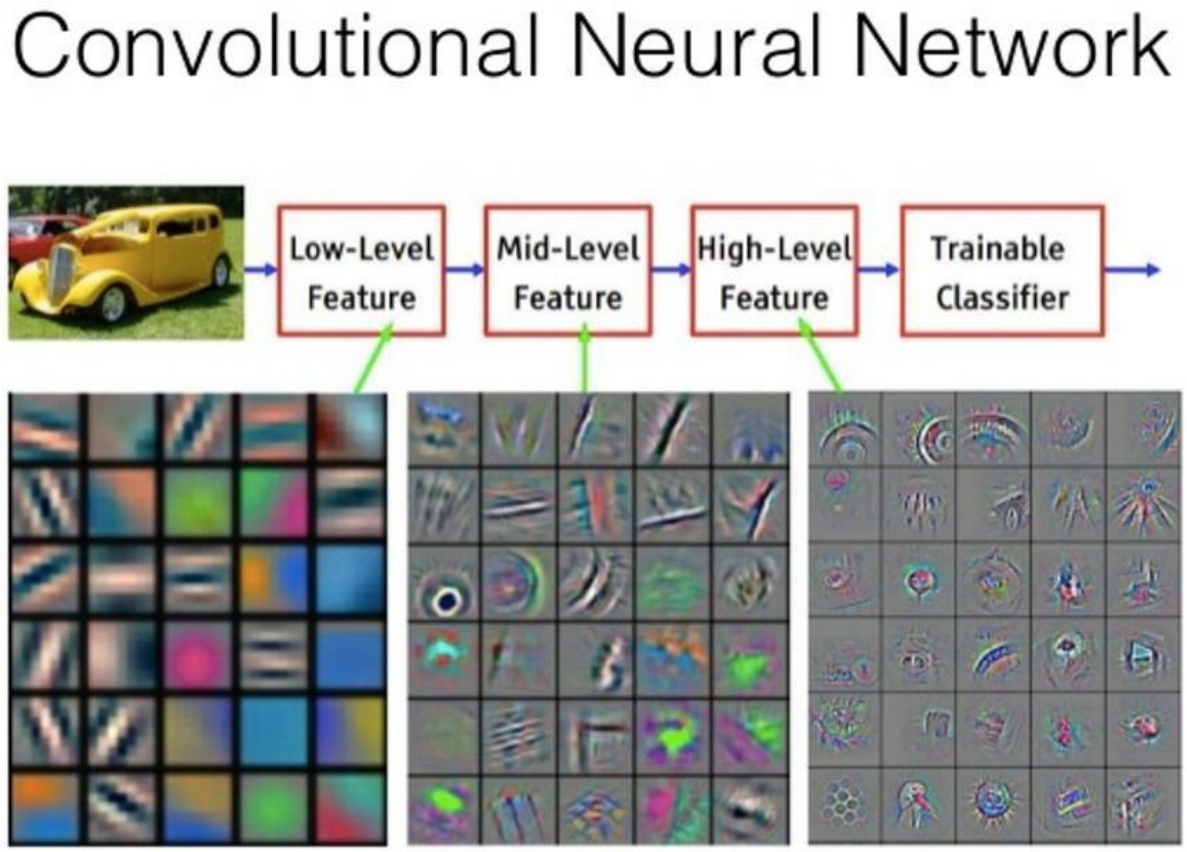
Input

A Matrix of pixel values in the shape of [WIDTH, HEIGHT,

CHANNELS]. Let’s assume that our input is [32x32x3].

Convolution

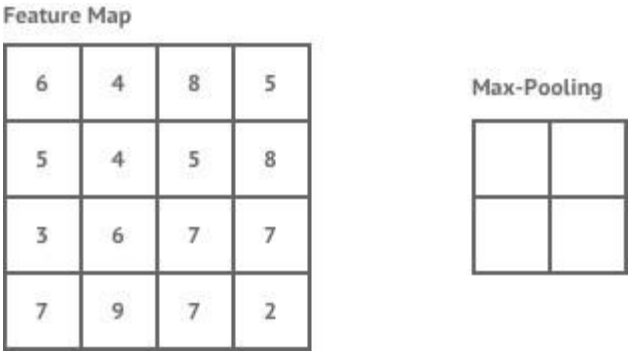
The purpose of this layer is to receive a feature map. Usually, we start with low number of filters for low-level feature detection. The deeper we go into the CNN, the more filters we use to detect high- level features. Feature detection is based on ‘scanning’ the input with the filter of a given size and applying matrix computations in order to derive a feature map.



Convolution Operation

Pooling

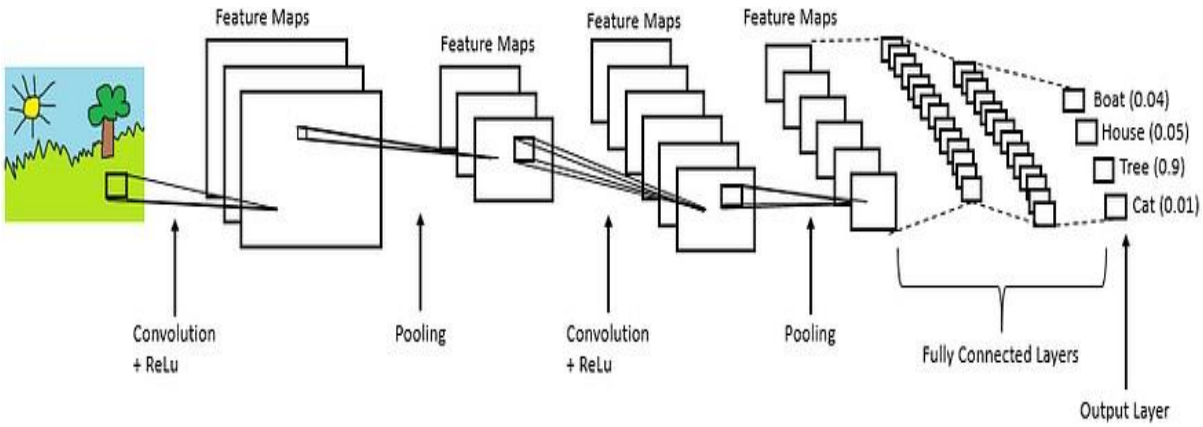
The goal of this layer is to provide spatial variance, which simply means that the system will be capable of recognizing an object even when its appearance varies in some way. Pooling layer will perform a downsampling operation along the spatial dimensions (width, height), resulting in output such as [16x16x12] for pooling_size=(2, 2).



Pooling Operation

Fully Connected

In a fully connected layer, we flatten the output of the last convolution layer and connect every node of the current layer with the other nodes of the next layer. Neurons in a fully connected layer have full connections to all activations in the previous layer, as seen in regular Neural Networks and work in a similar way.



CNN Overview

Image Classification

The complete image classification pipeline can be formalized as follows:

- Our input is a training dataset that consists

  of *N* images, each labeled with one of 2 different classes.

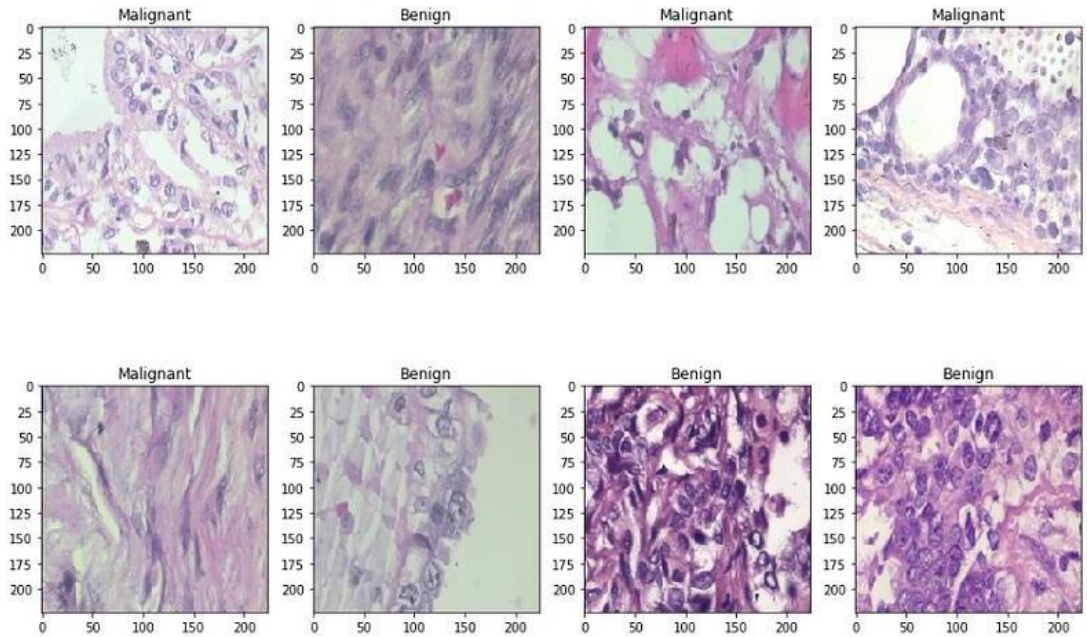
- Then, we use this training set to train a classifier to learn what every one of the classes looks like.

- In the end, we evaluate the quality of the classifier by asking it to predict labels for a new set of images that it has never seen before. We will then compare the true labels of these images to the ones predicted by the classifier.

Where is the code?

Let's start with loading all the libraries and dependencies.Next I loaded the images in the respective folders.

After that I created a numpy array of zeroes for labeling benign images and similarly a numpy array of ones for labeling malignant images. I also shuffled the dataset and converted the labels into categorical format.
Then I split the data-set into two sets — train and test sets with 80% and 20% images respectively. Let's see some sample benign and malignant images.



Benign vs malignant samples

I used a batch size value of 16. Batch size is one of the most important hyperparameters to tune in deep learning. I prefer to use a larger batch size to train my models as it allows computational speedups from the parallelism of GPUs. However, it is well known that too large of a batch size will lead to poor generalization. On the one extreme, using a batch equal to the entire dataset guarantees convergence to the global optima of the objective function. However this is at the cost of slower convergence to that optima. On the other hand, using smaller batch sizes have been shown to have faster convergence to good results. This is intuitively explained by the fact that smaller batch sizes allow the model to start learning before having to see all the data. The downside of using a smaller batch size is that the model is not guaranteed to converge to the global optima.Therefore it is often advised that one starts at a small batch size reaping the benefits of faster training dynamics and steadily grows the batch size through training.

I also did some data augmentation. The practice of data augmentation is an effective way to increase the size of the training set. Augmenting the training examples allow the network to see more diversified, but still representative data points during training.

Then I created a data generator to get the data from our folders and into Keras in an automated way. Keras provides convenient python generator functions for this purpose.

The next step was to build the model. This can be described in the following 3 steps:

1. I used DenseNet201 as the pre trained weights which is already trained in the Imagenet competition. The learning rate was chosen to be 0.0001.

2. On top of it I used a globalaveragepooling layer followed by 50% dropouts to reduce over-fitting.

3. I used batch normalization and a dense layer with 2 neurons for 2 output classes ie benign and malignant with softmax as the activation function.

4. I have used Adam as the optimizer and binary-cross- entropy as the loss function.

Let's see the output shape and the parameters involved in each layer.

```
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
densenet201 (Model)          (None, 7, 7, 1920)        18321984
_________________________________________________________________
global_average_pooling2d_1 ( (None, 1920)              0
_________________________________________________________________
dropout_1 (Dropout)          (None, 1920)              0
_________________________________________________________________
batch_normalization_1 (Batch (None, 1920)              7680
_________________________________________________________________
dense_1 (Dense)              (None, 2)                 3842
=================================================================
Total params: 18,333,506
Trainable params: 18,100,610
Non-trainable params: 232,896
_________________________________________________________________
```

Model summary

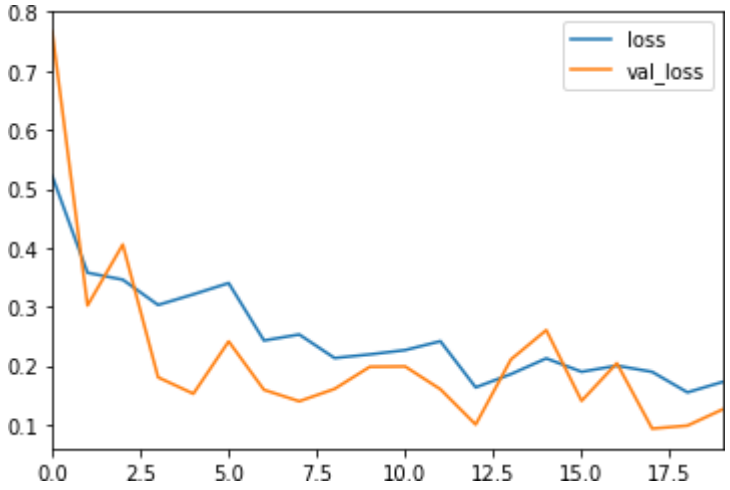
Before training the model, it is useful to define one or more callbacks. Pretty handy one, are: ModelCheckpoint and ReduceLROnPlateau.

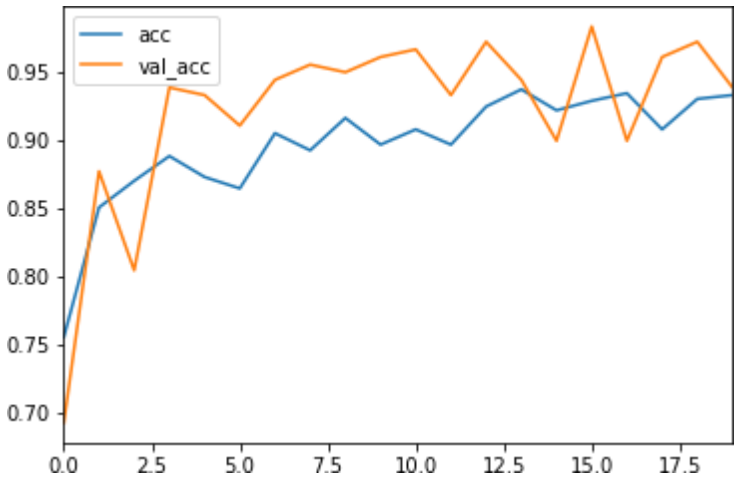
- **ModelCheckpoint**: When training requires a lot of time to achieve a good result, often many iterations are required. In this case, it is better to save a copy of the best performing model only when an epoch that improves the metrics ends.

- **ReduceLROnPlateau**: Reduce learning rate when a metric has stopped improving. Models often benefit from reducing the learning rate by a factor of 2–10 once learning stagnates. This callback monitors a quantity and if no improvement is seen for a 'patience' number of epochs, the learning rate is reduced.

Performance Metrics

The most common metric for evaluating model performance is the accurcacy. However, when only 2% of your dataset is of one class (malignant) and 98% some other class (benign), misclassification scores don't really make sense. You can be 98% accurate and still catch none of the malignant cases which could make a terrible classifier.





Loss vs epoch

Accuracy vs epoch

Precision, Recall and F1-Score

For a better look at misclassification, we often use the following metric to get a better idea of true positives (TP), true negatives (TN), false positive (FP) and false negative (FN).

Precision is the ratio of correctly predicted positive observations to the total predicted positive observations.

Recall is the ratio of correctly predicted positive observations to all the observations in actual class.

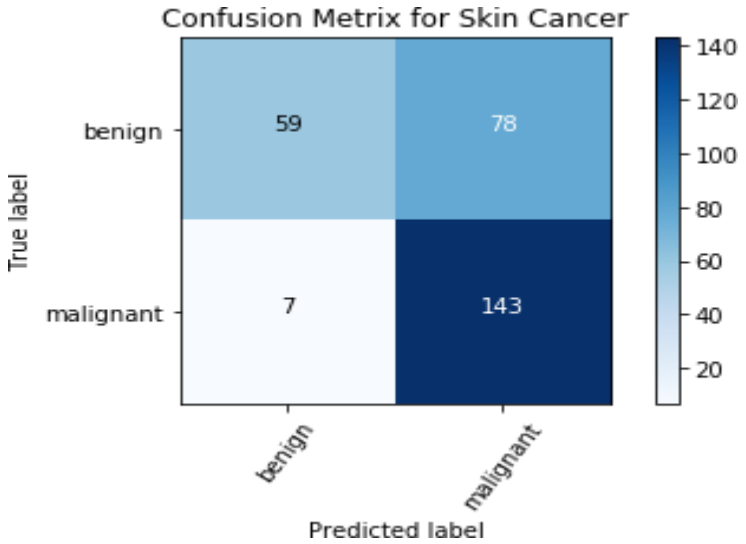
F1-Score is the weighted average of Precision and Recall.

$$F1 = \frac{2 * (Recall * Precision)}{(Recall + Precision)}$$

The higher the F1-Score, the better the model. For all three metric, 0 is the worst while 1 is the best.

Confusion Matrix

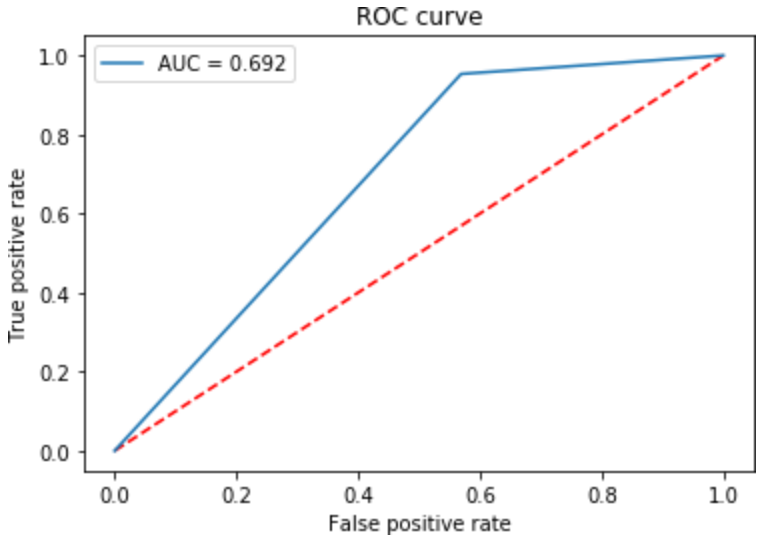
Confusion Matrix is a very important metric when analyzing misclassification. Each row of the matrix represents the instances in a predicted class while each column represents the instances in an actual class. The diagonals represent the classes that have been correctly classified. This helps as we not only know which classes are being misclassified but also what they are being misclassified as.



Confusion matrix

ROC Curves

The 45 degree line is the random line, where the Area Under the Curve or AUC is 0.5 . The further the curve from this line, the higher the AUC and better the model. The highest a model can get is an AUC of 1, where the curve forms a right angled triangle. The ROC curve can also help debug a model. For example, if the bottom left corner of the curve is closer to the random line, it implies that the model is misclassifying at Y=0. Whereas, if it is random on the top right, it implies the errors are occurring at $Y=1$.



Results

Accuracy	Precision	Recall	F1 score	ROC-AUC
98.3%	0.65	0.95	0.77	0.692

Final results

Conclusions

Although this project is far from complete but it is remarkable to see the success of deep learning in such varied real world problems. In this blog, I have demonstrated how to classify benign and malignant breast cancer from a collection of microscopic images using convolutional neural networks and transfer learning.