Department of systems and Biomedical Engineering
Faculty of Engineering - Cairo university

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SBME Second Year - MTH2245

Breast Cancer Detection using Neural Networks

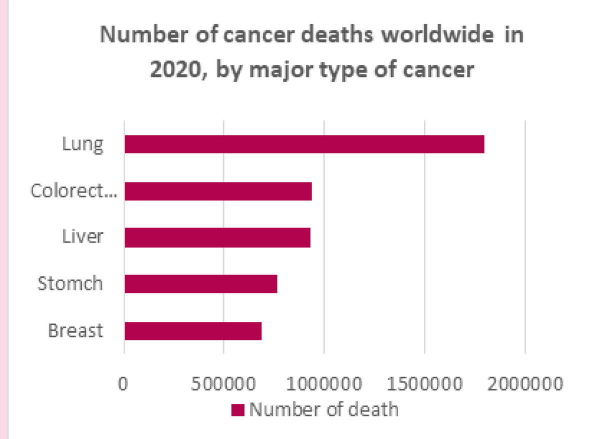
Dr. Samah El-tantawy

Abstract

During last decades, artificial intelligence algorithms have altered the world with their applications in all different fields, including medicine. Convolutional neural networks (CNNS) are developed from scratch using partial differential equations, they then are tested and used in the research to detect breast cancer based on patients' breast images (Both ultrasound and x-ray images). Partial differential equations are used in the backpropagation to calculate the gradient of the loss function with respect to parameters to help optimize and update the neural network weight and achieving the best weights that will affect the model's accuracy.

Introduction

The most commonly occurring cancer in women is breast cancer (BrC). As claimed by the World Health Organization (WHO), BrC was diagnosed in 2.3 million women, and 685,000 deaths were recorded globally in 2020. Besides, BrC is the 5th-most deadly disease out of distinct cancer types.



In Egypt, breast cancer is the most common malignancy in women, accounting for 38.8% of cancers in this population, with the estimated number of breast cancer cases nearly 22,700 in 2020 and forecasted to be approximately 46,000 in 2050. It is estimated that the breast cancer mortality rate is around 11%, being the second cause of cancer-related mortality after liver cancer.

Otherwise, in Egypt, most women don't practice a total checkup every 6 months, due to poverty and financial status. This might be a reason for many women having breast cancer without their awareness, so because of the great seriousness of this disease, we thought this project would help solve the crisis in Egypt.

Literature Review

Spanhol FA, et al. 2016	**Accuracy between 80 to 85%**	Use of multi-classifiers KNN, SVM, quadratic linear analysis, and RF.
Scarpazza C, et al. 2020	**Accuracy of 88%**	SVM was trained on both human-made features and CNN-extracted features
Alruwaili M, et al. Jan 2022	**Accuracy of 70%**	They introduced a framework based on the concept of transfer learning. Furthermore, a variety of augmentation procedures, including multiple rotation combinations and shifting
Nanglia S, et al. Feb 2022	**Accuracy of 78% at its pea**	To identify breast cancer in its early stages. leverages Stacking to create the ensemble model utilizing three separate algorithms: (KNN), (SVM), and Decision Tree.

Mathematical Modelling

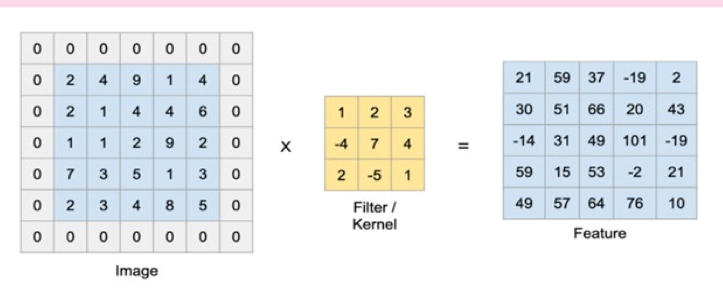
Convolutional neural networks (CNNs) are particularly useful for finding patterns in images to recognize objects, so we use kernels (filters) to extract the features from the images. Kernels slide along input features and provide feature maps that can be calculated by:

$$\sum_{p=1}^{p} W_{(p)} \cdot (\text{pixel})_p$$

Using the kernel alone causes the "edge effect" due to change in the output image matrix dimensions as follows:

$$\text{Width}_{new} = \text{Width}_{old} - \text{Width}_{filter} + 1$$
$$\text{Height}_{new} = \text{Height}_{old} - \text{Height}_{filter} + 1$$

This problem can be fixed by using padding



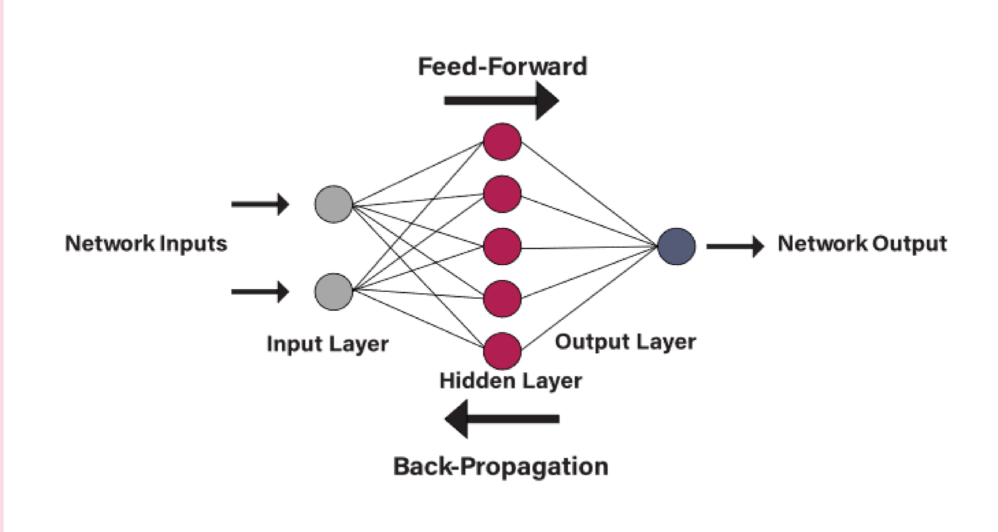
We use the pooling technique to reduce the dimensions of the feature maps. It is used to map a patch of pixels to a single value, we are using 2x2 max-pooling in our model.

12	20	30	0
8	12	2	0
34	70	37	4
112	100	25	12

2×2 Max-Pool $\longrightarrow$

20	30
112	37

To be trained, a neural network relies on both forward and backward propagation



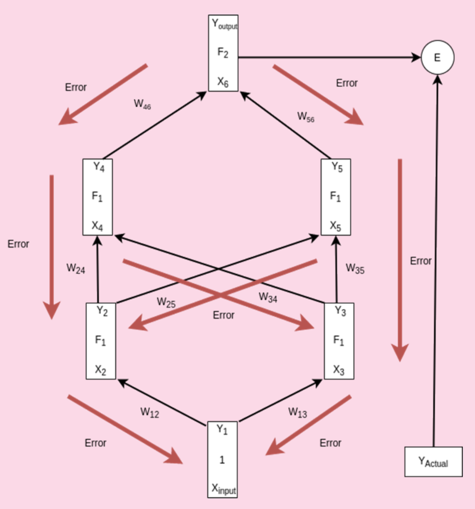
Forward propagation is used to calculate the intermediate variable and output of the neural network from the input values. The intermediate variable can be calculated as:

$$Z^{[L]} = W^{[L]} \cdot a^{[L-1]} + b^{[L]}$$
$$a^{[L-1]} = g^{[L]}(z^{[L]})$$

Where Z^[L] is the activations of layer L, W^[L] is the weighted parameters of layer L, a^[L-1] is the output of layer L-1 (Previous layer), b[L] is the bias of layer L, and g^[L]() is the activation function of layer L. After calculating the output of the hidden layer, the activation function is used to make it the input of the next layer, as needed, ReLU, and Sigmoid functions will be used in this neural network.

Sigmoid: $\sigma(z) = \frac{1}{1+e^{-z}}$, **ReLU:** $g(z) = \begin{cases} z & \text{if } z > 0 \\ 0 & \text{otherwise} \end{cases}$

Predictions are made using forward propagation. However, they come out with a margin of error that needs to be treated, this is where backpropagation comes to use. Backpropagation aims to minimize the cost function by adjusting the network's weights and biases.



The change in error with the change of weight for all edges can be calculated by:

$$\frac{\partial E}{\partial Y_i} = \sum W_{ij} \cdot \frac{\partial E}{\partial x_j}$$

Where ∂E/∂Yi is the change in error with the change of weight, Wij is the weight for each neuron i in layer j. We can then update the weights and start learning for the next epoch using the formula:

$$W_{new} = W_{old} - \propto \cdot \frac{\partial E}{\partial W_{old}}$$

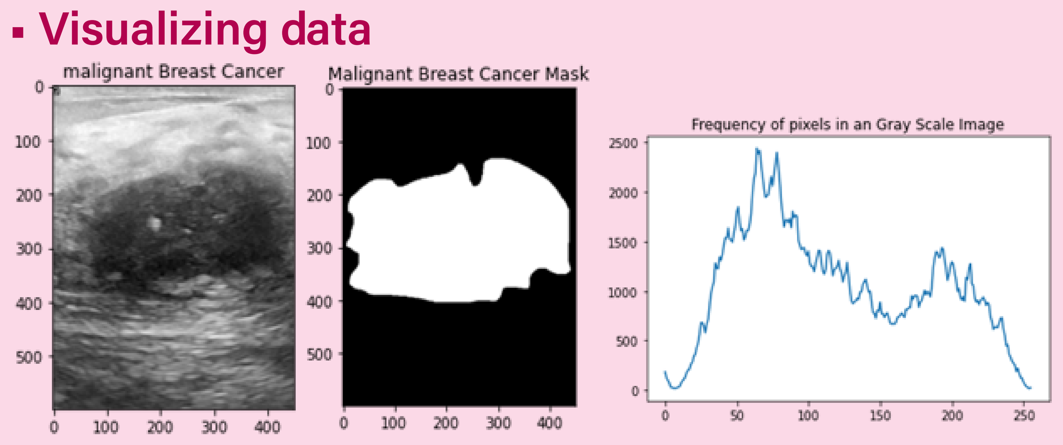
Where ∝ is the learning rate, W_{new} is the new weight, and $\partial E / \partial W_{old}$ is the change in error with the change of the previous weight.

Experimental Work

Exploring data :

We are using "Breast Ultrasound Images Dataset" (Dataset BUSI) which is collected by Dr. Aly Fahmy. Data is categorized into three classes: Normal, benign, and malignant.

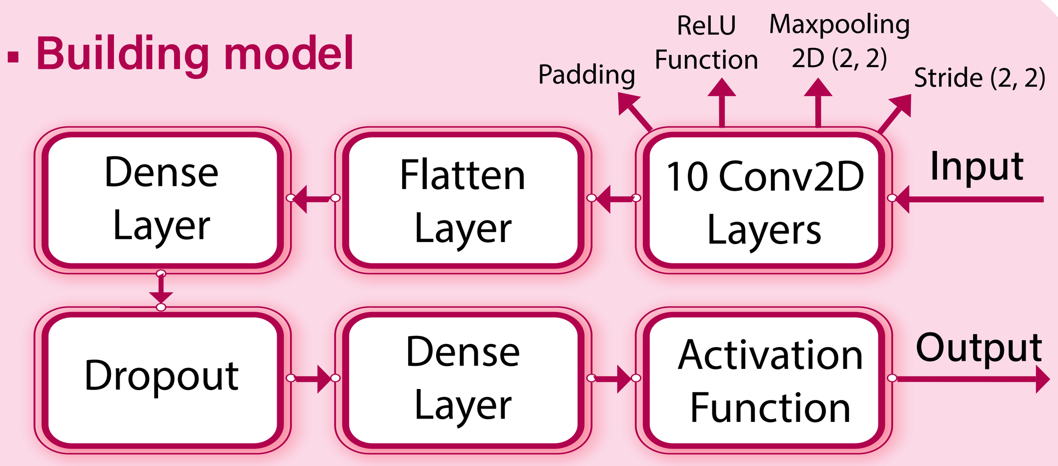
Visualizing data



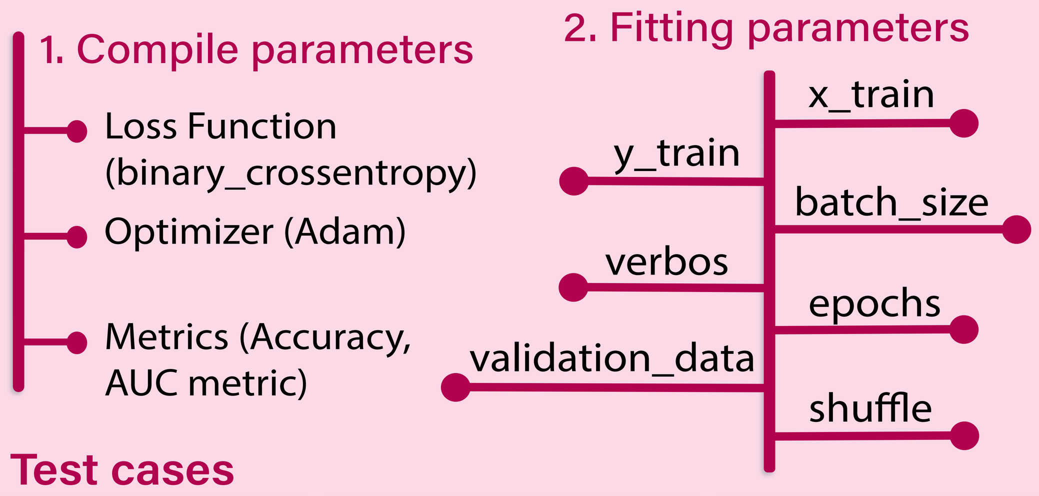
Data preprocessing and synthesis

While exploring the data, we notice data is very small in size, to solve this problem we will use **image augmentation** techniques.

Building model

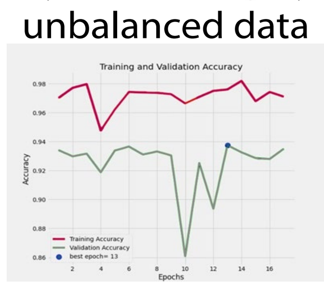


Training model



Test cases

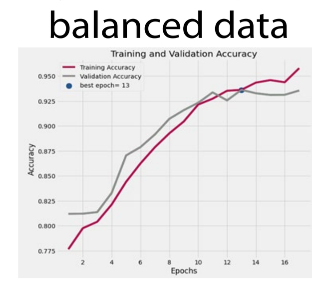
1 Using 3 Conv2D layers with highly unbalanced data



✗ Learning curves don't converge to each other

Accuracy : 93.7%
Loss : 0.3

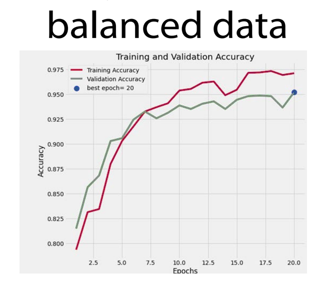
2 Using 3 Conv2D layers with quite balanced data



○ Training and validation accuracy are increasing and converging, but we are seeking better accuracy

Accuracy : 94.5%
Loss : 0.18

3 Using 10 Conv2D layers with balanced data



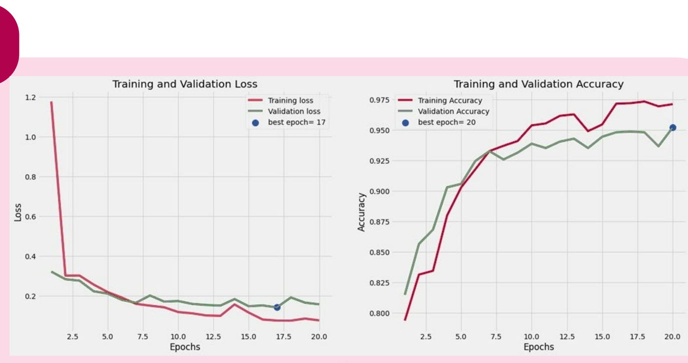
✓ Training and validation accuracy are increasing and converging, training accuracy increased

Accuracy : 95.2%
Loss : 0.15

Results

Our model has been trained 20 epochs to determine the accuracy and the validation accuracy, and it give the following results: Accuracy: 97.1%, Validation accuracy: 95.2%

We also used our model to predict breast cancer based on x-ray images, and the model showed positive results



Conclusion

As we have gone through this project, we found that using CNNs to analyze visual imagery data, then pooling the data to reduce images size by mapping a patch of pixels to a single value, and then using forward propagation and backpropagation to detect masks and filters in different images are all strong deep learning techniques and algorithms that can be further used in the diagnosis and detection of other different types of cancers and diseases.

Future Work

We reached quite acceptable results. However, many things can be done to reach better results and validation accuracy, the following steps may be considered:

- Using DCGANs which uses AI to create new images based on existing images. It can increase the data size more efficiently than using image augmentation technique.
- Using transfer learning by using another model trained on huge amount of data similar to our data, then fine tuning its weights using our neural network on our small dataset to increase accuracy.
- Deploying the model a web application, so that it can be used as a service by anyone to automatically detect breast cancer when the patient uploads a medical image of their breast.

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@eng-st.cu.edu.eg

Abdallah Magdy - **Abdulrahman** Emad - **Fatma** Ehab - **Muhammad** Alaa - **Muhammad** Ibrahim - **Omar** Emad - **Omar** Nabil - **Ziad** Ahmed
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