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Journal of Discrete Mathematical Sciences and Cryptography

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/tdmc20

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Journal of Discrete Mathematical Sciences & Cryptography
ISSN 0972-0529 (Print), ISSN 2169-0065 (Online)
Vol. 25 (2022), No. 3, pp. 661–669
DOI : 10.1080/09720529.2021.2014130

Deep learning based breast cancer detection system using fog computing

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Abstract

Among the different types of cancers, more women are suffering from breast cancer. Breast cancer can be identified by mammograms or using ultrasounds. Early detection of the cancer can be used to minimize the complexities the women will face. Deep learning based techniques such as convolutional neural networks (CNN) are used to detect the cancer from mammograms or ultrasound scans. In this study, VGGNet based CNN is used to detect the cancer cells. A novel architecture for collecting, processing and storing of patient data is proposed in this study involving a fog layer. This study achieved a high accuracy, sensitivity and specificity compared to previous studies.

Subject Classification: *68T07.*

Keywords: *Breast cancer, Deep learning, Convolutional neural networks, Fog computing.*

I. Introduction

Breast cancer is the most common cancer among women worldwide. 19.3 million new cases of cancer are reported in 2020. 2.3 million new cases of breast cancer are found among them [1]. In 2018 the most common cancer was lung cancer and breast cancer came in second place. But in 2020 that situation is changed. This can be due to unhealthy habits of the people. By increasing the awareness of people, the causes for breast cancer can be reduced. The number of deaths can be reduced by early detection and diagnosis of the disease. Mammography is one method of screening

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for breast cancer. It can be used to detect the cancer before physical symptoms appear [2]. This method uses radiation to take a breast image. Radiation is harmful to the patient as well as to the radiologist. Apart from that the accuracy of the diagnosis depends on the radiologist's experience. According to [3], the error rate is 30% when radiologists interpret the results.

DL methods are used in different medical imaging to identify tumors and cancers [5], [6]. Using DL for diagnosis can generate large amount of data in a hospital environment. Storing this information locally is not a solution. The cloud computing can be used to store the data in the cloud and even the algorithms can be done on the cloud server [7], [8].

However, there are some disadvantages as well. Storing the data on the cloud and analyzing it and then sending the result back to the hospital takes time when there is a large amount of data to be processed. This even has an impact on the network latency. As a solution to this, fog computing is introduced. There is a fog layer between the edge device which is the ultrasound machine and the cloud server. This fog layer can do the processing of the data and send the result to the edge device and store the results in the cloud for later access. This removes the burden on the network since only processed information is sent to the cloud whereas if the data is directly sent to the cloud, all the raw data should be sent over the network [9]. The challenge of using fog computing with DL algorithms is that because of the resource constraints on the fog device, the algorithms need to be optimized for the fog device. In this study, a novel architecture involving fog computing is introduced to detect breast cancer from ultrasound images using DL algorithms.

The remaining of the paper is organized as follows: The related work for this study is described in Section II. Section III explains the artificial neural networks and in Section IV the design of the system is explained. The results are reported, analyzed, and discussed in Section V. Finally, the conclusion of the paper is drawn in Section VI.

II. Related Work

Several studies implemented DL methods for breast mass detection. In [10] they proposed a Convolutional Neural Networks (CNN) for feature extraction stage in Figure 1. They used R- CNN's Region Proposal

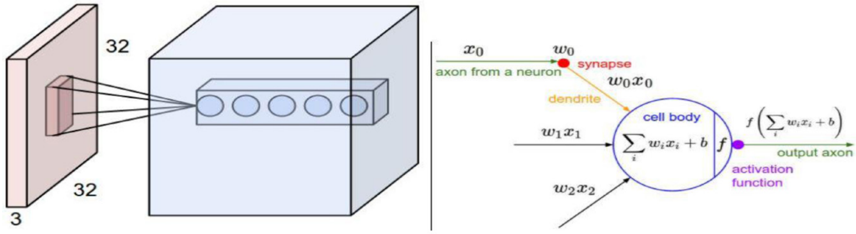

Figure 1

CNN architecture

Network and Region of Interest (ROI) portion for mass detection. They used mammogram images and for preprocessing Gaussian and median filters were used. They achieved a detection accuracy of 91.86% and a sensitivity of 94.67%. In [11], they proposed a cheat sheet to be used with CNN for some attributes taken from ROI, to classify mammogram images. The cheat sheet is used to encode some patterns before sending them to the CNN as a preprocessing step. They used four datasets and tested them fifteen times and achieved a mean accuracy of 92.1% and mean sensitivity and specificity of 91.4% and 96.8% respectively.

Monteiro et al. [16], used fog computing and cloud computing architecture for healthcare. The fog layer was created using a Raspberry Pi and this layer was used to preprocess the data. To store the data and to analyze the stored data, a cloud service was used. They also described the challenges of using this architecture. Rocha et al. [17] proposed an e-health system to detect epileptic seizures using a fog and cloud computing architecture.

Tuli et al. [18] developed HealthFog system which uses deep learning to analyze heart diseases. This was done on the edge devices and fog enabled cloud was used to evaluate the system.

III. System Design

In this paper a fog computing based system is proposed to detect the cancer mass from breast ultrasound images of the patients. This can be implemented inside a hospital without incurring a large cost. This system comprises of three layers and they are edge, fog and cloud. The entire system is shown in Figure 2.

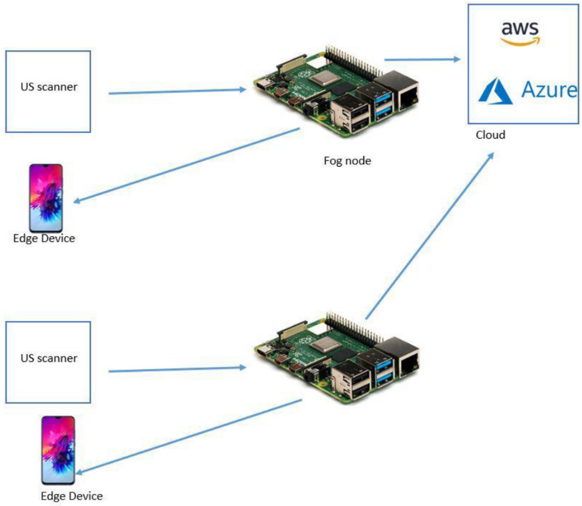

Figure 2

Overview of the system

3.1 *System Architecture*

In this proposed architecture, the ultrasound scanner and the mobile phone is acting as the edge devices. The data from the ultrasound scanner is sent to the next layer which is the fog layer implemented on the Raspberry Pi 4. At the last stage the data is sent to the cloud for storing. Multiple edge devices can be connected to a single fog node and this helps to reduce the amount of fog nodes inside the hospital premises. A fog node can be easily set up in an area where there is a network connection and power supply and it takes only a small space area.

Initially, using data available online the CNN model is trained. This DL model is stored in each fog layer device. When new data is coming from the ultrasound scanner, the DL model stored in the fog device predicts the result for the patient. This result is shown to the user in the mobile phone and simultaneously send to the cloud for storage.

Message Queuing Telemetry Transport (MQTT) protocol is used to transfer data between edge device and the fog node, fog node and the cloud. This protocol is the commonly used protocol in the Internet of Things applications. This is a light weight protocol based on client server model. MQTT broker is handling client's requests and transmitting data between broker and the devices. When a device is sending data to the

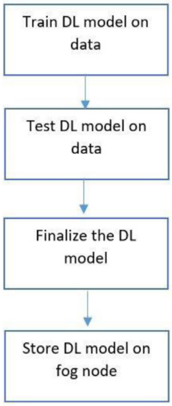

Figure 3
Process of creating the DL model

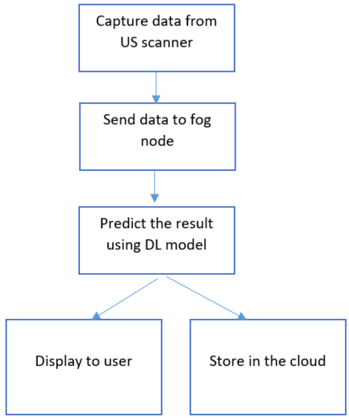

Figure 4
Process of predicting the result

broker, it is called publishing. Devices subscribe to topics which they need to receive data from the broker.

3.2 *Process*

The flow chart for the system is shown in Figures 3 and 4. In the Figure 3, the DL process is shown. The model is trained on the training data first in one of the fog nodes and to validate the model, test data is used. When using the dataset, a mask is created for each image and these images are used for training, testing and validating of the model. After reaching the preferable accuracy, the DL model is stored on all the fog nodes.

Once that is done, the system is ready to accept data from the ultrasound scanner, as shown in Figure 4. The edge device will send the data to the closest fog node using the MQTT protocol. The fog node will use the DL model stored in the device to predict cancer. Finally, the result will be shown to the user by sending information to the edge device as well as stored in the cloud.

IV. Evaluation

4.1 *Dataset*

An online dataset is used to validate the DL model [22]. These data were collected from women ages between 25 and 75 from 600 patients.

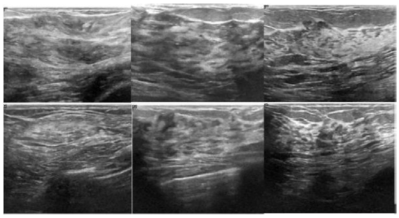

Figure 5

Sample normal images from dataset

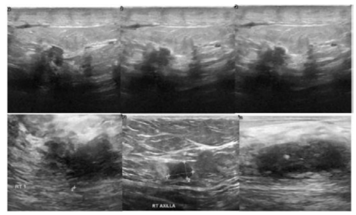

Figure 6

Sample malignant images from dataset

The ultrasound images were collected in a DICOM format in Baheya hospital. LOGIQ E9 ultrasound sound system was used for this purpose. Preprocessing of images were done to remove the duplicate images and images were converted from DICOM format to PNG format. A sample from the dataset is shown in Figures 5,6.

4.2 *CNN*

The dataset is first divided in to training, testing and validating groups randomly. The training data is used to train the CNN. A VGGNet CNN is used in this study with multiple stacked convolutional layers including 3 x 3 filters. This network is a sequentially structured model. 31 layers are added to the network. DEPTHWISE-CONV-RELU-POOL blocks are defined for this network. Each block has separableConv2D, activation, batch normalization, max pooling and dropout layers. At the final stage FC-RELU and softmax layers are added.

Figure 7

Training Accuracy

Figure 8

Training loss

4.3 *Results*

After training the following training accuracy and training loss are achieved. The Figures 7 and 8 shows the training accuracy and training loss. The accuracy for the system is 98.5%. For this study a specificity of 0.9783 and a sensitivity of 1.0 are achieved. Precision, recall, f1 score and support for normal are 0.96, 1.0, 0.98 and 23 respectively. Precision, recall, f1 score and support for malignant are 1.0, 0.98, 0.99 and 46 respectively.

Accuracies of 0.76,0.87, 0.88, 0.92 are achieved in [13], [14], [15] and [11] for CNNs to detect breast cancer. But this study achieved an accuracy of 0.9855 which is much higher than the previous studies. Although [16] and [17] used fog computing for healthcare, they didn't use DL techniques in those studies. Therefore, this study achieves a higher accuracy as well as a novel architecture involving fog computing for breast cancer detection.

V. Conclusion

Breast cancer is one of the most common cancers in the world. More women are suffering from this disease and early diagnosis can be used to reduce the fatalities. For this purpose a VGGNet based CNN is used in this study. A major problem of using DL in healthcare is the amount of data generated per person. As a solution to the storing problem of these data, a novel architecture involving three layers is proposed in this paper. The data received from the edge devices are sent to the fog layer for processing and the results are stored in the cloud for long term storage. This study achieved better accuracy compared with previous studies.

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