Technology Driven Thyroid Cancer Diagnosis: Improvements in Efficiency

IE 3100M System Design Project (AY2019/2020)

Group 19: Shen Linying | Ling Yiqi | Liang Xinran | Li Zihe

Academic supervisor: Prof Andrew Lim, Dr Tan Sing Kuang

Industrial supervisor: Prof Ayliana Dharmawan

National University of Singapore

Tan Tock Seng HOSPITAL

Overview

Company Background

Tan Tock Seng Hospital (TTSH) with 175 years of advanced medical care and development, is one of Singapore's largest multidisciplinary hospitals. The hospital has always been looking for innovative ways to improve their service care delivery.

TTSH has most of the specialties with the following core strength in Geriatric Medicine, Infectious Diseases, Rehabilitation Medicine, Respiratory Medicine, Rheumatology Allergy and Immunology.

Problem Description

Thyroid is one of the 10 common Cancers in Singapore and the trend continues to increase. Besides clinical examination, the diagnosis of Thyroid Cancer is done through Ultrasound to detect anomalies in the images. For undetermined cases, Fine Needle Aspiration (FNA) procedures is performed and conclusion is made based on Histology report.

Efficiency
The increase in volume of Thyroid Ultrasound is far more rapid than the increase in number of personnel which resulted to longer turn around time of Ultrasound report.

Accuracy & Cost
The noise and speckle of the ultrasound image and the ability of the operator to correctly acquire the image can affect reading performance. This may lead to a higher percentage of suspicious and undetermined cases that require extra-fine needle aspiration (FNA) costing more time and money.

Objective

- Develop a decision support system based on deep learning that can provide automatic diagnostics for thyroid nodules.
- Improve the service quality of thyroid cancer detection system in TTSH. Alleviate the problem of insufficiency in the number of radiologists and high dependency on the expertise.
- Increase diagnostic speed and accuracy and decrease medical costs and risks for patients

Decision System | Service Quality | Performance

Skill Set

Project Management
- Model building for real world problem & solution analysis
- Model validation

AI (Deep Learning)
- Used AI (deep learning) technique to build the model
- Convolutional Neural Network

Programming
- Used Python to implement the model
- Used PyTorch as the base

System Thinking
- Applied system thinking to analyze the problem and build the model

Methodology

Problem Analysis
- Analyze the problem given by TTSH
- Understand the process of traditional ways of thyroid diagnosis
- Form basic ideas of the proposed solution and the model

Data Collection & Processing
- Collect data from open sources
- Process data by different methods and choose the best way
- Do data augmentation to prevent the model from overfitting

Model Building
- Build the model with PyTorch in Python language
- Use convolutional neural network model to implement the model
- Adjust the parameters to fit the case

Validation
- Use 5 folded cross validation method to evaluate the model
- The validation result is the performance of the model

Implementation
- Compare our model's performance with the traditional process to show feasibility
- Communicate with TTSH to deliver the model

Model Building & Result

Classification Criterion

Thyroid Imaging Reporting and Data System(TI-RADS)
Malignant: TI-RADS 4a, 4b, 5
Benign: TI-RADS 1, 2, 3

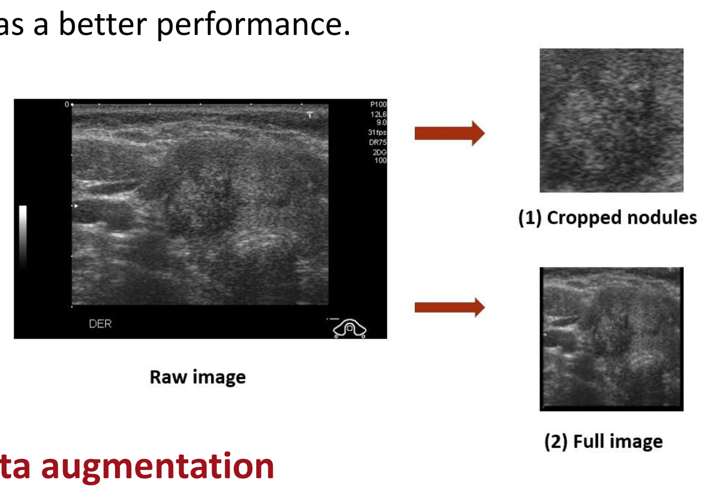
Data source

1) Open source thyroid ultrasound image database proposed by Pedraza
2) Beijing Tongren Hospital thyroid image data

After removing data without classification labels, we have in total:
→ Malignant: 286 Benign: 79

Pre-processing

We removed the disturbance in the background and resized all images to the same scale. The final output of the pre-processed image is 3-channel images with size 128(height) * 128(width). We built models with cropped modules and full image and found the model using full image has a better performance.



Data augmentation

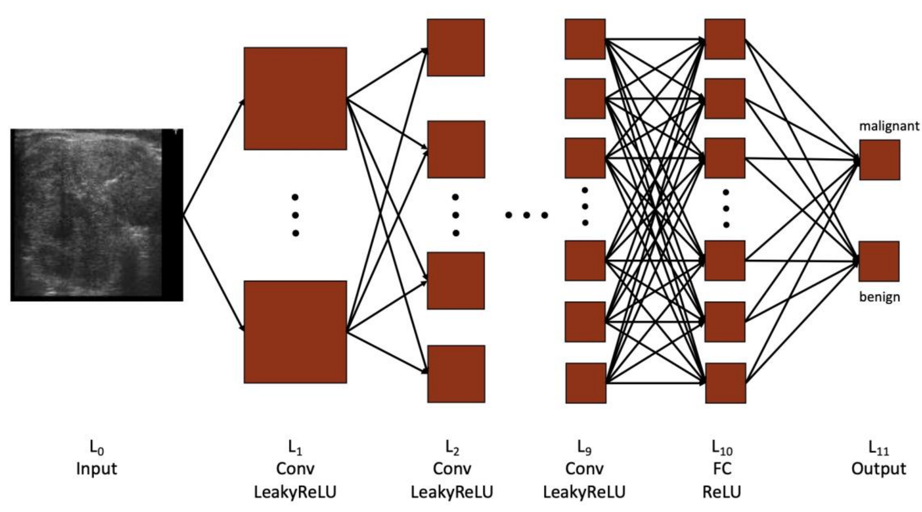
Horizontal flip, vertical flip and random rotations, normalization

Coding Environment

python | PyCharm | PyTorch

CNN Model

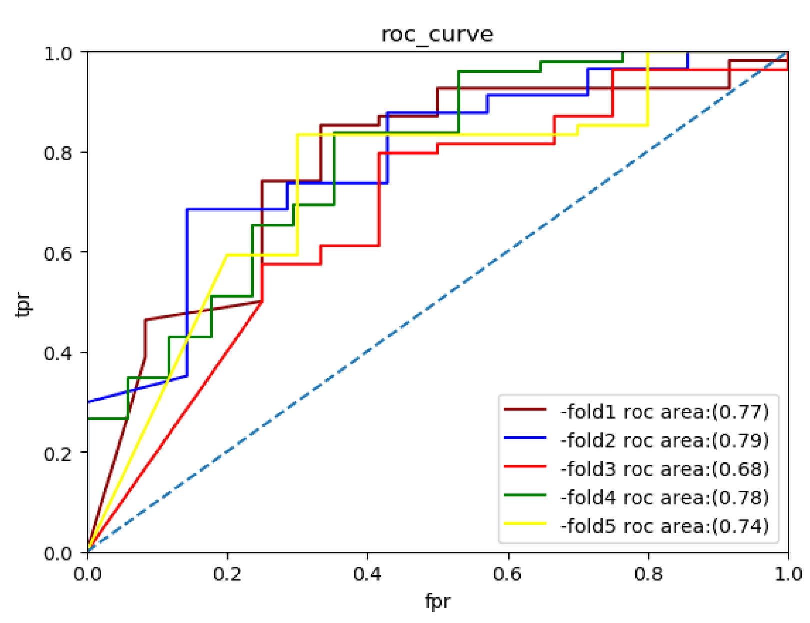
In our CNN model, we created nine convolutional layers, added batch normalization, used LeakyReLU as the activation function, and threw the max-pooling layer.
Optimizer: Adam **Loss function:** Binary Cross-Entropy(BCE) loss
Training batch size: 32 **Input image:** 128*128*3



Results

Evaluation Metrics:
Accuracy, True Positive Rate (TPR), True Negative Rate (TNR), and the area under the ROC Curve (AUC).

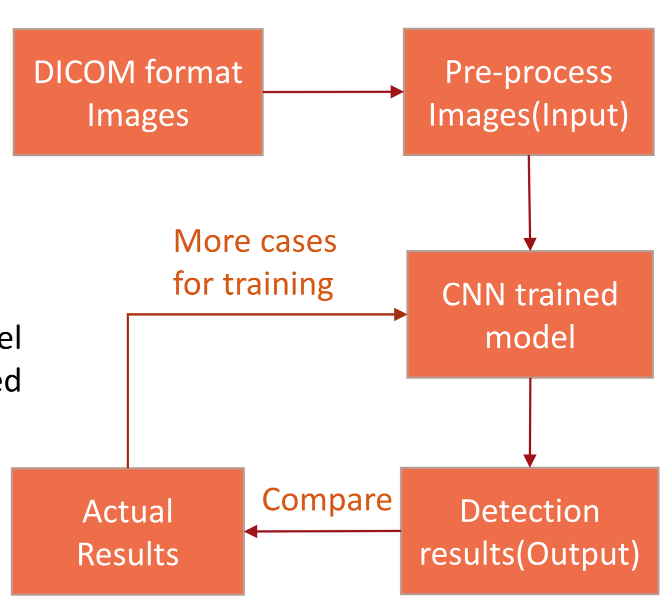
Metrics	Accuracy	TPR	TNR	AUC
Fold 1	0.8484	0.8387	1	0.77
Fold 2	0.9219	0.9355	1	0.79
Fold 3	0.8333	0.8750	1	0.68
Fold 4	0.7424	0.8333	0.6666	0.78
Fold 5	0.8906	1	0.75	0.74
Average results	**0.8573**	**0.9088**	**0.8833**	**0.752**



Implementation

Prediction python file

We designed a prediction python file that can:
- read the images from a folder
- transform the DICOM format images to jpg images
- implement the model with the optimized parameters
- produce diagnostic results
- Compare actual results and output



Demo Output

The output is the file name of the image and the diagnostic results given by the CNN model.

It took 7.96875 seconds for diagnosing 6 images. Compared to the manual detection time of 10 minutes for each case, the model's diagnosis time obtained a high improvement in detection efficiency.

```
Load successfully
10_1.jpg is Malignant
127_1.jpg is Benign
29_1.jpg is Malignant
30_1.jpg is Malignant
67_1.jpg is Malignant
68_1.jpg is Malignant

Process time:  7.96875

Process finished with exit code 0
```

Recommendations

Limitations

The model has two major limitations
- **Translation invariance:** a slight movement of a singe object may not properly activate the neural networks to recognize it. Data augmentation helps alleviate this problem, but it can not be eliminated
- **Lack of data:** There are only 365 images for training, this means the data is insufficient to provide a comprehensive model.

Conclusion & Future Works

- CNN is one of the Deep Learning techniques suitable for analyzing images, and can be used to analyze Thyroid Ultrasound images to assist in decision making
- Retrain the developed CNN model with the actual data;
- With more data to retrain the developed CNN model, the accuracy of the developed DSS will be largely improve