Deep Learning Based Heart Disease Prediction

Project Plan

03 October, 2021

CHOI Chong Hing  3035564940
GAO Enge         3035533070

Supervisor: Dr. Wong, Kenneth K.Y.
Contents

1 Introduction ........................................... 2
  1.1 Overview ........................................... 2
  1.2 Modern Heart Examination ....................... 2
  1.3 3D Echocardiography ................................ 3
  1.4 3D Landmark Detection ............................ 3
  1.5 Objectives ........................................... 3
  1.6 Project Contribution ............................... 4
  1.7 Project Plan Outline ............................... 4

2 Methodology .......................................... 5
  2.1 Introduction ........................................ 5
  2.2 Landmark Detection CNN .......................... 6
    2.2.1 Landmark Detection CNN: Dataset .............. 6
    2.2.2 Landmark Detection CNN: Validation .......... 6
  2.3 Heart Diseases Prediction CNN .................... 6
  2.4 Summary ............................................. 6

3 Project Schedule ..................................... 7
  3.1 Overview ........................................... 7
  3.2 Project Schedule .................................... 7
  3.3 Current Progress ................................... 8
  3.4 Future Plan ......................................... 8

4 Conclusion ........................................... 9


1 Introduction

1.1 Overview

Heart disease is one of the leading causes of death both locally and globally. It accounts for over 17.9 million deaths globally [1], and 77 thousand deaths in Hong Kong each year [2]. A large number of patients causes high demand for medical resources, including heart examination, hospitalisation and treatments. Early detection of heart disease could prevent patients from having severe damage. Therefore, an early heart examination is very crucial in lowering the risk of death.

1.2 Modern Heart Examination

Modern heart examination captures 27 different cross-sections and some other views of the heart using 2D echocardiography. Unlike coronary angiogram, where a special dye is injected into the vein to capture the heart images, the echocardiogram method is non-invasive, making it a very common heart test. During an echocardiogram test, an ultrasound device sends out an ultrasound signal to the heart and receives the reflected signal to reconstruct the 2D heart image.

![Figure 1: An illustration of an echocardiogram examination [3]](image)

However, as illustrated in Figure 1, there are bones between the device and the heart, which will block the ultrasound signals. Therefore, echo examination is very difficult and time-consuming, and could only be performed by trained specialists. The trained doctors have to control the device accurately so that the signals could travel through the gaps between the bones to obtain the correct heart slice views. One complete echo examination could take up to 45 minutes or more. This lengthy process causes a long waiting time of an average of 81 weeks for an echo examination in Hong Kong public hospitals, delaying the diagnosis and treatment of patients. To reduce the examination time, 3D echocardiography is brought as a solution.
1.3 3D Echocardiography

Similar to 2D echocardiography (2D echo), 3D echocardiography (3D echo) uses a similar technique to obtain heart information.

As illustrated in Figure 2, a 3D echo device shoots an array of ultrasound signals, whereas a 2D echo device shoots only one ultrasound signal. Using 3D echocardiography, a volumetric 3D representation data of the heart could be obtained in under 10 seconds. The specialists do not need to manoeuvre the device to capture views using the 3D echo device.

However, the specialists are trained to interpret the 2D cross-section views of the heart only. The volumetric data captured by a 3D echo device is hard to be interpreted. The visualization of volumetric data is non-trivial either. To solve this problem, our project proposes a solution using a 3D landmark detection algorithm.

1.4 3D Landmark Detection

A 3D landmark detection algorithm can find specific landmarks (points) in a 3D space. Having three points in 3D space, a 2D plane could be defined in that 3D space. Therefore, identifying three points for each view from the 3D data, the 27 standard views could then be reconstructed. This type of algorithm is typically constructed using a convolutional neural network (CNN) using deep learning technique, like Loc-Net [5], an CNN that identify the position of the bifurcation of the carotid arteries. These networks comprise multiple layers so that the higher-level features could be extracted from the raw data input, giving the landmarks needed.

1.5 Objectives

In this project, we aim to implement two convolutional neural networks to reduce the examination time. The first CNN will be the 3D landmark detection algorithm, where the landmarks for the 27 views could be extracted so that the views could be reconstructed. With the volumetric data and the reconstructed 2D views, the second CNN will be trained to predict heart diseases directly.
1.6 Project Contribution

With the increasing demand for heart examinations and the lack of specialists, it is anticipated that the waiting time for an examination will increase accordingly. This project will change the method of heart examination completely, in a faster and easier way. It is hoped that this project will reduce heart examination time from 45 minutes to less than 3 minutes, and, consequently, reduce the waiting time from 81 weeks to less than 10 weeks.

1.7 Project Plan Outline

This report is structured into four chapters. The first chapter offers an overview of heart examination and the background of the project. It also gives the objectives and the significance of the project.

Chapter two analysis the methodology of the project. The training methods for the two CNNs will also be explained.

Chapter three shows the current progress of the project. It also presents the project schedule and the current challenges.

Chapter four concludes the report, summing up all the results made and the coming plan.
2 Methodology

2.1 Introduction

This chapter explains the methods used in training and testing the two CNNs in this project. It also presents the data collection methods, as well as data analysis methods including data augmentation and processing. Figure 3 shows the overview of the methodology for the project. The blue part corresponds to the first objective - Landmark Detection; while the red part corresponds to the second objective - Heart Diseases Prediction. Details will be explained in the following subsections.

Figure 3: Overview of Methodology
2.2 Landmark Detection CNN

The 3D landmark detection CNN takes the 3D raw data as input and outputs the landmarks for the 27 views. The network processes a huge amount of data, so the size of the network is often very deep, resulting in a long training time. To overcome the huge size of the network, a combination of different deep learning architectures will be used to build the network, including U-Net and multi-scale shift networks. Previous research has shown that such a multi-scale network can reduce the size of the network, and consequently, reduce the training time for the network [5]. The landmark detection CNN will be trained using 3D raw data of different patients, where the landmarks of the views are labelled. The model will adjust itself by the distance differences between the predicted and labelled points.

2.2.1 Landmark Detection CNN: Dataset

The 3D raw data will be provided by the Chinese University of Hong Kong, which contains the unlabeled 3D echo data from local patients in the past 10 years. To obtain the labelled 3D data, software with an easy-to-use graphical user interface for labelling data will be developed. This software will be developed as an extension of 3D Slicer [6], a free, open-source software widely used in the medical industry. 500 - 2000 patient data is planned to be labelled for training and testing the model.

2.2.2 Landmark Detection CNN: Validation

Other than using 3D labelled data to validate the model, the model could also be tested with a 2D view classification CNN. A view classification CNN is a model that could classify different views by checking the similarity between the input image and the views. A view with a higher score represents that the network has high confidence that the input image is of that view. This could determine how good is the landmark detection network by giving scores to the reconstructed views.

2.3 Heart Diseases Prediction CNN

The heart diseases prediction CNN takes the patient 2D views data, and outputs the possibility of the patient having a heart disease. Similar to the landmark detection CNN, this network processes a large amount of data. Therefore, different architectures will be implemented, trained and tested. The training and testing datasets include the 2D labelled data and the reconstructed 2D data from the prediction of landmark detection CNN. Data augmentations, including flipping, rotation, and scaling, will also be applied to enlarge the dataset.

2.4 Summary

This chapter explained the methodology used in the project. The CNN models used were presented, together with the training and validation processes. The data collection and processing methods for different types of data were also explained. The next chapter will present the project schedule.
3 Project Schedule

3.1 Overview

This chapter presents the project schedule, together with the current progress of the project. The project schedule will be presented in Section 3.2, while Section 3.3 will explain the progress of the project. At last, the future plan will be discussed in Section 3.4.

3.2 Project Schedule

This project is a 3-year project, commencing in May 2021. The following table shows the tentative schedule for the project.

<table>
<thead>
<tr>
<th>Timeline</th>
<th>Task</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>May 21 - Jun 21</td>
<td>Literature Review</td>
<td>Completed</td>
</tr>
<tr>
<td>Jul 21 - Sep 21</td>
<td>Labelling Software</td>
<td>Near Completion</td>
</tr>
<tr>
<td>Oct 21 - Dec 21</td>
<td>Labelling Landmarks</td>
<td>Pending</td>
</tr>
<tr>
<td>Oct 21 - Dec 21</td>
<td>View Classification CNN</td>
<td>In Progress</td>
</tr>
<tr>
<td>Jan 22 - Apr 22</td>
<td>Landmark Detection CNN</td>
<td>Pending</td>
</tr>
<tr>
<td>After Apr 22</td>
<td>Build Reconstructed 2D View Dataset</td>
<td>Pending</td>
</tr>
<tr>
<td>After Apr 22</td>
<td>Heart Diseases Prediction CNN</td>
<td>Pending</td>
</tr>
<tr>
<td>After Apr 22</td>
<td>Build Clinical Software</td>
<td>Pending</td>
</tr>
</tbody>
</table>

For the coming year, we will focus on implementing the view classification CNN, while the doctors will label the 3D data. After labelling the data, we will start implementing the landmark detection CNN. It is hoped that at least a demo could be done before April 2022. Other parts of the project, including building the heart disease prediction CNN and clinical software, will be out of the scope of our final year project.
3.3 Current Progress

Currently, the labelling software is almost done. The labelling task can begin very soon. For the view classification CNN, datasets are currently being collected. Meanwhile, a first demo of the view classification CNN for classifying other datasets, including the Fashion MNIST dataset, an image dataset of different types of clothing, has been implemented. The demo could achieve around 92% accuracy for the Fashion MNIST dataset.

![Diagram of the project components]

Figure 4: Overview of Current Progress

Figure 4 above shows the status of different components in the project. The current progress is satisfactory.

3.4 Future Plan

The labelling task will start in October 2021. It is hoped that it would be completed before the end of 2021 so that the implementation of landmark detection CNN could be started. At the same time, the view classification CNN that evaluates the landmark detection CNN will be developed in the same period. By the end of the final year project, we hope that a basic version of the landmark detection CNN that reconstructs the views could be presented.
4 Conclusion

This project proposes a faster way to do an examination using two CNN models with 3D echocardiography. The two models, Landmark Detection CNN and Heart Detection CNN, could use 3D raw echo data to reconstruct standard views and do predictions of heart diseases. Different deep learning state-of-the-art architectures and methods will be implemented and tested to build the models. Our final year project will focus on implementing the view classification CNN and the early development of the landmark detection CNN. Using the new method proposed, it is hoped that the examination time and waiting time could be reduced accordingly.
References


