BUILDING PREDICTION SYSTEM FOR HEART DISEASES USING DEEP NEURAL NETWORK

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1. Introduction

A variety of disease that attacks your heart is referred to as heart disease. Now, the heart is the most vital organ in our bodies. It circulates blood throughout our bodies, ensuring that oxygen reaches all parts of our bodies. A life-threatening condition may occur if something is wrong with the heart. That demonstrates how vital the organ heart is to us. Let us now discuss heart disease and why it is such a concern in our society. For your information, heart diseases were announced as the top killer in Malaysia for the year 2021 (Department of Statistics Malaysia, 2021). Malaysia is rich with varieties of foods from all regions around the world. Most foods in our country contain a sheer amount of oil and herbs used in it making them heavy in cholesterol and calories. It is undeniable that although our bodies require cholesterol to produce healthy cells, high cholesterol levels can increase the risk of heart disease. A high amount of cholesterol intake in the blood will lead to fatty blockage in the blood vessels, and those deposits eventually accumulate to the point that blood flow through your arteries becomes restricted. This condition will then cause a heart attack or heart disease. There are other indicators that can be used to determine whether someone is at risk of heart disease, which will be explored further in our research.

Patients' information and data are becoming more publicly available for use in research on this topic every day. It makes it easier to get the dataset for us to do our research project. To be honest, applying machine learning to the medical field is no longer unusual. More researchers are collaborating with medical practitioners to employ current technologies to aid in identifying or predicting a patient's health status based on their diagnosis results. Thus, because of this matter, we decided to propose a deep neural network (DNN) based prediction system to predict heart diseases. The machine learning model will be used in our proposed system to predict the likelihood of patients developing heart disease. We will also compare the results after testing the system to see how accurate it is and why DNN would be the ideal machine learning model for this research topic.

2. Dataset description

We used a heart dataset taken from Kaggle's website to make predictions of heart disease. This dataset contains 918 observations with 12 attributes. A brief description of the dataset is shown in Table 1 with the last attribute, 'HeartDisease' that displays whether the patient is in a normal condition, 0, or has heart disease, 1. Furthermore, in this dataset, 54.45% of patients in the age range between 37 and 76 years old have high chance of getting heart disease. The first attribute age contains the age of the patient with 28 years old as the youngest and 77 years old as the oldest. Sex attribute classifies the gender of the patient based on male or female. ChestPain attribute is the chest pain type consisting of typical angina (TA), atypical angina (ATA), non-anginal pain (NPA), and asymptotic (ASY) chest pain. The restingBP is a blood pressure measurement taken while the patient is at rest with range values of 0 to 200 mm Hg. The cholesterol attribute is the amount of cholesterol taken from the patient using a BMI sensor. Next is fastingBS which is measured after the patient has done an overnight fast. RestingECG is the result of the test that measures the electrical activity of the patient's heart where the results consist of normal, ST-T wave abnormality, ST, and showing probable or definite left ventricular hypertrophy by Estes' criteria, LVH. The maxHR attribute is the patient's maximum heart rate that was calculated by subtracting their age from 220 and is also the average of the maximum number of the heartbeat per minute during exercise. ExerciseAngina displays the information in which the patient got angina when doing exercises with the answer either yes or no. The oldpeak is the result of ST depression; a sign of myocardial ischemia, of which coronary insufficiency is a major cause that is measured by using an overlying electrode. The slope of the ST depression is shown in the ST_Slope attribute where the results are either up: upsloping, flat, or down: downsloping.

No. Values	Attributes	Description	Range
1.	Age	Age of the patient	28 - 77
2.	Sex	Gender of the patient	M of F
3.	ChestPain	Chest pain type	TA, ATA, NPA, ASY
4.	RestingBP	Resting blood pressure (mm Hg)	0 - 200
5.	Cholesterol	Cholesterol fetched via BMI sensor (mg/dl)	0 - 603
6.	FastingBS	Fasting Blood Sugar > 120 mg/dl	1 or 0
7.	RestingECG	Resting Electrocardiographic Results	Normal, ST, LVH
8.	MaxHR	Maximum heart rate achieved	60 - 202
9.	ExerciseAngina	Exercise induced angina	Yes or No
10.	Oldpeak	Previous peak	-2.6 - 6.2
11.	ST_Slope	Slope of the peak exercise ST segment	Up, Flat, Down
12.	HeartDisease	Presence or absence of heart disease	0 or 1

Table 1: Heart Dataset Description

2.1 Data Pre-processing

Data pre-processing is a step to make the dataset more presentable and easier to visualize that includes removing unwanted columns or null values. Since this dataset has no null values, we only apply another pre-processing step which is the standardization method using StandardScaler(). Standardization is very helpful in creating consistent data as it involves the process of translating the data into a range between -1 and 1. As we can see in Table 1, some of the columns have categorical values. Hence, the conversion from categorical to numerical using scikit learn is done in order to standardize the datatype of all attributes. The data standardization is using the following equation where X represents the column inputs and X_ST represents the transformed values:

$$X\_ST = \frac{X - Mean\ of\ X}{Standard\ Deviation\ of\ X}$$

3. Deep Learning Model

Deep Learning Models perform classification tasks directly from images, text, or sound. Deep learning models can achieve state-of-the-art accuracy, sometimes exceeding human-level performance. Models are trained by using a large set of labeled data and neural network architectures that contain many layers.
In this research, we will try to classify heart disease using the k-Nearest Neighbors (kNN) algorithm. In this algorithm, data is divided into training and test data sets. The training dataset is used for model building and training. K- value is decided which is often the square root of the number of observations. Now the test data is predicated on the model building.

3.1 Hyperparameter Tuning

A hyperparameter is a parameter of the model that is set before the start of the learning process. Different machine learning models have different hyperparameters. We will use the Exhaustive Grid Search technique for hyperparameter optimization. An exhaustive grid search takes in as many hyperparameters as you would like and tries every single possible combination of the hyperparameters as well as many cross-validations as you would like it to perform. An exhaustive grid search is a good way to determine the best hyperparameter values to use, but it can quickly become time-consuming with every additional parameter value and cross-validation that you add.

We will use three hyperparameters- n-neighbours, weights, and metric.

1. n-neighbours: Decide the best k based on the values we have computed earlier.
2. weights: Check whether adding weights to the data points is beneficial to the model or not. 'uniform' assigns no weight, while 'distance' weighs points by the inverse of their distances meaning nearer points will have more weight than the farther points.
3. metric: The distance metric to be used will calculate the similarity

4. Experimental Setup

4.1 Flowchart of the steps in the experiment.

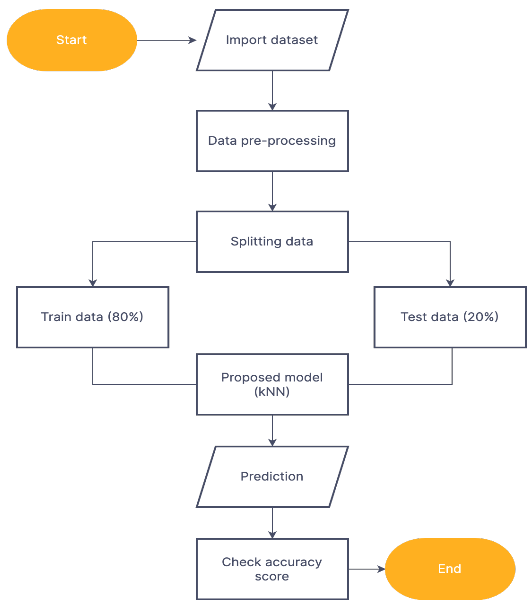

Figure 1: The proposed system flowchart

5. Analysis of Result

A comparative analysis between Artificial Neural Network and k-Nearest Neighbours has been done for heart disease prediction. Figure 2 below shows the confusion matrix that displays the summary results of the heart disease classification that is classified according to 4 classes: True Negative (TN), False Negative (FN), False Positive (FP), and True Positive (TP).

		Predicted Values	
		0	1
Actual Values	0	True Negative (TN)	False Positive (FP)
	1	False Negative (FN)	True Positive (TP)

Figure 2: Confusion Matrix for Binary Classification

5.1 Evaluation Metrics

In order to measure the performance of this supervised machine learning task with multiple classes as output, a performance metric tool called confusion matrix as can be seen in Figure 2 is used. A confusion matrix is a table with four different projected and actual value groupings (Narkhede, 2018).

As this dataset in our research employs the values 0 and 1 for classification if the predicted value is 0 as the actual value should be then it will be classified as True Negative (TN). However, if the value displayed is 1 when the actual value should be 0, it will fall into the False Positive (FP) category. For the actual value of 1, if the predicted value turns out to be 0, it will become False Negative (FN), whereas if the value is 1 as it should be then the category is True Positive (TP).

Using the confusion matrix helps measure the model's performance easier because we can easily see the values of TN, TP, FP, and FN. The formula for calculating these values is given below:

5.1.1 Accuracy

Accuracy (ACC) will reveal just how many of our predictions were completely right. For us to know that the model is operating successfully, accuracy should be at maximum.

$$\mathbf{ACC} = \frac{(\mathrm{TP+TN})}{(\mathrm{TP+TN+FP+FN})} X\ 100$$

5.1.2 Precision

Precision or *Positive Predictive Value (PPV)* is the accuracy of a model's positive prediction.

$$\mathbf{PPV} = \frac{\mathrm{TP}}{(\mathrm{TP+FP})} X\ 100$$

5.1.3 Sensitivity

Sensitivity or *Recall* or *True Positive Rate (TPR)* is computed by dividing the number of positives by the number of positive predictions made. 1.0 is the best value for sensitivity while 0.0 is the worst of it.

$$\mathbf{TPR} = \frac{\mathrm{TP}}{(\mathrm{TP+FN})} X\ 100$$

5.1.4 Specificity

Specificity or also known as *True Negative Rate (TNR)* is computed by dividing the total of negatives by the number of valid negative predictions. Specificity, like sensitivity, has the greatest value of 1.0 and the worst value of 0.0.

$$\mathbf{TNR} = \frac{\mathrm{TN}}{(\mathrm{FP+TN})} X\ 100$$

5.1.5 F1 - Score

The arithmetic average of precision and recall is called as F1-Score. It considers both false positives and false negatives. As a result, it functions well on a skewed dataset.

$$\mathbf{F1} = \frac{2\mathrm{TP}}{(2\mathrm{TP} + \mathrm{FP} + \mathrm{FN})} X\ 100$$

5.2 Performance Comparison

To prove that DNN that we have applied has better performance, we compared it with another prediction method which is Artificial Neural Network (ANN) by using evaluation metrics. In the following, we are discussing the performance comparison obtained by using ANN and DNN by using a bar chart diagram.

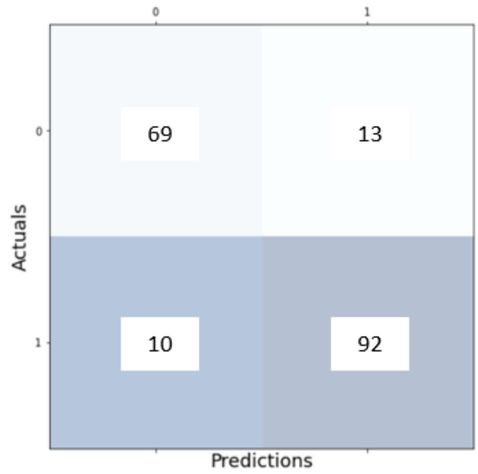

Figure 3: Confusion matrix

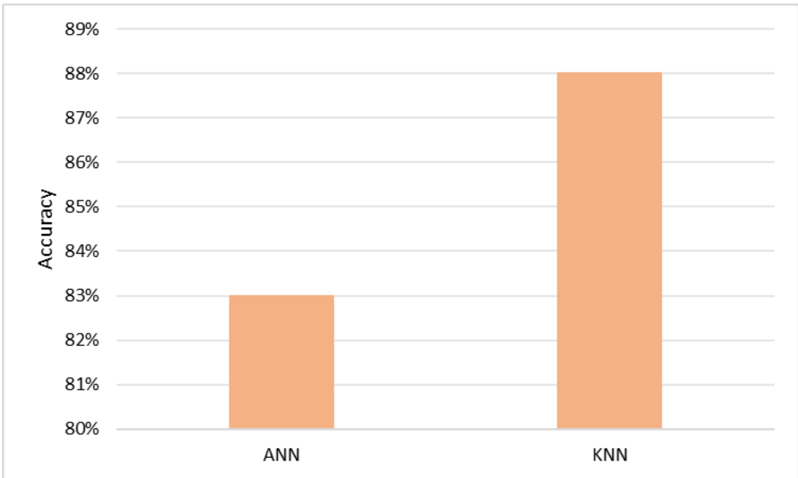

Figure 4: Performance comparison of classifiers based on Accuracy

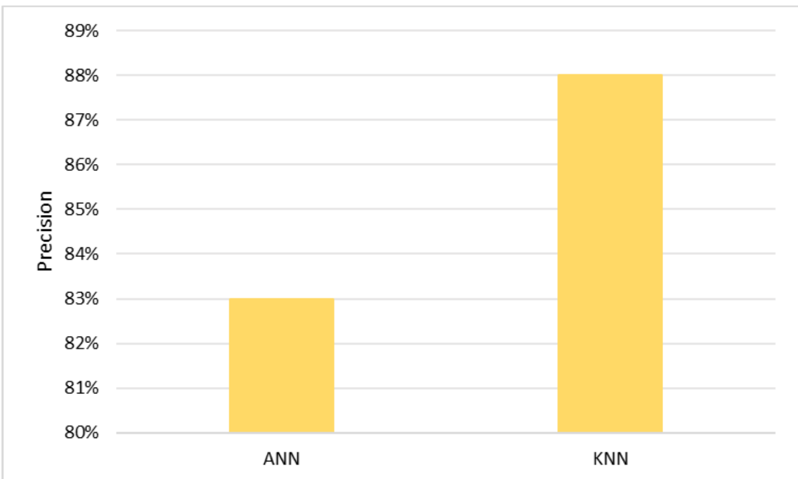

Figure 5: Performance comparison of classifiers based on Precision

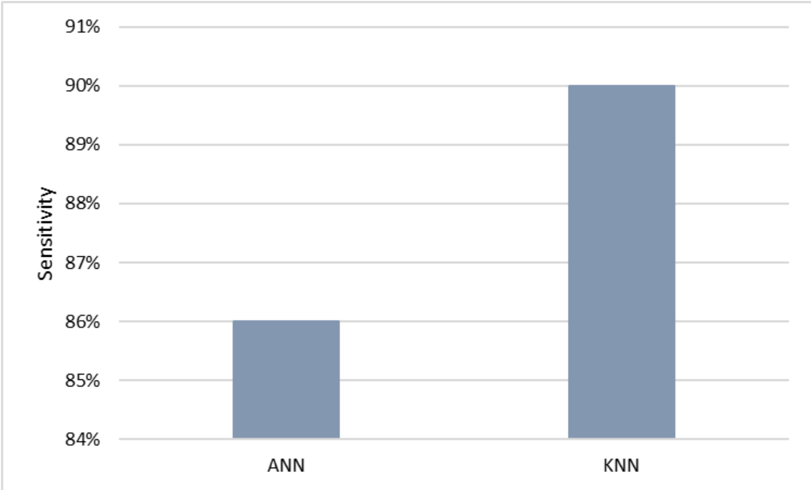

Figure 6: Performance comparison of classifiers based on Sensitivity

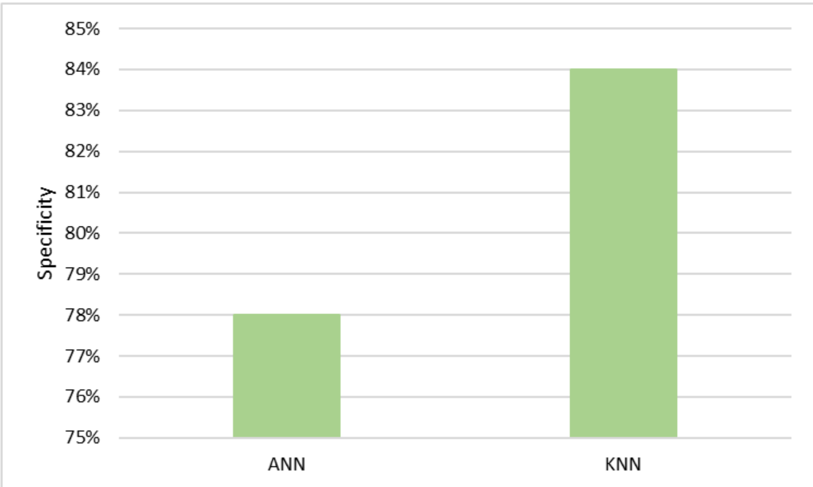

Figure 7: Performance comparison of classifiers based on Specificity

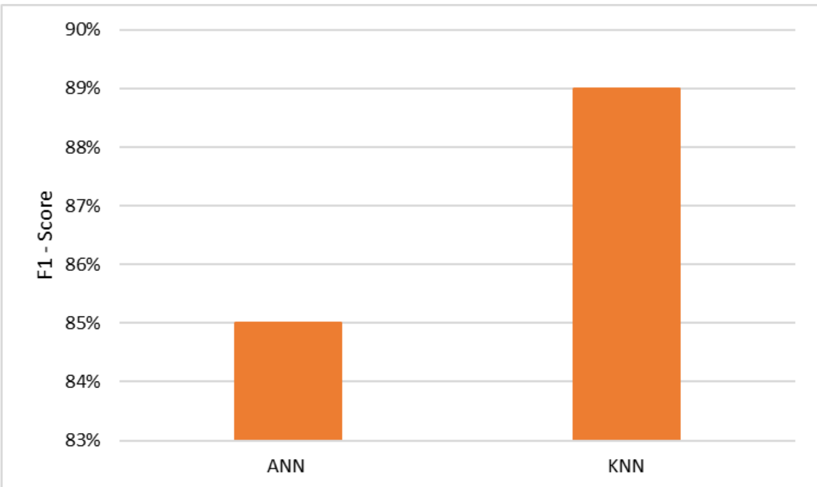

Figure 8: Performance comparison of classifiers based on F1-Score

	Artificial Neural Network (ANN)	k-Nearest Neighbors (KNN)
Accuracy	83%	88%
Precision	83%	88%
Sensitivity	86%	90%
Specificity	78%	84%
F1-Score	85%	89%

Table 2: Comparison of the evaluation between Artificial Neural Network and k-Nearest Neighbours

To present how good our heart disease prediction is, we compared it between Artificial Neural Network and k-Nearest Neighbours using the same dataset and the same performance measure. As observed from Table 2, the proposed DNN prediction which is k-Nearest Neighbours outperforms works reported.

6. Conclusion

For this research project, we proposed a prediction system for heart disease using the deep neural network (DNN) algorithm. A DNN is a model that has a multilayer of hidden layers compared to an artificial neural network (ANN) that only consists of one hidden layer (Johnson, 2020). This is why the DNN model outperforms the ANN model in terms of accuracy. Our comparison analysis using the evaluation metrics of comparing the accuracy, precision, sensitivity, specificity, and the F1-Score, also reveals that the KNN model which belongs to DNN performs considerably better than the ANN model. We trust that by using the DNN technology, we will be able to anticipate cardiac disease at an earlier stage and save more lives in the near future. This will be a significant milestone in the medical field, particularly in the field of heart disease.

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