Pattern of symptom correlation on type of heart disease using approach of pearson correlation coefficient

Tb A Munandar1,*, S Sumiati1 and V Rosalina2

1 Informatics Dept., Faculty of Information Technology, Universitas Serang Raya, Indonesia
2 Computer Eng. Dept., Faculty of Information Technology, Universitas Serang Raya, Indonesia

*tbaimunandar@gmail.com

Abstract. The relationship of a symptom on a type of disease provides information on how strong the disease is affected by the symptom. The strength of the relationship of symptom has not been much researched, yet it is very interesting and important to do in order to strengthen the formation of final hypothesis, especially in the development of expert system. This research was conducted to map the relationship of a symptom on the type of heart disease, based on the echocardiography value and the result of electrocardiogram measurement. About 150 data of patients with heart disease were analyzed using the approach of Pearson correlation coefficient. The research result showed that the type of disease such as atrial septal defect was much affected by the aorta symptom, the value of left atrium, the ESD, the PR [PQ], and the QRS. The type of coronary artery disease was much affected by the symptom of the values of EDD and ESD. Most of the symptoms did not have a strong relationship for the type of diastolic dysfunction disease. For the type of rheumatic heart disease, about 62.86% symptoms had relationships, spread from the weak relationship, the moderate, the strong, the very strong, and even to the perfect relationship. The type of normal resting echocardiography disease had the relationship level of “no relationship” between the higher symptoms, compared to the rheumatic heart disease; and as well as the types of left ventricular hypertrophy disease and the hypertensive heart disease.

1. Introduction
The development of information technology today has been widely used in various sectors of life, one of which is in health sector. There are many computational approaches, especially for machine learning, data mining and text mining, which are used to help the health sector, especially for providing better services and more accurate disease diagnosis results, and to help identify the heart disease [1,2]. Decision tree approach, for example, is used to predict the factors that cause heart disease [3-5], classification of heart disease[6-8], and the prediction of the risk of a heart attack on a person, as all of which can also be done on a mobile basis by utilizing smartphone technology [9]. In general, the computational approach is not only used in cases of heart disease, but also of other diseases, for example, for predicting diabetes with classification approaches such as naive bayes, random forest and naive bayes tree [10]. In the health sector, especially for heart disease, it is used to diagnose someone indicated with heart disease, one of them is by looking at the patient's medical record in the form of electrocardiogram (ECG) data.
The ECG data for heart disease patients usually contain electrical signal information based on the capture of the device that is attached to the patient's body and then raises the ECG signal label that informs the patient's heart condition when examined. Usually, the ECG data is in the form of an electrical signal graph of the heart condition that contains P, Q, R, S, T and U values and even a combination of several signals forming peaks and valleys. Through this electrical signal information, the doctor then diagnoses the type of heart disease suffered by the patient, although there may also be other additional indicators used.

This study was the first step of other researchers conducted in an effort to develop a tele-expert cardiovascular system model to be able to identify heart disease based on symptoms that have the highest level of association with diagnosis. Basically, there are lots of indicators, especially from ECG data, that can be used to determine someone suffering from certain heart diseases. However, from many indicators generated on the ECG data, there are several indicators (symptoms) that may have a strong relationship or even have no relationship at all to the diagnosis of heart disease. A computational approach is used to determine the relationship between indicators (symptoms) based on ECG data, one of which is by using Pearson Correlation Coefficient (PCC).

2. Heart disease
Heart disease is a condition where when the main blood vessels are damaged while supplying blood to the heart [11]. There are many types of heart disease in the medical world with symptoms that are specific to each disease. Some of them are coronary heart disease, heart failure and leaky heart valve. Coronary heart disease is mainly caused by blocked blood flow to the heart due to the accumulation of fat in the walls of blood vessels. Heart Failure is mainly caused by the failure of heart to pump blood properly, so that the function of the heart is disrupted. Leaky Heart Valve is mainly caused by the failure of heart does not develop normally which disrupts the work of the heart.

3. Electrocardiogram
Electrocardiogram (ECG) is the result of examining the condition of a person's body against the heart organ based on the recording of electrical signals [12]. ECG signals usually consist of six main labels that make peaks and valleys. The six main labels are P, Q, R, S, T, and U. In the implementation, several signal labels are then combined into an interval that is read at once, for example, PR interval is a combination of the signal distance from P to Q, then to R, QRS is a combination the signal distance from the peak Q to R, then to S. Likewise, with other combined signals such as QT, ST and RR.

4. Pearson Correlation Coefficient (PCC)
The correlation coefficient is a measure used to determine the degree of linear relationship with two continuous variables. This correlation value also shows how close the point value data distribution is to the straight line. The positive correlation value shows that if the value of a variable increases, the value of other variables will increase, and vice versa [13]. To calculate the correlation value one of them can be done using equation (1).

\[
 r_{xy} = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i - \bar{x})^2} \sqrt{\sum_{i=1}^{n}(y_i - \bar{y})^2}}
\]

Where \( r_{xy} \) is the correlation coefficient between variables x and y, while \( x_i, y_i \) are the independent variables x and y for \( i^{th} \) data and x and y are the average values of the variables \( \bar{x} \) and \( \bar{y} \).

5. Research methodology
This study was started by collecting the data from the patients suffering from heart disease in one of the public hospitals in Indonesia. The collected data were in the form electrocardiogram records and patient echo data amounted to 150 datasets. The next step was the interpretation of the types of heart disease
into easily understood terms since the data obtained still contained the types of disease in medical terms in the form of abbreviations and specific disease codes. After the interpretation, there was an analysis on the pattern of correlation of symptoms to the type of disease using the Pearson correlation coefficient (PCC) approach.

6. Results and Discussion

6.1. The analysis of the symptom patterns on types of heart diseases of the patients

Based on 150 data of patients suffering from heart disease obtained from RSUD dr. Dradjat Prawiranegara of Serang City, there were 25% indicated suffering from Hypertensive Heart Disease, 23% suffered from Coronary Artery Disease, 18% suffered from Left Ventricular Hypertrophy Suspect Hypertensive Heart Disease, 15% suffered from Normal Resting Echocardiography, 12% suffered from Rheumatic Heart Disease, 4% suffered from Diastolic Dysfunction, 2% suffered from Atrial Septal Defect and 1% suffered from Cardiac Repair.

The analysis of symptom patterns on types of heart disease was carried out using the Pearson Correlation Coefficient (PCC) approach. The overall symptom pattern was analyzed for the types of disease to determine which symptoms had the highest effect on all types of heart disease according to the 150 data available. This section only discusses the analysis of symptom patterns that had stronger effect on the types of disease and not per type of disease. The analysis of symptom patterns on types of heart disease was conducted by using Weka software. The results of the analysis showed that the symptoms shown by the attributes of heart function had the highest effect on the types of disease suffered by the patients. Another following symptom was analyzed by looking at the attributes of ESD, Left Atrium, PW Diastolic value, and PW Systolic value and so on. The rank of the correlation of symptoms on the types of heart disease can be seen in Table 1.

| No. | Symptoms Attributes | Value of PCC | Attribute ID | Rank |
|-----|---------------------|--------------|--------------|------|
| 1   | HEART FUNCTIONS     | 0.2959       | 3            | 1    |
| 2   | ESD                 | 0.2801       | 5            | 2    |
| 3   | LEFT ATRIUM         | 0.2539       | 2            | 3    |
| 4   | PW Diastole         | 0.1947       | 8            | 4    |
| 5   | PW Systole          | 0.1795       | 9            | 5    |
| 6   | EDD                 | 0.1732       | 4            | 6    |
| 7   | IVS Diastole        | 0.1673       | 6            | 7    |
| 8   | IVS Systole         | 0.1165       | 7            | 8    |
| 9   | HR                  | 0.0915       | 10           | 9    |
| 10  | AORTA               | 0.0786       | 1            | 10   |
| 11  | QT                  | 0.0648       | 14           | 11   |
| 12  | P                   | 0.0598       | 15           | 12   |
| 13  | QT                  | 0.0563       | 13           | 13   |
| 14  | PR [PQ]             | 0.0354       | 11           | 14   |
| 15  | QRS                 | 0.0331       | 12           | 15   |

6.2. The analysis of the correlation between the symptoms perceived and types of heart disease

Several studies identifying the correlation of symptoms to heart disease do not always use the pearsons correlation coefficient (PCC) approach and do not use electrocardiogram (ECG) medical record data. In Gloria, Kalyanasundaram, and Srinivasan identification of symptomatic correlations of types of heart disease is carried out using the PCC, Snedecor and Cochran approaches [14-16]. The indicators used are not based on Electrocardiogram data measurements but rather by looking at indicators of age, sex, obesity, total cholesterol and diabetes suffered. The correlation between symptoms and types of disease was seen based on the PCC value generated and was then interpreted based on the De Vaus correlation coefficient. The De Vaus correlation coefficient value is shown in Table 2.
Table 2. The Interpretation of de Vaus correlation coefficient.

| Coefficient | Correlation Strength          |
|-------------|-------------------------------|
| 0.00        | No Correlation                |
| 0.01 - 0.09 | Non-significant Correlation   |
| 0.10 - 0.29 | Weak Correlation              |
| 0.30 - 0.49 | Moderate Correlation          |
| 0.50 - 0.69 | Strong Correlation            |
| 0.70 - 0.89 | Very Strong Correlation       |
| > 0.90      | Almost Perfect Correlation    |

The colour explanation in Table 2 is an initiative carried out in this study to facilitate the mapping of the level of correlation of each symptom in the PCC value table which will later be displayed for each type of disease. The order of colour degradation does not show any level to determine whether a correlation is strong or not. The use of colour is only to make it easier to interpret PCC values between symptoms and certain types of heart disease.

The PCC values were calculated between the symptoms and certain types of disease. For example, the Atrial Septal Defect has all of its symptoms calculated based on equation (1) on this type of disease to find out how strong the correlation between symptoms in order to support the identification of a patient's heart disease. The following is an example of calculating the PCC value for the symptoms (attributes) of AORTA on the symptoms (attributes) of LEFT ATRIUM for Atrial Septal Defect suffered by the patients. Table 3 shows the medical data of patients identified with Atrial Septal Defect for AORTA and LEFT ATRIUM symptoms, and is used to calculate PCC values between AORTA and LEFT ATRIUM.

Table 3. Medical data of patients with atrial septal defect.

| Symptoms Attributes | Patient 1 | Patient 2 | Patient 3 | Average value |
|---------------------|-----------|-----------|-----------|--------------|
| AORTA               | 22        | 32        | 26        | 26,7         |
| LEFT ATRIUM         | 26        | 37        | 38        | 33,7         |
| HEART FUNCTIONS     | 79        | 52        | 72        | 67,7         |
| EDD                 | 33        | 26        | 38        | 32,3         |
| ESD                 | 17        | 24        | 22        | 21,0         |
| IVS Diastole        | 7         | 12        | 10        | 9,7          |
| IVS Systole         | 9         | 16        | 13        | 12,7         |
| PW Diastole         | 7         | 13        | 9         | 9,7          |
| PW Systole          | 10        | 19        | 14        | 14,3         |
| HR                  | 136       | 91        | 64        | 97,0         |
| PR [PQ]             | 80        | 142       | 200       | 140,7        |
| QRS                 | 100       | 120       | 129       | 116,3        |
| QT                  | 298       | 406       | 350       | 351,3        |
| QTC                 | 448       | 500       | 362       | 436,7        |
| P                   | -15       | 75        | 40        | 33,3         |

Identified disease

| Attributed Symptoms | Atrial Septal Defect | Atrial Septal Defect | Atrial Septal Defect |
|---------------------|----------------------|----------------------|----------------------|

The calculation of the PCC values between AORTA (AO) and LEFT ATRIUM (AK) can be shown as follows:

\[ r_{AO,AK} = \frac{\sum_{i=1}^{n}(AO_i - \bar{AO})(AK_i - \bar{AK})}{\sqrt{\sum_{i=1}^{n}(AO_i - \bar{AO})^2 \cdot \sum_{i=1}^{n}(AK_i - \bar{AK})^2}} \]
The calculation was continued for each symptom on the other symptoms, in pairs, to see the correlation value between the symptoms of Atrial Septal Defect disease. One of the results of calculating the PCC correlation value for each symptom with other symptoms for Atrial Septal Defect is shown in Table 4.

Based on the PCC values in Table 4, it can be seen that the attributes (symptoms) of AORTA (AO) on EDD, ESD, IVS Diastole (IVS-D), IVS Systole (IVS-S), PW Diastolic (PW-D), PW Systolic (PW-S), DQT and P values have an almost perfect correlation on a person's diagnosis to suffer the Atrial Septal Defect. The very strong correlation is shown by the values of the attribute (symptom) of AORTA with LEFT ATRIUM, while the rest has a moderate relationship or even has no relationship at all. There are three symptoms (attributes) that have an almost perfect correlation with the symptoms of the LEFT ATRIUM (LA) to support the diagnosis of Atrial Septal Defect in patients. All of the symptoms are ESD, PR [PQ] and QRS values. There are six symptoms that have a very strong correlation with LEFT ATRIUM, while the rest are identified as having no correlation with LEFT ATRIUM to determine which patients suffer from Atrial Septal Defect.

**Table 4.** PCC correlation value for each symptom of atrial septal defect disease.

|    | AO  | LA  | HF  | EDD | ESD | IVS-D | IVS-S | PW-D | PW-S | HR | PR  | QRS | QT  | QTC | P  |
|----|-----|-----|-----|-----|-----|-------|-------|------|------|----|-----|-----|-----|-----|----|
| AO | 1   |     |     |     |     |       |       |      |      |    |     |     |     |     |    |
| LA | -0.98 | 1   |     |     |     |       |       |      |      |    |     |     |     |     |    |
| HF | -0.67 | -0.64 | 1   |     |     |       |       |      |      |    |     |     |     |     |    |
| EDD| 0.93  | 0.93 | -0.87 | -0.36 | 1   |       |       |      |      |    |     |     |     |     |    |
| ESD| 0.97  | 0.88 | -0.92 | -0.48 | 0.99 | 1     |       |      |      |    |     |     |     |     |    |
| IVS-D| 0.98 | 0.87 | -0.93 | -0.51 | 0.98 | 0.39 | 1     |      |      |    |     |     |     |     |    |
| IVS-S| 0.99 | 0.70 | -0.99 | -0.72 | 0.90 | 0.95 | 0.96 | 1     |      |    |     |     |     |     |    |
| PW-D| 0.99 | 0.78 | -0.97 | -0.63 | 0.95 | 0.98 | 0.98 | 0.99 | 1     |    |     |     |     |     |    |
| PW-S| 0.99 | 0.86 | -0.99 | -0.59 | 0.96 | 0.99 | 0.99 | 0.99 | 0.99 | 1   |     |     |     |     |    |
| HR | -0.52 | -0.95 | 0.38 | -0.28 | -0.78 | -0.70 | -0.68 | -0.45 | -0.56 | 1   | -0.99 | 1     |     |     |    |
| PR | 0.41  | 0.90 | -0.26 | 0.39 | 0.70 | 0.61 | 0.58 | 0.34 | 0.46 | -0.99 | 1   |     |     |     |    |
| QRS| 0.58  | 0.97 | -0.45 | 0.20 | 0.64 | 0.62 | 0.52 | 0.52 | 0.34 | -0.99 | 1   |     |     |     |    |
| QT | 0.99  | 0.88 | -0.92 | -0.47 | 0.98 | 0.99 | 0.98 | 0.98 | 0.98 | 0.98 | 1   | 0.49 | 0.65 | 1   |    |
| QTC| 0.47  | -0.21 | -0.60 | -0.97 | 0.13 | 0.26 | 0.29 | 0.54 | 0.43 | 0.49 | -0.60 | -0.43 | 0.39 | 1   |    |
| P  | 0.97  | 0.99 | -0.92 | -0.47 | 0.99 | 1.00 | 0.99 | 0.95 | 0.98 | -0.71 | 0.62 | 0.76 | 0.98 | -0.25 | 1   |
For symptoms that shown by the range of HEART FUNCTIONS (HF), there is only one symptom that have a very strong correlation, namely EDD, and one with moderate correlation, namely HR, while the rest are stated to have no correlation at all. The range of EDD symptom values has a moderate correlation with HR symptoms and a less significant correlation with QRS symptom range. The rest show no correlation at all. Almost all symptoms have correlation with ESD symptoms, except HR symptoms that have no correlation at all and QRS that has non-significant correlation relationship. The symptoms (attributes) of ESD, mostly, have an almost perfect correlation with other symptoms and have two very strong correlations with other symptoms. Whereas two symptoms, such as HR, have no relationship at all, namely with ESD symptoms to produce a diagnosis of Atrial Septal Defect. Meanwhile, QTC symptoms has a non-significant correlation.

The other symptoms, such as IVS Diastolic, IVS Systolic, PW Diastolic, PW Systolic, PR [PQ], QRS and QT generally have a correlation that can be said to have an effect on other symptoms to support the identification of Atrial Septal Defect. As for the symptoms (attributes) of HR for other symptoms can be stated to have no correlation at all. In general, from 15 existing symptoms (attributes), there were 0.723.

| AO | LA | HF | EDD | ESD | IVS-D | IVS-S | PW-D | PW-S | HR | PR [PQ] | QRS | QT | QTC | P |
|----|----|----|-----|-----|-------|-------|------|------|----|--------|-----|----|-----|---|
| 1  | 0.17 | 1 | 0.01 | -0.22 | 0.37 | 1 | 0.10 | 0.58 | -0.50 | 0.10 | 0.49 | 0.05 | -0.27 | -0.04 | 0.09 | 1 | 0.50 | 0.04 | -0.26 | -0.02 | 0.08 | 0.08 | 0.07 | 1 | 0.18 | 0.25 | 0.01 | -0.16 | 0.04 | 0.27 | 0.24 | 1 | 0.15 | 0.12 | 0.25 | 0.02 | -0.04 | 0.24 | 0.24 | 0.07 | 1 | 0.04 | 0.02 | 0.04 | -0.05 | -0.09 | -0.10 | 0.30 | -0.02 | 1 | 0.12 | 0.00 | 0.01 | -0.10 | -0.08 | -0.05 | 0.12 | 0.41 | -0.10 | 0.11 | -0.09 | 1 | 0.25 | 0.12 | 0.37 | -0.41 | 0.32 | 0.43 | 0.32 | 0.44 | 0.12 | 0.06 | 0.12 | 0.05 | -0.02 | 0.06 | 0.69 | 0.10 | -0.10 | 0.01 | 0.05 | 0.26 | 0.05 | 0.07 | 0.45 | 0.39 | 0.10 | -0.15 | 0.54 | 0.08 | 0.32 | -0.25 | -0.01 | 0.10 | 0.27 | 0.20 | 1 | 0.10 | 0.04 | 0.04 | -0.10 | -0.09 | -0.02 | -0.04 | 0.18 | 0.32 | -0.25 | -0.01 | 0.10 | 0.27 | 0.20 | 1 | 0.32 | 0.25 | 0.04 | 0.04 | -0.10 | -0.09 | -0.02 | -0.04 | 0.18 | 0.32 | -0.25 | -0.01 | 0.10 | 0.27 | 0.20 | 1 |

Table 5. PCC correlation value for each symptom of coronary artery disease.

For Rheumatic Heart Disease, the correlation between the symptoms turned out to be dominated by the "no correlation" between symptoms. 37.14% of symptoms have no correlation with each other. The remaining 62.86% have different correlations; 18.10% have "non-significant correlation", 21.90% have weak correlation, 16.19% have moderate correlation, 4.76% have strong correlation, 0.95% have very strong correlation, and 0.95% have almost perfect correlation.

For symptoms that shown by the range of HEART FUNCTIONS (HF), there is only one symptom that have a very strong correlation, namely EDD, and one with moderate correlation, namely HR, while the rest are stated to have no correlation at all.
Similarly in this study, the correlation between symptoms developed for the Normal Resting Echocardiography type of disease was also dominated by the "no correlation" level, as shown based on the calculation of PCC values of 41.90% of the symptoms stated to have "no correlation". The remaining 62.86% have different correlations; 10.48% have "non-significant correlation", 21.90% have weak correlation, 18.10% have moderate correlation, 26.67% have strong correlation, 1.90% have very strong correlation, and 0.95% have almost perfect correlation.

In the case of other type, the correlation between symptoms that cause Left Ventricular Hypertrophy showed that 41.90% have "no correlation", while remaining 58.10% have different correlations between symptoms; 10.10% have "non-significant correlation" between symptoms in Left Ventricular Hypertrophy, 21.90% have weak correlation, 12.38% have moderate correlation, 2.86% have strong correlation, and 2.8% have very strong correlation. There was no correlation categorized as almost perfect between the symptoms referred to the hypothesis of Left Ventricular Hypertrophy.

The last type of disease in this study, namely Hypertensive Heart Disease, showed that 50.48 have "no correlation" between symptoms, while 16.19% have "non-significant correlation" between the existing symptoms, 21.90% of each symptom had "weak correlation", 6.67% have "moderate correlation", 0.95% have "strong correlation" between the symptoms and 3.81% have "very strong but not almost perfect correlation" between symptoms for making the hypothesis of hypertensive heart disease

7. Conclusion
Based on the results of study and analysis of 150 data on patients suffered from heart disease patients using the Pearson correlation coefficient approach, it was found that the Artial Septal Defect was more affected by aortic symptoms, left atrial values, ESD, PR [PQ] and QRS. Coronary Artery Disease was more influenced by symptoms of EDD and ESD values. Most symptoms did not have a strong correlation in Diastolic Dysfunction. In Rheumatic Heart, there were 62.86% of symptoms have a various correlations, from weak, moderate, strong, very strong and almost perfect. In Normal Resting Echocardiography, there were more symptoms have "no correlation" level than those in rheumatic heart, left ventricular hypertrophy and hypertensive heart.

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