FUZZY EXPERT SYSTEM ON DIAGNOSIS ATHEROSCLEROSIS

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UNIVERSITI TUN HUSSEIN ONN MALAYSIA
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A project report submitted in partial fulfillment of the requirement for the award of the Degree in Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
Universiti Tun Hussein Onn Malaysia

JANUARY 2017
Dedicated for:

Beloved mum and dad,
Puan Zainon binti Md. Ali and Mahadi bin Ismail

Dearest sisters and brothers in law
&
Lovely niece and nephew
ACKNOWLEDGEMENT

In the name of Allah, The most Gracious and Merciful.

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ABSTRACT

Heart disease is one of the major factors of death worldwide. Atherosclerosis is the major factor of heart disease. Atherosclerosis is a disease in which plaque builds up inside the arteries that eventually likely to be hardened over time thus narrows the arteries. This project is developed to monitor the atherosclerosis risk among people, which can tell their current health condition. This system could change the perspective of one's life for better living. 20 people consist of 10 male, 10 female have been used as a test subject in this project. An Arduino prototype of Atherosclerosis monitors have been developed by applying the fuzzy logic method for testing and analyze the possibilities of atherosclerosis based on several input data obtained from the subject. The selected input data are age, body mass index (BMI), intima media thickness (IMT), blood pressure (BP) and blood glucose level (BGL). Since all the subjects are young in age, the chance of them to have the atherosclerosis is low.
ABSTRAK

Penyakit jantung adalah salah satu faktor utama kematian di seluruh dunia. Aterosklerosis adalah faktor utama penyakit jantung. Aterosklerosis adalah penyakit di mana plak membina di dalam arteri yang akhirnya mungkin akan keras dari masa ke masa dengan itu menyempitkan arteri. Projek ini dibangunkan untuk memantau risiko aterosklerosis di kalangan rakyat, yang boleh memberitahu keadaan kesihatan semasa mereka. Sistem ini boleh mengubah perspektif kehidupan seseorang untuk hidup yang lebih baik. 20 orang terdiri daripada 10 lelaki, 10 perempuan telah digunakan sebagai subjek ujian dalam projek ini. Satu prototaip Arduino monitor Aterosklerosis telah dibangunkan dengan menggunakan kaedah fuzzy logic untuk menguji dan menganalisis kemungkinan aterosklerosis berdasarkan beberapa data input yang diperolehi daripada subjek. Data input yang dipilih ialah umur, indeks jisim badan (BMI), ketebalan media Intima (IMT), tekanan darah (BP) dan tahap glukosa darah (BGL). Oleh kerana subjek semua dalam usia muda, peluang mereka untuk mempunyai aterosklerosis adalah rendah.
CONTENTS

TITLE
DECLARATION
DEDICATION
ACKNOWLEDGEMENT
ABSTRACT
CONTENTS
LIST OF TABLES
LIST OF FIGURE
LIST OF SYMBOLS AND ABBREVIATIONS

CHAPTER 1 INTRODUCTION

1.1 Background of study
1.2 Problem statement
1.3 Aim
1.4 Objectives
1.5 Scopes

CHAPTER 2 LITERATURE REVIEW

2.1 Introduction
2.2 Measurands to be taken into account
2.2.1 Body Mass Index (BMI)
2.2.2 Carotid Intima Media Thickness (CIMT) 8
2.2.3 Blood Pressure (BP) 10
2.2.4 Blood Glucose level (BGL) 12
2.3 Soft computing 14
2.3.1 Neural Network 14
2.3.2 Fuzzy logic 15
2.2.3 The difference between Fuzzy Logic and Neural Networks 15
2.4 Previous Case studies 16
2.4.1 Measurement of Local Elasticity of Human Carotid Arterial Walls and Its Relationship with Risk Index of Atherosclerosis 16
2.4.2 Atherosclerosis Risk Assessment using Rule-based Approach 17

CHAPTER 3 METHODOLOGY 19

3.1 Introduction 19
3.2 System development 20
3.2.1 Data collection 20
3.2.2 Software implementation 24
3.2.2.1 Fuzzy Logic 24
   I. General outline of Fuzzy controller 25
   II. Fuzzy logic implementation block diagram 25
   III. Membership Function, Input and Output 25
   IV. Created rules 29
 LIST OF TABLES

2.1 Classification of BMI scores .................................................. 8
2.2 Classification of IMT categories .............................................. 9
2.3 Blood pressure chart categories ............................................. 11
2.4 Blood sugar level in diagnosing diabetes .................................. 12
2.5 Classification accuracy system for risky and non-risky patient ........ 18
3.1 Age range of subject ............................................................ 21
3.2 BMI range of subject ........................................................... 22
3.3 CIMT range reading ............................................................. 23
3.4 The blood pressure range ...................................................... 23
3.5 Blood glucose level range ...................................................... 24
4.1 Output range of fuzzy sets that represents Atherosclerosis disease .... 38
4.2 Result display of Atherosclerosis risk on LCD display prototype based percentage range on fuzzy sets .......... 47
4.3 Prototype testing step by step .................................................. 48
4.4 Subject data collection .......................................................... 50
LIST OF FIGURES

1.1 Atherosclerosis development 2
1.2 a) Normal artery, b) Narrowing of artery 3
1.3 Sequences in Atherosclerosis progression 5
2.1 The comparison of normal lumen of artery and artery with plaque 9
2.2 The relationship between incremental strain with arterial inner pressure 12
2.3 The average of elastic module $E$ of 54 patients and 30 healthy subjects. Values are mean measured in 3 cardiac cycle 16
2.4 CVD risk calculator 17
3.1 Data collection flow chart 20
3.2 Carotid artery classification 22
3.3 Blood pressure monitor 23
3.4 Accu-chek Performa blood glucose meter 24
3.5 Block diagram of fuzzy logic 25
3.6 Membership function for Age 26
3.7 Membership function for BMI 27
3.8 Membership function for IMT 27
3.9 Membership function for Blood Pressure 28
3.10 Membership function for blood glucose level 29
3.11 Rules editor 30
3.12 Screenshot of the Arduino IDE showing the Fuzzy inference system of Atherosclerosis 31
3.13 The average of IMT measurement (Pixel = 2.43, Millimeter = 0.64) 33
3.14 Arduino Uno R3 board with labels 34
3.15 Matrix keypad 35
3.16 LCD display 36
3.17 Prototype design 36
3.18 Operation flow chart 37
4.1 Membership function for Atherosclerosis condition 39
4.2 Rule viewer 39
4.3 Surface viewer for atherosclerosis condition based on BGL and BP 41
4.4 Surface viewer for atherosclerosis condition based on IMT and BMI 42
4.5 Surface viewer for atherosclerosis condition based on age and BMI 42
4.6 Surface viewer for atherosclerosis condition based on IMT and age 43
4.7 Surface viewer for atherosclerosis condition based on blood pressure and BMI 43
4.8 Surface viewer for atherosclerosis condition based on blood glucose and BMI 44
4.9 Surface viewer for atherosclerosis condition based on blood glucose and IMT 44
4.10 Surface viewer for atherosclerosis condition based on age and blood pressure 45
4.11 Surface viewer for atherosclerosis condition based on age and blood glucose 45
4.12 Fuzzy expert system on diagnosis atherosclerosis prototype 46
4.13 Block diagram on how hardware prototype works 46
4.14 Example of required input data display in LCD a) Age, b) IMT, c) BGL 49
4.15 The result display of LCD to indicate a) low risk, b) mid risk, c) high risk 50
# LIST OF SYMBOLS AND ABBREVIATIONS

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>AGEs</td>
<td>advanced glycation end products</td>
</tr>
<tr>
<td>Ant</td>
<td>Conjunction of attribute-value pairs</td>
</tr>
<tr>
<td>ANN</td>
<td>Artificial neural network</td>
</tr>
<tr>
<td>BGL</td>
<td>Blood glucose level</td>
</tr>
<tr>
<td>BMI</td>
<td>Body mass index</td>
</tr>
<tr>
<td>B-mode</td>
<td>Brightness mode</td>
</tr>
<tr>
<td>BP</td>
<td>Blood pressure</td>
</tr>
<tr>
<td>C</td>
<td>Class</td>
</tr>
<tr>
<td>CCA</td>
<td>Common carotid artery</td>
</tr>
<tr>
<td>CIMT</td>
<td>Carotid intima media thickness, intima media thickness</td>
</tr>
<tr>
<td>cm</td>
<td>Centimetre</td>
</tr>
<tr>
<td>CVD</td>
<td>Cardiovascular disease</td>
</tr>
<tr>
<td>HR</td>
<td>High risk</td>
</tr>
<tr>
<td>in</td>
<td>inches</td>
</tr>
<tr>
<td>IMT</td>
<td>Intima media thickness</td>
</tr>
<tr>
<td>KEX</td>
<td>Knowledge Explorer algorithm</td>
</tr>
<tr>
<td>kg</td>
<td>Kilogram</td>
</tr>
<tr>
<td>lb</td>
<td>Pound</td>
</tr>
<tr>
<td>LCD</td>
<td>Liquid crystal display</td>
</tr>
<tr>
<td>LDL</td>
<td>Low density lipoprotein</td>
</tr>
<tr>
<td>LR</td>
<td>Low risk</td>
</tr>
<tr>
<td>m</td>
<td>Meter</td>
</tr>
<tr>
<td>mg/dl</td>
<td>Milligrams per deciliter</td>
</tr>
<tr>
<td>mm</td>
<td>Millimetre</td>
</tr>
<tr>
<td>mmHg</td>
<td>Millimetres of mercury</td>
</tr>
<tr>
<td>mmol/l</td>
<td>Millimoles per litre</td>
</tr>
<tr>
<td>M-mode</td>
<td>Motion mode</td>
</tr>
<tr>
<td>Modulus E</td>
<td>Elastic modulus</td>
</tr>
<tr>
<td>Abbreviation</td>
<td>Description</td>
</tr>
<tr>
<td>--------------</td>
<td>----------------------------------</td>
</tr>
<tr>
<td>MR</td>
<td>Mid risk</td>
</tr>
<tr>
<td>N/A</td>
<td>Not applicable</td>
</tr>
<tr>
<td>NIH</td>
<td>National Institute of Health</td>
</tr>
<tr>
<td>NO</td>
<td>Nitrous oxide</td>
</tr>
<tr>
<td>NR</td>
<td>No risk</td>
</tr>
<tr>
<td>UTHM</td>
<td>Universiti Tun Hussein Onn Malaysia</td>
</tr>
<tr>
<td>VHR</td>
<td>Very high risk</td>
</tr>
<tr>
<td>w</td>
<td>weight</td>
</tr>
</tbody>
</table>
CHAPTER 1

INTRODUCTION

1.1 Background of study

Atherosclerosis is a disease in which plaque builds up inside arteries. Arteries are blood vessels that carry oxygenated blood to the heart and other parts of the body. Plaque is made up of fat, cholesterol, calcium, and other substances found in the blood [1]. Over time, plaque hardens and narrows the arteries. This limits the flow of oxygenated blood to the organs and other parts of the body and therefore can lead to serious problems, including heart attack, stroke, or even death [2]. The exact cause of atherosclerosis is not being known. However, atherosclerosis may start when certain factors damage the inner layers of the arteries. These factors include smoking, high amounts of certain fats and cholesterol in the blood, high blood pressure, high amounts of sugar in the blood due to insulin resistance or diabetes.

Furthermore, studies show that atherosclerosis is a slow, complex disease that may start in childhood [3]. Plaque may begin to build up where the arteries are damaged. Over time, plaque hardens and thus narrows the arteries. Eventually, an area of plaque can be rupture. When this happens, blood cell fragments called platelets stick to the site of the injury. They may clump together to form blood clots. Clots narrow the arteries even more, limiting the flow of oxygenated blood to the body. The atherosclerosis development can be shown in Figure 1.1.
Depending on which arteries are affected, blood clots can worsen angina, (chest pain) or cause a heart attack or stroke. Atherosclerosis can affect any artery in the body, including arteries in the heart, brain, arms, legs pelvis and kidneys. As a result, different diseases may develop based on which arteries are affected.

Therefore, it is important to have a system which can alert people with their health condition to prevent for the worst. This project proposed the development of the Atherosclerosis risk assessment monitoring system. This project will develop a prototype that will inform the present condition of the patients after certain measurand has been taken which include the age, body mass index (BMI), intima media thickness (IMT), blood pressure (BP) and blood glucose level (BGL). On the bright side, the system could probably save more life, times and money as it acts as early detection of cardiovascular and other related disease. Moreover, it may cause more people to lead for better healthy lifestyle.
The comparison between the normal artery and narrowing of artery due to plaque build-up is shown as Figure 1.2 where figure A is the normal artery with normal blood flow. The inset image shows a cross-section of a normal artery. Meanwhile, Figure B shows an artery with plaque build-up and the inset image shows a cross-section of an artery with plaque build-up [1]. The pathophysiologic process by which atherosclerosis occurs is complex and somewhat controversial. The working theory includes four steps [4]:

i. Endothelial cell injury
ii. Lipoprotein deposition
iii. Inflammatory reaction
iv. Smooth muscle cell cap formation
i. **Endothelial cell injury**  
This is likely the initial factor that begins the process of atherosclerotic plaque formation. Since the endothelium are constantly exposed to the circulation, any toxin present can result in damage (as occurs during tobacco use, diabetes and dyslipidemia). The continuous physical force exerted upon the endothelium also plays a role as commonly the greatest atherosclerotic plaque occurs at arterial bifurcations. Hypertension increases the physical force present.

ii. **Lipoprotein deposition**  
When the endothelium is injured or disrupted, lipoprotein molecules can gain entry where they are then modified by oxidation (via free radicals or oxidizing enzymes) or glycation (diabetics). This modified lipoprotein (modified LDL) is inflammatory and able to be ingested by macrophages creating “foam cells” causing a “fatty streak” in the arterial wall.

iii. **Inflammatory reaction**  
The modified LDL is antigenic and attracts inflammatory cells into the arterial wall. Also, after endothelial injury, inflammatory mediators are released further increasing leukocyte recruitment.

iv. **Smooth muscle cell cap formation**  
Smooth muscle cells migrate to the surface of the plaque creating a “fibrous cap”. When this cap is thick, the plaque is stable, however thin capped atherosclerotic plaques are thought to be more prone to rupture or erosion causing thrombosis.
The pathophysiological process of Atherosclerosis can be summarized as Figure 1.3 below.

![Figure 1.3: Sequences in Atherosclerosis progression. (Steven Lome, 2016)](image)

### 1.2 Problem statement

Generally, for certain disease that people may encounter, there are few symptoms or sign that will be appeared when they feel sick which makes them aware of their health and it is easier to take an action to prevent from the worst. Atherosclerosis will not show any sign or symptoms to the patients until the artery were totally blocks. People were not aware of the disease until they got heart attack or stroke. Therefore, this project proposed to develop Fuzzy expert system on diagnosis Atherosclerosis. So people will alert with their health condition as the system will indicate the level of atherosclerosis disease that they might have.
1.3 **Aim**

The aim of this project is to develop the Fuzzy expert system on diagnosis Atherosclerosis.

1.4 **Objectives**

To achieve the above aim, the objectives for the project are:

- To assess the risk factor of atherosclerosis.
- To develop a prototype that could monitor the risk of atherosclerosis

1.5 **Scope**

To detect the early stage of the atherosclerosis at common carotid, the development of atherosclerosis risk assessment monitoring system measurement is proposed. The measurands/parameters that will be considered in this project are:

a) Age  

b) Body mass index (BMI) 

c) Intima media thickness (IMT) 

d) Systolic blood pressure (BP) 

e) Blood glucose level (BGL)

All the parameters above will be categorized in each selected range. For BMI, four group will be categorized which are underweight, normal, overweight and obesity. For IMT, if the measurement is greater than 1.0 mm, the value will be considered as abnormal. The blood pressure category would be low, normal and high blood pressure (hypertension) while for blood glucose level they would be low, normal and high glucose level (diabetes). Furthermore, this project proposed to implement a fuzzy logic concept based prototype which embedding structured human knowledge into workable algorithm.
CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, the details of parameter that will be used for the data recording will be discussed. The parameters that would be used including body mass index (BMI), intima media thickness (IMT), blood pressure (BP) and blood glucose level (BGL). Moreover, previous case studies will also be discussed.

2.2 Measurands to be taken into account

2.2.1 Body Mass Index (BMI)

The body mass index (BMI) is a value derived from the mass (weight) and height of an individual. The BMI is an attempt to quantify the amount of tissue mass (muscle, fat, and bone) in an individual, and then categorize that person as underweight, normal weight, overweight, or obese based on that value. Commonly accepted BMI ranges are underweight: under 18.5, normal weight: 18.5 to 25, overweight: 25 to 30 and obese: over 30 [5]. The BMI can be calculated as below:

\[
\text{BMI} = \frac{\text{mass (kg)}}{\text{height}^2 (\text{m})} = \frac{\text{mass (lb)}}{\text{height}^2 (\text{in})} \times 703
\]  

(2.1)
In an analysis of 40 studies involving 250,000 people, patients with coronary artery disease with normal BMIs were at higher risk of death from cardiovascular disease than people whose BMIs put them in the overweight range (BMI 25–29.9) [6].

One study found that BMI had a good general correlation with body fat percentage, and noted that obesity has overtaken smoking as the world's number one cause of death. But it also notes that in the study, 50% of men and 62% of women were obese, according to body fat defined obesity, while only 21% of men and 31% of women were obese, according to BMI, meaning that BMI was found to underestimate the number of obese subjects [7]. Table 2.1 shows the classification of the BMI standard score.

<table>
<thead>
<tr>
<th>Classification</th>
<th>BMI score (kg/m²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Underweight</td>
<td>&lt;18.5</td>
</tr>
<tr>
<td>Normal</td>
<td>18.5-24.9</td>
</tr>
<tr>
<td>Overweight</td>
<td>25.00-29.00</td>
</tr>
<tr>
<td>Obese</td>
<td>&gt;30</td>
</tr>
</tbody>
</table>

2.2.2 Carotid intima media thickness (CIMT)

The carotid intima-media thickness (CIMT) test is a measurement used to analyze the degree of carotid atherosclerotic vascular illness. The test measures the thickness of the inner two layers of the carotid artery - the intima and media - and alerts physicians to any thickening when patients are still asymptomatic. Early discovery may demonstrate the requirement for a more forceful way to managing the risk factors associated with coronary illness and stroke.

Aging is a contributing component to expanded carotid intima-media thickness. Other danger variables incorporate high lipoprotein levels, hypertension, smoking, diabetes, corpulence and a stationary way of life. Physicians use CIMT testing to determine the "age" of the carotid arteries. Knowing that patients may not be experiencing the symptoms of atherosclerosis, there still may be subtle changes in artery thickness. Armed with this information, physicians may develop an aggressive
medical approach by prescribing medications such as blood pressure and cholesterol lowering agents and aspirin, and patients may be encouraged to make lifestyle and dietary improvements [8]. Figure 2.1 shows the comparison of normal lumen of the artery and artery with plaque.

In a study there was clearly stated that in the relatively aged population, increases in intima-media thickness as measured in the Common Carotid Artery (CCAs) were clearly related to locally detected atherosclerosis and known risk factors for atherosclerosis. Longitudinal studies are needed to clarify the role of arterial wall thickening in the atherosclerotic process [9]. The classification of CIMT is being shown as Table 2.2 below [11].

![Diagram of artery lumen with plaque](image)

**Figure 2.1:** The comparison of normal lumen of artery and artery with plaque.
(Hideyuki Hasegawa *et al*, 1998)

<table>
<thead>
<tr>
<th>Classification</th>
<th>CIMT (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>&lt; 0.8</td>
</tr>
<tr>
<td>Borderline</td>
<td>0.8-1.0</td>
</tr>
<tr>
<td>Abnormal</td>
<td>&gt;1.1</td>
</tr>
</tbody>
</table>

**Table 2.2:** Classification of CIMT categories.
(Carotidworld, 2016)
2.2.3 Blood Pressure (BP)

A heart will pump blood throughout the body to deliver energy and oxygen in certain pressure. However, if too much pressure in the vessels, it will put extra strain on the arteries and the heart, which will be led to a heart attack, stroke, etc. Blood pressure is measured in millimeters of mercury (mmHg) and is recorded as two figures:

\[
\frac{117}{76} \text{ mm Hg}
\]  

(2.2)

**Systolic blood pressure**

When the heart beats, it contracts and pushes blood through the arteries to the rest of the body. This force creates pressure on the arteries. This is called systolic blood pressure.

A normal systolic blood pressure is 120 or below. A systolic blood pressure of 120-139 is borderline high blood pressure, which has a great risk of developing heart disease. A systolic blood pressure number of 140 or higher, on repeated measurements, is considered to be hypertension, or high blood pressure.

**Diastolic blood pressure**

Diastolic blood pressure measures the pressure in the arteries between heartbeats (when the heart muscle is resting between beats and refilling with blood) which is also the bottom of the two numbers.

Typically more attention is given to the top number (the systolic blood pressure) as a major risk factor for cardiovascular disease for people over 50 years old. In most people, systolic blood pressure rises steadily with age due to increasing stiffness of large arteries, long-term build-up of plaque, and increased incidence of cardiac and vascular disease.

Table 2.3 shows the blood pressure chart reflects categories defined by the American Heart Association [12].
Table 2.3: Blood pressure chart categories.  
(American Heart Association, 2016)

<table>
<thead>
<tr>
<th>Blood Pressure Category</th>
<th>Systolic mm Hg (upper #)</th>
<th>Diastolic mm Hg (lower #)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal</td>
<td>Less than 120 and 120 – 139 or 140 – 159</td>
<td>Less than 80 or 80 – 89 or 90 – 99</td>
</tr>
<tr>
<td>Prehypertension</td>
<td>160 or higher or Higher than 180</td>
<td>100 or higher or Higher than 110</td>
</tr>
<tr>
<td>High Blood Pressure (Hypertension) Stage 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>High Blood Pressure (Hypertension) Stage 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypertensive Crisis (Emergency care needed)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When the heart beats, it pushes blood through the arteries in the entire body. Higher blood pressures mean that with each beat, arteries throughout the body swell and stretch more than they would normally. This stretching can injure the endothelium, the delicate lining of all arteries, causing arteries to become stiff over time. Healthy endothelium actively works to prevent atherosclerosis from developing. Injured endothelium, on the other hand, attracts more "bad" low density lipoprotein (LDL) cholesterol and white blood cells. The cholesterol and cells build up in the artery wall, eventually forming the plaque of atherosclerosis.

As stated in Table 2.3, hypertension can be classified as a condition when the blood pressure is getting higher which means the chance to have atherosclerosis is also high. Priya R. Mohan et al. [13] stated that since hypertension are often treated by orally medication such as beta blockers, calcium channel blockers, etc. As a result, these drugs gradually caused the artery to become stiffer over times.

However, there are some author stated that the atherosclerosis itself will cause the hypertension. As atherosclerosis caused by the builds up of plague, it then will leads to stenosis condition. Stenosis is defined by the narrowing of the artery. Therefore, since the artery become narrow, the pressure inside the artery will be increase. This then will cause the hypertension.
From the Figure 2.2 above, it shows that the strain in the radial direction is proportional to the blood pressure. The strain in the radial direction is the carotid intima media thickness. The known fact that is the thickness of arterial wall will cause atherosclerosis. Therefore, as the blood pressure increase, the percentage to get atherosclerosis also will increase.

2.2.4 Blood Glucose Level (BGL)

The blood sugar concentrated or blood glucose level is the amount of glucose (sugar) present in the blood of a human or animal. Table 2.4 shows the blood sugar levels in diagnosing diabetes [14].

Table 2.4: Blood sugar levels in diagnosing diabetes.

(Diabetes.co.uk, 2016)

<table>
<thead>
<tr>
<th>Plasma glucose test</th>
<th>Normal</th>
<th>Prediabetes</th>
<th>Diabetes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Random</td>
<td>Below 11.1 mmol/l</td>
<td>N/A</td>
<td>11.1 mmol/l or more</td>
</tr>
<tr>
<td></td>
<td>Below 200 mg/dl</td>
<td></td>
<td>200 mg/dl or more</td>
</tr>
<tr>
<td>Fasting</td>
<td>Below 6.1 mmol/l</td>
<td>6.1 to 6.9 mmol/l</td>
<td>7.0 mmol/l or more</td>
</tr>
<tr>
<td></td>
<td>Below 108 mg/dl</td>
<td>108 to 125 mg/dl</td>
<td>126 mg/dl or more</td>
</tr>
<tr>
<td>2 hour post-prandial</td>
<td>Below 7.8 mmol/l</td>
<td>7.8 to 11.0 mmol/l</td>
<td>11.1 mmol/l or more</td>
</tr>
<tr>
<td></td>
<td>Below 140 mg/dl</td>
<td>140 to 199 mg/dl</td>
<td>200 mg/dl or more</td>
</tr>
</tbody>
</table>
Normal blood vessels have an inner lining, called endothelium, that keeps blood flowing smoothly by producing local Nitrous oxide (NO). NO serves to relax the smooth muscles in the walls of the vessels and prevent cells from sticking to the walls. A disruption of this mechanism is thought to be at the heart of the increased formation of plaques in diabetes. High blood sugar, elevated fatty acids and triglycerides leads to stickier walls, encouraging the attachment of cells that produces a local tissue reaction. The local tissue reaction further traps floating particles and different blood cells, hopping up and hardening the vessel walls.

The metabolic abnormalities that characterize diabetes, such as hyperglycemia, increased free fatty acids, and insulin resistance, each provokes molecular mechanisms that contribute to vascular dysfunction. These include decreased bioavailability of NO, increased oxidative stress, disturbances of intracellular signal transduction, and activation of receptors for advanced glycation end products (AGEs). In addition, platelet function is abnormal, and there is increased production of several prothrombotic factors. These abnormalities contribute to the cellular events that cause atherosclerosis and subsequently increase the risk of the adverse cardiovascular events that occur in patients with diabetes and atherosclerosis [15].

The relationship between diabetes and atherosclerosis is being explored and discussed by the author in 1981. Diabetes is being known to have two types which are due to genetically and metabolic abnormalities and there are possibilities these two types of diabetes relationship with atherosclerosis may vary [16].

Based on autopsy study [16], there was no significant correlation between severity and duration of diabetes with atherosclerosis. The type of medical treatment for diabetes also was not related to atherosclerosis. However, when the patients with diabetes were being compared to non-diabetics, the diabetics possessed significantly more atherosclerosis with myocardial infarction, and other coronary artery disease. This result shows that person with diabetic has a great potential to have atherosclerosis. However the author claims that the progression of atherosclerosis is not depends on how severity of diabetes is.
2.3 Soft computing

2.3.1 Neural Network

Artificial neural network (ANN) are gadgets (algorithms or actual hardware) that are approximately displayed after the neuronal structure of the mamalian cerebral cortex however on much littler scales. An extensive ANN may have hundreds or a huge number of processor units, though a mamalian cerebrum has billions of neurons with a corresponding increment in greatness of their general association and developing behavior. Despite the fact that ANN analysts are for the most part not worried with whether their networks precisely take after natural frameworks, some have. For instance, specialists have precisely reproduced the capacity of the retina and demonstrated the eye rather well [17].

Artificial neural networks in light of straightforward models for neurons and their associations can be extremely effective both in reproducing the memory storing and recall process (the Hopfield network) and for pattern-based decision making and learning (the Perceptron model). Both of these networks have officially discovered wide application outside of neuroscience - in fields as different as signal processing, recognition and synthesis of speech, financial forecasting and modelling, and medical diagnosis [18].

In general, neural networks give great solutions for issues with the accompanying components:

i. The issue makes utilization of 'noisy' information

ii. Quick preparing might be required. We may not require the absolute best answer for the issue. We may very well need a sensibly decent one rapidly.

iii. There are no basic standards for tackling the issue - the sum total of what we have are an arrangement of test arrangements. The network can 'trained' on these so it creates great reactions to comparative new cases.

However, there are two vital issues with the utilization of these networks. The first is that there is no present comprehension of how huge (how many nodes and connections) a network must be in order to handle an issue of some given many-sided quality (the special case to this being the Hopfield network). The second
disservice with these networks can be the long circumstances once in a while expected to instruct the network the fitting reactions - these networks learn supervisedly - input data is fed many times to the network and the associations balanced in order to attempt to accomplish an objective yield. This "programming" stage can imply that a given pattern must be introduced to the network thousands of times [19].

2.3.2 Fuzzy logic

Fuzzy Logic has a place with the group of many-valued logic. It concentrates on settled and estimated thinking restricted to settled and correct thinking. A variable in fuzzy logic can take a truth esteem run somewhere around 0 and 1, rather than taking genuine or false in conventional twofold sets. Since reality esteem is a range, it can deal with incomplete truth. Start of fuzzy logic was set apart in 1956, with the presentation of fuzzy set theory by Lotfi Zadeh. Fuzzy logic gives a technique to settle on positive choices in view of uncertain and questionable information. Fuzzy logic is generally utilized for applications as a part of control frameworks, since it nearly takes after how a human settle on choice yet in speedier way. Fuzzy logic can be incorporated into control frameworks in light of little handheld gadgets to extensive PC workstations [18].

2.3.3 The difference between Fuzzy Logic and Neural Networks

Fuzzy logic permits settling on distinct choices in light of uncertain or equivocal information, while ANN tries to incorporate human speculation procedure to tackle issues without numerically displaying them. Despite the fact that both of these techniques can be utilized to take care of nonlinear issues, and issues that are not appropriately determined, they are not related. As opposed to Fuzzy logic, ANN tries to apply the reasoning procedure in the human cerebrum to take care of issues. Furthermore, ANN incorporates a learning procedure that includes learning algorithms and requires preparing information [20].
2.4 Previous Case studies

2.4.1 Measurement of Local Elasticity of Human Carotid Arterial Walls and Its Relationship with Risk Index of Atherosclerosis

Hideyuki Hasegawa et al [10] agreed that atherosclerosis has been a serious problem due to its high influence on chronic diseases such as myocardial and cerebral infarction. Atherosclerosis has been often diagnosed by measuring the thickness of the arterial wall or the area of the lumen of carotid artery. However, it is difficult to diagnose in early stage of atherosclerosis because there is not much different in the thickness of arterial wall. Therefore, to overcome the problem, the authors has been proposed the method to use ultrasound to measure elasticity of the arterial wall by measuring the small velocity signal on intima and adventitia of the arterial wall. Since the amplitude of change in thickness of the arterial wall is in several tenth micrometers, the elastic property of the arterial wall is evaluated in each local area of a few millimeters which corresponding to the width of ultrasonic beam instead of using the B-mode and M-mode from standard ultrasound device.

In this project, the test was being evaluated on carotid artery of 54 male patients with high risk factor of coronary heart diseases and 30 healthy male subjects. As a result, the elastic modulus $E$ is found to be increased with age. Moreover, the arterial walls of the patients were found to be much stiffer than the healthy subjects as can be seen in Figure 2.3 below.

![Figure 2.3: The average of elastic modulus $E$ of 54 patients and 30 healthy subjects. Values are mean measured in 3 cardiac cycles. (Hideyuki Hasegawa et al, 1998)](image-url)
2.4.2 Atherosclerosis Risk Assessment using Rule-based Approach

Petr Berka et al. [21] had been developed Atherosclerosis risk assessment using Rule-based approach. In this project Knowledge Explorer (KEX) algorithm was used to performs symbolic empirical multiple concept learning from examples, where the induced concept description is represented as weighted decision rules in the form $\text{Ant} \Rightarrow C(w)$, where $\text{Ant}$ is a conjunction of attribute-value pairs, $C$ is a single category (class), and weight $w$ from the interval $[0,1]$ expresses the uncertainty of the rule.

For composing weights the author use a pseudobayesian (Prospector-like) combination function.

$$x \oplus y = \frac{xy}{xy \oplus (1 - x)(1 - y)} \quad (2.3)$$

Figure 2.4 shows the testing set of patients. To compare results of the CVD risk calculators with the system as well with the opinion of domain expert, the authors turned the numerical risk score into binary values. The threshold 5% was taken from the Heart Score system. This allows them to express the performance of the calculators in the terms of classification accuracy as shown in Table 2.5.

The NIH system outperforms all the other systems in both overall accuracy and in accuracy for non-risk patients (thus making less errors by classifying risky patients as non-risky ones), the approach was comparable with the remaining two calculators. Anyway, none of the systems make reliable classifications of non-risky patients and
interesting trade-off between classification accuracies of both groups can be observed.

Table 2.5: Classification accuracy system for risky and non-risky patient.
(Petr Berka, Marie Tomečková, 2008)

<table>
<thead>
<tr>
<th>System</th>
<th>Overall accuracy</th>
<th>Accuracy Risk</th>
<th>Accuracy NoRisk</th>
</tr>
</thead>
<tbody>
<tr>
<td>NIH</td>
<td>0.76</td>
<td>0.84</td>
<td>0.63</td>
</tr>
<tr>
<td>ProCam</td>
<td>0.69</td>
<td>0.95</td>
<td>0.52</td>
</tr>
<tr>
<td>Heart</td>
<td>0.67</td>
<td>1.00</td>
<td>0.50</td>
</tr>
<tr>
<td>Our system</td>
<td>0.70</td>
<td>0.88</td>
<td>0.54</td>
</tr>
</tbody>
</table>
CHAPTER 3

METHODOLOGY

3.1 Introduction
This chapter discussed the steps and method that will be used in developing the project. It consists of software and hardware implementation. In software implementation, the data will be collected and analyzed meanwhile in hardware implementation, the data will be inserted into the system and the output will be displayed. In this chapter, the implementation of fuzzy logic control method also will be discussed.
3.2 System development

3.2.1 Data collection

Figure 3.1: Data collection flow chart

Figure 3.1 shows the flow chart for data collection. This flow chart represents a part of the process required to obtain and process the data before entering it into the hardware. The flow chart begins with subject recruitment with various physical appearances. With consents of the subjects, the data that will be taken are BMI, Blood pressure, IMT and Blood Glucose level. The data then will be analyzed with references of various sources and image of IMT scans will be analyzed and measure by using MATLAB. Finally, all the complete data will be recorded into the database.
Although the cause of atherosclerosis is unknown, a number of ‘risk factors’ have been identified [35], which have two types; reversible and irreversible. Reversible risk factors are crucial due to they may affect the development or progression of coronary artery disease, including cigarette smoking, hypertension, hypercholesterolaemia, lipoprotein, homocysteine, obesity and physical inactivity. Meanwhile, the irreversible risk factors are including the age, male sex, family history and diabetes mellitus. Therefore, 20 people are being selected to be the subject for this research which consisted of 10 male and 10 female of UTHM students. The data to be obtained will be age, body mass index (BMI), intima-media thickness (IMT), blood pressure (BP) and blood glucose level (BGL).

a. Age
The subjects selected in this research are in range age between 20 and 30. However, the coronary disease rises with the increasing age.

b. Body mass index (BMI)
The increased risk of coronary artery disease in obese individuals is largely due to associated hypertension, hypercholesterolaemia and diabetes. Obesity is determined by calculating the BMI by using the height and weight of the individuals.

c. Intima-media thickness (IMT)
To measure the IMT of the subject, ultrasound machine in the B- mode scan is being used. Mean IMT is calculated in the CCA between two interfaces: blood-intima and media-adventitia. IMT measurement can be performed either manually or by computer. In manual method, the measurements are being obtained by freezing the video monitor and using the cursor at multiple sites and averaging the values. Meanwhile, for computerized method, three measurements are being made which are on the far wall at anterior, lateral, and posterior projections which then the values will be averaged. Figure 3.2 shows the location of far wall in the carotid artery, which needed to be measured.
The value for normal IMT is less than 0.8mm [11]. As intima-media thickness will be increase with age, the value of 0.8mm to 1.0mm is being considered as intermediate or borderline. However, when the value of thickness is 1.1mm or greater, that is the actual value to be accepted as abnormal.

d. Blood pressure (BP)

Blood pressure each individual are being measured by blood pressure monitor. This parameter is important as hypertension is a condition where the blood pressure is high; for systolic (140-160mm Hg) than it should be (normal; 90-120mm Hg). The risk of coronary artery disease rise in the proportion to the level both systolic and diastolic blood pressure as hypertension will increase the risk to 2-3 times greater [35].

However, in this research, the only data on blood pressure that will be selected is systolic blood pressure due to elevation of systolic blood pressure predicts the risk of cardiovascular disease better than increases in diastolic blood pressure [37]. Figure 3.3 below shows the example of the blood pressure reading (117/81 mm Hg) of the subject taken by using the blood pressure monitor. To ensure the correct reading taken, the device must be on
the same level as the subject heart. Therefore, the subjects are required to be seated on the chair and relax, with no talking while the hand with the device is on the desk.

Figure 3.3: Blood pressure monitor

e. Blood glucose level (BGL)

Diabetes mellitus increases the risk of coronary artery disease in both men and women. It is an independent risk factor for cardiovascular disease [38]. For this parameter, a blood sample is being taken from the subject by pricking the finger using lancets in lancing pen and placed the blood on the test strip which being inserted into Accu-check performa blood glucose meter which can be shown in Figure 3.4.

There are two ideal conditions that must be considered before taking the blood glucose, which are either taking on fasting (or before breakfast) or two hours after lunch. This is because the number of glucose will be increase after eating. Therefore, this will affect the actual value of glucose in the blood and this value is not valid. However, these two conditions themselves have different ideal value. Thus, in this research, the condition selected will be on fasting (or before breakfast).
3.2.2 Software Implementation

3.2.2.1 Fuzzy Logic

Fuzzy logic was introduced by Zadeh in the 1960s and is now well established as an engineering discipline. Fuzzy logic is used for controlling a wide variety of devices. Fuzzy logic has been used in applications that are amenable to conventional control algorithms on the basis of mathematical models of the system being controlled, such as the high-frequency mechanical ventilator of Noshiro and coworkers. However, fuzzy logic has a particular advantage in areas where a precise mathematical description of the control process is impossible and is thus especially suited to support medical decision making [22].

Fuzzy logic is an approach to computing based on "degrees of truth" rather than the usual "true or false" (1 or 0) Boolean logic on which the modern computer is based. Fuzzy logic includes 0 and 1 as extreme cases of truth (or "the state of matters" or "fact") but also includes the various states of truth in between so that, for example, the result of a comparison between two things could be not "tall" or "short" but ".38 of tallness." Fuzzy logic seems closer to the way the brains work.
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