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Electrical and Computer Engineering

ALGORITHM TO ANALYZE THE HEART SOUND TO DIAGNOSE SOME HEART DISEASES

Abdulrahman A Mahmood AL-TANAKCHI

Master's Thesis

Supervisor

Prof. Dr. Galip CANSEVER

Istanbul,2023

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This thesis title ALGORITHM TO ANALYZE THE HEART SOUND TO DIAGNOSE SOME HEART DISEASES prepared by ABDULRAHMAN A MAHMOOD AL-TANAKCHI and submitted on 12/04/2023 has been **accepted unanimously** for the degree of Master of Science in Electrical and Computer Engineering.

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I hereby declare that all information/data presented in this graduation project has been obtained in full accordance with academic rules and ethical conduct. I also declare all unoriginal materials and conclusions have been cited in the text and all references mentioned in the Reference List have been cited in the text, and vice versa as required by the abovementioned rules and conduct.

Abdulrahman A Mahmood AL-TANAKCHI

Signature

DEDICATION

I devote and pledge this research work to my supervisor who is salient for guiding me through whole research work as well as my family for always assisting me in my hard time.

ABSTRACT

ALGORITHM TO ANALYZE THE HEART SOUND TO DIAGNOSE SOME HEART DISEASES

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The purpose of this thesis is to develop a novel algorithm with the intention of analyzing the sound of the heart In order to count how many there are, we must first: heart beats and the amount of time that elapses between the two primary sounds of the heart, known as S1 and S2. A purpose of this paper is to count how many times each number occurs of heart beats and the amount of time that elapses between the two primary sounds of the heart. Within the scope of this inquiry, we discuss a methodology that is focused on peak detection. Filtering and quantifying the temporal gaps that occur between the two most important cardiac sounds, S1 and S2, are our primary research objectives at this moment. When using the information obtained by our system, the suggested technique demonstrated a high degree of accuracy in determining S1 and S2 as the source of the data. This accuracy was roughly 95.6 percent in the data that they adopted from donors to collect their heart sounds and analyze them. This was determined by taking and analyzing the donors' heart sounds. The 15 persons who gave their blood were of diverse ages and genders (both male and female), and each donor was unique in their own way. However, because of the poor quality of the recordings, the accuracy of the tool dropped to 80.194% when it was used with data that was publicly accessible online. This was due to the fact that the recordings were of poor quality. Additionally, the system calculated the heart rate in addition to the S1 and S2 intervals, and it presented the results of these calculations via the use of bar graphs.

Keywords: Stethoscope, Auscultation, Heartbeat Sound Time Intervals, Lobb, Dobb, Phonocardiogram (PCG).

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1. INTRODUCTION

1.1 ANATOMY OF A HUMAN HEART

The duty of the heart is to pump blood that is devoid of oxygen from all regions of the body to a lungs, where the blood will first be oxygenated and then the heart will eliminate carbon dioxide from the blood. When the blood is transported from the lungs to the rest of the body by our circulatory system, the blood is then distributed to every region of the body. Every day7,200 liters of blood are pumped into the body by the heart each day.

The centre of the chest is where the heart is placed, and it slightly leans to a left side of the a body. The heart relaxes and contracts about 100,000 times every day, and 3 billion times inside a person's lifetime.

An newborn's heart is beating between 70 to 190 times per minute, compared to an adult's 60 to 80 beats per minute.

This short film on the heart gives a great insight in only ten minutes.

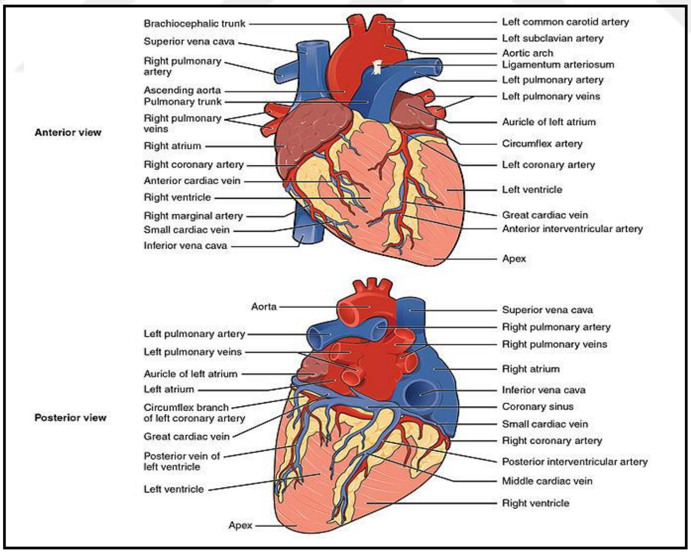

Figure 1.1: Explanation of The Heart[1].

Figure 1.2: The Position of The Heart Within The Rib Cage[1].

The pericardium surrounds the conical, hollow, and muscular heart, which is situated at the mediastinum's center. It is positioned posterior to a sternal body, with a median running through its middle and a third of it here on the right. The heart weighs roughly 255 g for women & 310 g for men, and it measures 12.02 x 8.50 x 6.0 cm (females). To address the nutritional needs of the various bodily areas, it carries blood there. The adjective "cardia" comes from the Greek word "cardia," which means "heart." [1][2]The oesophagus is posteriorly related to the descending aortic arch, azygos, and hemiazygos veins.• On the surface: the primary pulmonary trunk's bifurcation • Laterally, the pleura and lungs.[3]

Layers of the Heart Walls

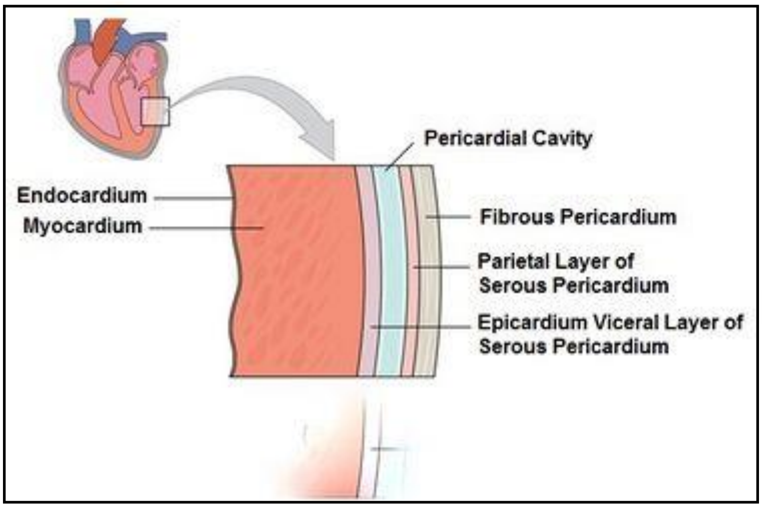

Figure 1.3: Layers of The Heart Walls [1].

The pericardium encloses three layers that make up the heart wall:

a. This visceral level of a serous pericardium forms the epicardium, an outermost layer of the heart's wall.

b. A middle layer of a muscular wall of the heart is called the myocardium., which contains excited the conducting system and tissue.

c.endocardium

an intermediate concentric layer; the subendocardial layer.Specifically, its subepicardial and subendocardial layers make up the majority of the remaining heart tissue.[4].

1.2 STRUCTURE AND FUNCTION

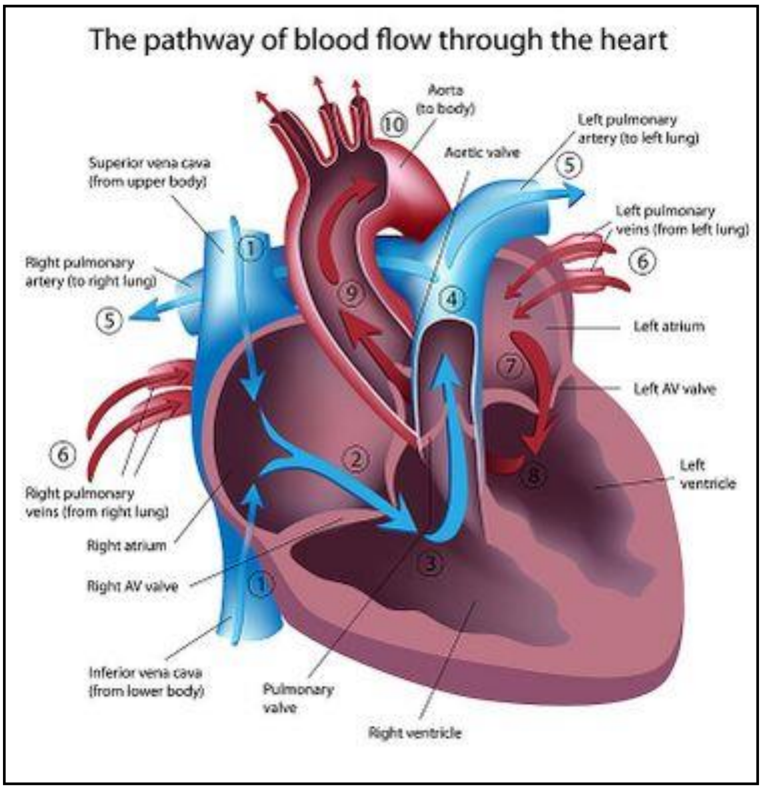

Figure 1.4: Structure and Function For Heart[5].

Every half of the heart is divided into two chambers by a constriction that separates the right and left sides of the organ. The top chamber of each half is known as the atrium, and also the bottom portion is known as the ventricle. Hence, a heart has four chambers.• Left atrium • Right atrium .Left and right ventricles are both present.

The sequence in which four chamber and four valves are encountered by the blood as it passes through the heart is the one to remember:

Blood is pumped from the right atrium thru the tricuspid valve into to the right ventricle, which is oxygenated in the lungs. Moreover, blood is pushed through pulmonary semilunar vein from of the ventricle in to pulmonary trunk. valve, Once leaving the body, it travels through the SVC, IVC, and coronary sinus before returning to the right atrium.[5]

The organism's left atrium pumps blood into the left ventricle through the bicuspid (mitral) valve in order to supply it with oxygen and nutrients. The ascending aorta is subsequently filled with blood by the left ventricle as it passes via aortic semilunar valves. The left atrium receives blood from across all 4 pulmonary veins on its way back to the lungs. [5]

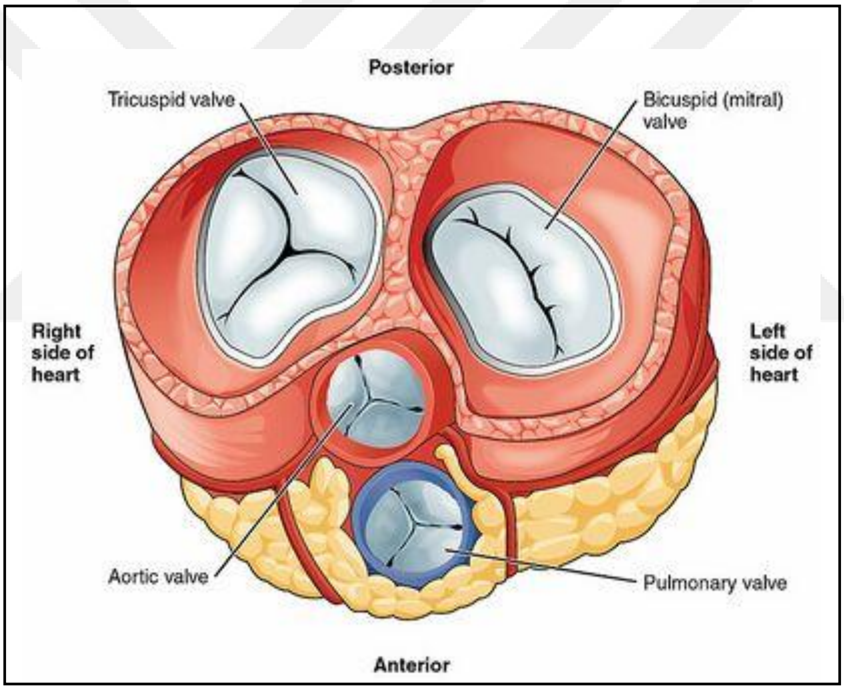

Figure 1.5: Heart Valves [6].

The heart's valves maintain the blood's one-way flow and stop it from regurgitating in the other direction. The heart contains Two sets of valves: a single atrioventricular twin and a set of semilunar valves. It has a total of four valves.. The sole function of the heart's four valves is to permit forward blood flow while obstructing backward flow. Each chamber's exit is protected by the a heart valve:

Here between atria and ventricles are atrioventricular valves.

a.the tricuspid valve (R sides of the heart) (R sides of the heart)

b.the tricuspid/mitral valve (left sides of the heart)

The ventricles' outflow channels have semilunar valves.

c.the left-side of the heart's aortic valve (R side heart)[6]

Moreover, view Cardiac Valve Defects

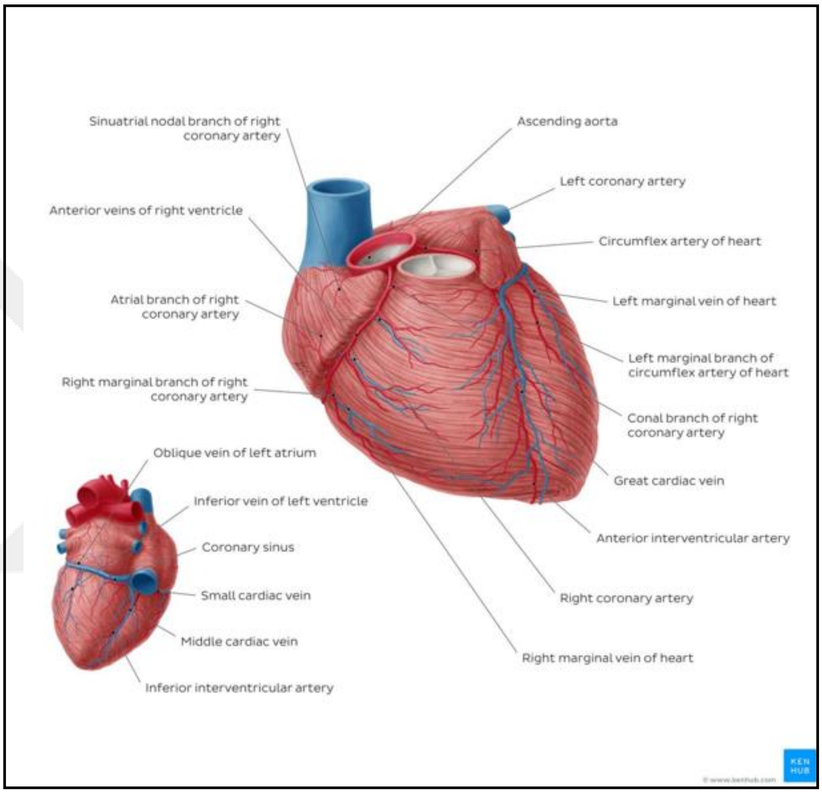

Figure 1.6: Blood Supply [7].

Two coronary arteries supply blood to the heart:

i. a left major coronary artery supplies the heart muscle with 80% of its blood flow. The narrow artery splits two branches are formed.

anterior descending artery on the left, whose distributes blood to a the circumflex coronary artery, which supplies the left ventricle's lateral and posterior areas with blood;anterior 2 of a interventricular septum and an adjacent section of a left ventricular anterior wall.

ii. Blood is supplied to the inferior wall of the left ventricle via a right ventricle, a right atrium, and all of the right coronary artery's branches. Coronary arteries & veins cover the surface of the heart. The coronary sinus enters the right atrium through left posterior atrioventricular groove., is where the majority of coronary veins congregate. All four of the heart's chambers can be directly accessed by other tiny veins known as thebesian veins. [7]

Anterior & posterior views of a coronary arteries & cardiac veins.

Additionally, see Coronary Artery Disease

Lymphatics and venous drainage

The coronary sinus and variable coronary veins are used for venous drainage.

Brachiocephalic nodes, located in front of the brachiocephalic veins, are where the lymphatic vessels mostly drain.

g.Tracheobronchial nodes, which are found near the trachea's distal end

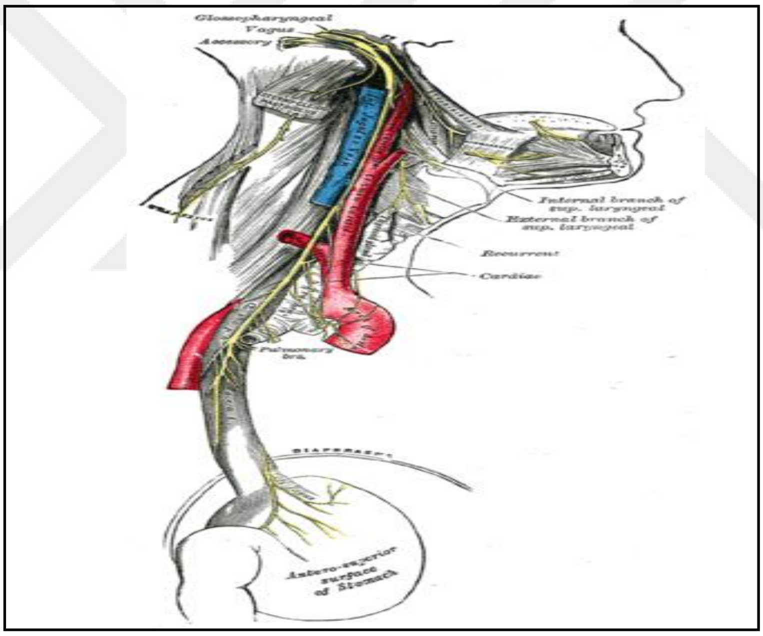

Figure 1.7: Nerve Supply[8].

The medulla oblongata has primary control over the heart. In the top portion of the medulla oblongata, there is a region known as the cardioacceleratory center, or pressor center, and a region known as the cardioinhibitory center, or depressor center, in the bottom portion. Since they work together to regulate things like heart rate, they are collectively referred to as the cardioregulatory center.

The sympathetic and parasympathetic components of the in autonomic nervous system feed a heart. While parasympathetic fibers originate in the depressor center, sympathetic fibers come from the pressor center. Likewise, Vagal Tone

a parasympathetic nervous system functions in reverse to reduce the heart rate, whereas a sympathetic nervous operates on the sinoatrial node to speed up depolarization and hence increase heart rate.

a sinoatrial node, the heart's own internal pacemaker, does not require a neurological system to function. The heart will stay beating even if all of its nerves are severed. In fact, it will beat more quickly than usual because the heart is often slowed by a parasympathetic supply. [8]

1.3 HEART CONDUCTION SYSTEM

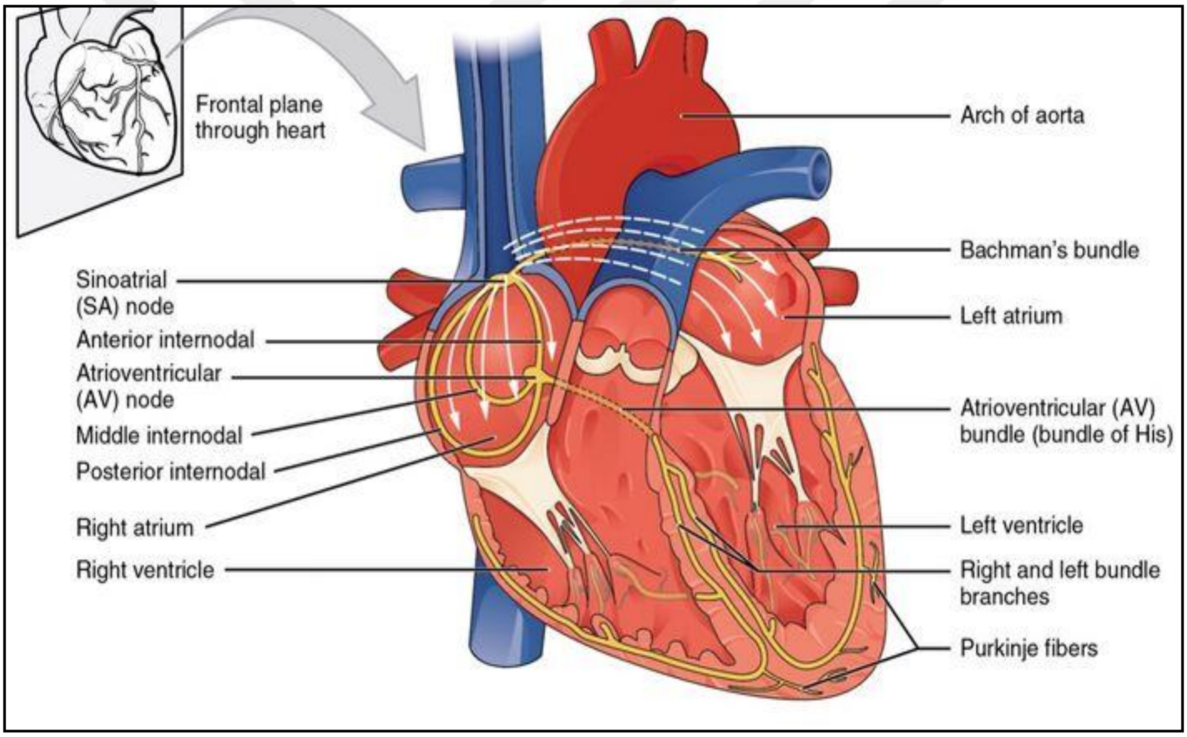

Figure 1.8: Heart Conduction System [9].

A timing of a chamber contractions and the ’s pumping action are controlled by an electrical conduction system. The system generates and transmits electric signals throughout the heart muscle, causing it to contract and pump blood. A cardiac muscle contracts in response to an electrical input. A sa node, the atrioventricular node, & the autonomic nervous system are three of the most important components of the an cardiac conduction system.

a. A heart's natural pacemaker is the sinus node. The sa node, a collection of cells, is located in the upper portion of the right atrium's wall. There, the electronic signals are produced. (The sinoatrial node, another name for the sinus node.)

b. Transporting the electrical signal generated by sinus node to cell to cell freely throughout the heart is the (AV node), a group of cells located in the middle of a chambers between the atria and ventricles.

c. Acting as a gate, the AV node slows an electrical current before allowing the signal to reach the ventricles. Whilst also delaying the stimulation of the ventricles, the atria are given time to close completely. The electrical current passes through the AV node and down specialized fibers that are woven before it reaches the ventricles, into to the wall of the lower heart chamber.

d. Controlling the firing of the sinus node, which initiates the cardiac cycle, is the responsibility of the autonomous nervous system, which corresponds to the portion of the nervous system that regulates blood pressure. The sinus node can increase the heart rate to twice the normal level in 3 to 5 seconds because it can quickly receive information from the autonomous nervous system. This quick reaction is crucial in exercise so because heart needs to beat more quickly to keep up with the body's increased oxygen demand. [9]

1.4 SINOATRIAL NODE

Martin Flack, a medical student, was the first person to identify a sino - atrial (SA) node in the early 1900s. A group of myocytes called an SA (sinus) node has The sinoatrial node, sometimes referred to as the sinuatrial node or SA node, is commonly referred to as the heart's pacemaker because it is the primary organ responsible for producing a regular heartbeat. It is the first component of the cardiac conduction system and is made up of specific cardiac muscle cells which are bundled into a node within the right atrium. The ability of these cells to self-excite allows the heart to contract without the aid of any external innervation heart to contract without the aid of any external

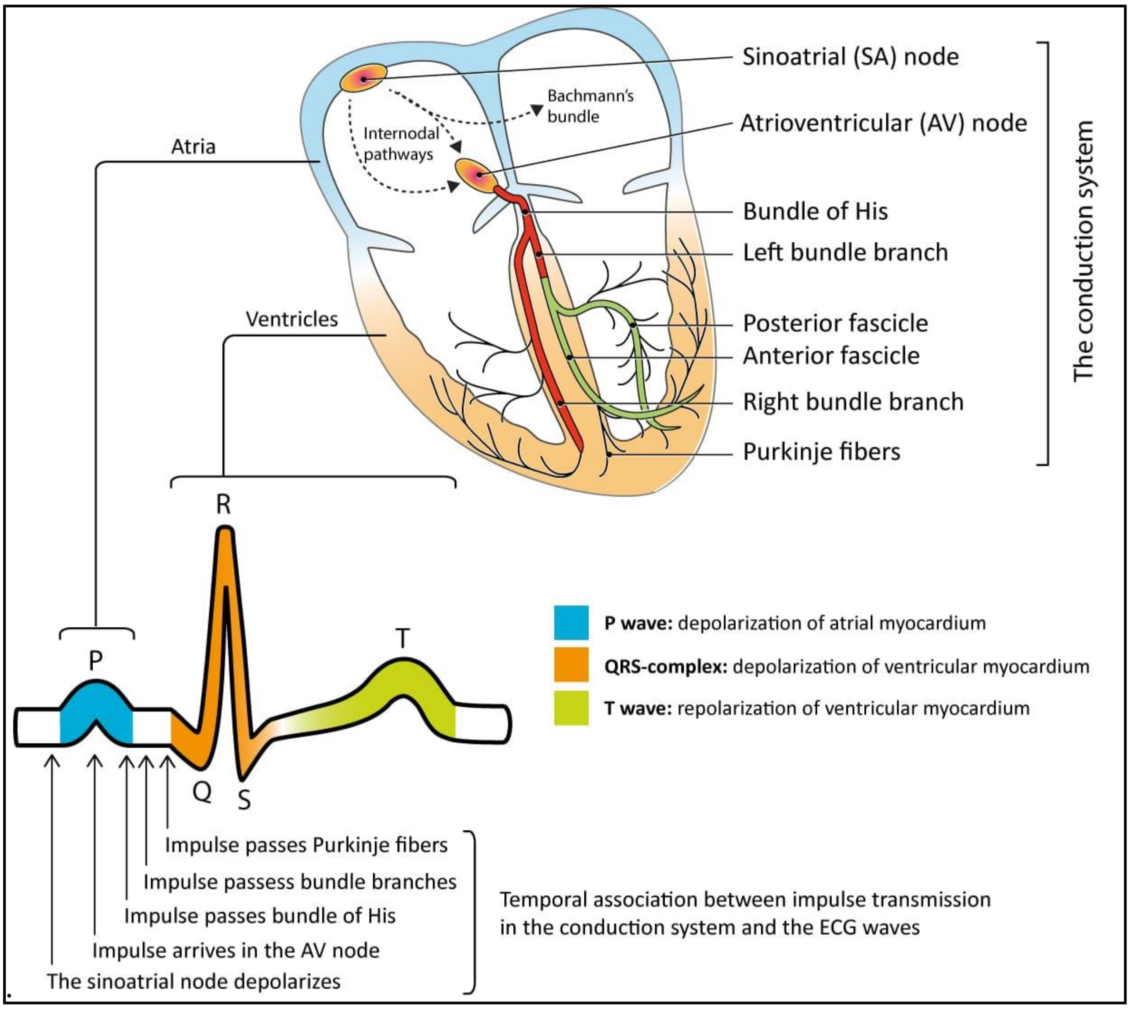

Figure 1.9: The Conduction System[10].

The right atrium's posterolateral sinus or venae cavae contains the sinuatrial node, which is where the words "sinu-" and "atrial" come from. This location is near to where the right atrium and superior vena cava meet, deep a crista terminalis. It is composed of a specialist cardiomyocyte, often referred to as node heart muscles cells or "pacemaker" cells, that are gathered into an extended elliptical bundles with such a length of eight to twenty-five cm. Compared to standard cardiomyocytes, node cardiac muscle cells have smaller and do not have intercalated discs. They have the ability to self-excite, which means they can generate electrical impulses on their own. Through gap junctions, they interact with and stimulate nearby/perinodal cardiomyocytes directly, causing the heart to contract.

Function

One of the many components of the cardiac conduction system is the sinuatrial node. The heart contracts as a result of impulses produced by an intrinsic conduction system, which also keeps the blood flowing properly through the heart chambers. The (atrioventricular), (AV) bundles (of His), the sinuatrial, (SA), right & left bundle branches, the atrioventricular, (AV) node, and the purkinje cells make up this system.

The node SA serves as the heart's pacemaker by sending impulses at the highest rate, and the other parts of a cardiac conduction system synchronize to its rhythm. Before reaching the AV node and other parts of a aforementioned conduction system, the SA node's impulses first caused the atria to constrict. Quick impulse transfer is made possible between these various components by specialized conducting fibers (crossing the myocardium four times as quickly as normal). Each of these buildings is localized differently and is in charge of activating the cardiac muscles in a specific region of the heart, which enables coordinated blood flow across the heart chambers.[10]

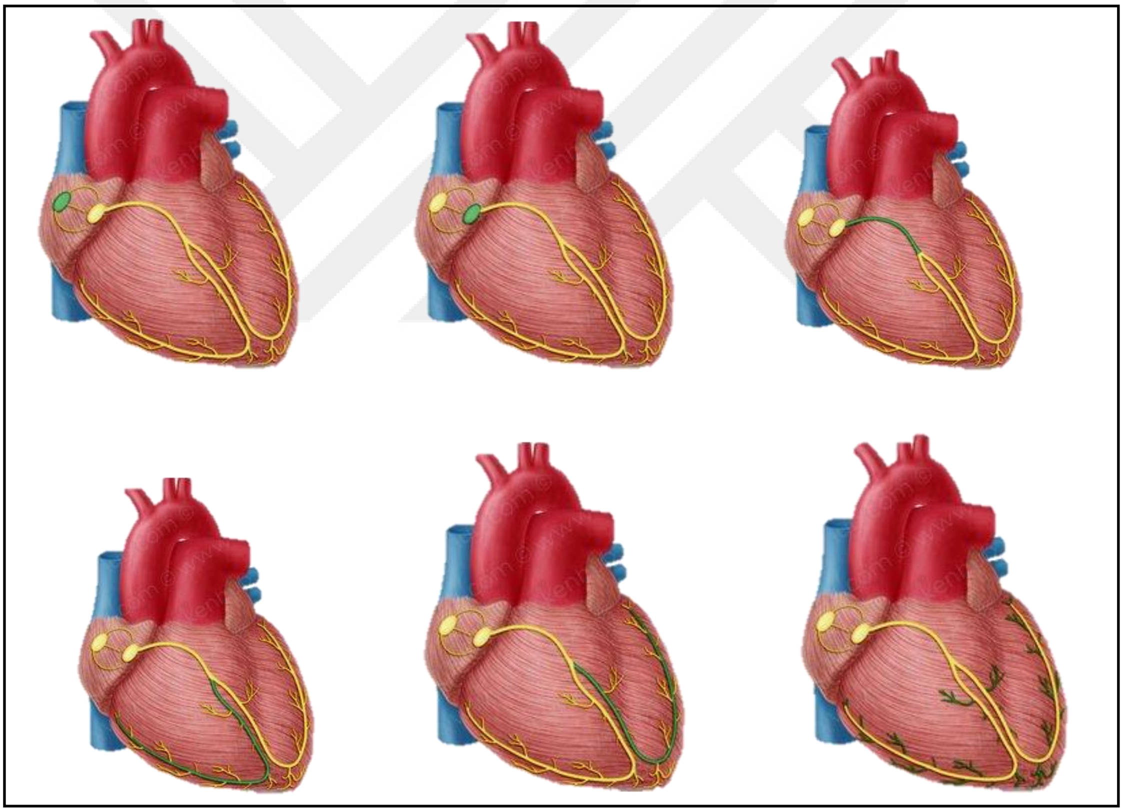

Figure 1.10: Layers of The Heart Wall[10].

The heart muscle can change pretty noticeably based on a variety of physiological and environmental conditions. In general, a normal heart rate is regarded as being between sixty to 100 beats a minute, which is the intrinsic rate at which SA node myocytes depolarize while at rest. The sinus node's input is carefully regulated by the autonomic nervous system. A firing of the sa node, which starts following cardiac cycles, is controlled by the autonomic fibers, which also have an impact on heart rate. The pace of action potential creation is slowed by parasympathetic input, which lowers pulse rate; on the other hand, the rates of such action potential production is sped up by sympathetic input, which raises heart rate. The sinus node is tightly controlled and under tight control, which enables the heart to adjust to different physiologic stimuli. At instance, the heart reacts to the body's increased need for oxygen during exercise, as well as the body's increased sympathetic input and heart rate. Since there are many myocytes in the sinus node, they are not necessarily the first to generate an electrical impulse. The pacemaker shift is the name given to this. For instance, one myocyte may generate an action potential faster than the one that generated the one before it, which would raise the pulse rate within normal ranges. This change is seen as excellent. Action possibilities that are lower than the last action potential created can also be produced by myocytes. This would result in a drop in heart rate that is still within normal range and is regarded as a lower shift. The change in the SA nodal pacemaker's origin seems to be influenced by whether the sympathetic or parasympathetic nervous systems are more active. The origins does seem to emerge more superiorly inside the sinus node when sympathetic predominance is present, whereas the origin appears to emerge more inferiorly when parasympathetic predominance is present.

Definitions of atrioventricular node in medicine

The electrical hub that connects the heart's lower and upper Atrioventricular node is the name given to chambers. abbreviation for AV node Electrical impulses must travel from of the heart to the ventricles through the AV node. One of the critical components of the heart's electrical system is indeed the AV nodal, which regulates heart pace.. The AV node only serves as an electric relay station before allowing that signal to reach the ventricles, lowering the electrical current supplied by the sinoatrial (SA) node. This delay allows the atria to close entirely even prior to the activation of the ventricles. The AV node is used as a conduit for the electrical current, which then travels down fibers implanted in the heart's lower chambers' walls to reach the ventricles[10].

1.5 ATRIAL FIBRILLATION

What is atrial fibrillation? The most often treated heart arrhythmia is atrial fibrillation, also known as AFib or AF. So when heart beats overly slowly, too quickly, or irregularly, it is called an arrhythmia. If a person has AFib, the two atria's regular pounding is irregular, which prevents blood from flowing as it should from of the two atria to the lower chambers of the heart (the two ventricles). AFib can happen in sporadic cases or be a persistent condition.

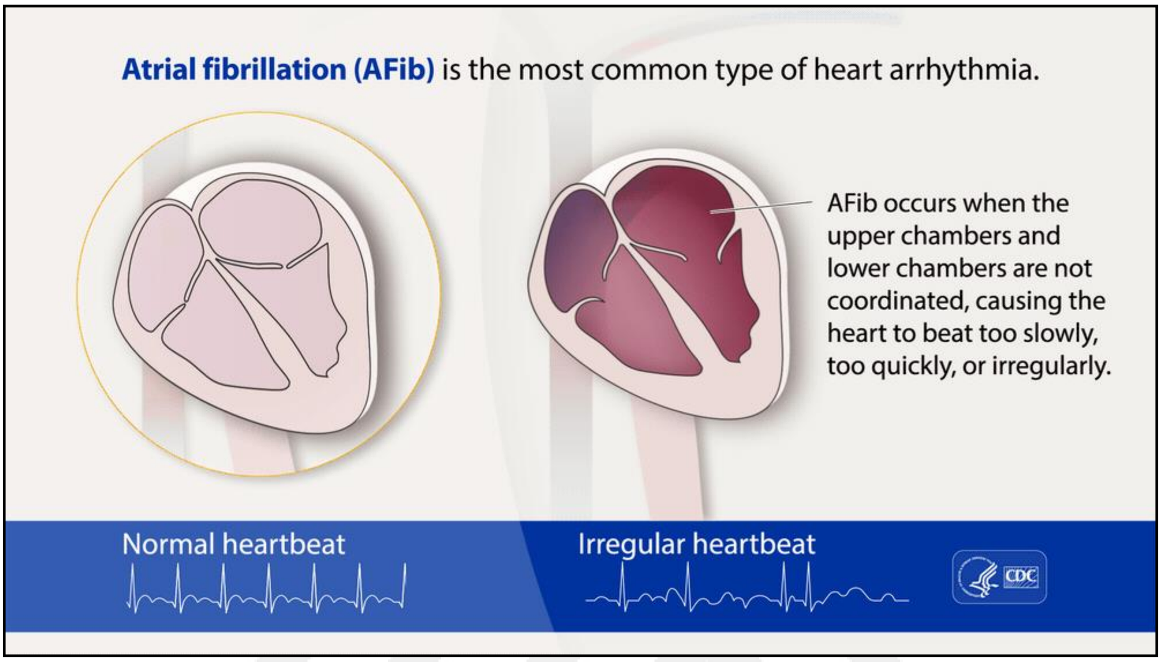

Figure 1.11: Atrial Fibrillation (AFib)[11].

AFib: what is it?

a most often treated cardiac arrhythmia is atrial fibrillation, also known as AFib or AF. So when heart was beating too slowly, too quickly, or irregularly, it is called an arrhythmia. If a person has AFib, the two atria's regular pounding is irregular, which prevents blood from flowing as it should from of the two atria to the a lower heart chamber that pumps blood (the two ventricles). AFib may represent a chronic condition or it could happen in isolated episodes.

Information on AFib In the United States, 12.1 million people are anticipated to develop AFib by 2030. [11]AFib was listed on 183,321 death records in 2019 and was the primary factor in 26,535 of those fatalities.[21] African Americans are less prone to develop AFib than people of European heritage. Women develop AFib at a higher rate than men since women typically stay longer than men and the prevalence of AFib cases rises with age.

What signs or symptoms indicate AFib?

Some AFib sufferers are unaware of their condition and show no symptoms. Others could have any or all of the symptoms listed below:

Abnormal heartbeat

Chest discomfort; Extreme weariness; Rapid, fluttering, or hammering heartbeats; Lightheadedness; Extreme exhaustion;

What are the AFib risk factors?

Age raises the likelihood of developing AFib. About 1 in 5 occurrences of AFib are caused by high blood pressure, a condition whose risk rises with age. [11]

AFib risk factors include.

Growing older and having high blood pressure

Obesity, European ancestry, diabetes, heart failure, ischemia of the heart, hyperthyroidism, chronic renal disease, moderate to severe alcohol consumption, smoking, and enlargement of a left side of a heart's chambers are all risk factors.

How are AFib and stroke related?

AFib raises a person's chance of having a stroke. AFib was linked to an approximately fivefold higher risk of ischemic stroke after typical stroke risk variables were taken into consideration. About one in every seven strokes are brought on by AFib.

Strokes caused by complications from AFib are frequently more severe than strokes caused by other underlying diseases. Strokes take place when a blood clots or fatty deposit called plaque within blood vessel lining obstructs the passage of blood to the brain.

AFib face various include: • Blood-thinning drugs to reduce the risk of stroke and prevent blood clots from developing. To treat AFib risk factors, there are three options: surgery, medication, and healthy lifestyle changes.

What results does AFib produce?

In the United States, AFib is the predominant diagnosis in more over 454,000 hospital admissions annually.

[22] Each year, the disease is a factor in roughly 158,000 fatalities. Since more than 20 years ago, the death rate of AFib has increased either as the main cause of death or as a contributing factor. [25] [26]

1.6 PULSE & HEART RATE

On average, your heart beats sixty to one hundred times every minute. For adults, your heart rate is expressed in minutes per beat. You can tell when your heart beats by touching your pulse. In measuring your heart rate, you can keep track Evaluate your own health & assess whether you're exercising with the proper vigor to reap the greatest health benefits.. [12]

How fast are you beating?

The amount of times your heart beats inside a minute is used to calculate your heart rate. In your body naturally modifies your heart rate to suit the task at hand or what is happening around you. As a result, your heart rate rises during moments of excitement, fright, or activity and falls during periods of rest, tranquility, or comfort.The pulse rate is a crucial sign of your general health. A high or slowly Heart rate is a potential indicator of heart illness or other medical issues. The ability to feel your heartbeat throughout the body may help doctors identify potential issues.. [12]

Does the rate of your heart differ from the rate of your pulse?

Although they are connected, the heart rate & pulse are not the same. the rate at which the heart beats. which it beats at any particular moment. You can sense your heart rate by feeling your pulse. Blood is compressed and propelled through your body's network of arteries each time your heart beats. Your heartbeat is the temporary increase in artery pressure caused by your heart pumping more blood through your body to maintain circulation. Your heart relaxes between beats, which lowers the pressure once more. Because of this, Instead of feeling like water streaming through a hose, each pulse feels like a single push. The arteries are located rather near to your skin in a number of locations, a few of which are simpler to feel than the others due to physical qualities. The simplest places for you or a medical practitioner too feel your pulse vary depending on the location.

What are the many methods for checking your pulse, and why are they significant?

Using the index and ring fingers together, lightly massage the following locations to feel your pulse:

Neck (carotid artery) (carotid artery). Begin above your earlobe and swipe a finger horizontally across your flesh.. You must be able to hear his pulse right below your jawline.

Wrist (radial artery). Here, with your palm facing up, is where your thumb's fleshy muscle and your wrist's bony bone converge.

Within the elbow (brachial artery). And with fingers of your opposing hand, begin at the hollow middle of your elbow. Pull those fingers slowly in the direction of your body along your skin. At the inside of your elbow, you must feeling your heart just a little bit out of balance. Healthcare professionals also may feel to your heart in other places than these arteries. Without proper training, finding these locations might be challenging, but they are incredibly useful if A provider is looking for a solution to a certain issue or problem.

Time-based (immediately before the fleshy ridge were your ear joins your face, level above your ear canal.).

Box (right above your heart, at the apex).

Belly, (abdominal aorta).

The area where your upper thigh & body meet (femoral artery).

On your feet. Behind your knee (popliteal artery) (posterior tibial and dorsalis pedis arteries).

How can I use my pulse to calculate my heart rate?

Once you've detected your pulse, you may calculate your heart rate by counting the number of pulses you take in 60 seconds (A simplest spots are often your neck or wrist).Just a small bit of arithmetic is all it takes to get an answer more quickly. The simplest techniques are as follows: Ten seconds of heartbeat counting. After 10 seconds have passed, multiply your count by six. 15 seconds of heartbeat counting. After 15 seconds have passed, multiply your count by four. 30 seconds of heartbeat counting. After 30 seconds have passed, double your count by two. Your "beats per minute," or heart rate, can be calculated using any one of the three techniques. "bpm" is the shorthand for beats per minute. Your heart rate at rest may be determined by measuring it while you're not moving about. This can be done before, workout or right after. The key to determining when your workout is just too tough, not hard enough, or even just right is to monitor your heart rate as you work out.

Should I be able to feel my pulse with my ears?

You can sometimes truly hear your heartbeat in your ears, sure. This condition, referred to as pulsatile tinnitus, can occasionally be treated by placing you head on your hand or arm. However, if you shift positions, the sound ought to stop. Call your doctor if you can still hear your heartbeat in your ears after shifting positions.

What pulse rate should I anticipate experiencing?

Your age and general health have an impact on your resting heart rate. Your heart rate tends to be greater while you're younger.

Children's typical resting pulse rate ranges are:

a.100 to 205 beat per minute for newborns (at birth to 4 weeks) (bpm).

b.Baby (between four weeks and a year): 100 and 180 bpm .

c.Toddler (ages 1 to 3): 98 to 140 bpm.

e.Kindergarten (ages 3 to 5): 80 to 120 bpm.

d.Students in school aged five to twelve years old): 75–118 bpm.

g.Teenagers (ages 13 to 18): 60 to 100 bpm.

The typical resting pulse rate range for individuals (age 18+) is 60 to 100 bpm. These prices apply to kids that are awake. When they are sleeping, they will probably be lower.

What happens if my resting heart rate isn't in the typical range?

Your resting heart rate could indicate a problem if it deviates from these parameters and becomes too high or low.

i.Tachycardia: This is a rare condition in which your heart rate at rest exceeds 100 bpm.

ii.Bradycardia: This condition occurs if your heart rate at rest is particularly low, below 60 beats per minute.

However, if you engage in a lot of physical activity, it's crucial to be aware that your resting heart rate may be under sixty beats per minute. Competitive athletes are capable of having resting heart rates of around 40 bpm. But then that rate will be alarmingly low for the ordinary person.

What are my ideal and desired heart rates?

The ideal heart rate is range for moderate-intensity exercise is your goal heart rate. Exercise that is moderately intense is appropriate since it is intense enough to benefit your heart while not being too demanding on your body.You may push your heart rate up to about 95% of your maximal heart rate if you want to workout really hard. However, you should use caution to avoid going too high. The possible hazards outweigh the advantages when you go too high. Before beginning an exercise program, you should consult your healthcare physician if you don't routinely exercise. This is really important if you have any health difficulties, especially ones involving the heart, lungs, or circulation. Your healthcare provider is the best resource for guidance on effective, safe ways to maintain you current activity level without jeopardizing your general health. [13]

Use the following chart for determine your maximum & goal heart rates. There are instructions for how to calculate it yourself, although the chart uses ages that really are multiples of five:

Tablo 1.1: To Determine Your Maximum and Goal Heart Rates [13].

Age	Maximum 220 - your age = maximum)	Goal (60–80% of maximal) maximum times 0.6) — High (maximum x 0.8)
20	200	120 - 160.
25	195	117 - 156.
30	190	114 - 152.
35	185	111 - 148.
40	180	108 - 144.
45	175	105 - 140.
50	170	102 - 136.
55	165	99 - 132.
60	160	96 - 128.
65	155	93 - 124.
70	150	90 - 120.
75	145	87 - 116.
80	140	84 - 112.
85	135	81 - 108.
90	130	78 - 104.
95	125	75 - 100.
100	120	72 - 96.

1.7 CAUSES HEART MURMURS

Your doctors uses a stethoscope to hear at your heartbeat during a checkup to see whether it is beating normally and with a regular rhythm. This provides information to your doctor on the condition of your heart. Unusual heartbeat-to-heartbeat sounds are known as heart murmurs. A "murmur" or any other unusual noises emanating from your heart may be an early sign of a serious cardiac disease, according to your doctor. odd heart sounds' symptoms Hearts murmurs and also other abnormal heart sounds are frequently only discernible when your doctor uses a stethoscope to listen to your heart. There can be no visible symptoms or indicators.

You could occasionally become aware of the warning signs or symptoms of a cardiac problem. Chest discomfort, a persistent cough, shortness of breath, fainting, intense perspiration, blue skin, especially on the lips or fingertips, unexpected weight gain or swelling, swollen neck veins, an enlarged liver, as well as various heart murmurs & other abnormal noises are examples.

The two sounds of a typical heartbeat are a lub (also known as S1) as well as a dub (S2). These noises are brought on by your heart's valves shutting.

Your heart may make additional or atypical noises if it is having issues. heart flutters A cardiac murmur is the most prevalent abnormal heart sound. When your heart beats, you may hear a puffing, whooshing, even rasping sound called a murmur.

Heart murmurs come in two different varieties:

unnatural (also known as physiological)

Both youngsters and adults have an innocent murmur. A sound of blood flowing normally via the heart is what causes it. Adults may have harmless heart murmurs as a result of exercise, fever, or pregnancy. Children who have congenital cardiac abnormalities, which are present from birth, will have an abnormal murmur. Surgery could be required to fix it. Adults with abnormal murmurs frequently have issues with the valves that separate their hearts' chambers. Regurgitation occurs when a valve doesn't seal completely and some blood escapes backward.

Stenosis refers to a valve that has become overly thin or stiff. A murmur may also result from it.

Depending on how loud the sound is, murmurs are rated. One on the scale represents a very faint sound, while six represents a sound that may not even require the use of a stethoscope to be heard. [27]28]

As systole murmurs (S1) or diastole murmurs (S2), respectively, they are classified as occurring during the first or second sound, respectively.

frantic rhythms

A "galloping" rhythm with extra heart sounds, S3 & S4, is another heart sound.

The diastole S2 "dub" sound is followed by an S3 gallop, sometimes known as the "third heart sound." It's probably safe for pregnant women or young athletes. It could be a sign of heart problems in older people.

Before the S1 systole "lub" sound, there is a sound called an S4 gallop. It's always a symptom of illness, most often the left ventricle or the heart failing.

Both an S3 & an S4 sound are possible. A "summation gallop," as it is known, can happen while your heart is pumping very quickly. A summation galloping is quite uncommon. [14]

other noises

You can also hear clicks or brief, high-pitched noises while your heart is beating normally. When one or both of your mitral valve flaps are excessively lengthy, this may be a sign of a mitral valve prolapse. Blood may occasionally regurgitate into your left atrium as a result of this.

People who have certain infections may hear rubbing noises. The most common cause of a rubbing sound is an infection of the pericardium, the sac that surrounds your heart, brought on by a virus, bacterium, or fungus.

the origins of heart sounds and other noises

There are four chambers in your heart. The ventricles are the two bottom chambers, while the atria are the two upper chambers.

Between these chambers are where the valves are. Your blood constantly runs in one direction because of what they do.

The mitral valve runs from the left atrium to the left ventricle, whereas the tricuspid valve connects your right atrium to your right ventricle.

The aortic valve travels from your left ventricle to your aorta, while the pulmonary valve travels from our right ventricle outside to your pulmonary trunk.

Your heart is encased in and shielded by your pericardial sac.

By using a stethoscope to listen to your heart or by running an echocardiography test, your doctor can determine whether there are any issues with these areas of your heart by listening for any unexpected noises that you may be hearing.

How are other noises, such as heart murmurs, assessed?

The stethoscope, a medical instrument used it to listen for your heart, lungs, or other organs within your body, will be used by your doctor to listen to your heart.

Your doctor could request an echocardiography if they see any issues. This test makes a moving image of your heart using sound waves to provide your doctor an better understanding of any abnormalities found. [14][15]

1.8 ECG SIGNALS

An electrocardiogram, often known as an ECG or EKG for short, is a test of the electrical activity of the heart that can be used to identify cardiac conditions. A similar electrical system to the one that operates your home's lights and appliances regulates your heartbeat. Your heart contracts in response to electrical in order to pump blood into your body.. These signals can be impacted by heart illness, irregular heartbeats, and other cardiac issues. Your doctor can detect heart illness and spot issues with the electrical system of your heart via an ECG. How then is an ECG performed? You will initially lay down on a table. While the test is being performed, you must lie absolutely motionless. Your chest, limbs, and legs will all have several little patches., or electrodes, affixed to them. Although Such patches won't hurt, and specific regions of hair regions might need to be shaved in order for the patches to adhere to your skin. After that, a machine is fitted with the patches. When the machine is turned on, you'll observe that it prints wavy lines on a paper towel. Your heart's electrical signals are represented by the lines. If the test findings are normal, you heart should beat uniformly between 60 and 100 per minute. One of the many cardiac illnesses that can be noticed on an ECG includes a rapid, slow, or abnormal heartbeat, a heart problem, coronary artery disease, aortic valve disease, or even an enlarged heart, to name just a few. If your ECG is abnormal, you may already have had a heart attack or you could shortly be more at risk for one. a state of good health and lack a personal or family history of heart disease, you don't need to get an ECG on a regular basis. So, if you are having heart problems, your doctor might suggest getting this test. An ECG is very reliable in making a variety of heart disease diagnoses, even though it can't always find every heart condition. You may continue to have a heart condition even though your ECG is entirely normal. A second ECG or other test may be recommended by your doctor[15]if your test findings are normal but he suspects you may have a heart issue.

How a Test is Administered

You'll be instructed to get on your back. The medical professional will clean numerous locations on your chest, arms, and legs. before applying electrode-like tiny patches to those locations. To ensure that the patches adhere to the skin, it might be essential to shave or clip some hair. It's possible to utilize fewer or more patches. [15]

The patches are connected to a system that transforms the electrical heart impulses to curved lines that may be printed on paper. The doctor examines the results of the test. You must remain still throughout the procedure. The medical professional can also request you to stop you breath for a brief amount of time while a test is being conducted. It's important to maintain your composure and warmth throughout the operation because any movements, including shivering, could influence the results of an ECG recording. This test can occasionally be carried out while you are exercising or under light stress to look at changes in the heart. This type of ECG is often known as a stress test.

How to Get Ready for the Exam

Make sure your healthcare practitioner is aware of any medication you are taking. Some medicines have the potential to affect test findings. Exercise and drinking cold liquids just before an ECG should be avoided as they may result in inaccurate readings.

The Experience of the Test

An ECG is not painful. Through the body, no electricity is transmitted. When first used, the electrodes could feel chilly. Rarely, some patients may get an itch or redness where the patches were applied.

Why is the Test Done?

An ECG is used to assess: Any cardiac damage Whether or whether your heart is beating regularly and how quickly it is beating the effects of heart-controlling medications or equipment (such as a pacemaker) Your heart's chamber sizes and locations The first test used to establish whether a person has cardiac disease is frequently an ECG. If: Your doctor decides to order this test a.You get palpitations or chest discomfort.

b.You have a surgical date.

c.You've experienced cardiac issues in the past.

d.You have a substantial family history of heart disease.

e.Regular Results

f.The most frequent normal test outcomes are:

i.heartbeats per minute: 60 to 100 Heartbeat: regular and even

ii.What Unusual Effects Mean Abnormal ECG findings might indicate:

iii.Affected or altered heart muscle

changes in the blood's electrolyte levels, such as those of potassium and calcium

congenital cardiac condition

Increasing heart size

Inflammation or fluid in the sac around the heart

Heart inflammatory disease (myocarditis)

current or previous heart attack

inadequate blood flow to the heart's arteries

irregular heartbeats (arrhythmias)

The following cardiac conditions can cause alterations on an ECG test:

a.Fluttering or atrial fibrillation

b.chest pain

c.heart attack

d.Atrial tachycardia with many foci

e.Supraventricular tachycardia that is sporadic

m.Chronic sinusitis

Syndrome Wolff-Parkinson-White

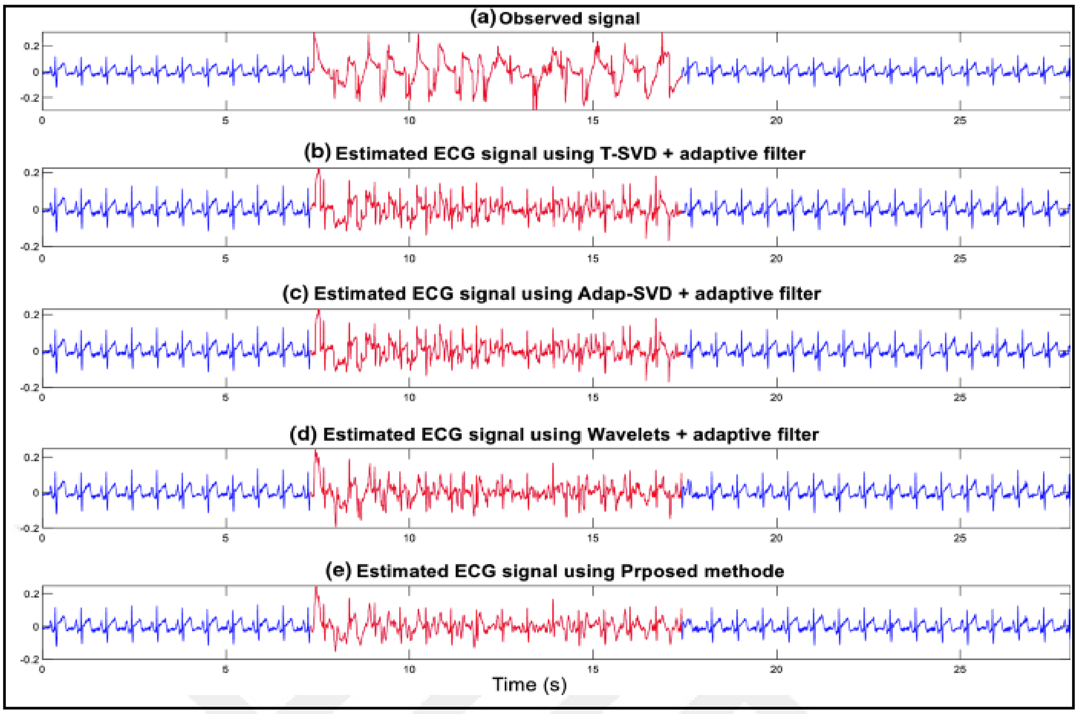

Figure 1.12: ECG Signals For Some Heart Diseases[15].

2. RELATED WORK

In fact, body auscultation is a common diagnostic technique in use in clinical settings to identify heart-related issues. The main benefit of employing this clinical method is the fact that it gives medical professionals a rapid and simple way to study heart sounds in order to diagnose cardiac disorders. Cost-effectiveness is a benefit of this. For (diagnostic reasons, digital signal can measure its distribution of frequency & amplitude content) (diagnostic purposes, digital signal can be measure the distribution for FR & amplitude content.) It was shown in the research that it is feasible Using signal processing and wavelet transform for the detection of cardiac abnormalities in order to differentiate between the sounds of a healthy heart and the sounds of a sick heart when listening to the a heart. A device connected to the internet was utilized to capture real-time data, or a REES52 sensors was employed to reduce noise. Using characteristics derived by signal amplitude dispersion and time- and statistically-based approaches, the difference between a normal and unhealthy heart can be determined. The findings of this investigation indicate that, for the goal of automating the diagnosis for cardiac illnesses, signal processing with both healthy and sick heartbeats has the potential can successfully distinguish between the characteristics of pulse sounds.[16]

2.1 LITERATURE REVIEW

We gain some understanding of the study topics related to the early identification of heart failure from earlier works. Signal analysis and artificial intelligence methods are currently being used to investigate the possibility of automatic heart sound classification. For the diagnosis of several cardiac disorders, auscultation of the heartbeat is still insufficient [16]. It does not give the analyzer information about the phonocardiogram signals that is both qualitative and quantitative . Healthy and abnormal cardiac sounds were contrasted by Singh et al. . Calculations were made for the probability distributions of the amplitude and frequency elements. Using signal processing, this was made possible. The findings demonstrated that sufficient distinction existed for signal processing-based automated identification of cardiac disorders. Discrete wavelet transform (DWT) was applied to a spectrogram by Dey et al. in order to assess and characterize the various approximated components' characteristics. Using this approach, an accuracy of 82% was attained. The segmented signals were analyzed using the same technique as by Kumar et al. , although Only the S3 components of the heart sound were examined through the use of segmentation and an algorithm. Its sensitivity & specificity were equal, coming in at 90.35% each. ((Huiying et al))[15], [17]. 's implementation of the a heart sound segmentation, which indicated a 93% accurate ratio, provided evidence that this research was conducted correctly. In addition to this, it used discrete wavelet transform (DWT) to construct envelopes of estimates based on the original signal.

All patient PCG sound recordings were analyzed by Gjoreski et al. Lymph circulation: physiology, pharmacology, and biomechanics [18] in order to do research on chronic heart failure. (CHF). After analyzing the data that categorized the CHF phases, a level of precision of 92% was determined to be present. In this particular investigation, both temporal and spectral evaluations of the signal were carried out. Continuous monitoring of the heart can be performed using a CHF detection device that is automated and can be calibrated. In accordance with findings from wavelet analysis and the randomized forest identifier, Qiao et al. presented a method for classifying the data that was collected on the heart sounds of adolescents. Using the use of heart sound segmentation approach, the sites of S1, systole, & diastole were determined. The random forest approach produced the most accurate results in terms of categorisation. An improvement of 3.01% was observed when the results were compared to the heart's typical frequency and time analyses. The next development was the conception of an ego wave foundation for heart sound denoising by Cheng and Zhang [19]. The results of the trials shown that the heat audio wavelet has the capacity to eradicate noise while still keeping the core properties of the signal, in contrast to other forms of conventional wavelets.. It was discovered that signal-to-noise ratio is higher, and the average square error was lower than it had been previously.

A categorization for heart sound is complicated by a number of important challenges, including the segmentation for sounds, the differentiation of heart sounds from lung sounds, and the wavelet transformation's changes in time shift. Das et al. [20]suggested utilizing an unsupervised method to locate S1 & S2 from phonocardiogram (PCG) recordings as opposed to the heart sound segmentation technique that has traditionally been employed. This cocained would replace the previous approach. The maximum FI-score that the approach could achieve for regular data was 98%, but for anomalous data, it could only achieve 92.5%. Bahreini et al. [21] advocated to use the fractal dimension as a way to differentiate between both the sounds S1 and S2, and they did it by employing a hidden Markov model. Tsai et et. demonstrated a one-of-a-kind periodicity coding deep autoencoder (PC-DAE) technique to overcome the challenge of distinguishing between the sounds of the heart and the lungs. However, in order to fully use the potential of this technology, [22]the inclusion in ECG physiological data is required.

The wavelet transform was used in another method that was described by Li et al. in order to differentiate between coronary heart disease and valvular heart disease. That imply that in order for foretell future future, it is necessary to examine heart sounds and establish clear differences between them. This empirical wavelet transformation was broken out by Li et al. into three modes , and a reasonable Se's remaining percentage was discovered to be 94.7%. Acta by Elamaran.'s investigation of the PCG signals also looked at the execution duration of the conclusions using Matlab R2016b. To detect congenital cardiac defects in young children, Xiao at al. A computer-assisted technique that utilizes deep learning. To evaluate the heart sounds, two separate lightweight deep convolutional networks were used. The techniques for automatically classifying & recognizing alterations in the cardiac cycle were critically examined and given a detailed examination by Dwivedi et al. It could be utilized to monitor & treat illnesses with the use of mobile technologies. SVM classifiers can be trained using wavelet analysis data, which can help with diagnosis. To ensure accuracy, it is essential to take steps to reduce noise. Liu et al. [23] applied wavelet threshold denoising to the preserved modes. The results demonstrate that under various SNR conditions, both signal-to-noise ratios of heartbeats reduce the root mean square error..[24]

One of the most important functions for maintaining life is the heart's capacity to beat rhythmically. A brand-new method of heart sound denoising was put up by Mondal et al. [25].In this, The results of coupling singular value decomposition and wavelet packet transformation were determined to be appropriate.. For remotely monitor asthma patients, Glazova et al. developed a device that measured the duration of tracheal sounds. This system, however, was unable to reach total independence. Machine learning techniques were utilized by Li et al. to examine all heart rate variability elements as from ECG data, however the model might be expanded to forecast the emergence of SVT. Mishra et al. focused solely on the pulse of the a wave domain from the cardiac diseases screening. The ability to discriminate between healthy and diseased cardiac sounds was assessed to use the detailed approximation coefficient of DWT. The greatest FI-score for a method was 98% for accurate data & 92.5% for incorrect data Bahreini et al. recommended using the fractal dimension for distinguish between both the sounds S1 & S2 to use a Markov hidden model. To get around the difficulty of differentiating between the sounds of the heart and the lungs, Tsai at al. showed an deep autoencoder with unique periodicity coding (PC-DAE) technique. However, adding ECG physiological data is required for this strategy to be expanded.[26]

Li at al. created a new technique employing the wavelet transform to discriminate between valvular and coronary heart issues. This implies that in order to forecast the future, it is critical to evaluate heart sounds and draw precise comparisons. Li et al. established three modes of an empirical wavelet transformation, and an appropriate rest of Se was discovered at a percentage. Mohammad-Taheri al al. examined a VT & VF detection using the slope of a ECG signal. The remaining 30% of the dataset was utilized for testing, and 70% of it was chosen for training. Yaseen et al.'s investigation of the heart sound looks at many categorizations. It offers an improved automated technique for categorizing heart disorders. The cardiac sound signal was subjected to a discrete wavelet transform (DWT) in order to extract its features. DWT characteristics were employed for classification and training using DWT to increase accuracy. The accuracy of this approach in identifying heart problems was 97%.[27]

The experimental results and the available Algorithms imply a positive trend. As a result, there is still potential for improvement in the area for creating effective models for automating the identification of cardiac illness using heart sounds. Several procedures and techniques employed by writers serve as examples of successful methods that can be applied to find a heart sounds across such a range of ages. The result is early discovery and continuing surveillance. Among the techniques explored were wavelet analysis, deep learning, machine learning, and PCG signal analysis. Nonetheless, the challenge of differentiating between heart and lung sound was present in virtually all research as a constraint. Through the use of various measures, the difference between a healthy and diseased heart is made. This indicates that there may be a vacuum in the prior work about the analysis and distinction of heart and lung sounds.[28].

2.2 MODELING CIRCUIT DEVICE & DATA COLLECTING PROCESS

an section outlines a procedures needed to build a device that will gather real-time data. In this study, a main circuit stethoscope element was used in order to get heart-generated data. A stethoscope is a listening instrument. to internal sound like heartbeats and has chest sections with rod-like shapes. The circuit for stethoscope signal amplification is built using an electret condenser microphone. It's necessary to clean up the original signal's noise. In this instance, the noise in the amplified signal is removed using a REES52 sensor. The most important part of the research is gathering silent data from the loud heartbeat. The data is processed on an Arduino Uno. These Excel datasets can be read by Matlab, which can then turn them into signals. We were able to compare the regular heart audio with only an unusual heart sounds & determine whether or not a person is healthy by listening at their heartbeat after the signal had been denoised and readied for further processing. sounding his heart out.[29]

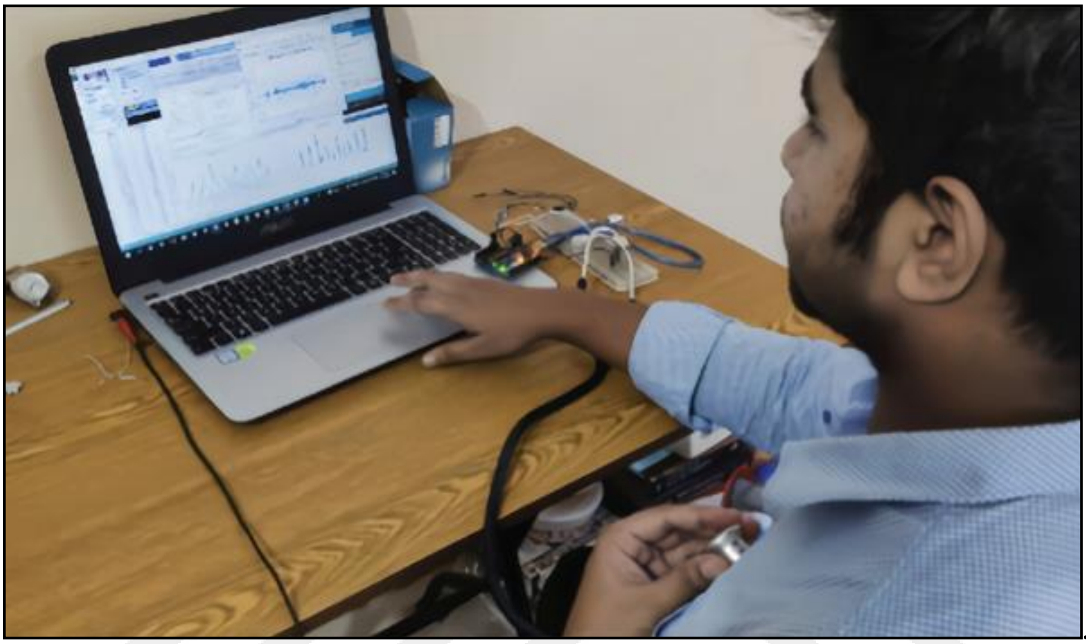
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Figure 2.1: During Project Implementation[29].

2.3 DATA ACQUISITION

The circuit is turned on and instructed to collect data from the heart after being successfully assembled and manufactured. A useful technique is electronic stethoscope auscultation. To learn more about the distinctions between healthy hearts and cardiac patients, this instrument can be used to examine the features and heart sounds across many domains. This study demonstrated how cardiac diseases might be automatically detected and tested for using parametric analyses of heart sounds. Data on actual heart sounds was gathered from healthy and ill individuals. We conclude that there are significant feature differences among healthy and ill sounds after performing some spectrum analysis.[30]

2.4 DATA DESCRIPTION

For establish common cardiac diagnoses or to determine the association between healthy & ill heart sounds, authentic genuine voice tapes of any and all normal and pathological heart sounds are accessible. Irregular heartbeats (arrhythmia), sick sinus syndrome, sinus tachycardia, heart failure, heart block, and cardiac muscle diseases (cardiomyopathy). Examples of additional health problems include congenital abnormalities, which are issues with the development of a and blood arteries from birth. A patient's heart audio changes if any of these conditions develop. weaker and less audible in comparison to someone who is completely free of those conditions. Following is a[31] list of some of the healthy & unwell patients whose heart sound signals were used:

a. Weird noises

an undiagnosed 24-year-old man with autism spectrum disorder (ASD). The left sternaled border of the heart may be slightly elevated as well as the pulse is still pounding strongly. The heartbeats are typical.[32]

ii) A 23-year-old man without symptoms who has a patent arteriosus lowercase d and upper left sternal borders (PDA). The heart rate and the radius & femoral pulse are both noticeably elevated throughout the assessment. Moreover, there was a little rise in heartbeat frequency. A 20-year-old patient's left up sternal boundary was discovered.[33]

A 20-year-old patient's left upper sternal boundary was discovered. He appears sick and worn out. continuing growth and lack of early symptoms.

b. regular heartbeat and pulse I am indeed a 23-year-old female without no symptoms, excellent health, and regular visits with the doctor.

(ii) A 20-year-old man listened merely at the left upper sternum with the stethoscope's diaphragm. boundary. Four places were treated, and after a comprehensive medical examination, normal physiological functioning, a healthy heartbeat, and a regular pulse, there were no symptoms. I listened to some recurring noises, including a few skin-related crackles from the microphone. Male teen, no symptoms [34]

(iii). To ensure that heartbeat and pulse are healthy, periodic checks should be made. at top left sternal boundary, and listened to it. The results and discussion compared the heart sounds of healthy and sick patients. Unambiguous research has demonstrated that the amplitude, variance, and energy of cardiac sounds of healthy and unwell people constantly vary. It seems obvious that the mean value for just a healthy guy would be higher if the amplitude were higher. Moreover, the three variables mean, variance, and energy aid in identifying both healthy and ill individuals.

2.5 PROCEDURE OF SUCCESSIVE DENOISING

The full, step-by-step denoising process is shown in Figures 3(a)-3 (e). REES52 sensor decreased the noise with in amplified stethoscope signal. The signal is then fed into Matlab. Wavelet decomposition enables a sophisticated signal analysis. Based on the demands for a noise-free signal, the wavelet decomposition level was chosen. Following wavelet transformation, the high-frequency subbands primarily include noise data and little to no signal data. Here, a light thresholding is applied to the different subbands. Ultimately, wave-rec was able to reproduce the signal as a wavelet.[35][36]

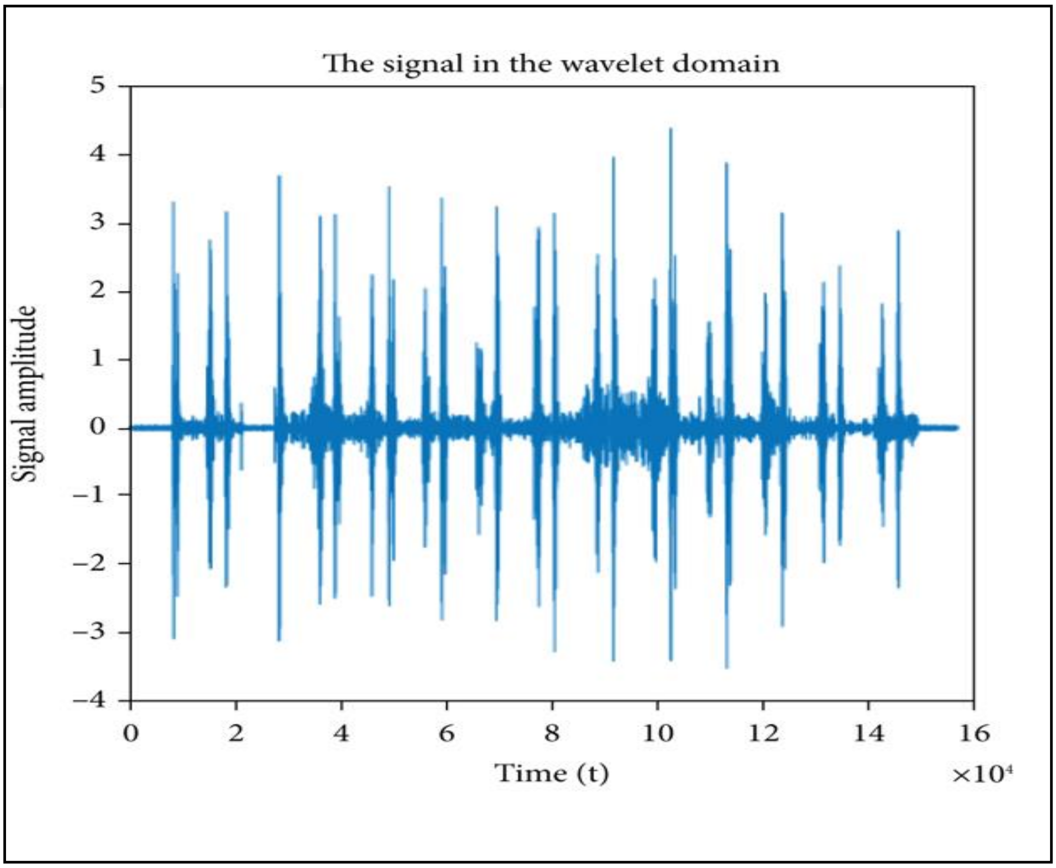

Figure 2.2: Signal Into MATLAB From REES52(a) [35].

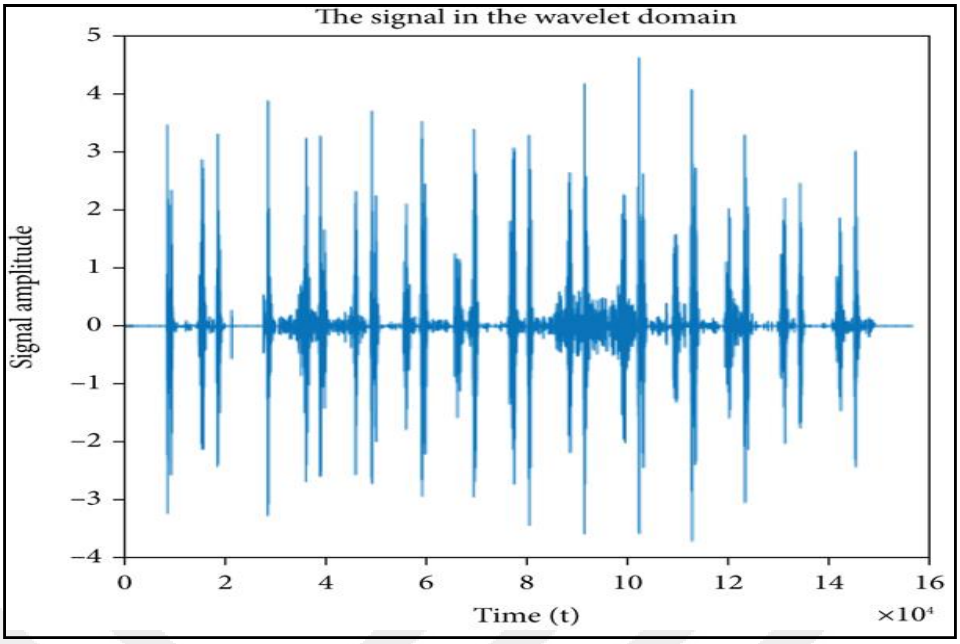

Figure 2.3: Signal Into MATLAB From REES52(b) [35].

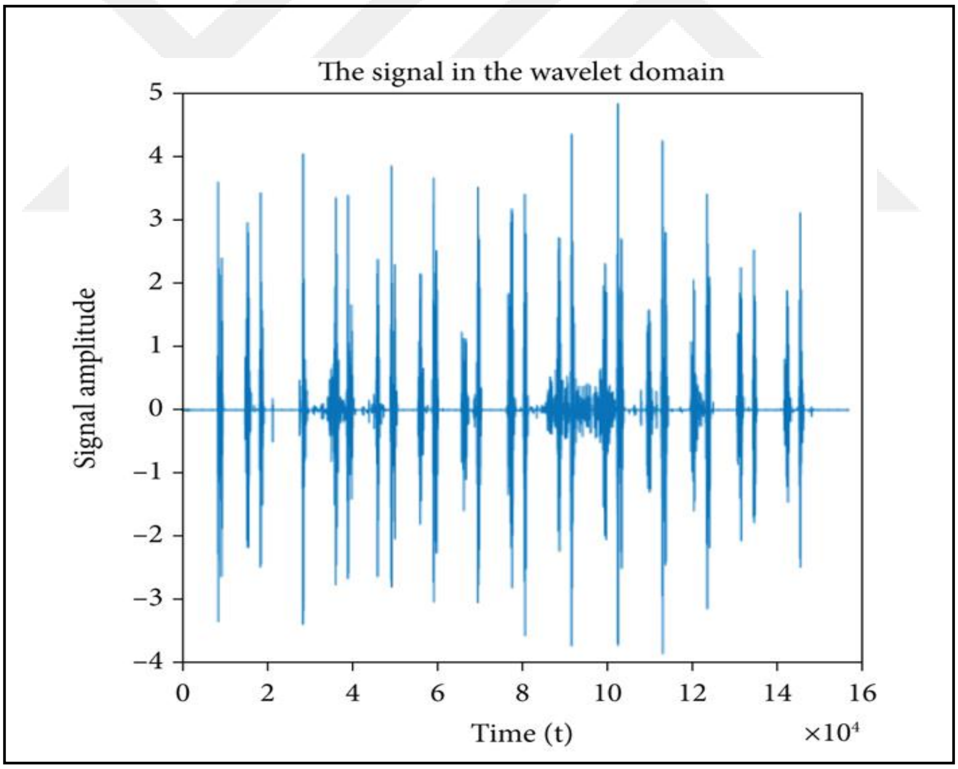

Figure 2.4: Signal Into MATLAB From REES52(c) [35].

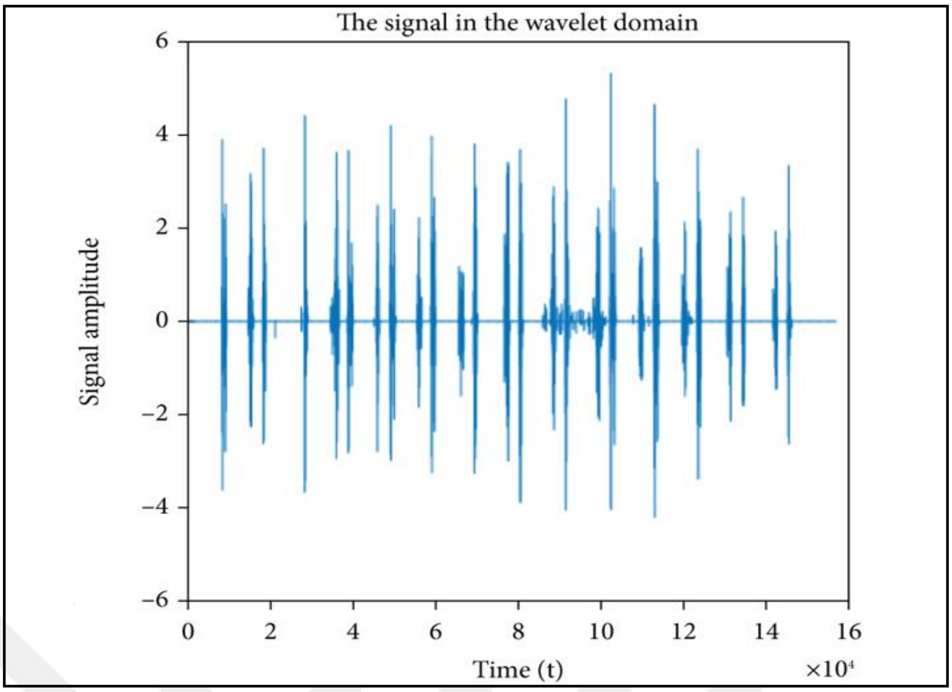

Figure 2.5: Signal Into MATLAB From REES52(d) [35].

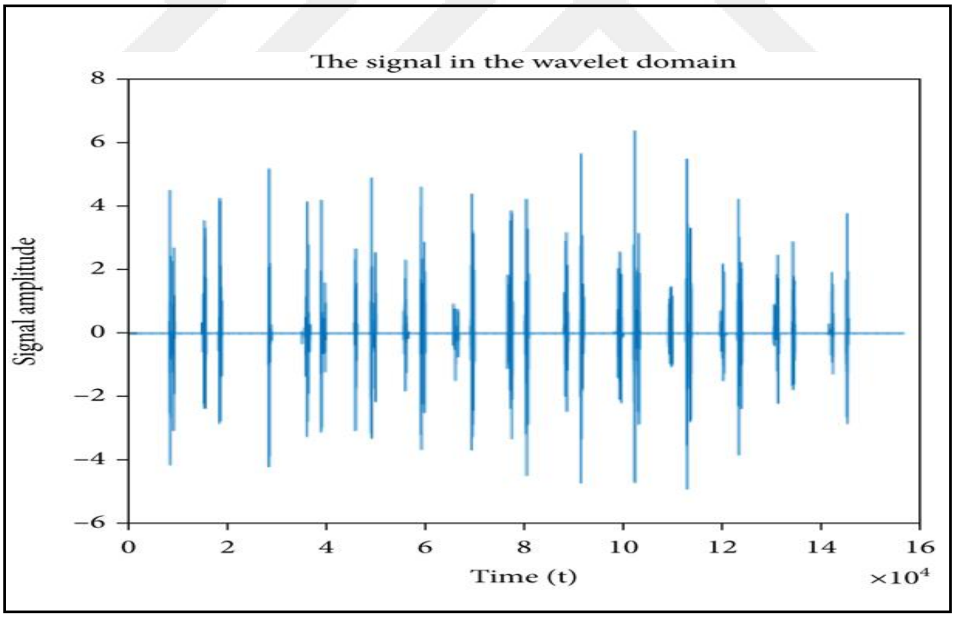

Figure 2.6: Signal Into MATLAB From REES52(e) [35].

Here, soft thresholding is employed to prevent an unplanned interruption of our data. The original pulse will remain audible, just the noise signals will be removed. Different thresholding levels explain each phase of the signal noise reduction process. Given that REES52 completed the first step of noise reduction, here is the second phase.[37]

2.6 THE RELATIVE ANALYSIS

a. Signal : Participants in both the healthy and ill groups generated two distinct signals. Their frequency and volume vary. Signals from a healthy heart have amplitude compared to a heart that isn't healthy is significantly higher..

b. A pulse from the a healthy body has a bigger magnitude and fluctuates gradually over time, as depicted by a spectrogram. On the other hand, ill individuals often have diminutive statures commensurate to their severity.

c. The normal distribution states that data near a mean occur more frequently than data that are distant from the median. symmetric with respect to the mean

e. To ensure accuracy, the obtained cardiac signals are denoised. accurate and effective analysis for heart sound (detailed coefficient [cD]). Here, Symlet wavelet layers 1 through 4 are utilized. Heart sounds from healthy and ill people differed in character & were distinct from one another.

f.

Wavelet levels for noise-free signals are substantially more accurate than symlet levels for noisy signals in terms of the approximation coefficient (cA). Even after being denoised, the properties of good and sick signals differ. Hence, this ecg signals approximation coefficient can be utilized to differentiate between healthy and sick persons.

So, we deduced that there are enough factors to distinguish between healthy and harmful sound waves, and they each exhibit various features. It motivates us to do more research to uncover even more distinctions between them. We discovered the following variables that helped us distinguish between them:[38]

2.6.1. Mean Value

The threshold level to distinguish between them is discovered to be between 0.07 and 0.09. A healthy signal has a mean value over 0.09; an unhealthy signal has a mean value below 0.07.

2.6.2. Variance

A heartbeat's variance is considered healthy if it is higher than 0.015. On the other side, it will be classified as harmful if the variation value is much less then 0.01.[39]

2.6.3. Energy(power)

a discrete wavelet translation coefficient's energy can be calculated using a simple energy equation, ene=(i=1)n(x)2/n). In this case, n stands for the quantity of cardiac samples. x is the amplitude of the signal. It was found that the threshold value needed to distinguish between them ranged from 2e-08 to 0.5e-05. Compared to healthy samples, unhealthy samples have significantly less energy. As just a result, one such energy is employed to differentiate between samples of healthy and unhealthy heart sounds. A healthy person does have a signal value greater than 0.5e-05 and a signal value just under 2e-08 for an unhealthy person.

A curvelet domain was examined to understand and analyze heart sound variations. Analyses of signal and discrete wavelet transforms are used to look at the characteristics of heart vibrations. A relevant numbers in the this section will be accompanied by real-time information gathered by the proposed gadget. Actual data has been discovered using a stethoscope and some technological tools. Auscultation of the body is among the most significant clinical tests for assessing heart issues. This medical technique enables skilled drs to hear and evaluate a heart's sound for just a diagnosis and is inexpensive and efficient. However, in Bangladesh's rural areas, there aren't many medical experts who can correctly interpret heart sounds. This issue was resolved by converting the stethoscope heart audio into an electrical signal using PLX-DAQ tools and a condenser microphone. Data from the Arduino serial monitor was converted into such an Excel data file using PLX-DAQ. Matlab converted the sound to a signal. Following that, each denoised signal has been plotted, & cardiac sounds that were normal and abnormal were contrasted. This was possible to tell a person's health as well as infirmity by contrasting the two images instead of relying solely on his heartbeat.[40]

2.7 SIGNAL ANALYSIS

A sound recording of a healthy person's voice was turned into an electrical signal in Figure 4(a). Electrical time-domain signals were perceived as being present in heart sounds. Multiple aspects of sound may be extracted using this format. It is evident in these data from the heart's lub dub. A time-domain recording of an electrical signal from a sick person is shown in Figure 4(b). The difference in amplitude between good and sick cardiac sounds was observed. The distinctions between healthy and ill subjects may be easily visualized. Such a comparison is shown in Figure 4(c), where it is possible to see how these signals' amplitude and frequency vary. The signal of a healthy individual has a substantially larger amplitude than that of a sick person. Despite the similarities between unhealthy & healthy sound visual signals, There's going to be variations in both the signal's magnitude and its mean value.[41]

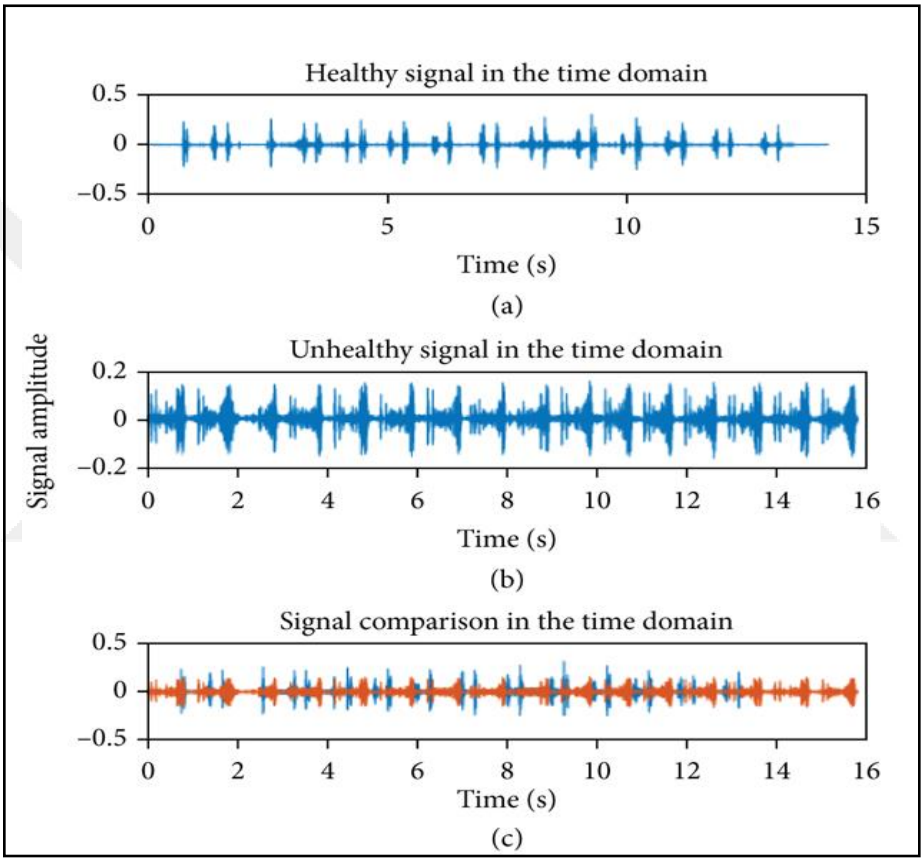

Figure 2.7:.Signal Amplitude[41].

3. METHODOLOGY

3.1 THEALGORITHM

The algorithm in this paper is divided into three main stages.

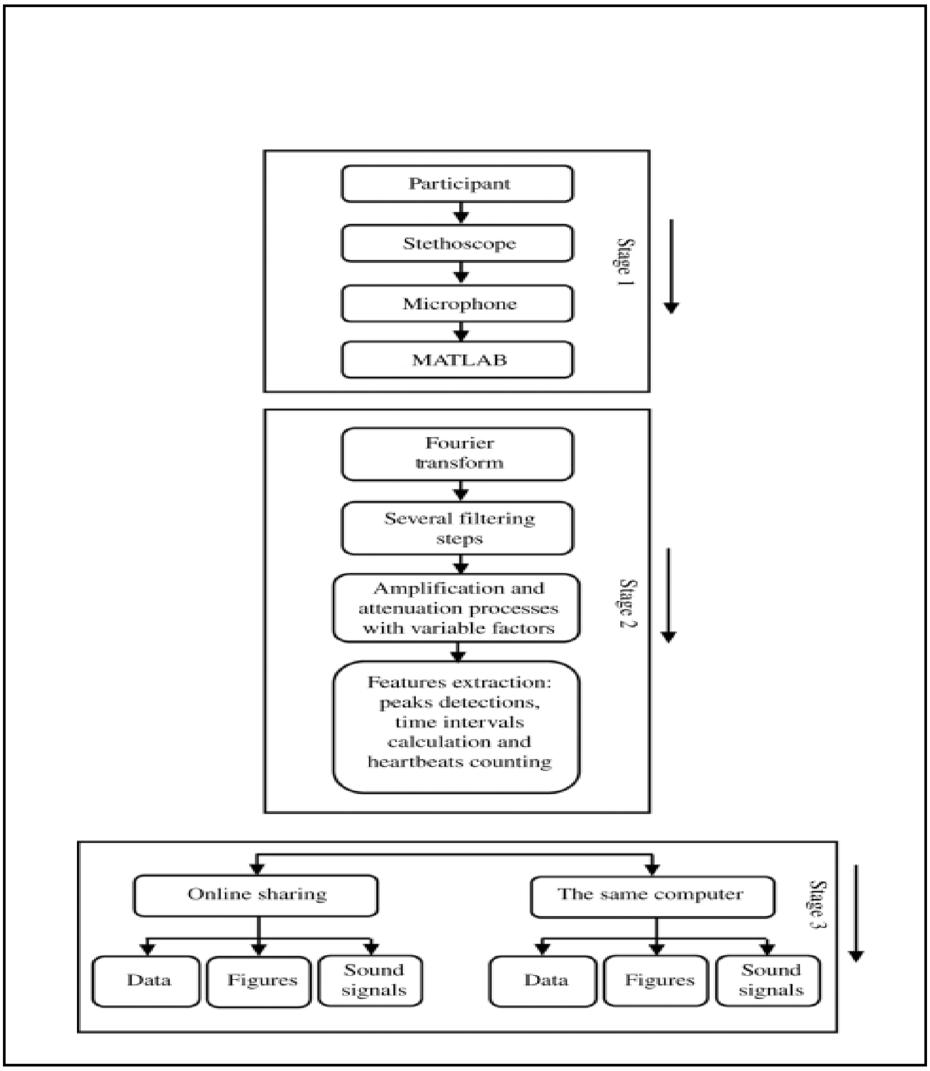

Figure 3.1: The Algorithm.

3.2 HARDWARE SIDE

Stethoscope has been used in this project to record the heart sound (Lub and Dub). The rubber tube of the stethoscope has been cut from one end and the other end was attached to the stethoscope drum . A small microphone been inserted to the free end of rubber tube . The sound signal which is detected by the microphone is converted to an electrical signal and then imported to the MATLAB program throughout the microphone port in the compute . The sound transmission tube from the stethoscope to the microphone that receives the audio signal is 20 cm long.

Figure 3.2: Stethoscope and Microphone.

3.3 SOFTWARE SIDE

In this section ,the MATLAB code used for recording and processing the audio signal will be explained in blocks. Each block will represent one step of the whole project . The first block here represent the process of recording the audio signal from the site over the heart. Stethoscope has been used to capture the audio signal from the chest over the heart as been explained beforehand .Lab Dub sounds will be recorded by the following MATLAB codes:

```
tic
% recObj = audiorecorder;
% recordblocking(recObj, 15);
% sound(recObj);
% x = getaudiodata(recObj);
% subplot(3,1,1)
% plot(x)
load('heartbeat1');
sound(heartbeat1);
 x=heartbeat1;
subplot(3,1,1)
plot(x)
```

Figure 3.3: Codes in Work.

by default the MATLAB will use {8000Hz} as sampling frequency. The period of signal recording will extend in 15 seconds and the final result will be multiplied by 4to calculate the heart rate per minute After the heart audio signal been recorded and saved in the computer , the MATLAB will cslima its specific frequency in under to design filters to get rid of and display the hearth sound signal . Fast Fourier has been used to calculate the power spectrum and the Frequency components of the signal . Tow ways in MATLAB wcrc used to calculate the power spectrum .The following in the first way:

```
%%
fs = 8000;
N= length(x);
Ts=1/fs;
tmax=(N-1)*Ts;
t=0:Ts:tmax;
f=-fs/2:fs/(N-1):fs/2;
z=fftshift(fft(x));
subplot(3,1,2)
plot(f,abs(z))
axis([0 4000 0 100])
```

Figure 3.4: Codes in Work.

As the default sampling frequency of the signal recourding in the first blok was [8000Hz] the sampling frequency [fs] used hare is also [8000Hz] The second way of calculating the frequency components of the signal is shown in the following block of MATLAB code

```
L=length(x);

NEFT= 2^nextpow2(L);

y=fft(x,NEFT)/L;

f=fs/2*linspace(0,1,NEFT/2*1);

subplot(3,1,3);

plot(f,2*abs(y(1:NEFT/2*1)));
```

After calculating and estimating frequency components of the signal filter design will be the next step before starting the filtration process the absolute value of the signal will be calculated on the absolute signal the following code is to calculate and display the absolute value of the recited audio signal…

```
%%
v=abs(x);%the recorded audio signal
figure(2)
subplot(3,1,1)
plot(t,v)
```

Figure 3.5: Codes in Work.

In this step we will design band pass filter on the absolute value of the recoiled audio signal that obtained from heart the band pass filter is designed according to the range of power spectrum (100 – 125HZ) with sample rate (8000HZ) is shown in the following block of MATLAB code :

```
%%
bpFilt = designfilt('bandpassfir','FilterOrder',20, 'CutoffFrequency1' ...
    ,100,'CutoffFrequency2',125, 'SampleRate',8000);
dataOut = filter(bpFilt,v);
coeff=ones(1,100)/100;
av=filter(coeff, 1, dataOut);
subplot(3,1,2)
plot(t,av)
```

Figure 3.6: Codes in Work.

The campus of the ban pass filter is red to the band pass filter in this step the low pass filter will smooth the signal and reject the high frequency noise to facilities the heart bout counting the cutoff frequency of the low pass filter was 10 HZ with sampling frequency 8000HZ.

```
%%
lpFilt = designfilt('lowpassiir','FilterOrder',8, ...
'PassbandFrequency',10,'PassbandRipple',0.2, ...
'SampleRate',8000);
dataLP = filter(lpFilt,av);
subplot(3,1,3)
plot(t,dataLP)%dataLP is the signal of low pass filter)
```

Figure 3.7: Codes in work.

In the last step the number of peiks located along the signal were counted and then divided by 2 as the recouded anded signal is communing two peaks for each heart heal reprented by the (lab and dab) sounds the resulted value afirr that was multiplied by (4) as the recording time was extended over 15 second only in order to get the heart rate per minute..

```
%%
for k=2:length(dataLP)-1;
if dataLP(k)>0.19
dataLP(k)=1;
else dataLP(k)=0;
end
end
pks = findpeaks(dataLP)
heart_beat=(6*sum(pks))/2
toc
```

Figure 3.8: Codes in work.

4. RESULTS AND DISCUSSION

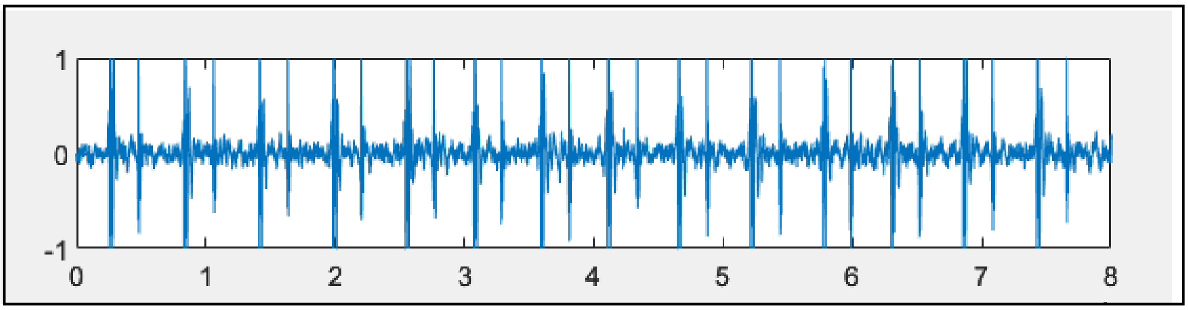

Figure 4.1: Audio Signal Recorded From the Heart.

This figure is the result of recording the sound signal of the heart directly through the stethoscope and been displayed by MATLAB Program. This signal represents the raw data without any processing or noise reduction.

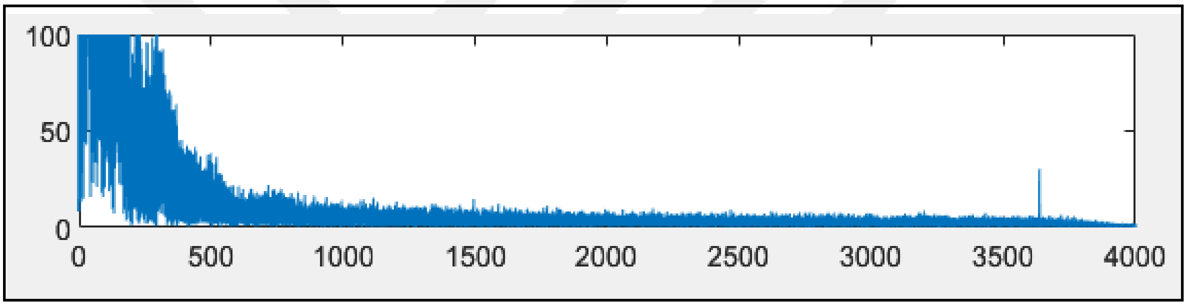

Figure 4.2:.Power Spectrum in Frequency Domain.

This figure is obtained by converting the signal of the heart from time domain to frequency domain . a purpose of this figure is to get the exact frequency of the heart sound which will be used in signal processing and noise reduction .

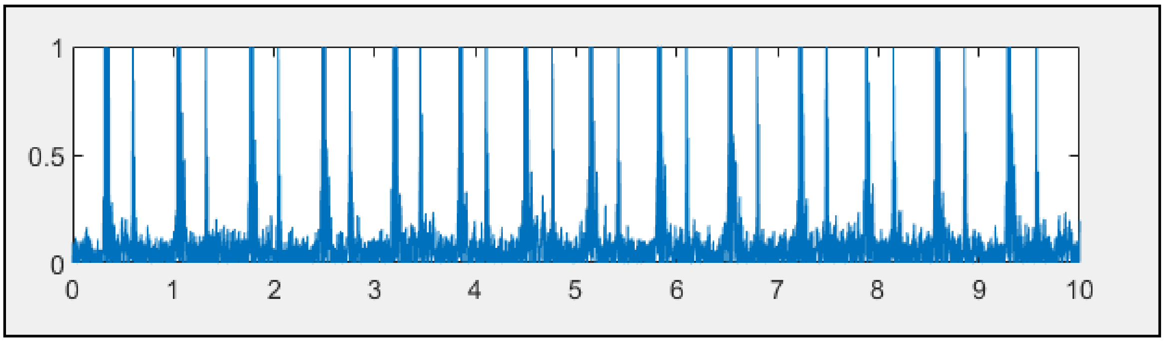

Figure 4.3: Signal With Absolute Value.

This figure is obtained after taking the absolute value of the sound signal of the heart because we need the positive part of the signal only for counting the heart rates. In order not to double the signal and calculate it incorrectly

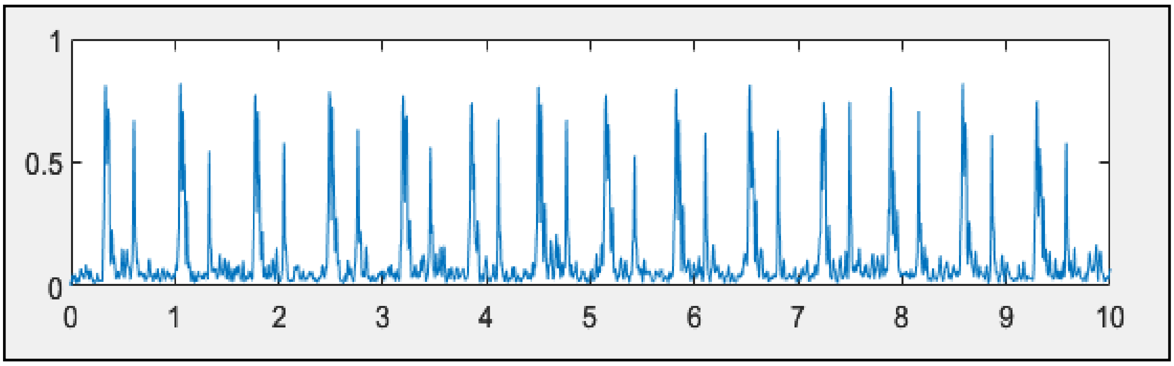

Figure 4.4: Signal After Smooth and Band Pass Filter.

This figure represent the resulted signal after being inserted to the band pass filter (100-125)Hz and smooth filter depending on the frequency range that has been calculated in the past step.

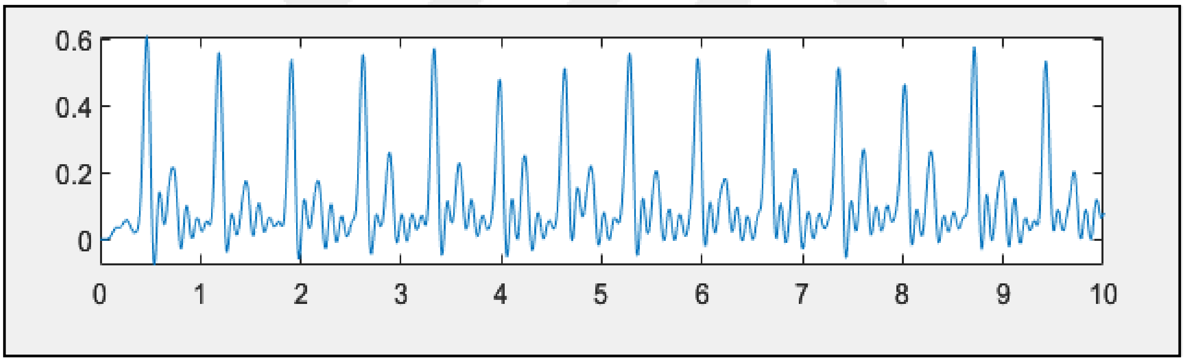

Figure 4.5:.Signal After Low Pass Filter.

This figure shows the output of the Low pass Filter with(10 Hz). This filter has smoothed the signal to facilitate the peaks counting. Below is a clear heart rate chart by which some diseases can be diagnosed

In addition to charting the systolic signal and heartbeat, the number of heart beats per minute is also counted.

Tablo 4.1: Data Table and Results of Heart Rate Analysis For 15 People.

no	Age	sex	heart rate
1	2 years	Male	90
2	15 years	Female	79
3	12 years	Male	83
4	24 years	Male	77
5	36 years	Male	82
6	22 years	Female	80
7	40 years	Male	74
8	69 years	Male	70
9	37 years	Male	84
10	7 years	Female	90
11	22 years	Female	82
12	20 years	Female	79
13	23 years	Female	87
14	29 years	Female	76
15	11years	Male	82

The program was tested on fifteen people of different ages and genders, and the program was good in giving results. The results were compared with a heart rate monitor called (Mayo Clinic) and the results were close to 95.6%. This proves the accuracy of the program in measurement. The test was also re-tested three times for each person during spaced time periods to ensure that the program worked well

Is for algorithm to determine the timing of the a heartbeat, S1 and S2 must be correctly identified with every cardiac cycle. Several flattening stages are applied to the data in order to generate envelopes for S1 and S2 as the two principal sounds. As the positive and negative sides all inputs are symmetric, the bad aspect of each signal was disregarded. The program located the apex of each envelope and its location. To symbolize the apex of the an envelope which serves as a hold for such fundamental sounds as S1 & S2, the program incorporated black stars within circles. The peaks & their locations were used to compute the heart rate &

time intervals. Figure 4.6 depicts a pulse audio waves passing through the basic filtering procedures..

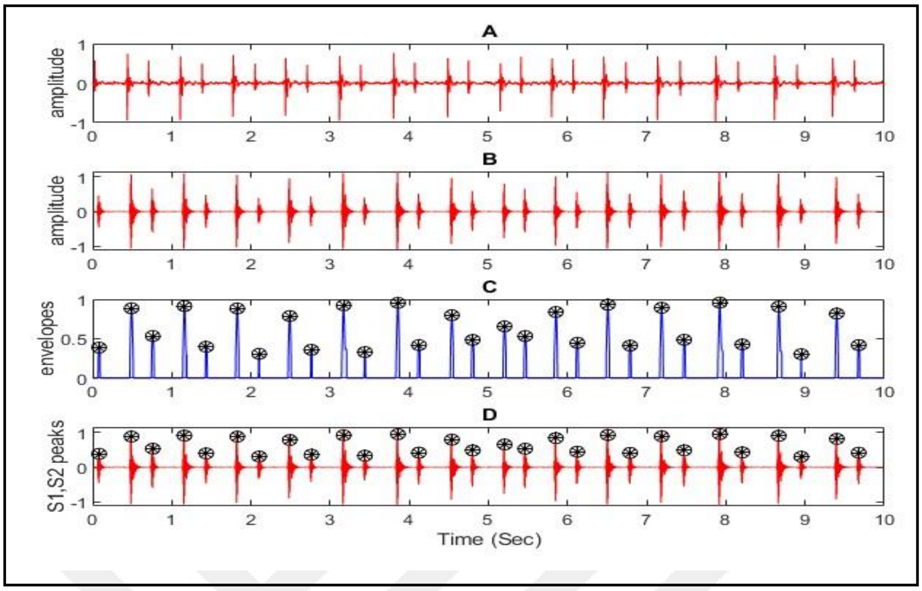

Figure 4.6: As It Passes Through The Primary Filtering Processes.

The suggested approach shown definite improvements in the heart sound signal filtering procedures. The algorithm's filtering procedures succeeded in eliminating the majority of the noise that accompanied the signals and improved the quality of a signals' targeted attributes (i.e. S1 & S2). Prior to and following the filtering steps, a noise to signal ratios (SNR) of a signals was determined. Any signal's noise level should be known in order to determine the SNR. It is uncertain very noisy the ecg signals signals are all in their present form, prior to and following filtering. Upon review of the recorded cardiac sounds, the majority of the noise is collected between each pairing of cardiac cycle (i.e. S2 to S1). To generate noise with the same duration for every signal, a small interval was inserted between consecutive heart cycle (S2 to S1) has been repeatedly recorded using the Audacity software. The noise of each signal from the heart was calculated using this method. MATLAB calculated a SNR for each signal using predicted noise for that signal. noises in both instances

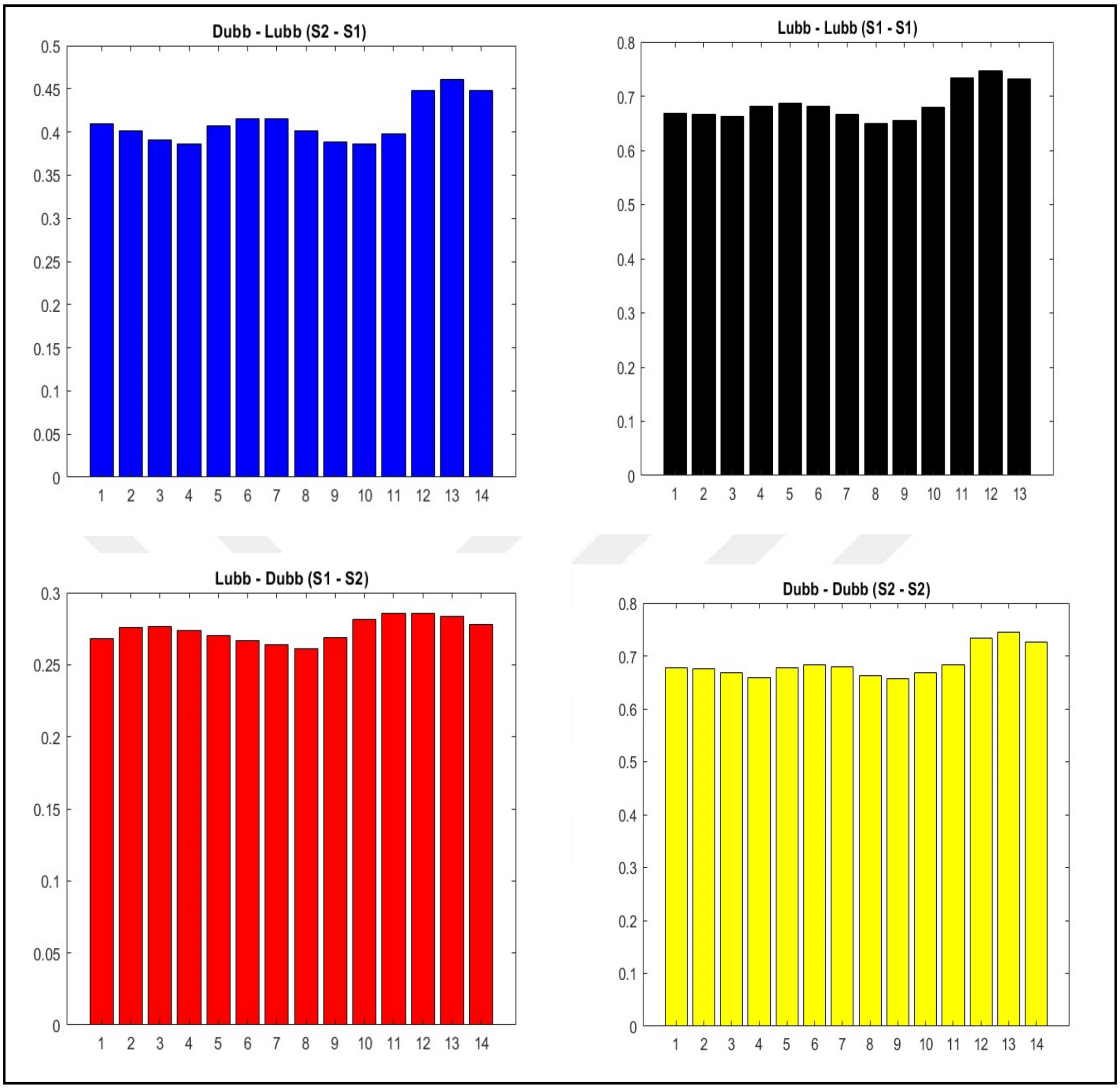

Figure 4.7: The Durations of The Participant's S1 and S2 Primary Heart Sounds.

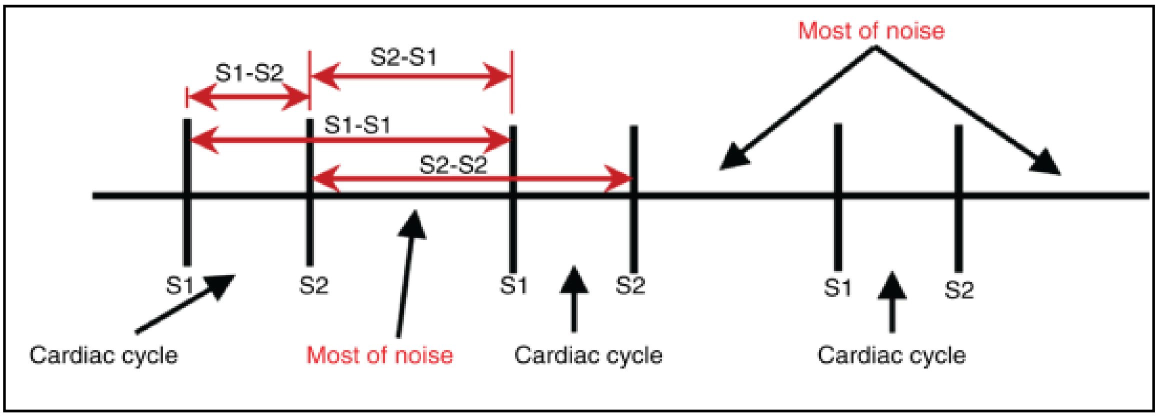

Figure 4.8: Simple Schematic of The Heart's Cycles.

The same loop, the separation between S 1 -S 2 as well as the separation between s 1 in the first pulsed and S1 of a second pulse are determined. Determine the separation between S1 of a second pulse and S2 the first pulse. Additionally, determine the separation between the S2s of the first and second pulses. This allows for the diagnosis of cardiac illness and the counting of heartbeats. Diseases are identified, including those characterized by a fluctuating heartbeat and others.

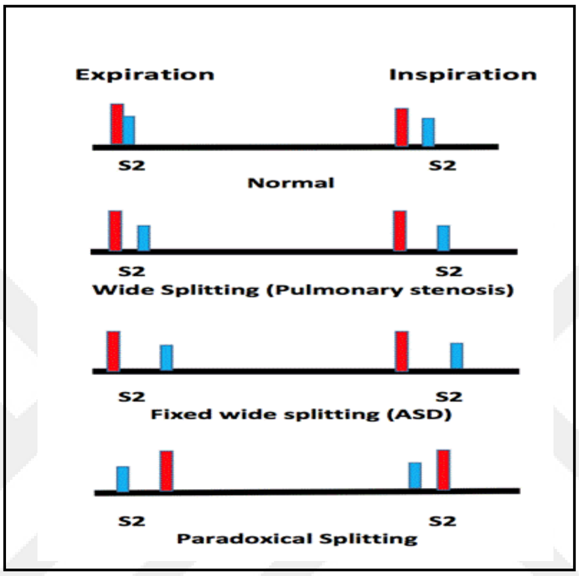

Figure 4.9: Clarify How The Distance Between A Normal Person and An Injured Person S1-S2.

The primary heart audio (S1 & S2) were detected & their intervals in time were calculated using the suggested technique, which was dependent on peak discovery. As a result, the algorithm's precision can be seen in its capacity to identify actual peaks (S1 & S2) and determine the intervals between them. The algorithm's accuracy was determined by dividing the percentage of actual peaks (S1 and S2) that were true positive detections into the number of complete real peaks (S1 & S2) & the number of undesirable peaks (peaks caused by noise) that were detected in the same signal.

$$\text{Accuracy} = \text{(True positive detection of (S1,S2))}/\text{(Total peaks (S1,S2) + unwanted peaks detection)} \times 100\%$$

Depending on the origin of the data utilized in the study, the algorithm's performance varied. The system demonstrated a high level of performance accuracy utilizing the data collected from the 14 individuals, with an average accuracy level of roughly 95.6%. When the free internet data, this percentage fell to roughly 81.2%. Table 4.2 displays the average and precision of an algorithm for every participant.

Tablo 4.2: Table Showing The Percentage of The Algorithm's Working Accuracy For Participants.

Subjects	**Percentage of accuracy in detecting S1 & S2.**
1	90%
2	98.3%
3	96%
4	94%
5	98.1%
6	99%
7	95.2%
8	91.8%
9	93.9%
10	100%
11	99.2%
12	94.8%
13	98.9%
14	88.1%
15	97.4%
Average, %	95.646%

There are a number of causes for the algorithm's accuracy being different between Table 3 & Table 4. One of the causes of the algorithm's poor performance was the high level of noise with in internet recorded dataset compared to less noise level of a recorded data from 15 individuals. Another factor is that our recording device captured heart sounds with greater quality than the electronic stethoscope's online dataset, which had a lesser quality. Due to all of these factors, it was more challenging to separate the real heart sound peaks (S1 & S2) from other noise peaks in the data.

The heart rate was also approximated for 60 seconds using the suggested technique by measuring a number of spikes (S1 & S2) during a specified recording times. The concept for calculating heart rate is expressed in the equation below:

$$\text{Heart rate per minute (recording time is 15 s)} = \left(\text{the detected peaks}(S1, S2)/2\right) \times 4$$

5. CONCLUSIONS

The stethoscope exam is still the technique of choice for cardiac diagnosis, despite the growing number of studies that focus on examining heart sounds as a primary way of investigation. The use of a stethoscope to do the examination is still the method of choice. On the other side, stethoscopes have a number of drawbacks, such as the fact that they produce a significant amount of ambient noise and make it difficult to time the pauses that occur in between heartbeats. Stethoscopes also have a number of additional drawbacks. at this work, we propose an method that is based at peak detection, with the objective of filtering, detecting, and estimating the intervals between the two primary heart sounds, S1 and S2. This methodology was developed that order to estimate the intervals between the two fundamental heart audio. The identification and tracking of peaks is the primary emphasis of our method. As can be seen in the following, the approach that was advised demonstrated a high degree of accuracy in distinguishing S1 and S2 while making use of the data that was captured by our system (about 95.6% of the time). However, when it was used with free data, the accuracy decreased to 80.194% owing to the poor quality of the recordings that were used. In addition, the system was able to compute the user's heart rate in addition to the interval intervals S1 and S2 and present the results of these calculations using bar graphs. These graphs displayed the data in a horizontal format. In addition, the problem could be recognized and diagnosed on the basis of the results, in particular a patient's heart rate and whether or not it is unusually rapid or slow. An further critical step is locating S1 and S2 inside the same pulse and calculating the distance between them. In addition, you should compute the distance between S2 of the first pulse and S1 of the second pulse, as well as the distance between S2 of the first pulse and S2 of the second pulse, which reflects the distance from the second pulse. By analyzing the data and graphs that are provided by the algorithm's findings, a variety of conditions can be identified using these findings. Some of these conditions include heart failure, weakening of the heart muscle, and constriction of the arteries. Many other conditions can also be identified using these findings. Also, count how many times your heart is beating in one minute.

5.1 FUTURE RECOMMANDATION

Developing the software properly and preventing mistakes while monitoring heart rate are both addressed in the following ideas. It is important to take into consideration the environment in which it is measured since certain noises might trigger the production of light, which can interfere with an accurate reading of the subject's heart rate.

Also, when the stethoscope is put on the patient's skin, it should not be moved at any point throughout the measurement in order to prevent any noise from being caused by the stethoscope's movement. The minimum distance that should exist between the skin and the microphone is twenty centimeters. This distance should never be less than this. Because poor sound quality while recording might lead to errors in judgment, it is best to make use of a robust and high-quality microphone in order to get a clear recording of the sound.

In the not too distant future, this technique may be used by artificial intelligence to automatically identify the specific illness that a patient is afflicted with. Where the algorithm is trained using artificial intelligence on the heart sounds or on the visual forms described in this work, and where the algorithm itself is responsible for doing the analysis of the heart sound. Therefore, sound samples are acquired from individuals who have certain cardiac problems and fed into the algorithm. This enables the system to be trained to detect and diagnose the ailment using artificial intelligence.

REFERENCES

[1] G. D. Huntley *et al.*, “Comparative study of bicuspid vs. tricuspid aortic valve stenosis,” *Eur. Hear. Journal-Cardiovascular Imaging*, vol. 19, no. 1, pp. 3–8, 2018.

[2] E. Kontautas, “Radiopaedia. Org.[online] Radiopaedia. org. Available at:< https://radiopaedia. org/articles/jefferson-fracture? lang= us>[Accessed 16 January 2021].▪ Yao, L. Et al2013. Imaging Evaluation Of The Cervical Spine.[online] Available at:< https://www. med-ed. virginia. edu/courses/rad/cspine/index. html>[Accessed 16”.

[3] J. J. Thaden *et al.*, “Sex-related differences in calcific aortic stenosis: correlating clinical and echocardiographic characteristics and computed tomography aortic valve calcium score to excised aortic valve weight,” *Eur. Heart J.*, vol. 37, no. 8, pp. 693–699, 2016.

[4] G. C. Curhan *et al.*, “Birth weight and adult hypertension and obesity in women,” *Circulation*, vol. 94, no. 6, pp. 1310–1315, 1996.

[5] N. Dey, G. Mishra, B. Nandi, M. Pal, A. Das, and S. S. Chaudhuri, “Wavelet based watermarked normal and abnormal heart sound identification using spectrogram analysis,” in *2012 IEEE international conference on computational intelligence and computing research*, 2012, pp. 1–7.

[6] R. Nandi *et al.*, “A novel nanohybrid for cancer theranostics: folate sensitized Fe 2 O 3 nanoparticles for colorectal cancer diagnosis and photodynamic therapy,” *J. Mater. Chem. B*, vol. 5, no. 21, pp. 3927–3939, 2017.

[7] A. C. Guyton and J. E. Hall, “Buku ajar fisiologi kedokteran,” 2007.

[8] K. L. Moore, A. F. Dalley, and A. M. R. Agur, “Lower limb,” *Clin. oriented Anat.*, vol. 3, pp. 403–468, 1992.

[9] Y. Miyasaka *et al.*, “Secular trends in incidence of atrial fibrillation in Olmsted County, Minnesota, 1980 to 2000, and implications on the projections for future prevalence,” *Circulation*, vol. 114, no. 2, pp. 119–125, 2006.

[10] S. Colilla, A. Crow, W. Petkun, D. E. Singer, T. Simon, and X. Liu, "Estimates of current and future incidence and prevalence of atrial fibrillation in the US adult population," *Am. J. Cardiol.*, vol. 112, no. 8, pp. 1142–1147, 2013.

[11] C. L. Ogden *et al.*, "Centers for Disease Control and Prevention 2000 growth charts for the United States: improvements to the 1977 National Center for Health Statistics version," *Pediatrics*, vol. 109, no. 1, pp. 45–60, 2002.

[12] K. M. Flegal and T. J. Cole, *Construction of LMS parameters for the Centers for Disease Control and Prevention 2000 growth charts*, no. 63. US Department of Health and Human Services, Centers for Disease Control and …, 2013.

[13] N. G. Schwarz *et al.*, "WHO 2006 child growth standards: implications for the prevalence of stunting and underweight-for-age in a birth cohort of Gabonese children in comparison to the Centers for Disease Control and Prevention 2000 growth charts and the National Center for Health Statistics 1978 growth references," *Public Health Nutr.*, vol. 11, no. 7, pp. 714–719, 2008.

[14] N. C. for H. S. (US), "Health, United States, 2008: with special feature on the health of young adults," 2009.

[15] N. P. Reddy, T. A. Krouskop, and P. H. Newell Jr, "A computer model of the lymphatic system," *Comput. Biol. Med.*, vol. 7, no. 3, pp. 181–197, 1977.

[16] J. H. Wilmore, D. L. Costill, and W. L. Kenney, *Physiology of sport and exercise*, vol. 20. Human kinetics Champaign, IL, 2004.

[17] N. P. Reddy, T. A. Krouskop, and P. H. Newell Jr, "Biomechanics of a lymphatic vessel," *J. Vasc. Res.*, vol. 12, no. 5, pp. 261–278, 1975.

[18] N. P. Reddy, "Lymph circulation: physiology, pharmacology, and biomechanics.," *Crit. Rev. Biomed. Eng.*, vol. 14, no. 1, pp. 45–91, 1986.

[19] S. M. Debbal and C. Hamza, "Heart sounds analysis using the three wavelet transform versions the continuous wavelet transform (CWT), the discrete wavelet transform (DWT) and the wavelet packet transforms (PWT)," *J. Cardiol. Interv.*, vol. 1, no. 1, 2021.

[20] D. M. Mirvis and A. L. Goldberger, “Electrocardiography In Braunwald E, Zipes DP, Libby P,” *Hear. Dis. 6th Ed. Pennsylvania, WB Saunders Co.*, pp. 103–104, 2001.

[21] D. M. Mirvis and A. L. Goldberger, “Electrocardiography In: Bonow RO, Zipes DP, Libby P, Mann DL.(eds.): Heart Disease. A Textbook of Cardiovascular Medicine.” Philadelphia, WB Saunders Company, 2011.

[22] D. M. Mirvis *et al.*, “Instrumentation and practice standards for electrocardiographic monitoring in special care units. A report for health professionals by a Task Force of the Council on Clinical Cardiology, American Heart Association.,” *Circulation*, vol. 79, no. 2, pp. 464–471, 1989.

[23] A. L. Goldberger, D. M. Mirvis, and G. M. Saperia, “Pathogenesis and diagnosis of Q waves on the electrocardiogram,” *UpToDate. Waltham, MA*, 2006.

[24] E. J. Benjamin *et al.*, “Amer Heart Assoc Council E, Prevention Stat C, Stroke Stat S (2019) Heart Disease and Stroke Statistics-2019 Update A Report From the American Heart Association,” *Circulation*, vol. 139, no. 10, pp. E56–E528.

[25] E. J. Benjamin *et al.*, “American Heart Association Council on, E., Preventio n Statistics, C., Stroke Statistics, S, 2019,” *Hear. Dis. stroke Stat.*, vol. 9.

[26] E. J. Benjamin *et al.*, “Heart disease and stroke statistics-2019 at-a-glance heart disease, stroke and other cardiovascular diseases,” *Am Hear Assoc*, vol. 139, pp. 1–5, 2019.

[27] E. J. Benjamin *et al.*, “Heart disease and stroke statistics—2019 update: a report from the American Heart Association,” *Circulation*, vol. 139, no. 10, pp. e56–e528, 2019.

[28] J. C. Seidell, H. S. Kahn, D. F. Williamson, L. Lissner, and R. Valdez, “Report from a Centers for Disease Control and Prevention Workshop on use of adult anthropometry for public health and primary health care.” Oxford University Press, 2001.

[29] N. C. for H. S. (US) and N. H. D. S. (US), *National hospital discharge survey*. US Department of Health and Human Services, Centers for Disease Control and …, 2010.

[30] N. C. for H. S. (US, “Health, United States, 2015: With special feature on racial and ethnic health disparities,” 2016.

[31] N. C. for H. S. (US), *Chartbook on Trends in the Health of Americans*. Department of Health and Human Services, Centers for Disease Control and …, 2002.

[32] C. W. Tsao *et al.*, “Heart disease and stroke statistics—2022 update: a report from the American Heart Association,” *Circulation*, vol. 145, no. 8, pp. e153–e639, 2022.

[33] C. Linde *et al.*, “Sex differences in cardiac arrhythmia: a consensus document of the European Heart Rhythm Association, endorsed by the Heart Rhythm Society and Asia Pacific Heart Rhythm Society,” *Ep Eur.*, vol. 20, no. 10, pp. 1565-1565ao, 2018.

[34] C. Antzelevitch *et al.*, “Brugada syndrome: report of the second consensus conference: endorsed by the Heart Rhythm Society and the European Heart Rhythm Association,” *Circulation*, vol. 111, no. 5, pp. 659–670, 2005.

[35] J. G. Andrade *et al.*, “The 2020 Canadian Cardiovascular Society/Canadian Heart Rhythm Society comprehensive guidelines for the management of atrial fibrillation,” *Can. J. Cardiol.*, vol. 36, no. 12, pp. 1847–1948, 2020.

[36] J. C. Nielsen *et al.*, “European Heart Rhythm Association (EHRA)/Heart Rhythm Society (HRS)/Asia Pacific Heart Rhythm Society (APHRS)/Latin American Heart Rhythm Society (LAHRS) expert consensus on risk assessment in cardiac arrhythmias: use the right tool for the right outcome, in the right population,” *EP Eur.*, vol. 22, no. 8, pp. 1147–1148, 2020.

[37] D. B. Diercks, G. M. Shumaik, R. A. Harrigan, W. J. Brady, and T. C. Chan, “Electrocardiographic manifestations: electrolyte abnormalities,” *J. Emerg. Med.*, vol. 27, no. 2, pp. 153–160, 2004.

[38] R. A. Harrigan and W. J. Brady, “ECG abnormalities in tricyclic antidepressant ingestion,” *Am. J. Emerg. Med.*, vol. 17, no. 4, pp. 387–393, 1999.

[39] N. Rotondo, M. L. Pollack, T. C. Chan, W. J. Brady, and R. A. Harrigan, “Electrocardiographic manifestations: acute inferior wall myocardial infarction,” *J. Emerg. Med.*, vol. 26, no. 4, pp. 433–440, 2004.

[40] P. Kligfield *et al.*, “Recommendations for the standardization and interpretation of the electrocardiogram: part I: the electrocardiogram and its technology: a scientific statement from the American Heart Association Electrocardiography and Arrhythmias Committee, Council on Clinical Cardiology; the American College of Cardiology Foundation; and the Heart Rhythm Society endorsed by the International Society for Computerized Electrocardiology,” *Circulation*, vol. 115, no. 10, pp. 1306–1324, 2007.

[41] M. Mishra, A. Singh, M. K. Dutta, R. Burget, and J. Masek, “Classification of normal and abnormal heart sounds for automatic diagnosis,” in *2017 40th International Conference on Telecommunications and Signal Processing (TSP)*, 2017, pp. 753–757.