Tracking of Anterior Mitral Leaflets in Echocardiographic Sequences for Detection of Rheumatic Heart Disease

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Declaration

I certify that this research work titled "*Tracking of Anterior Mitral Leaflets in Echocardiographic Sequences for Detection of Rheumatic Heart Disease"* is my own work. The work has not been presented elsewhere for assessment. The material that has been used from other sources, it has been properly acknowledged referred.

Signature of Student

Alishba Salahuddin

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Language Correctness Certificate

This thesis has been read by an English expert and is free of typing, syntax, semantic, grammatical and spelling mistakes. Thesis is also according to the format given by the university.

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Abstract

Rheumatic Heart Disease is an outcome of Acute-Rheumatic-Fever (ARF). Acute-Rheumatic-Fever is the provoking disease, which slowly damages heart valves. Rheumatic-Heart-Disease (RHD) in cardiac valve effects the mitral valve, which leads to thickened leaflets and that thickened leaflets results in fused tips. Thus, it reduces the mobility of leaflets, which in return reduces heart efficiency. In this thesis, the task is mainly concentrated on Anterior-Mitral-Leaflet (AML) tracking. The tracking is done by first pre-processing and segmenting the input video and then a system is designed to track the motion of those fast moving leaflets to assess heart efficiency. The proposed system does the tracking of AML on the data set (ultrasound mitral valve videos) provided by the Real Hospital Portuguese, in Recife, Brazil. The proposed system tracks a path from the video sequence by using the Mean shift algorithm. The updation of the target changes with the motion of the mitral leaflet and tracks it to assess heart efficiency.

Key Words: Rheumatic Heart Disease, AML, Data set, Mean Shift Algorithm, Heart, Leaflet, Tracking.

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CHAPTER 1: INTRODUCTION

1.1 Introduction:

Rheumatic-Heart-Disease (RHD) is produced by a serious issue of Rheumatic fevers. It is a damage to one or more heart valves. Chronic heart valve is damage due to this rheumatic fever. If rheumatic fever is diagnosed late or if it is left untreated, then this may result in heart failure too. Adolescents and children are mainly affected by this rheumatic fever. Rheumatic-heart-disease (RHD) is a damage to single or more than one heart valve that occurs due to leading rheumatic fever with time [1]. It is due to occurrence of frequent rheumatic fever .Stretched valves and scarred heart valves are examined in it .Blood do not normally flow through these damaged valves as the blood which is flowing through healthy valve is interrupted in this scenario. In addition, the blood may flow backward because the valve do not closes properly. As heart will be damaged, then the functioning of the heart valve will be impossible and requirement of surgery will be needed .If it is not treated properly or if the surgery is not done, then the damaged valves may result in more complex outcome i.e. with the passage of time the valve will continue deteriorating.

As stated by a study, published in England Journal of Medicine tells that the condition of injured or unhealthy heart valve leads to a rheumatic fever and this is produced by a bacterial infection. I has been decreased over the past 25 years around the world .If rheumatic fever is not treated , it will be very contagious and mostly for the children's who are living in the unsanitary and crowded areas . The rheumatic fever is due to the untreated strep throat and hence the fever damages heart valves over time. Ten or twenty years after infection, the symptoms of fatal heart condition may appear. It can kill or disable one person during their overall working time. [2]

This disease begins at the five to fifteen year's old .It slowly damages the heart valve and thus reducing the heart efficiency, which eventually leads to the cardiac failure [3]. Study, of "National and Global Region of Rheumatic-Heart-Disease(RHD), 1990-2015," it estimates deaths of '347500' persons from rheumatic heart disease (RHD) in year 1990 and in 2015 mainly '319400' deaths occurred. The standardized death rates of (RHD) was 9.20 /100,000 in year 1990 to '4.8'/ 100,000 in year 2015, whereas 48% reduction was seen. The Countries with maximum estimation of deaths in year 2015 were: India had '119,076' individual's deaths, China had '72,576' individuals deaths, Pakistan has '18,863' individuals deaths, US has '9,484' individual's deaths and the country Japan had ‘5,132’ individual’s deaths. If seen globally, totally it makes up ‘71%’ of deaths. More-than 10 per 100,000 are the highest death rates estimated, which occurred in Marshal Island, Lesotho, Fiji, Papa New Guinea, Solomon Island, Vanatua and India. In these endemic countries about 1% of the children’s are suffering from rheumatic heart disease (RHD) which is very fatal and injurious to the children’s and this is deduced on the lead study by an author named Dr David Watkins [4].

1.2 Symptoms of Rheumatic Heart Disease:

Symptoms are not always caused by rheumatic heart disease but when it does, causes symptoms. These are the following [5]:

1. Pain in chest.
2. Heart-palpitations.
3. Exertion results in breathlessness.
4. Lying down results in breathing problems.
5. Swelled parts.
6. Faintness occurs.
7. Strokes felt or fatal stroke.
8. Infected damaged heart valves results in fever.

Acute-rheumatic-fever can cause heart inflammation. It can be on heart surface known as ‘pericarditis’.It may occurs within heart known as ‘endocarditis’, or it may involve the heart muscle known as ‘myocarditis’. A persons experiencing with in heart disease is known as ‘endocarditis’ .One of the fours heart valves are persistent damage due to the inflammatory response and if this damage occurs once , then it may typically worsens or damages over the time period. Around half of the people who are suffering from acute rheumatic fever are suffered from rheumatic heart disease (RHD). Maximum of the cases are diagnosed around10-20 years after the rheumatic fever happened and those who have had multiples bout are at maximum risk. [6]

Rheumatic heart disease (RHD) is very much clear with different sewer problems depending on which of the valve is affected by it or the valve has been damaged in which way. Following are the most occurring forms of disease known as rheumatic heart disease:

1.3 Most Occuring Forms of Disease:

1.3.1 Disease of Mitral Valve:

Mitral Valve Disease occurs due to the excessive amount of calcium deposited on such valve. As it is a valve that lets the blood to pass from left-atrium(LA) to the left-ventricle(LV). The calcium deposition, which is around the mitral valve, can prevent valve opening completely known as 'mitral stenosis' or opening at-all. This results in valve leakage commonly knowns as 'mitral regurgitation. [7]

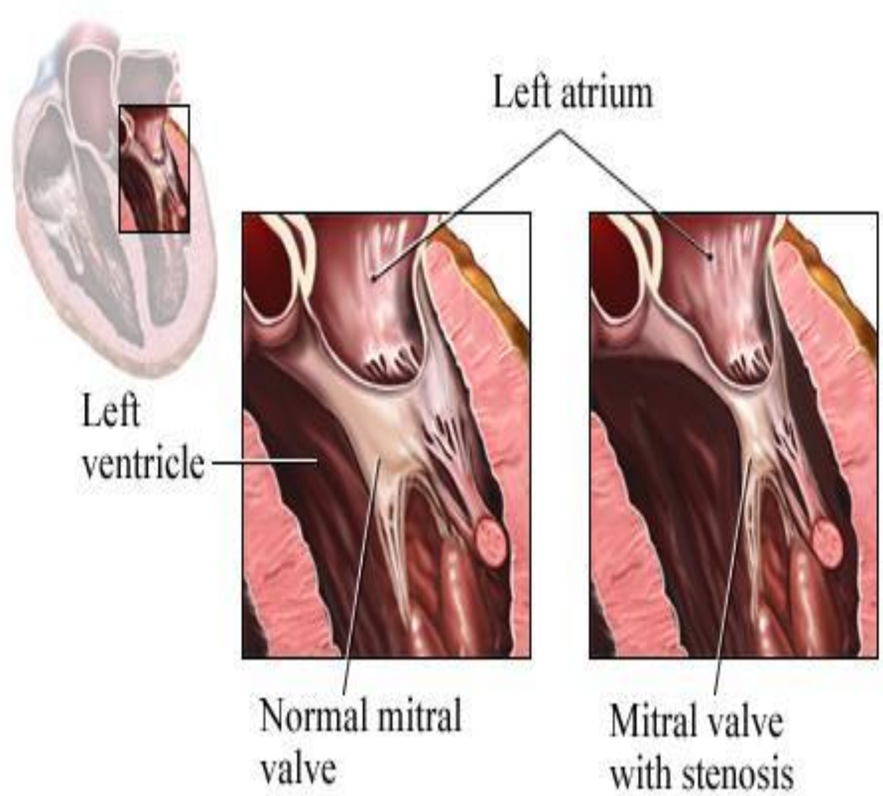

Figure 1.1 Valve with Stenosis. [8]

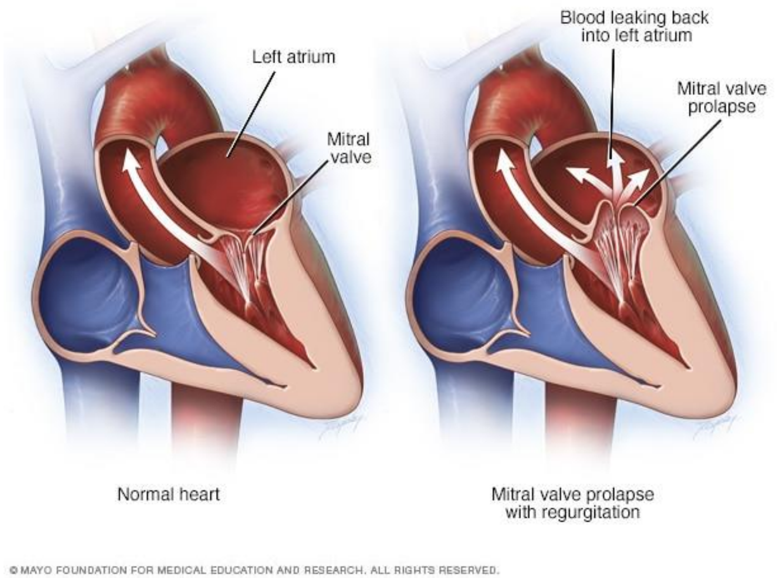

Figure 1.2 Valve with Regurgitation. [9]

1.3.2 Disease of Aortic-Valve: This the one, that occurs due to excessive calcium deposition, and it affects the aortic-valve separating left-ventricle (LV) from the aorta. This deposition can lead to development of 'aortic-stenosis', 'aortic-regurgitation', or both cases. [10]

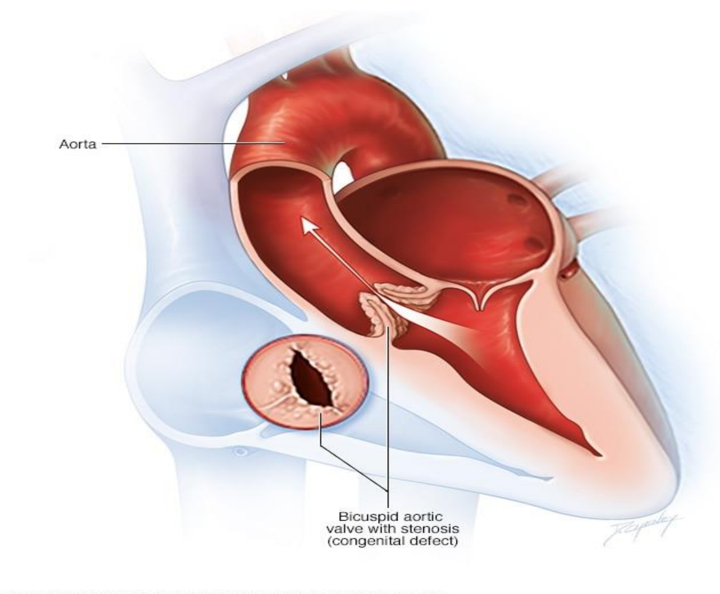

Figure 1.3 Aortic Valve Disease. [11]

1.3.3 Tricuspid Regurgitation: The Tricuspid Regurgitation includes the tricuspid valve and its separates the right-atrium (RA) from the left-ventricle (LV). This scenario normally accompanies mitral valve disease or/and aortic valve disease. [12]

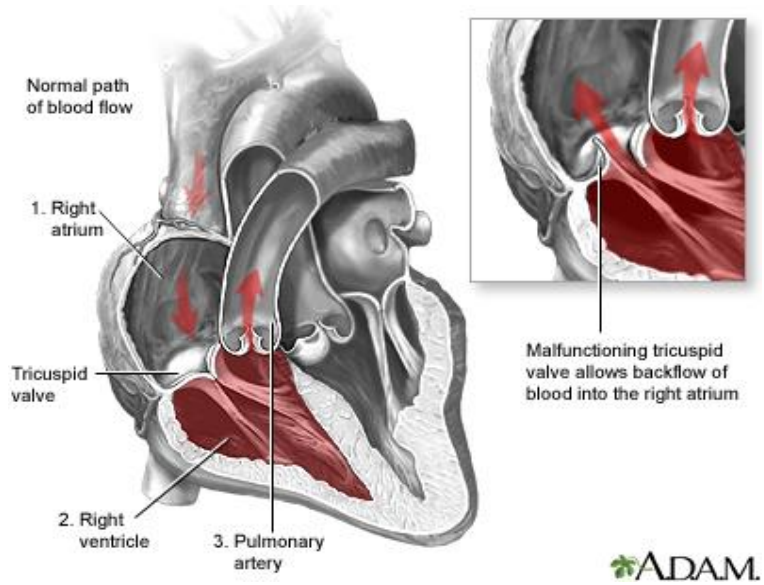

Figure 1.4 Tricuspid Regurgitation. [13]

1.3.4 Atrial fibrillation: The decreased blood flow causes the irregular or often rapid heart rate and is most commonly linked with the mitral 'stenosis. Electrical signals disturbance cause atrial fibrillation.Hypertension is the main reason behind the cause of atrial fibrillation.some people experience no symptoms with atrial fibrillation or some people are unaware until examined by the physician. [14]

Following are the symptoms of AF;

1. Fatigue
2. Feel of weakness
3. Confusion
4. Breath shortening

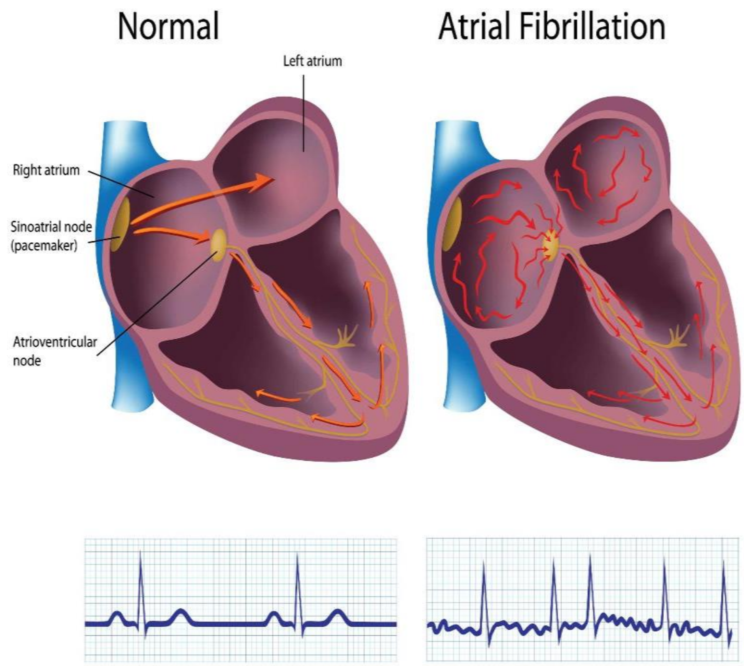

Figure 1.5 Atrial fibrillation [15]

About 2.5% of the industrialized countries suffer from valvular disease. It effects mostly after the age of 65, particularly for stenosis and aortic regurgitation. Whereas, in the developing countries, RHD is frequently detected by a systematic echocardiographic screening. In Europe, Rheumatic heart disease is representing about 25% of the valvular disease. People of age i.e. more than 65, are mainly effected by these valvular diseases. Moreover, about 31 % of the people are suffering from these cardiovascular diseases like aortic-stenosis(AS), aortic-regurgitation(AR), mitral-regurgitation(MR), mitral-stenosis(MS).

1.4 Occurance Of Valvular Disease:

The occurrence of the four valvular diseases i.e. namely,

1. Aortic-stenosis(AS),
2. Aortic-regurgitation(AR),
3. Mitral-regurgitation(MR
4. Mitral-stenosis(MS).

For the age 18 to 75 and over is shown in Figure 16.

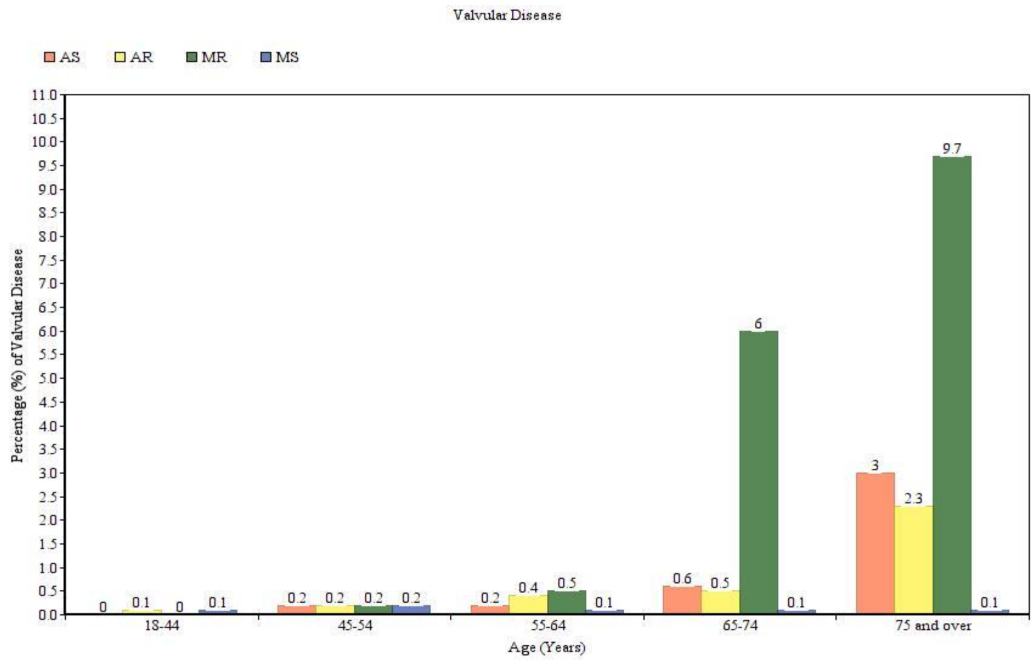

Figure 1.6 Occurrence of Valvular Disease [16]

1.5 Percentage Of Mortality By Cause:

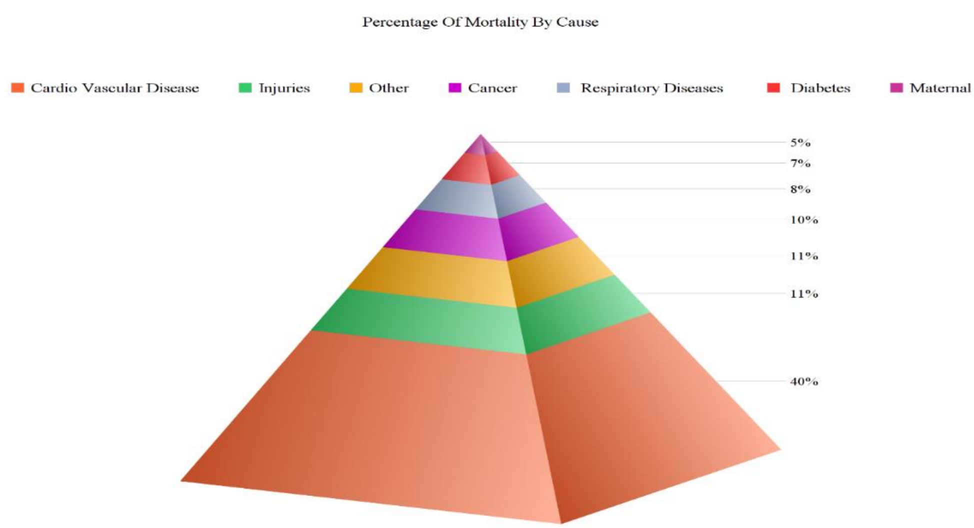

Figure 1.7 Percentage of Mortality by Cause. [17]

1.6 Complications:

Rheumatic heart disease (RHD) have many complications/problems, which may lead to heart problems and failures, which means

1. Blood is not effectively pump through the heart.
2. Heart is enlarged due to strain.
3. Other problems of rheumatic heart disease includes infected/damaged heart valves ‘infective endocarditis’.
4. Stroke may occur by clotting which is formed in heart with large size.
5. Clots may break and this result in blockage of blood vessel in brain. [18]

Rheumatic-Heart-Disease is disabling, chronic and harmful disease sometimes. It is 100% curable and preventable .Clearly, prevention is the best cure to deal a condition like rheumatic heart disease (RHD). Firstly, antibiotics are to be taken in this treatment to cure the strep throat or the scarlet fever. Both are caused by an A group streptococcal-bacteria. Once an individual is suffering from rheumatic fever, it is very important to cure further episodes. An individual with the little bit occurrence of rheumatic heart disease (RHD), continuous antibiotics treatments are required as a form of prophylactic-therapy, which is preventive. Inflammation reduction is due to steroids, aspirin or ‘non-steroidal-inflammatory-drugs’ known as ‘NSAIDs’ which may be prescribed.

Heart murmurs and heart abnormality should be annually checked by the physician for the persons who are experiencing or experienced rheumatic heart fever. If rheumatic heart disease is diagnosed , then it is very necessary to monitor the condition regularly with a diagnostic tools known as echocardiogram as these problems may worsen with the passage of time and if they aren’t examine properly, yearly or monthly , valve replacement or surgery will be required .The timing of a surgery replacement is crucial in that you want to perform the operation before the individual quality of life is badly finished but not so early as to risk the individual living longer the life-span of the artificial valve itself.

Now, this monitoring of the rheumatic heart disease is done by the device knows an echocardiogram. It uses the sound waves to develop the heart images. This mainly used test allows the doctors to check ones heart beat and blood pumping. Heart disease is identified by using the images obtained from echocardiogram. Echocardiogram is suggested by the doctors to check the following problems:

1. Check for the chambers of heart problems.
2. Check, if heart problems caused due to symptoms like breath shortening ,chest paining and congenital heart defects before birth are detected known as 'fetal echocardiogram'.

1.7 Diagnosis of Rheumatic Heart Disease:

Following are the diagnosis of this disease [19]:

1. *Physical Examination:* The heart murmur suggests that it is the disease i.e. RHD but few do not have murmur.
2. Past medical checkups should be observed including old rheumatic fever and throat issues.
3. Chest x-ray should be taken in account for knowing if the heart is enlarged or if the fluid is present in the lungs.
4. Electrocardiogram(ECG) should be done to verify if heart chambers are enlarged or if any abnormal heart rhythm (arrhythmia) is present.

Following are the Information which echocardiogram shows [20]:

1. **Change in Size of Heart:** Chambers of the heart are enlarged or the heart valve are thickened abnormally which are mainly fused valve, caused by the disease like blood pressure and damaged/weakened heart valves.

2. **Pumping Strength:** Echocardiogram includes the measurements like blood percentage. Blood pumped out of a ventricle versus blood pumped in one minute, its volume is noticed

too, which is termed to be cardiac output. Failure of heart occurs if heart is not pumping properly to meet the individual body requirements or needs.

3. **Injured Heart Muscle:** ECG assists the doctors in monitoring if all parts of the heart or walls are functioning accordingly/normally to one's heart pumping-activity. Heart wall with the areas, which move slowly due to weakness, may faulty during heart-attack, or lesser oxygen is received.

4. **Valve Problems:** Echocardiogram examines if the blood is flowing adequately through the heart valves i.e. if the heart valve are opening properly for the accurate blood flow and closing fully for the prevention of blood leakage.

In this research, our aim is to develop algorithm to reduce the valve problem by tracking the mitral valve properly. The heart valve does not open wide enough and closes fully. The proposed technique will pre-process and after segmenting the image, the proposed technique will track the mitral valve for better heart efficiency.

1.8 Motivation:

As being infected with the main infection, the symptoms does not appear too rapidly but may appear at the age of ten to twenty years old. It may kill or disable a person at their early age. It usually affects the children's of the age 5-15 years old. The study Rheumatic Heart Disease, year 1990 upto 2015," found 347500 deaths from Rheumatic Heart Disease(RHD) in year 1990 and 319400 deaths in year 2015.They make up 71% of deaths globally or in other words, it affects 33.4 million people globally. More-than 10..0 per 100,000.00 are the highest death rates estimated, which occurred in Marshal Island, Lesothoo , Fijji, Papua-new-guinea , Solomon island, Vanatua and India. In these endemic countries about 1% of the children's are suffering from rheumatic heart disease (RHD) which is very fatal and injurious to the children's and this is deduced on the lead study by an author named Dr , David Watkins .

Also, the cost of average surgery is much above than (US$ 25,000) than the primary prevention or the secondary prophylaxis to reduce recurrence of ARF using the penicillin (which is US$ 50 per person).

The main aim of this research is to design an algorithm, which can track the mitral valve leaflets. As a result of this research, the heart disease can be diagnosed and cured on time by early detection of abnormal mitral valve. Hence, the death rate can be reduced and precious lives can be saved.

1.9 Problem Statement:

Acute Rheumatic Heart disease leads to the thickening of the mitral valve leaflets, which in turn leads to damage the heart valve, heart enlarge and stroke. That occurs due to clot formation in the heart (enlarged) or injured valves. The tips of the mitral valve leaflets fuses in Rheumatic Heart Disease. The echocardiography make use of sound waves to make images of heart. This allows examining the blood pumping and heartbeat.

Therefore, the main aim of the work is to design a complete framework to identify and track the (fast moving) leaflets. The task is mainly attentive towards Anterior-Mitral-Leaflet(AML) tracking.

1.10 Scope:

The highest percentage of diseases are due to heart and circulatory disorders. Due to this research, it will become possible to detect any irregularity in heartbeat/ heart sounds waves and thus the patient can be sent to doctor on time and lives could be saved by giving treatment on time providing early detection of heart attacks. It can be very helpful in the developing countries like Pakistan especially in the rural area where there is lack of cardiologists and equipment required for the diagnosis of rheumatic heart diseases is available. Therefore, the development of a method to track the valve is critical requirement. This research will help in designing a system that can be part of to improve the health facilities in backward areas of Pakistan.

1.11 Objectives:

The main objective of this thesis work is to track the AML throughout the cardiac cycle in 2D echocardiography video. The conducted literature review in chapter 3 has revealed that;

1. The Anterior mitral leaflet and its neighbor regions such as the (‘myocardium’, ‘papillary muscles’, ‘septum etc). All these share almost the equal texture and contrast which result in no discrimination of features and it would be very hard to distinguish one structure from the other.
2. The AML (anterior mitral leaflet) shows very fast movement. It has an irregular deformation, which makes it very difficult and challenging problem for already existing methods to track its location.
3. The Existing Algorithms needed excessive parameters adjustments, leading from under and over segmentation of the fast moving leaflet. Such condition is very incapable to recover from the failure .

Therefore, the objective is;

1. To formulate an algorithm to track those fused fast moving leaflets in echocardiographic sequence.
2. To track the fast moving mitral valve leaflet to assess Heart Efficiency.
3. To provide aid to doctors in the diagnostics process.

1.12 Chapter vise Thesis-Structure :

Thesis report is organized in the following way.

Chapter 2 explains clinical background in detail. It presents circulatory system, structure & function of heart, Cardiac Cycle, Mitral valve and types of Mitral Valve diseases.

Chapter 3 presents the detailed systematic review of present state of the art techniques used for tracking mitral valve and research already done in this area. It discusses different types of methods used for segmenting and tracking the fast moving mitral valve leaflets.

Chapter 4 explains the complete methodology adopted to solve the problem highlighted in problem statement and to achieve the objectives. It presents complete flow of the proposed methodology and detailed explanation of algorithm according to each phase.

Chapter 5 presents the detailed result and the proposed methodology. The results are shown with the help of figures.

Chapter 6 states the summary of thesis and the future work that can be done in order to further improvise and extend this research.

CHAPTER 2: CLINICAL BACKGROUND

Such chapter defines medical terms for the better understanding of the Rheumatic heart disease and its consequences on the heart valve. RHD broader view is presented in this section to understand the pathologies of heart valve. Rheumatic Heart Disease and the role of echocardiography screening is discussed below.

2.1 Circulatory System :

The circulatory system [21] allows blood circulation and nutrients transportation to and from cells in the body. It is a massive system containing organs and vessels. It is responsible for transport of blood, oxygen, nutrients (electrolytes and amino acids etc.), carbon dioxide and hormones from and to cells. It provides sustenance and protection to the body and aids in its fight against diseases. Circulatory system is responsible for maintaining proper internal pH through bicarbonate ions acting as buffer solution and temperature of body via blood flow control through skin. The circulatory system often comprises of two independent systems; lymphatic and cardiovascular systems that works together [22].

The lymphatic system involves the circulation of lymph through the body. The path of lymph is larger than path of blood. Lymphatic system is composed of lymph, lymph vessels, lymph capillaries, lymph tissues and lymph nodes. The excess blood plasma that is filtered from interstitial fluid is known as lymph, which is transported back to lymphatic system.

The cardiovascular system involves blood circulation through the body and its important components are heart, blood vessels and blood [23]. Blood consists of red blood cells(RBC), plasma, white blood cells(WBC) and platelets. The heart through the network of veins and arteries pumps the blood. Almost 4 to 6 litters of blood are present in an adult person. Blood comprises of 7 percent of entire body weight. Cardiovascular system is responsible for the sustaining appropriate blood pressure. There are two types of circulation: Systemic circulation and pulmonary circulation. The systemic circulation includes the circulation of oxygenated blood to the body while pulmonary includes the path of blood inside lungs for oxygenation. In systemic circulation, the oxygen-rich blood is transported from heart to service the every cell of body and comes back to heart via vast network of arteries, veins and blood vessels. The pulmonary circulation transports deoxygenated blood to lungs from heart via pulmonary artery and oxygenated blood to heart from lungs via pulmonary veins. The Circulatory system with pulmonary and systemic circulation is shown in Figure 9. The circulatory system is most vulnerable to diseases than any other system in the body due to its hugeness.

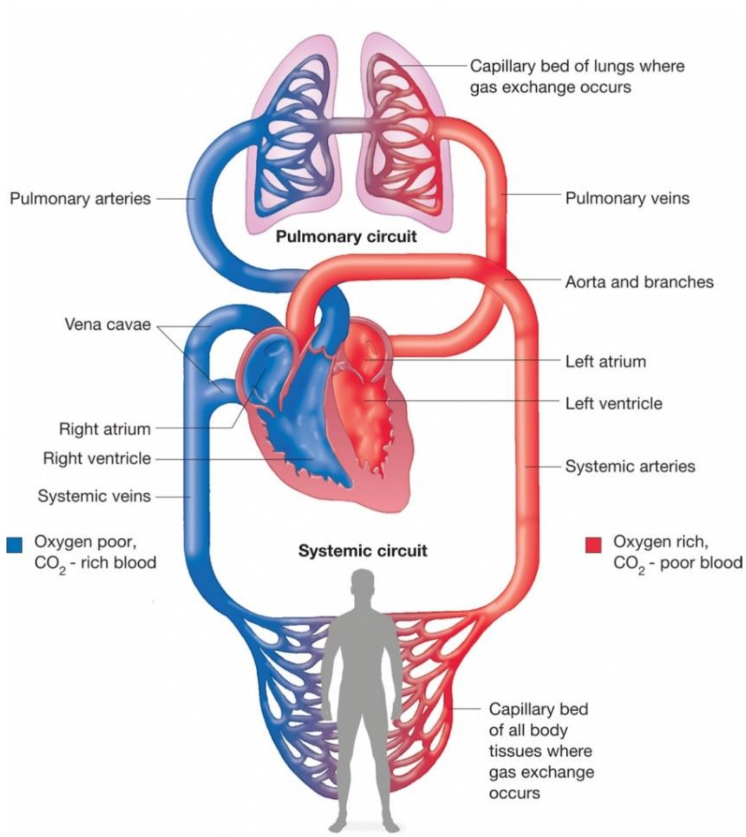

Figure 2.1 Circulatory system with pulmonary and systemic Circulation. [24]

2.2 Heart:

Heart acts as a pump and it is the main organ of cardiovascular system. [25]. Oxygenated blood is transferred to the body and deoxygenated blood is supplied to the lungs. It acts as double pump i.e. left and right side of heart purposes as separate pump. Heartbeat is created by concurrent pumping action of both sides of heart. The heart is a muscular organ, which is present in middle of chest, between lungs within thoracic cavity [26].

The heart has four chambers namely:

1. Lower left ventricle
2. Lower right ventricle
3. Upper left atrium
4. Upper Right atrium [27].

The location and chambers of heart is shown in Figure 10. The deoxygenated blood comes in to the right atrium from veins and passed into right ventricle to be pumped to lungs for removal of carbon di oxide and oxygenation. The oxygenated blood from lungs is pumped into LA and passed to LV, from where it is pumped to different organs of body through aorta. Contraction of left ventricle allows the blood pressure to be created. These four chambers are separated by the valves.

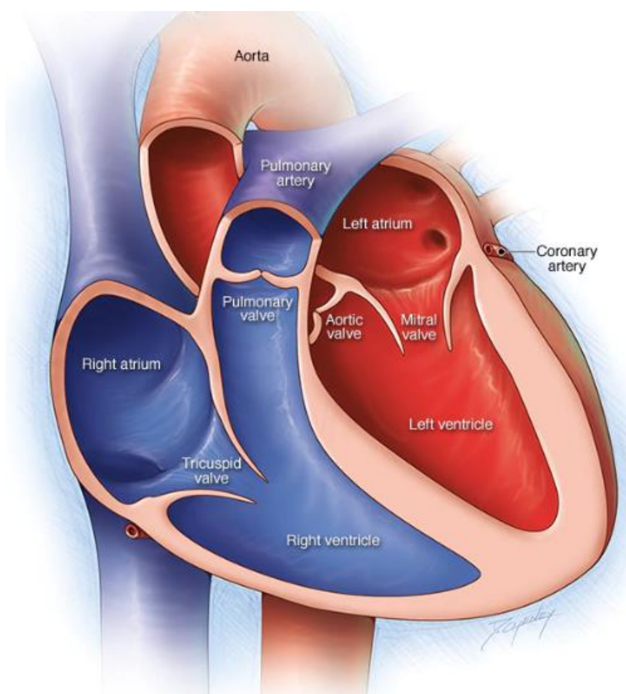

Figure 2.2 Heart Chambers. [28]

The atrio-ventricular valves is present between ventricles and atria. The tricuspid-valve is present between RA and ventricles. In-between LA and ventricle, mitral valve known as bicuspid valve is present. Heart wall comprises of three layers [29].

1. The Inner Layer known as Endo-cardium.
2. The Middle Layer. known as Myo-cardium.
3. The Outer Layer. known as Epi-cardium.

Myocardium or the middle layer of heart contain cardiac muscle tissue [30], which has two types of cells:

1- The Muscle Cells – Can Contract Easily
2- The Pacemaker Cells – Conduction System

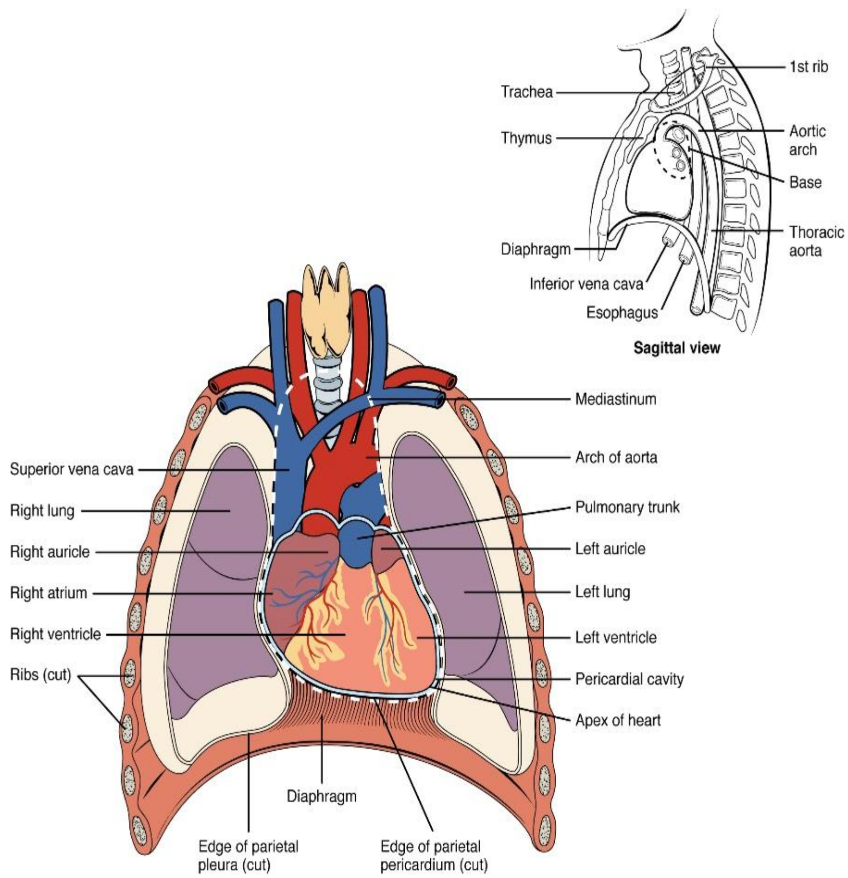

Figure 2.3 Position of Heart between Lungs within Thoracic Cavity. [31]

2.3 Cardiac Cycle:

Such cycle is absolute heart beat which comprises of electrical and mechanical events, that are repeated with all single heartbeat. The blood is circulated via systemic and pulmonary circuits as the heart beats. The atria and ventricles coordinates with each other for blood to be pumped efficiently. Complete cardiac cycle with the condition of valves is shown in Figure 12. It included two phases [32]:

1. A Systole termed as Contraction Phase.
2. A Diastole termed as Relaxation Phase.

Systole is contraction of atria or ventricles whereas diastole is relaxation and filling of ventricles or atria with blood. During systole, blood is pumped out of heart to the arteries whereas the blood is transferred to heart in diastole.

2.3.1 Systole:

Systole period represents the contraction of right and left ventricles and discharge of blood into aorta and pulmonary artery, which is allowed through the opening of aortic and pulmonic valves while the atrioventricular valves remains closed during systole period to prevent the flow of blood into the ventricles.

2.3.2 Diastole:

Diastole represents the relaxation of left and right ventricles and flow of blood from LA and RA into the LV and RV accordingly. The blood runs through the mitral and tricuspid valves. Blood from body is received by RA whereas LA gets the blood from lungs after oxygenation. Left and right atria contracts at the end of diastole period pushing an extra amount of blood into ventricles.

Frequency of cardiac cycle is known as heart rate, which is expressed in beats/minute. An adult have a normal heart rate i.e. sixty to hundred beats per minute.

Heart generates the electrical activity as a result of which atria and ventricles contract. It causes blood to be forced between heart chambers and throughout the body. Opening and closure of valves produces the vibration, which shows the condition of heart.

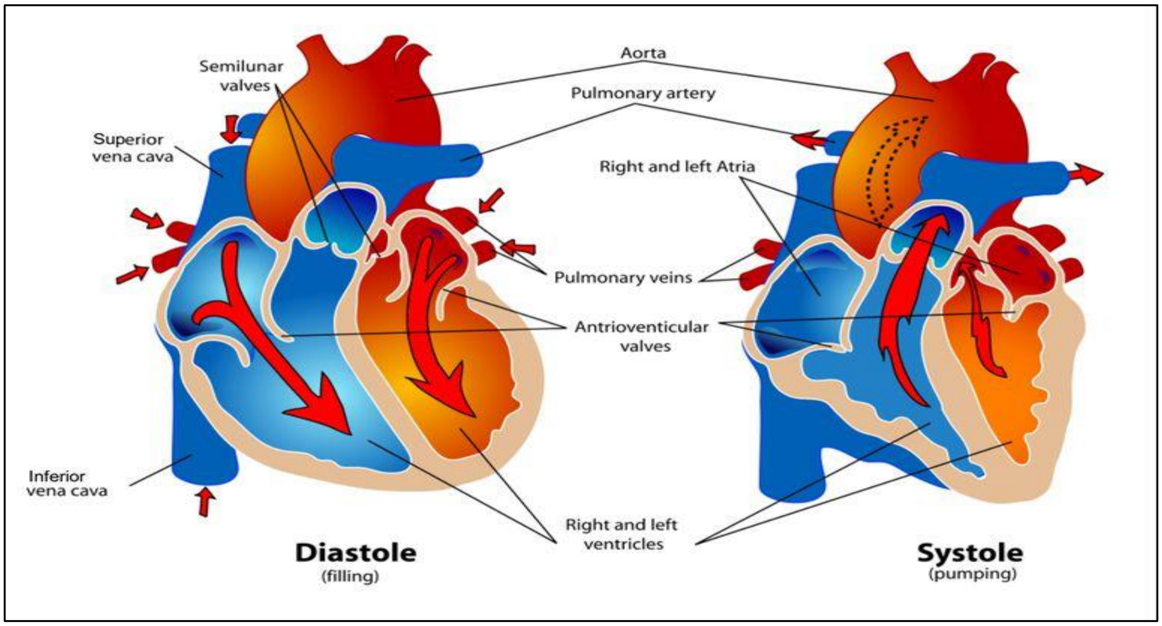

Figure 2.4 Condition of heart during Diastole and Systole period of Cardiac Cycle. [33]

Where as the opening and closing pattern of Mitral, aortic valve Vs aortic, atrial and ventricular pressure is shown in the figure below ;

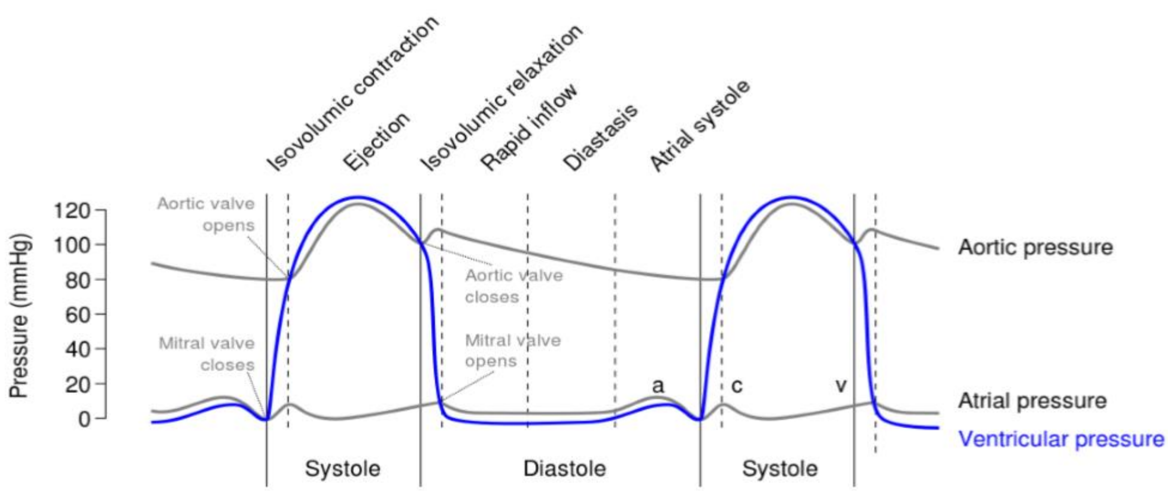

Figure 8.5 Cardiac events: systole and diastole, opening and closing pattern of Mitral, aortic valve VS aortic, atrial and ventricular pressure. [34]

2.4 Anatomy and Dynamics of Mitral valve:

Mitral valve lies between LA and LV i.e. left heart chambers. It covers an area of 4 – 6 cm2. The anatomical structure of the valve is very complex and it consist leaflets,

1. Annulus.
2. Papillary Muscles (PM).
3. Tendinea.

The Papillary Muscles are projections like finger, which are originated from the Left ventricular myocardium, from both anterolateral and posteromedial sections. Papillary Muscles tips are connected with inelastic chordae tendineae that support the mitral valve leaflets and are arranged to form a ring. Leaflets combined structure and annulus consist of the anatomical junction, which connects LV and LA. Its functionality is affected with the passage of time i.e. age.

Human's mitral valve leaflets have similar eyelid like appearance. However, the anatomy of the leaflet may varies from person to person. It consist of two leaflets, which totally differ, in structure and all. The two thin leaflets namely AML and PML are known as anterior-mitral-leaflet and posterior-mitral-leaflet. AML is semicircular in shape. It is a long leaflet. Whereas PML is shorter and its shape is quadrangular. Tendons are attached with the leaflet and it prevents them from collapsing. The anatomy of the mitral valve is shown in figure 14.

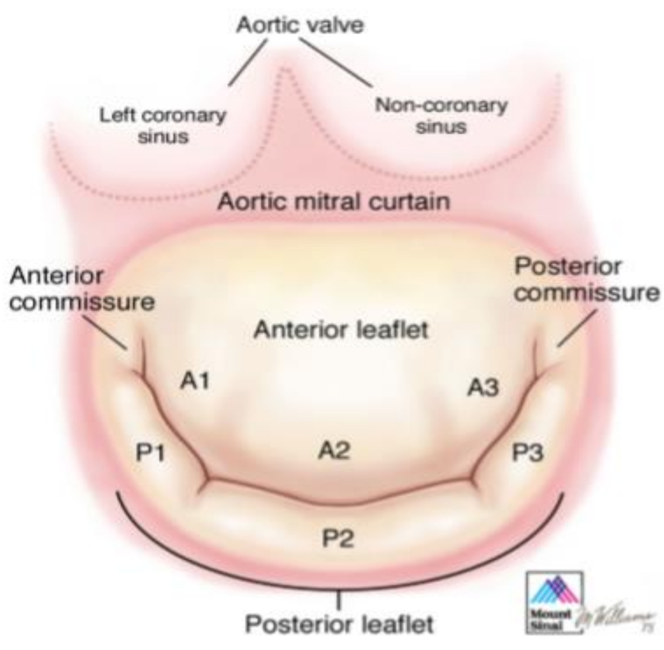

Figure 2.6 Mitral Valve Anatomy. [35]

2.5 Pathologies of the Heart Valve:

The Heart valves controls uni-directional blood flow. In pathological cases, the heart valves suffers two malfunctions namely,

1. Regurgitation
2. Stenosis

2.5.1 Regurgitation:

In this condition, the valve flaps do not shuts properly and hence causes the blood to flow back into RA of the heart. If it is not handled, then this may damage the muscles of heart. This condition is commonly caused by mitral valve prolapse, in which the leaflets bulge back into the left atrium as your heart contracts.

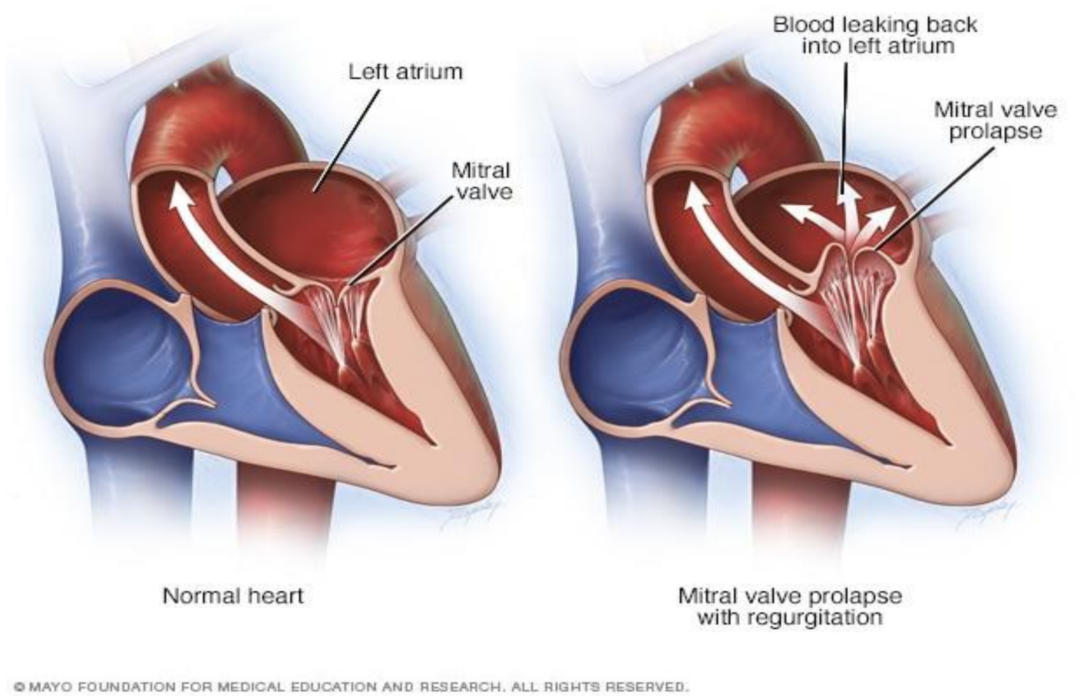

Figure 2.7 Mitral Valve Regurgitation. [36]

2.5.2 Stenosis:

In Stenosis, the flaps thickens and become stiff. They may fuse together. Thus narrow valve opening leads the reduction in blood flow from LA to LV.

Such disease treatment mainly depends on how worsen the condition is .Whether it is controllable or not. Doctor can suggest having a surgery for repairing the valve or replacing it.

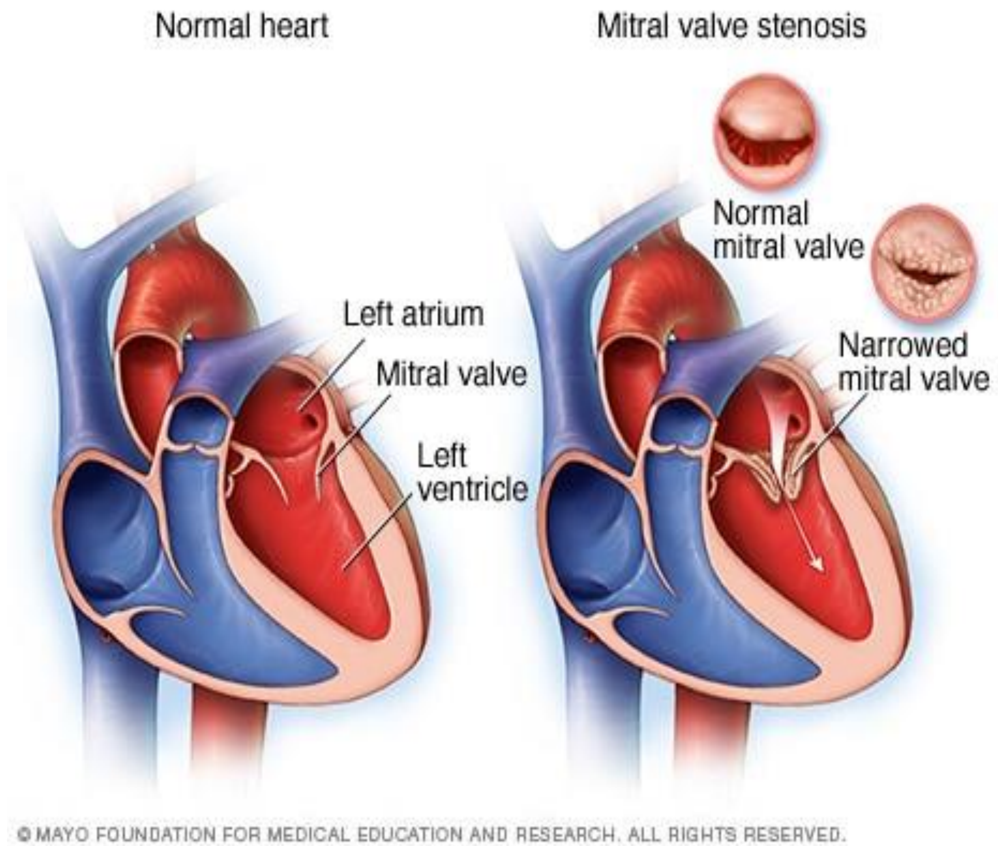

Figure 2.8 Normal and Stenosis. [37]

The cause behind this stenosis is as below.

2.6 Causes of Pathologies of the Heart Valve:

As , heart has four valves which keeps the blood to flow in correct direction. These valves includes

1. Mitral valve
2. Tricuspid valve.
3. Pulmonary valve

4. Aortic valve.

Each valve has cusps that open and close once during each heartbeat. Sometimes, the valves do not open or close properly thus disturbing the blood to flow through your heart to your body.

2.6.1 Cause of Mitral Valve Regurgitation:

The issues related with the mitral valve cause it. It is also termed as primary mitral valve regurgitation. Mitral-valve-regurgitation is often caused by the prolapse, in which the leaflets bulge back into the LA.

2.6.2 Cause of Mitral Valve Stenosis:

It is mostly caused by the fever known as rheumatic fever, which occurs due to the strep infection that can affect the heart.

2.7 RHD :

Rheumatic heart disease(RHD) is caused by a serious issues of Rheumatic fever. It is a damage to one or more heart valves. Chronic heart valve is damage due to this rheumatic fever .This disease is caused by group A streptococcus .It is found on pharynx and on the skin , as shown in the figure below. Acute Rheumatic Fever leads from a streptococcus infection.

The main symptoms are ;

1. Slightly fever.
2. Pain in joints.
3. Tirednes .
4. Bleeding from nose.

In few cases, fever may reach 40◦C and continues for many weeks. Person suffering from rheumatic fever is at chance of 50-60% of affecting with RHD. About fifty to sixty-five percent of the patients are at risk of developing. Frequent Rheumatic heart disease weakens the heart valves [38].

With the passage of time, the inflammation and healing process stiffens the heart valves and leaves scars that thicken these valve leaflets. Because of this damage, the heart valves may become pathological, causing blood to leak from the closed valves or restricting the flow of blood. No method has been discovered to cure it directly, only its reoccurrence can be controlled. Penicillin is prescribed in case any streptococcal infection is found. Its swelling and pain can be reduced by using along other medicines . [39]

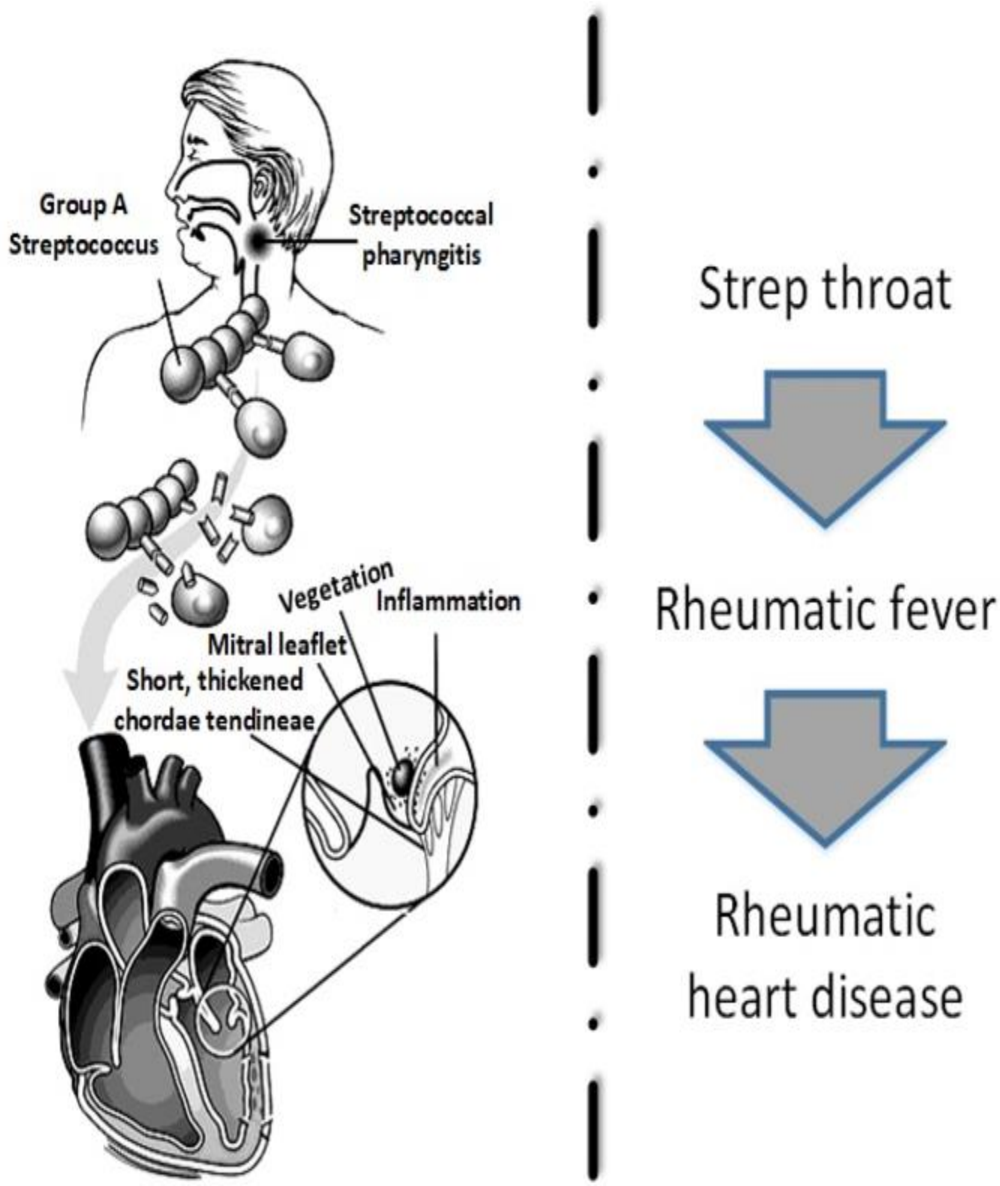

Figure 2.9 Repeated episodes of ARF and the mitral valve damage. [40]

2.8 Role Of Echocardiography Screening:

Echocardiography termed as echo test, takes “moving pictures” of the heart with sound waves. This common test allows the doctor to check ones heart beat and blood pumping. Shown in figure 18. [41]

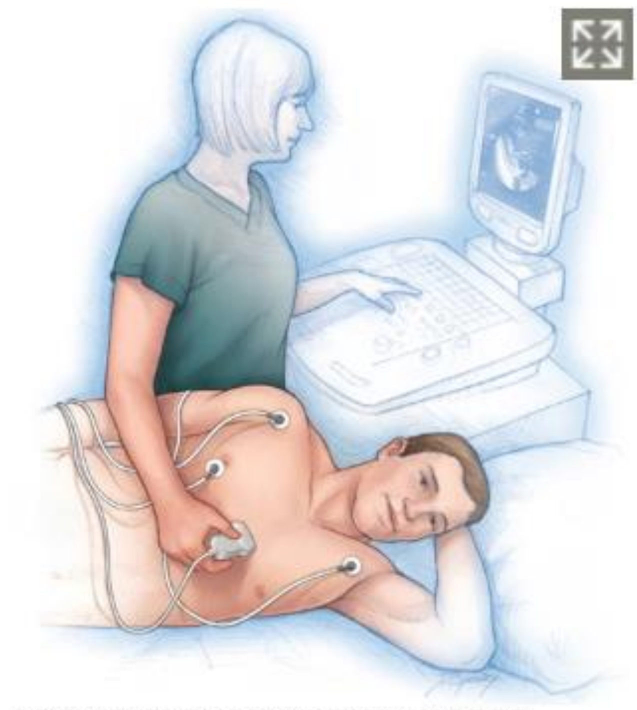

Figure 2.10 Echocardiography [42]

2.8.1 Types of Echocardiogram:

There are different types of echocardiogram. Namely;

1. Transthoracic.
2. Transesophageal.
3. Doppler.
4. Stress.

2.8.1.1 Transthoracic Echocardiogram:

In this procedure, the technician used to spread the gel on a device, which is known as transducer. Sonographer presses it softly and firmly on the skin. Its aim is to pass an ultrasound beam through the chest to one's heart. Transducer copies the sound wave echoes of one's heart and then the computer converts those echoes into the moving images which are seen on the monitor.

2.8.1.2 Transesophageal Echocardiogram:

Transesophageal echocardiogram is used for images that are detailed required and it takes a fine snap of heart with an echocardiogram.

This procedure includes the following steps

1. Throat is numbed and this is done by giving some relaxing medicine.
2. A flexible tube is put inside the throat and that tube is a transducer and it is passed through the mouth to the stomach knows as esophagus.
3. This transducer now records the sound waves i.e. echo's from the heart.
4. Now the computer convert the echo's into the moving images of the heart and can be seen on the monitor.

2.8.1.3 Doppler Echocardiogram

As sound waves changes the pitch whenever it bounces off the blood cells, which are in motion by the blood vessel and heart. Such changes can may guide the doctor to calculate the direction and hence the speed of blood flow in the heart. Blood flow problems are also checked by Doppler echocardiogram and checks the blood pressure in the arteries of one's heart .The blood flow is colorized and is displayed on the screen of monitor and doctor can easily pinpoint any problem if any.

2.8.1.4 Stress Echocardiogram

Few heart issues occur while the physical activity is carried out and those particularly involve the arteries which supply blood to the heart muscle. Coronary artery problems are checked by this stress echocardiogram .Whereas, this echo couldn’t provide any information regarding heart arteries blockage.

In such ECG:

1. Ultrasound image of one’s heart are taken before and immediately after any walk.
2. And if one person is unable to exercise then he is given some injections so that his heart pump as fast as during exercise.

Now, the next chapter presents the literature review of tracking and segmentation of mitral valve leaflets. Already proposed and used techniques have been discussed in the next chapter.

CHAPTER 3: LITERATURE REVIEW

Medical image processing is much popular and play a vital role in automated diagnosis of different diseases. Echocardiography assessment of cardiac valves is an example of medical image processing. Tracking of cardiac valves from echocardiography sequences plays very important role in diagnosis of Rheumatic Heart Disease. Since it delivers valuable information about heart condition and helps in disease detection to save precious lives. In most cases, mitral valve becomes pretentious. It leads to thickness of the leaflet that may result in the merging of the tip. This modifies their appearance and reduced leaflets motion, thus decreasing the efficiency of heart. Assessing such constraints offers diagnostic insight. Detection of Rheumatic Heart Disease at early stage is considered vital because disease does not occur at first stage, therefore the disease progression can be controlled.

Various image modalities are available to assess heart condition. One such modality is Echocardiography. It is a low cost, non-ionizing and non-invasive method; therefore, it does not involve insertion of any instrument inside body. It can provide real time analysis and tracking of rapidly moving structures. Echocardiography is very beneficial for diagnosis of cardiac diseases due its portability and thus can be used in backward areas with low health resources where specialist doctors are not easily accessible. Early evidence can be provided by echocardiography through which suspected case can be confirmed and can be treated accordingly.

Such mitral valve analysis can be done via identification on tracking of rapidly moving leaflets. Tracking of mitral valve can be done via different techniques suggested by literature. Some of the most recent used algorithms and advancements in this field is summarized in this chapter.

Remnyi et al. [43] describes guidelines for echocardiographic diagnosis of RHD. It defines three classification of RHD i.e. 'definite RHD', 'borderline RHD', and 'normal' on basis of evaluation in 2-Dimensyion i.e. continuous wave, and Color Doppler echocardiography. Rheumatic Heart Disease is further divided into three sub categories to reflect numerous disease patterns. He also found that mitral valve damage was prevailing with or without the involvement of three valves. The morphological features of valves can be evaluated using echocardiography such as thickened, fused, excessive leaflet tip motion and restricted leaflet motion. According to literature, most suitable view to access mitral valve is the Parasternal Long Axis (PLA) [44]. For measurement of these features, firstly, Anterior Mitral Leaflet (AML) is segmented and then tracking is done during full heart cycle.

3.1 Echocardiography Segmentation:

Partitioning a digital image into many regions is known as segmentation. Every region has some properties or the characteristics, like colour and intensity. Segmentation purpose is to make an image easier to quantify and analyze. In image analysis, segmentation is the first step and the image segmentation directly affects the results.

Thresholding is the low-level segmentation, which reduces the amount of data to be process, which results in loss of important information. It is not sufficient to get a robust segmentation as due to low quality image and noise. So high level techniques were used which include shape models, or active appearance models are more adequate for the medical images. They are sophisticated but in addition, they are computationally expensive.

Deformable models are also known as active-contour-models or known as snake. They were proposed by firstly Kass et al. [45]. It was thoroughly studied and used for the medical image segmentation [46] These contour models are further divided into two classes

1. PAC termed as Parametric Active Contours .
2. GAC termed as Geometric Active Contours.

In this section, fundamental concept of each model has been described;

In [47], Kaass et al. presented an repetitive minimization of energy method in which parametric contours change below influence of image forces. Its shape is controlled by an internal constraint. Such contours model is identified as snakes, that offer foundation for automatic/semiautomatic image segmentation and motion tracking. This algorithm also have various disadvantages like convergence and initialization. It encouraged the researcher to make such numerous methodology to develop the standard snake. The main limitation of this work lies with the image energy that has a limited capture.

Cohen et al. [48] presented a model with term as balloon force. It is a constant force, that push the snake points both inside and outside. Such new model reduced the dependency on the initialization. The pressure force [49] was introduced in the external energy term of the original snake. This ballon force model was to overcome the limitation of the initialization close to the object boundaries.

Balloon force model has some limitations which were further improvised in gradient vector flow model .The limitation of weight of the pressure force, that may overwhelm the curve at object boundaries with low gradient magnitude. The (GVF) [50] proposed to improvise and converge the curve into concave regions and to capture the range both inside/outside object of interest, The Gradient vector flow also replaces the external energy in the main snake model.

PAC models introduced in the previous sections, independently model the curve motion. In this section, curve motion is implicitly shown by the level-set .The concept was introduced by Sethian and Osher [51] . This concept is based on curve evolution. Later, it was applied for segmenting the image by Caselles et al. andMadlladi et al [52] [53].

To diminish the object boundary curve, Caselles et. al. [54] made a speed function F that incorporates both the the curvature information and image.

Active contours which are edge based, they are very sensitive to noise and they fail in finding the object boundaries for the noisy image. Chan and Vese [55] found a new Way that make the use of the region properties to stop the curve at the object boundary, with in a GAC framework.

In [56] Williams and Shah suggested an algorithm known as greedy snake which calculates the motion of every snake point on the plane of image using a distinct approach instead of calculating overall snake at one time. Researchers have also used Gradient–Vector-Flow energy. It minimized the dependence on initialization by enhancing the attraction range of the classical snake, Closed contours were also extensively used by researchers in segmentation and tracking of medical imaging applications, however open ended contours were rarely used for linear features like detecting coastline and variations from satellite images. [57]. Fixed and/or no boundary conditions were employed depending on the nature of the application. Closed contours are robust towards noise present in image. They have shape fragmentation and can track non-rigid movements. They are capable to integrate geometric constraints like shape [58].

Medical images consist of a heterogeneous intensity profile images i.e. ultrasound images. In some scenario, real object boundaries are not represented by region based active contour, based on global intensity statistics. Lankon et. al. [59] had noticed that object in the heterogeneous images has different intensity levels than background image along the object boundary, If it is locally analyzed. Based on the above assumption, the author propose a framework that computes the interior and the exterior regions locally along the contour.

3.2 Echocardiography Tracking:

In [60], an automated and unsupervised methodology for detection and tracking of mitral leaflet was presented and it was based on the outlier detection .The detection was done in a low rank matrix. The proposed methodology was tested on 2D&3D ultrasound. However, this methodology has limitation due to its high computational cost, requirement of parameter adjustment and its sensitivity to rank.

Another method for tracking the Anterior-Mitral-Leaflet (AML) is presented [61]. The proposed method employs open-ended active contours via eliminating its boundary conditions. Snake energy is improved and encourages the leftmost end point of the contour to converge on the moving tip of the AML, which modifies the external and internal energy of the contour extending the capture range. The proposed algorithm tracked contour points precisely with an average error of 4.9 pixels and a standard deviation of 2.1 pixels in 9 fully annotated normal sequences of real children clinical assessments.

A real-time and semi-automatic tracking algorithm of mitral valve in ultrasound video is proposed in [62]. The ultrasound videos contain parasternal view of mitral valve. In first frame, Anterior Mitral Leaflet is segmented manually and then tracking is done using mathematical morphological algorithms further defined by active contours for whole heart cycle. Lastly, quantitative analysis is done through medial axis extraction. Proposed algorithm was able to successfully segment frames with mean error of five pixels. The algorithm was robust in most difficult situations with large frame-to-frame displacement.

In [63], method is proposed for the detection of the AML in every frame. It uses only one point that is specified by the user on the posterior wall of the aorta and it is taken as the input in the very first frame. Virtual M-mode is used to transform echocardiographic videos into new image space. It transforms original image over scanning lines, which is estimated automatically. New space provides motion pattern of aorta's anterior and posterior wall and left atrium's posterior wall. Moreover, it also provides structures location in each frame, which is then used for initialization of active contours, followed by anterior mitral leaflet segmentation. Results shows the identification of AML.

Such methods based on active contours are not fully automated and require initialization of parameters before detection. User provides inaccurate contour, it will affect accuracy of tracking and will prolong tracking process. It also shows poor performance in noisy video sequences. To overcome this issue [64] proposed a strategy based on Artificial Bee Colony (ABC) approach. It provides better tracking results in noisy environment. This approach is faster than Active contours method and does not require initialization of tracking parameters. This technique is fully automated and cancels time delay due nonexistence of initialization parameters.

Even though the research on segmentation of anterior mitral valve leaflet have been technologically advanced, still the accurate identification of valve location is challenging and exciting task and research margin is available. It has many applications in deep learning and provides excitement and inspiration for deep learning scientists.

Due to incorporation of noise during acquisition process, the echocardiographic sequences are likely to be corrupted and the identification of heart valve become problematic job. Next chapter explains the methodology opted in order to improve the identification and tracking of anterior mitral valve within echocardiographic sequences while addressing the problems mentioned above.

CHAPTER 4: PROPOSED METHODOLOGY

This chapter explains the complete proposed methodology adopted for accurate tracking of mitral valve leaflets in echocardiographic sequence. The methodology aims to improve the heart efficiency by tracking the mitral valve leaflets, which may result in fused tips due to rheumatic heart disease. Flow Diagram of used scheme is represented in Figure 18.

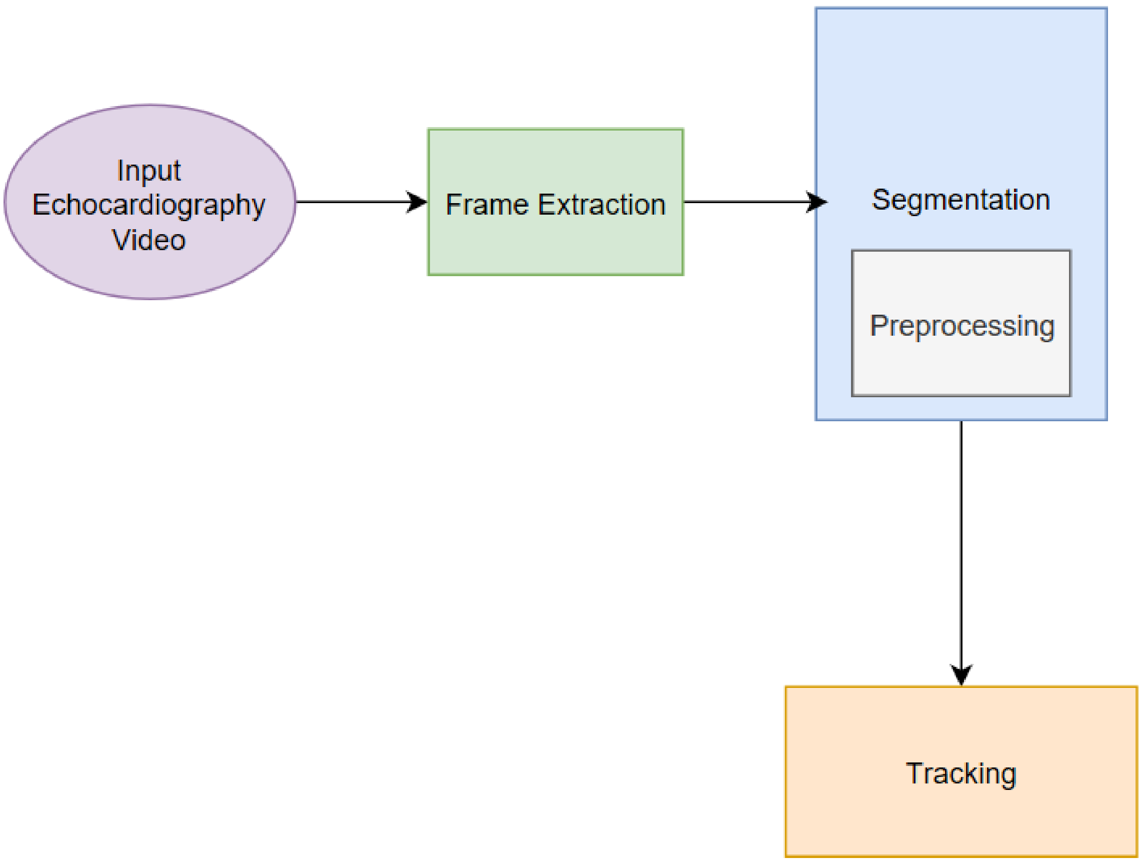

Figure 4.1 Generic Proposed Methodology

Where a data set of ultrasound videos is obtained from Real Hospital Portuguese. Frames of every individual video are extracted and after extracting the frames, image pre-processing has been done to further improvise its contrast and other features as discussed below.

4.1 Material:

The first step in the proposed algorithm is getting the videos of the echocardiography. The ultrasound videos of mitral valve are collected from the activities of Real Hospital Portuguese. It is located in Recife, Brazil. The dataset consist of the five different movement of mitral valve videos i.e. ultrasound mitral valve videos .These videos has been gathered for the purpose of monitoring and screening the Acute Rheumatic fever(ARF) in children. The data was collected using a M-Turbo model by SonoSite Ultrasound system, with C11x transducer (five to eight MHz).

There are total five videos of the echocardiography in mp4 format file. These videos are mainly focused on the heart area, near the aortic valve .These videos represent the monitoring of the heart valve (mitral valve) i.e. it’s functioning. For better observation, Mitral valve’s parasternal long axis view has been observed in the videos of the data set.

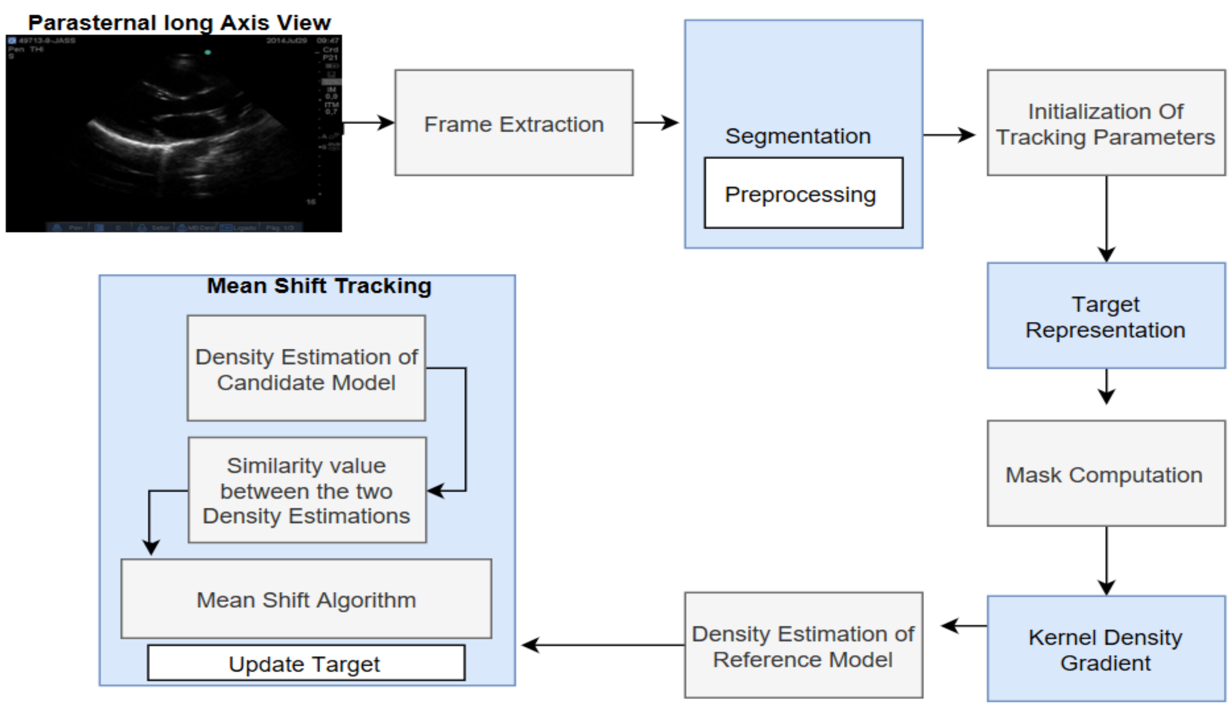

Figure 4.2 System Level Diagram of Proposed Methodology.

Firstly, the videos are imported from the ‘Videos folder’ and frames are extracted from them. As, five different mitral valve ultrasound videos has been tracked , so frames are extracted for every five individual mitral valve videos. These five echocardiography videos consist of total 819 frames. The description of video files along with their frames has been shown below;

Table 4.1. File Name and Frames.

Video Number	**Total Number Of Frames**
49653	131
49754	131
49760	360
49881	66
49713	131
Total : 5 Files	**Total :819 Frames**

All these videos are of different lengt , so they consist of different frames extraction too. After frames extraction the next process is pre-processing on the mitral valve leaflet.

4.2 Pre-Processing :

Preprocessing is an improvement of the imaged data that suppress the unwanted distortion or modifies important features for further processing. As the videos of the mitral valve need to be enhanced, So the initial frame is pre-processed first and then the next step is carried out. The preprocessing has been done on the image to converted it also into the binary image at the end.

In the preprocessing step, firstly the frame image is converted to double i.e. convert the extracted frame image to double the precision. Then image is filtered with the Gaussian-smoothing and has a standard deviation specified by sigma. This sigma is a scalar in this work and a square Gaussian kernel is used to smooth the mask. Now the grey thresholding is done on the image i.e. global image thresholding using Otsu method .It computes the level, global thresholding that is used to convert the image to binary. So till now, we have preprocessed the mask frame for a better tracking result.

For further preproceesing on binary image , the tiny objects from the binary image has been removed from the image .The concerned components namely objects that are fewer than the pixels P are removed from the binary image and produces a new binary image .In our case the pixel less than hundred are removed . Then the image is complemented i.e. its complement is taken which mean white pixels become black and black pixel become white.

Then the next step is to add the morphological structural elements with a disk radius. The morphological filtering of the image (binary image) is taken into account using compound operation i.e. opening and closing as the filters. Filters of shape can be considered in this case. i.e. opening with the disc structuring smoothens the corners from inside and similarly closing the disc smoothens the corners from outside too. This is done in the preprocessing phase after the eroded and dilated imaging is done. Eliminating noisy details but not object of interest is the interest, which is done by the size of structural element.

These preprocessing steps has been applied on every individual mask for the individual five ultrasound mitral valve videos . The mask obtained after the preprocessing is a segmented mask .

4.3 Image Segmentation:

Segmentation is partitioning a digital image to many regions. Every region has some properties or the characteristics, like colour and intensity. Segmentation purpose is to make an image easier to quantify and analyze.

In image analysis, segmentation is the first step and the image segmentation directly affects the results. The earlier methodology used to segment an image using active contour , shape based active contour and many other. All these methodologies has been discussed in the section literature review .These methodologies required a good contrast videos, whereas in our case we have low contrast ultrasound videos. The Doppler characteristics of these echocardiography videos does not create the high contrast, which also affects the fast moving mitral valve leaflet observation.Thus the state-of-the-art segmentation methods do not work in our scenario. So, we are resorting to manual segmentation.

As our part of interest is to track the fast moving mitral valve leaflet, for this segmented valve has been achieved by pre-processing the frame. Thus, obtained a binary image from a grey scale image. This binary image serves as a segmented image and such segmented image is obtained after few preprocessing steps discussed earlier. A binary mask is used as a reference frame to track the other next frames of mitral valve.

4.4 Variable Initialization :

Variable initialization for the further processing in other functions has been initialized in the main file naming MS Tracking .Some prominent variables used for tracking are discussed in such section .The first variable is index_start . It is the index for the frame. It is said to be 1, to start the tracking procedure from the first frame .If the index_start is said to be 5 or any other value then it will start from that specific frame till end .The next variable is similarity thresh. This is a similarity threshold initialized with some value i.e 0.16 .This variable is used in the main Mean Shift Tracking Algorithm i.e. if the similarity between the two densities estimation p and q is 0.16 then run the Mean Shift Algorithm .Where p is the candidate path and q is the target patch. Also maximum number of iterations to converge has been initialized in such section.
Kernel type Gaussian has been used to express the probability density function of the candidate and the target image. Such kernel type Gaussian is used to compute the mask of parzen window and the gradient of x and y axis respectively. All these will be discussed in further sections.

4.5 Target Representation:

After initialization, the first main step of the algorithm is to target the mitral valve in the initial frame . For this, we have to target the position of the mitral valve in the initial frame. Here the initial frame would be the segmented image. The binary image obtained in the preprocessing step is read in this function .As we have 5 different mitral valve videos, so few masked or binary images required the zero padding for equalizing the size of an image with the original image I. Such zero padding is done on the images in such section too.
Now we have equalized the size of the masked image and original image I. The images are of size 640x480. The width of an image is 640 whereas the height of an image is 480.The binary image and original image I are shown as below;

Figure 4.3 Original and Segmented Image

The next step in the algorithm is to find the upper left corner point of the mitral valve image. Find function is used to find the upper left corner of the image . The upper left corner points are termed as x0 and y0. These are found to be (219,173). Whereas, these points are the starting point of the mitral valve. We are going to track accordingly to this point, which is moving according to the direction of mitral valve. These points are used in making the target selection easy. An equation for the target selection has been made to exactly target the mitral valve patch . This target selection equation is termed as T ,which comprises of the points x0 and yo, along with H and W. Where H and W are the size required for patch selection . This size is the size of the rectangle selection. Target selection equation to select the required patch from the target is shown as below;

$$T = I(x0-25:x0+H-1,y0:y0+W-1,:); \qquad (4.1)$$

Thus the output of the function is a patch T, with its upper left corner x0 and yo of the mitral valve. And the patch size H and W.

4.5 Mask Computation:

Kernel is a way to place a data space of high dimensional vector space. So that the intersections of the data space with hyper-planes determine more complicated, curved decision boundaries in the data space. [65] .Basically, mask, convolution or a kernel, a mask is a small matrix useful for sharpening, blurring, embossing, detecting edges etc. It is achieved by convoluting an image and a kernel.

The Parzen window in the algorithm approximate the probability density by estimating the local density points (same idea as histogram). Here we will be convolving the points of the image with a kernel function or a window, using the scale parameter termed as sigma. Here k is the mask , H and W are the size of mask.

As there are following types of kernel namely;

1. Uniform
2. Triangular
3. Epanechnvikov

$$\Phi(x) = \begin{Bmatrix} 3/4(1 - X^2) & \text{if } |x| \leq 1 \\ 0 & \text{else} \end{Bmatrix} \tag{4.2}$$

4. Gaussian

$$\Phi(x) = e^{\frac{-x^2}{2\sigma^2}} \tag{4.3}$$

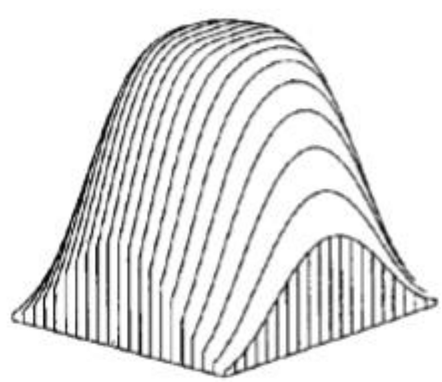

Figure 4.4 Gaussian kernel [66]

In the Algorithm ,Gaussian kernel has been used .It acts as a smoothing filter. Here, Gaussian kernel helps in image convolution with a function that is Gaussian and is same as applying a Gaussian blur to an image. Kernel Gaussian is used in image blurring and high frequency components are reduced which means it acts as a LPF, which allows the low frequency components to move through it, and blocking all the high frequency component through it.

Gaussian Kernel Equation 3 is applied in the Algorithm. The sigma value is very important to set perfectly as it acts as a smoothing filter .The value of the Sigma H and Sigma W are set to be ;

$$\sigma H=((RXH)/2)/3 \qquad (4.4)$$

$$\sigma W=((RXW)/2)/3 \qquad (4.5)$$

The key idea here is superposition of a kernel which is centered at every data point is equal to convolve that data point with a kernel as shown in equation below.

$$k(i,j) = e^{-0.5x}\left[\frac{(i-0.5H)^2}{(\sigma H)^2}+\frac{(j-0.5W)^2}{(\sigma W)^2}\right] \qquad (4.6)$$

So after finalizing the kernel mask k(I,j). the next step is to compute the gradient of kernel

4.6 Kernel Density Gradient Estimator:

As,

$$k(i,j) = e^{-0.5x}\left[\frac{(i-0.5H)^2}{(\sigma H)^2}+\frac{(j-0.5W)^2}{(\sigma W)^2}\right]$$

Represent the Gaussian mask of the targeted image found in the patch selection function. Now we want to compute the gradient of mask to find the mean shift vector in mean shift algorithm

.Basically the idea is, gradient of the superposition of a kernel which is centered at every data point is equal to convolve those data point with gradient of a kernel .

Now the gradient of the kernal is also computed with the respect to x-axis and y-axis respectively. As such gradient value will be used further in the Mean Shift Algorithm. It will be discussed in next steps i.e. how these gradient vectors are used to find the displacement vector required for mean shift vector.

Therefore, until now our aim was to obtain the Non-parametric Density GRADIENT Estimation for mean shift algorithm.

4.7 Density Estimation of Target PDF:

The Kernel density estimation [67] is to calculate the density of a random variable. Before calculating the density, the colour probability density function has been calculated of an image q, where q is the targeted image. The colour probability distribution has been found in order to find the region which has most similar distribution of colour.
In general , let xi be the location of the pixel of the targeted image. The radius of the kernal is set to be 1 and using the same kernal profile k . Hence, we can write the probability density function of the target model as ;

$$q = C\sum_{x=1,y=1}^{W,H} k(y,x) \tag{4.7}$$

Where C is termed as the normalization constant.
Ideally , we want an indicator function which will return almost 1 for the object pixels which we are tracking for and almost zero for others . Instead, we will be computing likelihood the maps in this section , where the value at a pixel is proportional to likelihood that the pixel comes from the patch we are tracking. Computation of the likelihood is based on the colour histogram. Where map contains almost N colours. Lmap is the number of bins which will guide that how many pixels lie in which bins and so on . After finding the density estimation, it has also been normalized known as C in the equation. Similarly, the densities of the candidate images are found using the above equation.

So the main output of the function are densities of the data sample of patch T, with a profile of kernel termed as k.

4.8 Iteration of Mean Shift Algorithm for Tracking:

4.8.1 Mean Shift Tracking:

Now the main procedure of tracking starts under this function . In order to find the probability distributions, the next frame are encountered for it i.e. there pdf's are found using previous discussed steps. Then Mean Shift Algorithm procedure is applied to move the point x and y to the target location in the next frame. For this, the initial left corner points are termed to be assigned as;

$$x=x0 \qquad (4.8)$$

$$y=y0 \qquad (4.9)$$

Their target equation is write to select a patch of mitral valve and this time; the density estimation function finds the density of candidate frame p. Now we have both the density or probability density estimations of target image and the candidate image termed as q and p respectively. In addition, we want to find the similarity of the two probability distribution i.e. which pixel lie in which bins. For this, a similarity function is made to compute the similarity between two pdfs.

4.8.2 Similarity Function of Target and Candidate Images:

As till now , we have found both the probability densities function of target and candidate image . Now this function measure the similarity between two density estimations i.e. between target image q and the candidate image p. P is the estimation of candidate image patch termed as T2 in the section. Our aim is to minimize the distance between two pdfs in order to compute the maximum likelihood so density estimated are computed with their kernal profile k in this section thus finds the similarity function between two pdf's.

4.8.2.1 Likelihood Maximazation:

The maximization of the likelihood target and candidate mainly depends on the weights .We want to maximize the weights i.e data need to be weighted. So, firstly the weight is assigned with the zeros (H,W) then the weights are found using the equation as below. The generic form of weights for the images are;

$$w_i = \sqrt{\frac{q(T(i,j))}{p(T(i,j))}} \qquad (4.10)$$

Since weights are strictly positive , further they will be used in finding the mean shift vector.

Thus the similarity value and weights are used in the extended Mean Shift Algorithm to see, if such value of f is less than the threshold then the Mean Shift Algorithm is applied .Else, if there is zero similarity between the two pdf then Mean Shift Algorithm is not applicable. And weights are using in finding the Mean Shift Vector in main equation of Mean Shift Algorithm. So the main outputs are the similarity value f and the weight mask for the gradient ascent in the extended mean shift algorithm are found in this section .

4.9 Mean Shift Procedure:

4.9.1 How Mean Shift Works: The Mean shift finds the local maxima of the probability density function or in other words, it finds the modes in an underlying probability density function.

The mean shift vector procedure is:

1. We have the data samples and then we take a region of interest from the data samples.
2. Firstly, we have to find the mean or the center of mass of these data samples.
3. Once the mean of the data samples are found .We, calculate the mean shift vector to check where the densest region is located.
4. The mean shift vector now moves to the other new denser location by mean shift vector.

5. Again, we have different region of interest. The mean is calculated again and from that mean, mean shift vector shifts the mean to find more densest region .This procedure continues until the densest region is found .

In our Algorithm, Before finding the mean shift vectors, the similarity function is taken into account to check whether the mean shift algorithm is applicable or not .For this, we have made a while loop to check if the value of f is less than to our f thresh value , only then algorithm is applicable .Representing if the two probabilities are similar at any glance , only then the algorithm is applied else not .

Now Mean Shift Algorithm runs here, totally depending on find the mean shift vector because every shift is found by this vector. But in our case, our strategy is , we want to find the center of windows in all frames , we will be connecting the centroids , which will lead to the tracking process. Also we have found the gradient of x and y, so directly applying all the previous values from the function in mean shift vector equation 11 and 12.

$$dx = \frac{num\_x + i \times w(i,j) \times gx(i,j);}{den + w(i,j)*norm([gx(i,j)\ gy(i,j)]);} \qquad (4.11)$$

$$dy = \frac{num\_y + j \times w(i,j) \times gy(i,j);}{den + w(i,j)*norm([gx(i,j)\ gy(i,j)]);} \qquad (4.12)$$

So,in next frame the location of the target or new location will be ;

$$\mathbf{y=y+dy} \qquad (4.13)$$

$$\mathbf{x = x+dx;} \quad (4.14)$$

where y is equal to yo and x equals to xo. This stage includes the target updation .So, the target is updated in the next frame using equation T2. We have a new patch .Now again its density is estimated using the function density estimation. The similarity function again finds the similarity value between two pdf i.e. the targeted image and next candidate image and hence in end Mean Shift Algorithm is applied to find the mean shift vectors.

Thus this section tracks the patch T in the videos sequence using the Mean Shift Algorithm by moving the point (x,y) to the target location in the next frame..

Till now, we have tracked five mitral valve videos using the Mean shift algorithm. Its results has been shown in next chapter.

CHAPTER 5: RESULTS AND PERFORMANCE EVALUATION

5.1 Dataset:

As the first step in the proposed algorithm is getting the videos of the echocardiography. The videos are collected from the activities of Real Hospital Portugues, . It's in Recife, Brazil. The dataset consist of the videos i.e. ultrasound mitral valve videos .These videos has been gathered for the purpose of monitoring and screening the Acute Rheumatic fever(ARF) in children.. The data was collected using a M-Turbo model by SonoSite Ultrasound system, with C11x transducer (5-8 MHz). Nine of these exams were fully annotated (manual segmentation of all frames) using support software and were used to test the novel algorithm proposed in this work.

There are total 5 videos of the echocardiography in mp4 format file. Frames are extracted from it. As frames are extracted for five different videos. So different videos contains the frames of different length depending on the size of echocardiography videos. The five videos consist of total 819 frames.

5.2 Rheumatic Heart Disease Tracking Results :

Tracking of the echocardiography video focusing the mitral valve leaflet has been shown in the snapshots below. Five different cases has been represented in the section below .The movement of mitral valve is different for five videos or cases. These five videos has distinguishing mitral valve leaflet i.e. slow moving leaflet, fast moving leaflet ,elongated leaflet and think/thick leaflet .

Whereas, in some videos, the mitral valve is not very clear .Tracking snap shots of the files

1.49653

2.49713

3.49760

4.49754

5.49881

has been shown below. Where the red rectangle box is meant to track the fast moving leaflet in the echocardiography videos using the Mean Shift Algorithm.

5.2.1 File 49653:

Tracking of the fast moving leaflet has been shown in the snap shots of the video. The mitral valve has been efficiently tracked by the Mean shift algorithm, which is shown with the valve under the red rectangle. Five different frames of the echocardiographic videos of mitral valve has been represented below, with a red rectangle meant to track the mitral leaflet patch. Below figure shows the tracking of mitral valve under the red rectangle area.

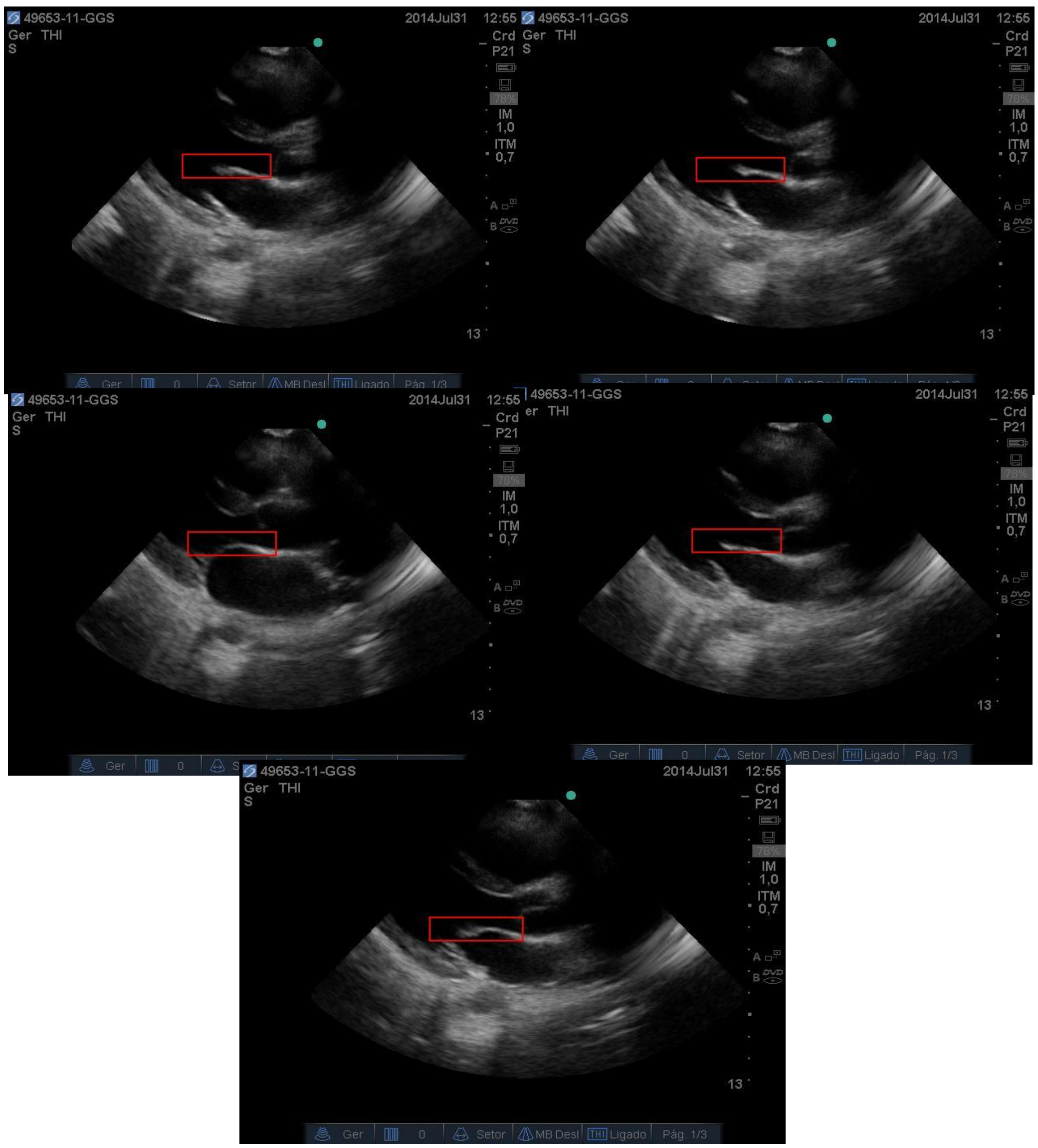

Figure 5.1 Mitral Valve Tracking

5.2.2 File 49713:

In such mitral valve video, the leaflet is thin and elongated in the shape. Five different frames of such video has been represented to show the result of tracking using proposed methodology i.e. Mean Shift Algorithm. In such videos, the valve has been tracked under the red rectangle box. As the valve is thin and elongated, so the algorithm tracks the tip of the valve properly. The variation in the result has been shown in next chapter.

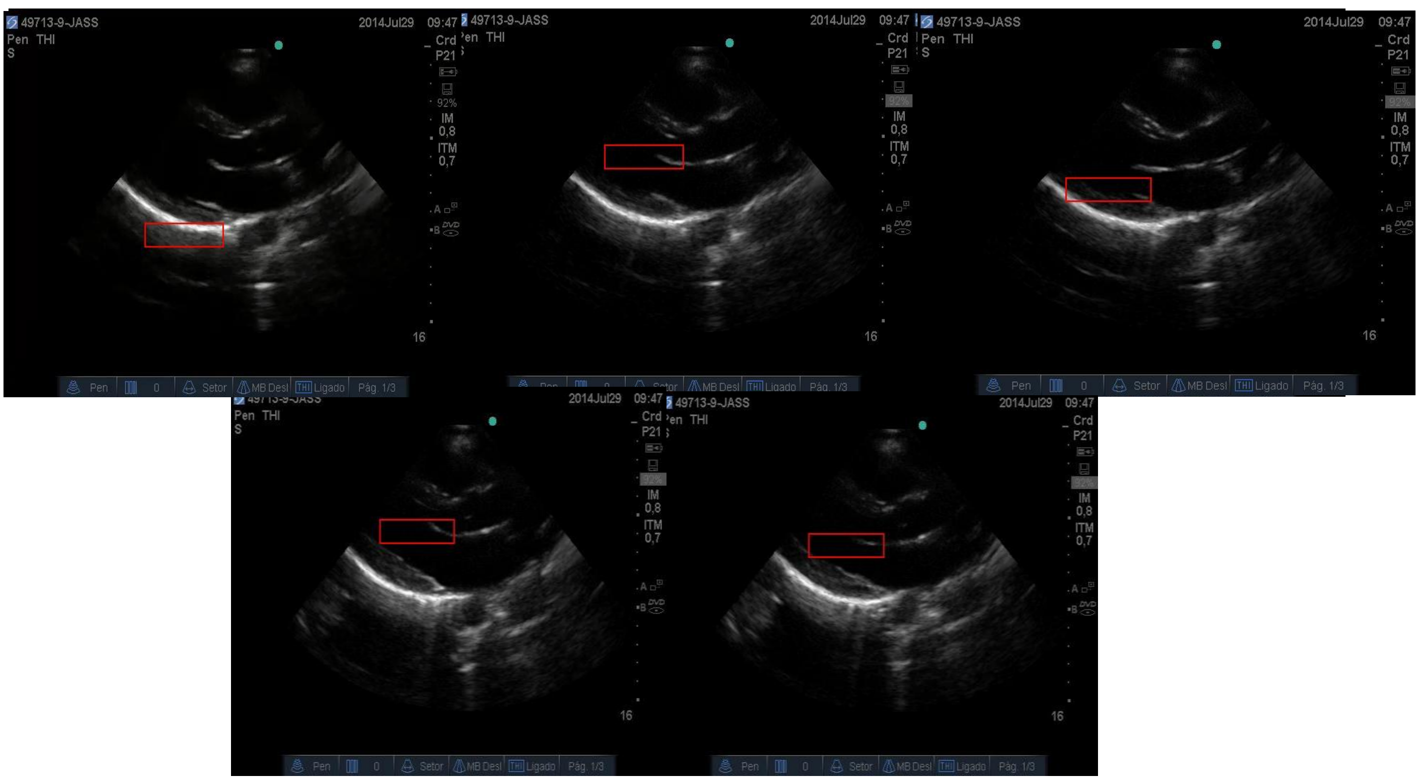

Figure 5.2 Thin and Elongated Mitral Leaflet Tracking

5.2.3 File 49754:

Such echocardiography video of mitral valve also include the thin and elongated leaflet. Whereas the leaflet is very invisible in fewer parts of the video due to some low contrast video. Four frames of such mitral valve has been represented to show the tracking results.

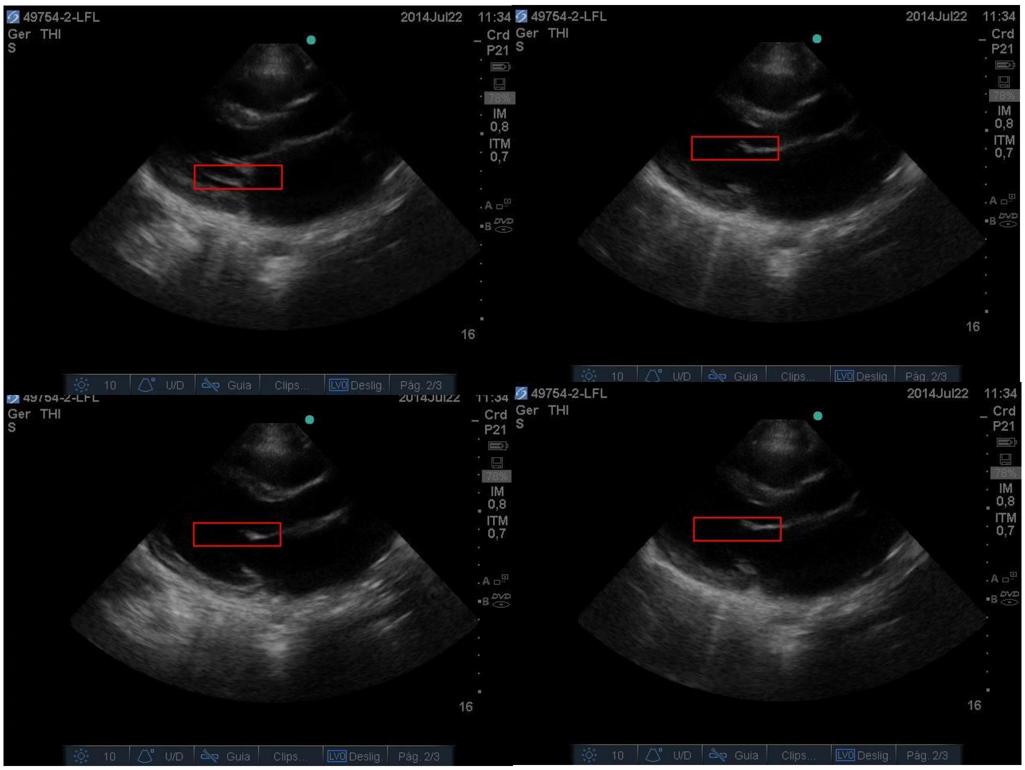

Figure 5.3 Thin and Elongated Mitral Leaflet Tracking

5.2.4 File 49760:

Below echocardiography, screen shoots represent the low contrast videos and irregular shaped mitral valve which also many times mixes with the valve above and below it.Thus making it very difficult to track as the tip of mitral valve is not efficiently being focused in such scenario. Five frames of echocardiography mitral valve video has been shown below, which shows that in fewer part of the videos the red rectangle also mixes the mitral valve with above and below valve .Thus unable to track the mitral valve efficiently . Its Justification has been presented in the next chapter.

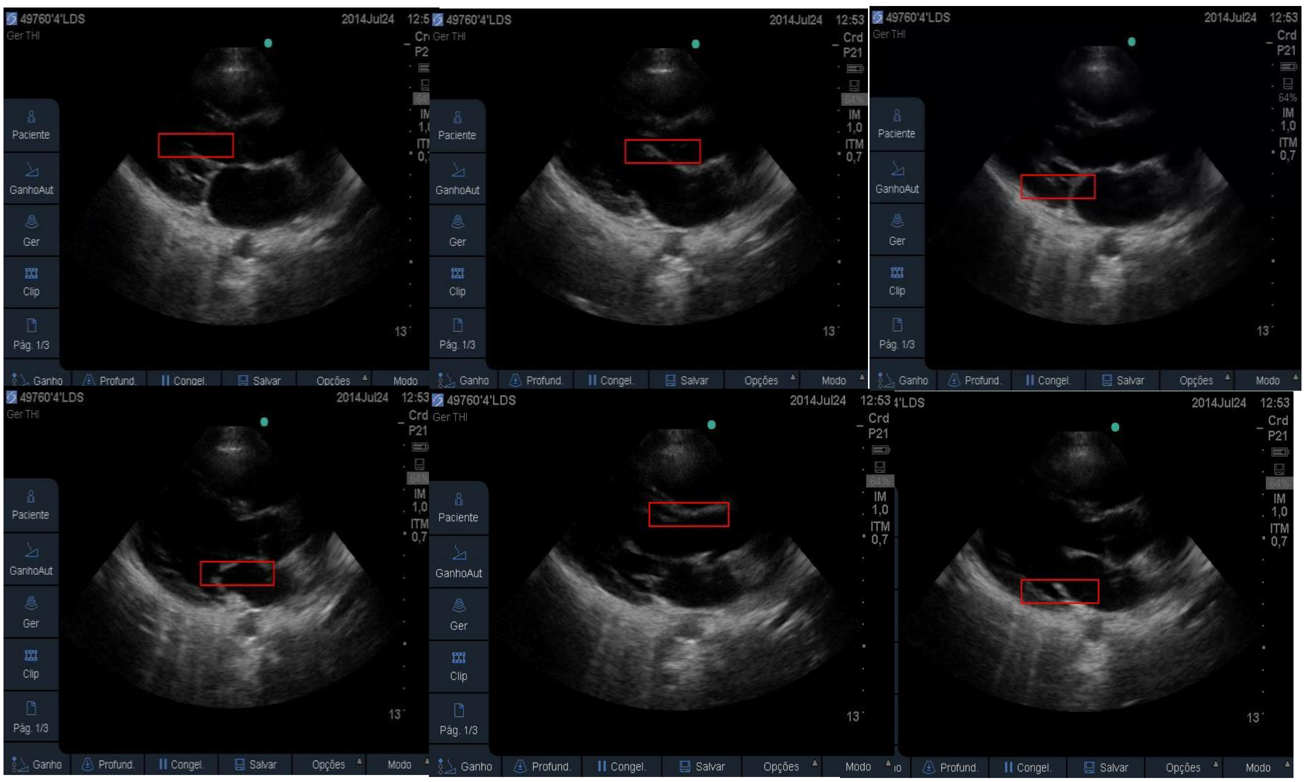

Figure 5.4 Irregular and Low contrast Mitral Leaflet Tracking

5.2.5 File 49881:

Below three screen shoots represent the very low contrast video of the mitral valve movement.The mitral valve tip is very unclear in the echocardiography videos. Thus it is very difficult to track the tip of mitral valve in the initial frames. Due to such problem, the algorithm is not able to track the tip point of the fast moving leaflet.

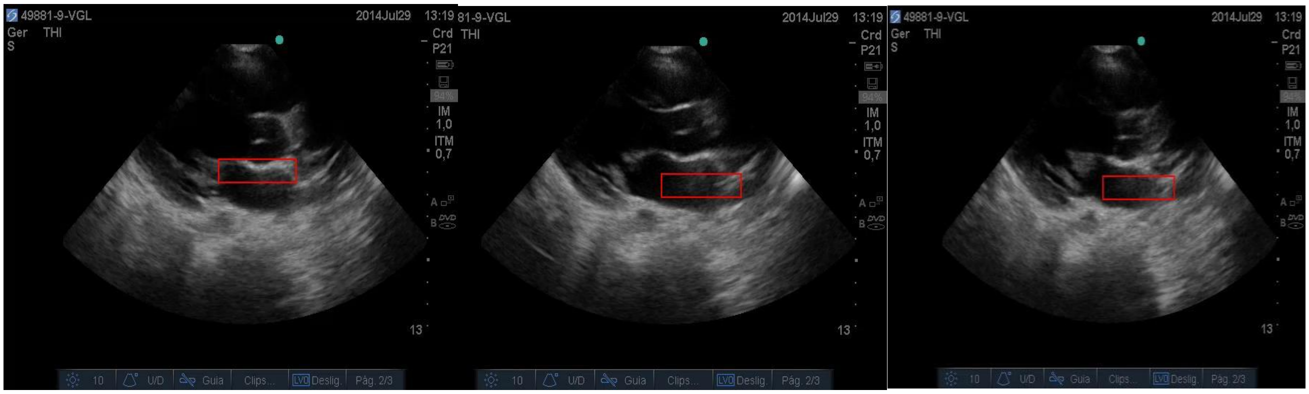

Figure 5.5 Tracking of Unclear Mitral Valve Tip

5.3 Justification of Results:

The results shown above includes some good and inappropriate results. The reason behind this difference is explained in this section ;

5.3.1 Appropriate Results:

As, we have five different echocardiography of mitral valve videos .Mean Shift Algorithm has been applied for all these five videos .The tracking results has been shown as above but there justification will be discussed in this part . The echocardiography videos with the file name

1. 49653
2. 49713
3. 49754

Are properly tracked with the proposed algorithm .The fast moving leaflet is tracked under the red rectangle which has been shown in the snap shots above. The mean shift algorithm shows good results of tracking for these videos.

Tracking mainly depends on the quality of the echocardiographic videos, which has been obtained by Real Hospital Portuguese. On these three echocardiography videos, tracking algorithm is properly tracking the fast moving leaflets due to the following reasons.

1. **High contrast :**

These videos are of high contract echocardiography videos, with the intensity values in the intensity range of the grey scale. These high contrast videos are prominently allowing the algorithm to focus on the fast moving mitral leaflet.

2. **Reliable Mean Shift:**

As these videos are of high contrast, so the Mean Shift Algorithm properly starts from the position of the model in the current frame .Its neighborhood is properly searched in the next frame and so the process repeats. Thus finds the best by maximizing the similarity function. Therefore, the mean shift calculation is more reliable in such case.

3. **Optimization Convergence:**

After the mean shift calculation, when optimization is applied on these videos, Mean shift algorithm converges at one location.

5.3.2 Significant Issues of Inappropriate Results:

The echocardiography videos with the file name 49760 and 49881 are not properly tracked with the proposed algorithm .The fast moving leaflet is not properly tracked under the red rectangle, which has been shown in the snap shots above. The mean shift algorithm shows inappropriate results of tracking for these videos due to the following reasons.

1. **Low Contrast:** These are of low contrast echocardiography videos, with the intensity values not in the intensity range of the grey scale. These low contrast videos are not allowing the algorithm to focus on the fast moving mitral leaflet because the leaflet contrast with the background is very low. Thus the algorithm cannot differentiate between the leaflet and the background and thus tracked the wrong part or the part which is nearly

resembling the neighboring areas of mitral valve leaflet. This is significant issue of bad tracking results on such videos.

2. **Leaflet Speed:** Leaflet speed is another issue of unreliable tracking. In such echocardiography mitral valve leaflet videos, the leaflet is moving with the high speed and thus camera is not capable to focus that high speed of leaflet .Due to this high speed ,the mitral valve location is unpredictable to track. Thus, the mean shift algorithm doesn't start from the position of the model in the current frame. Its neighborhood is not searched in the next frame and so on for all frames. Therefore, there is no similarity function find in such case. This miscalculation leads to no optimization and thus proper tracking of valve has not been achieved.

3. **Doppler Characteristics:** The Doppler characteristics of these echocardiography videos does not create the high contrast. which leads to the miscalculation in tracking the leaflet by Mean Shift Algorithm,

   So, a method is required that is favorable to these imaging challenges. The state-of-the-art is lacking in this.

5.4 Tracking Results:

The main task of our thesis work was to track the fast moving leaflet in the Echocardiography sequence using the Mean Shift Algorithm. The tracking results are shown along with their screen shoots. The summary of those results are as below;

- File 49653 represent the parasternal view of the mitral valve. The fast moving leaflet is properly visible in such ultrasound video. The valve is properly tracked by an Algorithm i.e. Mean Shift Algorithm
- File 49713 contains the thin and elongated shaped mitral valve. The tip is very much clear in the video. Thus allowing the algorithm to track the mitral valve.

- File 49754 contains thin, elongated and low contrast mitral valve movement. It is tracking results shows the tracking efficiency lesser than the previous files due to mainly low contrast ultrasound video, which does not allow the corner points to be tracked properly.
- File 49760 contains low contrast, irregular shaped valve that evenly mixes with upper and valve below it, making it very difficult to track in such scenario. All these share almost the equal texture and contrast which result in no discrimination of features and it would be very hard to distinguish one structure from the other. Thus valve is not properly tracked in such file.
- File 49881 contains low contrast with very unclear mitral valve tip .Thus this file has the lowest or inappropriate tracking results. The valve is not tracked in such file.

This chapter also explains the after tracking results which are concluded on the basis of dice coefficient.

Basically, Dice coefficient measures the similarity between two cases i.e ground truth image and after tracking image. In order to compute our tracking result efficiency, we are calculating the similarity between the segmented images and after tracking images. For dice calculation, both images are converted to binary image .If both the results are same, then the average dice coefficient is one, if both are very non-similar then the result is zero. In such a case, if some of the properties are similar and some are un-similar, then the values lies between zero and one.

Below table shows the dice coefficient results for the five different videos , along with their minimum ,max and average mean .Dice coefficient of ten different frames has been calculated for five different videos , which has been shown below along with the histogram.

Below five different files, represent the histogram of ground truth and after tracked images. Explained below;

5.4.1 File 49653:

Now we want to compute the dice coefficient between the two segmented images. For such file, we have two different segmented images .One is the ground truth segmented image i.e. obtained before tracking and the other one is the tracked segmented image after running the Mean Shift Algorithm.

The dice coefficient between the two-segmented images has been computed i.e. original segmented images and tracked segmented images. As there are many numbers of frames, both the same original segmented frame and tracked segmented frames were saved to conduct their dice coefficient. As there are many number of frames, dice coefficient of ten frames has been calculated .Then frames of ground truth image with the same frames of tracked segmented image has been compared to compute the dice coefficient between the two mask.

Below table shows the dice Coefficient of the two segmented images, with their mean dice coefficient to be 0.7 and there is no such frame in which there is no similarity. Therefore, such file has a good tracking result using the Mean Shift Algorithm i.e. Mean Dice Co-efficient 0.7. Also in the below histogram, the x-axis represent the range in which the dice coefficient lies whereas y-axis represent the number of frames or files. For example, four frames lie between the range of 0.70 and 0.80 and so like others.

Table 5.1.File 49653 Dice Coefficient Values

FRAME #:	**DICE COEFFICENT**
Frame 1	0.201292705447830
Frame 2	0.343996291145109
Frame 3	0.470007057163021
Frame 4	0.277726001863933
Frame 5	0.331914893617021
Frame 6	0.277144064216308
Frame 7	0.173371647509579
Frame 8	0.183438155136268
Frame 9	0.175040518638574
Frame 10	0.283464566929134

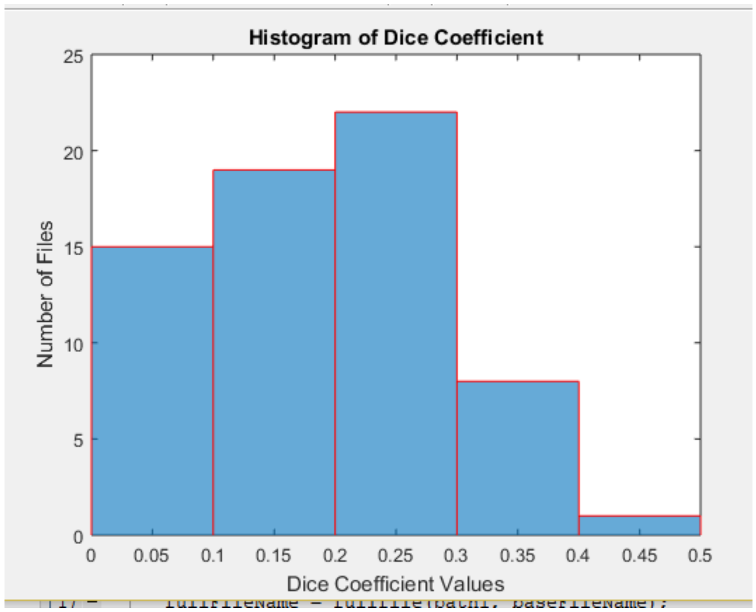

Figure 5.6 File 49653 Histogram

Standard Deviation = 0.1322

Mean Dice-coefficient: 0.2243

5.4.2 File 49713:

The ten frames of original segmented image and the tracked segmented image has been taken in order to compute the dice coefficient between the two images. 10 frames along with their dices has been shown in the table below, where a mean dice can be observed to be around 0.4 and a zero dice representing the particular frame with a zero similarity between the two segmented images. Below histogram, represent the number of files lying in the ranges representing the range of dice coefficient along x-axis.

Table 5.2.File 49713 Dice Coefficient Values

FRAME #:	**DICE COEFFICENT**
Frame 1	0.286365940192600
Frame 2	0.0865690642902610

Frame 3	0.140992167101828
Frame 4	0.142066420664207
Frame 5	0.143122676579926
Frame 6	0.132042253521127
Frame 7	0.110912343470483
Frame 8	0.122489959839357
Frame 9	0.196007259528131
Frame 10	0.190384615384615

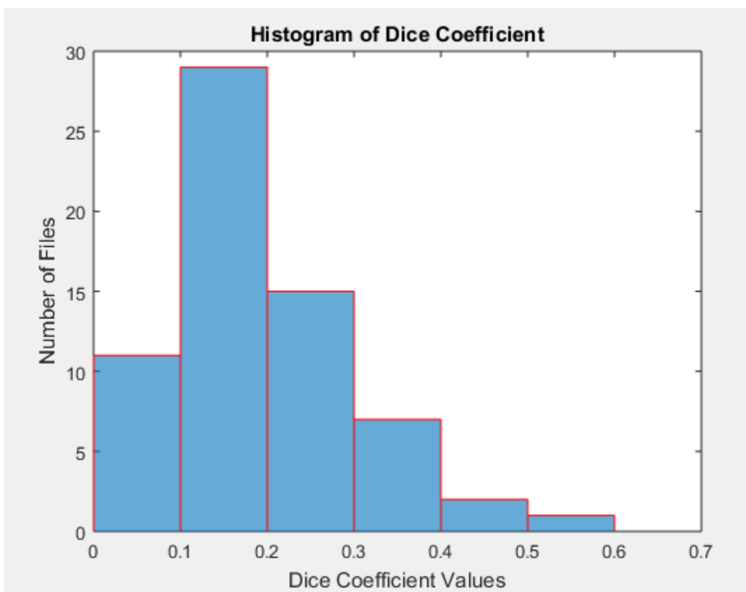

Figure 5.7 File 49713 Histogram

Standard Deviation: 0.0901

Mean Dice-coefficient: 0.1954

5.4.3 File 49754:

Again 10 frames of original segmented image and the tracked segmented image has been taken in order to compute the dice coefficient between the two images. 10 frames along with their dices has been shown in the table below, where a mean dice can be observed to be around 0.5 and a minimum of 0.4, which means this file has been tracked the mitral valve better than the previous file.

Table 5.3.File 49754 Dice Coefficient Values

FRAME #:	**DICE COEFFICENT**
Frame 1	0.328673043904832
Frame 2	0.311166875784191
Frame 3	0.209285187914517
Frame 4	0.269415807560137
Frame 5	0.291691572026300
Frame 6	0.290832455216017
Frame 7	0.259317585301837
Frame 8	0.316213494461229
Frame 9	0.191322530057501
Frame 10	0.216970998925886

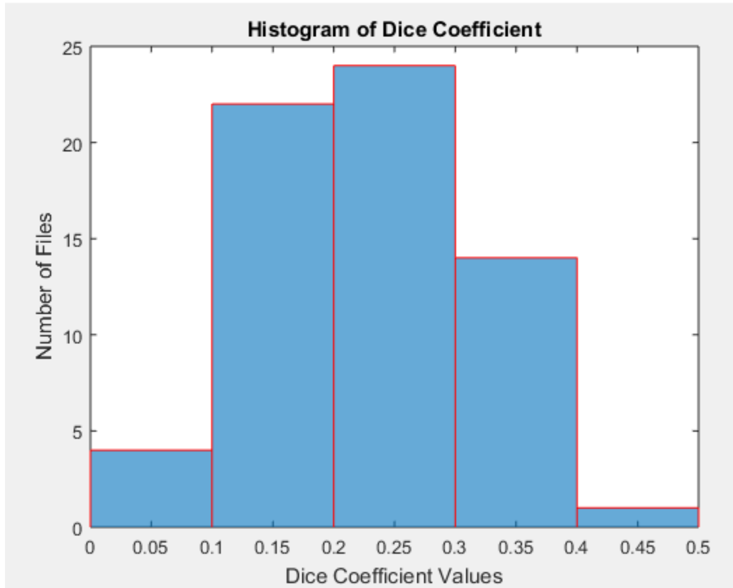

Figure 5.8 File 49754 Histogram

Standard Deviation: 0.0882

Mean Dice-coefficient: 0.2277

5.4.4 File 49760:

Now this was the file, with low contrast and unobservable mitral valve tip. The tip of the mitral valve was not clearly tracked by the algorithm is few frames. Thus, it can be shown in the table that the mean dice coefficient of both segmented frames is 0.3. These results were inappropriate, as the mean dice coefficient was low in number too.

Table 5.4.File 49760 Dice Coefficient Values

FRAME #:	**DICE COEFFICENT**
Frame 1	0.284395198522622
Frame 2	0.0762873490146217
Frame 3	0.0496124031007752
Frame 4	0.0474368783473604

Frame 5	0.0628099173553719
Frame 6	0.0939431396786156
Frame 7	0.133751306165099
Frame 8	0.0459418070444104
Frame 9	0.0801068090787717
Frame 10	0.284395198522622

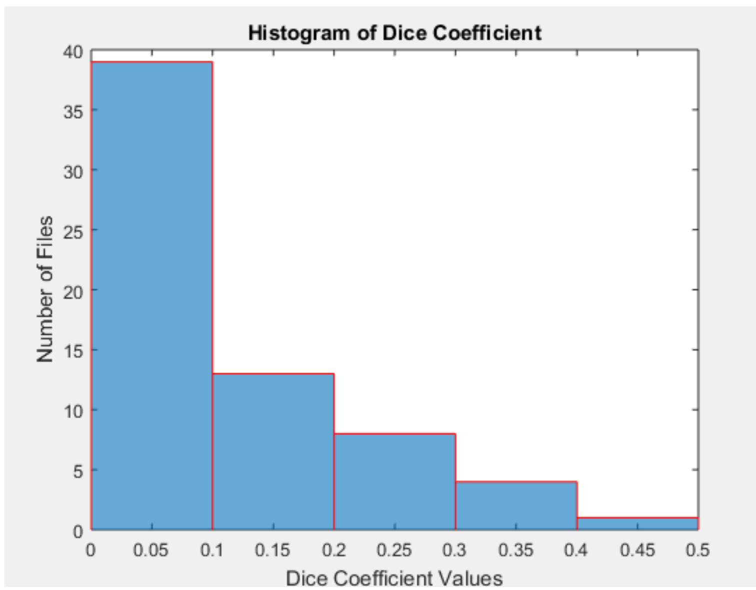

Figure 5.9 File 49760 Histogram

Standard Deviation: 0.1374

Mean Dice-coefficient: 0.1466

5.4.5 File 49881:

The last file of the mitral valve was low in contrast and few seconds in length. Thus making it very unreliable to track that low contrast fast moving leaflet in just 3 to 4 seconds .Thus the dice coefficient of the original segmented image and tracked segmented image is low i.e. Mean dice coefficient is 0.2.

Table 5.5.File 49881 Dice Coefficient Values

FRAME #:	**DICE COEFFICENT**
Frame 1	0.504251144538914
Frame 2	0.518908568693155
Frame 3	0.515949367088608
Frame 4	0.467836257309942
Frame 5	0.533135509396637
Frame 6	0.511563367252544
Frame 7	0.446692991115499
Frame 8	0.417559979581419
Frame 9	0.390711761736497
Frame 10	0.448092952765850

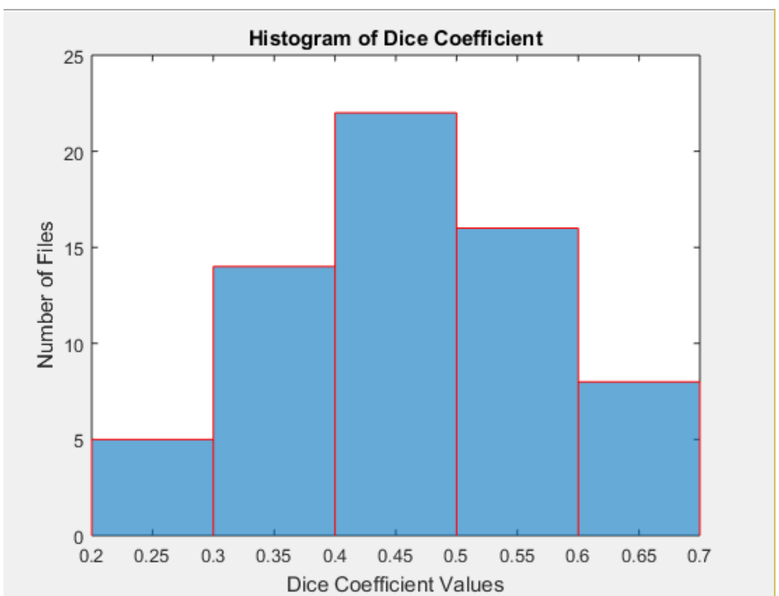

Figure 5.10 File 49881 Histogram

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Standard Deviation: 0.1048

Mean Dice-coefficient: 0.009

The Mean dice coefficient of the three valid resulted videos using the Mean Shift Algorithm is around 0.2 and the Mean Dice of other two inappropriate result found is lesser.

CHAPTER 6: CONCLUSION AND FUTURE WORK

Rheumatic Heart Disease is an outcome of Rheumatic Fever. RHD damages the heart valves. It effects the valve of the heart known as mitral valve. The fast moving leaflet need to be tracked in an echocardiography sequence using a tracking Algorithm.

Echocardiography videos are collected from the activities of Real Hospital Portuguese. It is in Recife, Brazil. The dataset consist of the videos i.e. ultrasound mitral valve videos. Total we have five echocardiography videos representing the fast moving mitral leaflet.

Tracking the mitral leaflet in echocardiographic sequence was done using the 'Mean Shift Algorithm'. To conclude the tracking results, a measure known as dice coefficient is calculated between before and after tracking echocardiographic images. The values of the dice coefficient for file 49653 is 0.2243 .File 49713 has a dice coefficient of 0.1954 and file 49754 has a dice coefficient of 0.2277.These three files represent a tracking results using the Mean Shift Algorithm with a dice coefficient almost around 0.2 .Whereas, the last two files i.e. 49760 has a dice coefficient of 0.1466 and file 49881 has a dice coefficient of 0.099, representing a lower dice coefficient value due to the inappropriate tracking results ,which are also shown along figures in chapter 5. .

6.1 Algorithms Applied for Tracking:

As Dice Coefficient measures the similarity between two binary images. So, Before tracking using Mean Shift Algorithm. Other Algorithms were also applied to track the fast moving leaflet in echocardiographic sequence. Those results have been shown in the table below (Table 6.1) along with their Mean and Standard Deviation. Gaussian Mixture Model and Kalman Filter were applied before Mean Shift Algorithm .But due to their inappropriate results, Mean Shift Algorithm was used to track the fast moving leaflet.

6.1.1Draw Back of Using GMM for Tracking Echocardiographic Videos :

Firstly, Gaussian Mixture Model(GMM) was used to detect the fast moving leaflet in the echocardiographic sequence . As detection is the initial step for tracking the valve. Mitral valve was detected in a very fewer frames . The detection in a video sequence was made by using a foreground detector, which was mainly based on the model named Gaussian mixture model(GMM).

Table shows the Mean Dice and Standard Deviation of the detected valve. The tracking result seem good because the dice of the only detected valve in the relevant frame has been calculated and shown. The valve has been detected in very fewer frame i.e. about 4/5 frames only. So, GMM detection couldn't be proceeded for tracking due to its fewer frame detection only .The reason behind lesser detection is the use vision.ForegroundDetector to detect the foreground. The ultrasound videos are of low quality images with low contrast. The foreground detector could not compare the greyscale video frame to the background model in order to estimate that every single pixel is a part of foreground or the background. It confuses the neighbor valve with the original mitral valve and hence it computes irrelevant foreground mask. and hence then by using the background subtraction ,foreground objects are detected with such irrelevant fewer mask .This leads to low detection using GMM in such echocardiographic videos.

So, the next algorithm used was the Kalman filter.

6.1.2 Draw Back of Using Kalman Filter For Tracking Echocardiographic Videos:

After using the GMM, kalman filter was applied to track the fast moving leaflet in the echocardiographic sequence. Valve is detected and tracked using Kalman filtering along with the blob analysis and the foreground detection. The mitral valve is tracked in some frames but not all. The results of kalman filter are better than the GMM Model.

In such scenario, valve is searched using the background subtraction and blob analysis. Once the valve is detected, the kalman filter is formed. This filter locates the location of mitral valve and checks whether the valve is detected or not .Once the mitral valve is detected, the filter predict the state on current frame. The kalman filter make use of new detected location to correct state, forming a filtered location .If valve is missing the filter rely on previous/old state to predict valve current location.

Thus again in such algorithm, the foreground detector could not compare the greyscale video frame to the background model in order to estimate that every single pixel is a part of foreground or the background. It computes irrelevant foreground mask too. Thus ,kalman filter in unable to track the mitral valve properly too.

6.2 Conclusion :

Below table shows the Mean Dice and Standard Deviation of three different Algorithms used. Result shows that Mean Shift Algorithm has an average Mean Dice Coefficient of 0.5. Where as, Kalman filter and GMM has a Mean Dice of 0.18 and 0.1 respectively, which is much lower than Mean Shift Algorithm. Also the Standard Deviation (i.e variation among binary images) of Mean Shift Algorithm is lesser than other two algorithm as shown below.

Thus Mean Shift Algorithm has a accuracy better than Kalman filter and GMM and thus leads to reliable tracking than other two algorithms.

Note: Below GMM represents Mean Dice and Standard Variation of Detected Valve Only (i.e for 4/5 frames. The Dice was almost zero for other frames.)

Table 6.1.Comparison of Mean Shift Algorithm, Kalman Filter and GMM.

Algorithms	**Mean Shift Algorithm**	**Kalman Filter**	**Gaussian Mixture Model (GMM)**
Measures / Files	***Mean Dice±Standard Deviation***	***Mean Dice±Standard Deviation***	***Mean Dice±Standard Deviation***
49754	0.1954±0.0882	0.1633±0.1015	0

49653	0.2243 ±0.1322	0.2068±0.1666	0.2760±0.1986
49713	0.2277±0.0901	0.1403±0.1252	0.2037±0.1227
49760	0.1466±0.1374	0.0861±0.1117	0.0867±0.1189
49881	0.0900±0.1048	0.2990± 0.1619	0.4866±0.1284

6.3 Future Work:

Echocardiography is widely used for the diagnosis of different cardiovascular diseases like Rheumatic heart disease. For accurate and on-time diagnosis of the Rheumatic Heart Disease, tracking the fast moving leaflet is very important. Tracking mainly depends on the echocardiography videos quality or contrast level. As some of our results does not track the mitral leaflet efficiently due to the low contrast, fast moving leaflet and manual segmentation. Thus, the applied methodology can further be improvised in future work.

Firstly, these low contrast ultrasound videos are very hard to handle .So adjustment of low contrast ultrasound videos should be made by focusing or converting these low contrast to good quality videos or getting some more high resolution video data set ,so that the mitral valve may differ from the background prominently. Secondly, different segmentation techniques can be implied to improvise the segmentation results of mitral valve from its closely like shaped valves. Thirdly, Fast moving leaflet should be handled, so that the camera can focus it clearly.

These issues will be resolved in future work and hence better tracking results can be achieve to properly access heart efficiency.

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