Technical report submitted to UGC Major Research Project

# HEART REGURGITATION SEVERITY ANALYSIS USING IMAGE PROCESSING TECHNIQUES

**UGC** Major Research project sanction **F. No. 43-308/2014(SR) dated 18.01.2016**

Technical report No. GPREC/ECE/UGC/Major Res proj/ GPREC/2018/Nov/1)

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**Annexure -VIII**

**UNIVERSITY GRANTS COMMISSION**
**BAHADUR SHAH ZAFAR MARG**
**NEW DELHI – 110 002.**

**Final Report of the work done on the Major Research Project.**
**(Report to be submitted within 6 weeks after completion of each year)**

1. Project report No. 1st/2nd/3rd/Final Final
2. UGC Reference No.F. F. No: 43-308/2014(SR) dated 18.01.2016
3. Period of report: from 01.07.2015 to 30.06.2018
4. Title of research project: Heart Regurgitation Severity Analysis using Image Processing Techniques
5. (a) Name of the Principal Investigator Dr. Pinjari Abdul Khayum
   (b) Deptt. Electronics and Communication Engineering
   (c) University/College where work has progressed G. Pulla Engineering College(Autonomous) Kurnool-518007, A. P.
6. Effective date of starting of the project 01.07.2015
7. Grant approved and expenditure incurred during the period of the report:
   a. Total amount approved Rs. 4,26,000-00
   b. Total expenditure Rs. 4,37,113-00

c. Report of the work done: (Please attach a separate sheet)

i. Brief objective of the project

(a) For better understanding the capabilities of image processing methods

(b) To study proposed suggestion of integrating image processing methods for effective quantification of valvular regurgitation.

(c) To classify, segment and quantify the parameters of Mitral Regurgitation (MR) echocardiography.

(d) To estimate the severity (mild/moderate/severe) analysis of MR disease images using PISA method.

ii. Work done so far and results achieved and publications, if any, resulting from the work (Give details of the papers and names of the journals in which it has been published or accepted for publication Yes, Results Achieved, Two publications, the details are given below

| S. No. | Paper Title | Name of the Journal/ Conference | Status |
|---|---|---|---|
| 1 | Mitral Regurgitation Severity Analysis Based On Features and Optimal HE (OHE) With Quantification Using PISA Method DOI: https://doi.org/10.1515/jisys-2017-0116 | Journal of intelligent Systems (Scopus Indexed Journal) | Published in October, 2017 |
| 2 | Feature Based Classification and Segmentation of Mitral Regurgitation Echocardiography Images Quantification using PISA method http://www.inderscience.com/info/ingeneral/sample.php?jcode=ijbet. DOI: 10.1504/IJBET.2017.10012825 | International Journal of Biomedical Engineering and Technology (Scopus Indexed Journal, Elsevier) | Accepted in Jan. 2017 |

iii. Has the progress been according to original plan of work and towards achieving the objective. if not, state reasons

-- YES, progress is according to original plan of work and objects achieved --

The improvement in imaging machinery enables to enhance the quantities of flow convergence, vena contracta and the regurgitant volume which finally leads to improvements in the quantification of valvular regurgitation.

iv. Please indicate the difficulties, if any, experienced in implementing the project_

- Difficulties not faced in implementation of the project.

v. If project has not been completed, please indicate the approximate time by which it is likely to be completed. A summary of the work done for the period (Annual basis) may please be sent to the Commission on a separate sheet.

- Project is completed -

v. If the project has been completed, please enclose a summary of the findings of the study. One bound copy of the final report of work done may also be sent to University Grants Commission.

- Bound copy of final report is attached -

vi. Any other information which would help in evaluation of work done on the project. At the completion of the project, the first report should indicate the output, such as (a) Manpower trained (b) Ph. D. awarded (c) Publication of results (d) other impact, if any

Publications attached

29.11.2018

SIGNATURE OF THE PRINCIPAL INVESTIGATOR

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29/11/18

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29.11.18

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Annexure – IX

**UNIVERSITY GRANTS COMMISSION**
**BAHADUR SHAH ZAFAR MARG**
**NEW DELHI – 110 002**

**PROFORMA FOR SUBMISSION OF INFORMATION AT THE TIME OF SENDING THE FINAL REPORT OF THE WORK DONE ON THE PROJECT**

1. Title of the Project: Heart Regurgitation Severity Analysis using Image Processing Techniques

2. NAME AND ADDRESS OF THE PRINCIPAL INVESTIGATOR


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4. UGC APPROVAL LETTER NO. AND DATE: F.No: 43-308/2014(SR)dated 18.01.2016

5. DATE OF IMPLEMENTATION : 01.07.2015

6. TENURE OF THE PROJECT : 01.07.2015 to 30.06.2018

7. TOTAL GRANT ALLOCATED : Rs. 4,26,000-00

8. TOTAL GRANT RECEIVED : Rs. 4,17,000-00

9. FINAL EXPENDITURE : Rs, 4,37,113-00

10. TITLE OF THE PROJECT : Heart Regurgitation Severity Analysis using Image Processing Techniques

11. OBJECTIVES OF THE PROJECT ………………………………

(a) For better understanding the capabilities of image processing methods

(b) To study proposed suggestion of integrating image processing methods for effective quantification of valvular regurgitation.

(c) To classify, segment and quantify the parameters of Mitral Regurgitation echocardiography.

(d) To estimate the severity (mild/moderate/severe) analysis of MR disease images using PISA method.

12.WHETHER OBJECTIVES WERE ACHIEVED ........................... (GIVE DETAILS)

YES, ACHIEVED

The segmentation and quantification method of MR images are helpful for the cardiologist to easily identify the affected jet area of the mitral valve. The severity analysis is also helpful to predict the severity level of the patients.

13.ACHIEVEMENTS FROM THE PROJECT ............................

The greatest achievement from this project is the successful development of the segmentation and quantification of mitral valve regurgitation using PISA method. This will save the patient's lifetime. Because MR disease has no symptoms and may causes sudden death. This quantification method is to identify the severity level of the patients and will aid the doctors to take the decision for what kind of treatment given to the patients based on the severity level.

14.SUMMARY OF THE FINDINGS ........................................... ( IN 500 WORDS )

In this Research work, there are several techniques are used to identify the severity of the Mitral Regurgitation (MR) using image processing techniques, the classification methods and also the quantification method. The quantification of the Mitral valve regurgitation from MR image is determined by comprising the following major tasks namely

- Preprocessing
- Feature extraction
- Classification
- Segmentation
- Quantification

In preprocessing, Gaussian filter and Gaussian smoothing filter is utilized to remove the bothersome agitating impacts. Preprocessing is a procedure of wiping out the bothersome clatter and agitating impacts from the echocardiogram picture. In the midst of preprocessing, if a couple of things overlying in a picture and the nearest of neighboring pixel regards in restorative pictures make the discovering procedure is a greatly troublesome errand. To bear such issues logically, a clean preprocessing technique should be regarded before preparing the picture. Morphology based preprocessing strategies that enhances the idea of restorative pictures.

In feature extraction, this is to remove the part going to process. In our examination, the features considered are Color and surface segment, Gray level (measurement) co-occasion (Co-occurrence) Matrix (GLCM) and Maximum power or intensity (MI). The shading is for the most part used as the major component for picture depiction. Shading space, shading assessment, and similarity estimation are the key parts of shading feature extraction. The surface is another component that can parcel portrayals into regions of intrigue and organize those regions. Surface gives us information about the spatial technique of the shades or powers canister an image. The most extraordinary intensity of the pictures sees the best tally of pixel qualities (0– 255) and the running with power respect. The GLCM addresses an undeniable technique for keeping an eye at first glance that considers the spatial relationship of the pixels. The GLCM can uncover express qualities about the spatial dispersing of the dim measurements in the surface picture. A shading histogram is a depiction of the dispersal of tints in a picture. For computerized portrayals, a shading histogram embodies the amount of pixels that have tints in each ensured once-over of shading groups that cover the picture's shading space and the arrangement of each conceivable shading. The histogram leveling typically results in the across the board uniqueness of a couple of pictures. The shading histogram may in like manner be shown as a smooth limit specific from the shading space that philosophies the pixel counts. . The division calculation can partition the histogram of a picture into various packs as shown by the order of the dull estimations of the prepared picture. The calculation is an unsupervised and altered one to divide the picture from the histogram data. The essential objective is to extend the ability of streamlining using the krill herd optimization (KHO) structure. The situation of an individual krill is perceived by three enhancements Movement begun by other krill people, Foraging activity and Random dissipating.

Support Vector Machine (SVM) classifier is utilized to portray the image as ordinary and irregular. The SVM procedure hopes to locate the best amending hyper plane among the courses by going for the planning cases that are masterminded at the authority of the class descriptors. These planning cases are known as help vectors. The planning cases except for the assistance vectors are the rejected vectors. By this strategy, diminished proportions of getting ready tests are successfully used and high arranging exactness is practiced using moderately minor planning sets.

In division, it will segment the stream region from the ordinary zone. Modified region growing or Changed region developing (MRG) technique and OHE division is used for MR fly region division. In this division procedure, RG is used to upgrade the edge in RG enhancement using some improvement systems. The strategy, for instance, Genetic (inherited) Algorithm (calculation) (GA) and GWO are used to develop the precision. The repeat of appearance of the changed diminish measurements encased in the picture can be broke down by investigating the picture's histogram. The base and most phenomenal limit are shown for histogram leveling. We find the wellbeing Fi in an alloted part for each square of the picture. The exactness is determined using the parameters for example, certified positive (TP), veritable negative (TN), false positive (FP), and false negative (FN). Picture division implies the route toward segregating an automated picture into different segments i.e. set of pixels, pixels in an area are near as exhibited by some homogeneity criteria, for example, shading, power or surface, with the ultimate objective to find and see articles and purposes of restriction in an image [9].Handy utilization of picture division go from separating of noisy pictures, therapeutic applications (discover tumors and different pathologies, measure issue. volume, PC guided restorative methodology, assurance and treatment arranging, examination of anatomical structures of echocardiographic pictures), discover inquiries in satellite pictures (road, timberlands, etc.), stand up to affirmation, novel finger impression affirmation

In assessment, proximal isovelocity surface region or area (PISA) estimation framework is to be gotten. The separated fly territory was supported by the PISA. In this technique, several parameters in the division were surveyed. For the appraisal of Valvular Regurgitation, the PISA system utilizing shading Doppler has been viewed as a solid and right quantitative procedure. Speculatively the stream blending district proximal to a discrete regurgitant opening in a dimension planar surface is a hemispherical volume. The circulatory system in this volume is meandered up towards the regurgitant opening along winding stream lines. Concentric hemispheric shells of essentially indistinguishable and restoring rates (speed isopleths) incorporate this zone of proximal stream extending speed. Shading stream mapping empowers to picture one of these sides of the equator that encourage with the Nyquist farthest compasses of the instrument. On the off chance that a Nyquist limit can be picked with the target that the stream mix has a hemispherical shape. The stream rate through regurgitant hole can be figured by duplicating the hemispherical surface with accomplice speed. Heart work MR imaging estimation (the present standard of reference imaging framework) includes deferred checking times and different apneas; additionally, as a result of the extensive proportion of data made, the standard technique, in light of manual division of cardiovascular pictures, has transformed into a dreary and executive ward process, as such diminishing MR imaging clinical accommodation. In this manner, the present work revolves around the headway and clinical endorsement of a self-loader division calculation for the anatomical and utilitarian evaluation of the two ventricles from heart cine MR examinations.

15.CONTRIBUTION TO THE SOCIETY ...................................

The societal benefits of this project is high and few of them are

- This will saves the lifetime of the people and this to avoid the sudden death of people.
- This method is also helpful to estimate the accurate value and also make decision to doctors for what kind of treatment is given to the patient.

16.WHETHER ANY PH.D. ENROLLED/PRODUCED OUT OF THE PROJECT: -No-

17.NO. OF PUBLICATIONS OUT OF THE PROJECT; 0 2 ( TWO )

( PUBLICATIONS ATTACHED)

| S. No. | Paper Title | Name of the Journal/ Conference | Status |
|---|---|---|---|
| 1 | Mitral Regurgitation Severity Analysis Based On Features and Optimal HE (OHE) With Quantification Using PISA Method DOI: https://doi.org/10.1515/jisys-2017-0116 | Journal of intelligent Systems (Scopus Indexed Journal) | Published in October, 2017 |
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G. Pulla Reddy Engineering College (Autonomous): Kurnool-518007

Accredited by NAAC ($A^{+}$) of UGC & NBA of AICTE

Affiliated to JNT University Anantapur, Anathapuramu, A.P

# DECLARATION

We hereby declare that the UGC Major Research Project entitled, "Heart Regurgitation Severity Analysis using Image Processing Techniques" submitted to the **University Grants Commission, New Delhi, India,** as a Principal Investigator and Co- investigator is an authentic work carried by us and has not been submitted elsewhere in any form previously for the award of any Degree, Diploma, Associate ship, Fellow ship or other similar work to any institution.

Date:29.11. 2018
Place: Kurnool

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# ABSTRACT

Echocardiography is the generally admired scientific specification for the appraisal of valvular regurgitation and gives critical information about bareness of mitral regurgitation (MR). MR is a normal heart infection which can be discovered just at the last stage. Mitral valve regurgitation is the spilling of blood backward direction from left ventricles to left atrium through mitral valve. It doesn't deliver any symptoms at its underlying state. Consistently, our heart circulates around 2,000 gallons of blood. The heart comprises of four chambers two upper chambers and two lower chambers to control the blood flow. The two upper chambers are called atrium, they get blood. The two lower chambers are called ventricle, they siphon blood. At the point when blood flows from the left atrium to the left ventricle the mitral valve opens.

In this research work, the main focus is on the seriousness examination of mitral regurgitation utilizing different methods named as classification, segmentation and PISA evaluation methods. Here the strategy works by first applying pre-processing systems in the echocardiogram image informational index with the end goal to diminish the commotion utilizing Gaussian and Gaussian smoothing filter. Therefore the filtered image plays out the capacity of highlight extraction, classification, segmentation and likewise the measurement. For classification method, Support Vector Machine (SVM) classifier is produced to secret echocardiogram images for the classification of normal and abnormal images. In examination, the highlights considered are Color and surface element, Gray level co-event matrix (GLCM) and Maximum force or Intensity (MI). The shading is principally utilized as the fundamental element for image portrayal. Shading space, shading measurement, and comparability estimation are the key parts of shading highlight extraction. The surface is another component that can section images into regions of intrigue and classify those regions. For segmentation, Modified region growing (MRG) method and Optimal Histogram Equalization(OHE) segmentation is utilized for MR area segmentation. In this segmentation process, region growing (RG) is utilized to enhance the threshold in RG advancement utilizing some optimization methods. At last the Proximal Iso-velocity Surface Area (PISA) measurement method is utilized to evaluate the estimations of fly area and this will chooses the seriousness of the influenced stream area. From the results, this proposed strategy accomplishes better accuracy in the sectioned and optimization method interestingly with the existing system.

**ACKNOWLEDGEMENT**

We are very much thankful to the University Grants Commission, New Delhi, for the sanctioning of Major Research Project and financial assistance to pursue the research work in the Department of Electronics and Communication Engineering, G.Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh. We also convey sincere thanks to the Management, Dr. P. Jayarami Reddy, Director, Dr. B. Sreenivasa Reddy, Principal and Dr. K. Suresh Reddy, Head of the department of Electronics and Communication Engineering, G.Pulla Reddy Engineering College (Autonomous), Kurnool, Andhra Pradesh, for providing basic infrastructure facilities in the Department of Electronics and Communication Engineering throughout the tenure of the project.

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# CONTENTS


| | | | |
|---|---|---|---|
| **DECLARATION** | | | **ii** |
| **ABSTRACT** | | | **iii** |
| **ACKNOWLEDGEMENT** | | | **iv** |
| **LIST OF FIGURES** | | | **viii** |
| **LIST OF TABLES** | | | **ix** |
| **LIST OF ABBREVIATIONS** | | | **x** |
| **CHAPTER 1** | **Introduction** | | 1 |
| | 1.1 | Overview | 1 |
| | 1.2 | Causes of mitral valve stenosis | 2 |
| | 1.3 | Mitral regurgitation | 3 |
| | 1.4 | Causes of mitral valve regurgitation | 5 |
| | 1.5 | Image processing | 6 |
| | 1.6 | Contributions of this thesis | 7 |
| | 1.7 | Objectives of this thesis | 8 |
| | 1.8 | Thesis Summary and Organization | 8 |
| **CHAPTER 2** | **Literature Survey** | | 9 |
| **CHAPTER 3** | **Feature-based Classification and Segmentation of Mitral Regurgitation Echocardiography Images Quantification Using PISA Method** | | 14 |
| | 3.1 | Introduction | 14 |
| | 3.2 | Proposed methodology | 15 |
| | | 3.2.1 Preprocessing | 16 |
| | | 3.2.2 Feature extraction | 16 |
| | | 3.2.2.1 Colour feature | 17 |
| | | 3.2.2.2 Grey level co-occurrence matrix (GLCM) | 17 |
| | | 3.2.2.2.1 Entropy (ENT) | 18 |
| | | 3.2.2.2.2 Correlation (COR) | 18 |
| | | 3.2.2.2.3 Contrast (CON) | 18 |
| | | 3.2.2.2.4 Homogeneity (HOM) | 18 |
| | | 3.2.2.3 Maximum intensity (MI) | 19 |

| | | | |
|---|---|---|---|
| | 3.2.3 | Echocardiogram image classification | 19 |
| | 3.2.4 | MR segmentation analysis | 20 |
| | 3.2.4.1 | Gridding | 21 |
| | 3.2.4.2 | Seed point selection | 21 |
| | 3.2.4.3 | Finding optimal threshold value | 22 |
| | 3.2.4.4 | Applying RG to the seed point | 22 |
| | 3.2.5 | Quantification MA using PISA | 22 |
| 3.3 | | Results and discussions | 24 |
| | 3.3.1 | Database description | 24 |
| | 3.3.1.1 | Performance evaluation parameters | 25 |
| | 3.3.1.2 | Experimental analysis in classification process | 25 |
| | 3.3.1.3 | MR jet area segmentation analysis | 25 |
| | 3.3.1.4 | Quantification analysis using PISA | 28 |
| 3.4 | | Summary | 29 |
| **CHAPTER 4** | | **Mitral Regurgitation Severity Analysis Based on Features and Optimal HE (OHE) With Quantification Using PISA Method** | 30 |
| 4.1 | | Introduction | 30 |
| 4.2 | | Proposed Methodology | 30 |
| | 4.2.1 | Pre-processing | 31 |
| | 4.2.2 | Feature Extraction | 32 |
| | 4.2.2.1 | Color and Texture Feature | 32 |
| | 4.2.2.2 | Maximum Intensity (MI) | 32 |
| | 4.2.2.3 | Gray-level Co-occurrence Matrix (GLCM) | 32 |
| | 4.2.2.4 | Grey-level Run-length Matrix (GLRLM) | 33 |
| | 4.2.3 | Feature-based Classification | 33 |
| | 4.2.4 | Abnormal MR Image Segmentation Process (OHE) | 33 |
| | 4.2.4.1 | Histogram Equalization Limits | 34 |
| | 4.2.4.2 | Threshold Optimization using KHO | 34 |
| | 4.2.4.3 | Fitness Evaluation | 36 |
| | 4.2.4.4 | Movement Induced by Other Krill Individuals | 36 |

| | | | |
|---|---|---|---|
| | | 4.2.4.5 Foraging Motion | 36 |
| | | 4.2.4.6 Physical Diffusion | 36 |
| | | 4.2.4.7 Crossover | 36 |
| | | 4.2.4.8 Mutation | 37 |
| | | 4.2.4.9 Optimal Threshold to the HE | 37 |
| | | 4.25 Quantification MA using PISA | 37 |
| | 4.3 | Results and Discussion | 37 |
| | | 4.31 Classification and segmentation Performance Analysis | 37 |
| | | 4.32 Parameter Quantification Analysis | 39 |
| | 4.4 | Summary | 39 |
| **CHAPTER 5** | **Result and discussion** | | 40 |
| | 5.1 | Tool used for research | 40 |
| | 5.2 | Results | 40 |
| **CHAPTER 6** | **Conclusion** | | 44 |
| **FUTURE SCOPE** | | | 46 |
| **REFERENCES** | | | 47 |

# LIST OF FIGURES


| Figure No | | Page No |
|---|---|---|
| 1.1 | Mitral valve in normal and abnormal condition | 2 |
| 1.2 | Mitral valve stenosis | 3 |
| 1.3 | Steps in image processing | 7 |
| 3.1 | Block diagram for proposed method | 16 |
| 3.2 | Support vector machine [SVM] | 19 |
| 3.3 | Block diagram for the steps involved in segmentation process | 21 |
| 3.4 | Doppler input colour image | 23 |
| 3.5 | Sample database images | 24 |
| 3.6 | Preprocessing images | 24 |
| 3.7 | Graphical user interface (GUI) for MR analysis process | 28 |
| 4.1 | Block Diagram for the Proposed Method | 31 |
| 4.2 | Block Diagram for the Segmentation Process | 34 |
| 4.3 | Flow Chart for KHO | 35 |
| 5.1 | Performance analysis for classifier | 40 |
| 5.2 | Comparative analysis | 41 |
| 5.3 | Comparative analysis for existing and proposed method | 42 |
| 5.4 | Comparative Analysis of the Different Classifiers | 42 |
| 5.5 | Comparative Analysis | 43 |

# LIST OF TABLES


| Table No | | Page No |
|---|---|---|
| 3.1 | Quantification of standard Doppler parameters for MR severity | 24 |
| 3.2 | Test results of echocardiogram image classification | 26 |
| 3.3 | Measured values of MR | 26 |
| 3.4 | Proposed segmentation results analysis | 27 |
| 4.1 | Results for OHE-KHO | 38 |
| 4.2 | Comparison of Segmentation Results | 38 |
| 4.3 | Quantified Parameters in Segmented Jet Area in MR Part | 39 |

# LIST OF ABBREVIATIONS

| | |
|---|---|
| MR | Mitral Regurgitation |
| MV | Mitral Valve |
| MI | Myocardial Infraction |
| LV | Left Ventricle |
| LA | Left Atrium |
| IMR | Ischaemic Mitral Regurgitation |
| PISA | Proximal Isovelocity Surface Area |
| GWO | Grey Wolf Optimization |
| GA | Genetic Algorithm |
| FCM | Fuzzy C-means Clustering |
| OHE | Optimal HE |
| EROA | Effective Regurgitate Orifice Area |
| CHF | Congestive Heart Failure |
| FMR | Functional Mitral Regurgitation |
| EF | Ejection Fraction |
| KHO | Krill Herd Optimization |
| SVM | Support Vector Machine |
| MRG | Modified Region Growing |
| GLCM | Grey Level Co-occurrence Matrix |
| GLRLM | Grey Level Run Length Matrix |
| RF | Regurgitation Fraction |

# Chapter 1

## INTRODUCTION

### 1.1 Overview

Heart valve stenosis [1] is one of the major issues among the heart diseases. In cardiovascular system, the heart valves play a major part as they control the blood flow within the heart chambers and human body [2]. The narrowing or insulting of the heart's mitral valve is known as mitral valve stenosis [3]. This limited valve doesn't open legitimately henceforth it hinders the blood stream into the principle siphoning council of your heart (left ventricle) [4]. At the point when the blood stream to the left ventricle is decreased or obstructed, the heart needs to work harder to siphon blood to our body [5]. This makes the left ventricle thicken and amplify. This additional work done by the heart reduces the measure of blood it can siphon, and this can cause side effects and additionally debilitate your heart muscle [6]. This may also lead to heart failure. Mitral valve stenosis can experience you exhausted in addition to causes many problems like short of breath, coughing up blood, chest discomfort. Mitral valve disorder be able to damage your heart and decrease the blood run [7].

Every day, our heart circulates about 2,000 gallons of blood. The heart composed of four chambers two superior chambers and two inferior chambers to control the blood flow [8]. The two superior chambers are called atrium, they accept blood. The two inferior chambers are called ventricle, they push blood [9]. When blood flows from the left atrium to the left ventricle the mitral valve opens [10]. When the heart works perfectly, the four valves open and close in a proper manner to circulate blood throughout the body. The mitral valve is situated on the left half of the heart, between two chambers: the chamber and the ventricle [11]. Blood is siphoned from the left chamber into the left ventricle, through the mitral valve [12]. The healthy mitral valve allows blood to pass from left chamber to left ventricle and keeps the blood from streaming back [13].

The working of mitral valve in normal and abnormal condition is shown in Fig.1.1. Mitral valve stenosis happens when the mitral valve opening is limited [14]. At the point when the mitral valve opening is limited, enough blood cannot move through it. Narrowing of mitral valve can also exist caused due to calcium build up in heart valves. Smoking is the major cause for increased calcium buildup in the heart and major arteries [15]. Mitral valve stenosis can cause assortment of issues, including weariness, trouble breathing, blood clumps, and heart disappointment [16].

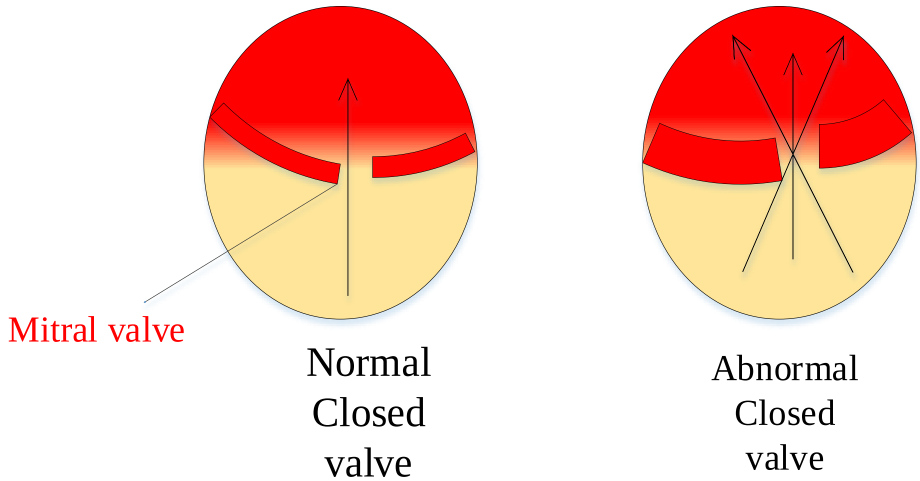



**Fig.1.1 Mitral valve in normal and abnormal condition**

An echocardiogram is the complete test used to affirm the determination of mitral valve stenosis [17]. An echocardiogram is an exceptional technique that utilizes ultrasonic sound waves to make pictures of the heart and its structures [18]. Echocardiograms are effortless, don't require an IV and just take around a hour to perform [19].

**1.2 Causes of mitral valve stenosis**

Mitral valve stenosis is normally caused by rheumatic fever [20]. Rheumatic fever is a youth ailment caused due to streptococcal bacteria. The heart and the joints are the organs affected due to rheumatic fever [21]. Hence the heart and the joints become very inflamed due to the infection caused by bacteria; this leads to endocarditis**,** myocarditis**,** and pericarditis in the heart and causes chronic disability in the joints [22]. The disorder which affects the heart's lining is called endocarditis **(**endocardium**)**. The disease which affects the heart's muscle is called myocarditis **(**myocardium**)**. The disorder which affects the membrane surrounding the heart is called pericarditis (pericardium) [23]. A congential heart deformity may prompt mitral valve stenosis in a child.

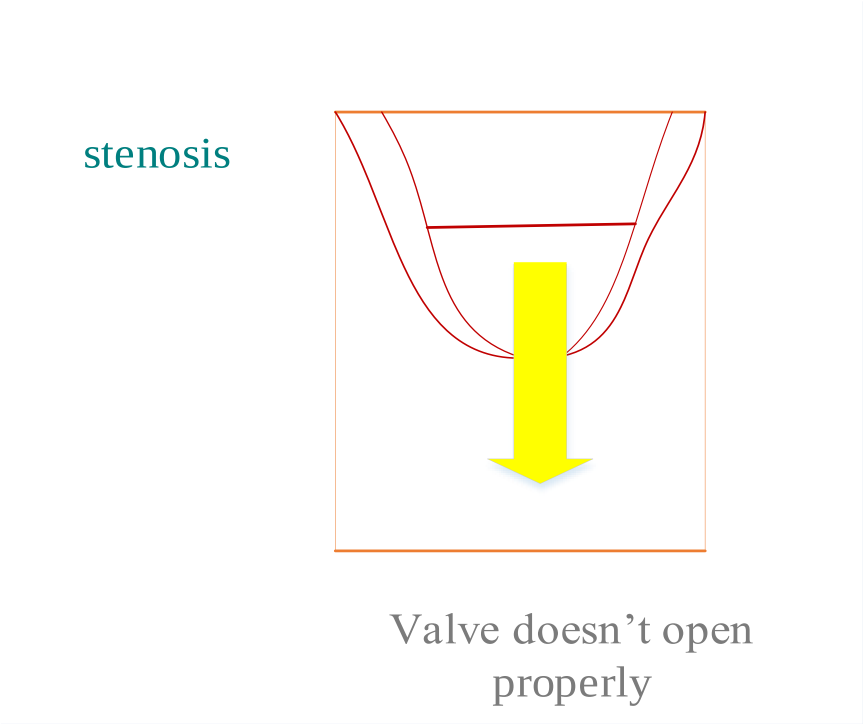



**Fig.1.2 Mitral valve stenosis**

Fig.1.2 shows the slighting of the heart’s mitral valve. This is known as mitral valve stenosis. The valve leaflet becomes fused and thickened hence the valve cannot open freely. The flow of blood is blocked, this even causes heart failure.

### 1.3 Mitral regurgitation

In the diseases of the mitral valve (MV), such as Mitral Regurgitation (MR) several factors have been appeared to influence tissue structure and piece that ultimately lead to valve failure [24]. MR occurs due to the unbalance between expanded tying powers and lessened shutting powers [25]. Maximum Intensity (MI) of the segments underlying the papillary muscles brings about renovating of that locale of the ventricle. MR is a condition in which your heart's mitral valve doesn't close firmly; thus the blood flows in reverse in your heart [26]. MR is frequently gentle and advances gradually i.e., you might not have any indications for a long time. MR has an expanded danger of heart disappointment, arrhythmia, and death [27]. Mitral regurgitation is classified into two types, primary MR and secondary MR.

The difference between primary (degenerative) MR and secondary (functional) MR is essential MR is because of natural sickness of at least one parts of the mitral valve device and optional MR which isn't a valve malady [28]. The mitral valvular apparatus is composed of its front and back pamphlets, the chordae tendineae, the papillary muscles, and the mitral annulus. Variations from the norm in any of these structures can create essential mitral spewing forth [29]. In case, if there is a primary defect in the leaflets, there is excess tissue or damaged support chord which is the cause for the primary MR [30]. Secondary MR is caused due to diseases in left ventricle. This occurs due to problem in left ventricle so blood moves backward through the mitral valve [31]. If dilatation of the heart muscle such as heart attack occurs, imperfections occur in "annulus". Finally this causes secondary stretching of the annulus hence the leaflets pull apart causing secondary MR.

Functional MR can be classified into two subgroups, ischaemic and no ischaemic MR [32]. The papillary muscles are conservatories of the endocardium, the myocardial film generally capable to ischaemic. Ischemic papillary muscle dysfunction counteracts ordinary valve shutting, taking into account prolapse and regurgitation [33]. Ischaemic regurgitation as a rule enhances when the ischaemic purposes, Infarction with interruption of a papillary muscle head produces severe mitral regurgitation [34]. More broad papillary muscle dead tissue can prompt transection of the whole muscle, which produces overpowering mitral regurgitation unfit with life.

MR caused by changes of left ventricular structure is known as Ischaemic mitral regurgitation (IMR) [35]. The clinical signs of MR and its severity are unpredictable in ischaemic MR. IMR is a visit confusion of left ventricular (LV) worldwide or provincial neurotic redesigning because of endless coronary supply route ailment [36]. IMR is defined as mitral regurgitation (MR) caused by chronic changes of LV structure and function due to ischemic heart disease [37]. It's anything but a valve sickness yet speaks to the valvular outcomes of expanded tying powers and diminished shutting powers [38]. It is accounted for in around one-fifth of patients following intense myocardial localized necrosis (MI) and one-portion of those with congestive heart disappointment. IMR is a successive difficulty of coronary supply route ailment and it exacerbates the visualization [39]. The frequency in ischaemic MR differs according to the technique used for its detection, the management of the patients, the timing post-myocardial infarction (MI), and infarct size [40].

### 1.4 Causes of mitral valve regurgitation

The heart has four valves for the flow of blood in the right bearing. These valves incorporate the mitral valve, tricuspid valve, aspiratory valve, and aortic valve. Every valve has folds (pamphlets or cusps) that open and closes once amid every heartbeat. Once in a while, the opening or closing of valves doesn't occur properly, disturbing the blood spill out of heart to the body. In mitral valve regurgitation, the mitral valve between the left chamber and left ventricle doesn't close firmly this makes blood release in reverse into the left chamber [41].

Some of the possible cause of MR includes,

- **Mitral valve prolapsed:** During the heart's contraction, the mitral valve's pamphlets swell again into the left chamber [42].
- **Damaged tissue cords:** The heart divider may tear or stretch for individuals with mitral valve prolapse, a tear can cause spillage through mitral valve [43].
- **Rheumatic fever:** Rheumatic fever can harm the mitral valve and cause mitral valve regurgitation [44].
- **Endocarditis:** Infection in lining of the heart origins mitral valve regurgitation [45].
- **Heart attack:** Heart attack [46] harms the region of the heart muscle which bolsters the mitral valve, influencing the capacity of the valve. Heart assault can cause sudden and severe mitral valve regurgitation.
- **Abnormality of the heart muscle:** When the blood pressure is high the heart has the work harder this causes enlarging of heart's left ventricle. This can extend or destroy the tissue roughly the mitral valve, which can outflow.

- **Congenital heart defects:** Some born babies have defects in their hearts and damage in heart valves [47].

- **Radiation treatment:** at times, radiation treatment for malignancy [48] can likewise cause mitral valve regurgitation.

- **Atrial fibrillation:** Atrial fibrillation [49] is a heartbeat problem which is a major reason for mitral valve regurgitation.

## 1.5 Image processing

Fig.1.3 shows the steps involved in image processing. Image processing includes acquisition, preprocessing, enhancement, segmentation, feature extraction, evaluation and display of images [50]. Image processing uses x-ray, ultrasound, MRI, nuclear medicine and optical imaging technologies to assess the current condition of an organ or tissue [51]. Image processing and examination can be utilized to establish the span, dimensions and arrangement of an appendage and run factors of blood [52].

Image acquisition [53] is used for the collection of images. Image preprocessing [54] includes removal of noise using filters. Image segmentation [55] enhances the image and stores the useful information and removes the useless information of the data or image using some techniques. Incomplete closure of the mitral valve which leads to backward stream of blood from left ventricle to left chamber is known as mitral regurgitation. Nowadays, echocardiography and magnetic resonance (MR) imaging are the majority commonly employed methods to analyse the morphologic characteristics of the mitral valve and the severity of mitral regurgitation.

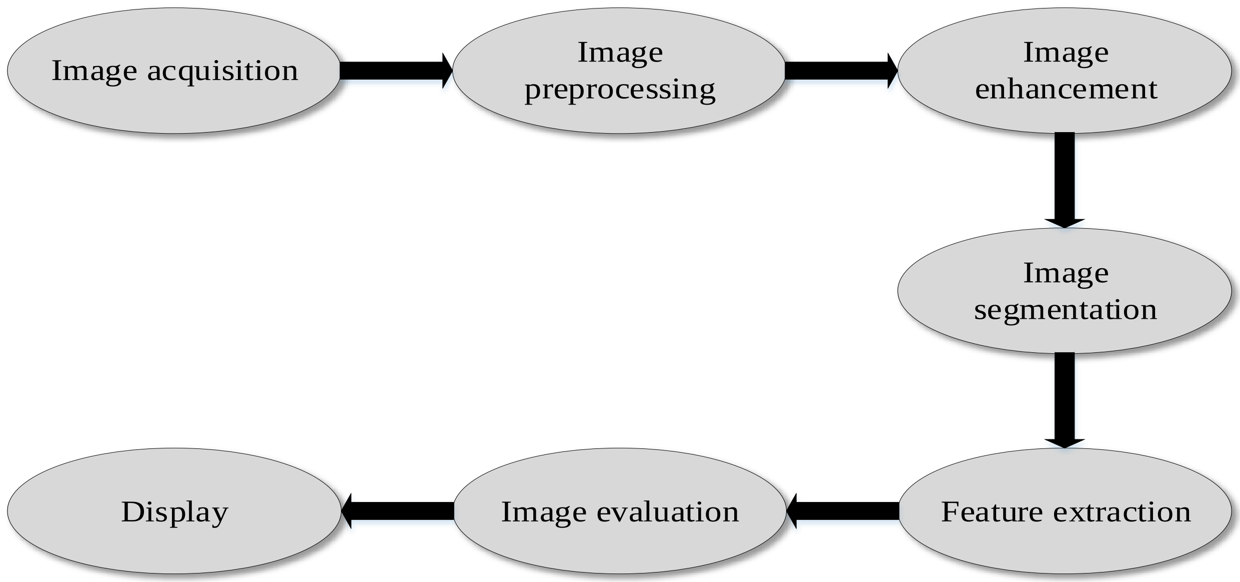



**Fig.1.3 Steps in image processing**

### 1.6 Contributions of this thesis

Our work in this research primarily focuses on the analysis of mitral regurgitation severity. In this research we built a feature-based categorization and fragmentation of mitral regurgitation echocardiography pictures evaluatuion using Proximal Isovelocity (PISA) method. It uses Grey Wolf Optimization (GWO) algorithm. GWO obtain maximum accuracy, sensitivity, and specificity compared to genetic algorithm (GA) and fuzzy c-means clustering algorithm (FCM). There are some limitations in using PISA method hence our research work is associated with Fuzzy with the PISA quantification approach. The PISA method examines the rigorousness of valvular and hereditary heart disorders. The PISA technique is generally used in echocardiography and it estimates the valvular insufficiency and limits mitral regurgitation (MR).

We also assessed the severity of mitral regurgitation based on features and Optimal HE (OHE) with quantification using PISA method. OHE system is used for the segmentation of jet area, which helps to separate the jet area of the image. The Gaussian filter is used in various situations of image processing. Gaussian filter provides noise free output image.

### 1.7 Objectives of this thesis

- For better understanding the capabilities of image processing methods.
- To study proposed thought of coordinating picture preparing strategies for viable evaluation of valvular regurgitation.
- To define a proficient evaluation of Mitral regurgitation utilizing picture handling strategies and proximal isovelocity surface territory (PISA) technique.
- To find the rigorousness (mild / moderate / severe) of mitral regurgitation.

### 1.8 Thesis Summary and Organization

The leftovers of this thesis is formated as follows– In Chapter 2, we discuss the related work done in the area of human heart regurgitation analysis. Chapter 3 describes about the feature-based separation and fragmentation of mitral regurgitation echocardiography images quantification using PISA method used for this research. In Chapter 4, we present our approach for mitral regurgitation severity analysis based on Features and Optimal HE (OHE) with Quantification using PISA Method. In Chapter 5, we describe the tool used for research. The summary and conclusion of this research work are presented in Chapter 6. Chapter 7 deals with references.

# Chapter 2

## LITERATURE SURVEY

In this section, we examine the related work done in this field over the past. Earlier, many technologies and algorithms have been developed for the severity assessment of human heart regurgitation. Several methods are proposed and proved.

For echocardiographic reviewing of local aortic disgorging (AR) and mitral spewing forth (MR) Sinsia A Gao et al [56] has proposed an integrative calculation. This examination points with examination of the likelihood of individual parameters and to evaluate the limit of the figurings to isolate extreme from moderate disgorging. The quantitative Doppler strategies are utilized to research the plausibility issues. The proposed American Society of Echocardiography (ASE) calculation for evaluating of spewing forth has the ability to discover merciless AR and serious MR utilizing Cardiovascular Magnetic Resonance (CMR).

To decide the essential mitral spewing forth seriousness Seth Uretsky et al [57] completed a qualified estimation of echocardiographic parameters utilizing Magnetic Resonance Imaging (MRI). In this exploration MRI examines were accomplished utilizing a 1.5-T or 3.0-T MRI scanner notwithstanding pictures was rethought and evaluated utilizing SuiteHeart programming. X-ray determined regurgitant volume (MRI-RV) was chosen by finding the divergence between the LV thump measurements and aggregate forward run.

These days factors like maturing, heart assault, rheumatic fever and so forth causes disappointment of aortic bioprosthetic valves. Thus Janarthanan Sathananthan et al [58] proposed Valve-in-valve (VIV) treatment with transcatheter aortic valve substitution (TAVR) which is a best choice for long-sufferings having aortic bioprosthetic valve disappointment.

Heart disappointment (HF) trouble in excess of 5 million long-sufferings in the USA and is anticipated to achieve extra than 8 million by 2030. Subsequently to amend heart disappointment Zhinuo J. Wang et al [59] broke down the left ventricular extended myocardial unbending nature and end-extended myofibril strain utilizing customized biomechanical investigation. The bio programmed demonstrate have as a highlighted with imaging and catheter data is utilized for the estimation of characteristic myocardial unbending nature for each patient.

Prosthetic heart valves relate to the current state of long-sufferings having heart valve affliction. In this paper Vrishank Raghav et al [60] has utilized Particle Image Velocimetry (PIV) as the stream appraisal system. PIV is utilized for the test investigation of run knolls associated with heart valve prostheses. This paper gives utilizable information to heart valve instrument makers and partners to quantify heart valve run playing fields for the potential for haemolysis and thrombosis.

Hicham Saaid et al [61] proposed a solitary adjustment multiplane stereo based component portrayal velocimetry which is used to examine run self-inspires in the cardiovascular territory. The self-alignment procedure connected here is utilized to spot on the attainable misalignments of the goal concerning the illumination sheet. All the run measurements are endorsed out under pulsatile stream conditions. The mechanical arrangement of the stereoscopic PIV gadget gives a choice and lively structure for high-objectives speed estimations.

Steady pneumonic spewing forth (PR) is an ordinary trouble in patients who have encountered cautious fix of intrinsic coronary disease. Subsequently Marıa Rodrıguez Serrano et al [62] directed an exploration to dismember lymphocyte explanation of these molecules in patients with serious PR. The quality verbalization case of GRK2 and b2-adrenoceptor was adjusted in long-sufferings with thorough PR contrasted it and the sound controls and patients with front line heart disappointment.

Mitral valve (MV) infection results in decrease in annular withdrawal and augmentation in the strain on the MV leaflets. Consequently Patrick S. Connell et al [63] utilized a pseudo-physiological stream hover to consider how to fix the influenced valve piece. Rice University stream circle framework (RUFLS) can rapidly impel changes in MVs in light of balanced hemodynamics.

To test the likelihood of looking over mitral disgorging (MR) earnestness Lior Gorodisky et al [64] endorsed heart appealing resonation (CMR) 4D speed vectors to gauge regurgitant volume (RVol). The regurgitant (RVol) is investigated utilizing proximal stream union. This credibility look at exhibits that CMR-based 4D-PISA can assess MR earnestness quantitatively with no geometric doubts.

To survey the seriousness of AS and MR, Pil Hyung Lee et al [65] led an examination utilizing quantitative investigation by mean weight inclination (MPG) estimation and aortic valve zone (AVA) estimation. In this paper two-dimensional and Doppler echocardiographic examinations were performed on all patients. Noninvasive evaluation with Doppler echocardiography is a standard strategy for examining the reality of AR and MR.

Valvular coronary illness (VHD) is an imperative open issue because of maturing of the populace. Consequently Tomaz Podlesnikar et al [66] completed an exploration in examination of myocardial fibrosis in valvular coronary illness utilizing cardiovascular attractive reverberation (CMR) imaging. CMR permits evaluation of responsive fibrosis utilizing T1 mapping procedures and supplanting of fibrosis and scar with the assistance generally gadolinium differentiate improvement (LGE).

To get to the volume and capacity of univentricular heart Francesco Secchi et al [67] completed an examination to show the blood-edge (BT) division programming for cardiovascular alluring resonation (CMR) cine pictures in patients with utilitarian univentricular heart (FUH). The image obtainment was gated to the electrocardiographic (ECG) banner to pass on a cine gathering all through the systole and diastole and to avoid cardiovascular antiquities.

An essential segment of cardiovascular occupation is the mitral valve (MV) which ensures appropriate directional blood keep running between the left heart hollows. In this paper Amir H. Khalighi et al [68] has clarified multi-goals geometric displaying of the mitral heart valve flyers. Iterative Non-uniform quick Fourier change (NUFFT) punished with the sparsity requirement is actualized to wipe out the false recurrence segments caused by as far as possible and recover an immaculate range. To quantitatively depict and address the multiscale geometry of MV flyers got from imaging data a novel demonstrating pipeline is proposed.

Expanded left ventricular divider thickness causes Hypertrophic cardiomyopathy (HCM). In this investigation Rafael Kuperstein et al [69] intended to survey the recurrence of again outrageous mitral heaving forward causing clinical breaking down in patients with HCM and to delineate the related clinical and echocardiographic and the elements related with this condition.

About 1% of conceived babies are influenced by some innate heart deformity (CHD). To assess inborn heart imperfection Kathleen Gilbert et al [70] proposed Atlas-based factual models. Vital part examination (PCA) is an unsupervised measurement diminish examination technique which is used in the Multi-Ethnic examination of Atherosclerosis. It explores the associations between traditional risk factors, cardiovascular shape and capacity of patients.

To dismember cardiovascular organ components and stream components Sheldon Ho et al [71] has recommended a non-meddling 4D high repeat ultrasound technique. 4D photos of the heart and supply courses are created through transient and spatial relationship joined with quadratic mean outfit averaging. Computational fluid components (CFD) was performed to understand the stream components in the ventricles of the heart. The imaging technique proposed has sufficiently high objectives to enable organ components estimation and CFD. Another image based CFD procedure is used to clear up the cardiovascular organ components and stream components of embryonic hearts.

Michinobu Nagao MD et al [72] proposed assessment of coronary stream using dynamic angiography with 320-identifier push CT and development clarity picture taking care of for revelation of ischemia. The motivation driving this examination is to propose another methodology for evaluating coronary stream using dynamic CT angiography for the whole heart and looks into its capacity for perceiving ischemia from mostly coronary stenosis. Development objectivity picture taking care of (MCIP) is a novel picture getting ready procedure, which performs deformable-enlistment to pursue all the voxels all through various stages. This imaging framework limits commotion, upgrades development reasonability and gives an apparatus to finish unequivocal voxels all stages.

Backwards deformable enlistment calculations (DRA) were detailed by Mariana M. Lamacie et al [73] for myocardial strain examination on cine MRI. In this examination collapsible enrollment based investigation is contrasted and MR include following and spot following echocardiography. It is demonstrated that DRA examination would be wise to quality entomb and intra-watcher reproducibility contrasting and FT for all harm measurements.

Ventricular dilatation causes disengagement of the Papillary Muscle (PM) thus Milan Toma et al [74] completed an exploration on liquid– structure correspondence examination of PM forces using a far reaching mitral valve portrayal with 3D chordal association. Fluid–association communication strategy is utilized to assess opening and shutting of the valve, and to build up the time subordinate chordal powers. The test in displaying FSI of heart valves is dealing with the reach between the pamphlets at cooptation. Exhaustive computational model incorporates the procedure of CT filtering, picture managing out to develop 3D model and raised quality, powerful work age. The geometric data for the MV show was gotten utilizing small scale registered tomography (lCT).

To fathom and foresee the direct and mechanics of nearby and prosthetic heart valves in standard and over the top conditions Arash Kheradvar et al [75] built up a multiscale displaying and computational demonstrating for killing the patterns in heart valves. This investigation clarifies the examination of heart valves, interventional and cautious frameworks, heart valve structure and general cognizance of strong and sporadic cardiovascular valve work.

# Chapter 3

## FEATURE-BASED CLASSIFICATION AND SEGMENTATION OF MITRAL REGURGITATION ECHOCARDIOGRAPHY IMAGES QUANTIFICATION USING PISA METHOD

### 3.1 Introduction

Valuation of mitral valve (MV) morphology explains the range of standard and non-standard attributes, with or without medical or hemodynamic importance. Morphology valuation helps in observation of the etiology and seriousness of valve disease, which are needed for administration development. Ischaemic mitral regurgitation (IMR) has been developed to have predictive hints where an 'effective regurgitate orifice (ERO) area' of more than 20 mm2 impacts in an extensively condensed long haul survival. The happening of mitral regurgitation (MR) in patient's distress isolated coronary artery by-pass surgery (CABG) is likewise identified with an enhanced mortality.

The heart valves have the important role in the cardiovascular system since they control the blood flow in the heart chambers and human body. Mainly the aortic and MVs cause harmonized opening and closing actions in a fast manner to direct the liquid collaboration separating the left atrium (LA), left ventricle (LV) and aorta. The patient's morphological, functional and hemodynamic interdependency problems have been given more importance. The patients who are experiencing cardiac catheterisation are not given injection of iodinated divergence agents. Some of the patients suffer from kidney dysfunction, while in others LV function may be reduced to a certain extend. The addition of energy obtained from the CWT was treated for each patient group to differentiate between patients with standard hearts and those patients with MR. Subordinate MR, ascending from mitral annular dilation and papillary muscle dysfunction, is a mainly found found in patients with congestive heart disappointment (CHF). It prompts the reason for left ventricular end-diastolic weight along with left plus right atria compressions and causes distention of the LV. Main ways to find out echocardiography in MR are assessment of hemodynamic severity, which include the impact on ventricular size, function and hemodynamic.

The significance of MR is for choices about operation and predict about the danger. Functional mitral regurgitation (FMR) is the development of LV dilatation in patients who suffer from heart failure with compact ejection fraction (EF) and is corresponds with poor prediction. The FMR increases in the course of the workout .The MV leads to the severity of FMR during execution rather than at rest.

TR caused by pamphlet abnormality or pacemaker lead impingement was meant as moderate TR. The possibility of the TR method was to build up an instinctual strategy of Doppler speed shape location that can be executed in typical echocardiography frameworks, to evacuate the intra-and between eyewitness variability. These days Doppler ECG takes an interest an imperative obligation in the inconvenient Detection of the sort of treatment focus that is required for a shout of MV spewing forth. Doppler echocardiography finds the nearness of spewing forth, as well as permits to comprehend components of disgorging, amount of its seriousness and outcome. The target of this audit is to think about the echocardiographic parts of FMR. It primarily center around a few highlights that are comparable and tricky in ordinary practice. Utilizing Doppler echocardiography, assessment of the nearness of valvular spewing forth has been obtained for close to nothing, picked gatherings, containing normal volunteers .This audit examinations the diverse methodology includes on the most proficient method to perform quantifiable void stretches out and isn't utilized to decide the standard mindfulness which is equipped for positive medicinal readings.

**3.2 Proposed procedure**

In medicinal cardiology, one of the fundamental points is the estimation of MR meticulousness for which gigantically influences the restorative goals creation strategy. To improve the evaluation, the AR in echocardiography pictures unmistakable stepladders is estimated in this examination exertion. On a very basic level uncover the 2D echocardiogram database to preprocessing drew in to dispose of the music and acquire some from the pretreated pictures. In the wake of separating the pictures, a few information order strategies are utilized to group them into standard MV pictures and irregular MV pictures. For this Support Vector Machine (SVM) direct piece work is utilized. After grouping strategy, strange pictures are considered for partition to segment the stream region in MR part utilizing segment extending with Modified Region Growing (MRG), here Grey Wolf Optimization (GWO) is utilized as the streamlining technique. Doppler echocardiography is recognized as the dependable and correct quantifiable strategy for evaluation of MR by assorted confinements with the help of PISA procedure to quantify the meticulousness of a MR

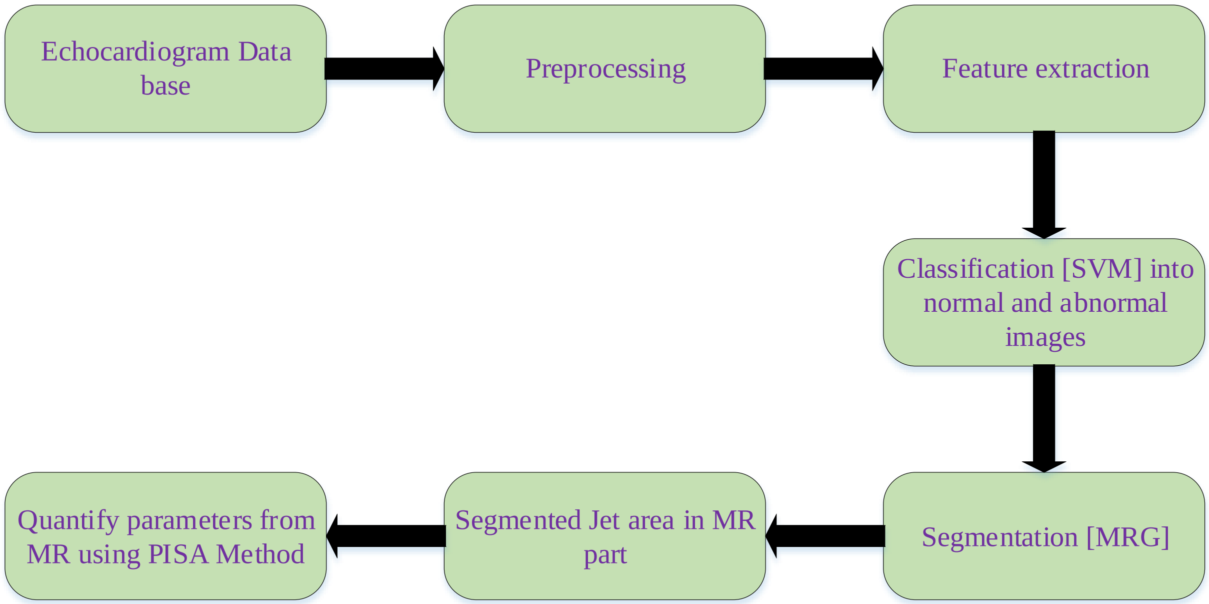



**Fig.3.1 Block diagram for proposed method**

The block diagram for proposed method is shown in Fig.3.1. The steps involved in the proposed system are,

### 3.2.1 Preprocessing

The Gaussian filter is a linear filter which can be utilized in various situations of picture dealing out. Digital echocardiography images are oppressed to sound and by using a Gaussian filter, hence the noise is decreased in preprocessing stages and finally a noise-free output image is obtained.

$$G_1(p) = \exp\left(\frac{-a^2}{2a\sigma^2}\right) \qquad (3.1)$$

Where $G_1(p)$ is the Gaussian function that represents the noise and $\sigma$ denotes a deviation.

### 3.2.2 Feature extraction

The feature extraction method includes the study of the echocardiogram pictures. For image characteristic abstraction, the spectral analysis technique is used. The alteration of the input information into the position of characteristics is proposed in feature extraction. In our research, the features engaged into account are:

- Colour feature
- Grey level co-occurrence matrix (GLCM)
- Maximum intensity (MI).

**3.2.2.1 Colour feature**

A colour histogram is a depiction of the dispersal of shades in an image. For digital representations, a colour histogram epitomizes the quantity of pixels that have shades in every secure list of colour arrays that cover the image's colour space and the arrangement of all feasible colours. The histogram equalisation typically results in the universal divergence of several images. The colour histogram may also be displayed as a smooth function distinct from the colour space that methodologies the pixel counts.

**3.2.2.2 Grey level co-occurrence matrix (GLCM)**

The grey level co-occurrence matrix (GLCM) represents an arithmetical technique for surveying the quality that takes into account the spatial relationship of pixels. The GLCM functions interpret the quality of an image by evaluating the rate of events of the sets of pixel with similar values. The GLCM can explain specific abilities about the spatial dispersal of the grey stages in the texture representation.

$$P_{ij} = \frac{F_{ij}}{\sum_{i,j=0}^{L-1} F_{ij}} \qquad (3.2)$$

Where $F_{ij}$ represents the frequency between two grey levels and L denotes the number of quantized grey levels.

GLCMs are obtained in more than one or two statistics. The statistics are for example,

- Entropy (ENT)
- Correlation (COR)
- Contrast (CON)
- Homogeneity (HOM).

#### 3.2.2.2.1 Entropy (ENT)

Entropy builds up the amount of data of an image that is required for the image density. The entropy evaluates the loss of information or message in a connected signal and calculates the image data.

$$ENT = \sum_{i=0}^{L-1} \sum_{j=0}^{L-1} - P_{ij} \log P_{ij} \tag{3.3}$$

Where $P_{ij}$ are the co-occurring probabilities stored inside GLCM.

#### 3.2.2.2.2 Correlation (COR)

Correlation calculate the linear dependency of grey levels of contiguous pixels. The tracing of the digital image correlation means a visual strategy which services tracing and image recording techniques for exact 2D and 3D dimensions of differences in images. The current applications are amazingly enormous and contain the image examination, image firmness, velocimetry and strain evaluation.

$$COR_{ij} = \sum_{i,j=0}^{L-1} \frac{(i - \Omega_i)(j - \Omega_i) P_{ij}}{\beta_i \beta_j} \tag{3.4}$$

Where $\Omega_i, \Omega_j$ - mean of row i and column j and $\beta_i$, $\beta_j$ - standard deviation of row and column of i and j.

#### 3.2.2.2.3 Contrast (CON)

Contrast constraint investigates the spatial rate of an image and the evolving instants of GLCM. It determines the dissimilarity between the maximum plus the minimum values of an adjacent list of pixels. It efficiently evaluates a number of local dissimilarities in the image. The maximum contrast of an image signifies the separation ratio or the energetic range.

$$CON = \sum_{i,j=0}^{L-1} P_{ij} (i - j)^2 \tag{3.5}$$

#### 3.2.2.2.4 Homogeneity (HOM)

The homogeneity restriction is also known as the contrary difference moment surveys the image homogeneity assuming higher qualities for slight grey tone variations in the pair components. An amount of local homogeneity is often used in the one-dimensional histogram thresholding. The homogeneity, is address to two sections such as the standard deviation and the incoherence of the strengths at each pixel of the image.

$$HOM = \sum_{i,j=0}^{L-1} \frac{1}{1+(i-j)^2} P_{ij} \tag{3.6}$$

**3.2.2.3 Maximum intensity (MI)**

The MI of the representations determines to the maximum reckoning of pixel rates (0 to 255) in addition to the pursuing intensity value. It denotes a graph that illustrates the quantity of pixels in an representation at each and every only one of its kind intensity value.

$$I = \max_{i=0}^{255} (\text{Count of pixel intensity}) \tag{3.7}$$

**3.2.3 Echocardiogram image classification**

MR quantification method initially sorts all regular and irregular images. The entire feature vector values are estimated in this classify method based on attribute MV normal images and MR in abnormal images. They are classified with the help of linear kernel SVM function.

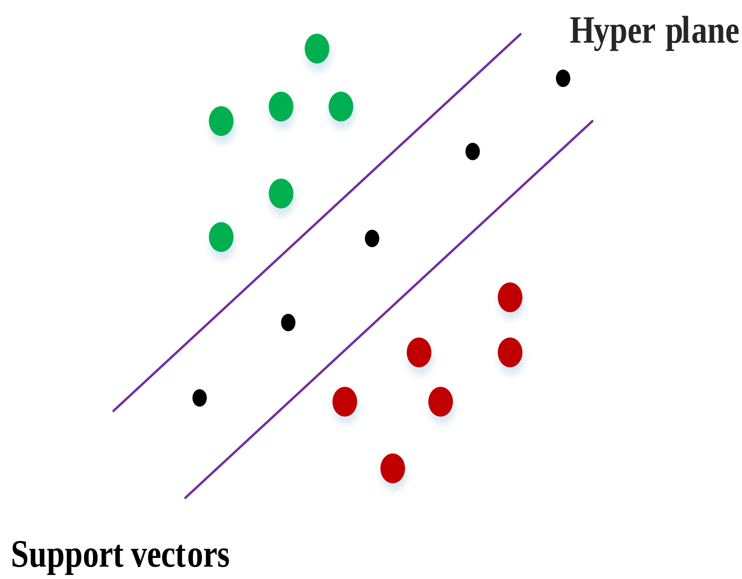



**Fig.3.2 Support vector machine [SVM]**

The fig.3.2 shows support vector machine method. The SVM strategy seeks to discover the best straightening out hyper plane among the courses by aiming at the training folders which are situated at the authority of the class descriptors. These training cases are known as support vectors. The training folders excluding the support vectors are the rejected vectors. By this method, reduced amount of teaching illustrations are successfully utilized and elevated sorting precision is attained using relatively minor training sets. SVM solves the optimisation problem. Hyper plane is proceeding as the decision exterior, the linear function is described as,

$$w = \sum_{i=0}^{M} \Omega_i . f_i . K(x, x_i) = 0 \tag{3.8}$$

Where $x$ represents a vector dragged beginning the key space, $\Omega_i$ is the Lagrange coefficient, $f_i$ is the corresponding target yield and $K(x, x_i)$ represents the internal product of two vectors.

$$w = \sum_{i=0}^{M} \alpha_i . f_i . x_i \tag{3.9}$$

$$b = wx_k - f_k \tag{3.10}$$

At present, the classes, along with being a collection of free, clear-cut labels, occur as randomly designed objects with associations characterized between them.

$$Class \Rightarrow Wx + y \tag{3.11}$$

Finally, the hyper plane-based classifies the signal through equation (3.11) utilized for classifying echocardiogram image with hyper plane value and predict the associated image.

### 3.2.4 MR segmentation analysis

Modified region growing (MRG) method is used for MR jet area segmentation. In this segmentation process, region growing (RG) is used to improve the threshold in RG development using some optimisation procedures. The procedures such as genetic algorithm (GA) and GWO are used to develop the accuracy.

Fig.3.3 shows the block diagram for the steps involved in segmentation process. In the RG, the seed point and threshold assessments are allocated automatically for the segmentation. The ideal threshold value is projected for the better fragmentation and this will raise the precision of the fragmented representation optimisation techniques that are abused. The MRG strategy includes four stages,

i. Gridding
ii. Seed point selection
iii. discovering optimal threshold value
iv. Pertaining RG to the seed point.

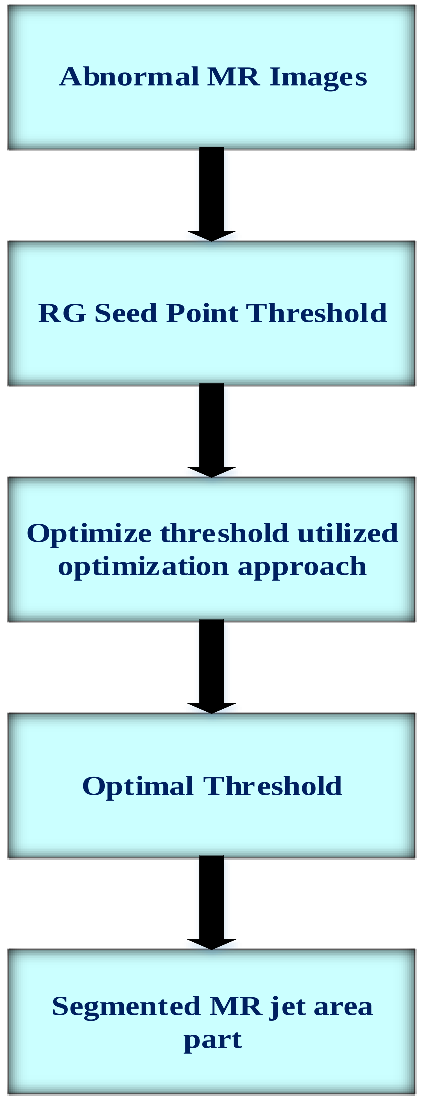



**Fig.3.3 Block diagram for the steps involved in segmentation process**

### 3.2.4.1 Gridding

Firstly, the image is distributed into many blocks (sb) and as it would appear like pertaining a lattice on the representation this methodology is recognised as gridding.

### 3.2.4.2 Seed point selection

In this scheme, the histogram appraisal is contracted to escort in the seed point. Considering the component that the histogram method is utilized for every pixel in the block, the appraisal of the pixel is arranged between 0 and 255 and the most commonly happening pixel value is assigned to be the seed point.

#### 3.2.4.3 Finding optimal threshold value

This technique is implementing to achieve the fragmented image as well as for the resolution the optimisation system is employed. In the entrance optimisation, the maximum accurateness is found out using GWO.

**Steps involved in GWO**

Step 1 Initialise the input threshold solutions as well as algorithm parameters.

Step 2 Evaluate the fitness function.

Step 3 Based on the fitness separate the search solutions into $T_\alpha , T_{\beta,} T_\delta$.

Step 4 Update the position of current search solutions.

Step 5 Again, evaluate the fitness function.

Step 6 Store the best solutions.

Step 7 Stop after the optimal solution is accomplished.

End

#### 3.2.4.4 Applying RG to the seed point

The final procedure is the RG methodology, where the value is achieved from the optimal threshold calculation method and the jet area of the image is extracted.

### 3.2.5 Quantification M R using PISA

In PISA technique, Doppler image is used to efficiently mention the MR. The rigorousness of valvular and habitual heart ailments is examined using PISA method. The value of this technique is that when fluid or liquid goes through a gap in a flat surface the flow speed is calculated. It is represented as flow convergence zone and the leakage of fluid is designed using PISA. This effect is known as Coanda effect.

Fig.3.4 shows doppler input colour image. Due to the leakage of blood flow in the MV region MR disease is caused. The outflow of blood is estimated by using PISA method.

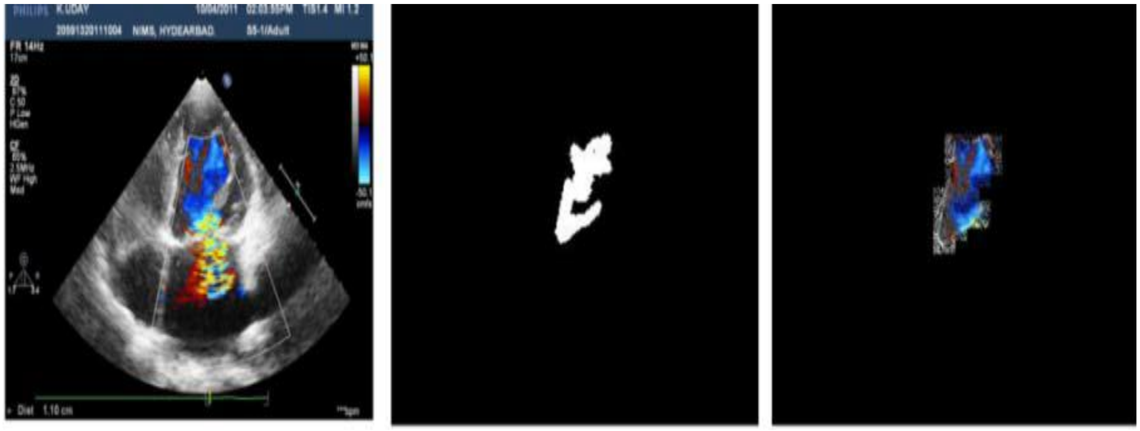


**Fig.3.4 Doppler input colour image**

PISA method is exploited to compute the severity, some measurable limitations are calculated. They are as follows:

a) Effective regurgitant orifice area (EROA)

This parameter is calculated using the instantaneous regurgitant flow.

$$EROA(PISA) = \frac{RF}{V_{\max}} \qquad (3.12)$$

b) Regurgitate fraction (RF)

Regurgitant fraction is the percentage of blood that brings up back through the aortic valve to the LV due to aortic insufficiency or due to mitral deficiency.

$$RF = \frac{RV}{Aortic\ flow} \qquad (3.13)$$

c) Regurgitate volume (R-volume)

This parameter calculates the flow of aortic blood and mitral blood flow in MR part.

$$R - volume = Aortic\ flow - Mitral\ flow \qquad (3.14)$$

These above state limitations are quantified in classify and segmented MR in echocardiogram images. Table 3.1 shows the normal values in Doppler parameters of MR severity assessment. The value of EROA, RF, and R-volume are calculated using equations 3.12, 3.13 & 3.14.

| Parameters | Mild | Moderate | Severe |
|---|---|---|---|
| EROA | < 0.20 | 0.20-0.39 | 0.40 |
| RF | < 30 | 30-59 | 60 |
| R-volume | < 30 | 30-49 | 50 |

**Table 3.1 Quantification of standard Doppler parameters for MR severity**

### 3.3 Results and discussions

This segment discuss about the classification and dissection grades in echocardiogram images for SVM and MRG with GWO technique. The evaluation successfulness of MR was verified by colour Doppler echocardiography representation. Then, some limitations are quantified using PISA method.

#### 3.3.1 Database description

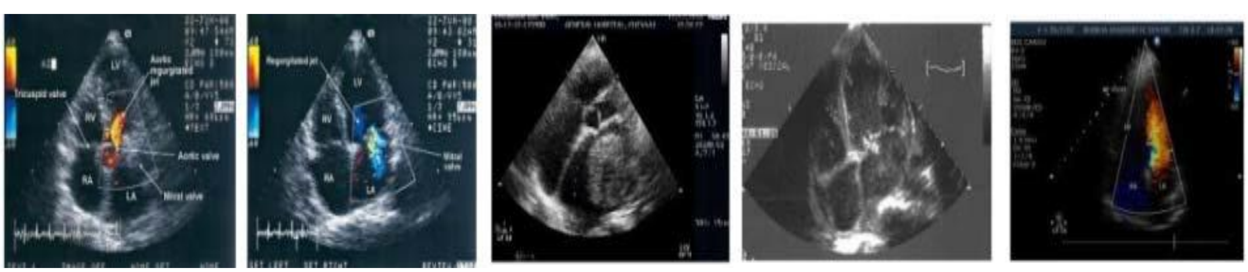


**Fig.3.5 Sample database images**

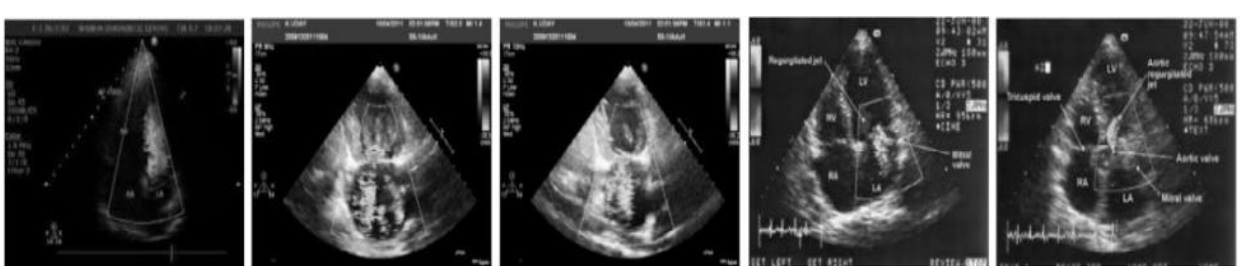


**Fig.3.6 Preprocessing images**

Fig.3.5 shows the database echocardiogram normal and abnormal images. Fig.3.6 shows the next relating preprocessing Gaussian filter in images. The database used here holds more than 100 images for classifying, segmenting and counting method. In the MR quantification method, 80% of the images are utilized for training and 20% are used as a testing period. Each images having various pixels but not more than 255 pixels. In this, the classification process histogram proposes 256 numbers determining the distribution of pixels between greyscale values. It also covers the full image from the echocardiogram.

**3.3.1.1 Performance evaluation parameters**

$$Sensitivity = \frac{TP}{TP + TN} \tag{3.15}$$

$$Specificity = \frac{TN}{TP + TN} \tag{3.16}$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \tag{3.17}$$

**3.3.1.2 Experimental analysis in classification process**

The classification of the normal echocardiogram images and abnormal MR images is discussed in this section. The performance parameter sensitivity, specificity and accuracy are shown in Table 3.2.

**3.3.1.3 MR jet area segmentation analysis**

In the fragmentation process, the MR jet area is fragmented using the projected method 'MRG' with threshold prediction by means of GWO. Table 3.3 shows the quantification measure parameters in MR part of Doppler echocardiogram images receiving RG with GWO and enumerated developed to PISA technique.

Table 3.4 shows the segmented MR jet area part with MR echocardiogram images. By using suggested MRG with GWO related to the other optimisation GA, the accuracy, sensitivity and specificity are in elevation.

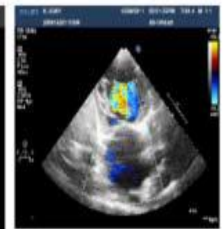
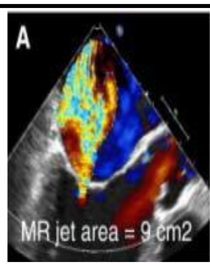
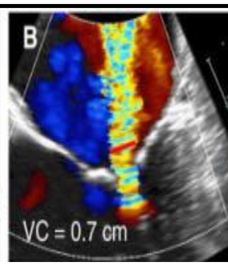
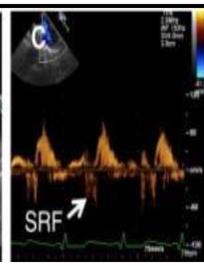
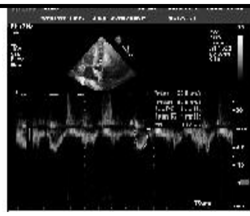
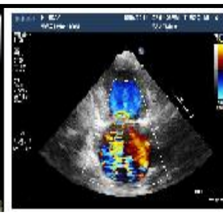
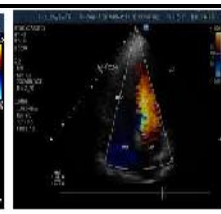
| Validation | Images | Accuracy (%) |
| --- | --- | --- |
| Validation 1 |     | 80 |
| Validation 2 |        | 88.2 |
| Validation 3 |     | 95.3 |

**Table 3.2 Test results of echocardiogram image classification**

| **Quantitative measures** | **Value** |
| --- | --- |
| EROA $(cm^2)$ | 0.03 |
| Regurgitant fraction (%) | 14.05 |
| R-volume $(cm^3)$ | 31.50 |

**Table 3.3 Measured values of MR**

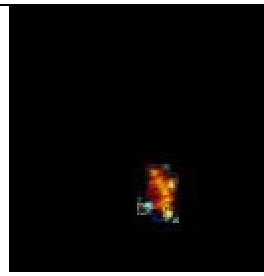
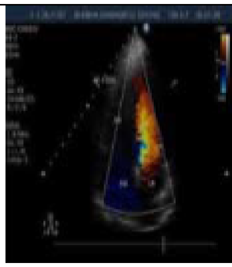
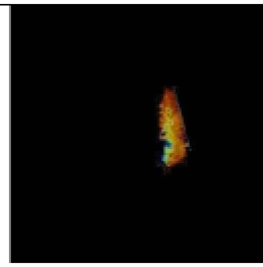
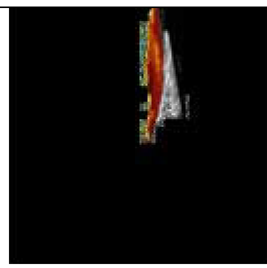
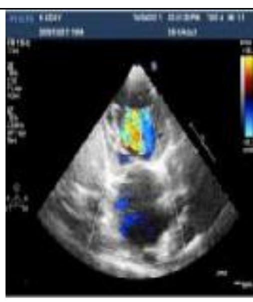
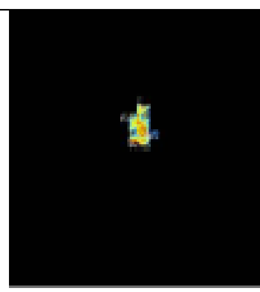
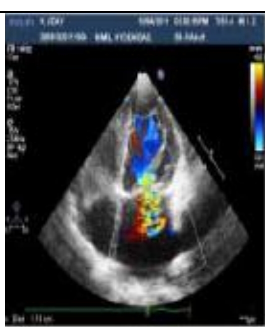
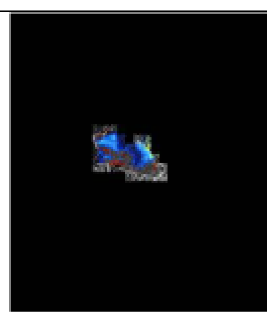
| Sl. no. | Original image | Segmented part | Sensitivity | Specificity | Accuracy |
|---|---|---|---|---|---|
| 1 |  |  | 0.97 | 0.98 | 0.98 |
| 2 |  |  | 0.91 | 0.99 | 0.99 |
| 3 |   |  | 0.58 | 0.89 | 0.88 |
| 4 |  |  | 0.83 | 1.00 | 0.99 |
| 5 |  |  | 0.37 | 0.98 | 0.96 |

**Table 3.4 Proposed segmentation results analysis**

### 3.3.1.4 Quantification analysis using PISA

A quantitative estimation of valve regurgitation is probably done using shade Doppler run charting for the region of flow convergence proximal to a regurgitate gap. The effectiveness of PISA technique in the quantisation of MR has been explained by trial inquiry. Nowadays, enveloping and non-enveloping Doppler echocardiography techniques are utilized to determine the aortic ERO region in AR.

Fig.3.10 shows the GUI production standards in quality mining, separation parameters and quantification dimensions recognised. The construction of this method is done by selecting the images and tracked by the exaction of the captioned structures. Finally the numerous limitations are assessed.

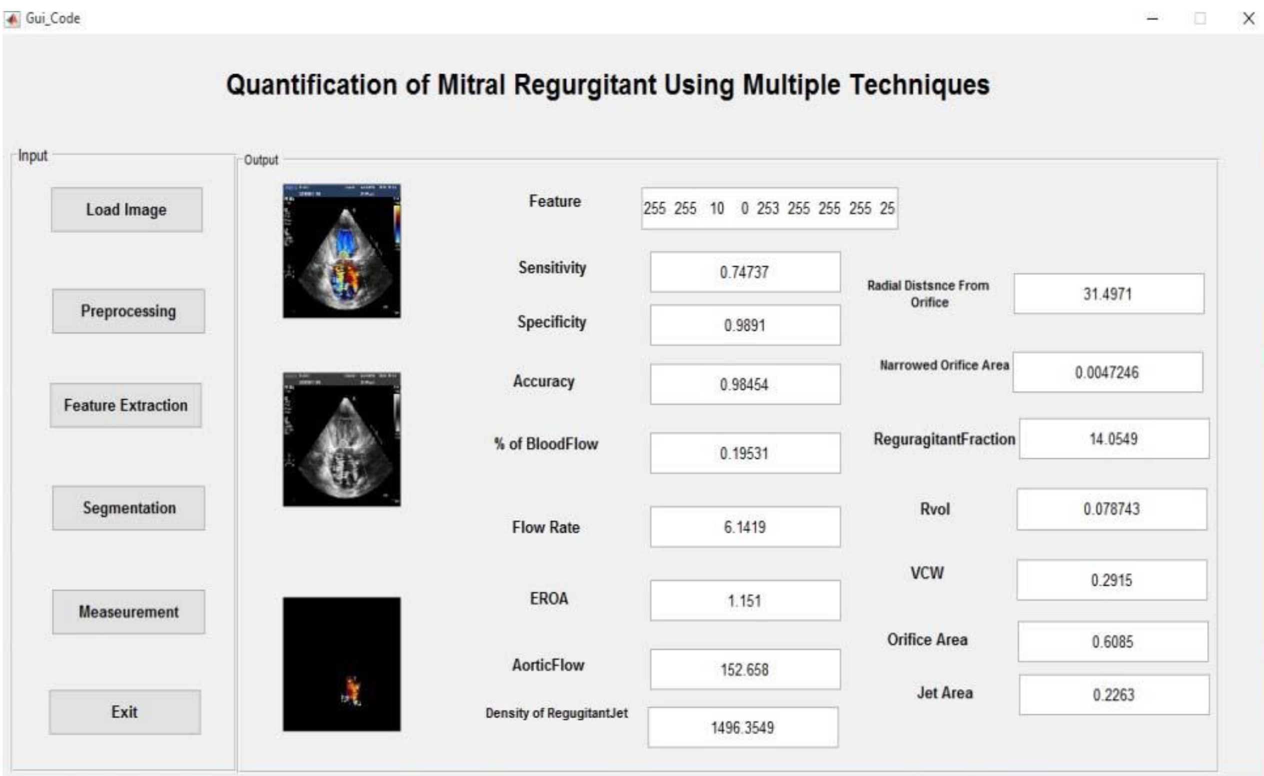



**Fig.3.7 Graphical user interface (GUI) for MR analysis process**

### 3.4 Summary

The feature-based categorization and segmentation of MR ECG representations evaluation using PISA method is discussed in this chapter. For classification, SVM accuracy is 87.8% and for separation MRG accuracy is 97.23%. The segmentation results prove that RG with GWO reaches maximum accuracy, sensitivity and specificity compared to RG-GA and FCM. Echocardiography delivers a high degree of specificity and selectivity. The proposed method concluded that fuzzy with PISA quantification approach achieves the accuracy rate of 99.05%.

# Chapter 4

## MITRAL REGURGITATION SEVERITY ANALYSIS BASED ON FEATURES AND OPTIMAL HE (OHE) WITH QUANTIFICATION USING PISA METHOD

### 4.1 Introduction

Heart valve stenosis is a major issue among the heart diseases. Mitral regurgitation (MR) has been a vital reason for morbidity and mortality. After myocardial infarction, MR happens generally in 10% to 20% of patients. MR is a unique heart valve disorder which is also known as mitral inadequacy. MR is classified as primary and secondary MR. Auxiliary MR causes papillary muscle dislodging, and annular dilatation. When there is MR, blood flows in reverse via the MV at what time the heart contracts. This diminishes the quantity of blood that is impels out to the body.

Echocardiography imaging is the productive imaging gadget for the finding and follow-up of MV infection. The usage of the echocardiography imaging strategy ought to be appropriately arranged for clear estimation of the MV structure which is essentially required for understanding the concealed etiology of MV disease and for organization and procedural game plan. It very well may be mulled over that the MR depends for the most part on imaging frameworks to examine utilitarian life structures and guide the fix procedure with the help of echocardiography picture quantization strategy.

### 4.2 Proposed Methodology

In restorative cardiology, one of the fundamental targets is the assessment of the MR thoroughness. To enhance the measurement of the AR in the echocardiography pictures, explicit stepladders are assessed in this examination effort. In this proposed strategy, the echocardiography picture database is considered as a preprocessing step, which is one of the highlights used to separate noteworthy information from the pictures for order utilizing SVM technique. Classification is finished in twofold stages, the preparation time frame and the testing time frame. In the division methodology to fragment the MR part of the pictures, the ideal histogram leveling (OHE) is utilized. The fragmented part is utilized for the evaluation examination to figure the morphologic parameters utilizing the PISA systems to quantify the seriousness of MR.

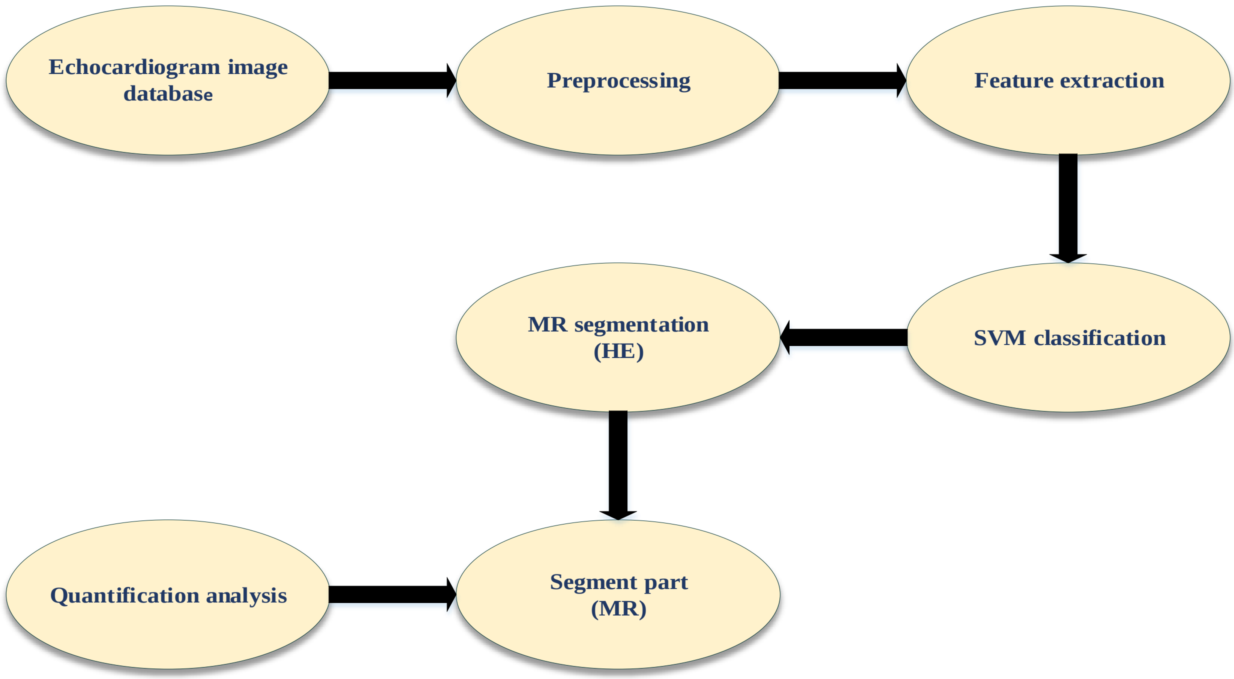



**Fig.4.1 Block Diagram for the Proposed Method**

The block diagram for the proposed method is shown in Fig.4.1. The severity of an MR in echocardiogram images is controlled by basic steps demonstrated as follows:

- Pre-processing
- Feature extraction
- Classification
- Segmentation
- Quantification.

### 4.2.1 Pre-processing

The Gaussian smoothing operator is used to "obscure" the images and to reduce noise and un-needed detail. The smoothing level can be determined by the standard deviation estimation of the Gaussian. Routinely, a Gaussian filtering is oppressed for the noise destruction strategy, which is resolved as

$$G(p) = \exp\left(\frac{-x^2}{2x\sigma^2}\right) \quad (4.1)$$

Where $G(p)$ is the Gaussian function that represents the noise and $\sigma$ denotes a deviation.

### 4.2.2 Feature Extraction

The feature extraction strategy includes the examination of the echocardiogram representations, and for this the spectral examination process is introduced. The features taken into consideration are:

- ✓ Color feature
- ✓ Texture feature
- ✓ Maximum intensity
- ✓ GLCM
- ✓ GLRLM

#### 4.2.2.1 Color and Texture Feature

The color is mainly used as the essential feature for image representation. Color space, color quantification, and comparability estimation are the key fragments of color feature extraction. The consistency is an additional characteristic that can section pictures into districts of intrigue and order those locales. Surface gives us information about the spatial game plan of the hues or powers canister a picture.

#### 4.2.2.2 Maximum Intensity (MI)

The maximum intensity of the images sees the best tally of pixel qualities (0–255) and the accompanying intensity esteem. The histogram of an representation consistently transmits to a histogram of the pixel intensity assessments in an image-processing context.

#### 4.2.2.3 Gray-level Co-occurrence Matrix (GLCM)

The gray-level co-occurrence matrix (GLCM) represents a factual technique of reviewing the texture that believes the spatial relationship of the pixels. The GLCM can uncover express qualities about the spatial dispersion of the gray altitudes in the consistency representation.

Depending upon the concentration of few feature like entropy, correlation, contrast and homogeneity the arrangement of gray-level co-occurring probabilities (GLCP) is estimated.

#### 4.2.2.4 Grey-level Run-length Matrix (GLRLM)

GLRLM is a matrix form which the texture features can be removed for texture examination. The GLRLM is produced as it takes after:

$$K(\theta) = \left( g(i,j) \middle/ \theta \right), 0 \le i \le M_g, 0 \le j \le K_{\max} \tag{4.2}$$

Where $Ng$ _ maximum gray level, $K_{\max}$ be the max length and $i, j$ be the matrix size values.

### 4.2.3 Feature-based Classification

Support vector machines based on the suggestion of decision planes that identify decision boundaries. A decision plane is one that disconnects between the understandings of articles having distinctive division enrolments. A hyperplane is a line that parts the data changeable space. In SVM, a hyperplane is decided to divide the points in the input changeable gap by their division, moreover class 0 or class 1. Here, linear function is considered for the classification procedure. This condition can be seen below:

$$w = \sum_{i=1}^{M} \alpha_i . f_i . x_i \,, \quad b = w x_k - f_k \tag{4.3}$$

### 4.2.4 Abnormal MR Image Segmentation Process (OHE)

Fig.4.2 explains the block diagram of the segmentation process. In this area, the MR jet area is separated by using strong histogram techniques. The segmentation algorithm can segment the histogram of an image into various clusters according to the classification of the gray estimations of the prepared image. The algorithm is an unsupervised and programmed one to segment the image from the histogram info. The main objective is to expand the proficiency of optimization using the Krill Herd Optimization (KHO) system.

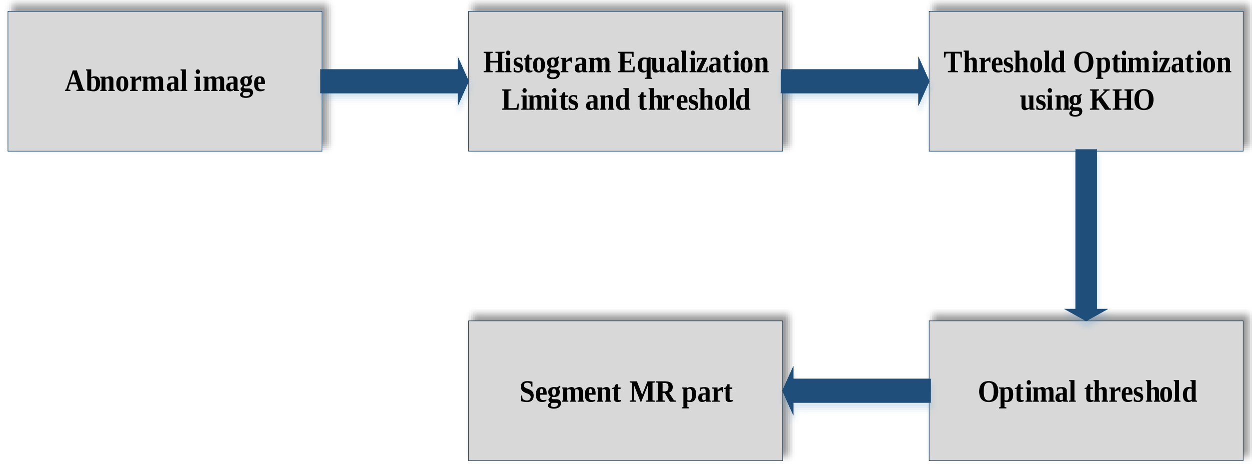



**Fig.4.2 Block Diagram for the Segmentation Process**

### 4.2.4.1 Histogram Equalization Limits

An image histogram is a kind of histogram that shows a pictorial portrayal of the tonal conveyance of the gray values in a digital representation. The recurrence of appearance of the different dim dimensions encased in the picture can be examined by surveying the image's histogram. The base and most extreme breaking point are displayed for histogram equalization.

### 4.2.4.2 Threshold Optimization using KHO

Krill herd (KH) is a novel swarm intelligence method used in favour of reducing the optimization issues. Fig.4.3 shows the flowchart for (KHO). The location of an person krill is detected by three movements:

- progress encouraged by other krill individuals
- Foraging action
- Arbitrary diffusion.

The location of the krill is detected by the given Lagrangian model,

$$\frac{dU_i}{dt} = P_i + Q_i + R_i \tag{4.4}$$

Where $P_i$ be movement actuated by other krill people, is the rummaging movement, and is the physical dissemination of the krill people.

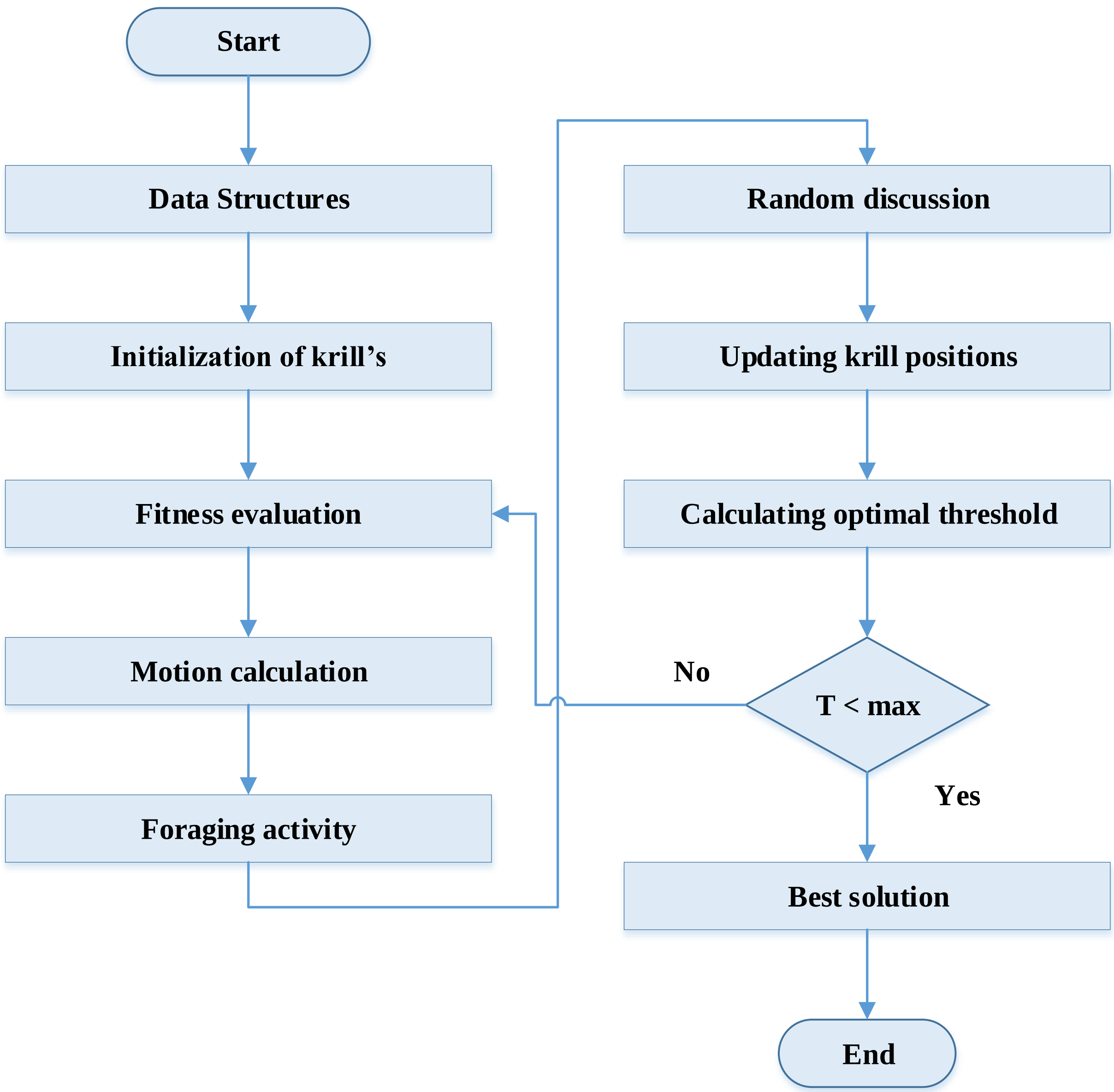



**Fig.4.3 Flow Chart for KHO**

#### 4.2.4.3 Fitness Evaluation

We find the fitness Fi in an assigned part for each square of the image. The precision is calculated utilizing the limitations for example, true positive (TP), true negative (TN), false positive (FP), and false negative (FN).

$$F_i = \max\left(\frac{TP+TN}{TP+TN+FP+FN}\right) \tag{4.5}$$

#### 4.2.4.4 Movement Induced by Other Krill Individuals

In the progression, the track of mobility of a krill person is settled together by the area swarm breadth, a target swarm thickness, and a shocking swarm thickness. The krill advancement can be depicted as

$$P_i^{new} = P^{\max}\gamma_i + \omega_n P_i^{old} \tag{4.6}$$

#### 4.2.4.5 Foraging Motion

The searching development is outlined comparably as twice the key compensating restrictions. The first is the nourishment area, and the next is the precedent knowledge about the food locale.

$$Q_i = F_m\delta_i + \omega_m Q_i^{old} \tag{4.7}$$

Here, $F_m$ is the foraging velocity, $\omega_m$ is the weight.

#### 4.2.4.6 Physical Diffusion

The physical diffusion of the krill folks is a consideration of it to be an unpredictable technique. This improvement can express the extent of a majority outrageous diffusion speed and a sporadic directional vector. It can be characterized as:

$$R_i = R^{\max}\lambda \tag{4.8}$$

#### 4.2.4.7 Crossover

The crossover worker is initially utilized as a part of the GA as a practical technique for overall improvement.

#### 4.2.4.8 Mutation

Mutation plays a major part in developmental algorithms, for example, ES and DE. The mutation is managed using mutation likelihood.

#### 4.2.4.9 Optimal Threshold to the HE

The last procedure in the segmentation process is achieved using the ideal threshold calculation process, which prompts an exact coerced separated jet area of the image.

### 4.2.5 Quantification of MR using PISA

A Doppler image was used to productively list MR. PISA technique is used to measure the rigorousness of valvular as well as inherent heart infections.

## 4.3 Results and Discussion

The proposed method of classifying, segmentation and quantizing results are compared with the existing method.

### 4.3.1 Classification and segmentation Performance Analysis

Tables 4.1 and 4.2 obviously examined the MR segmentation to prepare for the execution measurements. The sound from the aortic area may be extraordinarily feeble and creates an upheaval. The accurateness of the MRG among GWO is 94.05%.

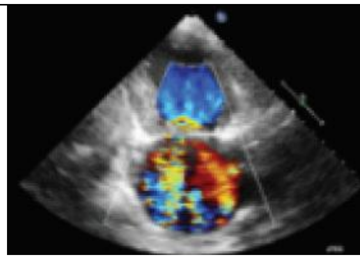
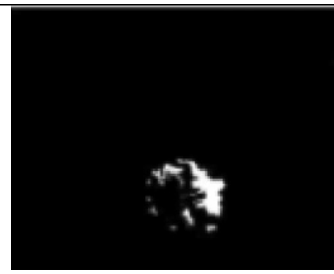
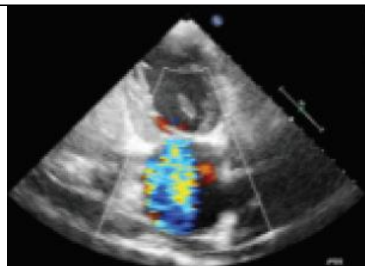
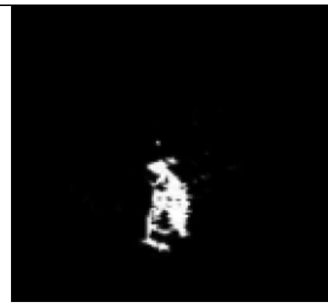
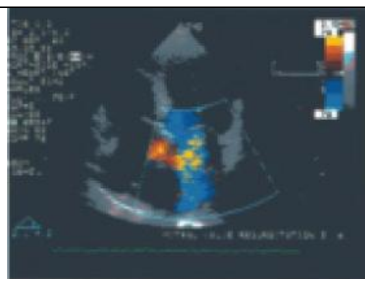
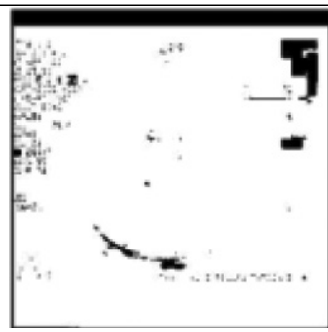
| S.No | Original image | Segmented image | Sensitivity | Specificity | Accuracy |
|---|---|---|---|---|---|
| 1 |  |  | 0.95 | 0.98 | 0.94 |
| 2 |  |  | 0.88 | 0.98 | 0.95 |
| 3 |  |  | 0.95 | 0.92 | 0.96 |

**Table 4.1 Results for OHE-KHO**

| **Techniques** | **Sensitivity** | **Specificity** | **Accuracy** |
|---|---|---|---|
| RG-GWO | 0.63 | 0.94 | 0.95 |
| HE-KHO | 0.92 | 0.96 | 0.95 |
| HE | 0.90 | 0.85 | 0.88 |
| FCM | 0.28 | 0.95 | 0.80 |

**Table 4.2 Comparison of Segmentation Results**

### 4.3.2 Parameter Quantification Analysis

The PISA method gives a quantitative technique to MR grading. Table 4.3 explains the quantification measure parameters in MR. Quantitative echocardiography measures the R-volume, RF, and EROA by 2D Doppler echocardiography and PISA strategy.

| **Measures** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|
| EROA ($cm^2$) | 0.11 | 0.15 | 0.08 | 0.09 | 0.18 |
| RF (%) | 28.56 | 17.56 | 16.55 | 29.56 | 28.5 |
| R-volume ($cm^3$) | 27.89 | 15.25 | 19.56 | 28.95 | 25.2 |

**Table 4.3 Quantified Parameters in Segmented Jet Area in MR Part**

### 4.4 Summary

In the logical basic leadership methodology about mitral retching forward, the correct endurance of the strictness of the disease is of manager reputation. A method is developed for stream region detachment and measurement in MR assessment in arithmetical articulations. In this chapter, MR segmentation is assessed by the optimal histogram equalization (OHE) system used to segment the jet area. For a better execution, threshold HE was improved with the help of the krill herd optimization method. With the MR quantification procedure, the segmented jet area was supported by the proximal isovelocity surface area (PISA). In this procedure, a few parameters in the segmentation were evaluated.

# Chapter 5

## RESULT AND DISCUSSION

### 5.1 Tool used for research

MATLAB 9.0 is the tool used for implementation. MATLAB represents Matrix Laboratory. It is an elite dialect for specialized registering. It incorporates calculation; representation and programming in a simple to utilize natural where issues and arrangements are communicated in comparative scientific arrangement. Regular uses incorporate

- arithmetic and calculation
- Algorithm improvement
- information achievement
- Modeling, simulation and prototyping
- information scrutiny, investigation and visitation
- technical and engineering graphics

### 5.2 Results

The results in the thesis are summarized below,

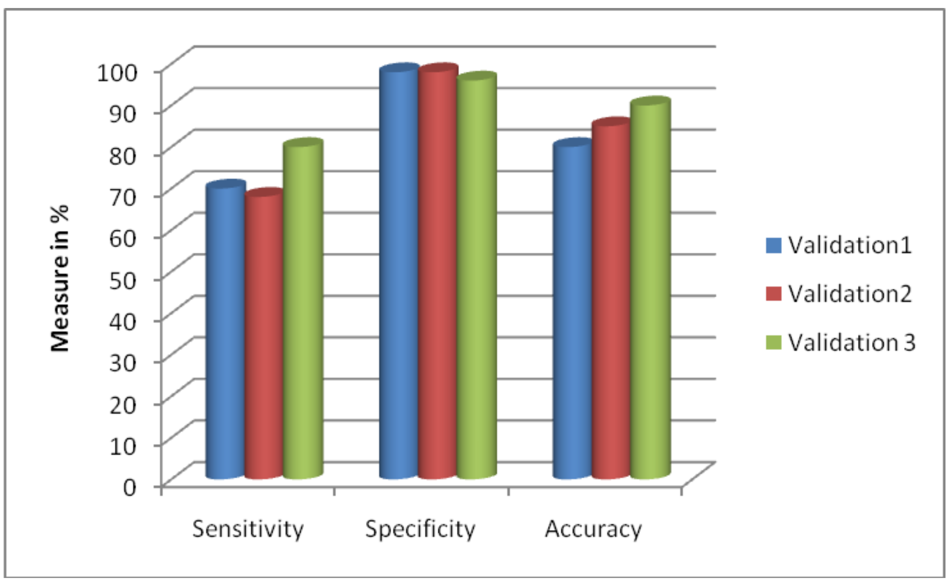



**Fig.5.1 Performance analysis for classifier**

Fig.5.1 shows the classification execution parameters in MR abnormal and normal image classify using SVM classifier. In the validation procedure, high accuracy 95.3% is attained in validation 3, the SVM accuracy is compared with validation 2 the difference is 13.23% similarly in validation 1. The estimated sensitivity value is related to the other validation, the variance in terms of percentage is 5.6%. In SVM analysis 70.83% accuracy, 99.41% sensitivity and 87.8% specificity is attained by the examination of echocardiography.

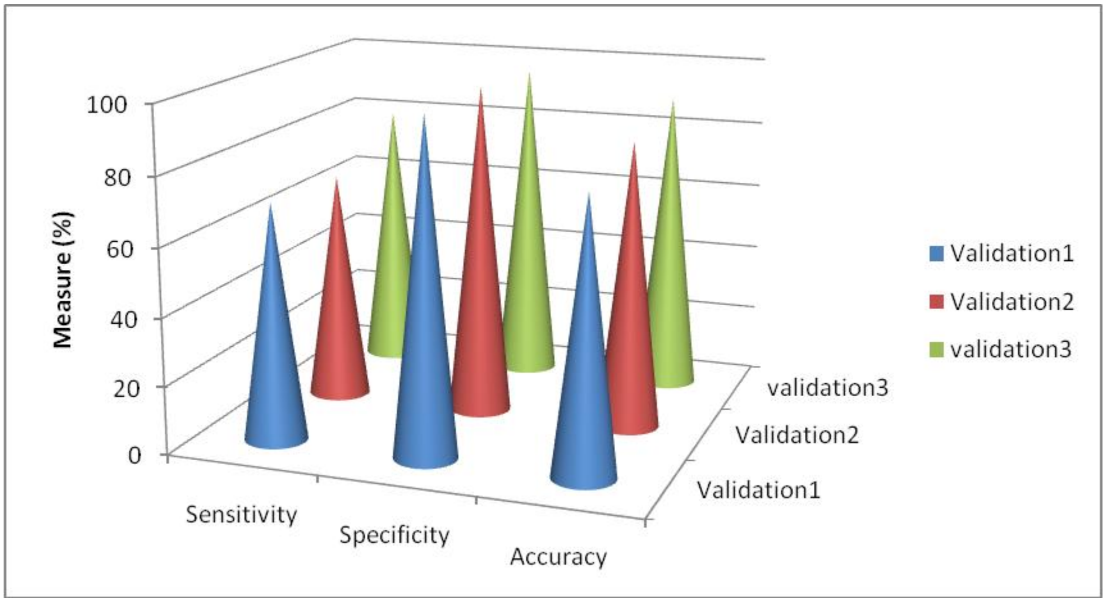



**Fig.5.2 Comparative analysis**

Fig.5.2 shows the assessment graph for the section rising with optimisation of GWO, GA and FCM. The accurateness of the MRG with GWO is 97.05%.

Fig.5.3 shows the comparative analysis for existing approach with proposed method. The bar graph compares the accuracy, sensitivity and specificity for the proposed to existing approaches. SVM attains only 78.23% accuracy but in proposed system the accuracy is 95.65%. The existing method attains 80.15% sensitivity but the proposed method achieves 91.89%. The specificity for SVM reaches 86.23% but the proposed system attains 94.98%.

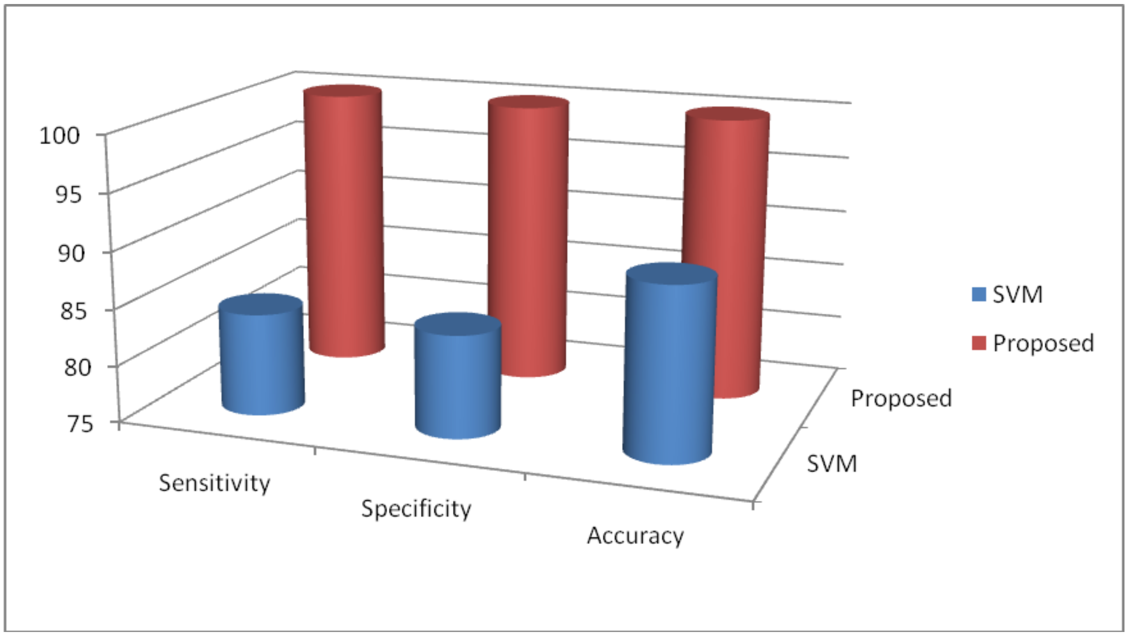



**Fig.5.3 Comparative analysis for existing and proposed method**

Fig.5.4 shows the diverse classifier systems using the echocardiogram image classification process. The proposed work gives the most extreme accuracy as 94.28%.

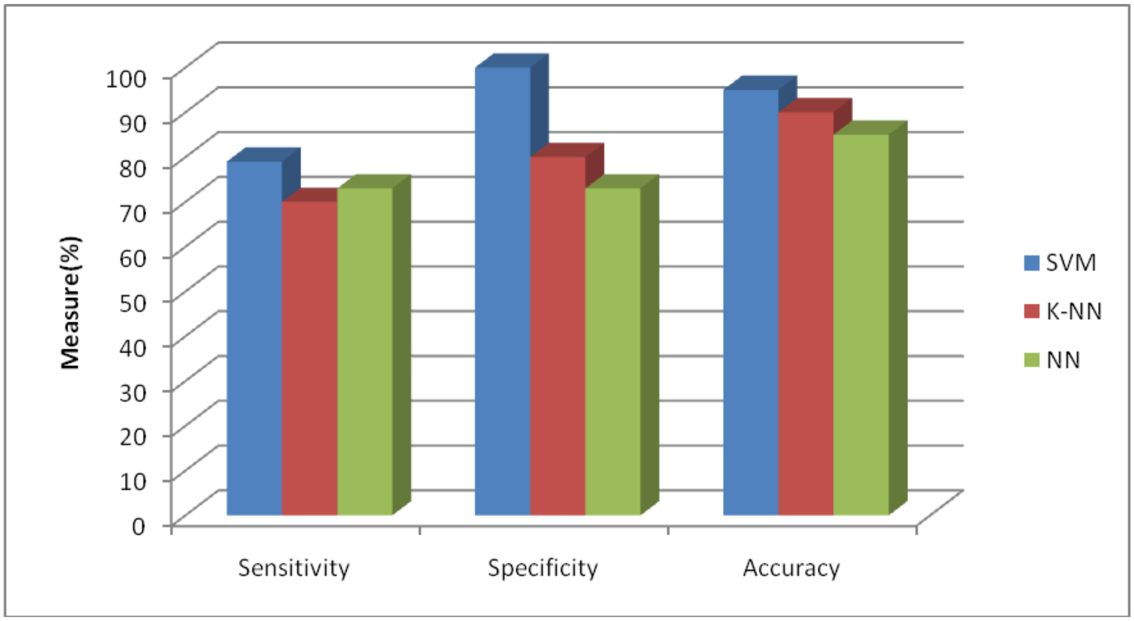



**Fig.5.4 Comparative Analysis of the Different Classifiers**

Fig.5.5 shows the results for obviously examined the MR segmentation to prepare for the execution measurements. The accuracy of the MRG with GWO is 94.05%.

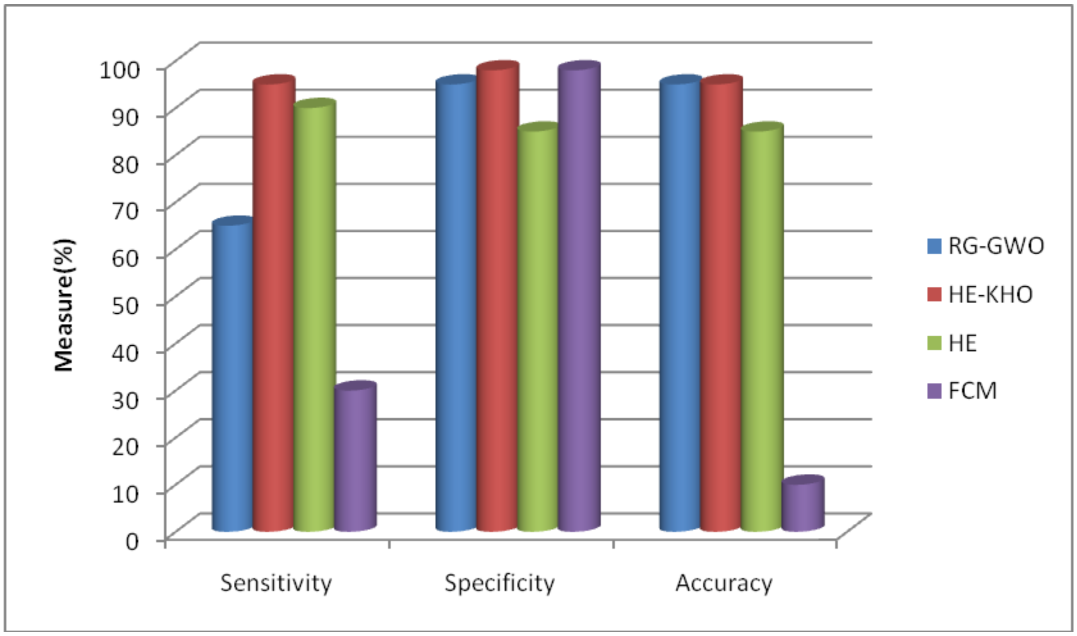



**Fig.5.5 Comparative Analysis**

From the results, it is concluded that the proposed methodology produce better accuracy in the segmented and quantification method when compared with the existing method.

# Chapter 6

## CONCLUSION

A large portion of the analytic systems taking a shot at spewing forth have been tested by the dynamic idea of injury and the specialist of a few hemodynamic and physiologic conditions on it. The consecutive representations are thought about rapidly in favour of a extra exact evaluation of interim modify in generally speaking previously point out versatile manners as well as in favour of enhanced planning to complete the medical procedure through the help of the upgrades in digital echocardiography. Mitral regurgitation is the abnormal turn around flow of blood from the left ventricle to the left atrium. To dodge this, the evaluation of the MR infection is to be calculated. In view of the measured esteem, the seriousness is to be calculated. To decide this, a portion of the image processing is performed. After the execution of this, the evaluation utilizing PISA method is to be calculated. The segmentation results for RG with GWO achieve most extreme accuracy, sensitivity and specificity, i.e., 97.05% contrasted with RG with GA and FCM. In this method of segmentation, this is to keep away from the process of oversegmentation. The enhancement in imaging hardware empowers to upgrade the amounts of flow combination, vena contracta and the regurgitant which at long last prompts upgrades in the measurement of valvular regurgitation. The fluffy with PISA measurement approach accomplishes the accuracy rate of 99.05%. Heart valve stenosis is a noteworthy issue among the heart sicknesses. Mitral regurgitation (MR) has been an essential explanation behind bleakness and mortality. After myocardial localized necrosis, MR happens for the most part in 10% to 20% of patients. MR is a novel heart valve issue which is otherwise called mitral deficiency. MR is classified as essential and optional MR. Helper MR causes papillary muscle dislodging, and annular dilatation. At the point when there is MR, blood flows backward through the mitral valve when the heart contracts. This decreases the measure of blood that is siphoned out to the cadaver. PISA method is utilized to measure the estimations of the influenced fly area. These decided qualities are useful to take the choice of the seriousness dimension of the sickness. On the off chance that the decided qualities are surpasses the threshold esteem, there is to settle on choice of the seriousness of the patient and subsequently save the sudden demise of the patients. Then dependent on the decided esteem, the seriousness level is to be calculated. This method is having the correct accuracy and precision because of its upgraded esteem. Echocardiography conveys high level of specificity and selectivity and is non-obtrusive. The MR regurgitation is anything but difficult to investigated utilizing standard windows. Segmentation of fly area for appraisal of MR is finished utilizing OHE method. The proposed system delivers better accuracy in the fragmented and evaluation method when contrasted and the existing method.

## FUTURE SCOPE:

Recently three dimensional Echocardiography make it in appearance in the cardiac clinic world. It can be used for the evaluation of the valve area, volume and other several parameters. The measurements of proximal isovelocity surface area provided with real-time color Doppler gives more accurate vales than two- dimensional color Doppler PISA.

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## PUBLICATIONS

1. Pinjari Abdul Khayum and Reddy Pogu Sudheer Babu 'Mitral Regurgitation Severity Analysis Based on Features and Optimal HE (OHE) with Quantification using PISA method' Journal of Intelligent Systems, 2017 pp 1-7.
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# Mitral Regurgitation Severity Analysis Based on Features and Optimal HE (OHE) with Quantification using PISA Method

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**Abstract:** Heart disease is the foremost reason for death and also the main source of incapability in the developed nations. Mitral regurgitation (MR) is a typical heart disease that does not bring about manifestations until its end position. In view of the hidden etiologies of heart distress, functional MR can be partitioned into two subgroups, ischemic and no ischemic MR. A procedure is progressed for jet area separation and quantification in MR evaluation in arithmetical expressions. Thus, a strategy that depends on echocardiography recordings, image processing methods, and artificial intelligence could be useful for clinicians, particularly in marginal cases. In this research paper, MR segmentation is analyzed by the optimal histogram equalization (OHE) system used to segment the jet area. For a better execution of the work, threshold in HE was improved with the help of the krill herd optimization (KHO) strategy. With the MR quantification procedure, this segmented jet area was supported by the proximal isovelocity surface area (PISA); in this procedure, a few parameters in the segmentation were evaluated. From the results, this proposed methodology accomplishes better accuracy in the segmented and quantification method in contrast with the existing examination.

**Keywords:** Mitral regurgitation, features, classification, quantification, Doppler echocardiography, histogram.

## 1 Introduction

Heart valve stenosis is a genuine issue among the heart diseases. Mitral valve (MV) stenosis is the most usual of the heart valve issue [17]. Mitral regurgitation (MR) is the most usually encountered valve injury in the current clinical practice [15], and for a while, it has been perceived as a vital reason for morbidity and mortality [10]. After myocardial infarction, MR happens generally in 10%–20% of patients [6]. MR, which is otherwise called mitral inadequacy, is a unique heart valve disorder [12]. Likewise, it is characterized as a clumsy MV, which brings about systolic regurgitation of the blood from the left ventricle to the left atrium [13] and is classified as primary and secondary MR [7]. Essential MR is brought on by a morphological variation from the norm of at least one segment of a complex MV contraption [1], i.e. handouts, chordae tendineae, papillary muscles or mitral annulus. In auxiliary MR [16], anatomically typical MV neglects to coat sufficiently in light of left ventricular (LV) renovating, papillary muscle dislodging, and annular dilatation [3]. When there is MR, blood spills in reverse through the mitral valve when the heart contracts. This lessens the measure of blood that is pumped out to the body [11]. Evaluating the seriousness of the disease is noteworthy in light of the fact that the inspectors utilize the severity data for further determination [3].

Echocardiography imaging is the majority effectual imaging device for the diagnosis and follow-up of MV disease [22]. The determination of MR or stenosis is, for the most part, fulfilled with the utilization of transthoracic imaging, with transesophageal imaging [19], given the backtest area; however, the utilization of the

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echocardiography imaging method should be properly situated for clear determination of the MV structure [23], which is basically essential in understanding the hidden etiology of MV ailment and for administration and procedural arrangement [4]. It can be reasoned that the MR depends vigorously on imaging systems to analyze utilitarian life structures and guide the repair methodology with the assistance of echocardiography image quantization strategy [5].

## 2 Literature Review

In 2006, Kara et al. [9] presented the diagnosis of mitral heart valve stenosis through an investigation with the Doppler signals' AR power spectral density graphic with the assistance of the artificial neural network (ANN). A multilayer feed forward ANN prepared with a Levenberg-Marquart backpropagation calculation was executed with MATLAB. An amend classification of 94% was accomplished, although four false classifications have been watched for the test gathering of 68 subjects altogether. The intended classification structure has around 97.3% sensitivity, 90.3% specificity, and the positive forecast was computed to be 92.3%. The expressed outcomes demonstrated that the proposed technique can be a powerful understanding tool.

The role of myocardial performance index in the assessment of left ventricular function in patients with valvular MR was demonstrated by Hussein et al. [8] in 2017. MR is the most regularly experienced valve injury in present-day clinical practice. The review included 50 patients with valvular MR and 50 fit subjects as a control gathering. Transthoracic echocardiography was completed for all patients and the control group. The echocardiographic estimations incorporated left ventricular end diastolic and end systolic measurements, left atrial breadth, launch portion (EF), and myocardial execution list (MPI). There was an immaterial change in the MPI among the patients with gentle MR and the controls (26.47%), and noteworthy changes in the MPI among the patients with direct and extreme MR and the control (29.41%, 41.17% individually) with $p < 0.05$.

In 2012, Saini et al. [18] recommended a separation of the regurgitation stream from the shading Doppler echocardiographic image amid the MR. Segmentation of the color jet range was not a simple task particularly when the base image was additionally a color image. The jet zone was easily identified with the seriousness of the MR. Here, the primary target was to section the shading mosaic pattern from the color Doppler image. For this, a multistep calculation was made. The jet range was acquired with the proposed technique, which fulfills the clinical outcomes. The work displayed here used the benefit of both components viz. modulated intensity gradient and texture gradient.

In 2016, Thomas et al. [21] displayed a strategy to measure MR utilizing phonocardiography (PCG). MR is a standout among the most widely recognized cardiovascular illnesses related with a deformity in the MR. They examined the multifractal way of heart sounds with mumble taken after classification and clustering utilizing Hurst examples. Along these lines, they could extend the distinction between severities of MR patients by matching the unpredictability of heart sounds from four noteworthy auscultation locales, utilizing an intricacy examination apparatus called the peculiarity spectra. The recreation demonstrated that the strategy can evaluate the seriousness of MR utilizing PCG.

In 2015, Sotaquira et al. [20] built up a novel semiautomated strategy for three-dimensional (3D) anatomic regurgitate opening (ARO) division and evaluation utilizing 3D transesophageal echocardiographic (TEE) datasets, and approved it versus physical planimetry on an arrangement of 25 patients with mellow to serious MR. The ARO two-dimensional (2D) anticipated region and the circularity index (CI) connected well with planimetry. The ultimate results affirmed the capability of this system in the estimation of a genuine 3D ARO shape. The proposed strategy could be a helpful option for the appraisal of patients with MR, given the natural state of the ARO and the constraints exhibited in current methodologies.

Wavelet analysis and classification of MR and normal heart sound based on the ANN was projected by MohdZin et al. [14] in 2003. They talked about the execution of fundamental wavelet change and discrete wavelet change for heart sound investigation. The components from the heart sounds were acquired from the fundamental wavelet change and were used to prepare and test the ANN. The ANN was prepared by 125 training data and tried with 52 data. The classification exactness was 94.2%.

In 2016, Balodi et al. [2] displayed a computer-aided diagnostic CAD framework for the appraisal of the seriousness of MR in light of image processing that does not oblige the intercession of the radiologist or clinician. Eight distinctive surface capabilities from the regurgitant region (chosen on a subjective basis) have been utilized as part of the current procedure. The outcomes showed that the proposed CAD framework may adequately help the radiologists in building up (affirming) the MR stages, in particular, in a gentle, direct, and serious manner.

In 1992, Zhani et al. [24] depicted a classifier outline, and its execution approval for quantitative evaluation of the MR in intracavitary differentiates 2D echocardiograms, in light of microbubble movement examination. A various-leveled direct classifier was worked for a four-class MR classification utilizing a preparation set of 202 differentiation echocardiographic image groupings. The following classifier's execution was assessed in test sets with a pivot technique; they got the less one-sided execution appraisals of separate 61.8% and 90.5% for the right classification and the halfway compact classification, which demonstrated the pertinence and potential value of computerized MR evaluation.

### 2.1 Limitations of Existing Approaches

From the study of existing research works, some limitations of the techniques used for MR are noted:

- The 2D proximal isovelocity surface area (PISA) imaging empowers circuitous visualization of the valve and jet shape without geometric presumptions, and it incorporates the behavior at low casing rates.
- In MR, the 2D PISA is biphasic with a peak that does not relate transiently to the peak angle that happens in mid systole.
- Despite that, when using the 2D PISA, it can be hard to judge the exact area of the orifice and the flow convergence shape. Any error presented is then squared, which can extraordinarily influence the subsequent stream rate.
- Evaluation of MR by utilizing the Doppler approach has not been routinely embraced in light of the potential for expansive mistakes in view of little errors in the cross-sectional zone determinations.

## 3 Proposed Methodology

In medical cardiology, one of the primary objectives is the quantification of the MR severity, which enormously influences the medical decision-making methodology. To enhance the quantification of the AR in the echocardiography images, particular stepladders are measured in this examination exertion.

In our new methodology, the echocardiography image database was considered as a preprocessing step, which is one of the few features used to extract significant data from the images for the existing classification [support vector machine (SVM)] procedure. Classification will be done in two imperative stages, in particular, the training stage and the testing stage. At this point, in the classification of the abnormal images for the segmentation procedure or segment, the MR part of the images, the optimal histogram equalization (OHE) will be used. An image containing just two principal gray level regions, the image histogram, can be demonstrated as a blend of two Gaussian density functions. After the assessment of the parameter of those two Gaussian functions, the mean and the standard deviation, the ideal threshold can be figured effortlessly. Here is a strategy for assessing threshold that produces least segmentation error; this procedure piece graph is shown in Figure 1. Now, the segmented part is considered for the quantification investigation to evaluate the morphologic parameters, for example, % of blood flow (%) flow rate, EROA, AF, density of regurgitant jet, radial distance from the orifice area, narrowed orifice area, regurgitant fraction, etc., utilizing the PISA techniques to measure the severity of an MR.

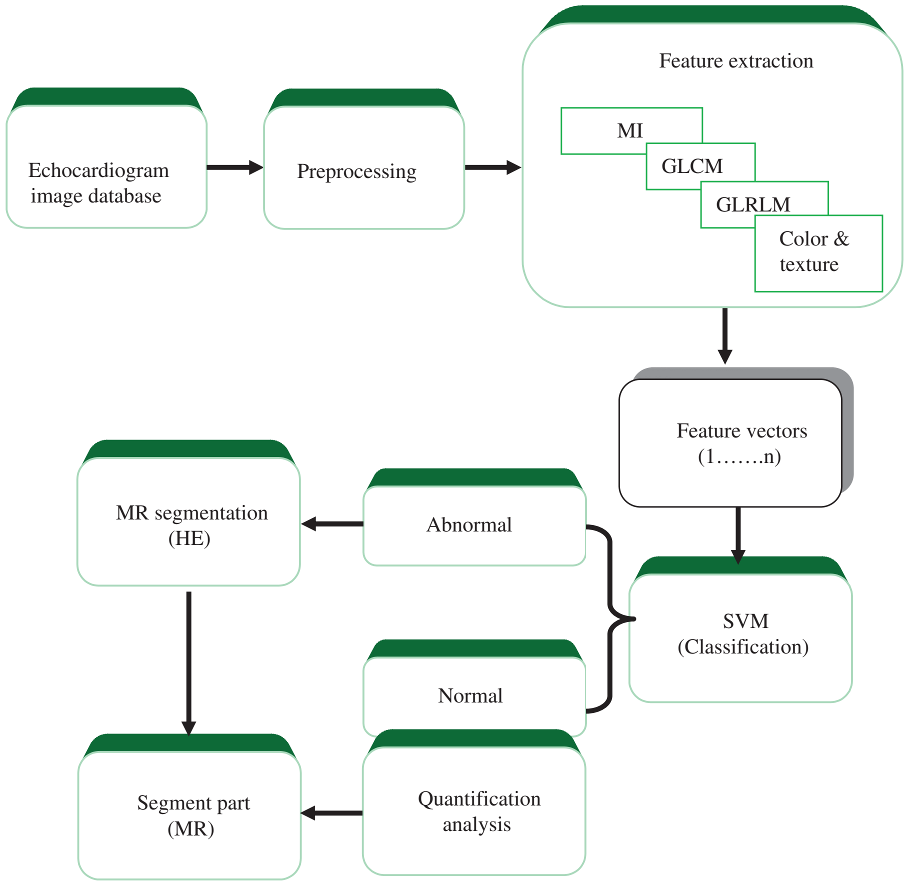



**Figure 1:** Block Diagram for the Proposed Method.

The severity of an MR in echocardiogram images is determined by imperative strides demonstrated as follows:

- Pre-processing
- Feature extraction
- Classification
- Segmentation and
- Quantification.

## 3.1 Pre-processing

The Gaussian smoothing operator is a 2D convolution operator, which can be utilized to "obscure" the images and after that expels noise and un-needed detail. It uses a kernel that is utilized as a part of image convolutions. The level of smoothing can be determined by the standard deviation estimation of the Gaussian. The yield esteem is a weighted average of every pixel's neighborhood. Routinely, a Gaussian filtering is oppressed for the noise destruction strategy, which is determined as

$$G(p) = \exp\left(\frac{-x^2}{2x\sigma^2}\right) \tag{1}$$

where $G(p)$ is a Gaussian function that represents the noise, and $\sigma$ denotes a deviation.

## 3.2 Feature Extraction

The feature extraction strategy incorporates the investigation of the echocardiogram images, and for this image characteristics' reflection, the spectral analysis process is introduced. By feature extraction, what is expected is the adjustment of the info data into the arrangement of attributes. In our examination, the features taken into consideration are:
- Color feature
- Texture feature
- Maximum intensity
- GLCM and
- GLRLM

i. **Color and Texture Feature**
The color is broadly utilized as an essential feature for image representation. This is essential as it is invariant concerning scaling, translation, and revolution of an image. Color space, color quantification, and comparability estimation are the key segments of color feature extraction. The texture is another feature that can segment images into locales of interest and classify those areas. In a few images, it can be the characterizing normal for regions and basic in getting a right examination. Texture gives us information about the spatial plan of the colors or powers canister an image.

ii. **Maximum Intensity (MI)**
The maximum intensity of the images notices the greatest tally of pixel qualities (0–255) and the accompanying intensity esteem. The histogram of an image regularly transmits to a histogram of the pixel intensity values in an image-processing context.

iii. **Gray-level Co-occurrence Matrix (GLCM)**
The GLCM, also called the gray-level spatial dependence matrix, symbolizes a factual method of reviewing the texture that considers the spatial relationship of the pixels. The GLCM can uncover express qualities about the spatial dispersion of the gray levels in the texture image. The arrangement of gray-level co-occurring probabilities (GLCP) is based on a concentration of a few features, which are entropy, correlation, contrast, and homogeneity.

iv. **Grey-level Run-length Matrix (GLRLM)**
GLRLM is a matrix from which the texture features can be removed for texture examination. A texture is understood, for instance, in gray intensity pixel in a particular heading from the reference pixels. The GLRLM is produced as it takes after:

$$K(\theta)=(g(i,j)/\theta),\ 0\leq i\leq M_g,\ 0\leq j\leq K\max \tag{2}$$

where $N_g$ is the maximum gray level, $K$ max is the maximum length and $i$, $j$ is the matrix size values.

GLRLM acquires more than a couple of measurements utilizing the gray co-props function. These statistics present data about the texture of an image. The statistics are, for example:
- Short-run emphasis (SRE)
- Long-run emphasis (LRE)
- Gray-level non-uniformity (GLN)
- Run-length non-uniformity (RLN)
- Run percentage (RP)

**Short-run emphasis (SRE):** This tends to emphasize short runs. The denominator is the total number of keeps running in the image and fills in as a normalizing component.

$$\mathrm{SRE}=\frac{1}{k_r}\sum_{i=1}^{M}\sum_{j=1}^{N}\frac{z(i,j)}{j^2} \tag{3}$$

**Long-run emphasis (LRE):** This ought to accentuation long runs. It measures the transport of long runs and is profoundly reliant on the occasion of long runs and is typically broad for coarse auxiliary textures.

$$\mathrm{LRE} = \frac{1}{k_r} \sum_{i=1}^{M} \sum_{j=1}^{N} z(i,j) * j^2. \quad (4)$$

**Gray-level non-uniformity (GLN):** GLN measures the likeness of gray-level values all through the image. The GLN is usually little if the gray-level qualities are indistinguishable all through the image.

$$\mathrm{GLN} = \frac{1}{k_r} \sum_{i=1}^{M} \left( \sum_{j=1}^{N} z(i,j) \right)^2. \quad (5)$$

**Run-length non-uniformity (RLN):** This measures the length's likeness of continuous running all through the image. The RLN is normally little if the run lengths are vague all through the image.

$$\mathrm{RLN} = \frac{1}{k_r} \sum_{i=1}^{M} \sum_{j=1}^{N} (z(i,j))^2. \quad (6)$$

**Run percentage (RP):** This feature is the extent between the total number of watched perseveres successively in the image and the total number of possible runs if all runs had a length of one.

$$\mathrm{RP} = \frac{K_r}{z(i,\, j) \times j}. \quad (7)$$

For the homogeneity and the course of continued running of an image in a particular direction, the RP is the greatest when the length of runs is 1 for each gray levels in a particular heading.

## 3.3 Feature-based Classification

Commencing the above feature extraction process, the feature vectors of all the echocardiogram images are kept. These vectors are considered in the abnormal and normal MR images using a SVM.

### 3.3.1 Support Vector Machine (SVM) Classifier

Support vector machines depend on the idea of decision planes that characterize decision limits. A decision plane is one that isolates between the arrangements of articles having distinctive class enrollments. A hyperplane is a line that parts the info variable space. In SVM, a hyperplane is chosen to most separate the points in the input variable space by their class, either class 0 or class 1. In two measurements, you can picture this as a line, and we expect that the greater part of our input points can be totally isolated from this line. Here, linear function is considered for the classification procedure. This condition can be seen below:

$$w = \sum_{i=1}^{M} \alpha_i . f_i . x_i, \quad b = w x_k - f_k. \quad (8)$$

## 3.4 Abnormal MR Image Segmentation Process (OHE)

In this area, we have reasonably separated the MR jet area by the strong histogram techniques. The initial step is a program segmentation algorithm in light of the discriminant investigation. The segmentation algorithm

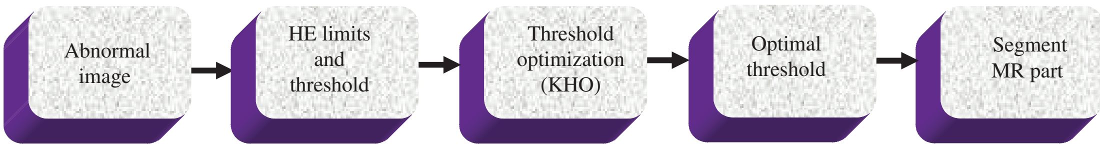



**Figure 2:** Block Diagram for the Segmentation Process.

can segment the histogram of an image into various clusters as per the classification of the gray estimations of the prepared image naturally. The algorithm is an unsupervised and programmed one to segment the image from the histogram data. Keeping in mind the end goal to expand the proficiency of optimization, the search space using the KHO system is found in Figure 2.

#### 3.4.1 Histogram Equalization Limits

An image histogram is a sort of histogram that presents a graphical portrayal of the tonal conveyance of the gray values in a digital image. By surveying the image's histogram, we can examine the frequency of appearance of the various gray levels enclosed in the image. For histogram equalization, the base and most extreme breaking point are exhibited. In this minimum and maximum process, the optimization systems are utilized to oblige the farthest point.

#### 3.4.2 Threshold Optimization using KHO

Krill herd (KH) is a novel swarm intelligence strategy for taking care of optimization issues. It is the disentanglement and admiration of the grouping of the krill swarms in the ocean. This flowchart is found in Figure 3. The position of an individual krill is dictated by three movements:

- Movement induced by other krill individuals;
- Foraging action; and
- Random diffusion.

The location of the krill is articulated by the following Lagrangian model

$$\frac{dU_i}{dt} = P_i + Q_i + R_i, \tag{12}$$

where $P_i$ is the motion induced by other krill individuals, $Q_i$ is the foraging motion, and $R_i$ is the physical diffusion of the $i^{th}$ krill individuals.

#### 3.4.3 Fitness Evaluation

In each square of the image, we find the fitness $F_i$ in an assigned part, and here, the fitness is the most outrageous accuracy of the divided part. The precision is discovered utilizing the parameters, for example, true positive (TP), true negative (TN), false positive (FP), and false negative (FN).

$$F_i = \max\left(\frac{\mathrm{TP}+\mathrm{TN}}{\mathrm{TP}+\mathrm{TN}+\mathrm{FP}+\mathrm{FN}}\right) \tag{13}$$

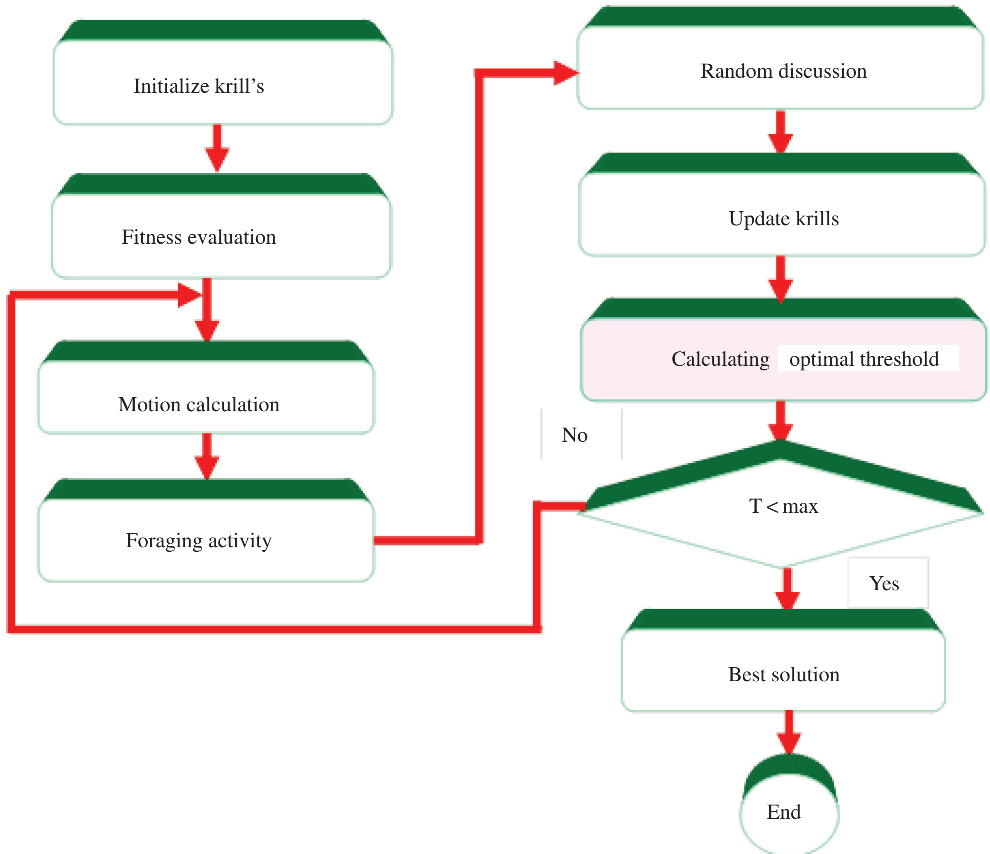



**Figure 3:** Flow Chart for KHO.

### 3.4.4 Movement Induced by Other Krill Individuals

In the advancement, the course of movement of a krill individual is settled together by the area swarm thickness (nearby effect), a target swarm thickness (target effect), and a shocking swarm thickness (terrible impact). The krill advancement can be portrayed as

$$P_i^{new} = P^{max}\gamma_i + \omega_n P_i^{old}. \tag{14}$$

In the above conditions, the documentations are clarified. $I_{max}$ is the greatest incited rate, $\omega_n$ is the idleness weight of the movement instigated in the extent [0, 1], $I_i^{old}$ is the last movement actuated, $\gamma_i^{old}$ is the nearby impact given by the neighbors, $\gamma_i^{target}$ is the objective heading impact given by the best krill individual, and neural network (NN) is the quantities of people.

### 3.4.5 Foraging Motion

The searching development is figured similarly as two key rewarding parameters. The first is the sustenance area, and the second is the past experience about the food area. This development can be conveyed for the $i^{th}$ krill individual as it takes after:

$$Q_i = F_m \delta_i + \omega_m Q_i^{old}. \tag{15}$$

Here, $F_m$ is the scavenging velocity, $\omega_m$ is the dormancy weight of the searching movement in the reach, [0, 1] is the last scrounging movement, $\delta_i^{food}$ is the nourishment appealing, and $\delta_i^{best}$ is the impact of the best wellness of the krill as such. As indicated by the deliberate estimations of the searching rate, it is taken as 0.02 ($ms^{-1}$).

#### 3.4.6 Physical Diffusion

The physical dispersal of the krill individuals is a consideration of it to be an unpredictable technique. This development can express the extent of a most outrageous dispersion speed and a sporadic directional vector. It can be characterized as it takes after:

$$R_i = R^{\max}\lambda. \tag{16}$$

Here, $R^{\max}$ is the maximum diffusion speed, and d is the random directional vector, and its arrays are random values between –1 and 1.

#### 3.4.7 Crossover

The crossover operator is first utilized as a part of the GA as a practical technique for overall improvement. A vectorized type of the hybrid is also used as a piece of DE, which can be considered as an additional change to GA.

#### 3.4.8 Mutation

Mutation assumes a vital part in developmental algorithms, for example, ES and DE. The mutation is controlled by mutation likelihood ($M_r$). Utilizing this new mutation probability, the mutation probability for the worldwide best is equivalent to zero, and it increments by diminishing the fitness.

#### 3.4.9 Optimal Threshold to the HE

The last procedure in the segmentation procedure is the esteem that is achieved from the ideal threshold calculation process, which prompts an exact coerced separated jet area of the image.

### 3.5 Quantification MA using PISA

A Doppler image was utilized to productively list MR. There has been a noteworthy thought in the PISA technique to inspect the severity of valvular and inherent heart infections. The PISA is a system, by and large, utilized as a part of echocardiography, and it gauges the valvular inadequacy, and it, for the most part, supports the disease called MR.

## 4 Results and Discussion

This anticipated examination part can be tried in the operational stage of MATLAB 2015 with i5 framework design and 4GB MR quantification prepare. This proposed strategy of classifying, segmentation and quantizing results are contrasted with the existing method.

## 4.1 Database Description

This examination methodology analyzes echocardiogram image database created from some web images and Nims hospital. This database contains more than 100 normal and abnormal images for quantification process. The methodology analyzes 100 patients for training and 10 patients for testing purposes.

### 4.1.1 Classification Performance Analysis

Figure 4 demonstrates the diverse classifier systems utilizing the echocardiogram image classification process. The systems are, for instance, NN, K-nearest neighbor (K-NN), and our proposed technique SVM with linear kernel function. The proposed work accomplishes the most extreme accuracy as 94.28%, contrasted with different classifiers, and furthermore, the KNN system creates the sensitivity of 71.25%, which contrasted the NN with the distinction of 2.56 with 3.58%. Correspondingly, the specificity parameters likewise achieve the better outcome in the SVM classifier.

### 4.1.2 Segmentation Performance Analysis

This segment is discussed in Figure 5, and Tables 1 and 2 obviously examined the MR segmentation to prepare for the execution measurements. This makes the tricuspid less imperative to be considered for our circumstance. In addition, the switch through the MR diminishes the blood coursing through the aortic locale achieving slight disturbance through the aortic valve. The sound from the aortic area may be extraordinarily feeble and creates an upheaval. The sharp parts from the aortic area add to the multifractal association. The consideration of the organized OHE with KHO identified with other two procedures; the distinction is 28.3% and 30.23% autonomously. Also, the accuracy of the MRG with GWO being 94.05% is seen to be correlated to 0.28% and 1.18% in the event of HE and FCM. Altogether, the expected framework demonstrates a basic trademark of 0.79% when related to the other two approaches with regard to the requirements communicated in the reference graph. The pushed accuracy level has significantly displayed, precluded from securing any scrawl of powerlessness, that the impelled procedure diagram is ordinary and best prescribed in perceiving the MR fly some segment of the echocardiogram picture. By techniques for surveying the aftermaths, it is immaculate that echocardiography is able to correct the MR division of echocardiography.

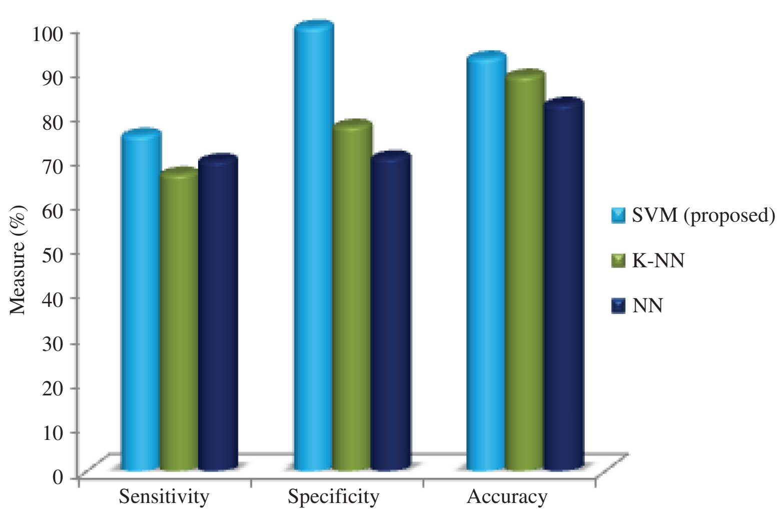



**Figure 4:** Comparative Analysis of the Different Classifiers.

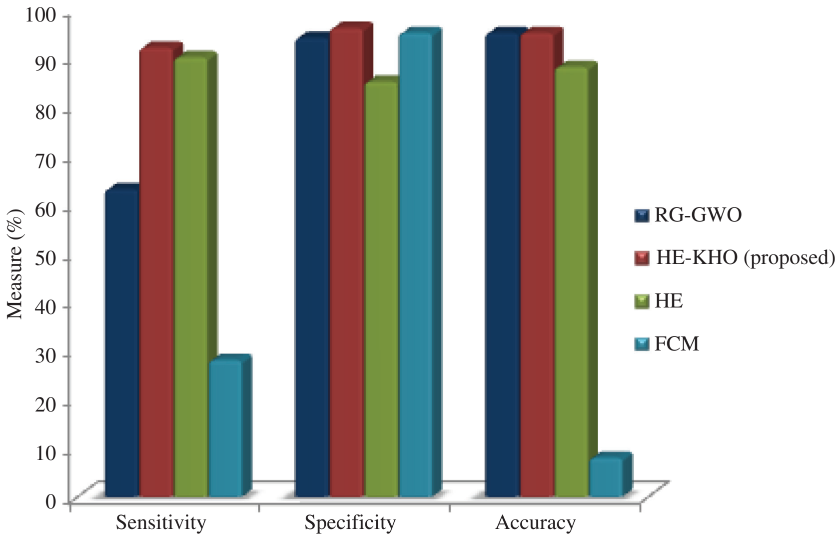



**Figure 5:** Comparative Analysis.

**Table 1:** Results for OHE-KHO.

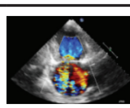
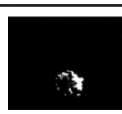
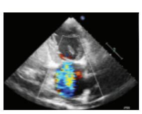
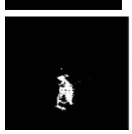
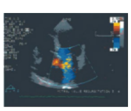
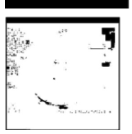
| S. no. | Original image | Segmented part | Sen | Spec | Acc | PPV | NPV | FPR | FDR | RI | GCE | VI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 |  |  | 0.95 | 0.98 | 0.94 | 0.28 | 1 | 0.08 | 0.85 | 0.98 | 0.05 | 0.85 |
| 2 |  |  | 0.88 | 0.98 | 0.95 | 1 | 1 | 0.85 | 0.86 | 0.05 | 0.09 | 0.92 |
| 3 |  |  | 0.95 | 0.92 | 0.96 | 1 | 1 | 0.99 | 0.09 | 0.19 | 0.28 | 0.95 |

**Table 2:** Comparison of Segmentation Results.

| Technique | Sen | Spec | Acc | PPV | NPV | FPR | FDR | RI | GCE | VI |
|---|---|---|---|---|---|---|---|---|---|---|
| RG-GWO | 0.63 | 0.94 | 0.95 | 0.48 | 0.98 | 0.03 | 0.60 | 0.92 | 0.03 | 0.30 |
| HE-KHO | 0.92 | 0.96 | 0.95 | 1 | 0.64 | 0.6 | 0.6 | 0.58 | 0.14 | 0.90 |
| HE | 0.90 | 0.85 | 0.88 | 0.58 | 0.66 | 0.58 | 0.78 | 0.92 | 0.19 | 0.85 |
| FCM | 0.28 | 0.95 | 0.80 | 0.64 | 0.82 | 0.04 | 0.35 | 0.69 | 0.11 | 0.97 |

### 4.1.3 Parameter Quantification Analysis

The PISA strategy gives a quantitative technique to MR grading. Despite that, the count requires a geometric suspicion of a hemispherical shape to the PISA area, which is not generally the situation. Also, it can be actually testing to quantify the PISA radius precisely. The color Doppler difference guide ought to be killed (ordinarily the default with general programming). The cine circle is then audited, outline by edge, amid systole to recognize the biggest PFCR where the principal isovelocity shell is obviously envisioned.

**Table 3:** Quantified Parameters in Segmented Jet Area in MR Part.

| Measures/Images | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Percentage of blood flow (%) | 0.85 | 0.84 | 0.75 | 0.79 | 0.85 |
| Flow rate (ml/s) | 6.15 | 6.19 | 6.12 | 5.59 | 6.02 |
| EROA ($cm^2$) | 0.11 | 0.15 | 0.08 | 0.09 | 0.18 |
| AF ($cm^3$) | 155.5 | 152.3 | 154.2 | 160.5 | 155.2 |
| Density of regurgitant jet | 40.56 | 38.5 | 39.56 | 40.25 | 38.2 |
| Radial distance from orifice area ($cm^2/m^2$) | 0.68 | 0.71 | 0.58 | 0.58 | 0.66 |
| Narrowed orifice area ($cm^2/m^2$) | 0.08 | 0.7 | 0.04 | 0.9 | 0.08 |
| Regurgitant fraction (%) | 28.56 | 17.56 | 16.55 | 29.56 | 28.5 |
| R-volume ($cm^3$) | 27.89 | 15.25 | 19.56 | 28.95 | 25.2 |
| Vena contracta width (%) | 0.30 | 0.28 | 0.31 | 0.28 | 0.29 |
| Orifice area | 2.33 | 2.38 | 2.85 | 2.78 | 3.5 |
| Jet width (%) | 0.18 | 0.19 | 0.18 | 0.29 | 0.30 |
| LVOT width (%) | 0.88 | 0.78 | 0.85 | 0.84 | 0.98 |
| Mitral flow (ml/s) | 132.5 | 1.8.5 | 125.6 | 140.5 | 131.2 |
| Aliasing velocity (cm/s) | 42.5 | 44.52 | 48.5 | 4.56 | 49.6 |
| Peak velocity (cm/s) | 1450 | 1385.2 | 1451.2 | 1458.5 | 1325.9 |

Table 3 shows the quantification measure parameters in MR and some portion of the Doppler echocardiogram images accepting HE-KHO, demonstrating the process. Quantitative echocardiography measures the joint check of RV, regurgitant part, and ROA by 2D and Doppler echocardiography and PISA strategy, independently. The effective ROA is a measure of the earnestness of the regurgitant damage. It is, furthermore, an essential determinant of the growth of the left ventricle and left chamber in mitral ejecting and gives additional information considering RV and division. Noninvasive Doppler echocardiography systems are used to evaluate the aortic ERO go in AR. The intelligent result of the ERO zone in portraying AR strictness and its ability to give supplementary material to the regurgitant piece have been revealed by these guidelines. Thus, to finish an abnormal state of consistency in reviewing the strictness of MR in all conditions, a mix of clinically reliable noninvasive philosophies is fundamental for describing the ERO district in Doppler echocardiography examination.

## 5 Conclusion

In the logical basic leadership procedure about mitral retching forward, the right endurance of the strictness of the disease is of manager reputation. The risk of operation aids the endorsement of strictness by a modifying framework. Currently, despite that, mitral regurgitating forward has no gold model alongside which to determine the regurgitant volume, stream rate, etc. In précis of all the above, it ends up being fittingly sure that the proposed way is, in each stage, appealing to all such systems indistinguishable. Truly, the expected strategy with its rareness is seen upon as the first of its kind in using SVM accuracy of 97.8% for the request and OHE precision as 99.63% for the division technique. New aftermaths unquestionably show that, in the course of action, division, and assessment, the segment is likewise the foreseen procedure, that is, the finest edge improves many outcomes than interchange techniques do. The MR index is a modestly fundamental semi-quantitative gauge of MR reality, which is potentially, for the most part, material in clinical practice as a clear procedure for evaluating patients with hemodynamic basic MR and, more goal, in their follow-up over a time frame.

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# Feature-based classification and segmentation of mitral regurgitation echocardiography images quantification using PISA method

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**Abstract:** Echocardiography is the enormously admired scientific specification for the evaluation of valvular regurgitation and gives significant knowledge on the bareness of mitral regurgitation (MR). MR is a general heart disease which does not cause indications till its final phase. A technique is advanced for jet area separation and quantification in MR assessment in arithmetical expressions. Previous to this separation method count preprocessing and some attributes are mined from the record to arrangement method. From the cataloguing method, support vector machine (SVM) classifier developed to confidential echocardiogram images. Entire abnormal images to the modified region growing (MRG) separation method to segment jet area of MR. This segmented jet area in MR quantification process passed out with the support of proximal isovelocity surface area (PISA). This procedure is based on mass diverse limitations like blood flow rate, regurgitant fraction, EROA, etc. From the outcomes, this projected effort associated with the current method fuzzy with PISA quantification process, the projected work attained accuracy rate 99.05% in the study of jet area segmenting and quantification method.

**Keywords:** echocardiogram; mitral valve; mitral regurgitation; classification; segmentation; quantification.

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## 1 Introduction

Valuation of mitral valve (MV) morphology exposes the range of standard and non-standard attributes, with or without medical or hemodynamic significances. Moreover, morphology valuation affords a perception into the etiology and seriousness of valve disease, being needed for administration development (Garbi and Monaghan, 2015). Schemes mitral regurgitation (IMR) has been exposed to have predictive insinuations (1) where an 'effective regurgitate orifice (ERO) area' of more than 20 $mm^2$ effects in a considerably abridged long-term survival (2, 3). The occurrence of mitral regurgitation (MR) in patient's affliction secluded coronary artery by-pass surgery (CABG) is also related to an improved mortality (Wierup et al., 2009; Grigioni et al., 2001).

The heart valves play a major part in the cardiovascular system as they control the blood flow within the heart chambers and human body (Ionasec et al., 2010). In specific, the aortic and MVs cause harmonised fast opening and closing actions to direct the liquid collaboration separating the left atrium (LA), left ventricle (LV) and aorta (Ao). Their problematic morphological, functional and hemodynamic interdependency has been newly highlighted (Lansac et al., 2002). Many patients experiencing cardiac catheterisation are not pertinent for injection of iodinated divergence agents. Some of them have kidney dysfunction, while in others LV function may be considerably reduced (Buckley et al., 2000). Then, the addition of energy attained from the CWT was treated for each patient group to distinguish among patients with standard hearts and those with MR (Bunluechokchai and Ussawawongaraya 2009). Subordinate MR, ascending from mitral annular dilation and papillary muscle dysfunction, is a common detecting in patients with congestive heart failure (CHF). It donates to the promotion of left ventricular end-diastolic pressure in addition to left and right atria compressions and triggers advanced distention of the LV (Bellone et al., 2002). Major indications for echocardiography in MR are assessment of hemodynamic severity, including the impact on ventricular size, function and hemodynamic (Ghoreyshi et al., 2011).

Exact quantification of MR effect is significant for choices about operation and forecasting danger. Present rules recommend the addition of exact, helpful and quantitative echocardiography attributes to categorise seriousness of MR (Thavendiranathan et al., 2012). The contributor heart was well-kept-up with St. Thomas' solution (flush-perfusion) and inserted using the biatrial, an astigmatic method. The entire ischemic time of the contributor's heart was 226 minutes (Bouma et al., 2012). congenital, degenerative, structural, infective or inflammatory diseases can aggravate dysfunctions, ensuing in stenotic and regurgitate valves (Ionasec et al., 2010). The blood flow is congested or in the case of regurgitates valves, blood leakages due to inappropriate sealing. Both disorders can seriously inhibit with the pushing purpose of the heart, producing life-intimidating situations (Ionasec et al., 2009). Functional mitral regurgitation (FMR) happens with the development of LV dilatation in patients with heart failure with compact ejection fraction (EF) and is related with deprived prediction (Otsuji et al., 2008). The FMR is aggravated in the course of the workout (Yamano et al., 2008) and hence, the result after MV repair may be connected to the severity of FMR during implement rather than at rest. Two cases with different energetic variations are in FMR for the period of apply (Kobayashi et al., 2010).

The TV morphology was prudently observed for TR device classification. TR caused by leaflet irregularity (such as prolapsed, Epstein's anomaly, post biopsy trauma or viscosity due to carcinoid syndrome) or pacemaker lead impingement was considered as gradual TR (Chen et al., 2013). The ideas of this analysis were to progress an instinctive technique of Doppler velocity contour detection that could be embedded in normal echocardiography systems, to abolish the intra- and inter-observer changeability (Gaillard et al., 2009). In present days, Doppler echocardiography takes main part in the early determination of the type of surgery that may be required for an exclamation of MV regurgitation (Omar et al., 2015). Doppler echocardiography not only detects the presence of regurgitation, but also permits to understand mechanisms of regurgitation, quantification of its severity and repercussions (Pathak and Barooah, 2013). The purpose of this review is to discuss the echocardiographic assessment of FMR (Thanammal and Sudha, 2016). It concentrates on some aspects that are particularly relevant and problematic in everyday practice (Patnaik and Jagannathan, 2006). Utilising Doppler echocardiography, assessments of the prevalence of valvular regurgitation has been obtained for small, selected groups, comprising mainly of normal volunteers (Ugarriza et al., 2009). This article analyses the methodological features on how to accomplish measurable void extends and is not planned to define the standard caution of which capacities should be done in distinct medical readings (Lang et al., 2006).

## 2 Literature review

In Ven et al. (2016), they have projected the dimensional quantities, systolic time interludes and blood flow rapidity, attained by normal 2D, M-mode and pulsed wave Doppler echocardiography, for quantification of AR. Echocardiography was achieved in 32 healthy horses and 35 horses with AR that was sectioned in three groups (mild, moderate or severe AR). From the documented images, LV left atrial and aortic dimensions, systolic time intervals and aortic blood flow velocities were restrained. Diastolic run-off in the aorta (AoDiastDecr) was designed as the variance in aortic diameter among initial diastole and late diastole. Stroke volume (SV) was designed from pulsed wave Doppler dimensions, by the bullet method (SV bullet) and by the area-length method. Pre-ejection period (PEP) and ejection time (LVET) were restrained from the M-mode images. Horses with AR presented an expansion of the LV, LA and Ao associated with the management group.

In Nappi et al. (2016), they recommended the advantage of papillary muscle surgery on lasting medical results of patients with ischemic MR. Ninety-six patients with simple ischemic MR were randomised to either lower sizing disruptive mitral annuloplasty (RA) or papillary muscle estimate with under sizing disruptive mitral annuloplasty (PMA), connected with whole surgical myocardial revascularisation. The key endpoint was variation in left ventricular end diastolic diameter (LVEDD) after five years, dignified as the complete variance from starting point, appraised by corresponding student t-tests. Subordinate endpoints involved variations in echocardiography parameters, overall mortality, the composite cardiac endpoint [major adverse cardiac and cerebrovascular events (MACCE)] and quality of life (QOL) during the five years.

In Moghaddasi and Nourian (2016), they have projected the micro-designs of echocardiography images so as to regulate the binary pattern (ELBP) and extensive volume local binary pattern (EVL scriptors which consist of particulars from distinctive perspectives of the heart in machine (SVM), linear discriminant analysis (LDA) and template Ma classifiers to regulate the sternness of MR based on textural descript to tensile even local binary pattern (ELBPU) and extensive volume Lo the best accuracy with 99.52%, 99.38%, 99.31% and 99.59%, respectively, f MR, moderate MR and severe MR subjects among echocardiography attains 99.38% sensitivity and 99.63% specificity for the recognition of issues.

In Martinez et al. (2016) and Saini et al. (2016), they have projected the valvular heart disease was a normal reason of improved mean pulmonary artery pressure (PAP). Aortic stenos are and MR is recurrently supplemented by pulmonary hypertension (PH), exclusively when they are plain and indicative. In asymptomatic patients, PH was rare, though the correct frequency is unidentified and chiefly stalks from the severity of the valvular heart disease and the attendance of diastolic dysfunction. In these asymptomatic patients, application PH is detected in about > 40%. One or the other PH at rest (systolic PAP > 50 mmHg) or in the course of workout (systolic PAP > 60 mmHg) PH was a prevailing factor of product and is autonomously related with condensed survival, regardless of the severity of the underlying valvular pathology.

In Argulian et al. (2016) and Khayum et al. (2011), they have suggested the MR was a general heart valve disease. It is described to be most important when it effects from the pathology of the MV device itself and subordinate when it was instigated by alteration of the architecture and/or purpose of the LV. Whereas, the analysis and organisation of MR depend deeply on echocardiography one must remember the warnings and inadequacies of such method. Clinical decision making usually centre son the signs for operation but it is difficult and orders an exact valuation of the mitral pathology, indication status of the patient and ventricular performance (right and left) among other descriptors. It was vital for healthcare donor sat all stages to be known with the clinical picture, diagnosis, disease course and management of MR.

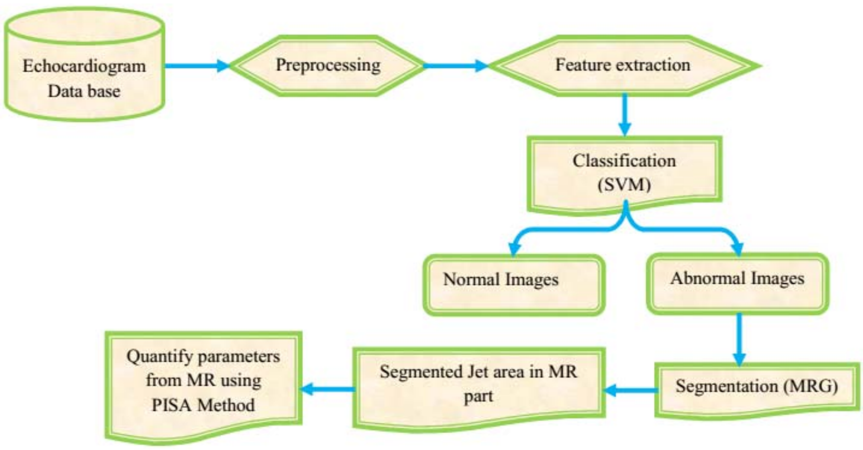
In Freud et al. (2016) and Khayum et al. (2012), they have suggested the pre- and postoperative echocardiograms of 24 patients who experienced melody MVR were reread. Along with typical quantities, preoperative probable quantities of the mitral annulus were accomplished whereby dimensions were assessed for melody sizing. A ratio of the slightest subaortic region in systole to the real MV dimension (Suba: MV) was evaluated for the threat of postoperative left ventricular outflow tract obstruction (LVOTO). Postoperatively, mitral gradients significantly enhanced, with low values comparative to the operative orifice area of the melody valve. No patients had major throwing up or perivalvular leak.

In Huntgeburth and Rudolph (2015) and Seshadri et al. (2016), MR is commonly stumbling upon in congestive heart failure (CHF) patients and is recognised to confound the clinical course of this disease. While MR in common is most frequently an outcome of progressive variations of the MV apparatus (primary MR), MR in CHF patients is usually triggered by changes in left ventricular geometry, however the structural integrity of the valve apparatus is not affected (secondary MR, SMR).have projected the different mechanisms of SMR in heart failure patients and clarify the diverse healing possibilities straddling from therapeutic methods over implantable procedures to develop heart function to recognised surgical and changing interventional healing possibilities for MV restoration.

## 3 Proposed methodology

In medical cardiology, one of the main goals is the quantification of MR severity which greatly affects the medical decision making procedure. To improve the quantification, the AR in echocardiography images distinctive stepladders is measured in this investigation effort. Primarily reveal the 2D echocardiogram database to preprocessing engaged to eliminate the harmonics and extract some from the pretreated images. After extracting the images, significant data classification method into categorise ordinary MV images and abnormal images that are MV with abnormal function MR images, this classification method support vector machine (SVM) linear kernel function is utilised. After classification method, abnormal images are ruminates the separation to section the jet area in MR part using section expanding with optimisation that is modified region growing (MRG), here grey wolf optimisation (GWO) is used for the optimisation method. After that Doppler echocardiography recognise as a reliable and exact measurable method for quantification MR by diverse limitations with the assistance of proximal isovelocity surface area (PISA) technique to measure the severity of an MR. The offered method for quantification of MR block diagram presented in Figure 1.

**Figure 1** Block diagram for proposed work (see online version for colours)



### 3.1 Preprocessing

The Gaussian filter is a linear filter that can be used in various situations of image processing. Digital echocardiography images are subjugated the sound and it is decreased in preprocessing stages through a Gaussian filter which offers noise-free output image. The input image signal is acknowledged as vector and the abnormalities are found. Usually, a Gaussian filtering is subjugated for the noise eradication method, which is specified as

$$G(p) = \exp\left(\frac{-x^2}{2x\sigma^2}\right) \tag{1}$$

where $G(p)$, a Gaussian function represents the noise and $\sigma$ denotes a deviation.

### 3.2 Feature extraction

The feature extraction method includes the study of the echocardiogram images and for this image characteristic abstraction, the spectral analysis technique is installed. By feature extraction, what is proposed is the alteration of the input data into the set of characteristics. In our investigation, the features taken into attention are:

- colour feature
- grey level co-occurrence matrix (GLCM)
- maximum intensity (MI).

#### 3.2.1 Colour feature

A colour histogram is a depiction of the dispersal of colours in an image. For digital images, a colour histogram embodies the number of pixels that have colours in each of a secure list of colour arrays that cover the image's colour space, the set of all feasible colours. The histogram equalisation normally gives rise to the universal divergence of several images; particularly when the efficient data of the image are indicated by adjacent diverse values. The colour histogram may also be signified and exhibited as a smooth function distinct from the colour space that approaches the pixel counts.

#### 3.2.2 Grey level co-occurrence matrix

The grey level co-occurrence matrix (GLCM) or else recognised as the grey-level spatial dependence matrix, signifies an arithmetical method of reviewing the quality that takes into account the spatial relationship of pixels (Pathak and Barooah, 2013). The GLCM functions interpret the quality of an image by assessing the rate of occurrences of the pairs of pixel with similar values. The grey level co-occurrence matrix can reveal specific abilities about the spatial dispersal of the grey levels in the texture image. The set of grey level co-occurring probabilities (GLCP) is stated in equation (2):

$$P_{ij} = \frac{F_{ij}}{\sum_{i,j=0}^{L-1} F_{ij}} \tag{2}$$

where $F_{ij}$ represents the frequency of occurrences between two grey levels, $L$ – number of quantised grey levels and $i$ and $j$ for a given displacement vector for the specified window size.

GLCMs acquire more than one or two statistics from them utilising the grey co-props function. These statistics propose material about the texture of an image. The statistics are for instance

- entropy (ENT)
- correlation (COR)
- contrast (CON)
- homogeneity (HOM).

#### *3.2.2.1 Entropy*

Entropy establishes the amount of data of an image that is required for the image density. Low entropy images like those encompassing a lot of black sky display very minute difference and massive series of pixels with the combine values. An image which is severely even seized entropy of zero. Accordingly, they may be flattened into some sensible small element. Instead, high entropy images like the image of greatly cratered areas on the moon retain a huge quantity of contrast from one pixel to the next and so it is not likely to reduce them as low entropy images. The entropy appraises the loss of data or message in a connected signal and calculates the image data.

$$ENT = \sum_{i=0}^{L-1} \sum_{j=0}^{L-1} -P_{ij} \log P_{ij} \tag{3}$$

where $P_{ij}$ – co-occurring probabilities stored inside GLCM.

#### *3.2.2.2 Correlation*

Correlation approximates the linear dependency of grey levels of contiguous pixels. The tracing of the digital image correlation denotes a visual method which services tracing and image recording methods for precise 2D and 3D dimensions of differences in images. It is commonly used to guess twist, dislocation, strain and optical flow. However, it is generally retained in several regions of science and engineering. A famous application is for assessing the gesture of an optical mouse. The connection to assess moves in datasets has been positioned as time ancient which was active in the digital images. The modern day applications are extremely massive and contain the image analysis, image compression, velocimetry and strain estimation.

$$COR = \sum_{i,j=0}^{L-1} \frac{(i-\alpha_i)(j-\alpha_i)P(i,j)}{\beta_i \beta_j} \tag{4}$$

where $\alpha_i$ and $\alpha_j$ – mean of row $i$ and column $j$ and $\beta_i$ and $\beta_j$ – standard deviation of row $i$ and column $j$.

#### 3.2.2.3 Contrast

Contrast constraint is the one that analyses the spatial rate of an image and the changing instants of GLCM. It specifies the difference between the maximum and the minimum values of an adjacent set of pixels. It efficiently assesses a number of local dissimilarities in the image. A low contrast image provides the GLCM attention term around the principal diagonal and features low spatial frequencies. The maximum contrast of an image signifies the separation ratio or the energetic range.

$$CON = \sum_{i,j=0}^{L-1} P_{ij} (i - j)^2 \quad (5)$$

#### 3.2.2.4 Homogeneity

The homogeneity restriction otherwise called the contrary difference moment assesses the image homogeneity supposing higher values for slight grey tone variations in the pair components. Hence, the homogeneity is an assessment which utters higher values for minor contrast images. An amount of local homogeneity is usually used in the one-dimensional histogram thresholding. The homogeneity, in effect, is address to two sections such as the standard deviation and the incoherence of the strengths at each pixel of the image.

$$HOM = \sum_{i,j=0}^{L-1} \frac{1}{1+(i-j)^2} P_{ij} \quad (6)$$

### 3.2.3 Maximum intensity

The MI of the images mentions to the maximum count of pixel values (0 to 255) and the following intensity value. The histogram of an image commonly transmits to a histogram of the pixel intensity values in an image processing context. And it denotes a graph depicting the number of pixels in an image at each and every unique intensity value establishes in the comparative image. In as much as there are 256 diverse possible strengths for an 8-bit greyscale image, the histogram realistically proposes 256 numbers representing the distribution of pixels between those greyscale values.

$$I = \max_{i=0}^{255} (count\ of\ \ pixel\ intensity) \quad (7)$$

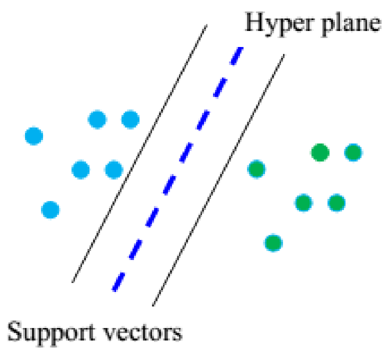
## 3.3 Echocardiogram image classification

Echocardiogram image classification centred on quality mining heading for stages, MA quantification method initially off all sort usual and unusual images. The whole feature vector values are measured in this classify method, based on this attribute MV normal images and MA in abnormal images are categorised with the support of linear kernel SVM function.

### 3.3.1 SVM with linear kernel function

The SVM method pursues to discover the best straightening out hyperplane among the courses by aiming at the training cases that are located at the authority of the class descriptors. These training cases are called the support vectors. The training cases except the support vectors are the rejected vectors. The hyperplane is exposed in Figure 2. By this method, not only used an optimal hyperplane set but also reduced amount of training samples are more successfully used and thus, high sorting precision is attained using relatively minor training sets. This MR classification process SVM with linear kernel function is used (Patnaik and Jagannathan, 2006).

**Figure 2** Support vector machine (see online version for colours)




Given a training set of $(j_i, k_i)$, $i = 1, 2, \dots n$ where $j_i \in R^n$ and $k \in \{1, -1\}^l$ SVM solves the optimisation problem. Hyperplane acting as the decision surface is linear function defined as

$$\sum_{i=0}^{M} \alpha_i . f_i . K(x, x_i) = 0 \tag{8}$$

where $x$ signifies a vector dragged from the input space, supposed to be of dimension $p_0$, $\alpha_i$ is the Lagrange coefficient, $f_i$ corresponding target output and $K(x, x_i)$ symbolises the inner product of two vectors prompted in the feature space by the input vector $x$ and input pattern $x_i$ pertaining to the $i^{\text{th}}$ example. This term is mentioned to as the inner-product kernel.

$$w = \sum_{i=0}^{M} \alpha_i . f_i . x_i, \quad b = wx_k - f_k \tag{9}$$

It also denotes an easy example representing a summary of classification. At present, the classes, along with being a collection of free, clear-cut labels, occur as randomly designed objects with connections defined between them. In the province of SVM-related tasks develop with the label of fundamental SVMs.

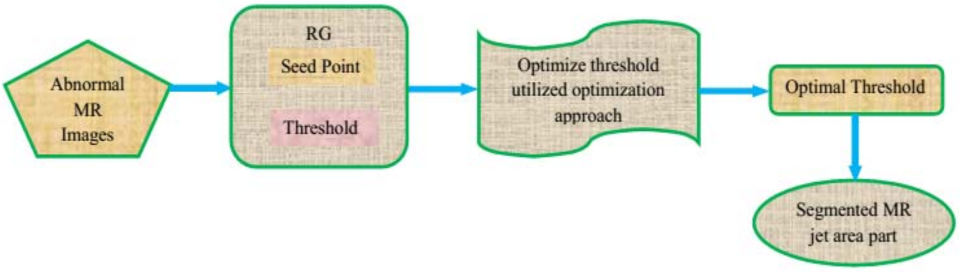
$$Class \Rightarrow Wx + y \tag{10}$$

Finally, the hyperplane-based classifies the signal through equation (10) used for categorising echocardiogram image with hyperplane value are effectually exploited to trace the class and predict the associated image.

### 3.4 MR segmentation analysis

MR jet area segmentation by MRG method is used. Normal MV function hang on the perfect reason of the difficult contact among the mitral lifts in the subvalvular apparatus, the mitral annulus and the LV and the jet area of MR is segmented. This segmentation process region growing (RG) with diverse optimisation procedures used to improve the threshold in RG development. By the way, the image segmentation signifies the mission of separating a digital image into several segments which are a set of pixels on the basis of definite similarity standard like the colour, intensity or texture, with an eye on employing and detecting objects and limits in an image, the schematic diagram of segmenting process exposed in Figure 3.

**Figure 3** Block diagram for segmentation (see online version for colours)




### 3.5 Modified region growing

In the usual RG method, when the intensity constraint is analysed by the adjacent pixels, some problem arises in the standard RG method as the shielding in the real images cannot be renowned and also the chance for sound to happen in the intensity value may effect in over-segmentation. In the RG, the seed point and threshold values are allocated automatically for the segmentation and this does not produce better consequences all the time (Ugarriza et al., 2009). At this point in the MRG, the MI value reached in the histogram is allocated to be the seed point and the threshold value is assigned automatically. The ideal threshold value is projected for the better segmentation and this will raise the precision of the segmented image optimisation techniques that are exploited. The procedures such as genetic algorithm (GA) and GWO are used to develop the accuracy thus heading to the optimisation of the MRG method encompassing four phases as follows:

- gridding
- seed point selection
- finding optimal threshold value
- applying RG to the seed point.

### *3.5.1 Gridding*

In the beginning, the image is distributed into many blocks ($s_b$) and as it looks like pertaining a grid on the image, this procedure is recognised as gridding. The gridding is completed to assign each spot with separate sections.

### *3.5.2 Seed point selection*

In this method, the histogram assessment is hired to escort in the seed point. Considering the element that the histogram technique is used for every pixel in the block, the assessment of the pixel is arranged between 0 and 255, and the most commonly happening pixel value is assigned to be the seed point. In the situation of each and every image, the blocks are separated and the seed point is fixed.

$$block(i,j) = f_i\left(z:(z+s_b)-1, l:(l+s_b)-1\right) \quad \begin{matrix} \text{for } (i=1\ldots\ldots 10):r \\ (j=1\ldots\ldots 10):c \end{matrix} \tag{11}$$

$$\left[Sz_{ij}Sl_{ij}\right] = find\left(block\{i,j\} == \max\left(block\{i,j\}\right)\right) \tag{12}$$

where $z = z + s_b$ and $l = l + s_b$.

### *3.5.3 Finding optimal threshold value*

This method is implementing to accomplish the segmented image and for the resolution, the optimisation system is employed. In the threshold optimisation, the maximum accuracy is found in the GWO associated to a couple of methods.

#### *Steps involved in GWO*

Step 1 Initialise the input threshold solutions $T_i = (1, \ldots\ldots, n)$ and also initialise algorithm parameters $a$, $A$ and $C$.

Step 2 Evaluate the fitness function for all initial solutions.

Step 3 Based on the fitness separate the search solutions in three categories:

- $T_\alpha$ the first best search solution
- $T_\beta$ the second best search solution
- $T_\delta$ the third best search solution.

Step 4 Update the position of current search solutions

Step 5 Again, evaluate the fitness function for each updated solutions

Step 6 Store the best solutions so far attained.

Iteration = iteration + 1

Step 7 Stop after the optimal solution is accomplished.

End

*Initialise process*

In the RG process, we select the seed point and the threshold to segment the jet area of MA image. Now, we modify the threshold $T_i$ and definite algorithm constraints such as $a$, $A$ and $C$ coefficient vectors.

*Fitness evaluation*

In each block of the image, we continue to place the fitness $F_i$ in a segmented part and here the fitness is the maximum accuracy of the segmented part. The accuracy is located using the limitations such as true positive (*TP*), true negative (*TN*), false positive (*FP*) and false negative (*FN*).

$$F_i = \left( \frac{TP + TN}{TP + TN + FP + FN} \right) \tag{13}$$

*Separate the solution based on the fitness*

Currently, we find the distinct explanation (threshold) based on the fitness value. Let the first best fitness solutions be $\alpha$, the second best fitness solutions $\beta$ and the third best fitness solutions $\delta$.

*Update the position*

We suppose that the alpha (best candidate solution), beta and delta have the enhanced information about the possible position of the target so as to repeat scientifically the pursuing performance of the grey wolves. Therefore, we reserve the first three best solutions achieved until now and need the other search agents (including the omegas) to review their locations consistent with the location of the best search agent. For recurrence, the new solution $T(t + 1)$ is assessed by using the procedures stated underneath.

$$T(t+1) = \frac{\vec{T}_1 + \vec{T}_2 + \vec{T}_3}{3} \tag{14}$$

$$D^{\alpha} = \left| C_1.T_{\alpha} - T \right|, \quad D^{\beta} = \left| C_1.T_{\beta} - T \right|, \quad D^{\delta} = \left| C_1.T_{\delta} - T \right| \tag{15}$$

$$T_1 = T_{\alpha} - A_1.\left(D_{\alpha}\right), \quad T_2 = T_{\beta} - A_2.\left(D_{\beta}\right), \quad T_3 = T_{\delta} - A_3.\left(D_{\delta}\right) \tag{16}$$

To have hyperspheres with diverse random radii, the arbitrary parameters $A$ and $C$ help the candidate solutions. Investigation and utilisation are definite by the adaptive values of $A$ and $a$. The adaptive values of the limitations $A$ and $a$ let the GWO transit them smoothly between the investigation and the utilisation. With lessening A, half of the iterations are committed to the investigation ($|A| < 1$) and the other half are dedicated to the operation. Surrounding the performance, the following calculations are active so as to afford a mathematical model.

$$D = \left| C.T_P(t) - T(t) \right| \tag{17}$$

The coefficient vectors are found by equation (18)

$$A = 2a.r_1 - a, \quad C = 2.r_2 \tag{18}$$

where $t$ specifies the current iteration, $A$ and $C$ are coefficient vectors, $T_P$ is the position vector of the prey $T$ and specifies the position vector of a grey wolf. The components of $a$ are linearly reduced from 2 to 0 over the course of iterations and $r_1$ and $r_2$ are random vectors in [0, 1]. After these modernising methods, again compute the fitness function, till finding supreme accuracy.

$$F_i(new)_{Optimal} = \max\left(\frac{TP + TN}{TP + TN + FP + FN}\right) \tag{19}$$

The GWO has only two main parameters ($A$ and $C$) to be accustomed. Though, we have retained the GWO algorithm as easy as possible for the least workers to be accustomed. The progression will be persistent until the maximum accuracy is attained.

### *3.5.4 Applying RG to the seed point*

The final procedure is the RG procedure, where the value that is achieved from the optimal threshold calculation method leads to a defined extracted jet area of the image.

## *3.6 Quantification MA using PISA*

PISA (Omar et al., 2015) technique Doppler image was used to efficiently enumerate the MR. There has been a significant consideration in the PISA method to examine the severity of valvular and congenital heart diseases. The PISA is a technique generally used in echocardiography and it estimates the valvular insufficiency and it mostly favours the disease called MR. For itself, we can undertake blood flow unites in a semicircular shape as it goes from the LV headed for the LA in someone with a single central jet of MR. The value of this technique is that when fluid or liquid goes through a gap or the small hole in a flat surface, it shows the flow speed just proximal to that gap. It is represented as flow convergence zone and that leakage of fluid is designed using PISA. This consequence is also called as Coanda effect, Doppler input colour image exposed in Figure 4.

**Figure 4** Doppler colour image and segmented image (see online version for colours)

MR is the disease which origins due to the leakage of blood flow in the MV region. While inhalation, the MV will be in the released state and there, the discharge of fresh oxygenated blood flows to the LV beginning LA. In course of exhaling the MV should be in closed position meanwhile the outflow of blood is seen in that area. This outflow of blood is called as MR disease and this is estimated by using PISA method. This PISA technique is exploited to compute the severity some measurable limitations are assessed. They are as follows:

a *Percentage (%) of blood flow*

A dripping MV permits blood to flow in two directions in the shrinkage. Some blood flows from the ventricle through the aortic valve as it should and some blood flows back into the atrium. This factor quantification process reflects MR image blood flow and pixel values.

b *Blood flow Rate (BFR)*

The prompt regurgitant flow can be considered from the PISA radius and can be used to evaluate the severity of MR. The amount of blood flow (regurgitant flow) can be considered when the PISA radius and velocity of the surface.

$$BF = 2\pi r^2 \times V_{aliasing} \tag{20}$$

c *Effective regurgitant orifice area (EROA)*

This parameter can be calculated using the instantaneous regurgitant flow. The formula can be derived from equation (21):

$$EROA(PISA) = RF/V_{\max} \tag{21}$$

Based on the principle of conservation of mass, the PISA method also permits us to measure the effective regurgitant orifice (the functional size of the 'hole').

d *Aortic flow (AF)*

This factor can be intended using the prompt regurgitant flow. The formula can be resulting from equation (22):

$$AF = \left(D_{LVOT}^2 \times 0.785\right)V_{\max} \tag{22}$$

e *Regurgitate fraction (RF)*

Regurgitant fraction is the percentage of blood that brings up back through the aortic valve to the LV due to aortic insufficiency or over the MV to the atrium due to mitral deficiency.

$$RF = \frac{RV}{Aortic\ flow} \tag{23}$$

f *Regurgitate volume (R-volume)*

This parameter calculates the flow of aortic blood and mitral blood flow in MR part.

$$R\text{-}volume = Aortic\ flow - Mitral\ flow \tag{24}$$

Mitral flow in R volume calculation process considers the velocity time integral (VTI) of the MR jet area.

g *Narrowed orifice area*

This constraint quantification method deliberates the PISA radius, maximum velocity through the pointed orifice area and aliasing velocity.

$$A_o = \frac{2\pi r^2 V_{aliasing}}{V_{\max}} \quad (25)$$

These above state limitations and circular space from orifice area are quantified in classify and segmented MR in echocardiogram images. Table 1 displays the normal values in Doppler parameters of MR severity investigation.

**Table 1** Quantification of standard Doppler parameters for MR severity

| *Parameters* | *Mild* | *Moderate* | *Severe* |
|---|---|---|---|
| EROA | < 0.20 | 0.20–0.39 | 0.40 |
| RF | < 30 | 30–59 | 60 |
| R-volume | < 30 | 30–49 | 50□ |

## 4 Results and discussions

This segment converses the classification and dissection grades in echocardiogram images for SVM and MRG with GWO technique. This segment grants the result formed by the suggested method while its quantification effectiveness of MR was verified using colour Doppler echocardiography image. Then, some limitations are quantified using PISA method and lastly the projected work associated to the present work Fuzzy segmentation with the PISA method.

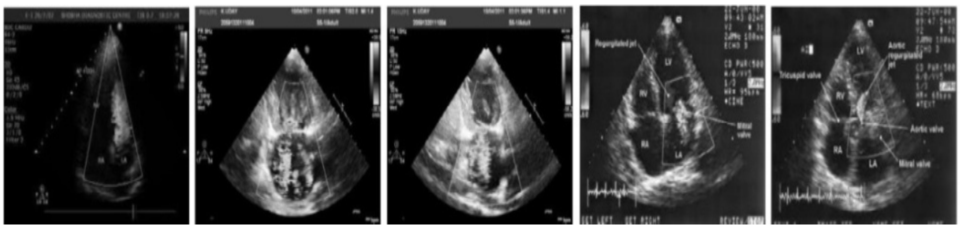
### *4.1 Database description*

The 2dechocardiogram image database was exploited in our projected work composed from Nims hospital and some images are grabbed from the web widely offered. This database holds more than 100 images for classifying, segmenting and counting method.

**Figure 5** Sample database images (see online version for colours)

In the MR quantification process, 80% of the images are used as training and 20% are utilised as a testing period. Each images having different pixels not more than 255 pixels but it has a 256 different possible strength for an 8-bit greyscale. In this, the classification process histogram realistically proposes 256 numbers representing the distribution of pixels between those greyscale values. It also covers the whole image from the echocardiogram. Figure 5 displays the database echocardiogram normal and abnormal images and Figure 6 shows the next relating preprocessing Gaussian filter in images.

**Figure 6** Preprocessing images



### 4.1.1 Performance evaluation parameters

$$Sensitivity = \frac{TP}{TP + TN} \quad (26)$$

$$Specificity = \frac{TN}{TP + TN} \quad (27)$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (28)$$

$$Positive\ predictive\ value\ (PPV) = \frac{TP}{TP + FP} \quad (29)$$

$$Negative\ predictive\ value\ (NPV) = \frac{TN}{TN + FN} \quad (30)$$

$$False\ positive\ rate\ (FPR) = \frac{FP}{FP + TN} \quad (31)$$

$$False\ discovery\ rate\ (FDR) = \frac{FP}{FP + TP} \quad (32)$$

$$Random\ index\ (RI) = \frac{a + b}{a + b + c + d} \quad (33)$$

where $a + b$ is the number of agreements between the partitions $X$ and $Y$ and $c + d$ is the number of disagreements between the partitions $X$ and $Y$.

$$Global\ consistency\ error\ (GCE) = \frac{1}{n}\min\left\{\sum_i E\left(S_1, S_2, p_i\right), \sum_i E\left(S_2, S_1, p_i\right)\right\} \quad (34)$$

where segmentation error measure takes two segmentations $S_1$ and $S_2$ as input, these values contain pixel.

$$Variation\ of\ information\ (VI)(X;Y) = H(X) + H(Y) - 2I(X,Y) \quad (35)$$

where $H(X)$ is entropy of $X$ and $I(X, Y)$ is mutual.

## *4.2 Experimental analysis in classification process*

In this section, it discussed the results of classification process classify the normal echocardiogram images and MR abnormal images the performance parameter sensitivity, specificity and accuracy are shown in Table 1.

**Table 2** Test results of echocardiogram image classification (see online version for colours)

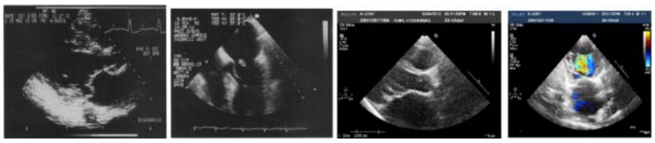
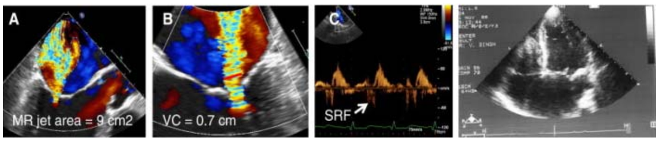
| *Validation* | *Images* | *Accuracy (%)* |
|---|---|---|
| Validation 1 |  | 80 |
| Validation 2 |   | 88.2 |
| Validation 3 |  | 95.3 |

**Figure 7** Performance analysis for classifier (see online version for colours)

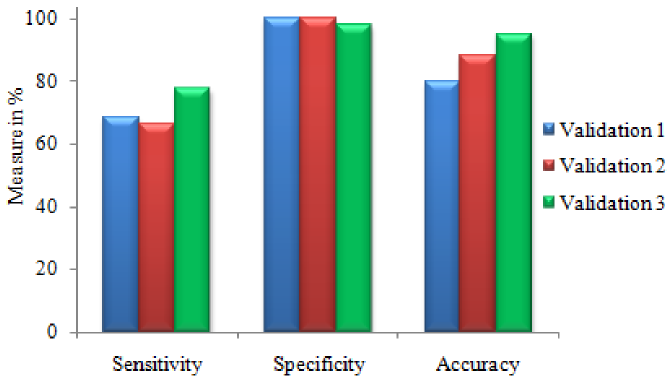



Table 2 and Figure 7 displays the classification execution parameters in MR abnormal and normal image classify in SVM classifier. At this point, wholly three authentication procedure ruminate four images for each course. In the validation procedure, high accuracy as 95.3% attained in validation 3, the SVM accuracy is compared to the validation 2 the difference is 13.23% similarly in validation 1. Then, the determined sensitivity value related to the other validation the variance in terms of percentage is 5.6%. Likewise, some considerable abnormalities among the linear SVM kernel functions are detected in the classification method validation 3. SVM analysis, 70.83% accuracy, 99.41% sensitivity and 87.8% in specificity by the examination of echocardiography videos for the analysis of the sternness of MR. In common, if two normal and MR groups are measured, the accuracy is 99.51%.

### *4.3 MR jet area segmentation analysis*

In the segmentation process, the MR jet area segmented by the projected method 'MRG' with threshold prediction by means of GWO. In Table 2, the original echocardiogram images comprising MR and the segmented portion of the echocardiogram images are exposed. The presentation processes such as sensitivity, specificity, accuracy, FPR, PPV, NPV, FDR, random index, global contingency error (GCE) and variation of information (VI). For the analysis method, some of the images are measured and in reverence of these images, the above-stated limitations are examined. These reckonings are defined by the usage of true positive (*TP*), true negative (*TN*), false positive (*FP*) and false negative (*FN*). This projected technique limitations associated to the GA and fuzzy C-means (FCM) segmentation method.

Table 3 displays that the segmented MR jet area part with MR echocardiogram images beside the several numerical presentation processes. This recommended MRG with GWO associated to the other optimisation GA the accuracy, sensitivity and specificity are in elevation. The extreme sensitivity gained is 0.97 (for image 1) when assessing the five test images. For image 2, this shows the good presentation of the suggested technique linked with the further methods. All the presentation valuation limitation showed best standards in GWO when they originate in contrast with the former two methods. Concerning the specificity measure, when the images numbered 5, 6 and 7 are taken as samples, the assessment therefore attained by using GWO is 99.96% though the assessment achieved by using the other two methods is 98%. Once this technique (MRG-GWO) originates in contrast with EP and HS, the positive predictive and negative predictive values display better execution as 98% when all the images are measured. Similarly, in other images too, the substantial modification in execution processes ensues among GWO and the other two methods. Beyond, the GCE factor displays the minimum fault in the proposed technique. Therefore, generally, the proposed technique has stated correctness of 99.05% associated with the other methods.

#### *4.3.1 Segmentation comparative analysis*

Figure 8 pleasingly shows the assessment graph for the section rising with optimisation which includes the GWO, GA and FCM. The compassion of planned GWO associated to other two methods the variance is 22.3% and 27.23% separately. Similarly, the accurateness of the MRG with GWO being 97.05%, it is seen condensed by 0.23% and 1.15% separately in the instance of GA and FCM. Altogether, the projected technique displays an important trademark of 0.75% when associated with the other two approaches in terms of the limitations stated in the bar graph. The advanced precision level has deeply demonstrated deprived of any jot of uncertainty that the advanced method graph is typical and best suggested in detecting the MR jet part of echocardiogram image. By means of evaluating the fallouts, it is perfect that echocardiography lets precise MR division of the echocardiography.

**Table 3** Proposed segmentation results analysis (see online version for colours)

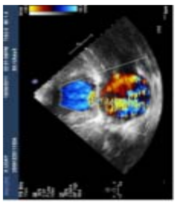
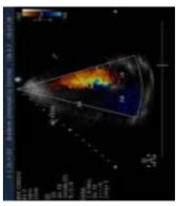
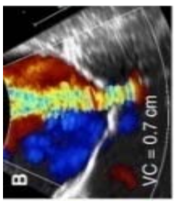
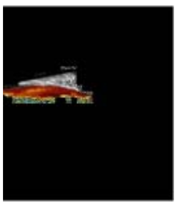
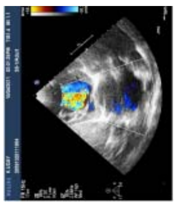
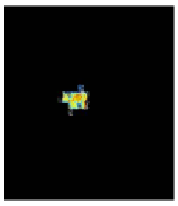
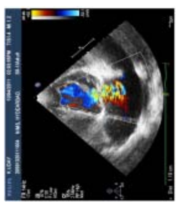
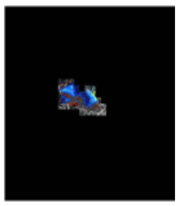
| *Sl. no.* | *Original image* | *Segmented part* | *Sen* | *Spec* | *Acc* | *PPV* | *NPV* | *FPR* | *FDR* | *RI* | *GCE* | *VI* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 |  |  | 0.97 | 0.98 | 0.98 | 0.25 | 1.00 | 0.02 | 0.75 | 0.96 | 0.01 | 0.16 |
| 2 |  |  | 0.91 | 0.99 | 0.99 | 0.80 | 1.00 | 0.01 | 0.20 | 0.98 | 0.01 | 0.10 |
| 3 |   |  | 0.58 | 0.89 | 0.88 | 0.19 | 0.98 | 0.11 | 0.81 | 0.79 | 0.07 | 0.71 |
| 4 |  |  | 0.83 | 1.00 | 0.99 | 0.64 | 1.00 | 0.00 | 0.36 | 0.99 | 0.01 | 0.08 |
| 5 |  |  | 0.37 | 0.98 | 0.96 | 0.24 | 0.99 | 0.02 | 0.76 | 0.93 | 0.04 | 0.30 |

**Figure 8** Comparative analysis (see online version for colours)

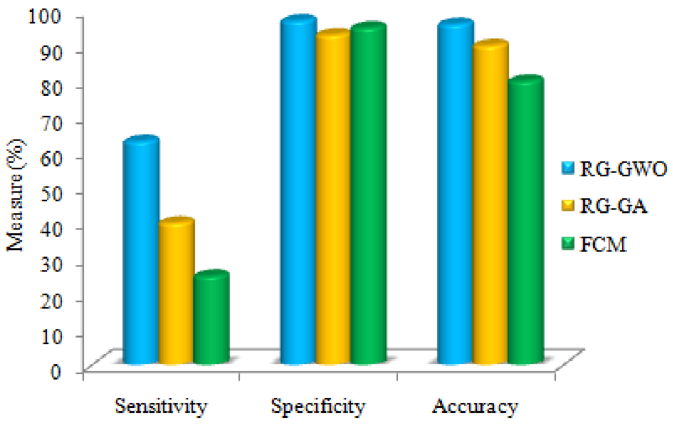



**Table 4** Measured values of MR

| *Quantitative measures* | *Value* |
|---|---|
| % of blood flow (%) | 0.81 |
| Flow rate (ml/s) | 6.14 |
| EROA ($cm^2$) | 0.03 |
| AF ($cm^3$) | 152.66 |
| Density of regurgitant jet | 37.90 |
| Radial distance from orifice area ($cm^2/m^2$) | 0.61 |
| Narrowed orifice area ($cm^2/m^2$) | 0.08 |
| Regurgitant fraction (%) | 14.05 |
| R-volume ($cm^3$) | 31.50 |
| Vena contracta width (%) | 0.29 |
| Orifice area | 2.33 |
| Jet width (%) | 0.23 |
| LVOT width (%) | 0.97 |
| Mital flow (ml/s) | 131.20 |
| Aliasing velocity (cm/s) | 44.00 |
| Peak velocity (cm/s) | 1,300.00 |

### *4.4 Quantification analysis using PISA*

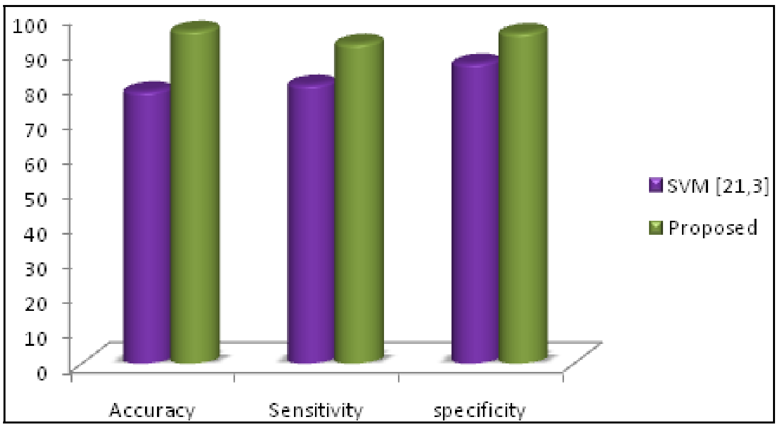
A quantitative estimation of valve regurgitation is probably using colour Doppler flow mapping for the region of flow convergence proximal to a regurgitate gap. Utilising proximal flow convergence region for the quantitative examination should not essentially be narrow to valve regurgitation but should also be valid to any constricting opening gash. In dimension inquiry chiefly contemplates the orifice area and EROA computation reflects the aliasing speed. A shortened formulation can be used as a quick transmission instrument. With the NY Quist boundary at 40 cm/s and the MR peak velocity expected to be 500 cm/s. Then, the axial (blue) plane is progressed to the centre of the PFCR (ventricular side of the MV) and changed using both of the long-axis views (red and green boxes) to find an en face view of the centre of the PISA.

Table 4 displays the quantification measure parameters in MR part of Doppler echocardiogram images receiving RG with GWO and enumerated developed to PISA technique. The quantification of ERO area in regurgitation by PISA method which is created on the idea of maintenance of quantity was newly proved clinically. The effectiveness of PISA technique in the quantisation of MR has been designated by trial inquiry. In recent times, invasive and non-invasive Doppler echocardiography approaches are used to estimate the aortic ERO area in AR. The Scientific consequence of the ERO area in defining AR strictness and its competence of providing supplementary material to a regurgitant segment have been exposed by these educations. Therefore, to achieve a high degree of consistency in assessing the strictness of MR in all situations, a mixture of clinically constant non-invasive approaches is necessary for defining the ERO area in Doppler echocardiography inspection.

### *4.4.1 Comparative analysis for existing approach (classification)*

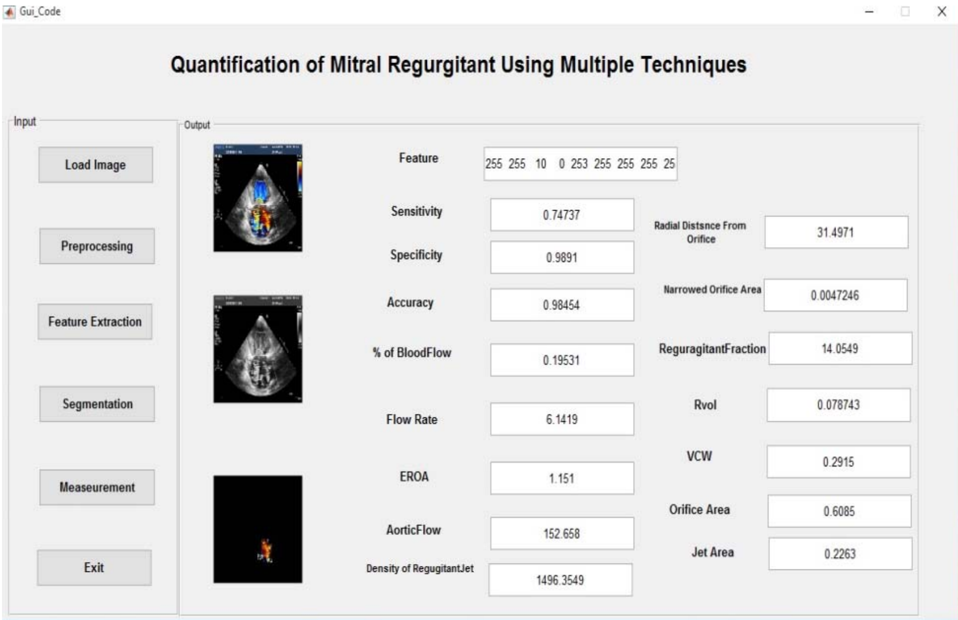
Figure 9 shows the comparative analysis for existing approach. The bar graph compares the accuracy, sensitivity and specificity for the proposed to existing approaches. Here, the accuracy for existing approaches, i.e., SVM attains only 78.23%, proposed techniques, i.e., SVM with linear classifier gives 95.65%, sensitivity for existing attains 80.15%, proposed achieves 91.89%, specificity for SVM reaches 86.23% and the SVM with linear classifier gets 94.98%. It clearly shows the proposed techniques achieve optimal result than existing approaches. For the quantification, Doppler with echocardiogram achieves a better result than existing Doppler assessment. Built-in graphics make it easy to visualise and gain insights from data. The desktop environment invites experimentation, exploration and discovery. These MATLAB tools and capabilities are all rigorously tested and designed to work together.

**Figure 9** Comparative analysis for existing vs. proposed (see online version for colours)




The original method is accomplished in the MATLAB platform specified in the associated graph. Figure 10 displays the GUI production standards in quality mining, separation parameters and quantification dimensions recognised. However, constructing the model, at the beginning, the images are selected, tracked by the exaction of the captioned structures. Afterward, numerous limitations are assessed.

**Figure 10** Graphical user interface (GUI) for MR analysis process (see online version for colours)




## 5 Conclusions

In the scientific decision-making method about MR, exact resolution for the severity of illness is chief reputation. The danger of operation permits authorisation of severity by a balancing technique. Presently whereas, MR has no gold model beside which to enumerate the regurgitant volume, flow rate, etc. In precise of all the above, it becomes suitably clear that the suggested way is, in every phase, desirable to all such approaches equivalent. Actually, the projected technique with its rareness is observed upon as the original of its kind in using SVM accuracy 87.8% for classification and MRG accuracy is 97.23% for separation. Here, mainly the segmentation results depict that the RG with GWO reaches maximum accuracy, sensitivity and specificity, i.e., 97.05% compared to RG-GA and FCM. New fallouts definitely demonstrate that in the classification, segmentation and quantification the separation as well the projected method, that is the finest edge, creates far better outcomes than the other methods do. The progress in imaging machinery enables to advance quantities of flow convergence, vena contracta and the regurgitant which finally leads to improvements in the quantification of valvular regurgitation. Investigational outcomes have been established to associate with some other events that occur for cardiac production capacities. This projected investigation composition can be tested in the operational platform of MATLAB 2015 with i5 system configuration and 4 GB MR quantification process. The proposed technique concluded that fuzzy with PISA quantification approach achieves the accuracy rate of 99.05%. It gives optimal result in the projected techniques compared to existing approaches. Echocardiography delivers a high degree of specificity and selectivity and is non-invasive. Research that identifies improved efficacy with optimisation will also be the key to uncovering new ways to achieve cost effectiveness of cardiography image classification and segmentation testing. The MR regurgitation is easy to accessed using standard windows. It is relatively independent of flow rate, driving pressure or entrainment and also not influenced by the presence of another regurgitant leak. It is no need for correction for convergence angle as with PISA measurement.

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