# EXPLORING THE SCOPE OF HALFTONE FEATURES TOWARDS DETECTION OF CRACK IN CONCRETE BLOCKS

**A THESIS**

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**Certificate of Recommendation**

This is to certify that AYUSHMAN (Exam Roll No: M4PRI19001 Registration Number: 140959 of 2017-2018 has completed his dissertation entitled, **“**EXPLORING THE SCOPE OF HALFTONE FEATURES TOWARDS DETECTION OF CRACK IN CONCRETE BLOCKS” under the supervision and guidance of Dr. ARPITAM CHATTERJEE, Assistant professor, Printing Engineering Department, Jadavpur University, Kolkata. We are satisfied with his work which is being presented for the partial fulfillment of the degree of M.Tech in printing engineering and graphic communication, Jadavpur University, Kolkata-700098.

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ABSTRACT

Crack detection in concrete is done conventionally by two types of methods i.e. destructive and nondestructive testing. The destructive test is pulled out test, and core cutter test which requires human supervision and probability of error may increase due to that. On the other hand nondestructive technique which uses ultrasonic pulse velocity method and radioactive method to detect crack require skilled manpower to operate those devices. Now a day's detection of crack-using computer vision is becoming popular. There are different computer vision techniques that are used to detect crack, for example, leaking defect detection in sewer pipelines.

Here a new method is proposed. This method is used for crack detection in concrete by computer vision using halftone features. Halftoning is conventionally used in the printing industry for the reproduction of images but since it can deliver binary images the halftone features can have the possibility in computer vision detection tasks. Some of the major advantages of the explored technique are it is fully automatic, less time consuming and high accuracy. In this work, the SVM classifier is used to classify the data into crack and no-crack classes where more than 95% accuracy have been achieved in an average. The thesis work shows that the reported halftone features based classification method can be a possible alternative to the existing automated crack detection systems.

# TABLE OF CONTENTS

# CHAPTER-1

# Introduction and Literature Review

## 1.1 Introduction

Crack in concrete is the symbol of improper work which has been carried out during the construction work in building civil infrastructure. Not only the improper work is the reason for a crack in concrete but also aging of concrete and natural disasters like earthquakes, storm, etc can also cause cracks. Crack in the building mostly occurred by the earthquake. Crack in concrete is one of the causes of structural failure. Types of crack occur in concrete can be classified as shrinkage, creep, settlement, hairline, vertical, diagonal, floor, and Temperature crack [1]. Shrinkage crack occurs in concrete because of improper curing of concrete. Curing means applying water to the part of the structure for a fixed time period after the casting [2,3]. Creep occurs on a certain point of the structure where the load is applied for a long time. The settlement is the type of failure in which structure is displaced from its original position due to the expulsion of air or water present in the foundation of the structures. Hairline crack is very thin crack appears in the concrete. These cracks are very small in size about 0.003 inches in width [4]. Hairline cracks do not cause structure stability problem, but it causes problems with leakage. Vertical crack as it names indicate that crack occurs vertically. Similarly, horizontal cracks occur horizontally and a diagonal crack occurs diagonally in structure. Temperature difference within concrete causes heat of hydration occurs at a different rate which results in a crack in the concrete. Other than this crack can also occur due to an error in design and detailing, an additional load applied on the structure, poor knowledge in construction and reinforcement corrosion. Cracks occur in the slab, column, beam, foundation, wall, and plaster of structure mostly it can be seen at the joint of the structure like beam wall joint and column wall joint. Cracks in concrete are the sign of the health of the structure. For structural health, it is important to monitor structure at regular interval of time. Otherwise, it can cause an accident, human life hazards losses of government and public property. Cracks can also occur in the structure due to the movement of the vehicle and also the aging of concrete. Hence, continuous monitoring of the concrete slab is most importance to maintain structural health.

There are two major types of test technique used in measuring concrete crack (i) destructive testing [5] and (ii) nondestructive testing [6]. Destructive testing is a method of detecting quality and defects of material while damaging and destroying the physical properties of the material. Examples of the destructive technique include core cutter test, pull out test. Non Destructive testing is detecting quality and defects of material without damaging the material. Example of nondestructive testing include penetration method, rebound hammer method, ultrasonic pulse velocity method, radioactive- method. Some of the crack identification instruments are a crack magnifier, crack width meter and crack monitor.[7] These of the instrument is operated manually that requires a good skill. The reading may differ from person to person according to his perception. It means that mistake happened during taking reading will be less in the developing method for that research has gone from past years and it is less time consuming and good accuracy But nowadays research has been carried out to improving this method. These methods are based on taking images of the sample applying a set of operation using computer vision method. These operations are Multiple sequential image Filtering, Morphological segmentation to leaking defect detection in sewer pipelines, Edge detection technique. Most of the above mention technique is subjective and human perception dependent. Hence computer vision method can be a potential tool towards automated round the clock monitoring of concrete crack. In the following section, a brief review of different reported techniques for concrete crack detection is prevented.

## 1.2 Literature Survey

| Author(s) | Year | Paper Title | Overview | Results |
|---|---|---|---|---|
| G.L Qian, S.N-GU and J.SJiang [8] | 1990 | The Dynamic behavior and crack detection of a beam with a crack | To establish a finite element model of a cracked beam by using the element stiffness matrix of the beam with a crack is first derived from an integration of stress intensity factors. | A Finite element model (FEM) is proposed. The advantage of this method is its calculation is simple and convenient. The relation obtained by this method is valid for the cracked beam in which the effect of crack closing is considered as well open crack |
| H.N. Koutsopoulos, and A.b Downey [9] | 1993 | Primitive-based classification of pavement crack images | Pavement distress data are collected and analyzed for their potential to improve the quality of information on pavement condition. An approach which is used for the automated classification of asphalt pavement | Results are obtained in five classes namely alligator, block, longitudinal, traverse and plain. The system gives an acceptable result with the data set of 59 images with only |

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| | | | distresses recorded on video or photographic film. An algorithm is developed for image enhancement, segmentation and distress classification. | a few misclassifications. |
| Andrew D. Dimarogonas [10] | 1996 | The vibration of cracked structures A state of the art review. | Local flexibility was introduced by the presence of a crack in a structural member which affects its vibration response. The system is non-linear local stiffness matrix description of the cracked section of the shaft leads to a coupled system while for an un-cracked shaft the system is decoupled. | Important outcomes obtained on this is recognition of the vibration coupling due to crack. Bilinear and nonlinear and parametric vibration effects characterize the vibration of cracked rotating shafts. Artificial neural networks have been developed in rotating shafts for empirical crack identification. |

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| Ikhlas Abdel-Qader, Osama Abudayyeh, Michael E.Kelly [11] | 2003 | Analysis of edge-detection technique for crack identification in bridges | There are four techniques which are used in automation for detection of crack and deterioration of the bridge. Which is Fast Haar transform (FHT), Fast Fourier transform, Sobel And Canny edge detection algorithms which are implemented in Matlab using 50 samples of concrete bridge images (25 crack and 25 without crack) | Result obtained out of four methods applied in crack detection the result obtained from FHT was significantly more reliable. |
| D. Lecompte, J.Vantomme and H.sol [12] | 2006 | Crack detection in a concrete beam using two different camera techniques. | There are two different measurement techniques which are used to measure the displacement of a discrete number of points on the surface of the beam during loading first one is a comparison of a no. of a digital image taken during the loading of | Light emitting diode (L.E.D) and Charge couple device (C.C.D) is suitable and used to indicate the larger region of the sample where the crack occurs and further strain calculation gives |

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| | | | the beam speckle pattern is obtained when loading is applied. The second technique is based on localization in space of a number of light emitting diodes, fixed to the surface of the beam principle of this technique is space intersection combined with three linear CCD camera and no. of infrared light emitting diodes. | a good idea about the actual crack. |
| S.Park, S.Ahmad, C.B Yun, Y.Roy [13] | 2006 | Multiple crack detection of a concrete structure using the impedance-based structural health monitoring technique. | An impedance-based damage detection technique which uses smart ceramic material Lead, Zirconate, Titanate in short known as PZT is used as a tool for the implementation of a built-in diagnostic system. This technique utilizes higher frequency for structural inspection .it monitor the change | The outcomes of the impedance-based damage detection method using both lateral and thickness model of PZT is fairly practical and reliable for real-time health monitoring and crack detection in the concrete structure. |

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| | | | of structural mechanical impedance | |
| Chia-chi cheng, Tao-ming cheny, chin-hung-chiang [14] | 2008 | Defect detection of concrete structures using both infrared thermography and elastic waves. | To apply infrared thermography with elastic wave technique. The result of the fusion of both the technique gathered and applied. | The Thermal image recorded show clear indication of hidden defects of various depth and areas of the sample. |
| Saumya Amarasiri, Manjniker Gunarante, Sudeep Sarkar [15] | 2010 | Modeling of crack depth in digital images of concrete pavements using optical reflection properties. | In Automated pavement crack detection and classification, technology has been improving in the recent year but the detection of crack width and depth can be calculated using the software with reasonable accuracy. It can be evaluated with the optical modeling of the images formation process. The focus of this method is to use optical modeling of shallow, longitudinal | When the reflection is obtained from the crack surface it was shown that the reduction in pixel intensities which are the cause for producing color contrast from the discontinuity can be modeled regularly. |

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| | | | and transverse crack and joint of concrete by using the variation of reflection due to the discontinuity of the structure. | |
| Takafumi Nishikawa, Junji Yoshida and Toshiyuki sugiyama,Yozo Fujino.[16] | 2011 | Concrete crack Detection by Multiple sequential image filtering. | In this technique, there are two steps involve (1)Development of an image filter for detecting major cracks using Genetic programming(G.P) and (2) Elimination of residual noise after filtering and detection of indistinct crack by iterative application of the image filter to local regions surrounding the cracks. | In this paper, a new robust image processing method for detecting crack propose and the result getting after applying this method to estimate crack width and detection crack is a good agreement with that measure manually. |
| Ghada Moussa, Khaled Hussain, [17] | 2011 | A new technique for Automatic Detection and Parameters Estimation of Pavement crack | The technique used in this paper is Novel reliable automated pavement assessment system base on image processing techniques and machine learning method. | A system which is proposed has the ability to (i) identify crack (ii) extract crack parameters (iii) Report the type, extent, and |

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| | | | | severity level of the crack in the output file. |
| Qin Zou, Yu Cao, Qingquan Li, Qingzhou Mao, Song Wang [18] | 2012 | CrackTree: Automated crack detection from pavement images | A new method of detection of pavement crack is developing called CrackTree. It is a fully automated method to define crack from pavement images. Problems arise during this method are Low contrast between cracks and the surrounding pavement, Intensity inhomogeneity along the crack, Possible shadow with similar intensity to the crack. | After applying this method to 206 no. of a sample of real pavement images the experimental results achieve a better result than several existing methods. |
| Lokeshwor Huidrom, Lalit Kumar Das, S.K sud [19] | 2013 | Method for automated assessment of potholes, crack, and patches from road surface video clips. | The method which is proposed in this method is a robust method for automated detection and assessment of potholes, crack and patches are detected and quantified | Information collected using the proposed method can be used for determining the condition of roads and maintain the road easily as |

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| | | | automatically using the various image processing technique. This method is implemented in a window environment using open cv library. | compared to the previous method. |
| Tung- Ching Su and Ming-Der Yang.[20] | 2014 | Application of Morphological segmentation to Leaking Defect Detection in Sewer Pipelines. | To find out the leaking in pipelines of sewerage system closed-circuit television (CCTV) is used traditionally in order to facilitate the rehabilitation process. In this paper, a novel method of computer vision using morphological segmentation based on edge detection is used to detect the crack.<br>Other than MSED (Morphological segmentation based on edge detection ) another operation are applied are Opening top-hat operation (OTHO) and closing | Edge detection is an important step in pre-processing of image segmentation. MSED try to find and correct image regions of sewer pipelines defect in CCTV images. Results of segmentation conclude that MSED and OTHO are useful for the detection of crack. |

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| | | | bottom-hat operation (CBHO). | |
| Ganda chen, Hulmin Mu, David Pommerenka and James L. Drewnlak [21] | 2015 | Damage detection of reinforced concrete beams with Novel distributed crack. | Novel cables sensors were designed based on the topology of its outer conductor under the condition of strain and measure the reflection coefficients. | This test shows that measured reflection coefficient correlates well with the measured crack width. |
| Prateek Prasanna, Kristin J.Dana, Nenad Gucunski, Basily B.Basily, Hung M.La [22] | 2016 | Automated crack detection on a concrete bridge | In this method, robotic imaging is used to obtain a bridge surface image set for automated on-site analysis. A novel automated crack detection algorithm the STRUM (Statically tuned robust multi-feature). Classifier and demonstrate result on real bridge data using a state of the art robotic bridge scanning system. | Spatially tuned robust multi-feature classifier for crack detection of bridge decks provides a method of crack on-site robotic scanning. it generates large image data set automated analysis has clear utility in rapidly assessing bridge condition. |

### 1.3 **Computer Vision**

Computer vision works like the human visual system Computer vision is an interdisciplinary scientific [23] field that deals with how computers can be made to gain a high-level understanding from digital images and video. Computer vision is concerned with the automatic extraction analysis and understanding of useful information from a single image or a sequence of images. Computer vision tasks include a method for acquiring, processing, analyzing and understanding digital images and extraction of high dimensional data in order to produce numerical or symbolic information understanding in the context means the transformation of visual images into descriptions of the world that can interface with other thought process and elicit appropriate action.[24][25]It involves different paradigms like pattern images processing, artificial intelligence, mathematics, physics, signal processing, and pattern recognition.

The idea of computer vision was originated in the late 1960s as an important branch of artificial intelligence. It works like the human visual system with intelligent behavior [26][27]. Nowadays the use of computer vision increasing day by day because this is the fast and less time-consuming technique in an artificial visual system. It is employed in diverse surveillance operation like face recognition, gesture recognition, object recognition, medical imaging, etc. The different aspects of computer vision can be shown below in figure 1.

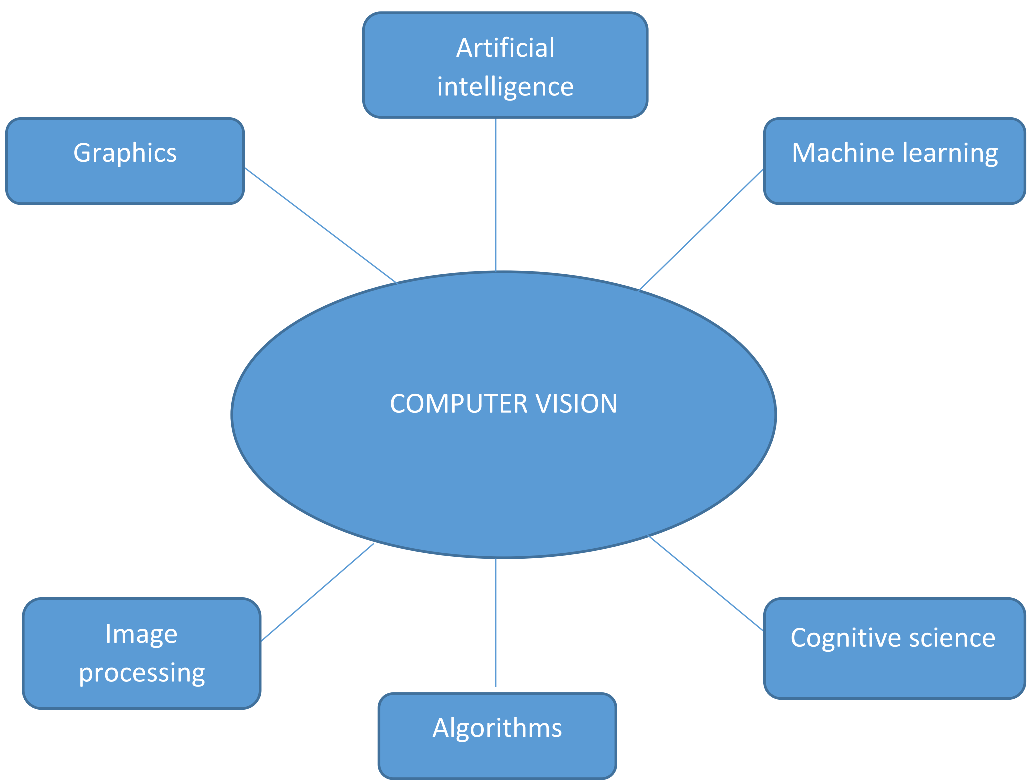


Fig1. Components of computer vision system [Source: Wikipedia]

**1.3.1 Artificial Intelligence -** It is the term which is used in computer science. It is also known as machine intelligence demonstrated by machines [28]. Artificial intelligence research is the study of intelligent agents according to computer science. Artificial intelligence allows computer programs to learn when exposed to new data without being programmed. Any other feature of intelligence or every aspect of learning in principle can be so precisely described that a machine can be made to stimulate it. An attempt will be made to find how to make machine use language from abstractions and concepts an attempt will be made, solve kind of problems now reserved for humans, and improve themselves. Any device which comes in a new environment and understands it and takes a decision to maximize its chance for achieving the success to its goal. According to Andreas Marcus Kaplan who is the professor of marketing at the ESCP Europe business school born in October 5,1977 who is specialized in the area of social media, viral marketing and digital world and Michael Haenlein who is the professor of marketing at ESCP Europe and the scientific director of the ESCP Europe research center define Artificial intelligence as Ability of system to interpret external data correctly. The idea of Artificial intelligence was first proposed by Warren Sturgis McCulloch who was an American neurophysiologist and cybernetic Ian with the partner Walter Harry Pitts Jr. who was a logician and worked in the field of computational neuroscience in 1943[29]. In 1956 Research on Artificial intelligence was born at a workshop at a Dartmouth college with a group of people some of them are Allen Newell, McCarthy, and Arthur Samuel. Artificial intelligence includes learning, reasoning, and self-correction. Machine vision, speech recognition, Expert system, gaming, Natural language system, Handwriting recognition, robotic intelligence are the application of Artificial intelligence. Artificial intelligence (A.I) can perform a task better than human in identifying pattern. The goal of A.I is to create a system which shows intelligent behavior, learn, demonstrate, explain and advice its users is known as an expert system. And implementing human intelligence in machine learning that thinks, understand, learn, and behave like humans. Artificial intelligence is built with the help of many areas such as computer science, psychology, neuron science, biology, math’s, sociology and philosophy. AI programming is quick and easy modification is possible in it.

There are seven (7) aspects of Artificial intelligence [ 30]

1. Encourage human brain to its higher function.
2. Programming a computer to use general language.

3. Arranging hypothetical neurons in a manner so that they can form concepts.
4. Problem complexity is defined and measured by Artificial intelligence.
5. Improvement by itself.
6. Abstraction: Defined as the quality of dealing with ideas rather than events.
7. Haphazardness and creativity.

**1.3.2 Machine Learning-** It is an application of artificial intelligence which makes the system to access data and use it to learn for themselves. Machine learning is used in the classification of the data from a different set of data point. It learns the data and builds a prediction model and when the new data comes in it can easily predict for it. The term machine learning was introduced in 1959 by Arthur Samuel.[31] According to Tom M. Mitchell Machine learning is a program of computer which is said to learn from experience E with respect to some class of tasks T and performance measure P if its performance at tasks in T, as measured by P, improves with experience E. There are many application of machine learning which is face detection in image, Analysis of MRI image, Handwriting recognition, Scene classification, social media services, online customer support, video surveillance, credit card fraud detection, spam filtering, Recommendation system, search engine result refining etc. Machine learning learns from the data set. If more the data set is available in classification given problem then the better model can be created with higher accuracy.

MORE DATA > BETTER MODEL > HIGHER ACCURACY

The ways of machine learning are of three types:-

1. Supervised learning:- As the name indicates that Supervised learning which means it is guided or instructed by the data. it has already a data set related to the problem. When a problem arises than machine learning uses the data set which set earlier in the system using supervised learning. The data set which is set earlier is known as the Training data. Training date contains information about the problem. Two types of algorithm namely Classification Algorithm and Regression algorithm are the types of supervised algorithm.[32] Name of Algorithm which comes under supervised learning is logistic regression, naive Bayes, support vector machine(SVM), random forest, linear regression, decision trees, K-nearest neighbors, polynomial regression.

2. Unsupervised learning:-In this case unlike supervised learning there is no train data set earlier to the model it means in this model computer itself learn the data and analyses the data when it comes to result whether the data has same features and some groups. The concept of clustering comes under unsupervised learning. Name of some clustering algorithm is k-means clustering, hierarchical clustering, mixture model and optics algorithms.[33]

3. Reinforcement learning- Reinforcement learning comes from supervised learning. But the difference between reinforcement learning and supervised learning are the idea of outcomes. Unsupervised learning we have an idea about what will be the outcomes. But in reinforcement learning, we do not know what will be the outcomes. Forgetting outcomes what action should be taken is measured by the reinforcement learning. Reinforcement learning is a reward best learning. It is behavior best learning. It means according to the behavior it is marked as good and bad. The main thing which makes it different is it gives Critic information. Critic information means is that it does not tell about what will be the output or result but it tells about the current state with respect to the past. Reinforcement learning has an element. There are five elements in reinforcement learning which are Agent, Environment, Reward, State, and Action.

**1.3.3 Cognitive Science-** Cognitive science is defined as the study of the mind in the scientific method and its process. Study of mind means that study of mind through learning and mental organization which draws on features of the psychology major, philosophy, linguistic and modeling of the computer. The cognitive science major/field is made up of several numbers of different majors, like linguistics, cognition, artificial intelligence, law, etc. Cognitive science is widely used in medical science and computer programming. Cognitive science is the scientific study of mind and its process. It is interdisciplinary. It examines the nature and tasks and the function of cognition. Cognitive science is the study of intelligence and behavior with the focus on how the nervous system represents processes and transform information. A human brain weighs approximately 3 pound and 1.4 kilograms it takes 2% of the total body weight. In the human being, the brain consumes a large amount of energy in proportion to its volume. Most of the energy consumption goes to sustain the electrical charge of neurons. Most categories species devote about 2 to 8% of basic metabolism to the mind. A mind is composed of 100 billion neurons connected into a neuron network. A neuron network made of neurons and connection between them called axons with synapse where neurons meet. Neurons generate an electric signal of the travel along the axons when the pose of electricity which is a junction called synapse. It causes a new transmit a decimal to be released which bind the receptors on other cells and they're by altering electrical activity. The property that makes the neurons unique is the ability to send a signal to specific target cells over a long distance. Each of the 100 billion neurons has on average 7 thousand synapses connection to other neurons. In its function, a neuron is a formal switch that is to say a cell is either on or off. A neuron has a number of input from other neurons. If their input is given are above the threshold that it is activated in voice. If neurons are activated then it sends a signal to other neurons which are connected to it. The output of neurons becomes the input to the next neurons. There are synapses change in their chemical composition as one learns in order to generate a strong connection in such a way a cognitive system is developed changes over time to form a new pattern of neural networks. A brain is physically built as neural network and cognition happen in the pattern. Every pattern corresponds to an ideal memory. At the same time If two neurons are turned at the same time then the connection becomes stronger otherwise, the connection becomes weaker. Brain processing is largely based on the process of pattern cognition which makes the under the biological structure of the brain. As a massive parallel processor with many neural networks. One of the advantages of this our net strength at making connections between different ideas, visual pattern, words and object. Pattern recognition builds through the particular model of the brain that undertakes what is going to reality testing. The mind is hierarchically layered network structure with hierarchically based on the abstraction that is a more basic pattern on the lower level are used building blocks for the higher more abstract pattern. Abstraction in it makes sense in a conceptual process by which general rule and concept are derived from the usage and classification of more specific examples.[34][35]

**1.3.4 Algorithms**:- An algorithms is the way of solving a problem in a specified way. It is step by step problem-solving approach. It is commonly used by data processing, calculation and computer, and other related mathematical operations.[35] The algorithm is also used to manipulate data in various ways, such as inserting a new data item, searching or sorting of an item. For different problem have a different problem-solving algorithm. The algorithm is related to every aspect of life but in a different manner. Like in computer science the way which is followed by the computer in solving the specific problem is called algorithms. In general, a step followed for solving any problem or completing any work is known as an algorithm of that problem or work.

**1.3.5 Image Processing**:- It is the process which is applied to digital images.[36] In digital image processing, we take the image and then convert it into different forms. It is used to get more information about the images stored in data form. An example of the use of image processing is fingerprinted scanning. Fingerprint scanner takes the images and compares the image which is store earlier in the data if it will match the data it allows to access otherwise not. An application of the fingerprint scanner can be seen in the ATM machine. In image processing there is two most basic term is used first one is resolution and second one is Pixel. In an image, the resolution is to define how many no. of element a picture content. Technically A image is in the form of a matrix which contains m*n element where m represent a number of rows and n represent the number of columns. When we talk about the value of the element it is known as Pixel and the value of the pixel is known as grey level. Image acquisition, image enhancement, image restoration, image morphology, image segmentation, image recognition are the steps of image processing. Image acquisition is the first step of image processing which contains two stages first one is capturing and the second one is digitization. After Digitization of the image, the further process image enhancement is applied in which it improves the quality of the image with the help of two methods Spatial which means dealing with the time constraint and another is Frequency domain which means frequency value. After the image enhancement image restoration are applied in this step removing of noise particle of the image is completed. It includes a filtration technique and many other techniques. After this image morphology which deals with the boundary and edges of the image. After the next image segmentation is applied to the image which segments the image into different labels. Labels are the value of the pixel. When we are talking about image processing then it is not necessary to applied image segmentation but when we use the live application of image processing like MRI scan, X-ray in medical science than the use of image segmentation comes in. Final steps are image recognition. In these steps, output image pattern is compared with standard image pattern and comes with the result what is the difference between them. The application [37]of image digital image processing is a medical application, color processing, pattern recognition, multimedia image processing, restoration and enhancement, video processing, robot vision, etc.

**1.3.6 Graphics**:- Graphic is the representation of an object in the form of image and visual representation. Computer graphics is creation storage and manipulation of images and models. Algorithms and data structures are used to draw pictures using a computer. It is an art of drawing pictures on a computer using programming. It can be a series of images and a single image. It is very useful in making a movie, video game, and computer program development. Application of graphics can be seen in daily life are drawing, printmaking, illustration, graphs, diagrams, symbols, maps, photography, Engineering drawing, computer graphics, and the graphics are frequently used in the following area for Business, Advertising, Political, Educations Film, and animations There are two types of graphics:-

1. 2D graphics- 2D computer graphics are usually split into two categories. Namely
    - Vector graphics:- It uses lines shape and text to create a more complex image. It is made with programs like Adobe illustrator and inks cape and were used for some older computer games.
    - Raster graphics:- It uses the pixel to make up a large image. Programs used to make these include Adobe Photoshop and coral paint shop pro.
2. 3D graphics:- 3D graphics are graphics that look like objects because they are three dimensional. it means computer understand that it has height, length, depth to display. Some programs used to make 3D graphics are Bryce, 3D Studio Max, Maya, and Blender.[38]

### 1.4 Scope and objective of this thesis

The literature review shows that the need for continuous monitoring of structural health which can be disturbed due to crack in concrete slabs. It also reveals the problem with manual subjective measurement technique. On the other hand, the proven potential of computer vision also motivates towards the application of computer vision in crack detection. Since crack in the image will cause change and distribution of intensity values this work aims to find the potential of halftoning methods forwards crack detection where halftone features to be used with machine learning algorithms in order to detect a crack in experimental concrete slabs. In this thesis research has been carried out to study of detection of a crack in a concrete sample using computer vision technique with the application of halftoning tool used in Matlab. The result of the technique which has been proposed earlier studied rigorously and further analysis was carried out. The goal of this thesis is to propose a new method of crack detection. Which is very simple to use to operate an analysis of the result more precisely. There are several methods of deducting crack is identified using computer vision some of them are mention in the section of the literature survey of the thesis. Hence the Scope of this thesis on the topic of crack detection using computer vision is possible. Sample collection, Image acquisition, image processing, Feature extraction, Data visualization, Vision system modeling, classification and lastly prediction these are the steps for achieving the goal of this.

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# CHAPTER-2

# Sample Collection and Image Acquisition

### 2.1 Introduction

In this chapter detail, discussion about sample collection, image acquisition, image transfer, and block division has been presented. During the sample collection, some important aspects, namely measurement of sample collected, the composition of concrete which is used as for sample, the reason of crack formation of concrete and the type of crack on the concrete have been considered. There are conventional methods of identifying a crack in concrete using instrument like crack Magnifier, crack width meter, crack monitor, crack meter, etc[1]. But here another method of crack identification is used. This method can be called as a digital method of identifying crack because of using the image for analysis of crack which is taken by the camera and further operation is applied which is done in Mat lab. Image acquisition is the first step of any digital image processing application when it is processing to get the details of the image[2]. It is the process of retrieving the image from any defined source like a camera. In this work, the images of the samples have been collected using the camera. Small samples of concrete block and mortar blocks which is taken for the experiment. Mortar means the composition of cement and sand. Mortar cube is made of cement sand in the ratio of 1:6. Which means mortar is made by using one part of cement and 6 part of sand. Size of the smaller cube is 70.6mm3[3]. Cement used for manufacturing this cube is Portland pozzolana cement(PPC). And the sand is used is ennore sand named due to the place Ennore which is situated 15 km north of Chennai. Where the company named TAEMIN is situated which supply Indian standard sand according to B.I.S (Bureau of Indian standards). Another sample which is larger in size is made of cement sand and aggregate. The aggregate of size 10mm is used in a bigger sample. Size of this bigger sample is 150mm3. The composition of cement, the percentage of ingredient available in cement, the role of the ingredient in cement, and the type of cement is discussed under this chapter[4]. Also, a brief idea of about the different type of crack and the reason for the formation of a crack, and their conventional method of measuring is given.

## 2.2 Sample Collection

There are three samples of concrete slab collected in two different sizes used in this work. The first sample of concrete is collected is of the bigger cube in size than the second sample and the other two samples are of the same size and smaller than the first sample. The reason behind the collection of three different sizes of the cube is to get the different crack pattern in the concrete. The different crack pattern in concrete is very useful to analyze the result of comparing the result between these two samples. The crack sample is used in this work for crack detection are the waste sample of concrete which is used earlier for the determination of compressive strength of concrete under the compressive strength tester machine. There are two types of the samples used by composition first one is mortar which is manufactured by cement and sand in the proper ratio and another is concrete block. The formation of the concrete block which is used as a sample of this thesis is completed by using the following ingredient namely Cement, sand and aggregates. Cement is used as a binding material between sand and aggregate to make concrete. Cement is the composition of the following ingredient within given percentage as follows Lime with 60 to 65 percent, Silica 17 to 25 percent, Alumina 3-8 percent, Magnesia 1 to 3 percent, Iron oxide 0.5 to 6 percent, calcium sulfate 0.1 to 0.5 percent, sulfur Trioxide 1-3, Alkaline 0 to 1 percent[4]. The function of the above mention ingredients are as follows Lime is an important ingredient of cement presence in sufficient quantity or insufficient quantity affects the strength of the cement. Lack of quantity of lime allows the cement to set quickly. In another hand excess of lime makes cement unsound and allow the cement to expand and disintegrate. Lime is also called known as calcium oxide or calcium hydroxide. Silica or silicon dioxide is also responsible for the strength of concrete. Silica is present in the form of dicalcium and tricalcium silicates. Alumina or Aluminum oxide affects the setting time of concrete. Alumina provides the quick setting property of cement. Which is useful for building a large structure like dam and construction of the road. Cement becomes weak if alumina present in it in excess. Magnesia or magnesium Oxide should not be more than 2 percent. An excess amount of magnesia reduces the strength of cement. Iron oxide provides color to the cement. It forms tricalcium alumino-ferrite after the chemical reaction with calcium and aluminum. It provides the hardness and strength of cement. Calcium sulfate is present in cement in the form of gypsum. Property of this in cement is to slow down the process of cement setting time. Sulfur trioxide present in cement in excess makes cement to unsound. Alkaline in the excess cause of efflorescence.[2] Efflorescence is a term used in civil engineering for the deposit of soluble salts formed in or near the surface of a porous material. The porous material is the type of material which contains pores on its structure. There are thirteen types of cement which are used in building the different concrete structure are given below [5].

1. Ordinary Portland cement - Ordinary Portland cement is the type of cement which is used almost all general construction work. Hence it is the most used type of cement. In short, it is called OPC.
2. Low heat cement - As its name indicates it produces low heat during the hydration. This type of cement is used in mass concrete construction such as a gravity dam. Due to the low heat of hydration, it prevents the formation of a crack in the concrete.
3. Quick setting cement:-Quick cement sets quickly in comparison to other cement. Quick setting cement is used where the work should be completed within a short period of time.
4. Rapid hardening of cement - Rapid hardening of cement achieves high strength earlier in comparison to another type of cement. The difference between quick setting cement and rapid hardening of cement is quick cement sets quickly but the rate of strength gain is similar to ordinary Portland cement while rapid hardening cement achieves strength quickly. Rapid hardening cement is used in the construction of the road.
5. Portland Pozzolana cement- Portland pozzolana cement is manufactured by grinding pozzolanic clinker with Portland cement. It has the property of resistance to the various chemical attack in comparison to the ordinary Portland cement. This type of cement used for concrete under water like bridge, piers, mass concrete and marine structure.
6. Sulfates resisting cement- To reduce the risk of sulfate attacks on concrete sulfate resisting cement is used in construction. This type of cement used in the construction where sulfate action by water like construction work near sea and sulfate action by the soil in a place like retaining walls, siphons, culverts, cannel lining, etc.
7. Blast Furnace slag cement - Blast furnace slag cement is manufactured by grinding the clinkers with about 60 percent slag. It is the mixture of finely granulated blast furnace slag and the ordinary Portland cement. It is used in the ready-mix concrete plant.
8. High alumina cement - High alumina cement is rapid hardening cement which is manufactured by melting mixture of bauxite and lime and grinding with clinker. Its compressive strength is very high as compared to ordinary Portland cement. It is used where concrete is subjected to high temperature, acidic action, and frost.

9. Hydrographic cement- Cement which is manufactured by mixing water-repelling chemical is called as hydrographic cement. It has high workability and strength. Hydrographic cement is used for building spillways, water retaining structures, etc.
10. Air entering cement - Air entering cement is manufactured by adding air entering agent such as glues, resign and the sodium salt of sulfate. It is used to improve the workability and frost action of concrete.
11. White cement- white cement is manufactured from raw materials free form iron oxide. It is used for decorative work such as designing the facing of slabs, external rendering of the building, swimming pools. White cement is costlier than other cement
12. Color cement- Color cement is manufactured by mixing the mineral pigment with ordinary cement. Color cement is also used for decorating purpose as white cement also.
13. Expensive cement- Expensive cement has a tendency to expand slightly with time. It does not shrink during casting of the concrete and after the hardening of concrete.

There are several reasons for crack formation in concrete which is discussed below with the image containing crack [6].

- Crack in concrete due to plastic shrinkage [7].
- Crack in concrete due to the expansion of concrete.
- Crack in concrete due to heaving action [8] of the surface.
- Crack in concrete due to the settling of concrete.
- Crack in concrete due to overloading on the surface of the concrete.
- Crack in concrete due to Thermal stresses [9] generated in concrete.
- Crack in concrete due to the weathering process.
- Crack in concrete due to corrosion [10] of reinforcement.
- Crack in concrete occurs due to an error in design and detailing.

There are various concrete crack measuring instrument is available which are discussed in brief further crack monitor, crack meter, crack magnifier, crack width meter, field Microscope.[1]

Crack monitor- It is designed to measure the rotation of the crack. It is made of polycarbonate with the accuracy of reading on the grid is +-0.5mm.

Crack meter- It is also used to measure the crack and surface joint in concrete. Crack meter consist of the sensor at the outer body of the tube and a sliding rod which is inner free connected to a sensor with vibrating wire. Which is vibrating during measurement of crack and surface joint. It is available in a different configuration such as electrical, mechanical (manual), vibrating wire, 1D, 2D,3D. It has features like long term stability, low cost, well performance in hostile site condition. It has also benefited like increase safety, increases productivity, high accuracy, high readability.

Crack Magnifier- It is the instrument which is used to magnify the crack image so that crack is measured more accurately. The crack magnifier can be used measuring the crack width of concrete exceeding the limit of 0.2mm to 0.3mm. These limits are the normal crack width limit. The crack magnifier is an inexpensive device for crack measuring than another device. A sample of concrete which is used in this work are measured with the use of Crack magnifier.

Crack width meter- It the very simple to use. It looks like a simple scale. It is used to measure crack when visual surveying has to be done. It is made of durable plastic with the graduations from 0.1 mm to 2.5mm.

Field Microscope- It is also a type of crack measuring instrument. Field microscope is small in size which makes it lighter in weight and easily portable. It consists of magnifiers by which object can be magnified to analyze the crack. Magnification up to 50 times by the microscope is used to measure accurately the width of cracks by using calibrated focusing ring. Field microscope has a magnification of 50x with the measuring range 1.6mm*0.02 mm and it has 1.7mm as a field of view. It also contained light at the top which is used to focus on the crack area during taking the reading.it contains the cell which is used as a source of light.

### 2.3 Image Acquisition

Image Acquisition [11] is the first step of any digital image processing work related to the vision system. Image acquisition is the process of redeeming of the image from a different source. Generally, it is hardware based processing of source. Unprocessed image is the main parameter of image acquisition. Unprocessed image means an image which is captured by the camera followed by processing through software like Matlab Representation of the visual characteristic of the image is digitally encoded to understand the structure of image machinery. In this work, image acquisition is done in the Dell Inspiron laptop i5 with the image captured by mobile namely Redmi Y1 ligh which has HD resolution of 720*1280 pixels results in the density of 267 PPI The image has been taken by mobile in the presence of daylight. The term image acquisition follows the following steps processing, compression, storage, printing, and lastly display the image. Image Acquisition can be done in three ways which are (i) image acquisition with the help of single sensor, (ii) image acquisition with the help of line sensor, (iii) image acquisition with the help of array sensor. [12]

(i) Image acquisition with the help of a single sensor- Photo dioxide is an example of a single sensor. The motion of the photodiode should be in the X direction as well as in the Y direction. Motion is provided by rotation in one direction. In the perpendicular direction motion provided by linear motion. This method is inexpensive but it is slow.

(ii) Image acquisition with the help of line sensor- Imaging in one direction provided by a sensor strip. Imaging in another direction is provided by perpendicular motion to the strip.

(iii) Image acquisition using an array sensor- Sensor in the form of a 2D array arranged in the array sensor. Array sensor is found in a digital camera because the sensor is in 2D. a full image will be formed by focusing on the energy pattern on the surface of the array. Sensor array produces an output proportional to the integral of light which is received by each sensor.

Online interfacing and offline interfacing are the two type of image retrieving method. In online interfacing capturing the image and modification in image done simultaneously. For example, the camera through with the image is taken is connected to the computer and then the image has been taken out from the camera to the computer for further modification by different software. Similarly in offline interfacing image is captured in camera and stored by them. Further, when the image is required it is taken out through the camera.

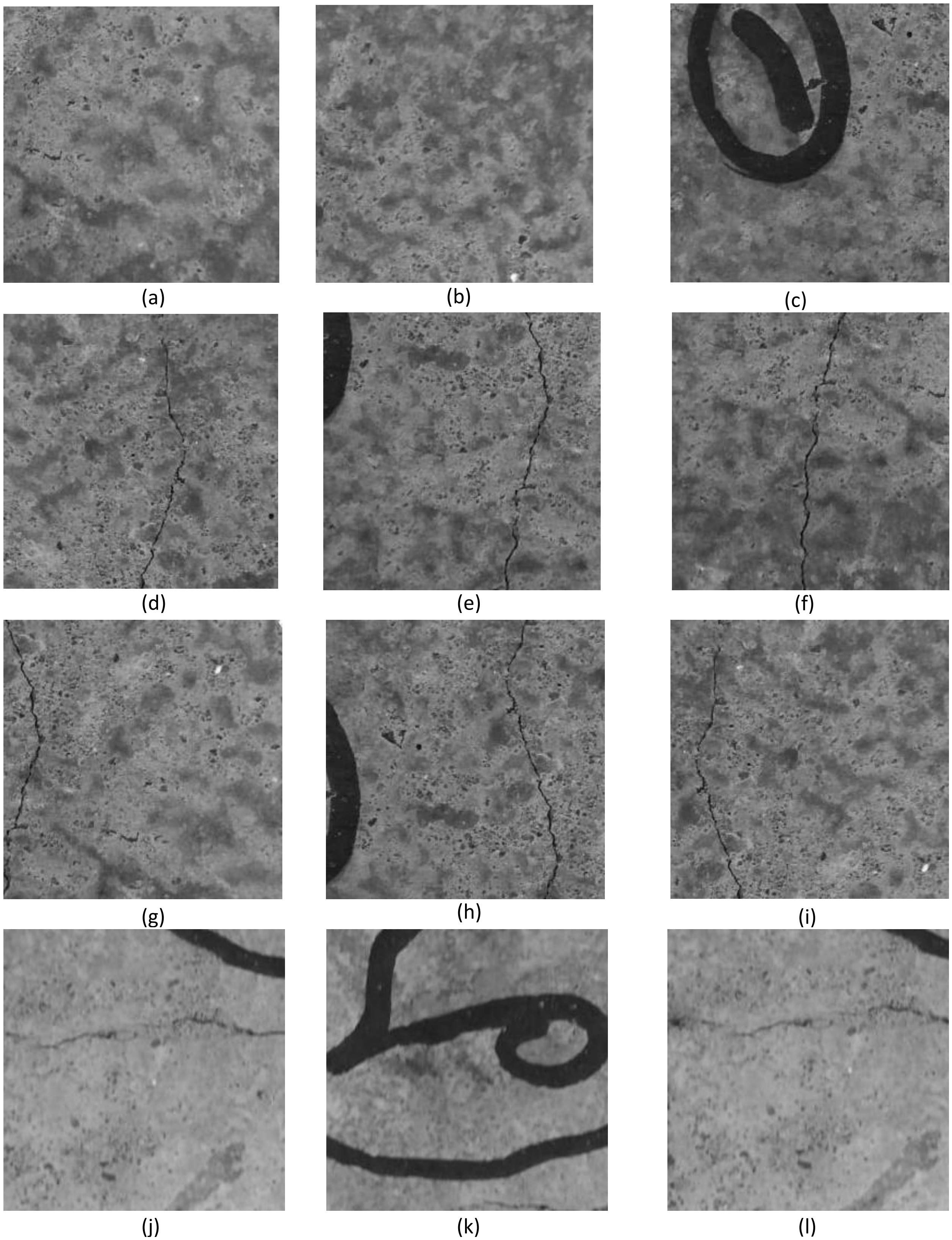
### 2.4 Image transfer and block division randomly

Sample Image captured by the camera is transferred to the computer and block division of size 50*50 has been done using the Matlab. Picture of the Sample image and block image are shown below. There are three main sample image and 90 block sample image. 30 sample for each block image. In which 60 sample pic shown below. The origin of the blocks was randomly initiated to ensure a random distribution between with and without crack block.

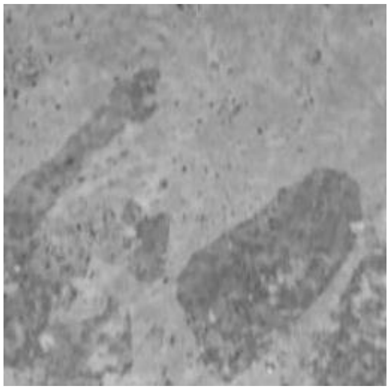
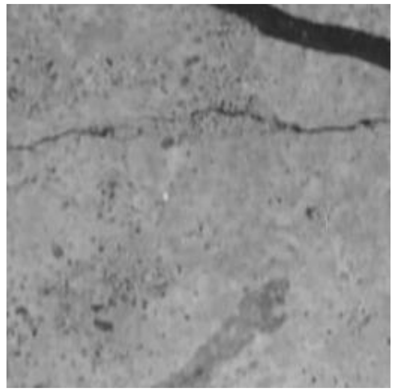
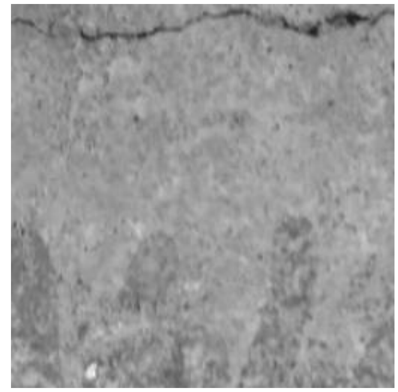
(a) Sample 1 of size 76.6mm$^3$

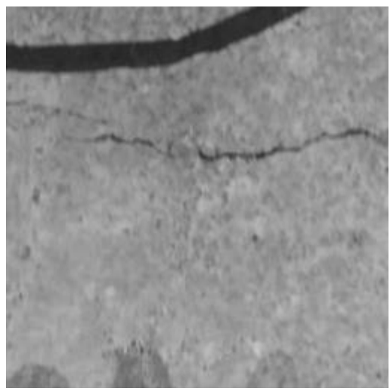
(b) Sample 2 of size 76.6mm$^3$

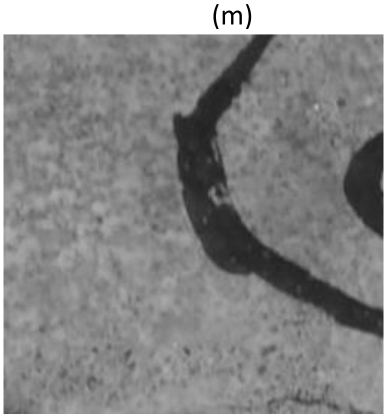
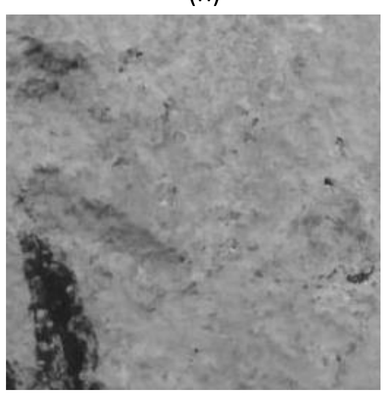
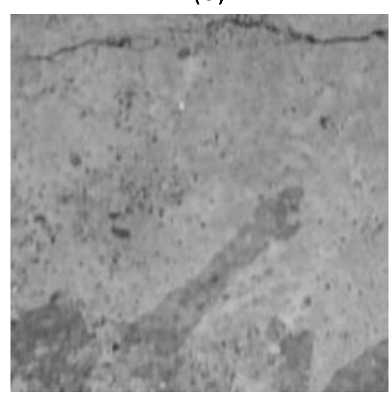
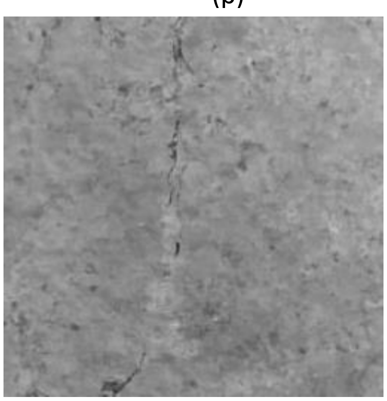
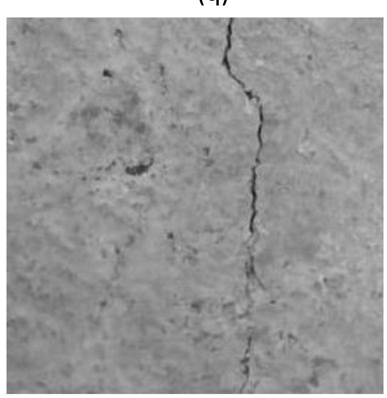
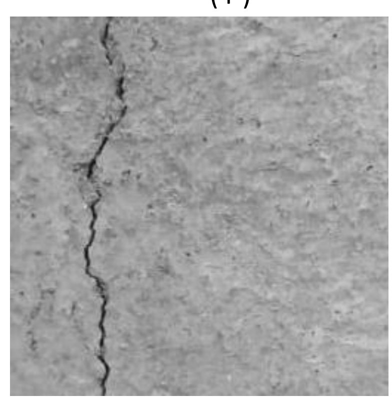
Fig.2.1 (c) Sample 3 of size 150 mm$^3$



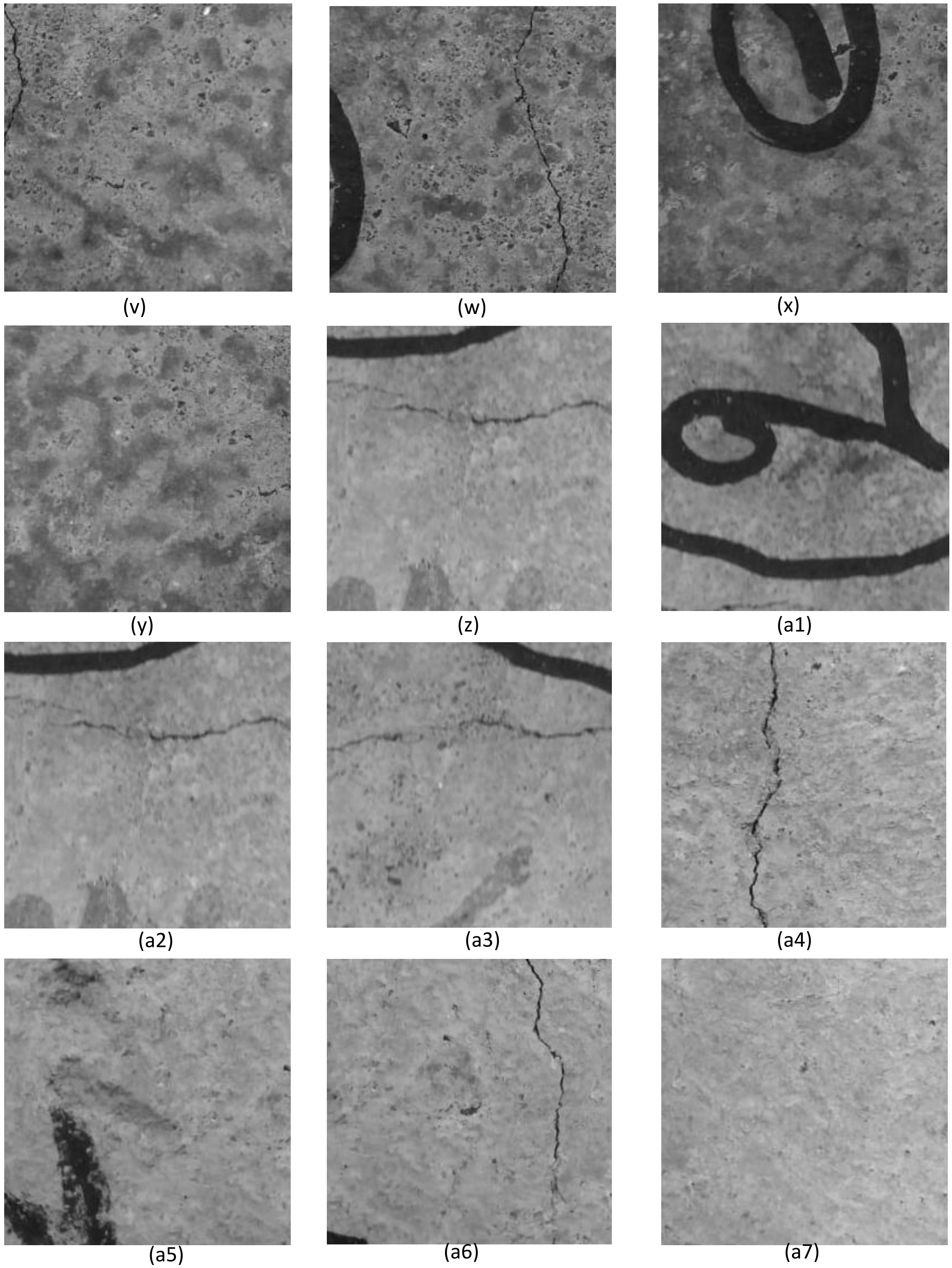

Randomly selected sample with crack and without a crack of picture form sample 1 and sample 2 as shown in fig2.2 from (a) to (l)


(j)

(k)

(l)

(m)

(n)

(o)

(p)

(q)

( r )

(s)

(t)

(u)

Randomly selected sample picture with or without a crack of sample 2 and sample 3. As shown in figure fig.2.3 from (j) to (u).




A randomly selected sample of sample 1 and sample 2 and sample 3 As shown in fig.2.4 from (v-z) to (a1-a7).

## 2.5 Conclusion

In this chapter, we studied the initial or basic steps of work which has been proposed in this thesis. These works include a selection of the sample. There are two different sizes of the sample which containing crack are selected for the test. It measured using the conventional method with the instrument known as field microscope approximately. Value of that three samples is 0.1mm for sample 1, 0.25mm for sample 2, 0.2 mm for sample 3.

## 2.6 References:-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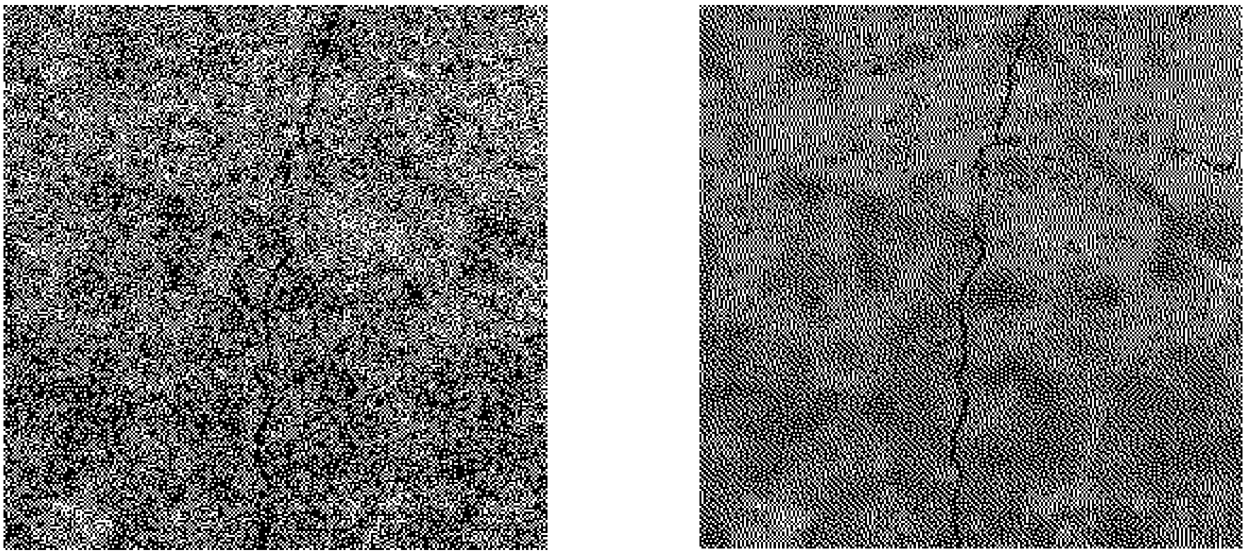
# CHAPTER-3

# Digital Halftoning And Halftone Features

### 3.1 Introduction

Halftoning is the combination of multiple dots which creates the illusion of continuous tone. Transforming an image which has greater amplitude resolution to lesser amplitude resolution is the process of halftoning[1]. Resolution of halftone pattern contains small or tiny black dots which are arranged in a regular pattern. Resolution of halftoning is expressed in line per inch. If the picture resolution of the source file is higher than greater details can be obtained. In the publishing industry and printing industry, it is used frequently. A picture or image is printed on paper using the halftone pattern. After magnification of the image, we can find that the image contains a series of the continuous dot in a regular pattern to form an image. Halftoning uses the reprographics [2] technique. Reproduction of images through the electrical and mechanical means is known as a reprographic technique. For example, xerography and photography. Halftoning are of three types these are traditional halftoning, digital halftoning and inverse halftoning. Digital halftoning process is used in the work. Digital halftoning is similar to halftone where the image is decomposed into a grid of halftone cells. To produce a bi-level image from a continuous tone image is a process of a grayscale digital halftoning[3]. Bi-level represent black part and white part of the images. Numerically it is represented as 1 and 0. The black part is denoted by 1 and the white part is denoted by 0. Digital halftone is used to print continuous tone image. Electronic display and Output device such as printers also need this technique due to limitation by its number of reproducible tones. Halftone process is an example of a dither pattern. Dither pattern or dithering is a process of creating a pattern of printed and unprinted areas that integrate to the required density. Halftone dots have a different geometric shape which may vary from perfectly round to square to elliptical. Selection of dot depends upon the application to avoid a problem like Dot gain and moire. Dot gain is also known as tonal value. Halftone technique is mainly divided into three classes. These are point neighborhood processing, point processing, an iterative technique. In neighborhood processing nearest pixel or neighbor pixel information is needed. An individual pixel of the original continuous tone image is proposed in point processing technique. In comparison to neighborhood processing and point processing, a new approach towards halftoning is made which is known as iterative [4] techniques. An iterative technique that gives a better result with higher computational complexity and sacrificing processing time. In this chapter, a brief overview of different halftoning techniques for crack detection is discussed with their resulted images. After the detailed analysis of the halftoning image containing crack provided in this chapter shows that crack detection using halftoning is a possible solution of the crack image. Example of halftone images are shown below

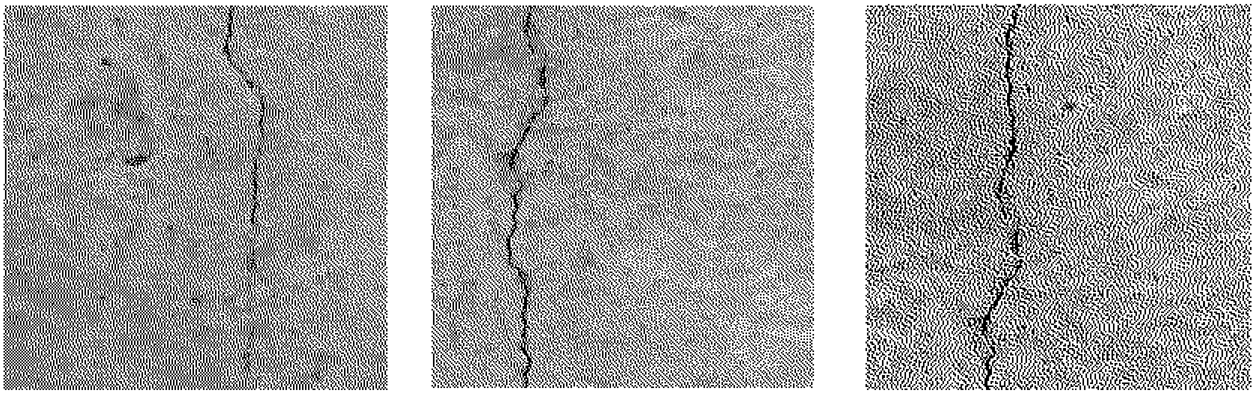


(a) (b)

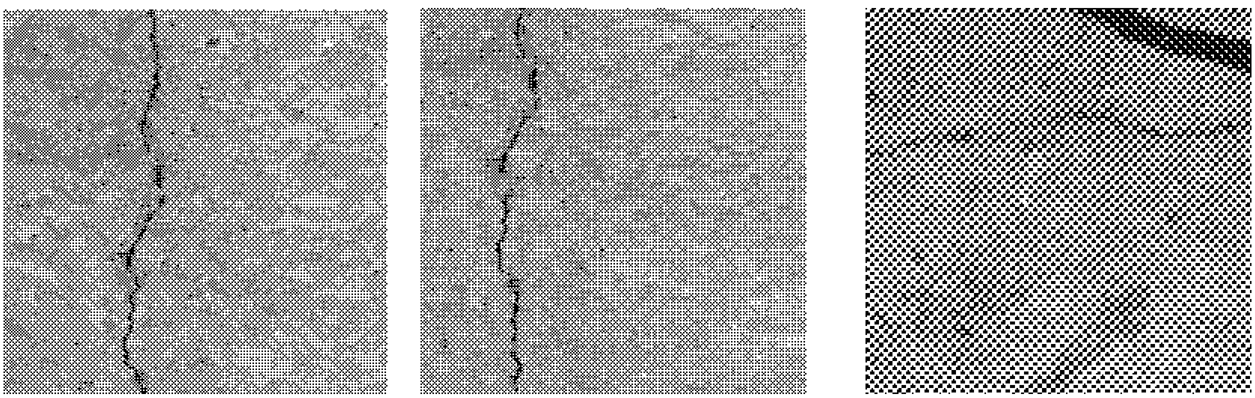
Figure. 3.1 Example of halftone image in fig. 'a' and 'b'

**3.2 Brief Survey of Popular Halftoning Techniques:-**

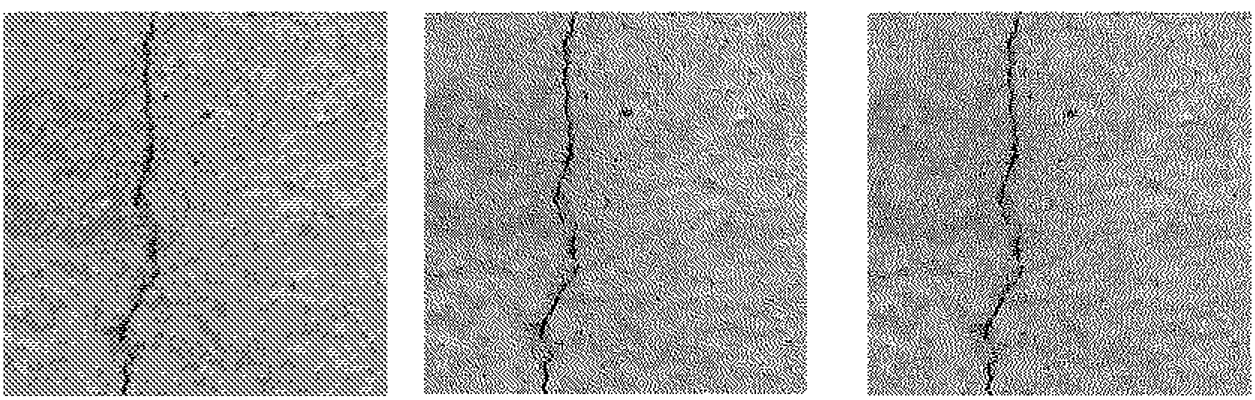
There are various halftoning algorithm is used for testing the sample image. And try to identify which one is best among them or which one is able to identify a crack in sample image more accurately and clearly. Name of these halftoning method is Blue noise mask (bnoise), Fixed edge enhancement error diffusion (edgerrfixed), error diffusion (errdiff), Javris, screen_9c (c- Clustered dot), screen_9u(u- unclustered dot), screen_16u, Stucki, Stucki serpentine scanning (Stucki-serp) and halftone image of sample is shown below.



(a) edgerrfixed (b) errdiff (c) stucki_serp



(d) screen 9u (e) screen16u (f) screen 19c



(g) Screen 9c (h) Stucki (i) stucki.serp

Fig-3.2 Example of halftone image from the different technique in fig. 'a' to 'i'

### 3.2.1 Point Processing Techniques:

In point, processing ordered dithering [5] is defined. Ordered dithering is an image dithering algorithm. It will produce a continuous image of higher colors on a display of less color depth which is used by a program. Microsoft Windows use it in 16-color graphics modes is an example of ordered dithering. The threshold is applied on the pixel displayed causing some of the pixels to be rendered at the crack or no crack sample of an image. An advantage of ordered dithering is computation of data, it means computation is less complex so it is faster and its substantial parallelism, easy implementation. Point processing taking has advantages as well as disadvantages. Disadvantages of this technique are noise of low frequency, false contouring, objectionable visually periodic pattern and an artificially synthesized image appearance.

**Clustered Dot Ordered Dithering-** The analog halftoning is followed by the screen matrix. The pixel grows around the halftone dot as the intensity approaches black and vice versa. Some important development is done by Holladay [6] and Kang[7]

**Dispersed Dot Ordered Dithering:-** Here the periodic image is used as a criterion of comparing input image. The screen image is called a threshold array. The order by which the dots are added to the lattice as brightness is increased is defined by the dispersed-dot dithering. Blue noise is the target spectral characteristic in the sample figure. Some important development is done by Bayer[8] and judic[9] in this regard.

### 3.2.2 Neighborhood Technique:-

As the name says neighborhood technique is related to the method of comparing one pixel to another pixel. When a single pixel is processing, it is distributed in a weighted fashion to its neighbor. For a long time, this algorithm is popular and used in many practical implementations since in different tonal levels the smooth transition can be seen by this technique.

Error Diffusion- An error is accumulated during the processing of each pixel. Diffusing of the error to its neighboring pixel in a weighted manner. Threshold operation is done in halftoning as the last process. Blue noise is the target area. Here Jarvis et. al. [10], Flyod[11], Stucki[12], stucki_serp are some of the major developments.

There are some advantages error diffusion have like its profile, error diffusion profile are satisfactory noise free profile. It has a smooth transition from one level to another by which improved halftone patterns will get. Error diffusion has also some disadvantages, in constant gray regions correlated artifacts can be seen. In shadow and highlighted region worm-like structure is formed due to directional hysteresis. Which is the reason for lack of sharpness especially at the edge in its general form.

**One Dimensional Error Diffusion:-**

One dimensional error diffusion is the simplest form of an algorithm. It scans the image one pixel at a time and one row at a time. Half gray value is used to compare the current pixel value. If the value is above the value than a white pixel is generated in the resulting image. A black pixel is generated when the pixel is below the halfway brightness. A full bright or full black pixel is the generated pixel so there is an error in the image. The error is then added to the next pixel in the image and the process repeats.

**Two-Dimensional Error Diffusion:-**

Visual artifacts are reduced by two-dimensional error diffusion. Where one-dimensional error diffusion tends to have severe image artifacts that show up as distinct vertical lines. This algorithm is as simple as one-dimensional error diffusion except. In this method the half the error is added to the next pixel, and one-quarter of the error is added to the pixel on the next line below and pixel forward and one-quarter of the error is added to the pixel on the next line below.

**Color Error Diffusion**

As we know the computer to display an image using RGB color. R stands for red, G stands for green, B stands for blue. Whereas printer prints the image using CMYK color. (CMYK stands for cyan, magenta, yellow black respectively) To get the same color effect of computer image on printer image an algorithm may be applied to each of the red, green, and blue channels of a color image. Such as Single color values that can be print by laser printers.

Firstly when converting the color channels into a perceptive color model which will separate lightness, hue and saturation channels, then to the hue channels better visual result may be obtained. Lightness channel is given by higher weight value of error diffusion than to the hue channels. A small difference of lightness in small local areas is better perceives by human vision than a similar difference of hue in the same area, and even more than a similar difference of saturation in the same area.

For example, if a small error is present in the red channel that cannot be represented and another small error in the green channel in the same cases the properly weighted sum of these two errors may be used to adjust a perceptible lightness error, which is represented in a balanced way between all three color channels, even when converting the green channel. In neighboring pixels, this error will be diffused. In addition, For each of these perceptive channels gamma correction may be needed if they do not scale linearly with the human vision, so that these gamma corrected linear channels linearly accumulated by the error diffusion before computing the final color channels of the rounded pixel colors using a reverse conversion to the native son gamma- corrected image format and from which the new residual error will be computed and converted again to be distributed to the next pixels. The point should be noted that limitation of precision during the numeric conversion between color models additional round off errors may occur that should be taken into account into residual error.

**Error Diffusion With Several Gray Levels**

To produce output image with more than two levels error diffusion is used. For producing 4,8, or 16 levels in each image plane such as display and electronic printer in compact mobile telephones application of error diffusion is used. The closest permitted level is determined instead of a single threshold to produce binary output, if any, is diffused as described above.

**Edge Enhancement Versus Lightness Preservation**

Error diffusion algorithm tends to make the next generated pixel be black when an image has a transition from light to dark. The next generated pixel being white due to the transition of dark to light At the expense of gray level reproduction accuracy it causes an edge enhancement effect. Error diffusion having a higher apparent resolution than halftone methods.

The effect shows fairly well in the sample picture. The crack details sign is well preserved, and the lightness in the sky, containing little detail. A cluster- dot halftoning image of the same resolution would be much less sharp.

Some popularly used weight kernels are discussed here with the corresponding result.

**Floyd Steinberg Kernel:**

In 1976 [11] Robert Floyd and Louis Steinberg firstly published the most popular 2D error diffusion formula. In this work, error represents finding a crack and no crack. In individual pixel error is accumulated were diffused to 4- neighboring pixel with the following different kernels.

| | | |
|---|---|---|
| | X | 7/16 |
| 3/16 | 5/16 | 1/16 |

**Javaris Kernel**

After publishing the dithering algorithm by Floyd and Steinberg in the same year an algorithm which is more powerful but lesser known is also published by Javaris kernel. In comparison to Floyd-Steinberg Jarvis kernel algorithm does not show better result.

| | | | | |
|---|---|---|---|---|
| | | X | 7/48 | 5/48 |
| 3/48 | 5/48 | 7/48 | 5/48 | 3/48 |
| 1/48 | 3/48 | 5/48 | 3/48 | 1/48 |

**Stucki Kernel:**

Nickle, Judice, Jarvis published their dithering formula. An adjusted version of it is published by Peter Stucki. Peter Stucki [12] made slight changes to improve processing time. There are different weight filter Stucki has as shown below in the table.

| | | | | |
|---|---|---|---|---|
| | | X | 8/42 | 4/42 |
| 2/42 | 4/42 | 8/42 | 4/42 | 2/42 |
| 1/42 | 2/42 | 4/42 | 2/42 | 1/42 |

A divisor of 42 is still not a power of two, but all the error propagation value are negative (-) so once the error is divided by 42, bit-shifting can be used to derive the specific value to propagate. The output of Stucki and JJN algorithms so due to its slight speed increase Stucki is often used.

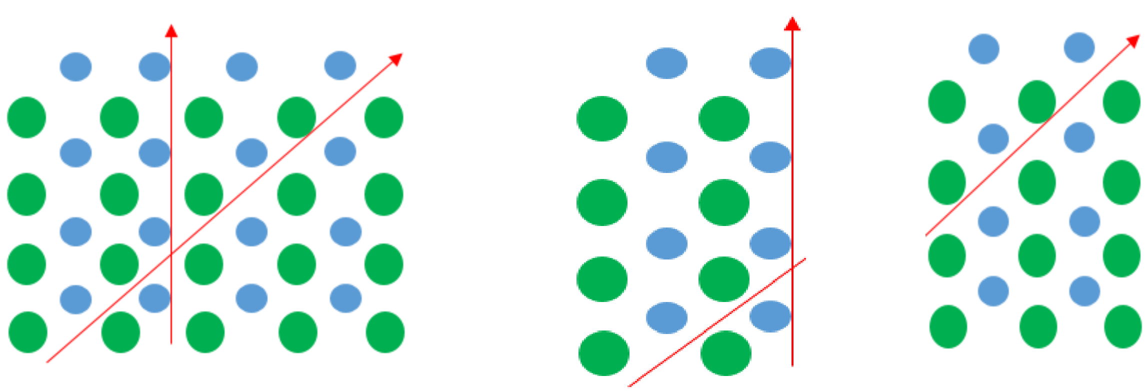
**Screen:**

Screen halftoning technique is are of different type of screen_9c, screen_9u, screen_16u. Almost all screen is giving good result in detecting the crack but the percentage of accuracy in screen_9c is more acceptable. The halftoning results clearly show that the screen halftoning algorithm provides a smoother transition between the different tonal values. Hence, this technique can be considered for further analysis as provided in the following section.

### 3.3 Analysis of Halftone Features

**3.3.1 Anisotropy-** Anisotropy [13] is the directional dependent property. Anisotropy is used to study the property of substance in any direction. The anisotropy substance has a different property in a different direction it means if a substance has some property in the horizontal direction and some property in perpendicular direction than Property in both directions is different from each other. Anisotropy $A(f_p)$ is an important statistic for the measurement of the isotropic nature of the dither pattern used by Ulichney[ 14]. Anisotropy can be assessed by equation (3.1) and plotted in a unit of decibels(dBs). $A(f_p)=1/K$ is the dither patterns result of perfectly isotropic dither pattern which was established by Ulichney.

$$A(f_p)=\frac{1}{N(R(f_p))-1}\sum_{f\subset R(f_p)}\frac{\left(\hat{P}(f)-P(f_p)\right)^2}{P^2(f_p)} \qquad \text{(i)}$$



(a) (b)

Figure 3.3. A molecule of crystalline solid substances (a) Phase1 and (b) Phase2

Cleavage itself acts as an anisotropy. When the atom is cleavage by perpendicularly and diagonally then in both the phase particles are separated which show the property of anisotropy. In general, Anisotropy has some property which are electrical conductivity, Thermal conductivity, and Refractive index. Electrical conductivity means following of current in a different direction through the medium. Similarly, thermal conductivity means following of heat in a different direction through the medium Refractive index is the property when the light comes to the molecule of crystal solid and it passes through it reflected in a different direction.

### 3.3.2 Radially Average Power Spectral Density (RAPSD):-

The radially averaged power spectrum (RAPS)[15] is the mean spectrum of direction-dependent such that the average of all possible directional power spectra. To view and compare the information contained in 2-D spectra in 1-D Radially averaged power spectrum is used. The function of radially average power spectral density to computes and plots the radially average power spectral density (RAPS) of the input matrix. In computing, this function does not consider the corner values outside averaging radius. Limitation of RAPSD is image must be in 2-D it may be a rectangular image or the other image. For example- Data with multi-color is not supported. Data of special resolution is also specified. To determine how similar the bi-level toned image and the original image are each other radially average power spectrum density is used as a measurement. Bi-level- toned image is preferable. In the pixel pattern, the bi-level toned image should not have directive biases and be radially symmetric. For power spectrum, this criteria has to be tested. Two dimensional Fourier transform on bi-level toned image and dividing it by a number of samples and squaring the result. is conducted by power spectrum which is symbolically represented as P(f). For the easy observation of characteristic P(f) is represented in three-dimension, the one-dimensional figure can be presented by the frequency. By partitioning the power spectrum into the circular ring of width delta one-dimensional figure is made.

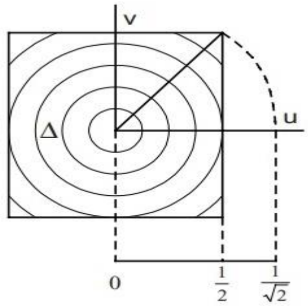



Figure. 3.4 power spectrum partitioning into a unit circular ring.

In this work, construction of processing filter the by utilizing the difference between a pixel containing crack and the local average to the surrounding area in the original image, Therefore, the effect of the processing filter is generated little for the flat area in tonal distribution. In this work crack as an error is defined as the difference between the original image and the error diffused bi-level- tone image, and for the display error will be presented in the evaluation. The density of the power spectrum is expressed as below when the two-dimensional Fourier transform is designed by $\tau$:

$$\hat{P}(u,v) = \frac{1}{I \times J} |\tau[g(i,j) - h(i,j)]|^2 \quad \text{(ii)}$$

A circular ring of the uniform width Δ is partitioned by the power spectrum on the basis of the center of power spectrum as seen in the above figure. It is noted from the figure the center of the circular ring is distant the circular frequency $f_r$ is from $\Delta_r/\sqrt{2}$. By integrating the power spectrum with the circular ring area and dividing it by number of samples gives the RAPSD $P_r(f_r)$ inciuded in the area as follows

$$P_r(f_r) = \frac{1}{N_r(f_f)} \sum_{i=1}^{N_r(f_f)} \hat{P}(u,v) \quad \text{(iii)}$$

Where Nr(fr) is the number of samples with the r-the circular ring area.

### 3.3.3 Halftone Features of The Crack Image

In this section, we observe the difference between crack and no-crack halftone in samples under the light of anisotropy and rapsd features. Figures 3.1 – 3.11 shows the anisotropy and rapsd plots for crack and no-crack concrete block images halftoned using different algorithms i.e. blue noise mask, screen 9c, screen 9u, screen 16u, screen 19u, edgerrfixed respectively. We can classify both the curve on the basis of homogeneity, frequency distribution, and radial distribution. The degree of homogeneity is different in the crack and no-crack images. Dissimilarity in the homogeneity distribution between crack and no-crack images is higher in case of Fixed Edge Enhancement error diffusion in short edgerrfixed as shown in their corresponding anisotropic plots. Similarly, the frequency distribution between the annular radial rings is different. The different curve has a different frequency distribution curve. Again dissimilarity in the frequency distribution between crack and no crack image is higher in case of fig. 3.15, 3.14, 3.13, 3.11 of RAPS and anisotropy of figure 3.8,3.9 when anisotropic plots and RAPS plot for radial frequency distribution is plotted, dissimilarity in radial frequency is found in anisotropy of figure 3.7, 3.8, 3.10.

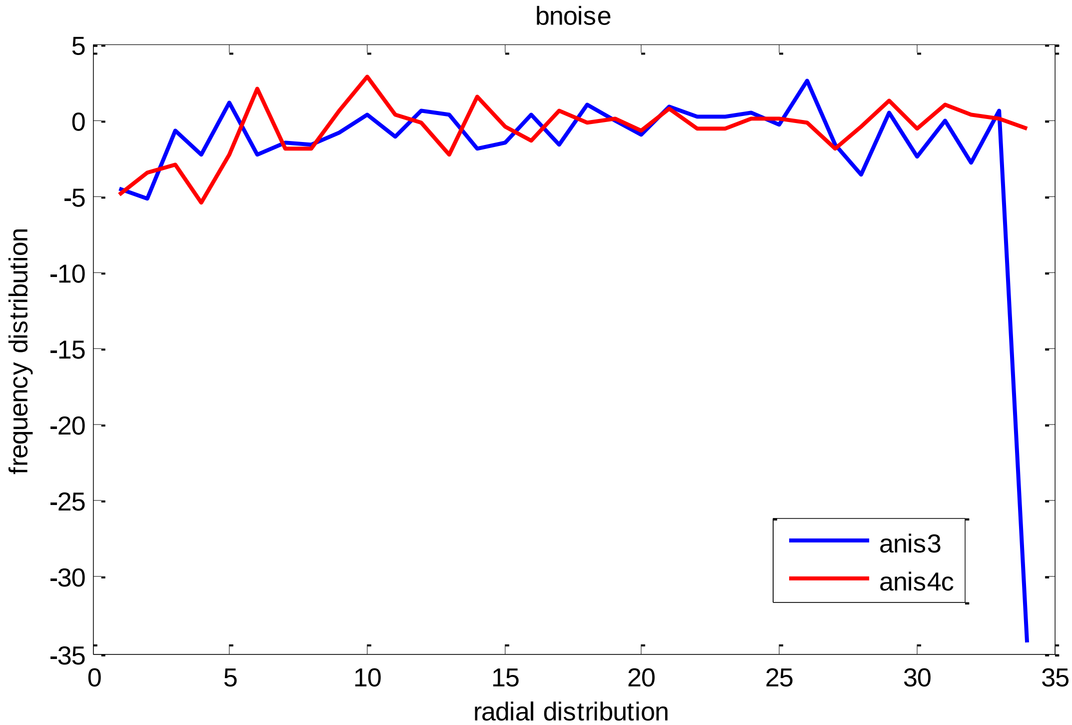



Fig.3.5 Anisotropy plot for bnoise halftoning

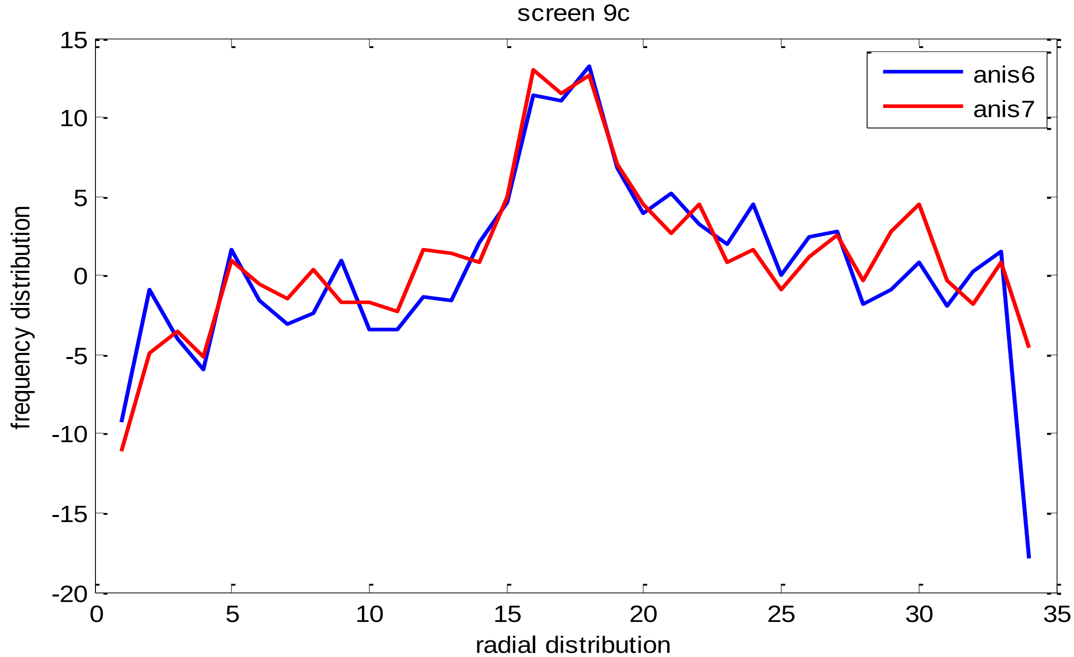



Fig.3.6 Anisotropy plot for screen 9c halftoning

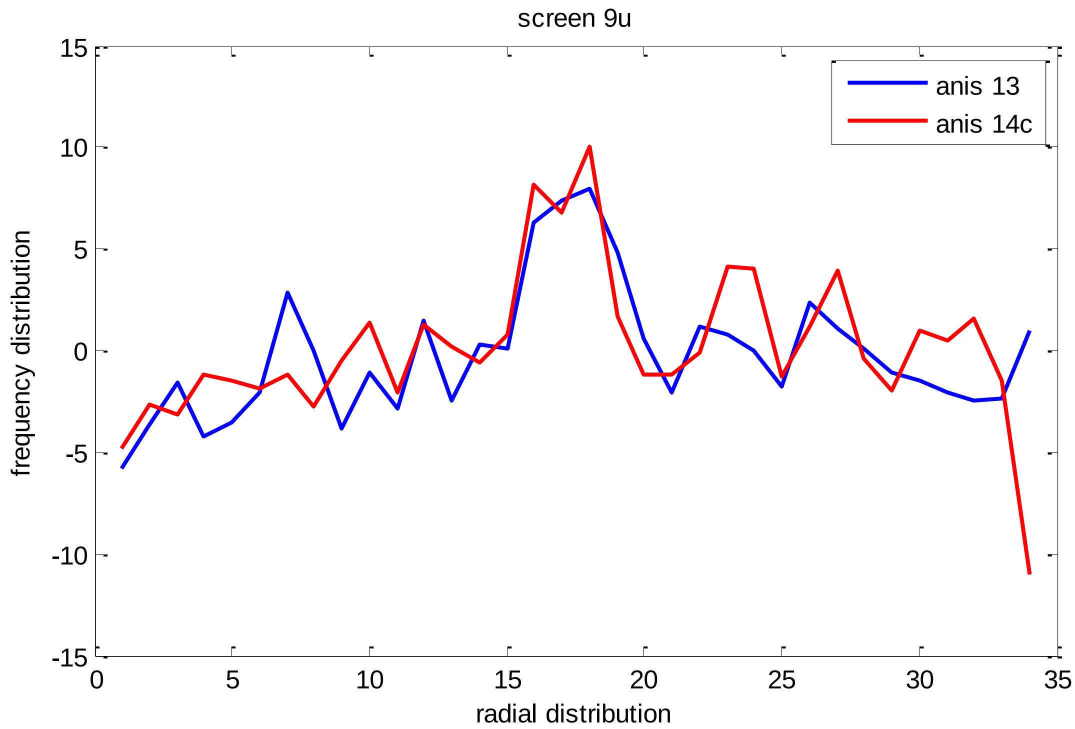



Fig.3.7 Anisotropy plot for screen 9u halftoning

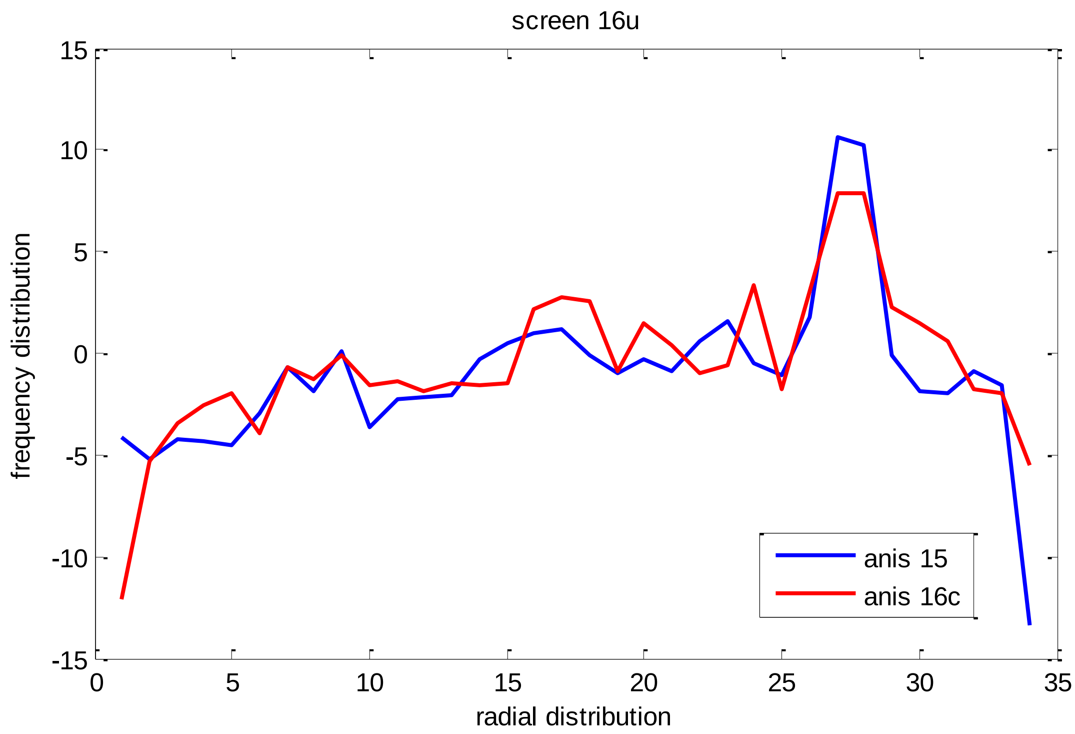



Fig.3.8. Anisotropy plot for screen 16u halftoning

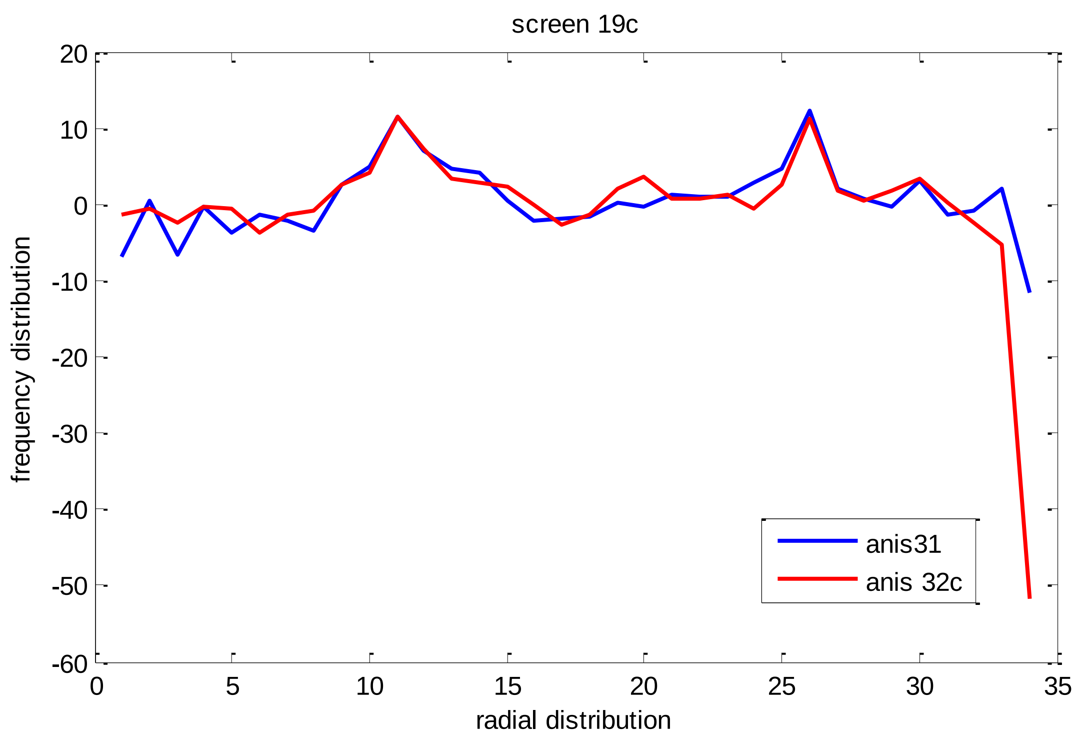



Fig.3.9 anisotropy plot of screen 19c halftoning

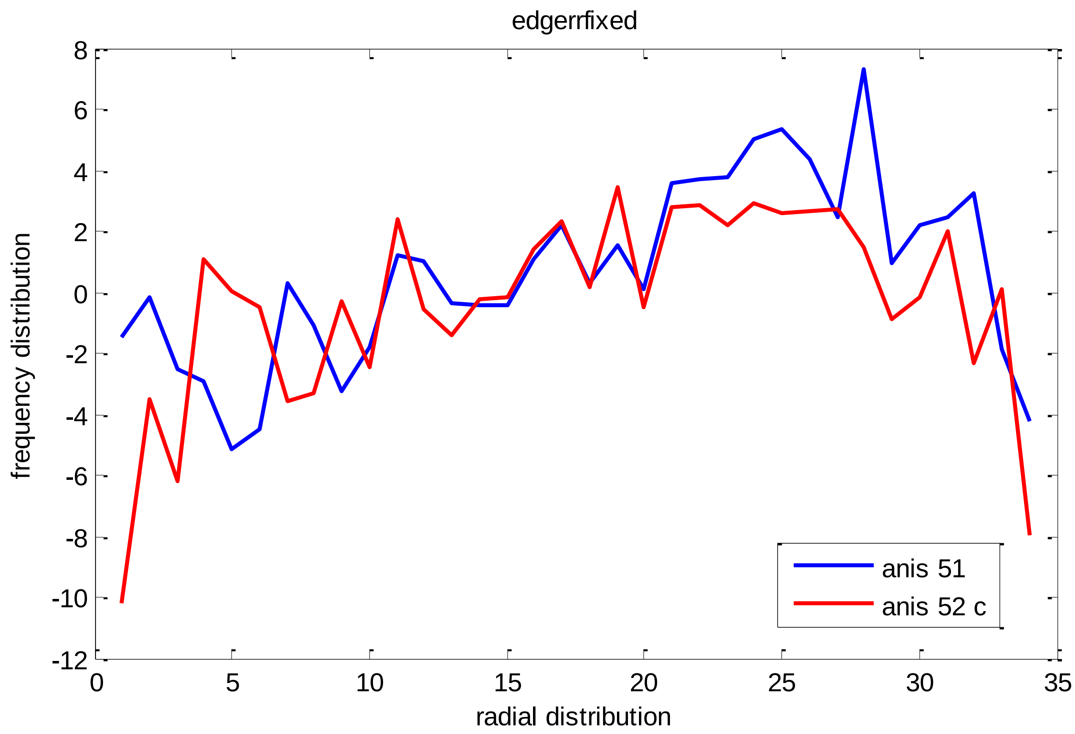



Fig.3.10. Anisotropy plot for edgerrfixed halftoning

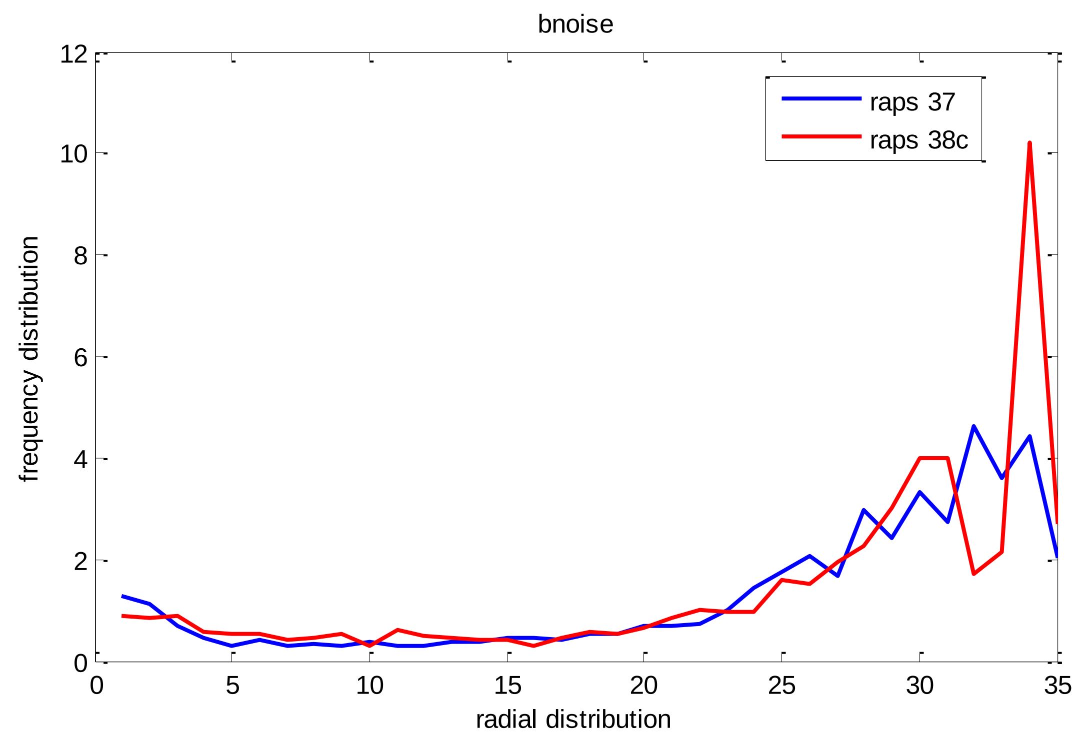



Fig-3.11. Rapsd plot for bnoise halftoning

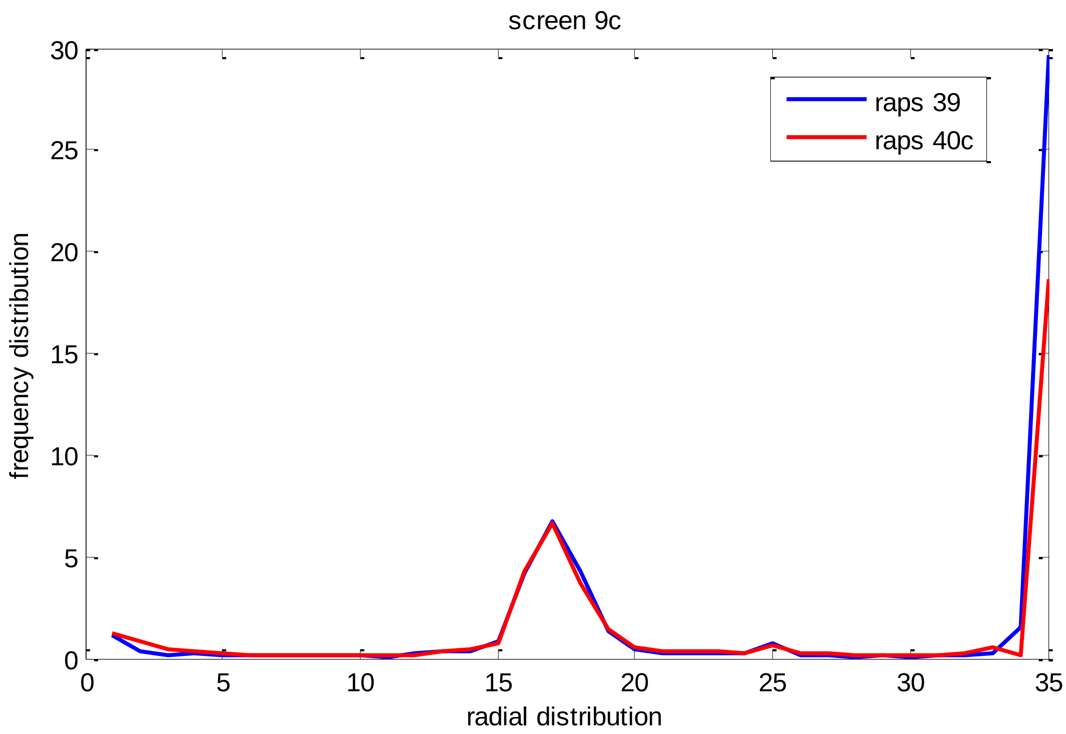



Fig.3.12. Rapsd plot for screen 9c halftoning

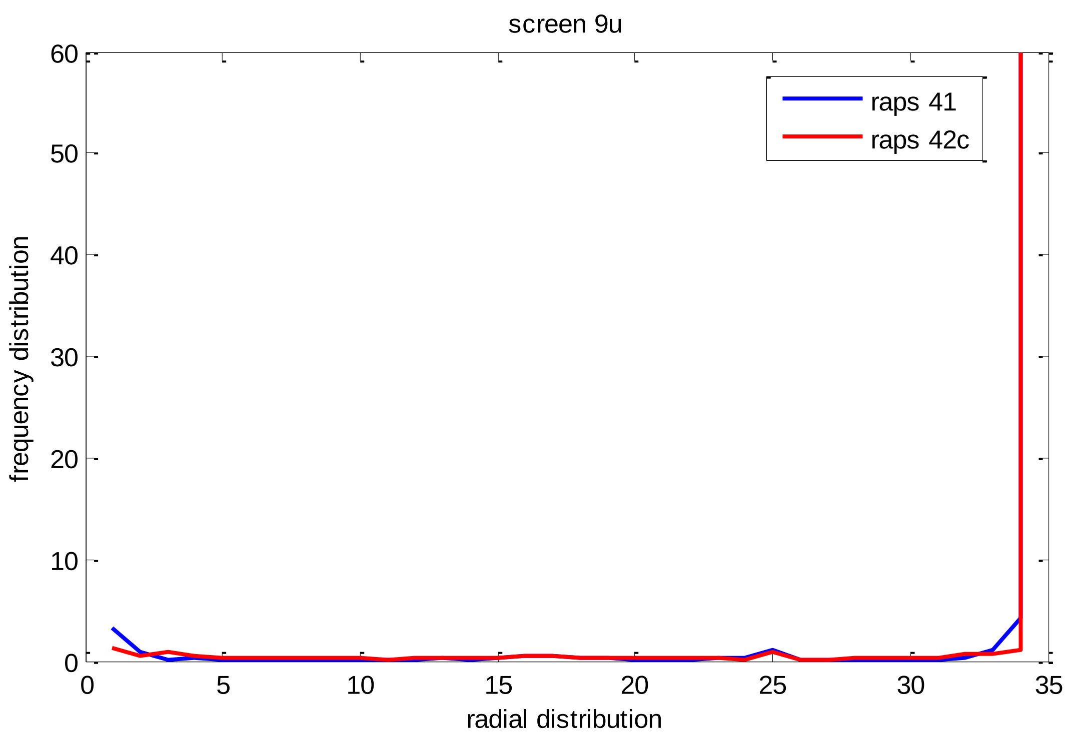



Fig.3.13. Rapsd plot for screen 9u halftoning.

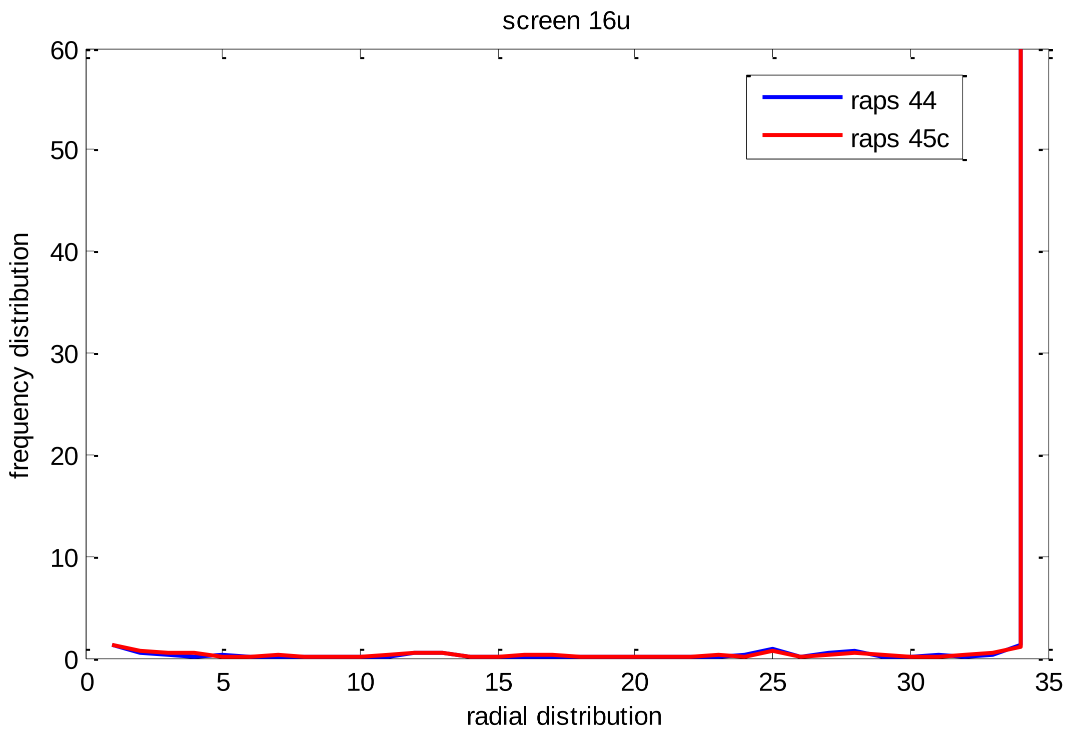



Fig. 3. 14. Rapsd plot for screen 16u halftoning

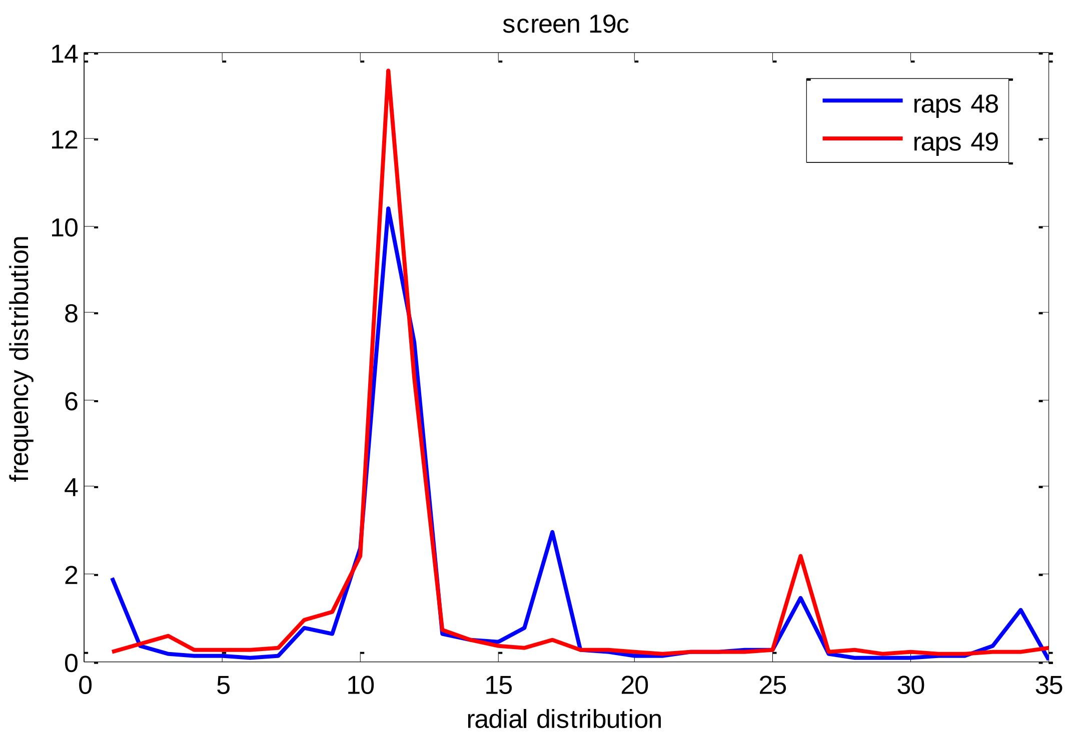



Fig. 3.15. Rapsd plot for screen_19c halftoning.

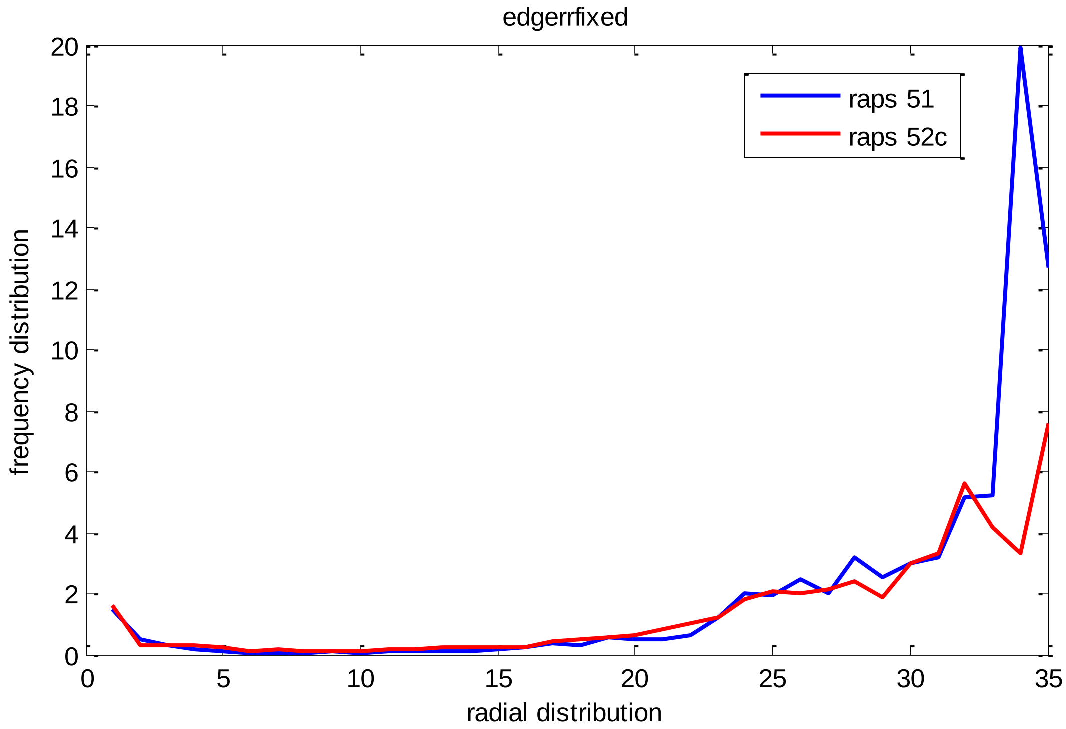



Fig.3.16. Rapsd plot for edgerrfixed halftoning.

From the above plot of radial distribution and frequency distribution data of crack and no crack sample image we conclude about the homogeneity, radial distribution, and frequency distribution as follows:-

(i) Homogeneity

- The property of data set of crack and no crack image is described by the homogeneity that how much similar curve is.
- Homogeneity should be as low as possible in this case.
- Lower the homogeneity higher the separation between crack and no creak image.
- From the above plot, we can say that Fixed Edge Enhancement error diffusion has lower the homogeneity among all the algorithm which is used to identify crack and no crack image.

(ii) Radial distribution

- Radial distribution is a function of a system of particles which is used to describe how density varies as a function of distance from a reference particle.

- Higher the radial distribution higher the separation between crack and no crack image are found.
- Radial distribution is higher in the case off anisotropy of algorithm screen_6u, screen_9u, screen_9c, and Fixed Edge Enhancement error diffusion as shown in the figure above.

(iii) Frequency distribution

- A frequency distribution is a mathematical function which shows that occurrence of the number of instances i.e crack and no crack in a data set.
- If frequency distribution has a higher curve than it shows that maximum crack contains on the region and this curve is used for comparing the crack and crack image.
- A frequency distribution is higher in the case of anisotropy and raps of algorithm screen_9u, blue noise mask, screen_9, and screen 19c blue noise mask respectively.

### 3.4 Conclusion

In this chapter, the possibility of the new technique is proposed to detection in a crack in concrete which is different from the conventional testing method. This technique is known as halftoning technique. There are different halftoning method namely error diffusion, Floyd Steinberg kernel, Javaris kernel, stucki kernel, and screen which is applied to the sample image containing crack in it. Screen halftoning method is of different type namely screen_9u, screen_9c, screen_16u, screen_19c. The result with different halftoning is analyzed and found that screen halftoning gives partially good result than the other halftoning method in most of the cases when the sample is taken. Hence crack detection using halftoning method may be the alternate option in comparison to the conventional method.

### 3.5 References

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# CHAPTER-4

# Data Clustering Analysis

### 4.1 Introduction

In this chapter analysis of halftoning data is done. Which is obtained from halftoning of sample image using different halftoning method and differentiate the data using anisotropy and radial average power spectral density as shown in the previous chapter. After halftoning of sample image a halftone data set is obtained. The data obtained are of two types either it contains crack or no crack so there is the possibility of making two clusters. Clustering of data is done by clustering algorithms [1].clustering can be considered as the most important unsupervised learning problem. Clustering used machine learning technique in which grouping of data point has been done from a number of the set of the data point [2]. Data point of the same group has similar features and properties on the other hand data have of the different group have dissimilar features and properties. There are a different type of clustering algorithm K-mean clustering algorithms, mean-shift clustering, agglomerative hierarchical clustering, expectation- maximization clustering using Gaussian mixture model, density-based spatial clustering of applications with noise[3]. out of the above-mentioned clustering algorithm, K-mean clustering is used in the work of this thesis. K-mean algorithm is the simplest algorithm among the above mention algorithm. K- mean algorithm is unsupervised learning algorithm. In unsupervised learning[4] there is no train data set earlier to the model it means in this model computer itself learn the data and analyze the data then it comes to result whether the data has same features and some groups. The concept of clustering comes under unsupervised learning. To extract knowledge about the features of the sample image classification and clustering are two most common technique is applied.

### 4.2 K- means Algorithm

In 1967[5] James MacQueen first used the term ‘k-means’ but the idea of this given by Hugo Steinhaus in 1956.[ 5]. Firstly in 1957, the standard algorithm is proposed by Stuart lioyd of Bell Labs. as a K-means is an iterative algorithm which is also known as an unsupervised learning algorithm that tries to partition the group of the large different dataset into a different small group. It is one of the simplest clustering algorithms. It follows the simple procedure to classify the data set by dividing the data set into a certain number of clusters. There are two clusters is introduced according to the work which has been carried out in this thesis. The aim of this algorithm is to find a group in the data, where a number of groups are represented by the variable ‘k’. The first cluster contains the data set for a crack sample and the second cluster contain the data set of uncracked sample. Data contain only binary value either ‘0’ or ‘1’. Where ‘0’ represent no crack and ‘1’ represents crack. A cluster within less variation has more homogeneous the data points are with the same cluster. The next step is to compare each point belonging to the given data set and associate it to the nearest center. The first step is completed when no point is pending and early group age is done. Resulting from the previous step at this point we need to re-calculate k new centroids as the barycenter of the clusters. A new binding has to be done between the same data set points and the nearest center after we have these new centroids. A loop is generated as a result of this loop we found that the k centers change their location step by step until no more changes are done[6]. The results of the k-means clustering algorithm are:

1. The centroids of the k clusters, which can be label new data.
2. Labels for the training data. i.e each data point is assigned to a single cluster[7][8].

Finally, this algorithm aims at minimizing an objective function known as the squared error function given by:

$$J(V) = \sum_{i=1}^{c}\sum_{j=1}^{c_i}(\|x_i - v_j\|)^2 \qquad \text{(i)}$$

Where, $\|x_i - v_j\|$ is the Eucliean distance between xi and vj.

‘$c_i$’ in i-th cluster ‘ci’ is the number of data point

‘c’ is the number of cluster centers.

### 4.2.1 Steps for K-mean Clustering Algorithm

Let X={y1, y2, y3, ……………………….,$y_n$} be the set of data points and V={u1,u2,……………..$u_n$} be the set of centers.

(1) Selection of ‘c’ cluster centers randomly.

(2) Distance calculation between cluster centers and each data point.

(3) Assigning the data point to the cluster center based on the shortest distance between the data point and cluster centers [8].

(4) Updating cluster centers using, $V_i = (\frac{1}{c_i})\sum_{j=1}^{c_i} x_i$ , where ' $c_i$ ' represent the number of data points in ' $i^{th}$ ' cluster.

(5) Calculation of distance between each data point and update cluster centers.

(6) Continue step 3 – 5 until no data point is reassigned.

An example of a k-mean algorithm is shown below:-

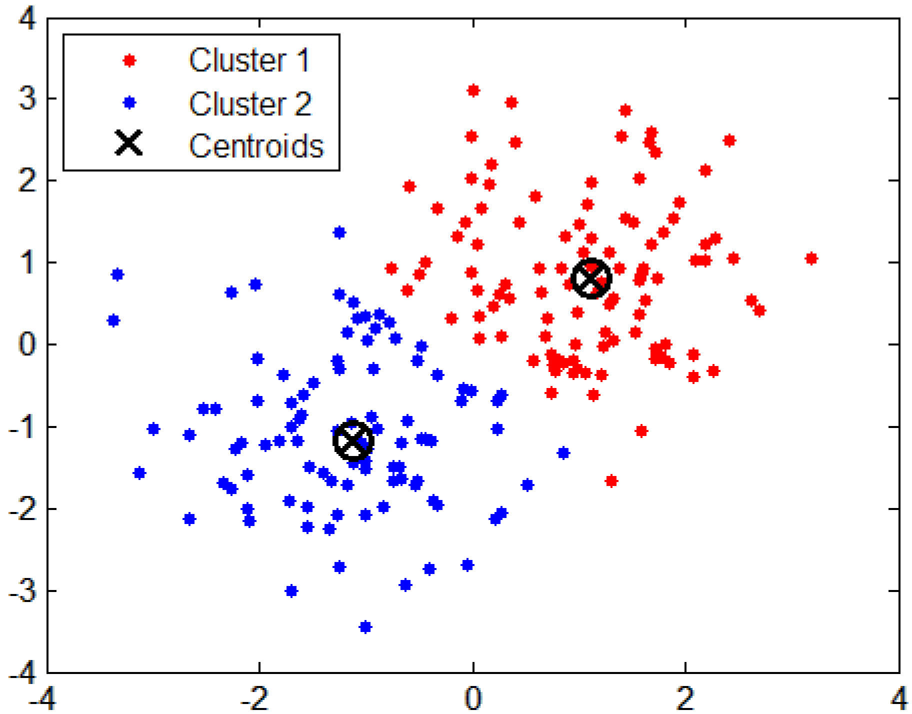


Fig.4.1-Separation of data by clustering algorithm [Source-Mine.humanoriented.com]

In the above image data is divided into two groups. So that K=2 and there are two clusters are identified from the dataset.

The output of executing a k-means on a dataset are:-

- K centroids: centroids for each of the k cluster identified from the dataset.
- Complete data set labeled to ensure each data point is assigned to one of the clusters.

### 4.2.2 Advantages

The following advantages of K-means make it popular in machine learning tasks [9]

(1) This method is easier to understand.

(2) Give the best result when data set are distinct or well separated from each other

(3) Relatively efficient.

(4) Fast and robust

### 4.2.3 Disadvantages:-

(1)The number of cluster centers specification is required by the learning algorithm.

(2) K-means will not be able to resolve them in case of overlapping data.

(3) In non-linear transformations, the learning algorithm is not invariant.

(4) Unequally weight underlying factors is measured by Euclidean distance.

(5) The local optima of the squared error function are provided by the learning algorithm.

(6) When mean is defined then only it is applicable not for categorial data.

(8) Noisy data and outliers are unable to handle.

(9) Non- linear data set cannot be determined by this algorithm.

## 4.3 Application of K-mean Algorithm.

Due to the popularity of k-mean algorithm. It is used in various application such as image segmentation, image compression, market segmentation, document clustering, etc. The goal of this cluster algorithm when a cluster analysis is either [10][11].

1. From the data, we are dealing with get a meaningful intuition of the structure
2. The cluster then predicts where different models will be built for different subgroups if we believe there is a wide variation in the behaviors of different subgroups. An example of that is clustering Animal into different subgroups and build a model for each subgroup to predict the probability of having pet animal among all the animals.

3. Document classification- Based on tags, topics, and the content of the document, cluster documents in multiple categories. This is a very standard classification problem and k-mans is a highly suitable algorithm for this purpose. In document classification, the initial process of the documents is needed to represent each document as a vector and to identify commonly used terms that help classify the document the term frequency is used. To help in identify similarity in document groups the document vectors are clustered.
4. Identifying crime localities-Data available related to crimes in a specific location in a city, the category of crime, the area of the crime and the association between the two can give quality insight into crime-prone areas.
5. Customer segmentation:-Marketers improve its customer base according to the use of clustering. Work on target areas, and segment customers based on purchase history, activity monitoring. For identifying the pre-paid customers in terms of browsing the internet, sending SMS and money spent in recharging the application of clustering is used. The classifications would help the company target specific clusters of customers for specific campaigns.
6. Delivery store optimization:-Good Delivery of goods is optimized by using a combination of k-means to find the optimal number of launch locations and a genetic algorithm to solve the truck route as a traveling salesman problem.
7. Insurance Fraud Detection- In fraud detection Machine learning has played a critical role and has numerous application in healthcare, automobile, and insurance fraud detection. According to past historical data on fraudulent claims, it is possible to isolate new claims based on its proximity to clusters that indicate fraudulent patterns.
8. Automatic clustering of IT alerts- Large enterprise IT infrastructure technology components such as network, storage, or database generate large volumes of alert message. Because alert message potentially points to an operational issue, they must be manually screened for prioritization for downstream processes.

### 4.4 K- mean of Halftones

In this section, the halftone features as obtained by rapsd and anisotropy [12]will be analyzed using k-means clustering. The result of clustering can be assessed using the plot and some distance based statistical results that show the resulted separability with the subjected feature. The plots of k-means are shown in Fig.s 4.2 – 4.10.

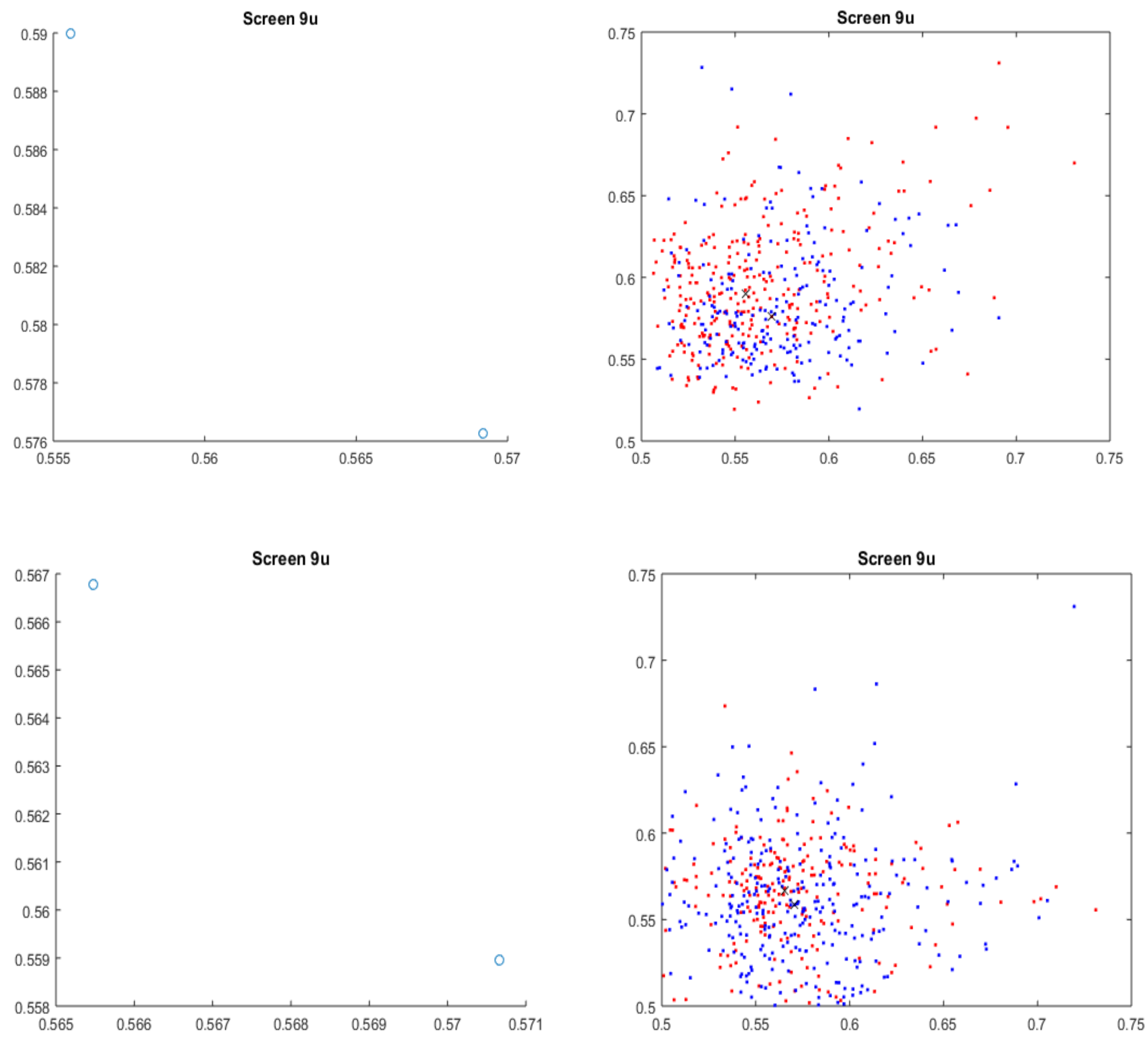


Fig. 4.2. The K-means result with features of screen 9c algorithm (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

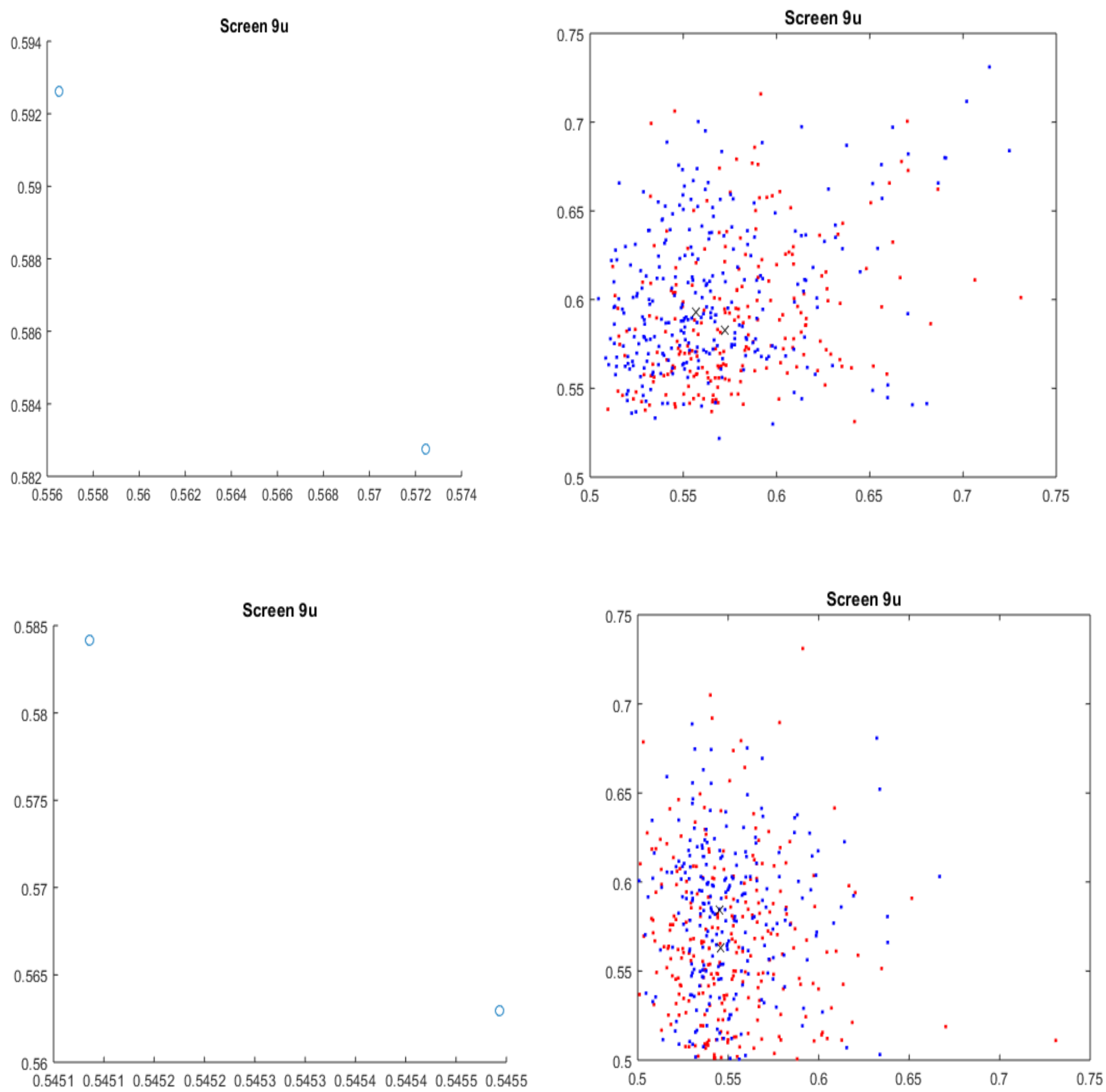


Fig. 4. 3. The K-means result with features of screen 9u algorithm (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

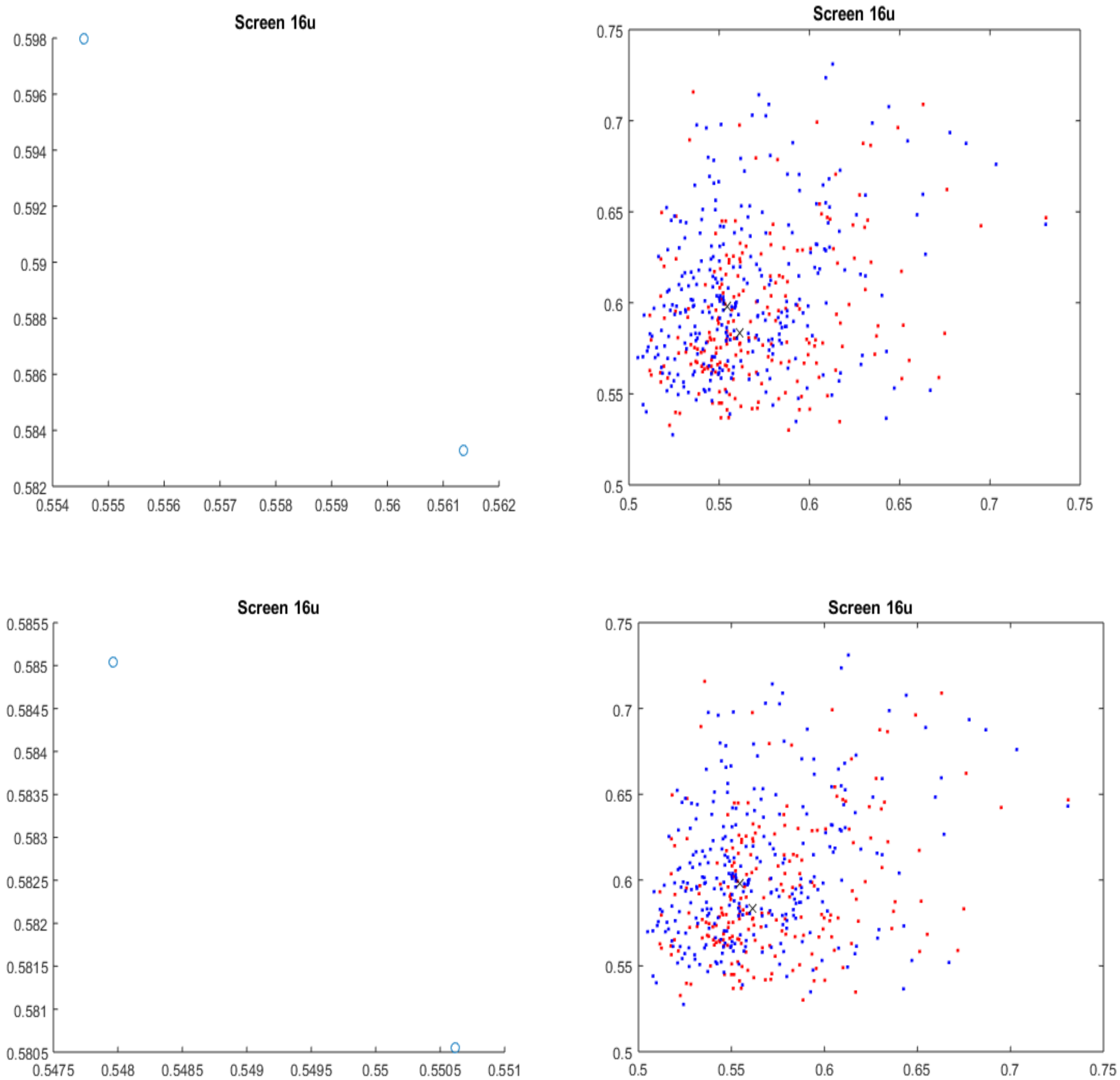


Fig. 4. 4. The K-means result with features of screen 16u algorithm (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

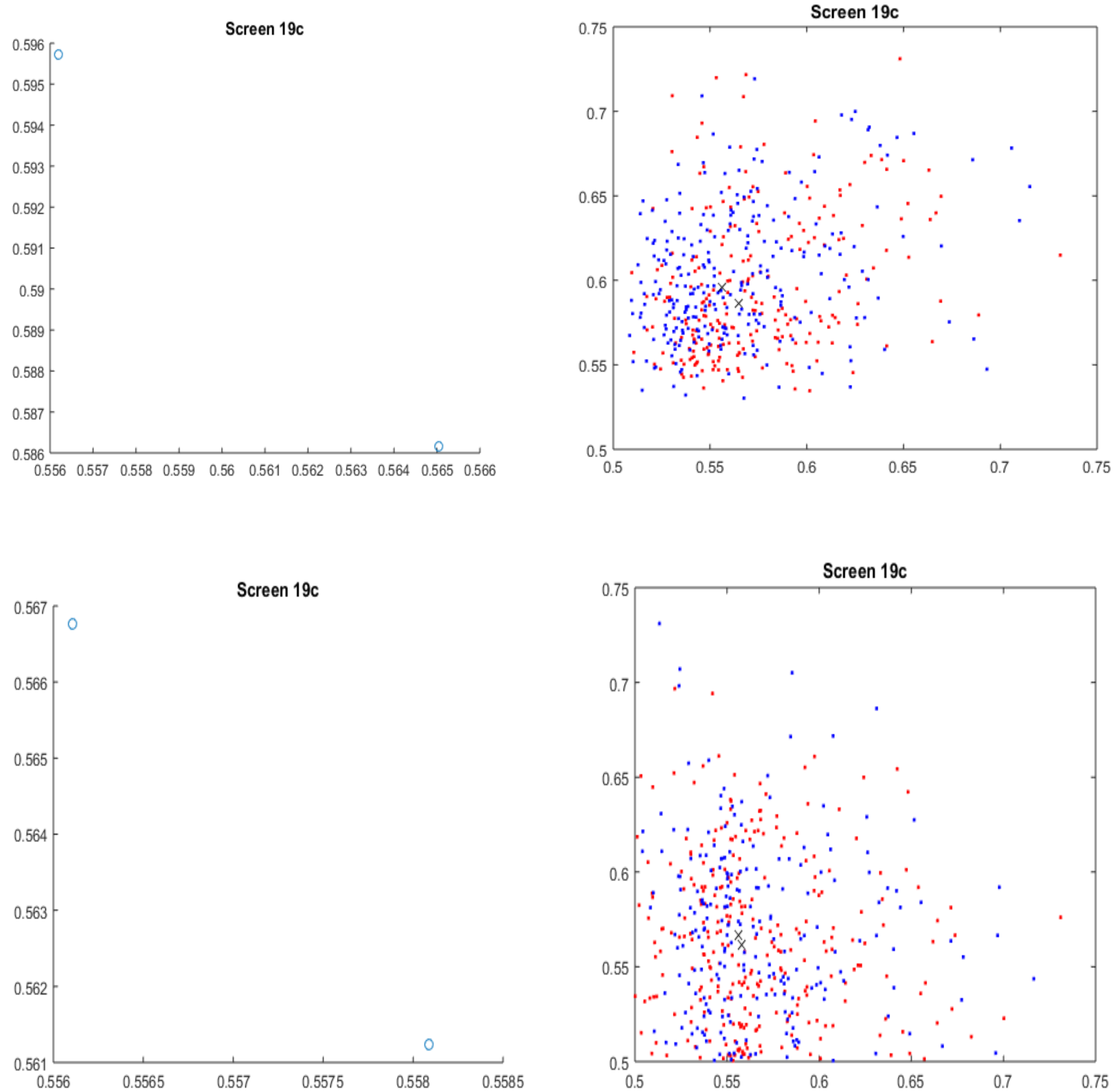


Fig. 4. 5. The K-means result with features of screen 19c algorithm (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

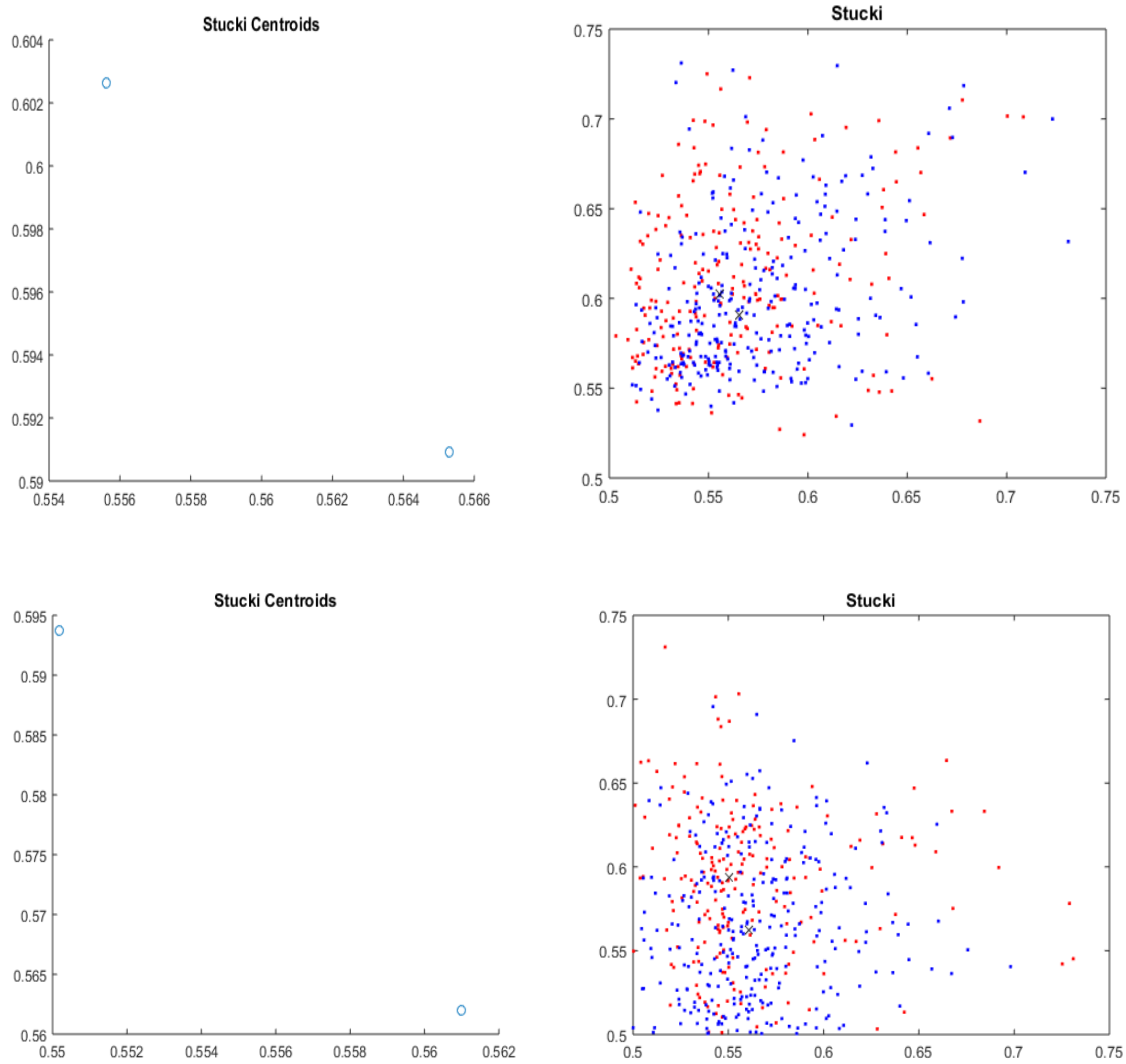


Fig. 4. 6. The K-means result with features of Stucki’s algorithm (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

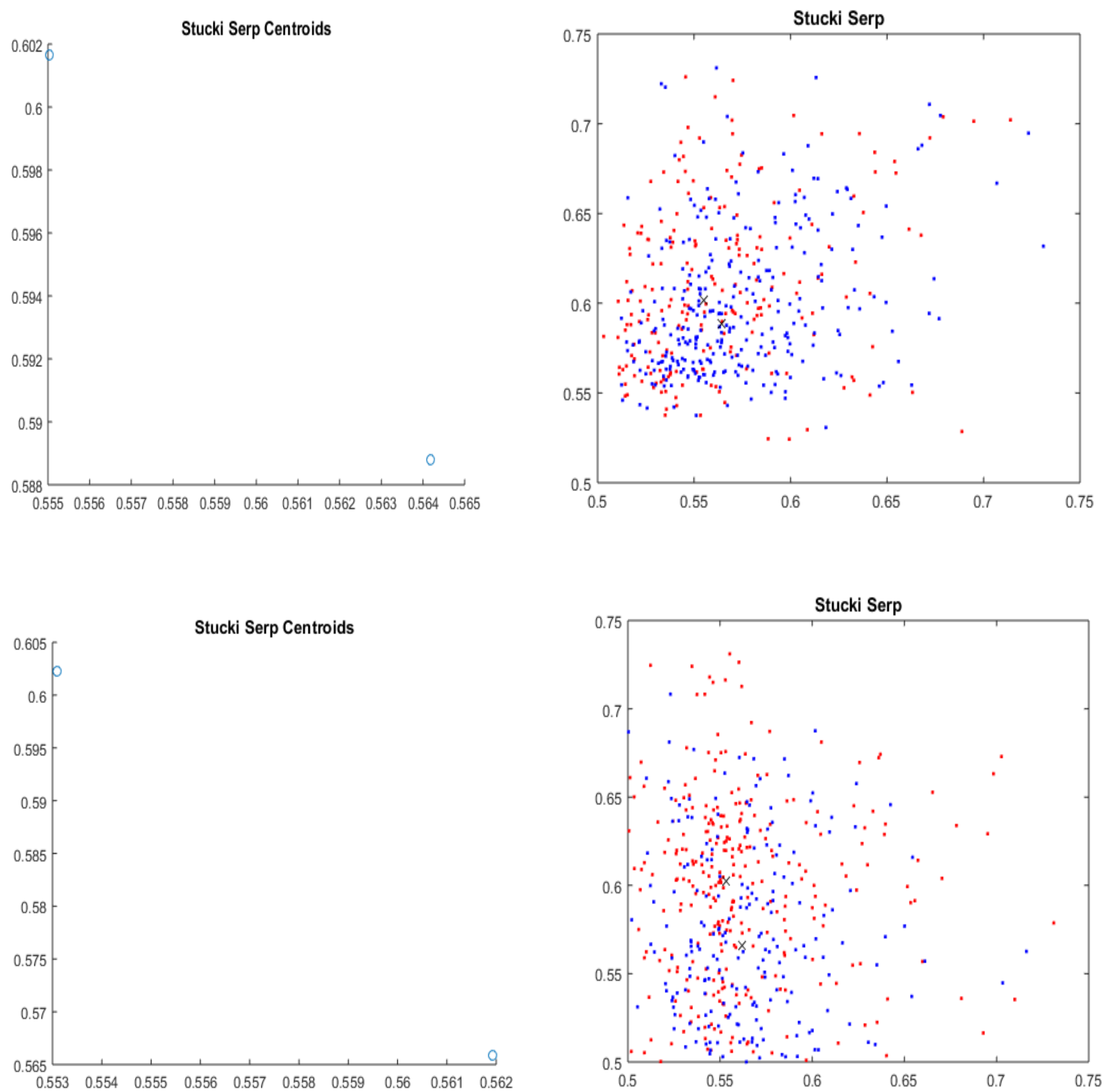


Fig. 4. 7. The K-means result with features of Stucki's algorithm with serpentine scanning (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

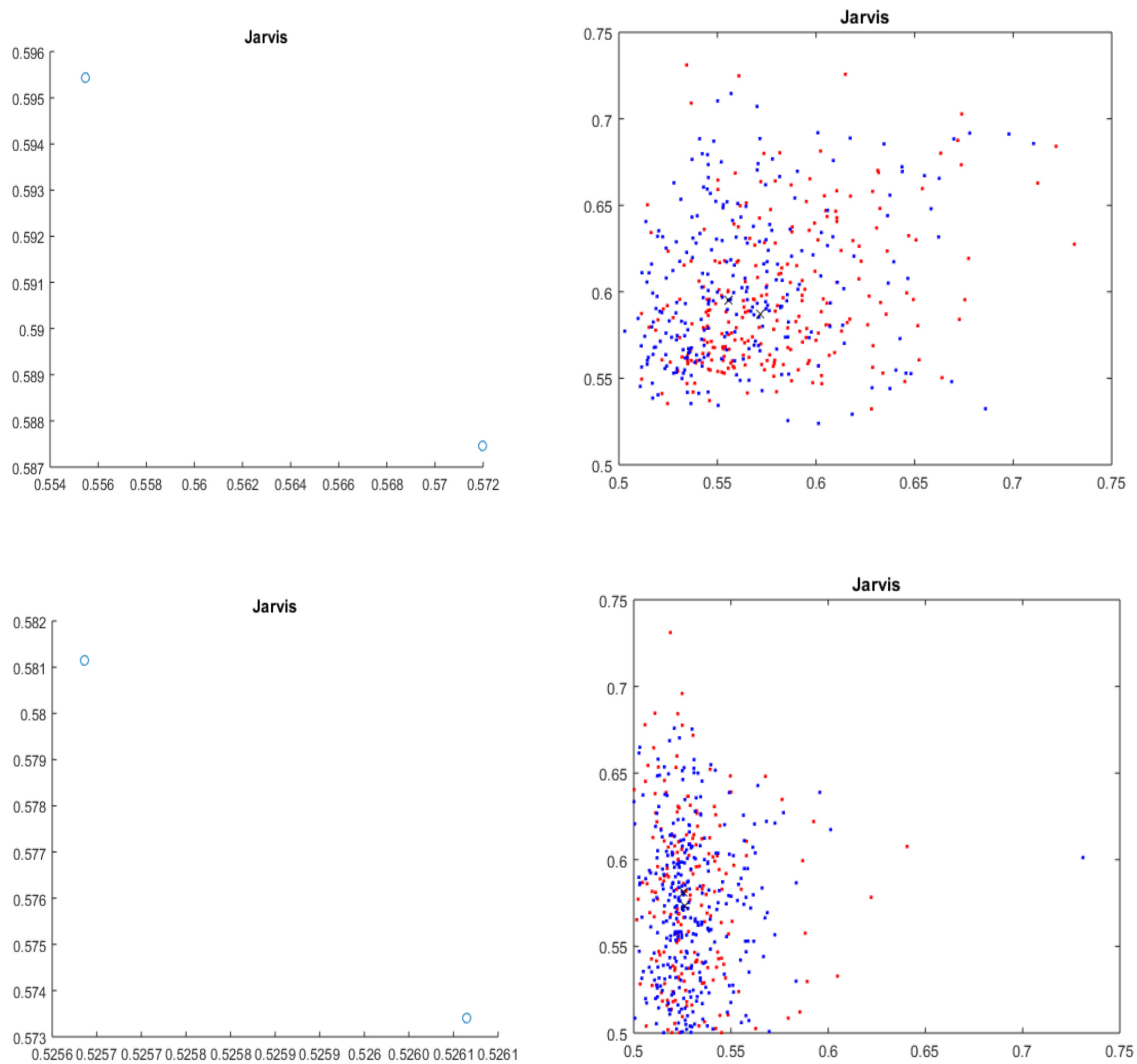


Fig. 4. 8. The K-means result with features of Jarvis's algorithm (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

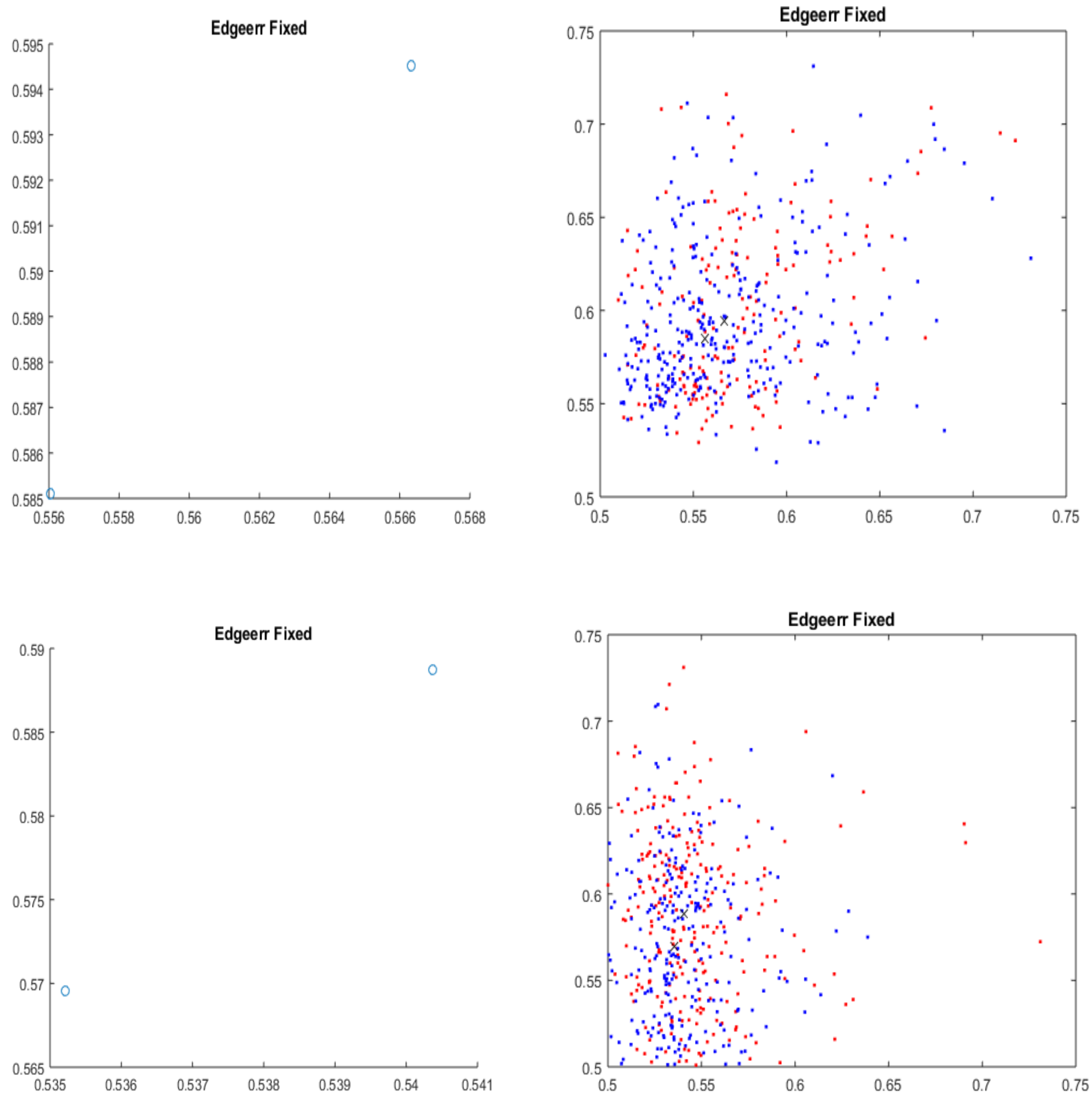


Fig. 4. 9. The K-means result with features of edge enhanced error diffusion algorithm (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

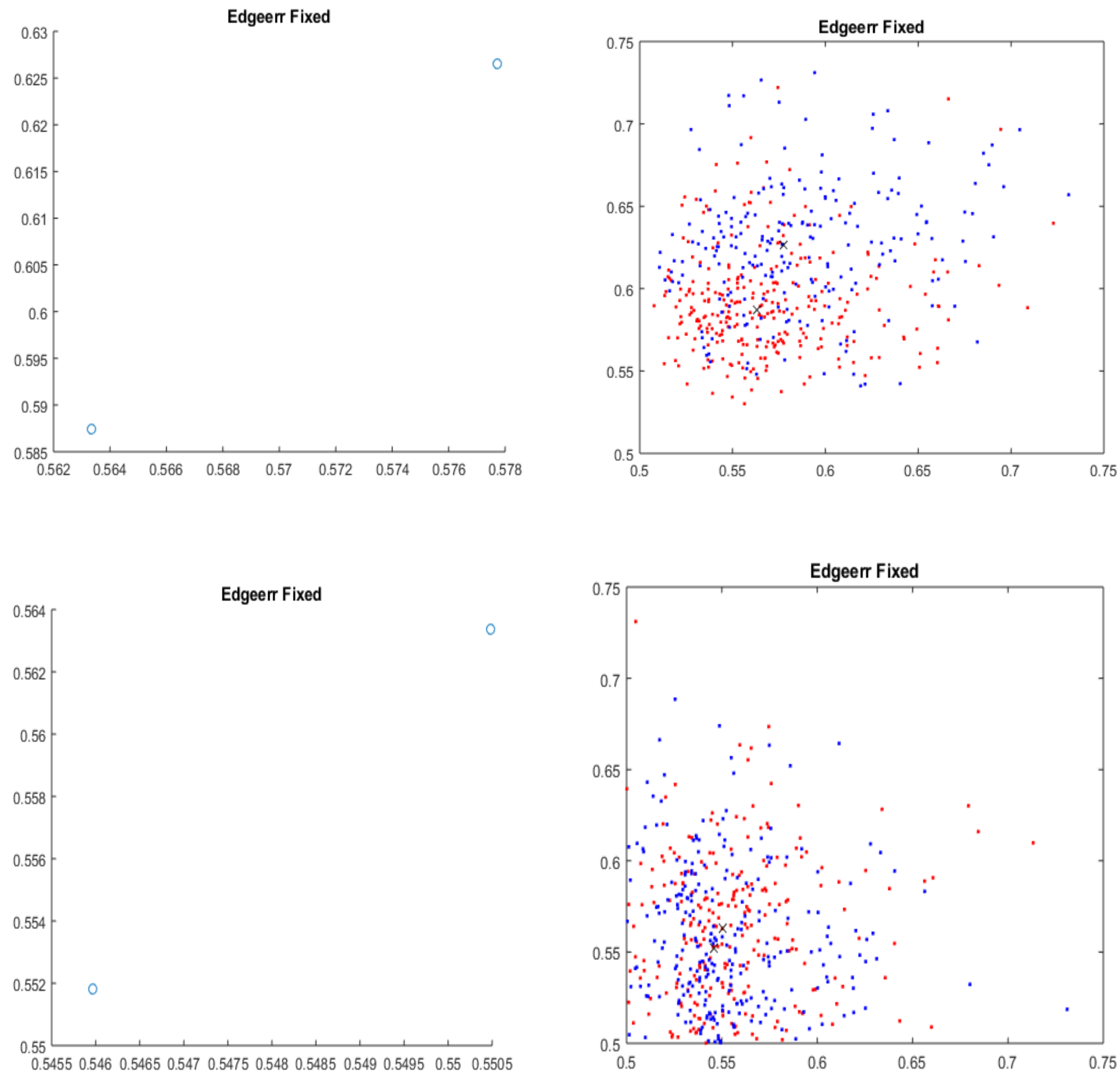


Fig. 4. 10. The K-means result with features of blue noise algorithm (top row left to right) cluster centroids and k-means plots of rapsd feature (bottom row left to right) cluster centroids and k-means plots of anisotropy feature.

The above figures show that the k-means can successfully produce 2 clusters but the degree of separations is different with different algorithms. If we see the centroids resulted with different algorithms, they are visibly separate as they are appearing in the considerable distance in the scatter plots with centroids shown in the left column of the above figures. While including the data-points to the plot with centroid it is showing the clusters with some outliers. These outliers are resulting in poor performance in clustering. However, in some cases, the separation is well visible, for example, in case of Jarvis and edge error diffusion the plots are showing better separability.

This separability can be better interpreted with the statistical measures shown in Table 4.1.

**Table 4.1.** Statistical analysis of k-means clustering

| **Parameter** | **Actual** | **Stucki serp** | **Stucki** | **Screen 19c** | **Screen 16u** | **Screen 9u** | **Screen 9c** | **Jarvis** | **Edgerr fixed** | **Bnoise** |
|---|---|---|---|---|---|---|---|---|---|---|
| Number of samples in different class | 360:140 | 305:195<br>276:224 | 287:213<br>292:208 | 295:205<br>283:217 | 299:201<br>293:207 | 270:230<br>249:251 | 308:192<br>249:251 | 262:238<br>285:215 | 314:186<br>243:257 | 306:194<br>258:242 |
| Within cluster sum of squares (WSS) | | 12.27<br>32.67 | 12.48<br>30.37 | 12.45<br>26.12 | 13.67<br>32.06 | 14.87<br>30.21 | 11.42<br>28.51 | 13.08<br>30.66 | 13.67<br>31.85 | 11.61<br>31.11 |
| Between clusters sum of squares (BSS) | | 35.71<br>70.91 | 38.39<br>66.35 | 35.95<br>59.33 | 45.87<br>75.69 | 48.17<br>69.21 | 38.17<br>63.81 | 38.41<br>67.54 | 38.04<br>69.68 | 26.87<br>66.84 |

# In column Top value represents rapsd features and the bottom value represents anisotropy features

Table 4.1 shows that most of the techniques can separate the data into 2 clusters (crack and no-crack). In multiple cases for example screen 9c, bnoise, edgeerrdiff with fixed threshold and Sucki serpentine scanning the partitioned examples are closely matching to the actual labeled classes. But, here the labeling of classes cannot be done. These partitioning values along with WSS and BSS values can be a good estimator towards feature efficiency measurement. As it can be seen in an overall measure rapsd features are providing better partitioning. In case of WSS values and BSS values as well rapsd features are resulting almost 3times of WSS values as BSS values which reflects that the points within the clusters are positioned closer while the cluster centers are distanced with a higher degree. In case of anisotropic features also the WSS and BSS values are acceptable but they are not showing that good separability as rapsd features. In a consolidated manner, it can be stated that Table 4.1 depicts the possible potential of rapsd and anisotropy of halftone features towards the classification of crack and no-crack concrete structures/slabs/blocks.

## 4.5 Conclusions

In this chapter data is analysis by the k-mean clustering algorithm. K-mean clustering algorithm is used to separate the data into two clusters for the halftone features obtained using different half toning algorithm. The centroid of both the cluster are well separated in all halftoning technique as shown in scatter plot but while including the data point to the plot with centroids than in only in some cases i.e Jarvis and edge error diffusion are showing better separability. In multiple cases for example screen 9c, bnoise, edgerrfixed with fixed threshold and stucki serpentine scanning the partitioned example are closely matching to the actual labeled class. For feature efficiency measurement WSS and BSS are the good estimators. RAPSD features are providing better partitioning almost 3times of WSS values as BSS and RAPSD have better seprability than anisotropy. The k-means analysis shows the potential of halftone features that can be subjected to the classification algorithms to classify crack and no-crack samples.

4.6 References

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# CHAPTER-5

# Classification Using Support Vector Machine

### 5.1 Introduction

A classification method is a product of arranging classes into a group of classes. Classification [1] is used for an arrangement or division of individual object into the classes or groups based on the common characteristic of the object. The process of learning a model that explain a different predetermined class of data. Learning and classification are the two-steps for this. A classification model is constructed in the learning step and the constructed model is used to prefigure the class labels for given data. Classification and clustering [2] are the two types of learning methods. The aim of this method to characterize objects into groups by one or more features. Classification and clustering process appears similar but there is a difference between the data mining. Classification model classifies the data into one of the numerous already defined definite classes. The classification model is supervised learning. Supervised learning means it is guided or instructed by the data. It has already a data set related to the problem called the trained data set. When a problem arises then machine learning uses the dataset which set earlier in the system using supervised learning. The dataset which is set earlier is known as training data. Training data contains information about the problem. Name of algorithm which comes under supervised learning is logistic regression, navie Bayes, support vector machine (SVM), random forest, linear regression, decision tree, and K-nearest neighbors, polynomial regression, etc. In this work for the classification of the sample data, the support vector machine is used.

### 5.2 Support Vector Machine (SVM)

Vladimir N. Vapnik and Alexey Ya. Chervonenkis invented the SVM algorithm in 1963. A way suggested creating nonlinear classifiers by applying the kernel to maximum-margin hyperplanes. By Bernhard E. Boser, Isabelle m. Guyon and Vladimir N. Vapnik.[3]Corinna Cortes and Vapnik proposed current standard incarnation in 1993 which is published in 1995.[4]. Support vector machine (SVM) is also known as support vector network. It is supervised learning models with associated learning algorithms that analyze data used for classification and regression analysis. A training data is given each marked as belonging to other of two categories. There are two categories crack or no crack. A crack or no crack is represented by '1' or '0' respectively. In a high- or infinite dimensional space Support vector machine construct a hyperplane or set of hyperplane which can be used for classification regression or outliers detection [5].To the nearest distance for the nearest training data point of any class of hyperplane has the largest distance since in general the larger the margin, the lower the generalization error of classifier [6]. Whereas in a finite dimensional space original problem may be stated. Generally, the sets to discriminate are not linearly separable in that space. The mapping used by SVM schemes is designed to ensure that dot products of pairs of input data vectors may be computed easily in terms of the variable in original space, by defining the term of kernel function k(x, y) selected to suit the problem to keep computational load reasonable. The hyperplanes in the higher- dimensional space are defined as the set of points whose dot product with the vector in that space is constant. Where such a set of a vector is an orthogonal set of the vector that defines a hyperplane. The vectors defining the hyperplanes can be chosen to be linear combination with parameters ($\propto_i$) of ithe mage of features vectors($x_i$) that occurs in the data base. With the choise of hypthe erplane, the point 'x'in the feature space that are mapped into the hyperplane, the point 'x' in the features space that are mapped into the hyperplane are defined by the relation $\sum_i \alpha_i k(x_i, x) = cons\tan t$ . Note that if k(x, y) becomes small as 'y' grows further away from 'x', each term in the sum measure the degree of closeness of the test point (x) to the corresponding data base point ($x_i$).In this way, the sum of kernels above can be used to measure the relative nearness of each test point to the data points originating in one or the other of the sets to be determined.

There are two types of classifier in SVM

- Linear SVM classifier.
- Non-linear SVM classifier.

Linear SVM classifier- we assumed that training examples plotted in space in linear classifier [7] model. These data points are expected to be separated by an apparent gap. It predicts a straight hyperplane dividing 2 classes, one for crack and other for no crack. While drawing the hyperplane, the primary focus is on maximizing the distance from hyperplane to the nearest data point of either class. Hyperplane drawn is called as a maximum- margin hyperplane. An example of linear classification shown in figure5.1,

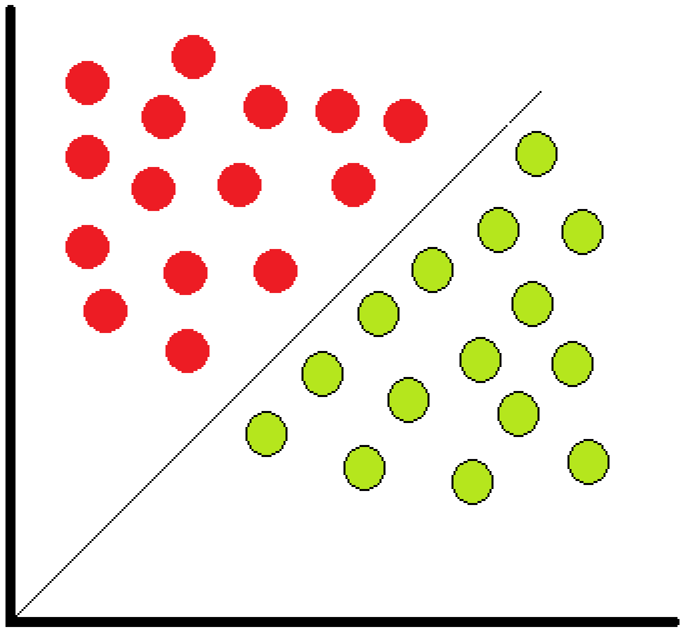


Fig.5.1 Linear separable

Nonlinear SVM classifier:- Non- linear classifier is proposed by Vapnik in 1992[8]. The non-linear SVM classifier is another important classifier technique. It becomes successful because for every problem related to the separation of data into different classes on the basis of straight line hyperplane is not considered as a good choice. So it was proposed to map p-dimensional space into much higher dimensional space. An example of non- linear classifier is shown below.

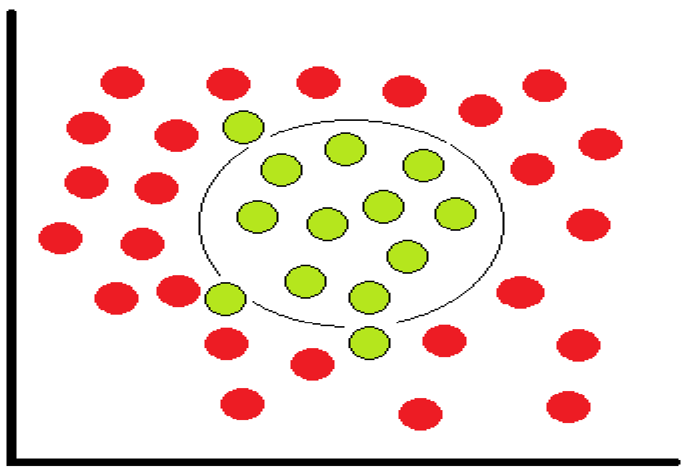


Fig. 5.2 Non-Linear Separable

Nonlinear hyperplanes drawn using Kernel. There is three standard kernels [9] namely (i) polynomial (homogeneous) kernel, (ii) polynomial (non-homogeneous) kernel, (iii) Radial Basis Function Kernel. Radial Basis Function kernel is most popular non-linear kernels. To draw completely non-linear hyperplanes it is used. Every kernel has a non- linear kernel function. High dimensional features space is built by the non-linear kernel function. There is a different type of kernel are developed in which some of them discussed below.

(i) Homogeneous Kernel- The polynomial homogeneous kernel function is represented by the equation given below.

$$k(\vec{x_i}, \vec{x_j}) = (\vec{x_i} . \vec{x_j})^d \qquad \text{(i)}$$

Where $k(x_{i,} y_j)$ is a kernel function, $x_i$ and $x_j$ are the vector of features space and d is the degree of polyna omial function.

(ii) Polynomial (non-homogeneous) Kernel- The polynomial nonhomogeneous kernel function is represented by

$$K(x, y) = (x^T y + c)^d \qquad \text{(ii)}$$

In the equation of this kernel, one constant term is also added. The constant term 'C' is also known as a free parameter. Combination of features is influenced by the polynomial non- homogeneous kernel. x and y are the features space vector.

(iii)Radial basis function kernel:- In 1964, Radial basis function(RBFs) is developed as potential functions[10] but in 1968 it was firstly used by Sprecht [11 ] for non-linear regression. In 1988, The idea of RBF neural network, in short abbreviated as (RBFNNs) is brought by Broomhead and Lowe [12 ] and by moody and Darken[13] in 1989. To obtain the more general and powerful radial basis functional link nets(RBFLNs) we combine RBFs with the random vector functional link nets (RVFLNs) of pao et al.[14][15]. RBFNNs architecture and training algorithms are simple and they train more quickly. Radial Basis function kernel is used to draw hyperplanes, completely non-linear type. The data related to this work (i.e crack and no crack) is also non-linear when plotting it on to the graph. So Radial Basis Function kernel is used here for separation of the data point. Euclidean distance is used here for distance metric square. The ordinary straight line distance between two points in Euclidean space is called as Euclidean distance. The two-dimensional

Euclidean plane encompasses Euclidean space in geometry. Euclidean space is named after the Greek mathematician Euclid of Alexandra. The function of Radial basis function kernel is shown below

$$K(X, X') = \exp\left(\frac{-\|X - X'\|^2}{2\sigma^2}\right) \qquad \text{(iii)}$$

A wide variety of application of Radial basis function neural network (RBFNNs) is given below

- Recognizing [16] patterns in data.
- Handwritten characters recognition.
- For detection of waveforms in physiological (EEG) signals [17].
- Real-valued functions approximation.
- Recognition of face and gestures.
- In an avionics system hardware integration of neurocomputers'[18]
- Objects and disease detection.
- Chemical process modeling.
- Curve fitting
- Predicting reservoir-induced earthquake.
- Adaptive interference [19] cancellation in signal estimation.
- Recognition of radar target.
- In a fermentation [20] process for estimation of biomass and recombinant protein.
- Identification of the speaker's voice.
- Analysis of time series and etc.

### 5.2.1 Advantage and Disadvantages of Support Vector Machine.

The advantage of the SVM technique can be summarized as follows:-

- Can provide a higher degree of flexibility [21].
- Does not require any assumptions about the form of the transformation.
- Provide better out of the sample generalization.

- Can work well in convex optimality problems.
- Can be widely used across different classes of engineering problems.

The disadvantage of the SVM technique is summarized as follow:

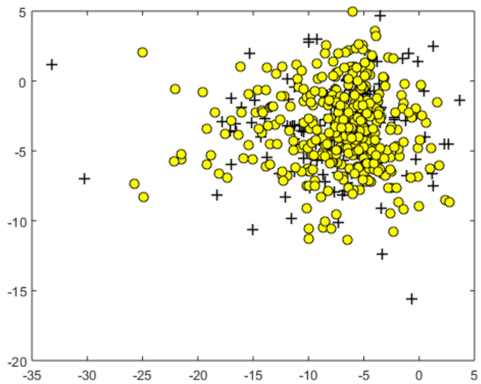
- SVMs is the lack of transparency in the result.
- Dimension may be very high.
- The main disadvantage of SVM is its several parameters that need to be set correctly to achieve the best classification result.

### 5.2.2. Application of SVM.

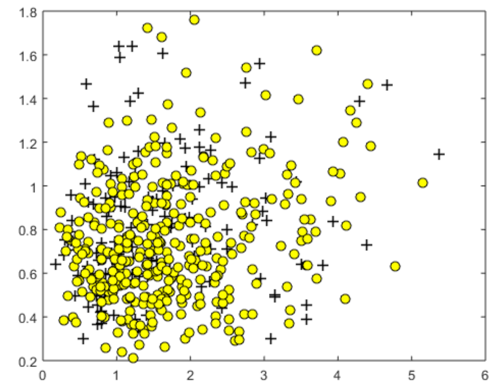
- Shallow semantic parsing is based on support vector machine for some method.[22]
- Using SVM it is the classification of the image can also be performed.
- Using SVM hand written character can be recognized.[23 ]
- SVM algorithm has been applied in many fields. For example, it is applied in the biological and other science.
- SVM weights have been suggested as a mechanism for interpretation of the SVM model.[24]
- To interpret SVM models in the past weights of support vector machine is used.

### 5.3. Application of SVM to Halftone Features for Classification of Crack and No-Crack

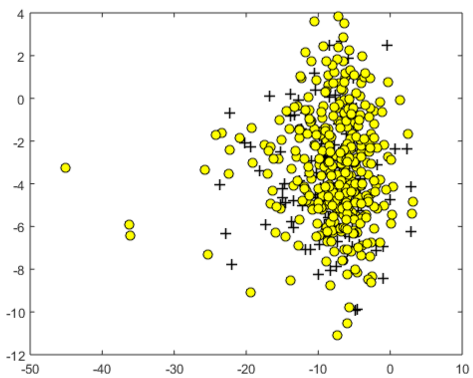
The choice of SVM kernel whether to be linear and non-linear can be arrived observing the data plots shown below.



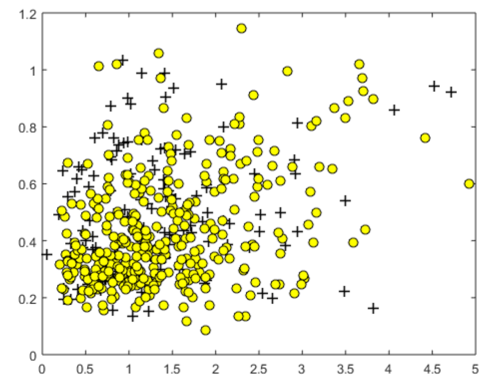
(a) Bnoise anisotropy



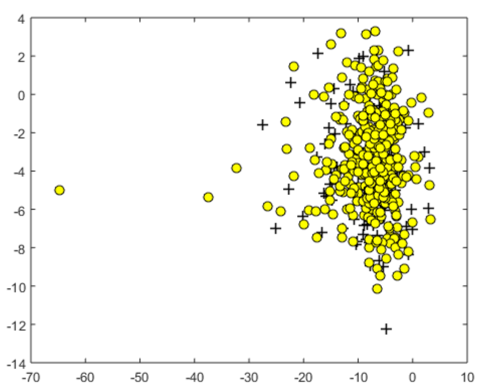
(b)Bnoise raps



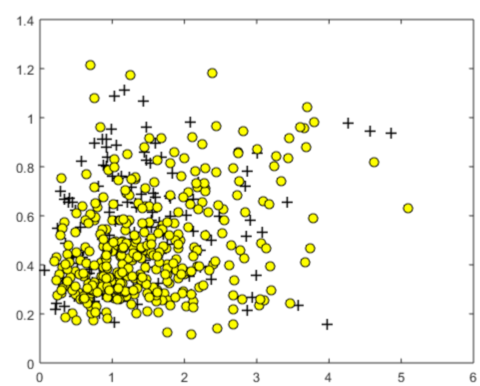
(c)Edgerrfixed anisotropy



(d)Edgerrfixed raps

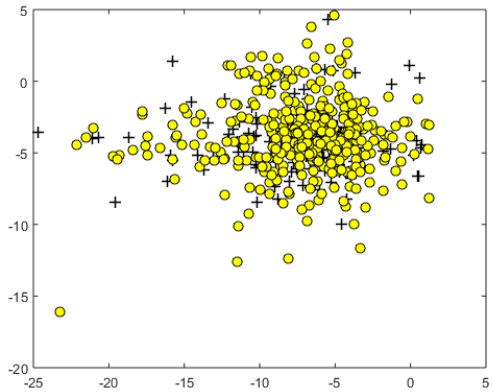


(e)Javris anisotropy

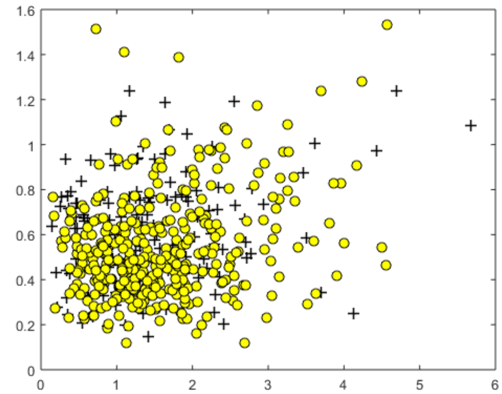


(f)javris raps

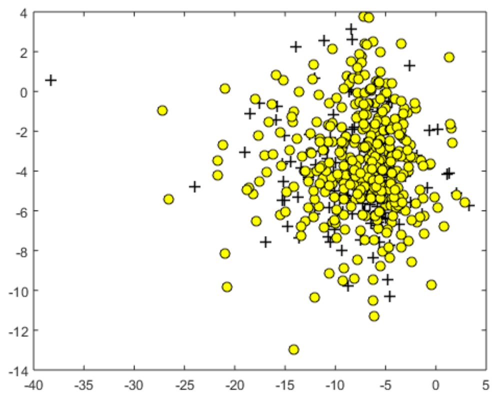
Fig. 5.3 SVM kernel (a to f)



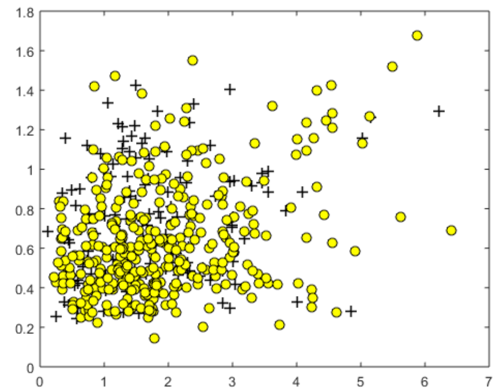

(a)Screen 9c (anisotropy)



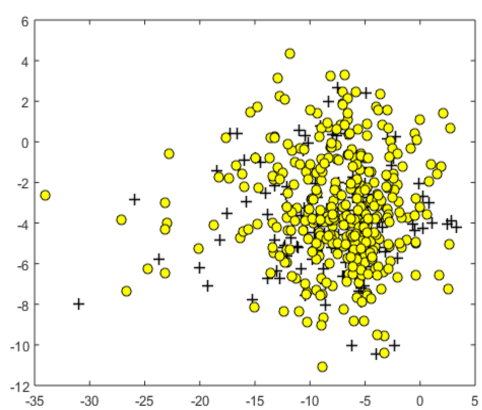

(b)screen 9c (raps)

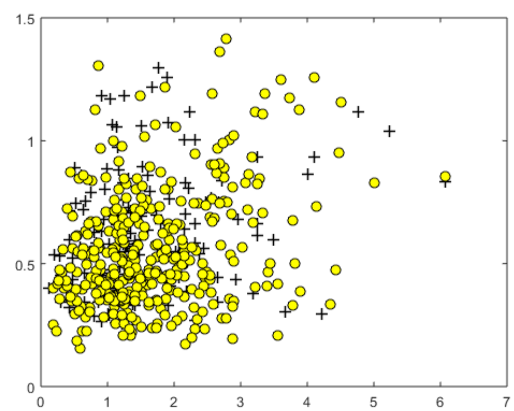



(c)Screen 9u(anisotropy)

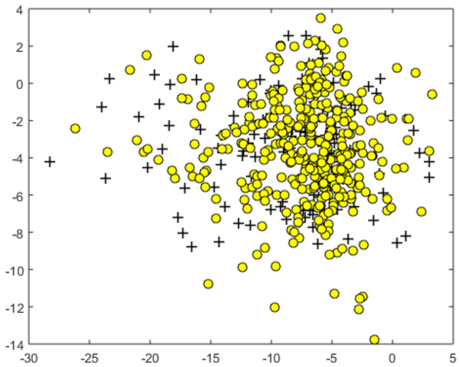



(d)screen 9u(raps)

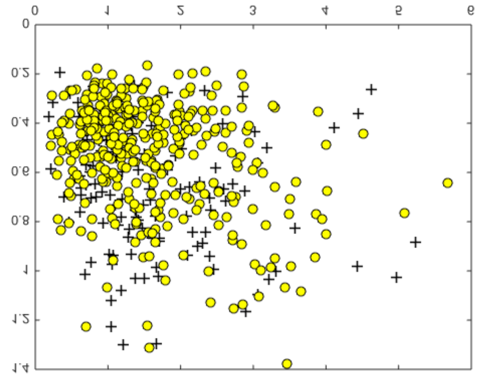


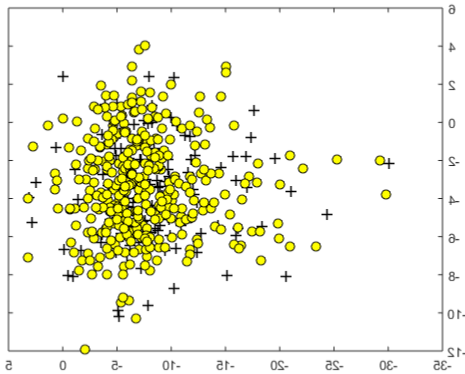

(e)Screen 16u (anisotropy) Fig.5.4 SVM kernel(a to f) (f)screen 16u (raps)



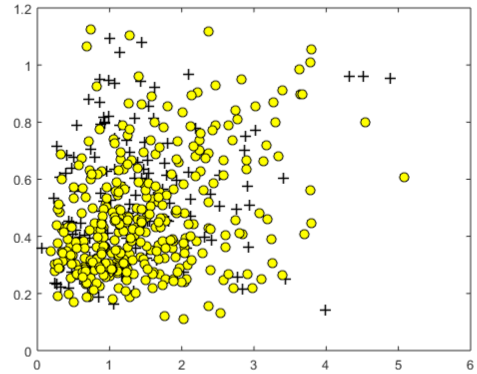

(a)Screen 19c (anisotropy)



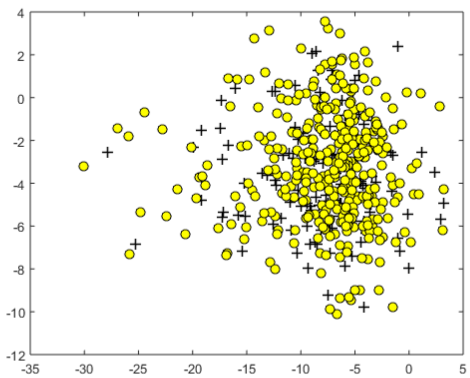
(b) screen 19c(raps)



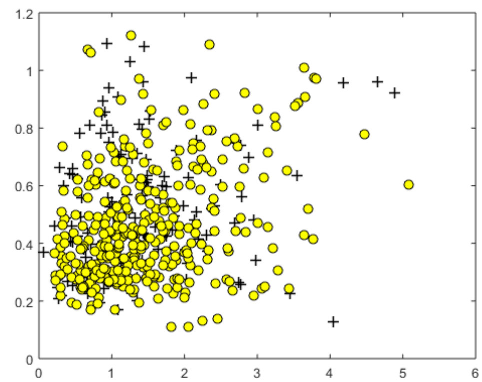
(c)Stucki (anisotropy)




(d)Stucki (raps)




(e)Stucki.serp (anisotropy)




(f)stucki.serp(raps)

Fig.5.5 SVM kernel (a to f)

From the above plots it can be seen that it is difficult to classify the data linearly that is by drawing a linear partition between the crack and no crack data. Support vector machine algorithm is able to classify both the classification i.e. linear and nonlinear classification. The kernel is used to classify all the data under SVM. There are many kernel in which some of them are the polynomial (homogenous) kernel, polynomial non homogenous kernel and Radial basis functional kernel (RBF). RBF is suitable for nonlinear classification because it classifies the non- linear data more accurately. Since the data is not linearly well separable the choice is made with RBF kernel due to its non-linear separability. In the following table, the outcome of 10-fold cross validation is given where 90% of the data is used for training and the rest 10% of data is used for testing. But, the training and testing is continued 10times in a cyclic order so that all the data are considered at least once for training and testing.21

### 5.4 K fold Cross-Validation for Estimation of Prediction Error.

When the prediction is the aim of any work than the estimation of prediction accuracy is important. Cross-validation is popular for estimation of prediction error[25] i.e. A dataset of known data on which training is run, which is given by a model is known as training data set and unknown data set of data set against which model is tested is known as a testing set or validation dataset. Aim of cross-validation is to test the dataset or model ability to predict new data that was not used in estimating it in order to flag problem like overfitting. Here K-fold cross-validation is used where k= 10. An exam example of k-fold cross-validation with k equal to '4' is shown below. The 10-fold cross-validation results for the halftone features as used in our work has been shown in Table 5.1. The results of Table 5.1. Have been obtained using μ=.1 and sigma=.1. The values of mu and sigma have been arrived through testing the SVM classifier with different combinations of mu and sigma.

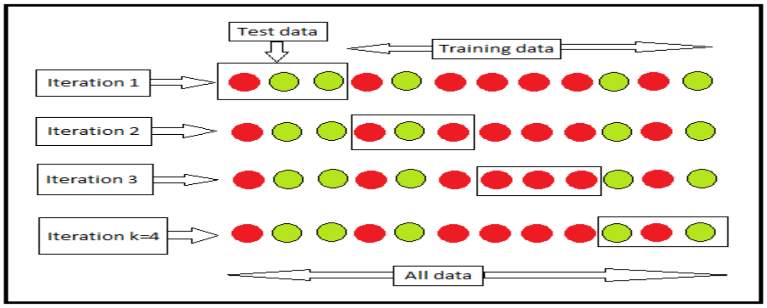



Fig.5.6 Diagram of k-fold cross-validation with k=4

Table 5.1. Results of 10-fold cross-validations.

| Features | Linear kernel | RBF kernel |
|---|---|---|
| **Stucki.serp** | | |
| 1. RAPSD | 72 | 96 |
| 2. Anisotropy | 82 | 90 |
| **Stucki** | | |
| 1. RAPSD | 82 | 98 |
| 2. Anisotropy | 80 | 98 |
| **Screen 19c** | | |
| 1. RAPSD | 82 | 98 |
| 2. Anisotropy | 76 | 96 |
| **Screen16u** | | |
| 1. RAPSD | 72 | 94 |
| 2. Anisotropy | 80 | 90 |
| **Screen 9u** | | |
| 1. RAPSD | 64 | 92 |
| 2. Anisotropy | 84 | 92 |
| **Screen 9c** | | |
| 1. RAPSD | 80 | 98 |
| 2. Anisotropy | 86 | 92 |
| **Javris** | | |
| 1. RAPSD | 82 | 96 |
| 2. Anisotropy | 80 | 92 |
| **Edgerrfixed** | | |
| 1. RAPSD | 76 | 96 |
| 2. Anisotropy | 82 | 92 |
| **Bnoise** | | |
| 1. RAPSD | 84 | 96 |
| 2. Anisotropy | 80 | 94 |

The result of 10 fold cross validation for linear kernel and radial basis function kernel shown above. From the above result, we can say that the radial basis function kernel has a higher degree of prediction than the linear kernel. Radial basis function has a 95% prediction of crack and no-crack data. The classification plot (actual vs. predicted) are shown in the following figures.

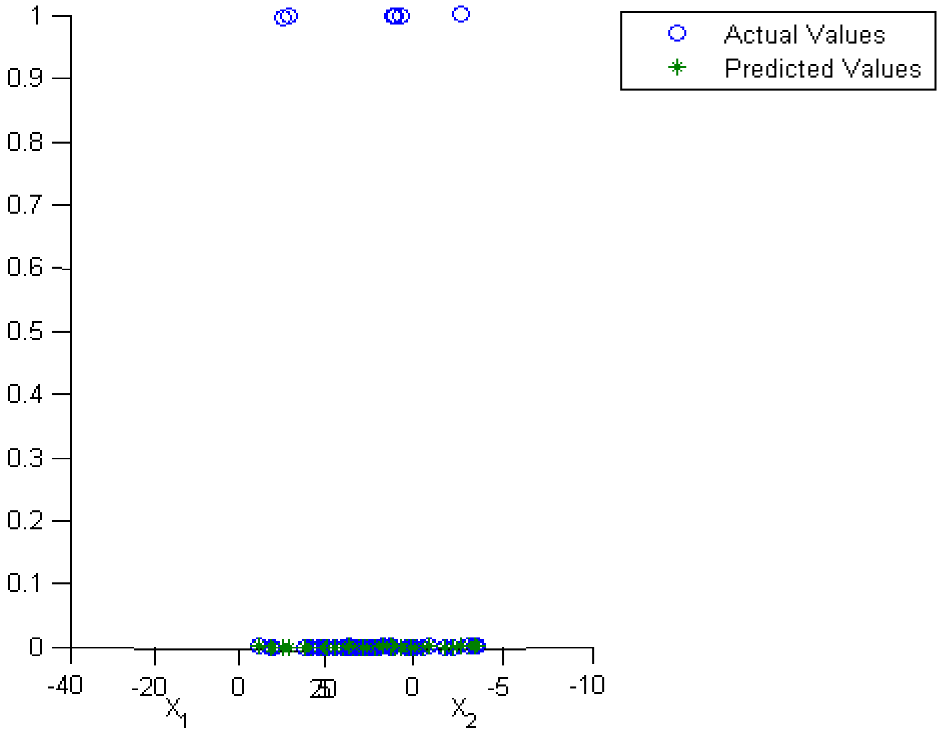



Fig.5.7 Actual vs Predicted value plot of Anisotropy for Stucki.serp

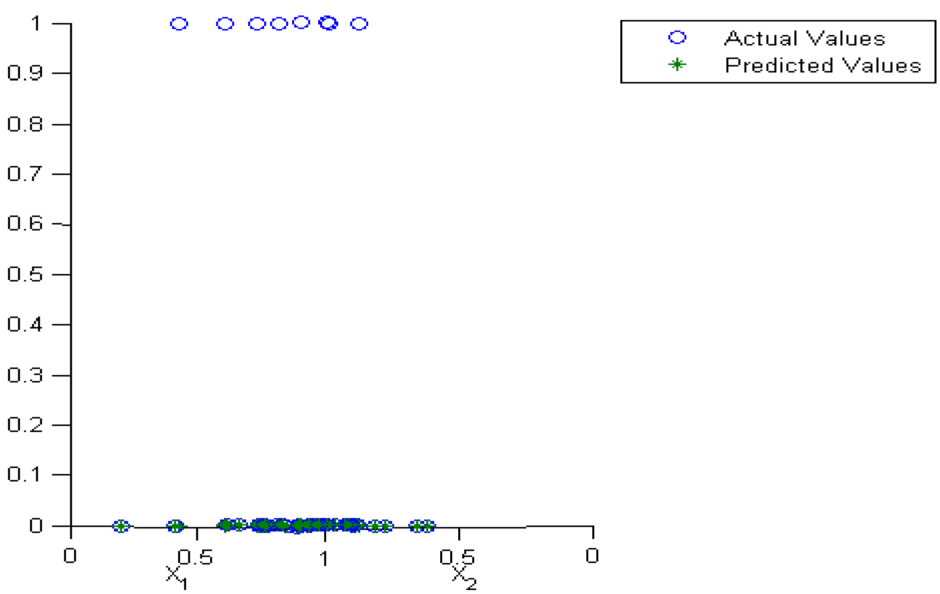



Fig.5.8 Actual vs Predicted value plot of RAPS for Stucki.serp

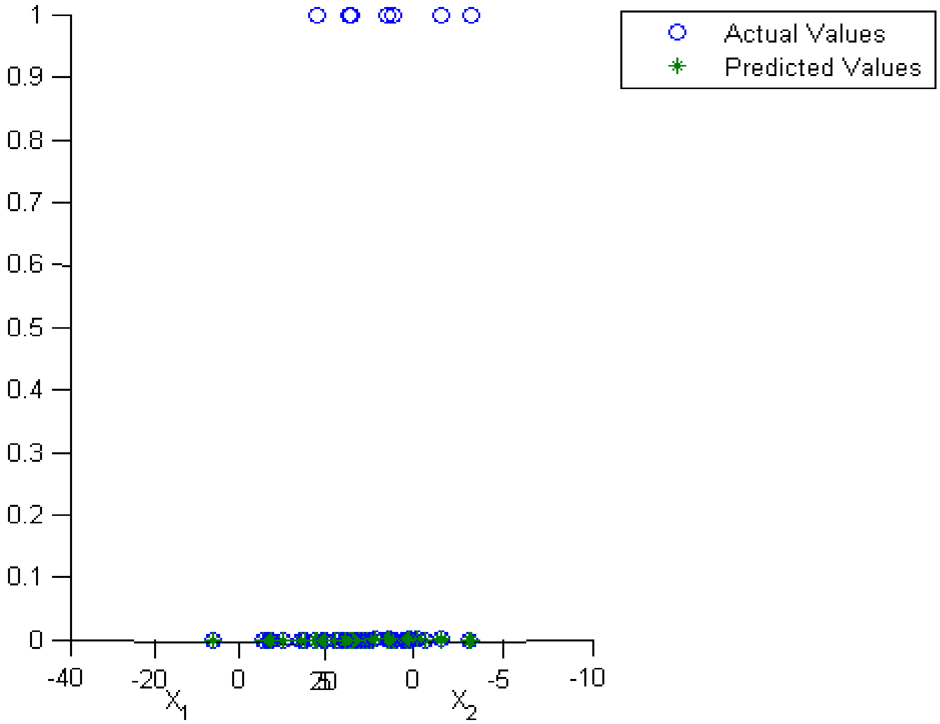



Fig.5.9 Actual vs Predicted value plot of Anisotropy for Stucki

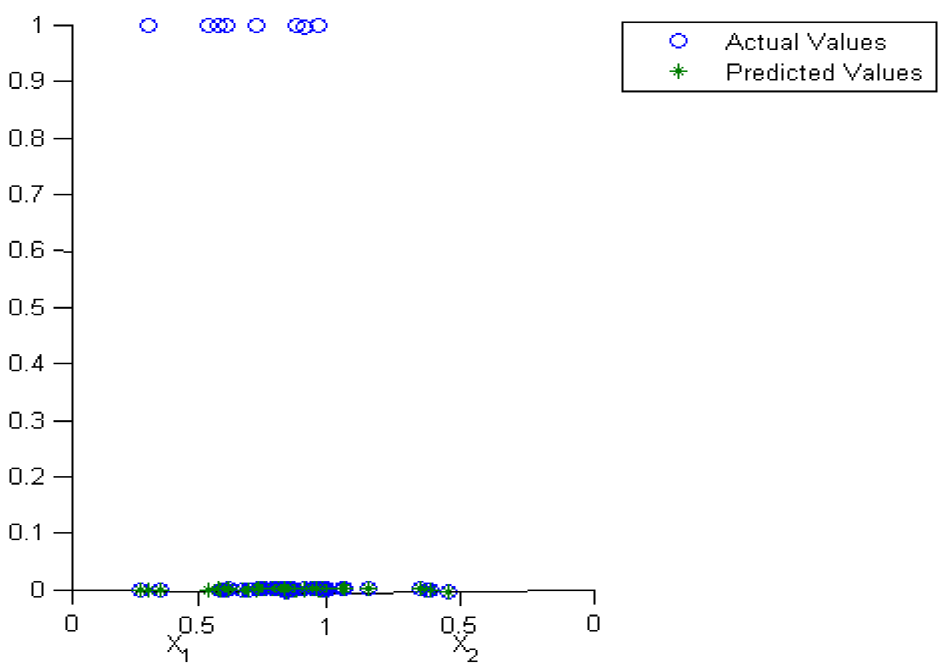



Fig.5.10 Actual vs Predicted value plot of RAPS for Stucki

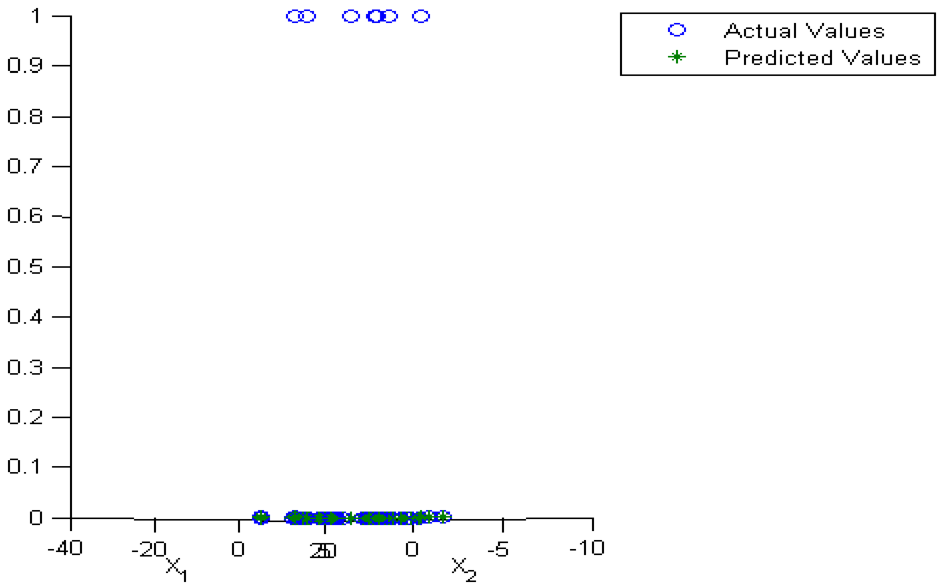



Fig.5.11 Actual vs Predicted value plot of Anisotropy for Screen 19c

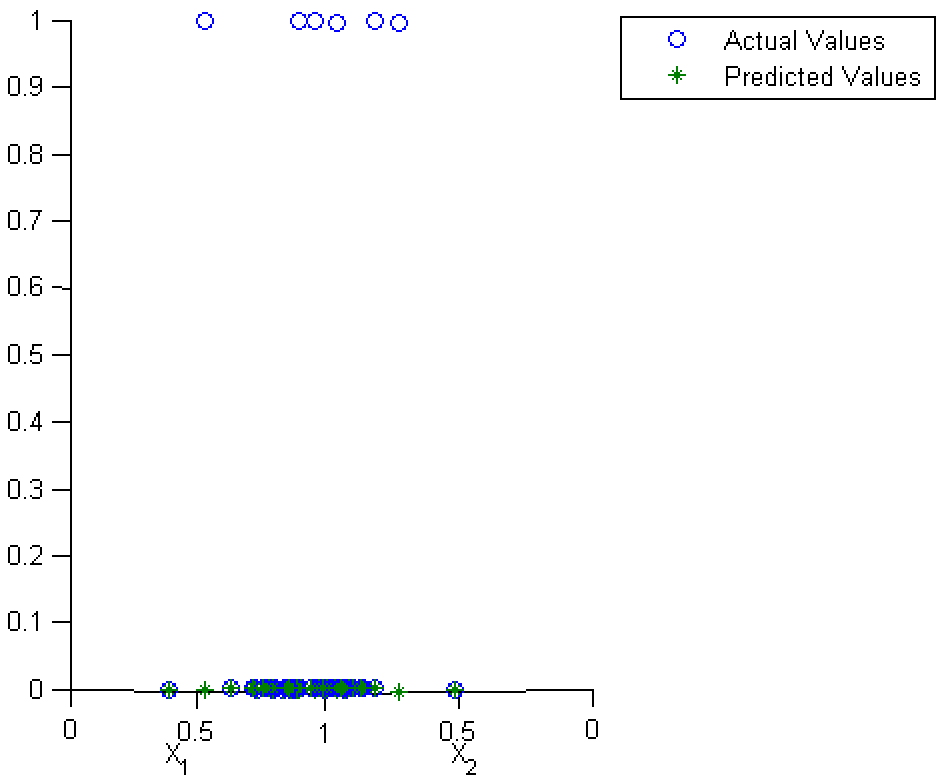



Fig.5.12 Actual vs Predicted value plot of RAPS for Screen 19c

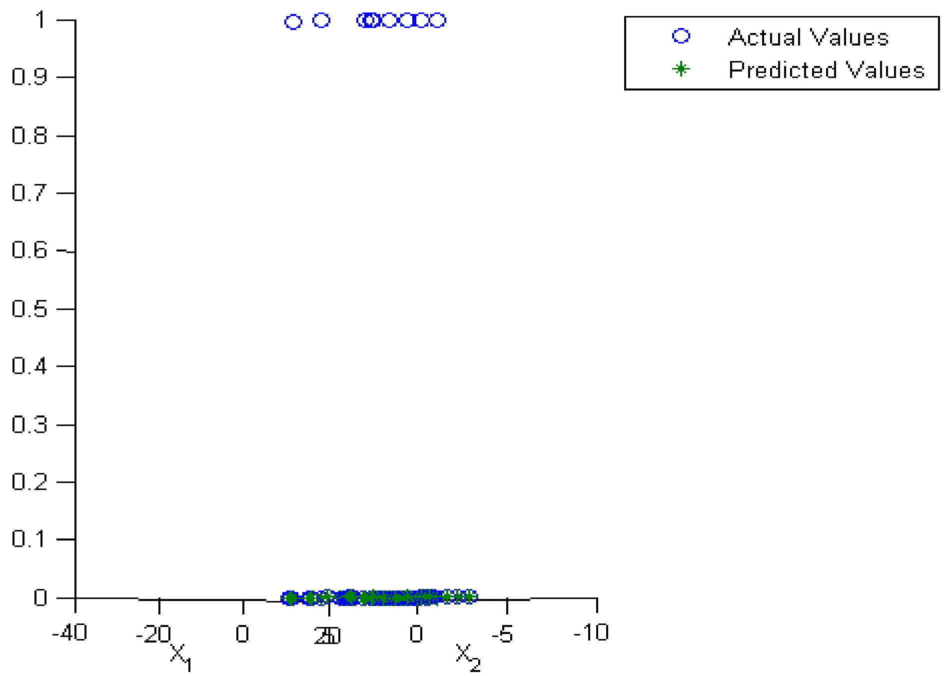



Fig.5.13 Actual vs Predicted value plot of Anisotropy for Screen 16

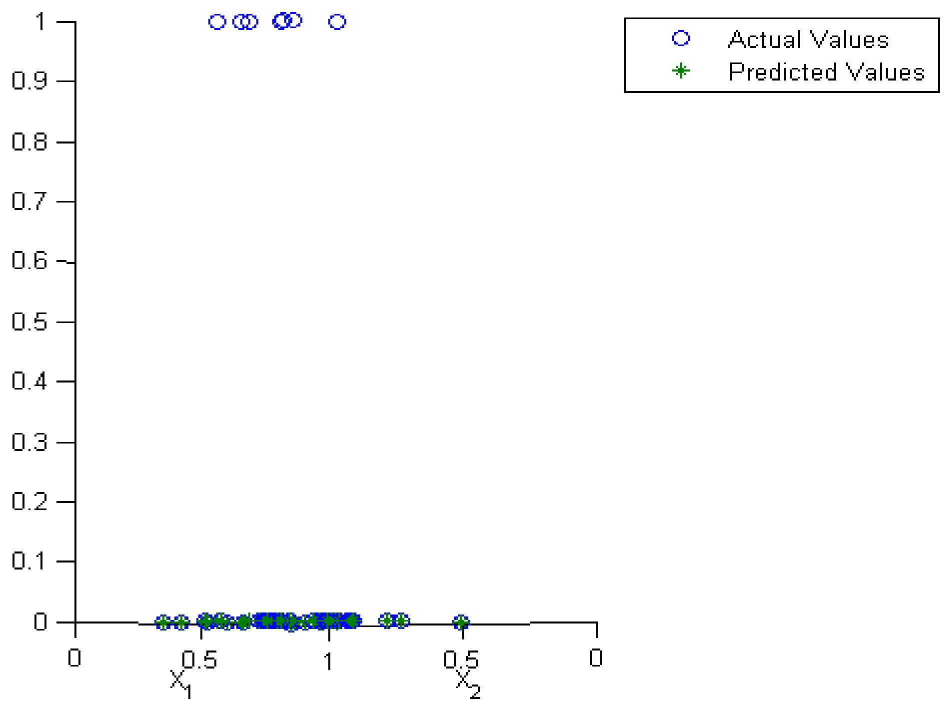



Fig.5.14 Actual vs Predicted value plot of RAPS for Screen 16u

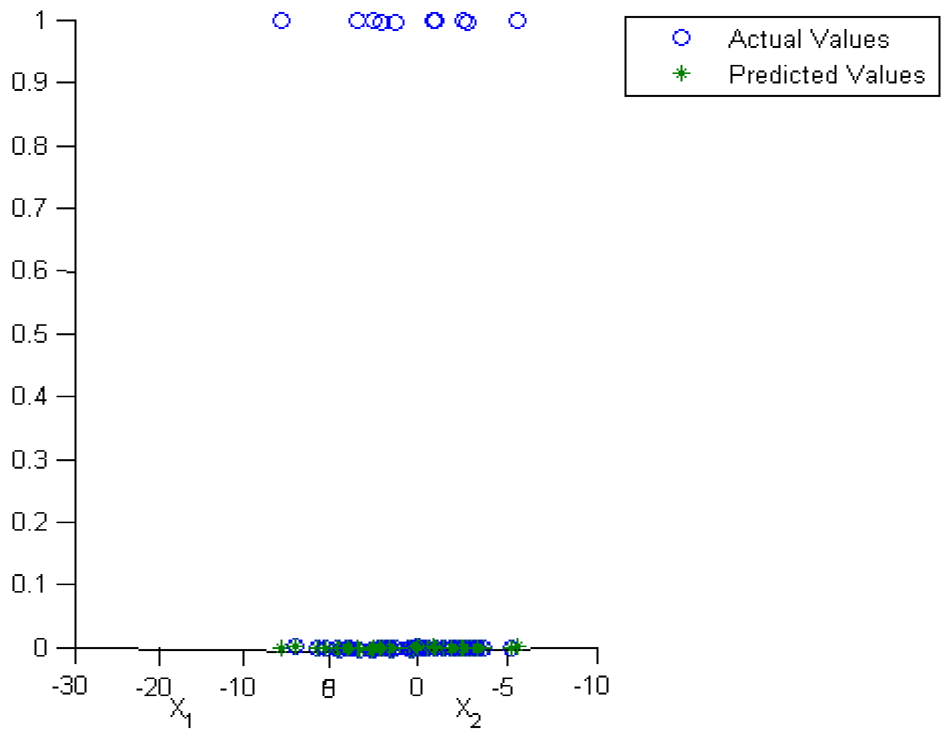



Fig.5.15 Actual vs Predicted value plot of Anisotropy for Screen 9u

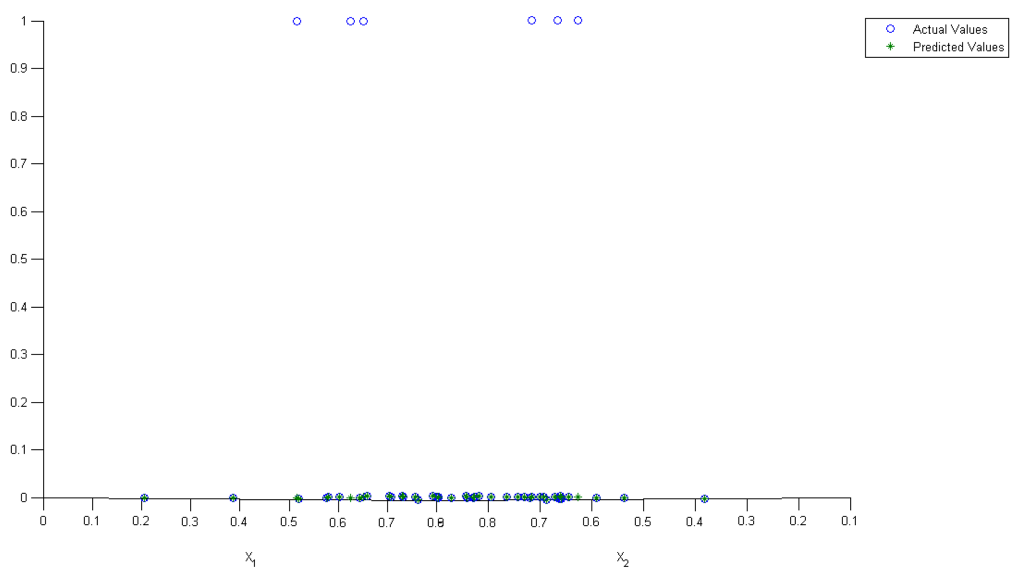



Fig.5.16 Actual vs Predicted value plot of RAPS for Screen 9u

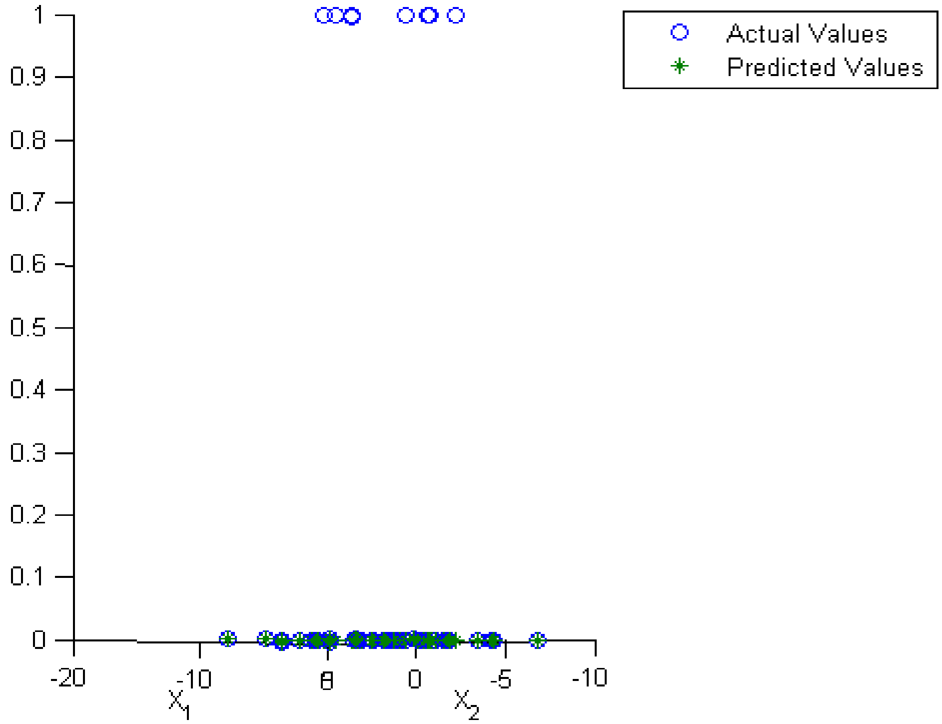



Fig.5.17 Actual vs Predicted value plot of Anisotropy for screen 9c

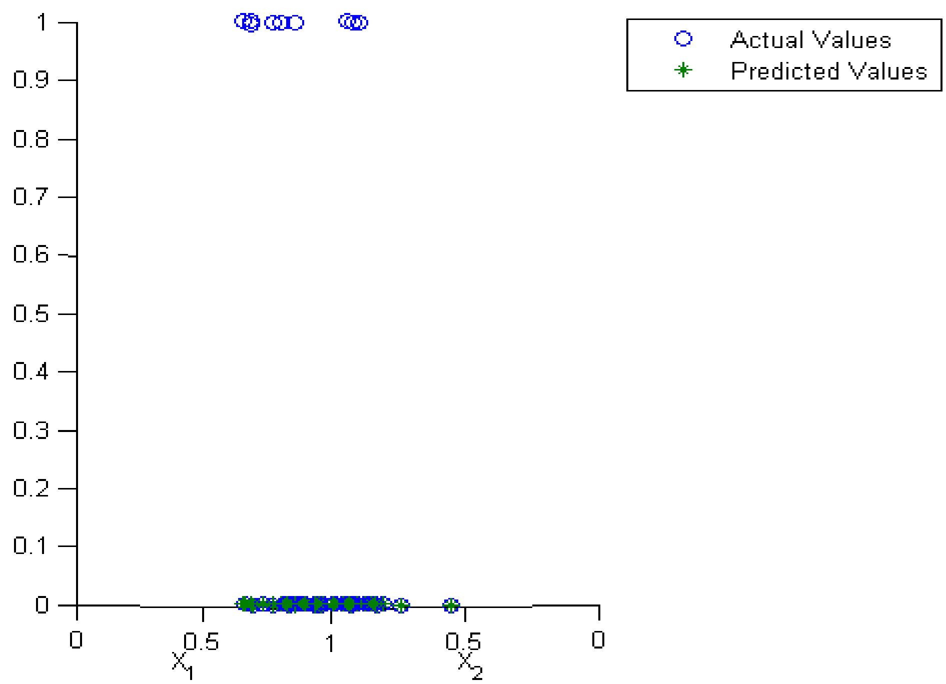



Fig.5.18 Actual vs Predicted value plot of RAPS for screen 9c

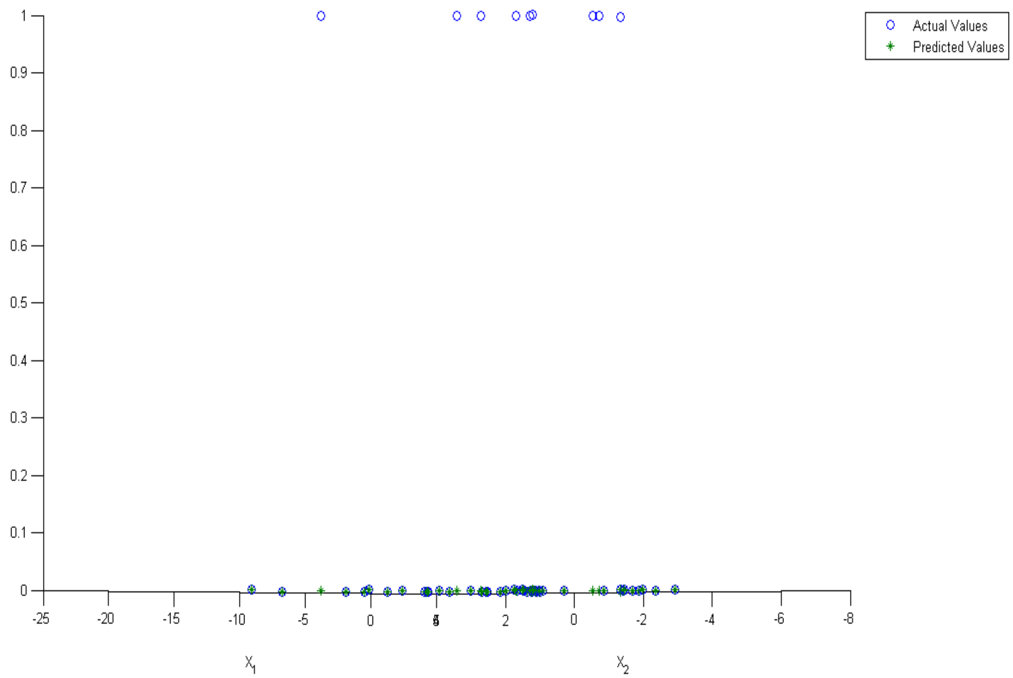



Fig.5.19 Actual vs Predicted value plot of Anisotropy for edgerrfixed.

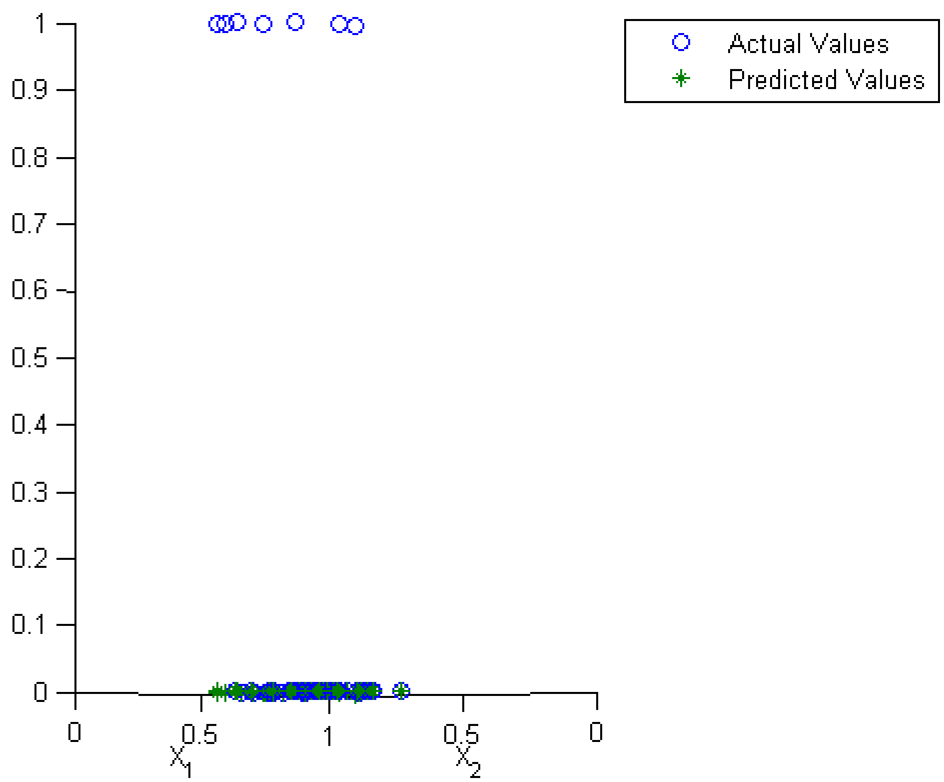



Fig.5.20 Actual vs Predicted value plot of RAPS for edgerrfixed.

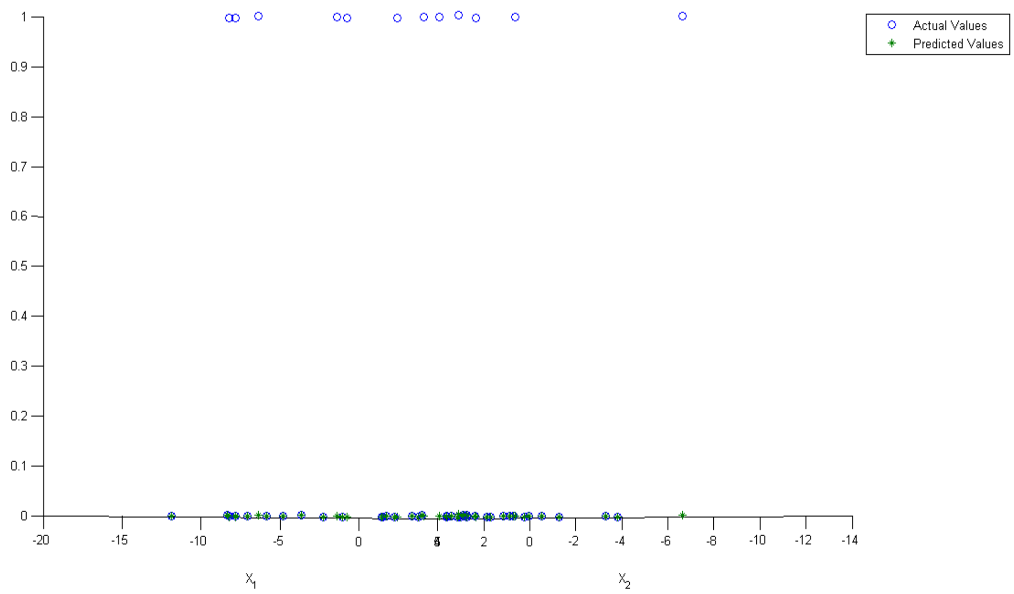



Fig.5.21 Actual vs Predicted value plot for Anisotropy of bnoise

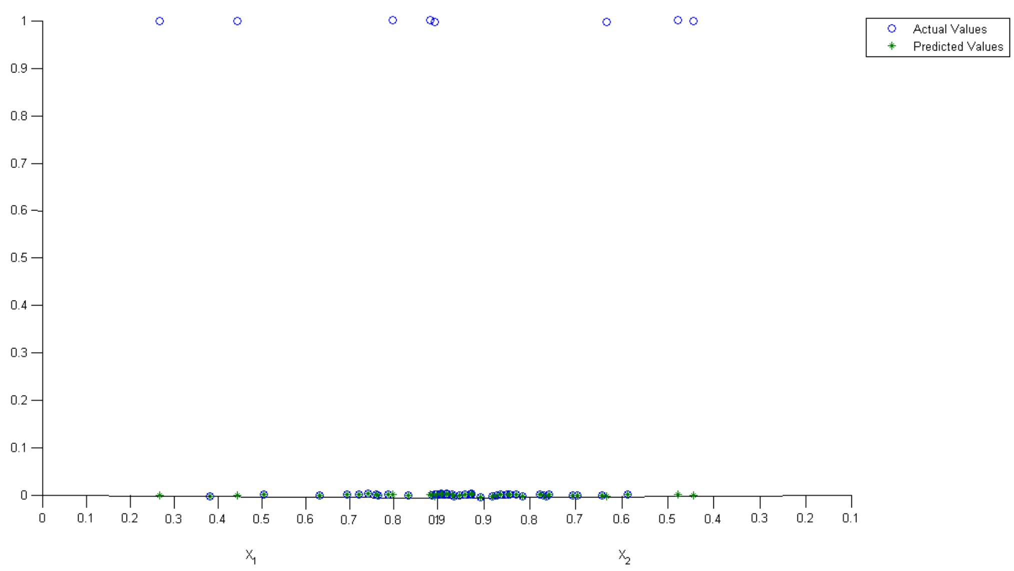



Fig.5.22 Actual vs Predicted value plot for RAPS of bnoise

From the shown plots of actual versus predicted value in the different halftoning method for anisotropy and rapsd it can be observed that both the rapsd and anisotropy has a good result but rapsd has a better result than anisotropy. In anisotropy only in stucki.serp halftoning method actual data match predictive value to some extent. But in rapsd actual versus predicted value for edgerrfixed show better than screen 9c and screen 16u. it has also a good result. The good result indicates the degree of matching of actual data with predictive data. Higher the degree of matching actual versus predicting better the result obtained.

**5.5 Classification Accuracy Measurement Using Precision-Recall and F1 Score.**

The process of identifying non- similar item and behaviors between two objects is called Anomaly detection. It is difficult to the identification of anomalies for every domain. For example, threat detection for cyber-attack[26,27], early diagnosis of medical diseases, etc. But in this work anomaly are identifying crack and no-crack. In time series data anomalies can be detected. Today, Precision and Recall are standard matrices for evaluating time series classification. The idea of Precision and Recall have been around since the 1950's. It is formulated to evaluate document retrieval algorithms by counting the number of documents that were correctly returned against those that were not[28]. Precision is the fraction of all detected irregularity(pattern of crack or no crack) in the sample that is irregular in real, whereas Recall is the fraction of all real variation that is successfully detected. The recall is also known as sensitivity and whereas precision is known as confidence. Precision and recall are defined as follows:

$$\text{Precision} = TP \div (TP + FP) \quad \text{(iv)}$$

$$\text{Recall} = TP \div (TP + FN) \quad \text{(v)}$$

Where TP represents true positive which means there is no crack in the actual image as well as no crack in the predicted image. Similarly, TN represents true negative which means crack in the actual image as well as the crack in the predicted image.

FP represents false positive which means in actual image crack are appear but in the predicted image, there is no crack and FN represents false negative which means in actual image crack does not appear but in predicted image crack will appear.

F1 Score is the function of precision and recall. Mathematically it is defined as follows

$$F1= 2*\frac{\text{Precision}*\text{Recall}}{Precision+\text{Re}\,call} \qquad \text{(vi)}$$

Table 5.2 Comparison of classification performance using rapsd features

| Technique (RAPSD) | True +ve | True -ve | False +ve | False –ve | precision | Recall | F1 |
|---|---|---|---|---|---|---|---|
| Stucki.serp | 0.76 | 0.22 | 0.02 | 0 | 0.97 | 0.98 | 0.98 |
| Stucki | 0.76 | 0.2 | 0.02 | 0.2 | 0.97 | 0.97 | 0.97 |
| Screen 19c | 0.7 | 0.28 | 0.02 | 0 | 0.97 | 0.99 | 0.98 |
| Screen 16u | 0.64 | 0.28 | 0.02 | 0.6 | 0.97 | 0.92 | 0.94 |
| Screen 9u | 0.74 | 0.18 | 0.02 | 0.6 | 0.98 | 0.93 | 0.95 |
| Screen 9c | 0.78 | 0.16 | 0.02 | 0.4 | 0.98 | 0.95 | 0.96 |
| Javris | 0.60 | 0.34 | 0.02 | 0.4 | 0.96 | 0.94 | 0.95 |
| Edgerrfixed | 0.74 | 0.24 | 0.02 | 0 | 0.97 | 0.99 | 0.99 |
| Bnoise | 0.62 | 0.34 | 0.4 | 0 | 0.94 | 0.99 | 0.97 |

Table 5.3 Comparison of classification performance using anisotropy features.

| Technique (Anisotropy) | True +ve | True -ve | False +ve | False -ve | precision | Recall | F1 |
|---|---|---|---|---|---|---|---|
| Stucki.serp | 0.66 | 0.26 | 0.08 | 0 | 0.89 | 0.99 | 0.94 |
| Stucki | 0.74 | 0.20 | 0.06 | 0 | 0.93 | 0.99 | 0.96 |
| Screen 19c | 0.62 | 0.22 | 0.16 | 0 | 0.80 | 0.99 | 0.89 |
| Screen 16u | 0.60 | 0.26 | 0.14 | 0 | 0.81 | 0.99 | 0.89 |
| Screen 9u | 0.70 | 0.22 | 0.08 | 0 | 0.89 | 0.99 | 0.95 |
| Screen 9c | 0.60 | 0.32 | 0.08 | 0 | 0.88 | 0.99 | 0.94 |
| Javris | 0.66 | 0.28 | 0.06 | 0 | 0.92 | 0.99 | 0.96 |
| Edgerrfixed | 0.66 | 0.26 | 0.08 | 0 | 0.90 | 0.99 | 0.94 |
| Bnoise | 0.72 | 0.24 | 0.04 | 0 | 0.95 | 0.99 | 0.97 |

Table 5.2 and 5.3 show the results of classification using precision, recall, and F1 score. As it can be seen in those tables that in all the cases for both RAPSD and anisotropy the classification accuracy i.e. the sum of TP and TN are coming about 95 %. At the same time the more than while it is coming 95% precision, recall and F1 score in most of the cases confirm the accuracy as well as repeatability of the presented classification. However, in some cases, the F1 score is lower in case of anisotropy compared to that with RAPSD features, but the F1 scores of anisotropy features are also in an acceptable range. Therefore, the halftone features can be considered as a possible alternative to existing features used for computer vision based structural health monitoring.

## 5.6 Conclusion

This chapter presents the scope of SVM classifiers towards the classification of crack and no-crack concrete samples using halftone features. The nature of the feature plots reveal that the crack and no-crack points are non-linearly distributed hence the performance of non-linear RBF kernel-based classification is better than the linear kernel. On an average 95% and above classification accuracy has been obtained using 10-fold cross-validation and Classification accuracy measurement parameter i.e. precision, Recall, F1 Score. Such acceptable performance can be considered to claim the presented halftone feature based SVM classification method as a possible alternative of the instrumental methods for crack detection in concrete structures.

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# CHAPTER-6

# Concluding Remark

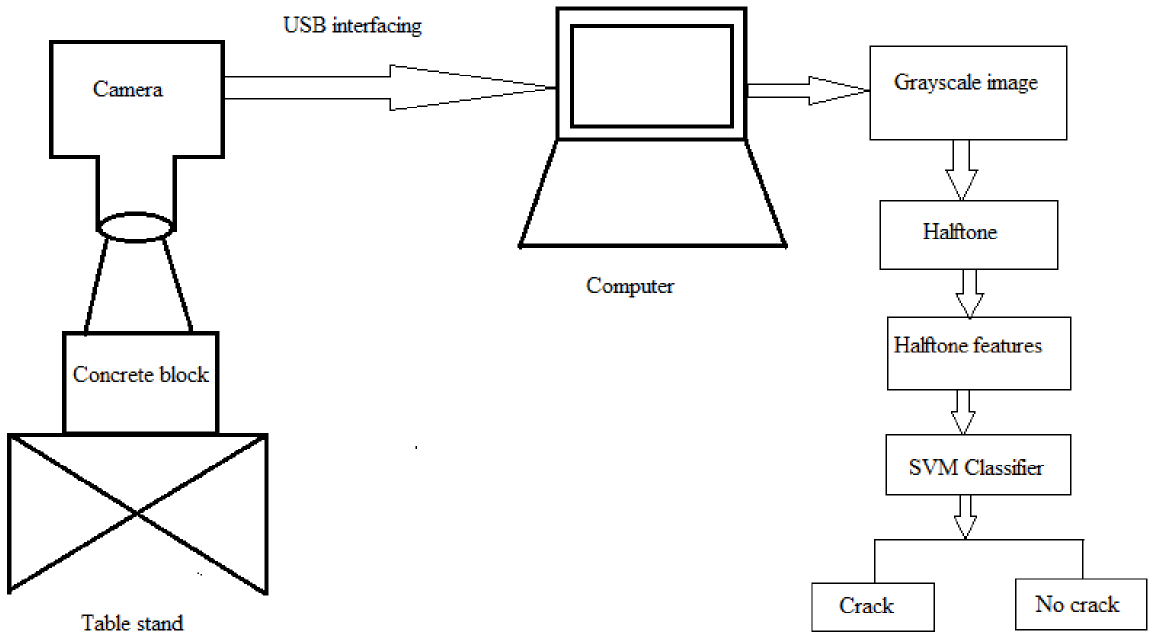
### 6.1 Introduction

Cracks in concrete are the sign of the health of the structure. So inspection of the crack should be done at regular interval of time. So that if any damage is found then it should be corrected before any accident will take place. There are a number of conventional methods that are used to measure crack i.e crack magnifier, crack width meter and crack monitor, etc. All these methods are performed manually. Now a days the development of a technique for detection of crack by computer vision is becoming popular. Some name of computer vision technique which is used to detecting crack is impedance based, Percolation based image processing, multiple sequential image filtering, etc.

This work approached to develop detection of crack by computer vision using halftone features. Firstly the concrete sample contains cracks were collected and images of a crack in concrete samples/blocks were captured through a mobile device. The clarity of the pictures was ensured by the lighting and focus of the mobile camera. After taking image that were processed in Matlab® where images were converted from RGB to grayscale. Then the images were divided randomly into '30' sub-images. Using different halftoning technique namely blue noise mask (bnoise), fixed edge enhancement error diffusion (edgerrfixed), Stucki.serp, Stucki, screen 19c, screen 16u, screen9u, screen9c and Javris. The anisotropy and RAPSD features were extracted from the halftone images obtained using those techniques. The features were labeled as '0' for no-crack and '1' for crack. Using the K-mean clustering algorithm features data were divided into 2 clusters. The centroid of both the clusters were well separated as examined statistically in all halftoning techniques but for data point Javris and edge error diffusion shown better seprability. After clustering of data point classification of data,the point was carried out. Classification of data point was done by support vector machine classification algorithm where data is classified using both linear and non-linear kernel. The results and analysis revealed that the data is better classified by the non-linear kernel as the data is not linearly separated.

### 6.2 Proposed System

In real-time applications, the work can be implemented as the following diagram in Fig. 6.1. The camera in the diagram can be a CCTV type which can continuously send the images of the structure under surveillance. The computer in the monitoring room can bring still frames of images from the CCTV video footage and that can be analyzed thought he halftones feature and machine learning based system to identify the occurrence of crack. This can be even clubbed with the alarming system which can send alarm when the crack comes to the designated devices.




### 6.3Major Findings

The major findings from this work can be summarized as below;

- Halftone features can be applied for detecting crack in the concrete.
- About and above 95% classification accuracy can be achieved with the support vector machine classifier using halftoned features.
- It does not require huge manpower.
- This method is less time consuming and non-destructive.
- This can be a less expensive monitoring system for structural health.

## 6.4 Future Scopes

Some of the important future scope for the extension of this work can be listed as;

- Use of other halftone and textural features for enhanced classification.
- Detection from video streaming of the structure health.
- Application of other classifiers like Fuzzy, neural networks, RFS, etc.
- More accuracy can be achieved by this technique as it is fully computer vision based.
- App-based development for on-the-go structural health monitoring.

## 6.5 Conclusion

The work presents the potential of digital halftoning, a process generally used for printing of continuous tone images, as it can play important roles by means of halftone statistic features towards crack and no-crack image detection. The real-life application based on investigations made in this thesis is presented in this chapter. The major findings and possible future directions of research works are also presented. Overall, the thesis work reveals the possibility of using halftone features and machine learning algorithm towards the development of a computer vision system for structural health monitoring that can be advantageous in terms of less time consumption, easy to handle, less expensive and less manpower intensive.

# Appendix

All the established technique and the new method used in this thesis are tested with the Matlab environment. All are given below.

Program 1: function rand_block_selection

```
a=rgb2gray(cr3);
s=size(a);
bl=50;
s1=s(1)-bl;
s2=s(2)-bl;
for i=1:k
m = randint(1,1,[1 s1]);
n = randint(1,1,[1 s2]);
bl1=a(m:m+bl-1,n:n+bl-1);
 imshow(bl1)
feat(i,:)=reshape(bl1,1,2500);
end
```

**Program 2: Digital halftoning**

Installing halftoning tool and apply it to image.

```
ab30=errdiff(im2double(sam3_b30));
a1b30=bnoise(im2double(sam3_b30));[1,2],[1,1],[0,0],0;
a2b30=bed(double(sam3_b30),[3,3],[0,1,0;1,1,1;0,1,0;],[
1,0,1;0,0,0;1,0,1],0);
```

**Program 3: Features extraction**

```
[raps_ft,fr,count]= RAPSD (x,[m],[FM],[DM,DN]);

[anis_ft,fr,count]= ANIS (x,[m],[FM],[DM,DN]);
```

**Program 4: Clustering of data by kmean algorithem**

```
%load('feat2.mat');
F=raps_ft(:,:);
% kmeans(double(F_bnoise),2);
[idx, Cntrs, sumd]=kmeans(double(F),2);
%idx=ans;
X1=F(idx==1,:);
X2=F(idx==2,:);
m=[mean(X1) mean(X2)]
M=mean(m);
WSS=sum(sum((X1-m(1)).^2)+sum(sum((X2-m(2).^2))))
BSS=sum((size(X1,1)*(M-m(1)).^2))+sum(size(X2,1)*((M-
m(2)).^2));
C=(WSS+BSS)
scatter(anis_ft(idx==1,1),anis_ft(idx==1,2));hold on
scatter(anis_ft(idx==2,1),anis_ft(idx==2,2));
```

**Program 5: Classification of data by SVM classifier**

```
for i=1:10
tr_t=randperm(500,50);
xtest=data(tr_t,1:end-1);
ytest=data(tr_t,end);
for j=1:50
    fx2ts(j,:)=alpha(j)*kernel(xtest,xtest(j,:),'g')';
end
fxt=sum(fx2ts)';
disp('[Actual Values  Predicted Values]')
disp([ytest(1:10) ,fxt(1:10)])
% Mean Square error (Gaussian Kernel)
mse=norm(ytest-fxt)^2/N;
% Plotting
figure
hold on
scatter3(xtest(:,1),xtest(:,2),ytest)
scatter3(xtest(:,1),xtest(:,2),fxt,'*')
hold off
xlabel({'X_1'});
ylabel({'X_2'});
view([-46.4 -0.40]);
```

```
legend1 = legend('Actual Values','Predicted Values');
Me(i)=mean(round(fxt)==ytest)*100
end
```

**Program 6: Classification performance measurement**

```
tp=sum(p2==0 & ytst==0)/50
fn=sum(p2==1 & ytst==1)/50
fp=sum(p2~=1 & ytst==0)/50
fn=sum(p2~=1 & ytst==1)/50
prec=tp/(tp+fp)
rec= tp/(tp+fn)
F1=2*(sum(prec.*rec))/sum(prec+rec)
```