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Design and Development of Automatic Appendicitis Detection System using Sonographic Image Mining

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Abstract*— The acute appendicitis necessitates emergency abdominal surgery and in the past decade, sonography has gained acceptance for examining patients with acute abdominal pain. Sonographic imaging is dynamic, noninvasive, rapid, inexpensive, and readily accessible. Manual analysis of sonographic image is a tedious process and consumes enormous time. This research work aims at bringing out an automatic system to detect acute appendicits by taking sonographic images as input. This paper describes the image mining system that automates the diagnosis of acute appendicitis with significant time reduction. The experimentation methods, results of the testing using real data are detailed in this paper. The data set of 44 patients' sonographic images collected from a reputed hospital in India has been used as input. The conclusion is that region based segmentation algorithm followed by Euclidean distance method yields accurate diagnosis of appendicitis.

***Index Terms*—Image Mining, Euclidean Distance, Data Mining, Appendicitis, Region-Based Segmentation Algorithm.**

I. INTRODUCTION

The biological research relies on both visual and numerical data to confirm a proposed hypothesis and use of high throughput approaches in biomedical sciences has resulted in increased data collection. These could be predominantly text data like micro array data, human genome data and data from proteomics experiments or image data from micro arrays, immune histochemistry, immune cytochemistry and MRI. Non-textual data size can grow quite remarkably in today's systems [9, 10, 11].

Appendicitis is an inflammation of the appendix and there is no effective medical therapy for it patients consult the doctor and get treatment promptly. Most patients recover without difficulty and if treatment is delayed, the appendix can burst, causing infection and even death. Appendicitis is the common acute surgical emergency of the abdomen. Appendicitis occurs most often between the ages of 10 and 30 [13]. Image Mining is a budding technology that effectively combines computer vision, image understanding and machine learning, helping to diagnosis appendicitis in ultrasound images [12].

This paper describes diagnosis of appendicitis in sonographic images using Euclidean Distance Technique. Section II describes an overview of the image mining, Section III represents Related Work for Diagnosing Appendicitis, Section IV demonstrates a background needed to understand appendicitis, Section V describes a Existing Methods for Appendicitis Diagnosis; Section VI describes System Description. Section VII details about the results and discussions. Section VIII represents an experimental study. Finally, Section IX concludes the paper..

II. IMAGE MINING

Image mining deals with the extraction of image patterns from a large collection of images [42]. Discovering knowledge from data stored in alphanumeric databases, such as relational databases, has been the focal point of data mining. The advances in secondary storage capacity, low storage cost, more and more nonstandard data is being accumulated. The central research issue in image mining is how to preprocess image sets that supports the application of data mining algorithms [14]. Advances in image acquisition and storage technology have led to great growth in very large and detailed image databases [15]. A huge amount of image data is generated in our daily life. These images involve a great number of useful and implicit information that is difficult for users to discover. Image mining can automatically discover this implicit information and patterns from this high volume of images. Image mining is an extension of data mining to image domain [36].

Researches in image mining are broadly carried out in two main directions. The first direction involves domain-specific applications where the focus is to extract the most relevant image features into a form suitable for data mining [16, 17, 18]. The second direction involves general applications where the focus is to generate image patterns that maybe helpful in the understanding of the interaction between high level human perceptions of images [19, 20, 21].

III. RELATED WORK

G. Prabhudesai et al. proposed that artificial neural networks can be a useful aid in diagnosing acute appendicitis. They used an back propagation algorithm and the weights of the connections were altered in an attempt to reduce the mean square error of the whole data set [27]. E.Sivasankar et al. proposed that Back propagation Neural Network and Bayesian Based Classifier can be an useful aid in Diagnosing Appendicitis [13].

R. Balu and T. Devi proposed a method for identification of acute appendicitis using Euclidean distance on sonographic image [32]. Aleksander and Jan Komorowski proposed a computer model, based upon clinical attributes with additional access to the results of certain biochemical tests which performed better than a classifier realized by probability estimates given by a team of

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physicians, based only upon the clinical attributes [28]. Ikramullah Khan, Ata ur Rehman used an Alvarado scoring system which depends on the presence and absence of certain variables and which provides an accurate guide to whether or not the patient has the appendicitis [29]. Mesut Tez and Selda Tez proved that neuro fuzzy systems can incorporate data from many clinical and laboratory variables to provide better diagnostic accuracy in acute appendicitis [30]. R. Balu and T. Devi have explored the image mining in depth in order to propose algorithms for improving the efficiency and effectiveness of image mining [36].

IV. APPENDICITIS

Introduction of new imaging technology in graded compression ultrasound has changed "the rules of the game". The adult appendix is a long diverticulum's averaging 10 cm in length that arises from the poster medial wall of the cecum, approximately 3 cm below the ileocecal valve [11]. The appendix may lie in a retrocecal, subcecal, retroileal, preileal, or pelvic site which influences the clinical presentation [12, 13]. The maximum incidence of the disease occurs in the second decade; thereafter, disease incidence declines with age [14, 15]. The primary pathogenic event in the majority of patients with acute appendicitis is luminal obstruction [16-18]. Fecoliths, which results from the inspissations of fecal material and inorganic salts within the appendiceal lumen, are the common cause of obstruction [19-21]. The existence of appendicitis is found out using the distance measure on the sonographic image of the patient who is diagnosed for appendicitis [32].

The appendix is an appendage or appendix like structure. It is a wormlike intestinal diverticulum's extending from the blind end of the cecum; it varies in length and ends in a blind extremity [41]. Ultrasound is available and inexpensive modality with the potential for highly accurate imaging in the patient suspected to have acute appendicitis. Although skill is an important factor in all ultrasound examinations, it has particular importance in the examination of the patient with right-lower-quadrant pain. Nonetheless, the criteria for the ultrasound based diagnosis of acute appendicitis are well established and reliable [22-24]. Ultrasound is highly useful in identifying an alternate diagnosis [25]. Symptoms of appendicitis include pain in the lower right abdomen, loss of appetite, nausea and or vomiting, with or without fever and mild diarrhea or constipation. The pain could be higher in appendicitis in pregnancy, or even lower in those with very long appendix. Early symptoms of appendicitis are those symptoms that most people with this condition may recognize and complain. They include lower right sided abdominal pain of gradual onset, feeling sick and loss of appetite [26].

V. EXISTING METHODS FOR APPENDICITIS DIAGNOSIS

The diagnosis of appendicitis begins with physical examination. The Patients often have an elevated temperature, and usually these will be moderate to severe tenderness in the right lower abdomen. The inflammation has spread to the peritoneum, there is a frequently rebound tenderness. Rebound tenderness is worse when the doctor quickly releases his hand after gently pressing on the abdomen over the area of tenderness [32].

A. Leukocytes Count

The white blood cell count in the blood usually becomes elevated with infection. In appendicitis, before infection sets in, it can be normal, but most often there is at least a mild elevation even early. Appendicitis is not the only condition that causes elevated white blood cell counts and almost any infection or inflammation can cause this count to be abnormally high. Therefore, an elevated white blood cell count alone cannot be used as a sign of appendicitis [33].

B. Urinalysis

Urinalysis is a microscopic examination of the urine that detects red and white blood cells, and bacteria in the urine. Urinalysis is abnormal when there is inflammation or stones in the kidneys or bladder. The urinalysis may be abnormal with appendicitis because the appendix lies near the ureter and bladder and if the inflammation of appendicitis is great enough, it can spread to the ureter and bladder leading to an abnormal urinalysis. Most patients with appendicitis have a normal urinalysis and suggests appendicitis more than a urinary tract problem.

C. Abdominal X-Ray

An abdominal x-ray may detect the fecalith (the hardened and calcified, pea-sized piece of stool that blocks the appendiceal opening) which may be the cause of appendicitis, in case of children.

D. Ultrasound

An ultrasound is a painless procedure to identify organs within the body. Ultrasound can identify an enlarged appendix or an abscess. Nevertheless, during appendicitis, the appendix can be seen only in 50% of patients. Therefore, not seeing the appendix during an ultrasound does not exclude appendicitis. Ultrasound can exclude the presence of conditions involving the ovaries, fallopian tubes and uterus that can mimic appendicitis.

E. Barium Enema

A barium enema X-ray test, liquid barium is inserted into the colon from the anus to fill the colon. This test, shows an impression on the colon in the area of the appendix inflammation from the adjacent inflammation impinges on the colon. Barium enema can exclude intestinal problems that mimic appendicitis, of Crohn's disease.

F. Computerized tomography (CT) Scan

In patients computerized tomography scan of the area of the appendix is useful in diagnosing appendicitis and peri-appendiceal abscesses in excluding other diseases inside the abdomen and pelvis that can mimic appendicitis [33].

G. Laparoscopy

Laparoscopy is a surgical procedure and small fiber optic tube with a camera is inserted into the abdomen through a small puncture made on the abdominal wall. Laparoscopy shows a direct view of the appendix and the inflamed

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appendix can be removed with the laparoscope. The disadvantage of laparoscopy compared to ultrasound and computerized tomography is that it requires a general anesthetic [33].

VI. System Description

An automatic system for detecting acute appendicitis from sonographic images consists of five steps: (a) The first step is image capturing; the ultrasound image is acquired from patient database through mat lab (b) The second step is image preprocessing; the appendicitis regions such as label, marks on the image are removed (c) The third step is image enhancement; noise in the preprocessed image is removed through median filter (d) The fourth step is Performance Evaluation; where performance of median filter has been analyzed completely (e) The final step is Euclidean distance calculation; The distance is the predominant measure to bring out the diagnosis. The Euclidean distance is used here to find out the measure of the acute appendicitis.

A. Automatic System

The Automatic appendicitis detection is a difficult task on the adjustment and the density of the appendicitis and challenging task of researchers due to high degree intensity and textural similarity arise between normal and appendicitis areas. Ultrasound is an effective tool in the study of the human abdomen and provides a great knowledge of normality and diseased anatomy for medical research.

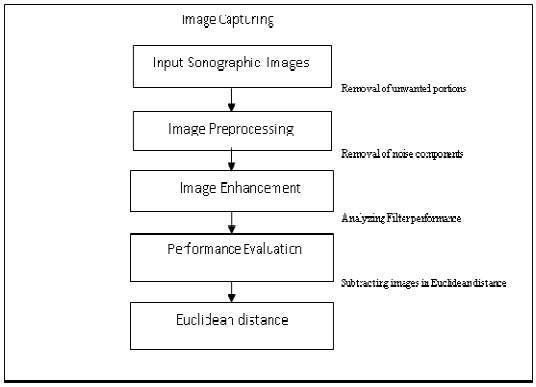

Fig.1. Flow Diagram for Automatic System

B. Image capturing

Image Capturing is a process to acquire the digital image into Matlab. In this module medical image was given as input and all types of medical images can be acquired in this module. Images of a patient obtained are displayed as an array of pixels and stored in memory. Large matrix will specify a black and white image and 0 corresponds to black and 1 to white. A grey scale image can be specified by giving a large matrix whose entries are numbers between 0 and 1. A black and white image is specified by giving a large matrix with integer entries. The lowest entry corresponds to black and the highest to white. Ultrasound image from the database is obtained through imread command in mat lab. The exact path of the image should be given as the argument to imread command. The image of the patient is displayed as an array of pixels and stored in the memory. In mat lab, captured image is displayed using imshow command by passing a variable as the argument and the image can also be displayed in the image viewer using imtool command.

C. Image preprocessing

The prime objective of the preprocessing is to improve the image data quality by suppressing undesired distortions and also enhancing the required image features for further processing. The irrelevant data present in the image has been eliminated using the pre-processing technique. The pre-processing technique eliminates the incomplete, noisy and inconsistent data from the image in the training and test phase [22].

D. Region-Based Segmentation Algorithm

In preprocessing module image acquired will be processed for correct output. Pre-processing was done by using algorithm and for all images the pre-processing should be done so that the result can be obtained in a better way. To find out the transformation between two images precisely, they should be preprocessed to improve their quality. In the images are too noisy or blurred, they should be filtered and sharpened and for removing the unwanted portions of the image, region-based segmentation algorithm has been developed.

The main idea is to classify a particular image into a number of regions or classes. Thus for each pixel in the image, there is a need to somehow decide or estimate which class it belongs to. This paper lies on an integrated boundary finding approach. Given the raw image and the region classified image, it does not matter which method is being used to get the region classified image as long as the output of that method gives reasonable results [31].

E. Median Filtering

Histogram equalization [23, 24] helps to improve the contrast of the image without affecting the structure. In signal processing, it is often desirable to be able to perform some kind of noise reduction on an image or signal. The median filter is a nonlinear digital filtering technique, often used to remove noise and such noise reduction is a typical pre-processing step to improve the results of later processing. Median filtering is very widely used in digital image processing because, under certain conditions, it preserves edges while removing noise [25].

Median filtering is a non-linear signal enhancement technique for the smoothing of signals, the suppression of impulse noise. The median filter is a spatial filter but it replaces the center value in the window with the median of all pixel values in the window. This filter is applied to remove the high frequency component in the image. The merit of filter is that, it can remove the noise without disturbing the edges. The kernel of median filter is usually square but can be of any shape.

F. Edge Detection

The edge detection method called the canny edge detection with the threshold value of 0 has been used. Edge feature along with the color feature gives good efficiency [22]. Edge detection technique can be used significantly to reduce the

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amount of data in an image and time structural properties of an image can be preserved for further analysis. In proposed method, canny edge detection technique has been used with the following criteria [22]. The probability of detecting real edge points should be maximized while the probability of falsely detecting non-edge points should be minimized. This corresponds to maximizing the signal-to-noise ratio and the detected edges should be as close as possible to the real edges. One real edge should not result in more than one detected edge [22].

G. Image Enhancement

The preprocessed images will have some noise which should be removed for the further processing of the image. The Image noise is most apparent in image regions with low signal level such as shadow regions or under exposed images. In conventional enhancement techniques such as low pass filter, median filter, Gabor filter, Gaussian filter, prewitt edge-finding filter, and normalization method are employable for this work. Dimitris et al. presented a new method on Gabor Filter which is applied to remove the tagging lines and enhance the tag-patterned regions in the image. Karnan et al. designed a new CAD system for Image enhancement using median filter and Tsai et al. studied low pass filter to take care of local noisy fluctuations, the bone and soft tissue outlines are eliminated. Ladan et al. studied edge finding filter for reducing noise and prewitt filter for improving the image quality.

H. Euclidean distance

In this paper, the appendicitis is detected using the distance measure in order to confirm the patient is diagnosed with appendices. The distance is predominant to bring out the diagnosis. The Euclidean distance is used to find out the measure of the acute appendicitis.

Euclidean distance is the distance between two points in Euclidean space of points P and Q in two dimensional Euclidean spaces. P with the coordinates (p1, p2) and Q with the coordinates (q1, q2) and construct a line segment with the endpoints of P and Q. This line segment will form the hypotenuse of a right angled triangle. The distance between two points' p and q is defined as the square root of the sum of the squares of the differences between the corresponding coordinates of the points. In two-dimensional Euclidean geometry, the Euclidean distance between two points a = (ax, ay) and b = (bx, by) is defined as:

$$d(a,b) = \sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2}$$

This algorithm computes the minimum Euclidean distance between a column vector x and a collection of column vectors in the codebook matrix cb. This algorithm computes the minimum distance to x and finds the column vector in cb that is closest to x. It outputs this column vector y, its index, idx, cb, and distance, the distance between x and y.

Step1: load the column vector x;

Step2: load the code book;

Step3: minimum distance is initially set to the first element of cb.

Step4: set idx=1;

Step5: compute distance by normalized values of (x-cb) for all cb;

Step6: if d is less than distance set distance is equal to d;

Step7: set idx=index;

Step8; end

Proposed method Algorithm

$$d(a,b) = |p - q|$$

$$\sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2 + \cdots + (p_n - q_n)^2}$$

$$= \sqrt{\sum_{i=1}^{n} (p_i - q_i)^2}$$

In one dimension, the distance between two points, x1 and x2, on a line is simply the absolute value of the difference between the two points: [32]

$$\sqrt{(X_2 - X_1)^2} = |X_2 - X_1|$$

In two dimensions, P = (p1, p2) and q = (q1, q2) is:

$$\sqrt{(p_1 - q_1)^2 + (p_2 - q_2)^2}$$

This tutorial computes the minimum Euclidean distance between a column vector x and a collection of column vectors in the codebook matrix cb. The function has three output variables:

- y, the vector in cb with the minimum distance to x
- idx, the index of the column vector in cb corresponding to the closest vector
- distance, the distance between x and y

VII. RESULTS AND DISCUSSIONS

An experiment has been conducted on ultrasound scan image based on the proposed flow diagram for automatic system as shown in Fig.1. The sonographic image is first captured as an input image, and then decorrelation stretch has been used to remove the noise component from that image. Fig.2 represents the original input image and Fig.3 shows the result of histogram equalization of original image, which is used to reduce the noise at the scanning phase.

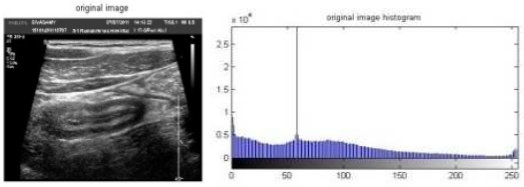

Fig.2. Ultrasound Scan Image

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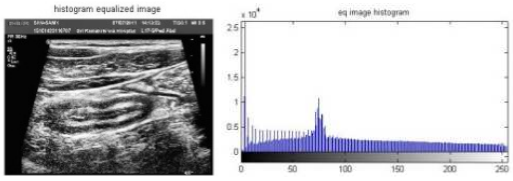

Fig.3. Histogram equalized image

Decorrelation stretch has been used to find the edge feature in the ultrasound scan image. Using this technique the noise component is removed from the image Fig.4.

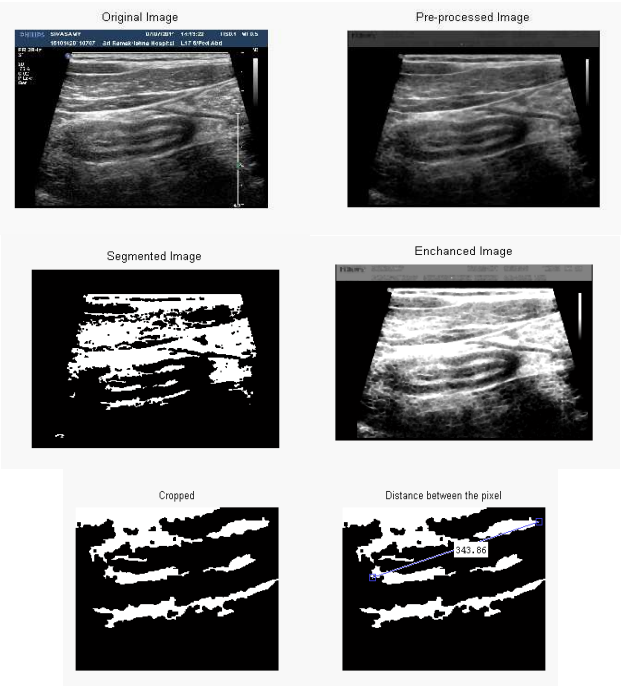

Fig.4. Automatic Appendicitis Detection on Sonographic Images

VIII. EXPERIMENTAL STUDY

The study period was from Dec 2010 – Jul 2011 and ultrasound imaging was done in all patients. The Patients were followed up until the discharge diagnosis was made and acute appendicitis of sonographic image findings in 44 patients was done. In the experimental study the total numbers of 44 instances studied were in the range of 16 – 52 years. It is noted that mean age of these referral instances are the range 33 – 34. Male and female sex ratio is in the range of 2:1. The column chart clearly shows the sex distribution for these 44 instances.

A. Results

The images are classified in two different sizes based on the thickness of appendicitis with *greater than 6 mm* and *less than 6 mm*. The proposed system is tested with 44 instances and the results show that out of 44 instances, 36 instances show thickness measured as greater than 6 mm. A sonologist has been consulted and the results obtained from the sonologist on the 44 samples reveal that 36 patients were affected by appendicitis. A comparison of the results obtained from the proposed system with the results obtained from the sonologists is shown in table I.

TABLE I. Comparison of Proposed Method and Real Result

S NO	AGE	SEX	Real Results	Proposed Results
1	42	M	+	+
2	26	M	+	+
3	31	M	+	+
4	25	M	+	+
5	18	M	-	-
6	21	M	+	+
7	40	M	+	+
8	21	M	+	+
9	24	M	+	+
10	29	M	-	-
11	34	M	+	+
12	24	M	+	+
13	27	M	+	-
14	42	M	+	+
15	35	M	+	+
16	37	M	+	+
17	40	M	+	+
18	16	M	-	-
19	22	F	+	+
20	28	F	+	+
21	30	F	+	+
22	23	F	+	+
23	41	F	+	+
24	25	F	+	+
25	37	F	+	+
26	32	F	+	+
27	51	F	+	+
28	31	M	+	+
29	26	M	+	+
30	27	M	+	+
31	38	M	+	-
32	52	M	+	+
33	48	M	+	+
34	34	M	+	+
35	27	M	+	+
36	21	F	+	+
37	32	F	+	+
38	27	F	+	+
39	16	F	+	+
40	35	F	+	+
41	18	F	+	+
42	42	M	-	-
43	31	M	-	-
44	42	M	-	-

TABLE II. Comparison of Proposed Method and Real Result

Size	Results from Proposed method	Results from Sonologist
≥ 6 mm	36	38
< 6 mm	8	6

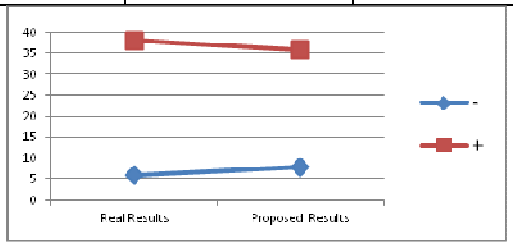

Fig.5. Graph of Patients Ratio

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B. *Performance evaluation criteria [38]*

i). *Confusion Matrix*

The confusion matrix determines the performance of the proposed method and is shown in Table4. This matrix describes all possible outcomes of a prediction results in table structure. The possible outcomes of a two class prediction can be represented as True Positive (TP), True Negative (TN), False Positive (FP) and False Negative (FN). The normal and abnormal images are correctly classified as True Positive and True Negative respectively. A False Positive is incorrectly classified as positive (yes) when it is a negative (no). False Positive is the False alarm in the classification process. A false negative is when the outcome is incorrectly predicted as negative when it should have been in fact positive [38].

A confusion matrix (Kohavi and Provost, 1998) contains information about actual and predicted classifications. Performance of such systems is commonly evaluated using the data in the matrix. In the confusion matrix 'a' is the number of correct predictions that an instance is negative, 'b' is the number of incorrect predictions that an instance is positive, 'c' is the number of incorrect of predictions that an instance is negative, 'd' is the number of correct predictions that an instance is positive.

TABLE III. Confusion Matrix [38]

		Predicted	
		Negative	**Positive**
Actual	**Negative**	a	b
	Positive	c	d

Several standards have been defined for the 2 class matrix: The accuracy (AC) is the proportion of the total number of predictions that were correct. It is determined using the equation:

$$AC = \frac{a+d}{a+b+_c+d}$$

The recall or true positive rate (TP) is the proportion of positive cases that were correctly identified and calculated using the equation:

$$TP = \frac{d}{c+d}$$

The false positive rate (FP) is the proportion of negative cases that were incorrectly classified as positive and calculated using the equation:

$$FP = \frac{b}{a+b}$$

The true negative rate (TN) is defined as the proportion of negative cases that were classified correctly and calculated using the equation:

$$TN = \frac{a}{a+b}$$

The false negative rate (FN) is the proportion of positive cases that were incorrectly classified as negative and calculated using the equation:

$$FN = \frac{c}{c+d}$$

Finally, precision (P) is the proportion of the predicted positive cases that were correct and calculated using the equation:

$$P = \frac{d}{b+d}$$

$$g-mean_1 = \sqrt{TP*P} \qquad g-mean_2 = \sqrt{TP*TN}$$

$$F = \frac{(\beta^2+1)*P*TP}{\beta^2*P+TP}$$

where, TP, TN, FP, and FN are the number of True Positive cases (abnormal cases correctly classified), the number of True Negative (normal cases correctly classified), the number of False Positives (normal cases classified as abnormal), and the number of False Negatives (abnormal cases classified as normal) respectively. The accuracy is the proportion of correctly diagnosed cases from the total number of cases and sensitivity measures the ability of the proposed method to identify abnormal cases. Specificity measures can be the ability of the method to identify normal cases.

		Predicted	
		Negative	**Positive**
Actual	**Negative**	6	8
	Positive	38	36

ii). *Sensitivity and Specificity [37]*

Sensitivity and specificity are statistical measures of the performance of a binary classification called classification function. Sensitivity measures the proportion of actual positives and specificity measures the proportion of negatives. These two measures are closely related to the concepts of type I and type II errors. A theoretical, optimal prediction aims to achieve 100% sensitivity and 100% specificity; any predictor will possess a minimum error bound known as the Bayes error rate.

	Predicted	
	Positive	Negative
Positive	True Positive 38	False Positive 8
Negative	False Negative 6	True Negative 36

Sensitivity relates to the test's ability to identify positive results of the medical test used to identify a disease. The sensitivity of a test is the proportion of people who have the disease to who test positive for it [37]. This can be written as:

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$$sensitivity = \frac{number\ of\ true\ positives}{number\ of\ true\ positives + number\ of\ false\ negatives}$$

Sensitivity
= TP / (TP + FN)
= 38 / (38 + 6)
= 38 / 44
≈ 86.36%

Specificity relates to the ability of the test to identify negative results of the medical test used to identify a disease. The specificity of a test is defined as the proportion of the patients who do not have the disease to who will test negative for it. This can be written as:

$$specificity = \frac{number\ of\ true\ negatives}{number\ of\ true\ negatives + number\ of\ false\ positives}$$

= TN / (FP + TN)
= 36 / (8 + 36)
= 36/44
= 81%

IX. Conclusion

This paper proposes an automatic appendicitis detection system for ultrasound images. The Euclidean distance is used to find the measure of the acute appendicitis and images are preprocessed with various techniques and the Euclidean distance is highly focused. The proposed system offers many advantages including better accuracy, greater noise reduction, faster speed and greater automation. The developed sonographic image mining system to detected acute appendicitis yielded a sensitivity of 86% and specificity of 81%. This work can be further extended to an automatic appendicitis detection system for ultrasound images using Euclidean and Manhattan distances.

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