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Novel Supervised Learning Scheme for Optimizing the Classification Performance of Breast Cancer MRI

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Abstract: ***Usage of machine learning has been always proven potential in identifying the best solution from the set of complex variables with the highly inter-twined relationship of problems. Similarly, supervised learning approach is one essential operation under machine learning that has always contributed in the area of healthcare and diagnostics. However, there are still some problems associated with the detection and classification of complex disease condition that is yet to be solved. The proposed system introduces a novel supervised learning approach along with a novel feature extraction scheme which is more progressive and less iterative. The proposed system considers a case study to perform classification of breast cancer using Magnetic Resonance Imaging (MRI) where it is subjected to normalization first followed by a novel segmentation process that compliments the classification operation too. The study outcome shows that the proposed system offers better classification performance in contrast to existing supervised approaches.***

Keywords ***: Breast Cancer, Supervised, Learning, Training, MRI.***

I. INTRODUCTION

Medical image processing has contributed a lot in the area of diagnosis with its highly capable technologies [1]. Although its successful usage has assisted disclosing various valuable information about the disease condition, still it encounters exponential challenges when it comes to detection of cancer [2]. Out of all the forms of cancer, breast cancer is one of the most frequently witnessed among women in almost every part of the world. Hence, medical imaging can assist in minimizing the mortality rate and enhance the perspective of survival so that precise clinical diagnosis is possible. At present, mammography is cost-effective as well as the standard mechanism of diagnosing breast cancer as it can successfully make out the difference between the infected tissue of cancer and normal breast tissue. Irrespective of its frequent adoption, there are also pitfalls of using mammograms. It has been found that the degree of sensitivity of the mammogram is a bit lower among the women who have dense breast tissue. Although such kinds of tissue may be caused due to some health condition, it becomes challenging for mammography to identify whether such forms of tissues are malignant or benign. Apart from mammograms, ultrasound is also used for capturing the disease condition; however, it too suffers from the limitation that is highly dependent on the judgment of the operator. Such problems are found to be overcome by using an explicit scanner that uses a one-dimensional array ultrasound transducer for extracting all the essential information. However, Magnetic Resonance Imaging (MRI) is one of the best options to investigate the radiological image of the breast very closely [3][4]. Usage of such non-invasive mechanism in order to investigate different bones, tissues, and organs brings more clarity to the images that are constructed on the basis of potential radio waves and magnetic fields. Such waves are capable of generating the virtual design of internal organs with higher accuracy. Apart from this, it is also capable of generating a cross-sectional image along with images with diversified dimensions. Such images can be generated without even utilizing hazardous radiation. The other advantages of using MRI are its capability to generate images with higher resolution, higher detailing, etc. However, there are many cases where MRI images also introduce ambiguity that affects the identification and classification process. At present, there are various research works being carried out towards breast cancer identification and classification [5]-[9], but there is no single work that has been proven to be standardized or has been adopted commercially. This is basically a case of optimization and requires the domain of machine learning to solve it effectively. At present, there are many supervised learning techniques used for performing optimization with a core objective to find an effective solution. By solution, it means searching and identifying the exact location and condition of the cancerous site. However, there is a various problem associated with it. The first problem is training operation of existing solution which has higher iteration as well as time-consuming. response. The second problem associated with the existing training-based solution is its higher dependencies of the dataset. It will mean that more the dataset more is accuracy and hence the process of achieving the scalability is reduced. Therefore, the proposed paper introduces a novel supervised learning technique that is very much different from any of the existing systems in terms of i) non-inclusion of the iterative process, ii) faster response time, iii) higher accuracy, iv) superior feature extraction time, etc. The organization of the paper is done as follows: Discussion of current research work is carried out in Section 'A' followed by a briefing of problem identification in Section 'B'. Briefing of the proposed methodology in terms of the solution is made in Section 'C'.

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Design details of algorithm implementation are made in Section II followed by analysis of the result obtained in Section III. In the end, the conclusion discusses the summary of the contribution of the proposed research work towards improving the classification performance of breast cancer.

A. Background

There are various research-based approaches towards assisting in the process of breast cancer classification in the existing system [10]. Usage of the *convolution-based neural network* is reported in most recent work of Bardou et al. [11]. The authors have also used the support vector machine for training in order to enhance the diagnosis process. The most recent approaches of neural network called the *deep neural network* are also found to offer benefits in the designing multi-classifiers in cancer cell classification process (Beevi et al. [12]). Bejnordi et al. [13] have used a *super-pixel classification* approach in multi-scale in order to perform involuntary detection of in-situ breast cancer. Development of a unique classifier using *logistic regression* is also proven to offer better classification performance in the case of micro-calcification (Bekker et al. [14]). The work carried out by Cruz et al. [15] has investigated different forms of the classifier to assess their impact on the classification of breast lesions. Another unique mechanism of performing classification is *theragnosis* using computer vision for evaluating the early stage of cancer. The work carried out by Gangeh et al. [16] has used *local binary patterns* for a similar purpose with higher accuracy of detection. Usage of shear strain imaging was reported to offer detection and effective classification performance when there is a need for classifying a higher number of radiological images (Hendriks et al. [17]). Study towards an emphasis on the *selection of feature and extraction* was carried out by Al-Junaid et al. [18] using cascaded DNA methylation technique to obtain higher classification performance. Usage of the *unsupervised* learning algorithm also offers better classification performance as witnessed in many research works. The work carried out by Kallenberg et al. [19] have addressed the segmentation problem and evolved up with a ranking-based solution to identify breast cancer using *deep learning mechanism*. Usage of convolution neural network was found to be implemented by Liu et al. [20] for performing classification of breast cancer data in structured form. The approach of *multi-label learning* was introduced by Mercan et al. [21] where a supervised approach was applied over the region-of-interest. This approach was also claimed for performing multiple degrees of classification. Pardo et al. [22] have used *density estimation method* using directional kernel over region-of-interest to perform classification. Selection of filter feature followed by the extraction process has been put forward by Raweh et al. [23] using the methylation density method to find the outcome with higher reliability. Reis et al. [24] have used multiscale feature along with tree classifier in order to perform classification operation. Implementation of deep learning for performing segmentation and classification is carried out by Saha and Chakraborty [25]. Usage of swarm intelligence is also found to offer better performance towards the feature selection process as seen in the work of Sakri et al. [26]. Apart from this, there are many other researchers e.g. Spanhol et al. [27], Xu et al. [28], Zhang et al. [29], Zhang et al.[30] et al. Hence, there has been various work carried out by existing researchers towards solving the classification problem of breast cancer. The next section highlights the problems of the existing system.

B. Identification of Problem

The significant research problems are as follows:

- Usage of supervised techniques e.g. neural network, support vector machine, etc have higher dependencies on training images, which is not cost effective
- Existing system subjects the images directly to the optimization approach where the accuracy estimation ignores the presence of any form of artifacts or non-uniformities.
- Usage of feature extraction approaches are quite lengthy and depends upon a highly iterative operation which yields deformities in the classified image.
- Usages of simple and empirical approaches are actually missing in existing techniques along with less novelty in optimization approaches.

The statement of the problem is "to design and incorporate a simple and cost-effective supervised learning approach that offers a good balance between reduced iteration and enhanced classification performance for breast cancer." The next section discusses the proposed solution.

C. Proposed Solution

The proposed system is a continuation of our prior research work [AR] towards breast cancer detection and classification using an integral transformation scheme. The current work offers more enhancements on the top of this model by incorporating a novel supervised learning approach. The schematic representation of the proposed system is as follows:

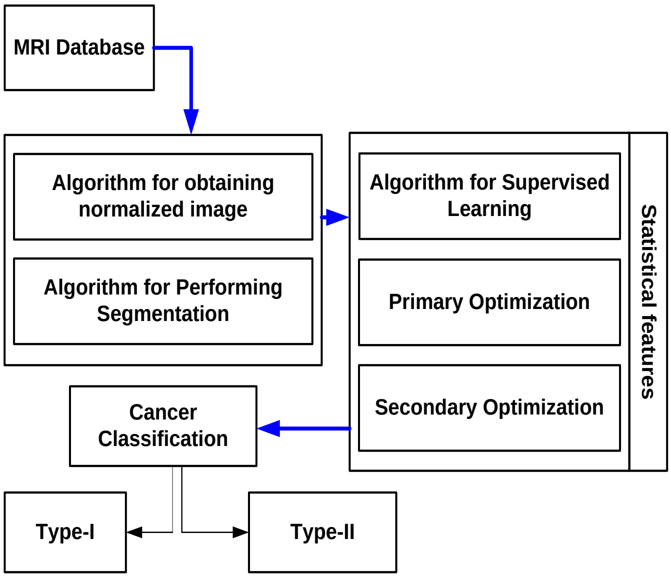

Figure 1 Schematic Representation of the proposed system

The proposed system is designed and developed using an analytical research methodology, where the complete process takes place in two set of operation.

The first operation includes taking the input image and subjecting it to a novel structural feature extraction scheme followed by a novel supervised learning algorithm. The first approach performs extraction of the normalized image from the input of Magnetic Resonance Imaging (MRI) of breast carcinoma followed by a unique segmentation scheme. The output obtained from the first block of operation is now considered as input for the second operational block where a novel supervised learning approach is implemented. The first stage is called as primary optimization which offers an optimal search optimization for exploring the best result while performing progressive training mechanism by the proposed system. Finally, the secondary optimization is applied for further confirming the identified stages of breast cancer in the form of Type-I and Type-II. The study considers that Type-I cancer has a non-lethal tumor in the breast while Type-II cancer is a life-threatening one. The essential contribution of the proposed system is all about introducing a novel classification and optimization approach toward breast cancer. The next section discusses algorithm implementation.

II. DESIGN OF ALGORITHM

The algorithm essentially offers a mechanism to perform classification on the basis of structural morphology. The goal of this algorithm is to perform a proper understanding of the criticality of the breast carcinoma in the form of type-I and type-II stage. The concept of design of the proposed system considers type-I and type-II stage associated with less and more critical stage of breast carcinoma. The idea of this algorithm design is mainly to apply sophisticated processing in order to obtain a normalized image followed by the elimination of any form of artifacts and a supervised learning procedure. The novelty of the proposed system is basically the implementation of a novel integral transformation scheme associated with the supervised learning process.

A. Designing a Novel Structural Feature Extraction Scheme

The prime purpose of this scheme is to carry out a novel form of feature extraction technique in order to facilitate better optimization process while performing learning operation in the next stage. The primary concept of this implementation is that if better quality of information can be obtained and retained than a decision for identifying the criticality of the disease condition becomes more comprehensive. The complete morphological-based scheme of feature extraction involved in the proposed system is carried out considering three different algorithms that are discussed below:

i) Algorithm for obtaining Normalized Image

The goal of Algorithm: This algorithm takes the input of I_{in} (input image) that after processing yields an outcome of I_1 (Normalized image). The contribution/novelty of this algorithm is that it offers an edge of information to the input image by addressing the artifacts that lead to a superior version of the normalized image at the end. The step of this algorithm is as follows:

Algorithm for obtaining Normalized Image

Input: I_{in} (input image)

Output: I_1 (Normalized image)

Start

1. $I=f(I_{in})$
2. **For** i=0 to max(s(I))
3. $[O_1\ O_2] \rightarrow \sum(\sum(a)+\sum(b))$
4. **If** $O_2>O_1$
5. I=I(c);
6. **End**
7. **End**
8. $I_1 \rightarrow f_1(I)$

End

Description of Algorithm: After taking the input image (I_{in}), the algorithm applies a function f(x) that can digitize the graphic file and store under a matrix I (Line-1). It then obtained its maximum size with respect to a number of rows and columns of the complete matrix file I and apply the process of normalization (Line-2 onwards). The algorithm also considers the problems of possible orientations to its extremities. In case the image suffers from the extreme right or left oriented i.e. O_1 and O_2 than it rectifies the extremities. The computation of the left and right extremities O_1 and O_2 are computed considering the summation of two parameters a and b that represents the left and right part of the matrix I (Line-3). In the case of the maximum orientation of right (Line-4), the image is rectified to obtain the left orientation (Line-5). The variable c represents fine-tuning attribute to change the right to left orientation in order to obtain the processed image I (Line-5). The next part of the function implementation f_1(x) in Line-8 is responsible for eliminating any form of artifacts present within the image. The operation of the function is as follows: The function takes the input of the processed image I and performs elimination of the black pixel followed by dynamic thresholding. In order to perform thresholding, the proposed system applies gray thresholding on the processed image which is further converted to a binary image. The highest region on the binary image is then extracted that is further followed by the elimination of the border area.

ii) Algorithm for Performing Segmentation

The goal of the Algorithm: The prime goal of this algorithm is to perform an effective segmentation process that could further offer clarity in the decision process. The significance of this operation is so because there are possibilities of various background and unnecessary objects in the peripheral part of the breast that is required to be eliminated. This implementation scheme is therefore very much novel as existing segmentation just performs foreground and background differentiation only, where the proposed system emphasizes the context. This algorithm takes the input of I_1 (normalized image) that after processing yields an outcome of I_2 (Segmented Region). The significant steps of the proposed algorithm are as follows:

Algorithm for Performing Segmentation

Input: I_1 (normalized image)

Output: I_2 (Segmented Region)

Start

1. $\psi \rightarrow \rho(I_1(arb(I_1)))$
2. $\eta \rightarrow I_1(u)$
3. $[h\ x_i] \rightarrow f_{his}(\eta)$

4. *compute* cut-off, T→g_1/g_2;
5. **For** j=k_1: k_2
6. **If** *l*>T
7. c_1→c_1+l*h(δ)
8. c_2→c_2+h(δ)
9. **End**
10. **End**
11. T→(c_1+ c_2)/2
12. I_2→ η(log(η>T)

End

Description of the Algorithm: The proposed algorithm offers an extensive step of operation in order to enhance the conventional segmentation operation. The algorithm first finds the sum of all the elements present in matrix I_1 and store in a temporary matrix which is further searched for all the elements corresponding with zero. The function ρ(x) is designed for that purpose so that the encapsulation window ψ can capture all the distinct binary feature of the processed image randomly (Line-1). The next part of the implementation is associated with the elimination of unwanted regions from the processed image of the encapsulation window. For this purpose, an encapsulation window is initialized and it is incremented to obtain the matrix η (Line-2). The algorithms than applies image histogram f_{his}(x) on the matrix η in order to obtain histogram *h* and index x_i followed by computation of two attributes e.g. g_1 and g_2. The calculation of g_1 and g_2 is carried out by incrementing index and using the hash value obtained. This attribute is used for computing the threshold *T* (Line-4). An iterative counter is constructed with minimum and the maximum value (k_1 and k_2). The system also put forward logic where updated index *l* is considered as only those matrix η whose value is greater than threshold *T* (Line-6). The computation of two coefficients c_1 and c_2 is carried out in a similar manner as that of g_1 and g_2 respectively (Line-7, 8). Finally, the computation of the updated threshold is carried out with respect to c_1 and c_2 (Line-11). Finally, a logical operator *log* is applied over the pixels that are compliance of the condition η>T (Line-12). The contribution/novelty of this algorithm is its mechanism to carry out a distinct way of performing segmentation keeping accuracy in mind. The output image is I_2 (Segmented Region) which is now ready to be subjected for the supervised learning approach in its next stage.

B. Designing a Novel Supervised Learning Scheme

- *The goal of Algorithm:* In order to carry out an effective classification process of breast cancer, it is essential to ensure the proper and effective approach is required to maintain a higher degree of accuracy. This can be achieved using a supervised learning approach. This approach assists in offering a better form of training in order to perform complex classification process. It also offers flexibility to induce higher specification of the classes with respect to the demands of the applications. Another best part of such approach is its memory management aspect. A closer look into the proposed system shows that a preprocessing operation is performed over the input of the MRI of breast followed by dynamic segmentation. However, still, there are possibilities of large number signal and their shortlisting process during classification operation will be quite time-consuming. Hence, an effective and simple feature extraction process is required in order to complement the process of classification process using a supervised learning technique. Another advantage of incorporating a feature extraction process in this stage is to improve the accuracy along with a lesser number of iterations to be involved in the process of supervised learning. However, different from any existing system, the proposed system implements a new supervised learning technique that uses computational approach for optimizing the problem with an aid of iterative method with a core objective of enhancing candidate solution and finally incorporating more accuracy using rule-based optimization process. The significant steps of the proposed algorithm for supervised learning are as shown below:

Algorithm for Supervised Learning

Input: I_2 (segmented region)

Output: Flag (classification outcome)

Start

1. I_4→f_3(I2)
2. I→p_{opt}(I4)
3. I_{ROI}→I4[min-max (xs, ys)]
4. reg_{ion}→f5(reg (nc, nr))
5. I5→IROI.reg_{ind}
6. I6→ϕ (I5, reg_{ind})
7. out→s_{opt}
8. If out<0.5
9. Flag type-I
10. Else
11. Flag type-II
12. End

End

- *Description of Algorithm:* The algorithm takes the input of segmented region I_2 that after processing yields the outcome of Flag to indicate a binary classification of breast cancer. The algorithm initially applies a function $f_3(x)$ which is basically a transformation operation carried out over I_2 (Line-1). The complete supervised algorithm implementation of the proposed system is further carried out by two sequential steps that are briefed as follows:
- *Primary Optimization*: The proposed system constructs a function p_{opt}(x) that is developed on the basis of stochastic search methodology. The prime aim of this function is to explore the best solution with respect to its fitness function. A two-dimension Cartesian coordinate system can be used to represent this problem. The system considers that all the elite outcomes bears following information i.e. present position of solution (α_i), the present speed of the best solution (β_i), and elite outcome (γ_i), where i represents each potential solution. The elite outcome of the *i* solution is computed as,

$$\gamma_i(t_2) = \begin{cases} \gamma_i(t_1) & \theta(\alpha_i(t_2) \geq \theta(\gamma_i\ (t_1)) \\ \beta_i(t_2) & \theta(\alpha_i(t_2) \leq \theta(\gamma_i\ (t_1)) \end{cases} \qquad (1)$$

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The above expression uses t_1 and t_2 as two consecutive times of solution. The proposed optimization principle assists in narrowing down the selected region of breast cancer from the selected input image and is stored in a matrix (Line-3). A min-max approach is applied over the segmented region that can explore the region of interest automatically generation I_{ROI} (Line-3).

The center pixel labels are obtained from the decomposed image along with the extraction of all the pixels that are found to have similar values of background. The labeled images are only selected and stored in the registered index matrix (reg_{ind}) that finally generates the best solution of the image. A dot product of a matrix of the region of interest and the registered index is carried out to obtained global best outcome i.e. I6 (Line-6). In this process, another function $f_5(x)$ is used for obtaining a local best outcome from the registered matrix with respect to a number of rows and columns i.e. nr, nc (Line-4). The final outcome of the proposed algorithm can be seen in Line-5 as I_5.

- *Secondary Optimization*: This is another sequential step that finally performs classification of the type of the breast cancer. However, this step starts with the implementation of the feature extraction process one more time. However, this process is not iterative as this feature extraction $\phi(x)$ is carried out considering various statistical parameters e.g. skewness, kurtosis, etc (Line-6). All the normalized values are considered in order to obtain the feature vectors. Finally, a rule-based mechanism is constructed in order to perform a classification where the core decision is concluded on the basis of statistical parameters constructed. One of the significant advantages of this model is that it offers an inclusion of a logical function s_{opt} (Line-7) that uses the statistical parameters from the processed image in order to perform binary classification of type-I and type-II cancer of the breast. It also offers a higher degree of flexibility of inclusion of detection as well as classification of multiple other associated clinical condition of the breast cancer if the medical information associated with the inference of MRI is predefined to the designer of this algorithm. Therefore, the proposed system offers a better form of classification technique using a cost-effective supervised learning scheme.

III. RESULT ANALYSIS

The assessment of the proposed study is carried out on MATLAB where the MRI of breast cancer dataset is used. Each input images are in the format of PGM with uniform filesize of 1 MB. The complete assessment was carried out to understand the classification performance of Type-I and Type-II of breast cancer.

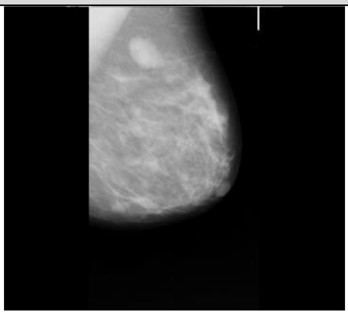
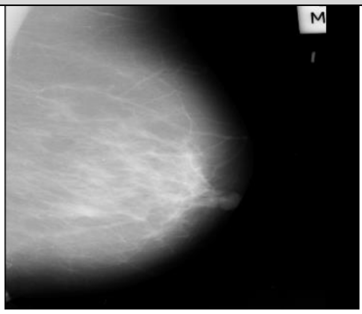
A. Result Analysis Strategy

As the proposed system introduces a novel classification method using a very unique supervised learning system the performance cannot be judged so easily. Hence, the study performs the visual assessment as well as numerical assessment to understand the robustness of the proposed system. For this purpose, separate directories are made where the type-I and type-II images are reposited just to offer validation of the proposed outcome. The final step is to carry out the construction of the database using the proposed supervised learning approach discussed in the prior section. After completion of training, a test image is applied.

B. Analysis of Visual Outcomes

A closer look at the visual outcomes in Table 1 shows that the proposed system offers a very user-friendly approach to perform the analysis. After taking the input image, the first step is to perform elimination of all sorts of the unnecessary region using normalization process, which yields a normalized image. The next process is all about reading the normalized region using an encapsulated window (shown as a red-bounding box in Table 1 in the fourth step). Finally, a transformation process is applied to 4levels of decomposition (higher possible level of decomposition is 8). The decomposed region is now shown subjected to the primary optimization where the region inflicted with cancer is shown to be highlighted. Applying secondary optimization will finally lead to the generation of flag message of classification stating of the input image is identified for Type-I or Type-II cancer of breast MRI. Apart from this, a statistical value is also derived that shows the numerical distinction between type-I image and type-II image.

Table 1 Visual Outcomes of Proposed Study

Cases	Normal	Abnormal
Input image		

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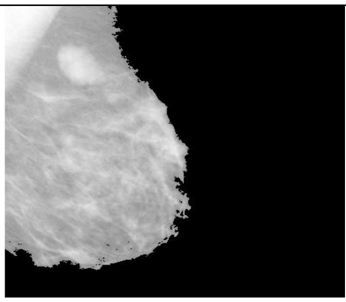
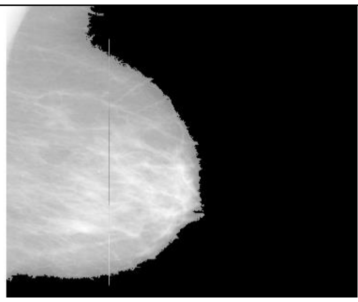
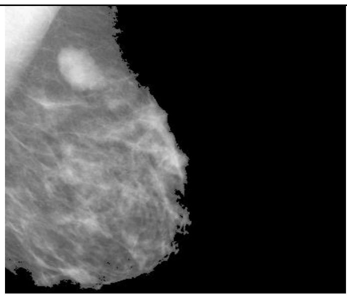
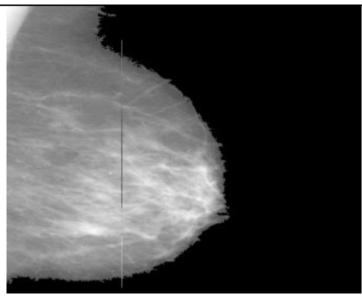
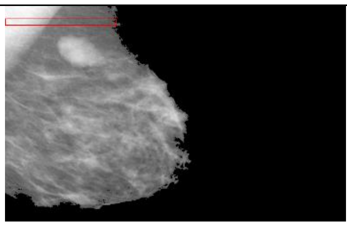
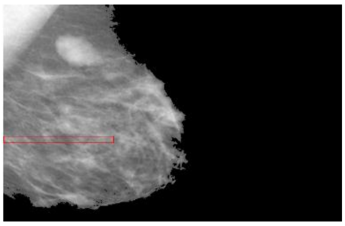
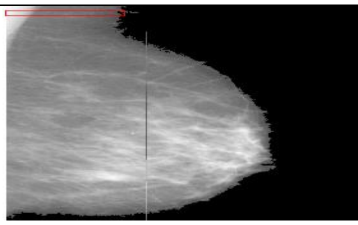
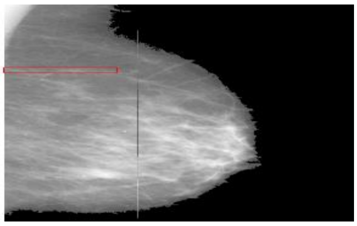
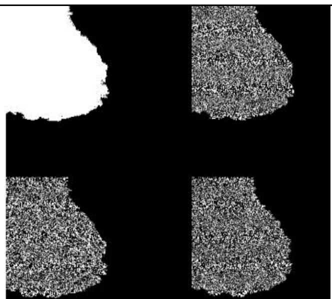
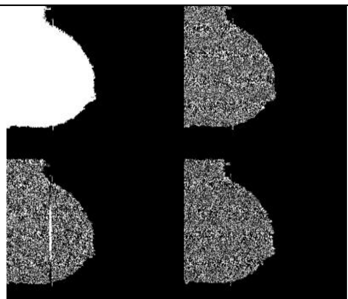
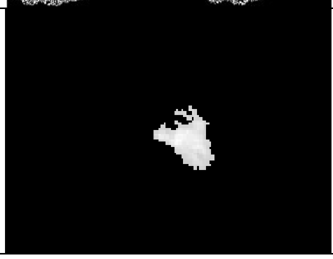
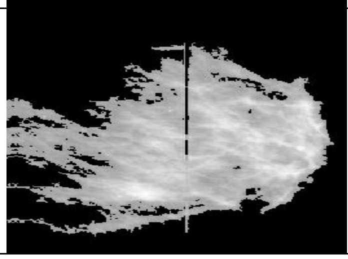
Elimination of unnecessary region			
Normalize image			
Selection of encapsulation window		 	 
Applying Transformation			
After applying primary optimization			
After applying secondary optimization -Flag message		**TYPE-I**	**TYPE-II**
Statistical Parameters	Mean	0.66735	0.77714
	Standard deviation	0.26501	0.73887
	Skewness	0.7798	0.91015
	Kurtosis	0.10592	0.22722

C. Comparison with other Techniques

As the proposed system uses a supervised learning approach for performing classification of cancer, the outcome was also compared with another existing approach as exhibited in Table 2.

Table 2 Inference of Existing Approach

	Neural Network	**Support Vector Machine**	**Self-Organizing Map**	**Proposed System**
Mode of training	Iterative	Iterative	Iterative	Progressive
Memory Saturation	Medium	High	Medium	Low
Accuracy	Medium	Low	Medium	High
Case Usage Flexibility	Depends upon a Higher set of training	Depends upon classifier design	Medium flexibility	High

The outcome shows that proposed system excels better outcome from existing learning approach (neural network, support vector machine, and self-organizing map) with respect to the mode of training, memory saturation, accuracy, and case usage flexibility. The prime reason behind this is it is absolutely not recursive and uses a progressive method that causes unique and faster search completion of best result while performing training and validation. Owing to the usage of feature extraction-based methods in multiple steps in different order, the proposed system offers higher accuracy that compliments the analysis of the type-I and type-II. Apart from this, the proposed system also offers cost-effective training process that leads to the faster response time of 0.87611 seconds on a core i3 processor whereas the existing system shows approximately 5.7122 seconds on the similar test bed.

IV. CONCLUSION

The paper has introduced a very novel mechanism to carry out a supervised learning approach. The significant contribution of the proposed study are as follows viz. i) the proposed system offers a very unique feature extraction method that not only extracts statistical attributes but also extracts various essential information within it, ii) the algorithms are completely nonrecursive unlike any machine learning approach or supervised learning techniques, iii) the proposed approach offers better identification, classification, and response rate and can explore the area of cancer quite faster.

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