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REVIEW ARTICLE

A Review of Denoising Medical Images Using Machine Learning Approaches

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ARTICLE HISTORY

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Abstract: ***Background*:** This paper attempts to identify suitable Machine Learning (ML) approach for image denoising of radiology based medical application. The Identification of ML approach is based on (i) Review of ML approach for denoising (ii) Review of suitable Medical Denoising approach.

***Discussion*:** The review focuses on six application of radiology: Medical Ultrasound (US) for fetus development, US Computer Aided Diagnosis (CAD) and detection for breast, skin lesions, brain tumor MRI diagnosis, X-Ray for chest analysis, Breast cancer using MRI imaging. This survey identifies the ML approach with better accuracy for medical diagnosis by radiologists. The image denoising approaches further includes basic filtering techniques, wavelet medical denoising, curvelet and optimization techniques. In most of the applications, the machine learning performance is better than the conventional image denoising techniques. For fast and computational results the radiologists are using the machine learning methods on MRI, US, X-Ray and Skin lesion images. The characteristics and contributions of different ML approaches are considered in this paper.

***Conclusion*:** The problem faced by the researchers during image denoising techniques and machine learning applications for clinical settings have also been discussed.

Keywords: Image denoising, ultrasound, filtering techniques, classifiers, wavelets, curvelets, data mining methods.

1. INTRODUCTION

The increasing number of patient data in medical images imposes a research challenge for the scientific treatment for diagnosing, detecting and prediction of the diseases. Now-a-days, the interests of the radiologists are attracted towards the medical data mining for patience care. Medical data mining and image denoising is the state of art challenge for researchers. The rapid growth is an outcome of the requirement for cost-effective, accurate, fast and persistent treatment. The detection and prediction of imaging is getting easier by the advancement in the technology. The quick development is an outcome of the requirement for more fast, precise and less intrusive treatment. Advanced technology in radiologic imaging gear has additionally energized the use of imaging. The higher determination comes at the cost of a continually expanding normal number of patients. The expanding number and quality of the images debilitates to overpower radiologist's abilities to translate them. In numerous genuine radiologic rehearses, mechanized and smart images investigation and strategy, for example, processing, segmentation, and CAD and detection in addition to the use of intelligent algorithm in case of cancer problem in broad area and demand in market.

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Machine Learning techniques are increasingly getting success in image-based diagnosis, disease detection and disease prognosis. To reduce the operator dependency and get better diagnostic accuracy, CAD system is a valuable and beneficial means for breast tumor detection and classification, fetal development and growth, brain functioning, skin lesions and lungs diseases [1].

1.1. Medical Denoising using Machine Learning Techniques

Image denoising using Machine Learning Techniques plays important role in the various application area of medical imaging such as pre-processing (noise removal from Ultrasound (US) Images, segmentation (MRI of Brain Tumor, lungs infection using X-ray), Computer Aided Diagnosis (CAD) for breast cancer, Fetus development and many more). Further, denoising of medical images using Data Mining Methods are analyzed in Fig. (**1**).

1.1.1. Data Collection

The first step includes data collection [2] from various civil hospitals, medical colleges, and laboratories. The data include the images of various medical applications such as (US of fetus development, MRI of brain functioning, US for breast Computer Aided Diagnosis (CAD) and detection, X-Ray of Chest, Skin Lesion) and even the personal data such

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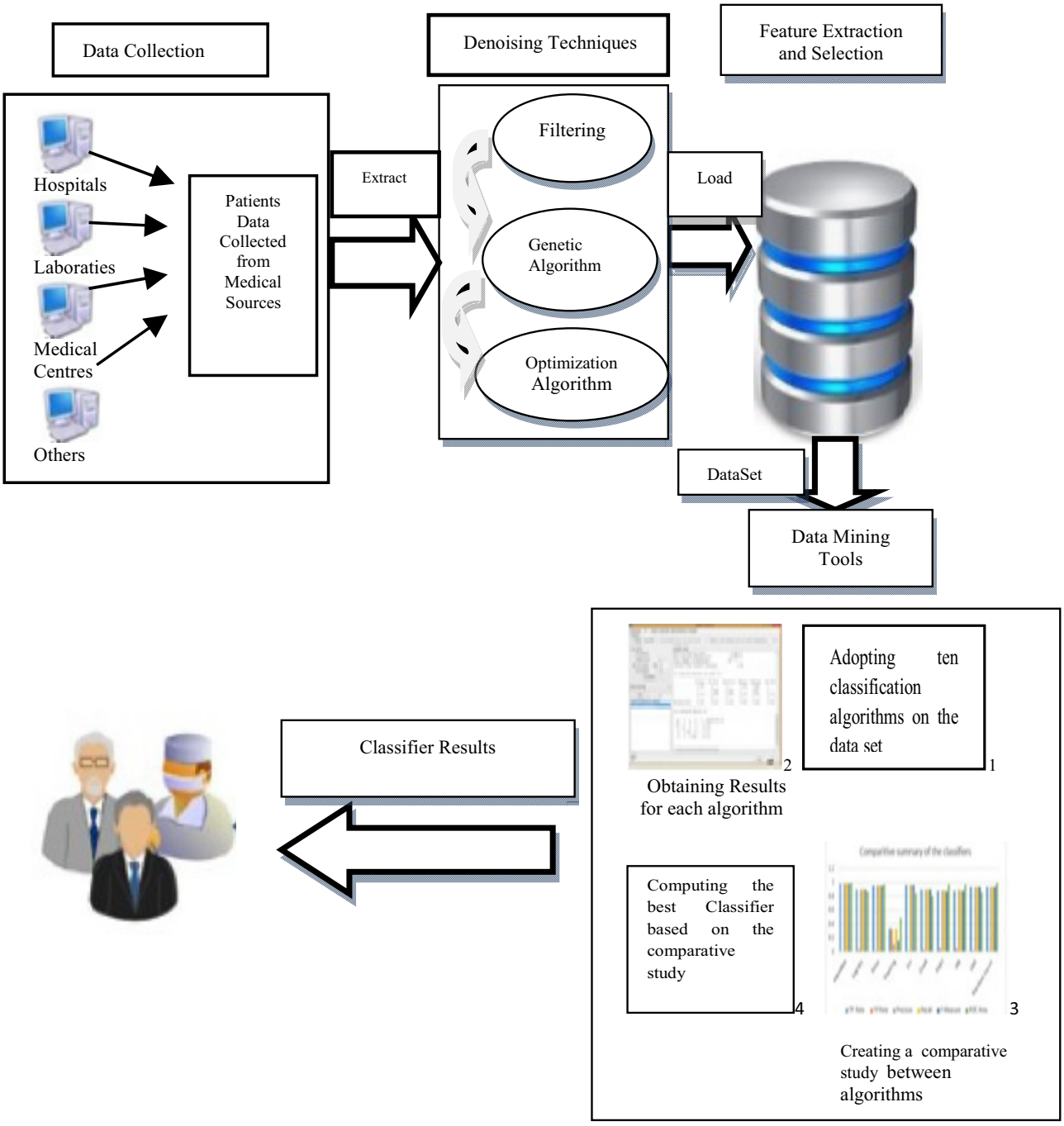

Fig. (1). Analysis of Denoising Medical Images using Data Mining Tools [2].

as gender, age, the symptoms that include the laboratory investigation results, diagnosis and treatment they received.

1.1.2. Denoising Techniques

The review analysis of different filtering techniques along with the advantages and disadvantages is discussed in Table **1**.

The analysis study, Table **1** includes various denoising filtering methods mainly in US images after being applied according to the advantages preserves better image and visual quality of input image. The outcomes proved that suggested techniques emerge significantly better in values of different quantitative measures such as Peak Signal to Noise Ratio (PSNR), Signal to Noise Ratio (SNR), Edge Preservation Index (EPI) and Coefficient of Correlation (CoC). The visual results have also clinically validated by a radiologist as surveyed.

1.1.3. Feature Selection and Detection

Feature is actually a critical step for ultrasonic image classification. Feature extraction methodologies evaluate the preprocessed images in order to extract the most prominent

Table I. Analysis of denoising filtering techniques.

Analysis of Denoising Filtering Techniques	Features	Advantages	Disadvantages
Homomorphic Wavelet [3]	Threshold can be extended that gives better result	Reduce speckle noise	Complex technique
Soft Thresholding [4]	"Optimal recover model and Statistical inference"	Reduce as well as smooth the noise	Large threshold cuts the coefficients
Non Homomorphic [5]	Relies on characterization of the marginal statics of the signal and speckle wavelet coefficients	Reduce the computational complexity of filtering method	Not a robust method for estimation distribution parameters
Adaptive wavelet domain Bayesian processor [6]	Combines the MAP estimation with correlated speckle noise	Speckle noise suppressed and remaining structure of image is not effected	Not effective technique
Wavelet based statistical [7]	Use realistic distribution of wavelet coefficients	Feature preserve, better for medical images, fast computation	Highly complex
Versatile technique for visual enhancement [8]	Combining MAP and speckle and signal wavelet coefficients	High correlation and structure similar and quality index	Cover only medical images not other
Wavelet thresholding (normal shrink) [9]	Sub band adaptive threshold	Normal shrink is faster as compare to bayes shrink	Need to reduce the number of bits while using normal shrink
Joint optimization quantization and wavelet packets (JTQ-WP) [10]	Covers both us images and natural images	Highly compressed approach	Cost function is high
Curvelet and contourlet [11]	Noise improvement rectangle	High PSNR can be achieved	Consider only Gaussian noise not other noises

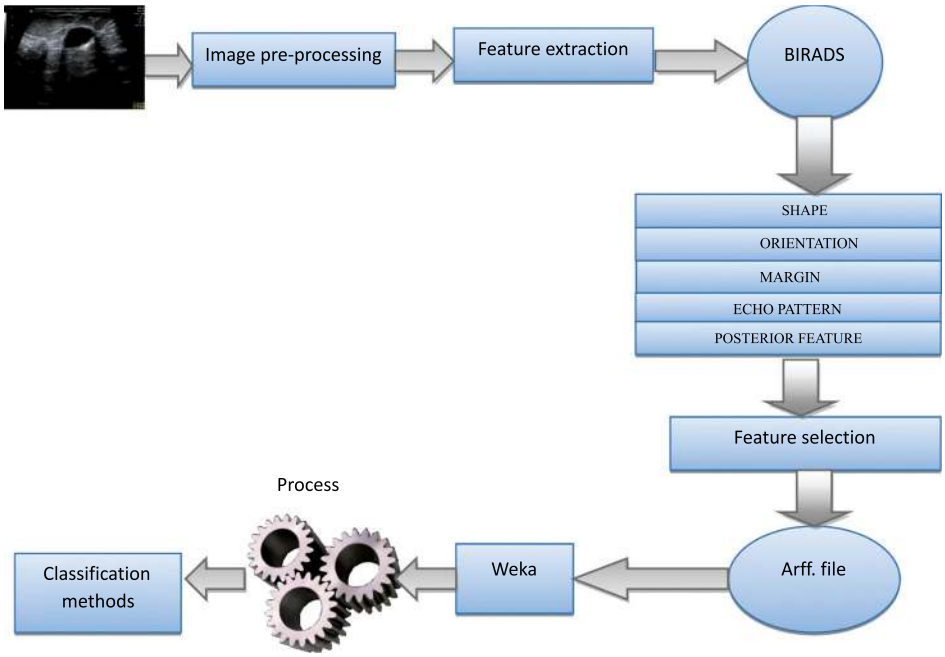

Fig. (2). Example of analysis of US CAD and detection of breast.

features which represent different sets of features based on the pixel intensity relationship statistics. For different medical application these features may vary. For example: For US CAD System features are explained in Table **2** and Fig. (**2**). Each and every feature set includes individual image parameters.

1.1.3.1. BI-RADS Features

A standardized lexicon for sonography, Breast Imaging Reporting and Data System (BI-RADS) for US was developed in 2003 by the American College of Radiology. With the 5th edition of BI-RADS US examination [12], dominating sonographic properties are categorized into five illustrative

areas mentioned in Table **2**: "Margin, shape, posterior acoustic features, echo pattern and orientation".

Shape - Breast lesion could be round, oval or irregular.

Orientation - Orientation identifies the way regarding very long axis from the tumor [13]. If the very long axis on the cancer parallels your skin layer line, a positioning is actually parallel, or maybe ''greater compared to tall" otherwise, a positioning is actually anti-parallel, or maybe ''taller compared to wide".

Margin - Margin qualities will be an essential BI-RADS type throughout determining the likelihood of malignancy. This kind of BI-RADS type has several subcategories devoted to different qualities on the cancer mark up, including: ''indistinct,' ''angular,' ''microlobulated" and also ''spiculated,' 'that are concern features.

Echo pattern - Echo pattern may possibly be determined by checking structure which plays a crucial role from the difference in between lesions on the skin inside and ultrasound imaging.

P*osterior Features* - Acoustic shadowing [13] is considered a hard finding that is worrisome for malignancy. Shadows are dark areas that appear immediately posterior to the tumors with decreasing or increasing shadow effect. Some tumors have complete posterior shadows, some have partial posterior shadows depending on the degree of desmoplasia of the tumor and some do not have shadows at all.

1.1.4. Data Mining Tools and Classification Algorithm

Machine learning explores the study and construction of algorithms that can learn from and make predictions on data. Machine learning focuses on prediction, based on known properties learned from the training data shown as:

Decision Tree - Breast Decision tree learning works on the decision tree as a predictive model which maps observations about a product to conclusions concerning the item's target value. It's among the predictive modelling approaches found in statistics, data mining and machine learning. The target is to make a model that predicts the worth of a target variable centred on several input variables. It is a rule-based decision tool. Decision trees are widely used in the field of pattern recognition, with an efficient training procedure and model construction.

Artificial neural network (ANN) – ANN is a self-learning approach that imitates the properties of biological nervous systems. It is a framework that progresses its parameters in light of outside or inside data that moves through the system amid the learning stage.

Support vector machine (SVM) - SVM is a type of supervised learning method that analyzes data and used for classification and regression analysis [13]. SVM is used to classify the type of breast tumor *i.e*. malignant and benign lesions. The main idea in SVM is to make a hyper plane in an infinite and a high dimensional space. Classification trees are used to identify the class to which the data belongs. Regression trees are used to predict the value of the target variable.

Random Forest (RF) - RF or random decision forests are an ensemble learning method for regression, classification and other tasks, that operate by constructing a variety of decision trees at training time and outputting the class that is the mode of the mean prediction (regression) or classes (classification) of the patient trees. Random forest is correct measure for decision trees habit of over fitting for their training set.

The survey analysis of Table **3** shows that the limitation of existing methods is the poor accuracy rate. Hence im-

Table 2. Representing benign and malignant BI-RADS features.

BI-RADS Features	Features Favouring Benign	Features Favouring Malignant
Shape	Oval	Irregular and Round
Orientation	Parallel to skin	Not parallel to skin
Margin	Circumscribed	Microlobulated, Indistinct, Angular, Spiculated
Echo Pattern	Abrupt interface	Echogenic halo
Posterior Feature	-	Shadowing, Combined pattern

Table 3. Data mining method.

Machine Learning Method	Advantages	Disadvantages
Decision Tree	Low complexity	Accuracy depends on the design of the features and tree
Artificial Neural Network	Robustness and widely applicable	Initial value, Long training time Over-training and Dependent.
Support Vector Machine	Repeatable training process, good performance	Supervised learning, parameter dependent.
Random Forest	Resistance to over training, Improve prediction accuracy	Fundamentally discrete, Large number of trees may make the algorithm slow for real-time prediction

provement is required to make them more consistent. The accuracy rate can be improved by merging different classification algorithms according to the advantages being considered.

2. REVIEW OF MEDICAL DENOISING APPROACHES

Medical Images include different types of noise which show distortion and many problems during diagnosing the disease. The review of image denoising filtering techniques along with the advantages of tools, techniques is discussed in Table **4**.

The comparative study of various speckle reducing filters for US images shows that wavelet filters outperforms as compare to other standard speckle filters. These standard filters operate by smoothing over a fixed window and it produces artifacts around the object and sometimes causes over smoothing. New threshold function is better as compare to other threshold functions, gives a lesser amount of mean square error and higher SNR. The wavelet based method leads to fast computation and despeckling with well-preserved image details for better diagnosis.

Table 4. Review of medical denoising approaches.

Title, Author, Publication, Year	Classes	Tools/Techniques	Advantages
Title: "Homomorphic wavelet thresholding technique for denoising medical ultrasound images" [3] Authors: "S. Gupta, R. C. Chauhan and S. C. Saxena" Publication: "Journal of Medical Engineering & Technology (2005)"	Image denoising	Novel Homomorphic Wavelet Thresholding	It outperform the most effective wavelet based denoising
Title: "De-Noising by Soft-Thresholding" [4] Authors: "David L. Donoho" Publication: "IEEE Transaction On Information Theory (1995)"	Image denoising	Abstract De-Noising Model	Increases statistical inference
Title: "Robust non-homomorphic approach for speckle reduction in medical ultrasound images" [5] Authors: "S. Gupta, R.C. Chauhan and S.C. Saxena" Publication: "Medical & Biological Engineering & Computing (2005)"	Speckle reduction	Non-Homomorphic technique	Low complexity
Title: "Locally adaptive wavelet domain Bayesian processor for denoising medical ultrasound images using Speckle modeling based on Rayleigh distribution" [6] Authors: "S. Gupta, R.C. Chauhan and S.C. Saxena" Publications: "IEEE(2005)"	Speckle reduction	Discrete Wavelet Transform, MAP estimator	Suppresses speckle noise effectively
Title: "A Wavelet Based Statistical Approach for, Speckle Reduction in Medical Ultrasound Images" [7] Authors: "Savita Gupta, L. Kaur, R.C. Chauhan and S. C. Saxena" Publication: "IEEE (2003)"	Speckle reduction	Novel Multiscale Nonlinear for Speckle Reduction	Fast computation and better diagnosis
Title: "A versatile technique for visual enhancement of medical ultrasound images" [8] Authors: "L. Kaur, S. Gupta, R.C. Chauhan , S.C. Saxena" Publication: "Science direct (2007)"	Visual enhancement of image	Versatile Wavelet Domain despeckling	Provide better performance in speckle smoothing and edge preservation
Title: "Wavelet-based statistical approach for speckle reduction in medical ultrasound images" [9] Authors: "S. Gupta, R.C. Chauhan and S.C. Saxena" Publication: "Medical & Biological Engineering & Computing (2004)"	Speckle reduction	Novel Speckle-Reduction	Fast computation and Despeckling

(Table 4) Contd…

Title, Author, Publication, Year	Classes	Tools/Techniques	Advantages
Title: "Medical ultrasound image compression using joint optimization of thresholding quantization and best-basis selection of wavelet packets" [10] Authors: "L. Kaur, S. Gupta, R.C. Chauhan, S.C. Saxena" Publication: "Science direct (2007)"	Image denoising	Image Coding Algorithm	Performance of JTQ-WP coder is concluding better
Title: "Performance evaluation of wavelet, ridgelet, curvelet and contourlet transforms based techniques for digital image denoising" [11] Authors: "Vipin Milind Kamble, Pallavi Parlewar, Avinash G. Keskar, Kishor M. Bhurchandi" Publication: "Springer (2015)"	Image denoising	X'let transform	Provide effective de-noising
Title: "Denoising Of Medical Ultrasound Images In Wavelet Domain" Authors: "Amit Jain" [14] Publication: "International Journal Of Engineering And Computer Science (2015)"	Image denoising	Wavelet Transformation, Wavelet Thresholding	Preserves image and visual quality
Title: "Image Denoising using Wavelet Thresholding" [15] Authors: "LakhwinderKaur, Savita Gupta and R.C. Chauhan (2002)"	Image denoising	Adaptive Threshold Estimation	Provide smoothness and Effective edge preservation
Title: "Image denoising using curvelet transform: an approach for edge preservation" [16] Authors: "Anil A. Patil and Jyoti Shinghai" Publication: "Journal of scientific and industrial research (2010)"	Image denoising	Soft Thresholding Multiresolution	Improve smoothness
Title: " Ideal spatial adaptation by wavelet shrinkage" [17] Authors: "David l. donoho and iain m. johnstone" Publication: " Biometrika (1994)"	Speckle reduction	Signal-dependent Multiplicative Speckle Noise Model, Discrete Wavelet Transform and Modeling of Wavelet Coefficients	Smoothness increases

3. RECENT RESEARCH PAPERS EXPLORING MEDICAL DENOISING USING MACHINE LEARNING APPROACHES

Most of the radiologists are showing great interest in the Machine Learning ML methods due to huge amount of patient data and advantages of methods to reduce time, cost effectiveness and rapid result. Out of 45 reviewed papers, Table **5** shows the strengths and limitations of 8 main review papers. Table **6** shows the review of medical denoising approach along with the relevant ML approach since 1992 and up to 2015.

Table **5** and Table **6** analysis shows that the major gap is the quantity and quality of data set. Most of the papers have chosen the limited data set thereby affecting applicability on large dataset. The running time for detection and classifying algorithm affects the efficiency of system and number of patience that being diagnosed by radiology.

4. GAPS IN LITERATURE REVIEW

The following research gaps have been identified on going through literature related to the various techniques of medical denoising using Machine Learning methods:

- Most Real life medical images provide different types of noise distortions as a challenge in image denoising.
- Compressive framework including new algorithms to improve further denoising performance is missing.
- Robust methods for the estimation of distribution parameters to improve further the denoising performance have not been designed yet.
- Optimization algorithm like particle swarm optimization, ant colony optimization etc are not been suggested to reduce noise level.
- Data Mining Methods for separation based on subset superset approach for classifying according to noise level are not been identified.
- Noise based clustering for reduction of noise not been distributed and easily reduced.
- Research on statistical approaches is great challenge in machine learning technique.
- No Benchmark Dataset is provided for researcher to evaluate the performance using different algorithms.

Table 5. Machine learning methods.

Title Author Publication	Application & Dataset	Techniques	Parameters	Strengths	Limitations
Title: "Machine Learning and radiology" [1] Author: "Wang S., Summers R.M" Publication: "Elsevier 2012"	CAD for breast US, Brain MRI, Content based retrieval CT or MRI, Text Analysis Dataset: Varies Application wise For eg: 12,000 images for content based image retrieval CT or MRI images	SVM, Naive Bayes, Neural Networks, Linear Models, Graphs Matching, Cluster Analysis, PCA, kNN.	Costs, Accuracy, Disseminating Expertise	"Reduce cost, Improve Accuracy, Disseminating in short supply"	Machine learning statistical approaches are not defined.
Title: "A Comparative Study of Classification Algorithms in E-Health Environment" [2] Author: " M.A. Hassan" Publication: "IEEE Conf (2016)"	MEDICAL IMAGES (E-HEALTH ENVIRNMENT) DATASET: 600 INSTANCES FROM PUBLIC HOSPITAL SAUDI ARABIA	Classification Algorithms (Bayes Net, Logistic, K Star, Stacking, JRIP, One R,PART, J48, LMT, RF)	Precision ,TP "True Positive" , Recall, FP "False Positive", F-Measure, Time, ROC Area	"ROC Area concludes Random Forest has highest Rate". "Bayes Net, K star, Stacking, OneR, J48 take least time 0.01 followed by PART 0.08 sec, then Logistic with 5.4 Sec and LMT took 12.2 sec." "Bayes Net is the best classifier for patient data set in terms of performance metrices with TP 0.987, FP 0.002, Precision Rate 0.988, Recall rate 0.987, F-measure 0.988,ROC 0.994,time 0.01 sec."	Decision making of classifiers is limited on huge dataset
Title: "Computer-Aided Diagnosis for Breast Ultrasound Using Computerized BI-RADS Features and Machine Learning Methods" [13] Author: Shan, J., Alam, S.K., Garra, B., Zhang, Y. and Ahmed, T. Publication: Science Direct (2015)	CAD FOR BREAST ULRASOUND DATASET: 283 US IMAGES (133 BENIGN AND 150 MALIGNANT)	ANN,SVM, Decision Tree, Random Forest, Student's t –test	Shape, Orientation, Margin , Echo Pattern, Posterior Feature	"Best ROC performance" "Better performance of clustered classifiers in a tumor classification task."	Hybridization of classifiers has been ignored
Title: "Machine Learning Approaches in Medical Image Analysis: From detection to diagnosis" [18] Author: "Bruijne M." Publication: "Elsevier (2016)"	DETECTION OF DIABETIC RETINOPATHY, BRAIN MRI IMAGES ETC DATASET: 35,000 IMAGES OF DIABETIC RETINOPATHY.	Machine Learning Diagnosis Methods, Imaging Protocols, Labels	Confounding Factors- Age, Gender, Curves Visual Performance	"Train strong Models on little data, Improve access on Data, Best make use of image structure, Properties in designing models"	Theoretical base is explained

(Table 5) Contd…

Title Author Publication	Application & Dataset	Techniques	Parameters	Strengths	Limitations
Title: "Hybrid Approach for automatic segmentation of fetal abdomen from ultrasound images using deep learning" [19] Author: "H. Ravishankar, S. Prabhu, V. Vaidya, N. Singhal" Publication: "IEEE Conf (2016)"	ULTRASOUND OF FETAL ABDOMEN DATASET: 70 IMAGES	"Convolutional Neural Networks" (CNN) ,"Gradient Boosting Machine" (GBM)	"Gray Level Co-Occurrence Matrix" (GLCM), Haar, " Local Binary Pattern"(LBP)", "Histogram of Oriented Gradient" (HOG), "Support Vector Machine" (SVM), "Random Forest" (RF)	"HOG feature outperform Haar Features by more than 4%." "DSC overlap over all 70 test cases of combined approach jumped to 0.9, which suggests a 5% and 6% improvement over GBMs and CNNs." "Gestational Age (GA) difference was obtained for 78% for GBM and 75% for CNN."	Parameters evaluation is not explained properly.
Title: "A Novel Approach for Classifying Medical Images using Data Mining Techniques" [20] Author: "Mangai J. A." Publication: "IJCSEE (2013)"	Fundus Images Dataset: "32 very severe images and 61 normal Fundus images "	"k nearest neighbor (kNN) , Support Vector Machine(SVM)and Naïve Bayes(NB)"	Discretization Method :Receiver Operating Characteristics(ROC) in terms of accuracy and area Minimal Description Length (MDL)	AUC outperform "NB classification performance outstanding" "NB is 0.94 as compare to kNN and SVM"	Data set is limited to only fungus retinal images
Title: "Computer-aided diagnosis of breast masses using quantified BI-RADS findings" [21] Author: "Woo kyung moon" Publication:"Science Direct (2013)"	Breast CAD US images Dataset: 244 US images (166 Benign & 78 Malignant)	"Computer-aided analysis with quantitative information BI-RADS Method", Chi-Square Test	Specificity, Accuracy, PPV, NPV, pAUC	"CAD quantitative combination (0.96 vs 0.93, p=0.18)" "Partial AUC (Area Under Curve) over 90% sensitivity of proposed as compared to Conventional CAD(0.90 vs 0.76, p<0.05)"	Use of all tumors in the feature selection process
Title: "Automated breast cancer detection and classification using ultrasound images: A survey" [22] Author: "Cheng H.D" Publication: ELSEVIER (2010)	Breast US Images Dataset: No Benchmark Database, vary DB1 to DB6 according to different papers.	Filters, Wavelet, Neural Network, Morphological Processing, Classifiers	"Specificity, Accuracy, Sensitivity, Positive predictive value (PPV) , Negative predictive value (NPV) , Matthew's correlation coefficient(MCC)"	"Number of NPV and PPV are unbalanced then MCC gives better evaluation then Accuracy." "More Breast CAD systems employs SVM, ANN and BNN method, MCC should be evaluated Criteria"	Performance Evaluation of the approaches is not described properly.

Table 6. Explored medical denoising and machine learning techniques.

Title, Author, Publication	Dataset	Features	Tools/Techniques Used	Classification Approach
Title: "Image denoising using curvelet transform: An approach of edge preserving" [16] Author: "Anil A Patil and Jyoti Singhai" Publication: "Journal of Scientific and industrial research (2010)	3 different gray scale images: Lena and Barbara with size 512X512 and Cameraman with size 266X256	Variance Measure, Mean square Error, PSNR value	Bayes Shrink soft thresholding model, Edge preserving smoothing algorithm (SNN filter, MHN filter)	Generalized Gaussian Distribution Modeling of Sub band Coefficients

(Table 6) Contd….

Title, Author, Publication	Dataset	Features	Tools/Techniques Used	Classification Approach
Title: "A Novel Approach for Classifying Medical Images Using Data Mining Techniques" [20] Author: "J. Alamelu Mangai, Jagadish Nayak and V. Santhosh Kumar" Publication: "IJCSEE (2013)"	Retinal fundus images of size 576x720 pixels.	Mean, variance, skewness and kurtosis	Classifiers such as SVM, kNN, and NB	Machine Learning classifiers
Title: "Automated breast cancer detection and classification using ultrasound images: A survey" [22] Author: "H.D. Cheng, Juan Shan, WenJu, Yanhui Guo, Ling Zhang" Publication: "Elsevier (2010)"	Standardized Breast Images	Spiculation, Elipsoid Shape, Branch Pattern, Brightness of Nodule, Margin Echogenity	Filtering, Wavelet approaches, Histogram thresholding, Active Contor Model, MKF, Neural Network, Bayesian Neural Network, Decision Tree, SVM, Template Matching	CAD based System detection
Title: " Image Coding Using Wavelet Transform" [23] Author: "Marc Antonini, Michel Barlaud, Pierre Mathieu, and Ingrid Daubechies" Publication: "IEEE TRANSACTIONS ON IMAGE PROCESSING (1992)"	"The intensity of each pixel is coded on 256 grey levels (8 bpp), 256 by 256 black and white images."	Entropy, PSNR	Wavelet Coefficients, Vector Quantization	Machine Learning
Title: "An Efficient Denoising Technique for CT Images using Window based Multi-Wavelet Transformation and Thresholding" [24] Author: "Syed Amjad Ali, Srinivasan Vathsal, K. Lal Kishore" Publication: "European Journal of Scientific Research (2010)"	CT images of size 256X256	PSNR values computed, Additive White Gaussian Nose removed	Window based Multi-wavelet transformation and thresholding, band pass filtering technique	"Multi-wavelet classification windows based"
Title: "A GA-based Window Selection Methodology to Enhance Window-based Multi-wavelet transformation and thresholding aided CT image denoising technique" [25] Author: "Prof. Syed Amjad Ali, Dr. Srinivasan Vathsal, Dr. K. Lal Kishore" Publication: "International Journal of Computer Science and Information Security (2010)"	Industrial CT volume data sets	Number of window selected, Gene length, Mutation Rate, PSNR values	Window based Multi-wavelet transformation and thresholding, Genetic algorithm	Window Based Multi-wavelet classification
Title: "Qualitative and Quantitative Evaluation of Image Denoising Techniques"[26] Author: "Charandeep Singh Bedi, Dr. Himani Goyal" Publication: "International Journal of Computer Applications (2010)"	Standardised Images	CoC, PSNR and S/MSE	Various Spatial filters like Median Filter, Lee Filter, Kuan Filter, Wiener Filter, Normal Shrink, Bayes Shrink	Image Denoising Using Spatial Filters
Title: "Multilevel Threshold Based Image Denoising in Curvelet Domain" [27] Author: "Nguyen Thanh Binh and Ashish Khare" Publication: "JOURNAL OF COMPUTER SCIENCE AND TECHNOLOGY (2010)"	Five thousand images of different image sizes: 64 × 64,128 × 128,256 × 256,512 × 512 and 1024×1024	Curvelet coefficients, the mean and the median of absolute curvelet coefficients	Curvelet Transformation and Cycle spinning	Curvelet based Thresholding

(Table 6) Contd….

Title, Author, Publication	Dataset	Features	Tools/Techniques Used	Classification Approach
Title: "Digital Image Denoising in Medical Ultrasound Images: A Survey" [28] Author: "N. K. Ragesh, A. R. Anil, Dr. R. Rajesh" Publication: "ICGST AIML-11 Conference (2011)"	Ultrasound images	Scattere density, Texture based contrast, MSE, RMSE, SNR, and PSNR	Multi-scale thresholding, Bayesian Estimation and Coefficient correlation, Application of Soft Computing like Artificial Neural Networks (ANN), Genetic Algorithms (GA) and Fuzzy Logic (FL)	Designing better algorithms correlating the Ultrasound image formation concepts and advanced Digital image processing techniques
Title: "Adaptive image denoising using cuckoo algorithm" [29] Author: "Memoona Malik, Faraz Ahsan, Sajjad Mohsin" Publication: "Springer (2014)"	Standard512× 512 images ('Lena', 'Pirate', 'Mandrill')	IQI, VIF, both IQI and PSNR or both IQI and VIF	Cuckoo search algorithm	Comparisson of Cuckoo Search With existing Artificail intelligence techniques
Title: "Segmentation and detection of breast cancer in mammograms combining wavelet analysis and genetic algorithm" [30] Author: "Danilo Cesar Pereira, Rodrigo Pereira ramos, Marcelo Zanchetta do Nascimento" Publication: "Elsevier (2014)"	Database taken from Digital Database for Screening Mammography (DDSM)	"Distribution separation measure, target to background contrast enhancement measurement based on entropy, target to target background contrast enhancement measurement based on standard deviation, combined enhancement measure"	Wavelet transform, genetic algorithm	Artifact removal algorithm fusing gray level enhancement method and image denoising and using wavelet transform and wiener filter
Title: "Mixed Curvelet and Wavelet Transforms for Speckle Noise Reduction in Ultrasonic B-Mode Images" [31] Author: "A.A. Mahmouda, S. El Rabaiea, T.E. Tahaa, O. Zahrana, F.E. Abd El-Samiea and W. AlNauimy" Publication: "Information Science and computting (2015)"	Six ultrasonic B-mode images (Liver, Kidney, Fetus, Thyroid, Breast and Gall	PSNR value, Coefficient of Correlation (CoC)	Wavelet and curvelet transform	Wavelet transform handles homogeneous areas while curvelet transform handles areas with edges
Title: "Image Denoising Method based on Threshold, Wavelet Transform and Genetic Algorithm" [32] Author: "Yali Liu" Publication: "International Journal of Signal Processing (2015)"	Images of Lena and Saturn Planet	Hard Threshold Function, Soft Threshold function	Wavelet Transform, Genetic Algorithm	Genetic Algorithm

CONCLUSION

This paper focuses on the review of various denoising methods along with machine learning approaches to develop a systematic decision for diagnosing and prediction for medical images [33-45]. The representation of the machine learning *i.e*. based on various numbers of methods which focuses on prediction, based on known properties learned from the training data has been considered. The observation through literature survey is that the accuracy rate of the existing methods is poor so improvement is required to make them more consistent as Naive Bayes outperforms in accuracy as compared to kNN and SVM. The most important task is that benchmark database of Ultrasound scanned images should be accessible to public to compare and evaluate different algorithms based on CAD system dynamically.

CONSENT FOR PUBLICATION

Not applicable.

CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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Declared none.

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