An Automated System to Preprocess and Classify Medical Digital X-Rays

Sumera, K. Vaidehi, and R. Manivannan

Abstract Considering, the reality (fact) that innumerable medical (digital) images are collected at hospitals and numerous medical tests centres on a daily basis, a clear manifestation is that these images must be composed, stacked and accessed accurately for future references (CBIR). Sole motivation (reasoning) for proposition of this attempted work is to give a provision for categorizing or classifying medical X-rays automatically at macro-level (global level) to aid lab technicians (analysts) in their day job. GLCM is employed to draw out features or characteristics of (images) X-rays and resultant is utilized in building classification model by taking an advantage of SVM. Six different classes (groups) of X-ray images are taken, namely chest, foot, skull, neck, palm and spine. The proposed attempt to put forward a medical X-ray image classification process involves pre-processing of X-rays with an aim of making them fit for further processing. Digital X-rays in this current research are subjected to Pre-processing using a filtering operation (median filter), histogram filtering (or equalization) and CLAHE. The upshots of each are recorded. Subsequently, segmentation (connected component labelling), feature extraction (GLCM), classification (SVM). Lately post implementation, the outcomes vividly depict around 91% accuracy is acquired utilizing median filter accompanying GLCM and SVM whereas pre-processing images using, histogram equalization (HE) yielded 89% accuracy. Third blend (combination) of CLAHE, GLCM and SVM outshined with 96% accuracy. Consequently, CLAHE in estimation (comparison) to other Pre-processing methodologies outperformed classification results.

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1 Introduction

One can offer a tremendous contribution to facilitate doctors and radiologists in (their) work of clinical diagnosis by designing an approach (structure) that could automate their tasks instead of alternately letting them perform manual observations. It gets quite tedious and also incurs surplus time for medical practitioners to manually perform image interpretation. Hence, new vogues for processing of images automatically through computers and medical systems and classifying those images are welcomed now-a-days. Benefitting this needy trend of therapeutic systems, this chore concentrates on developing a methodology (or system) to automate categorization (classification) of X-ray images into six groups. These six groups of X-ray images considered in this study are chest, foot, spine, neck, skull, palm. Images considered in this study are taken from IRMA image CLEF database. This thesis comprises of-four fragments. Fragment 2 provides some information on existing trends, information on work proposed is summarized in Fragment 3, Fragment 4 shows performance assessment with respect to current developed system. Finally, experimental outcomes are handed over to Fragment 5. Fragment 6 gives conclusion.

2 Existing Trends

Enormous work has been done in past and till date by experts across globe in developing medical systems to aid and automate medical diagnosis wherein [1] introduces an effort to interpret digital images, improve diagnosis quality using techniques like median filter, histogram Equalization, for quality enhancement, PCA, K-nearest-neighbour techniques, were applied for selecting features and classification [2]. Introduces a case-study wherein analysis of malicious software is done based on machine learning approaches. Reference [3] introduces a work wherein an effort has been made to develop a CBIR system to retrieve mammographic images of breast tissue and classify them as dense, fatty, glandular using statistical features and SVM. Reference [4] introduces research on a similar area (with splitting/merging scheme) wherein contrast equalizing histogram, FD, ZM and classifiers like KNN, MLP are used. Reference [5] presents work on TRUS images which uses techniques like M3 filter, DBSCAN clustering, SVM to demonstrate a close curative system. Reference [6] presents a work of similar kind wherein classification of images (breast mammograms) based on breast mass is proposed in which segmentation is performed using fuzzy C-means, GLCM features are taken out and adaboost, back propagation, neural networks, sparse representation classifiers are used. Reference [7] presents work wherein pectoral breast muscle cropping is done where Haralicks' and Zernike descriptors facilitate extraction of features. Classifiers like BPN with SVM operate which resulted accuracy of 95.83%. Reference [8] presents a machine learning based approach to detect/identify images with glaucoma. A series of preprocessing and morphological operations are applied followed by segmenting optic-cup part and extracting rim-disc/cup-disk ratios as features and finally classifying using SVM. Reference [9] In this abstract, collection of (Lung) images are Pre-processed and manipulated with respect to pixel values to either remove distortion, filter the image, enhance contrast for making images fit for better visualization and interpretation [10]. Automated categorizing (of microorganisms) is suggested using SVM classifier. Before performing classification, system feeds image (to module) for Pre-processing then a phase to extract features. Reference [11] introduces thesis presenting a methodology for, classification of lung images in which lung data (images) are collected via lung database with a motto to group them as cancerous/non-cancerous. Prior to the final conclusion, images undergo a set of manipulations constituting Pre-processing (median filter), segmenting (fuzzy c means), GLCM and lastly SVM. Reference [12] shows a machine learning approach to recognize symbols (mathematical symbols) which are handwritten. Reference [13] shows an implementation of a system to detect expressions from a real time dataset of faces by making use of SVM for classification of facial emotions into six categories [14]. Proposes a detection system to ascertain type of breast tissue using GLCM features and FLDA classifier that yielded an accuracy of 72.93% using features based on texture and 82.48% using cascade features [15]. This paper gives an overview on different aspects/studies in educational data mining [16]. Introduces a survey/study on Detection of outliers based on machine learning approaches by considering IOT data for analysis. Reference [17] presents a case study on spam detection based on machine-learning approaches.

Reference [18] Presents classification implementation wherein an approach to classify X-rays by applying M3-filter (better image quality), CCL for segmenting, attributes related to texture, shape are withdrawn by operating with GLCM then classification via SVM [19]. Presents a work on image fusion using guided filters [20]. Introduces a review/study on multi-focus-mage fusion using diversified mechanisms.

3 Proposed Trend

Medical (diagnostic) images accumulated from IRMA (medical image dataset) are fed to Pre-processing module wherein CLAHE (Contrast Limiting AHE (adaptive histogram equalization)) algorithm enhances image calibre (Besides this, other filtering methods like median filter, histogram Equalization; are used to examine, compare the overall system performance) accompanied by segmentation utilizing Connected component Labelling. Texture features for interested region (ROI) are pulled out using GLCM statistics. SVM model is built to which images are fed for classification. System architecture is pictorially introduced in Fig. 1.

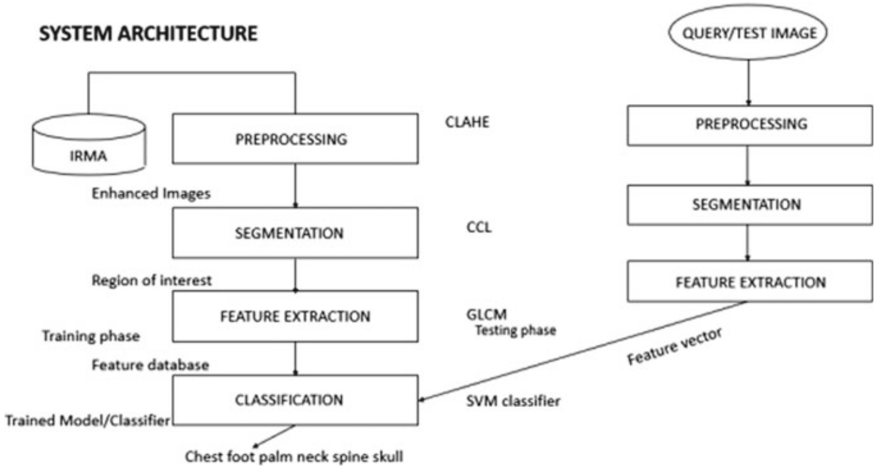

Fig. 1 Architecture of proposed trend

3.1 A Module to Improve Quality of Images-Pre-processing

For quality intensification (also termed as image enhancement), intensities (or intensity values, pixel values) of digital X-rays are modified which gives finer visualizing, interpretation and displaying experience. It lowers noise within image. One among the pitfalls of median filter is to pull out any outliers (along) with fine or minute details since its' hard for it to differentiate (distinguish) between the two. Median rate (value) will very minutely be affected by anything diminutive in size. Histogram Equalization emphasizes (stresses) on finding image's global contrast that gives too dark, too light images. Since it is not ideal for image enhancement, a variation called CLAHE is implemented here. CLAHE concentrates on finding the local contrast of image areas thereby uniformly distributing image intensities. It also clips off or limits contrast to escape noise amplification if any. Sample images demonstrating Pre-processing strategies (techniques) are shown below in Figs. 2, 3, 4, and 5.

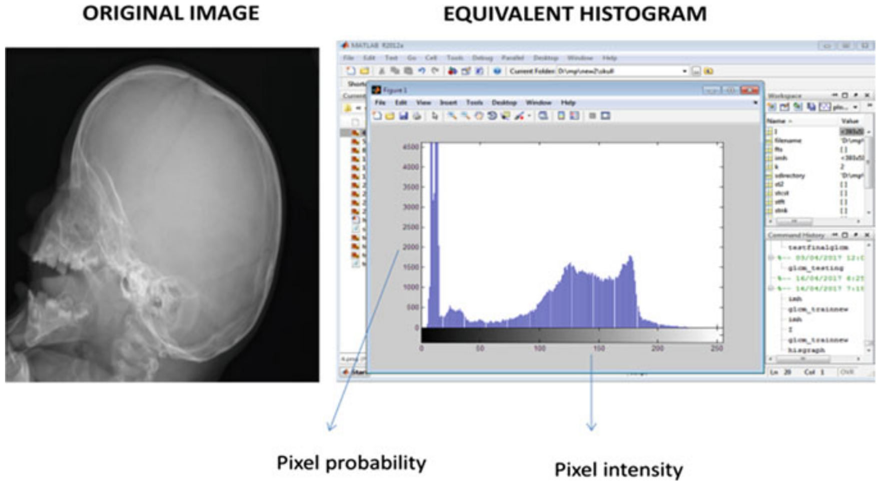

Fig. 2 Original (skull X-ray) image

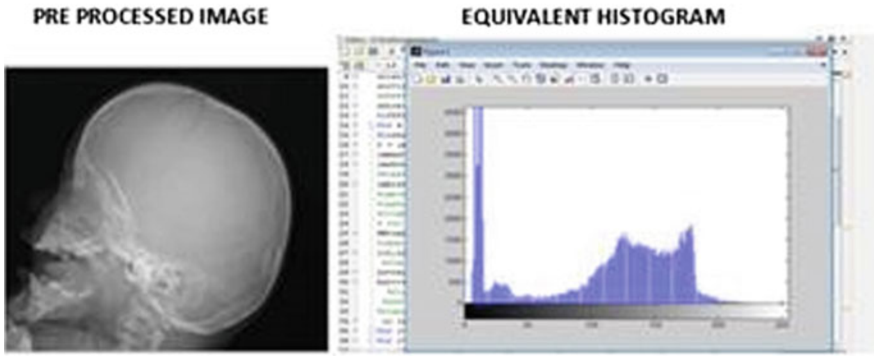

Fig. 3 Image (X-ray) after Pre-processing (median filter)

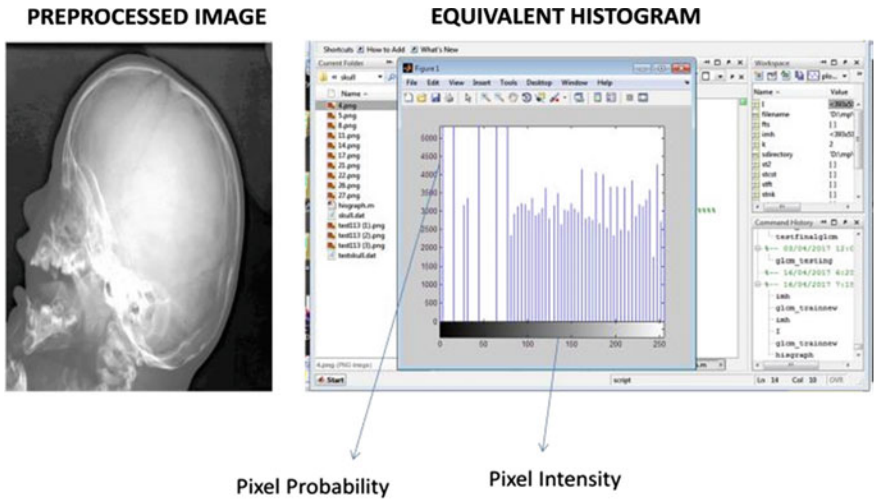

Fig. 4 Image (X-ray) after pre-processing (histogram equalization)

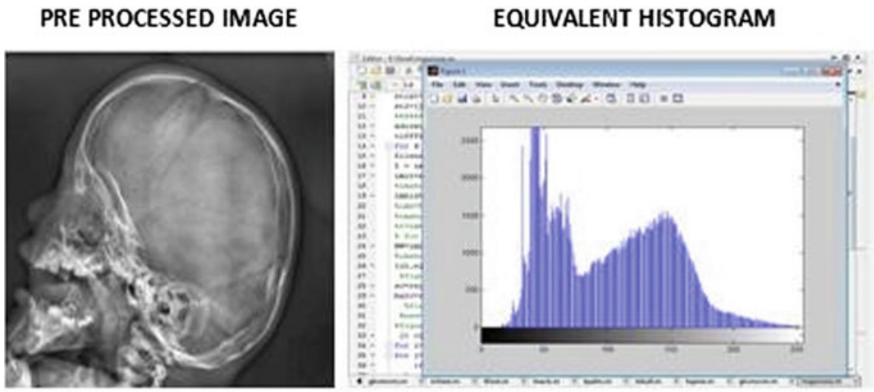

Fig. 5 Image (X-ray) after pre-processing (CLAHE)

3.2 A Module to Extract the Region of Interest-Segmentation

ROI (segmented part) whose features need to be extracted is found using CCL (Connected Component Labelling). This segmentation mode scans an X-ray, group pixels of it considering pixel connectivity. Pixels inside same group share indistinguishable characteristics. Each group of pixels are assigned a label, largest labelled component is the desired region-of-interest (ROI). Since CCL provides a very efficient, user-friendly way to segment the images thereby providing further ease to calculate and display portions of images based on 4-connectivity or 8-connectivity, this has been used in this work.

3.3 A Module to Calculate Statistics-Feature Extraction

When load (input) to algorithm is bulky to be processed (when image sizes are large enough), this input (images) can be represented as compact (feature vector). Here, a statistical methodology called GLCM (Gray Level co-occurrence matrix) is utilized for withdrawing of textural feature-based particulars of the images. GLCM matrices takes (original image's) pixel intensity co-occurrences into consideration and forms a matrix. Resultant matrix is operated to discover texture statistics (features). Proposed work presented here dealt with extraction of 22 features altogether, couple of them are: correlation, dissimilarity, contrast, variance, entropy, energy homogeneity, etc.

3.4 A Module that does the Purpose-Classification

Feature sets of X-rays (used here) computed in previous segment are forwarded to establish a classifier (SVM here). Since all six categories/classes of images are finely pre-processed and features are withdrawn using ROI, SVM here analyzes these feature sets (of images) and classifies them into six categories where images belonging to same class share similar feature values. SVM principal is depicted pictorially. See Fig. 6.

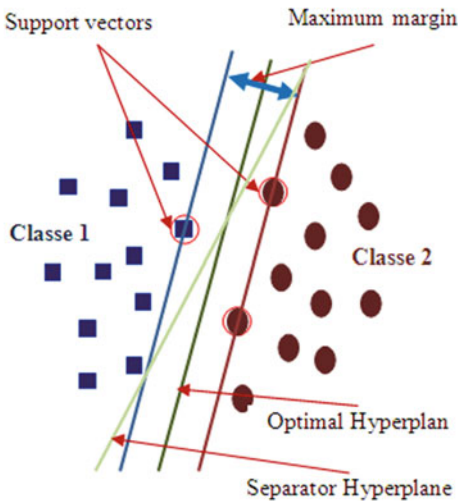

Fig. 6 SVM principal

4 Performance-Evaluation

Thankfully, Machine Learning (ML) approaches/algorithms are furnished with innumerable alternatives to calculate correctness (accuracy) of any model being developed. This study aims at calculating accuracy (how well did the classifier performed) of classifier by utilizing a confusion matrix (which is a-combination of True positives (TP), True negatives (TN), False positives (FP),False negatives (FN) of predicted versus actual task results. Here the classifiers' quality is ascertained using specificity, accuracy, sensitivity and specificity measures.

$$\text{Sensitivity} = \text{TP}/(\text{TP} + \text{FN})\ \text{Specificity} = \text{TN}/(\text{TN} + \text{FP})\ \text{Precision} = \text{TP}/(\text{TP} + \text{FP})$$

$$\text{Accuracy} = (\text{TP} + \text{TN})/(\text{TP} + \text{TN} + \text{FP} + \text{FN})$$

5 Investigational Outcomes

Eventually, CLAHE Pre-processing worked best with GLCM, SVM offering 96% accuracy unlike median filtering, histogram filtering wherein classification result or accuracy was found as 91% ,89% respectively. Overall performance results of classifying X-ray images preprocessed using **CLAHE** are tabulated in Table 1 wherein; for the class Skull, precision, sensitivity, specificity values are 100%, 80%, 100% respectively with an accuracy of about 96.55% in contrast to the class Foot wherein the accuracy is much lesser i.e.; about 89.65%.Overall performance results of classifying X-ray images preprocessed using **Histogram Equalization** are tabulated in Table 2 wherein; for the class Neck, precision, sensitivity, specificity values are 100%, 70%, 100% respectively with an accuracy of about 94.82% in contrast to the class Spine wherein the accuracy is much lesser i.e.; about 84.48%.Overall performance results of classifying X-ray images preprocessed using **Median Filter** are

Table 1 Performance results (measures) for GLCM, SVM- with CLAHE

X-ray- image	Precision (%)	Sensitivity (%)	Specificity (%)	Accuracy (%)
Skull	100	80	100	96.55
Foot	64.28	90	89.5	89.65
Palm	88.88	80	97.1	94.82
Chest	100	87.5	100	98.27
Neck	100	90	100	98.27
Spine	100	70	100	94.82
Overall performance	92.91	82.91	97.76	96

Table 2 Performance results (measures) for GLCM, SVM -with histogram equalization.

X-ray image	Precision (%)	Sensitivity (%)	Specificity (%)	Accuracy (%)
Skull	77.77	70	95.83	91.37
Foot	80	80	95.83	93.10
Palm	66.66	60	93.75	87.93
Chest	54.54	75	90	87.93
Neck	100	70	100	94.82
Spine	66.66	20	97.91	84.48
Overall performance	74.27	62.5	95.9	89

Table 3 Performance results (measures) for GLCM, SVM with- median filter

X-ray-image	Precision (%)	Sensitivity (%)	Specificity (%)	Accuracy (%)
Skull	70	70	93.75	89.65
Foot	100	70	100	94.82
Palm	66.66	80	91.66	89.65
Chest	100	62.5	100	94.82
Neck	100	80	100	96.55
Spine	66.66	20	97.91	84.48
Overall performance	83.88	63.75	97.22	91

tabulated in Table 3 wherein; for the class Neck, precision, sensitivity, specificity values are 100%, 80%, 100% respectively with an accuracy of about 96.55% in contrast to the class Spine wherein the accuracy is much lesser i.e.; about 84.48%. Figures 7, 8 and 9 presents output X-rays (images) post pre-processing, segmentation when those images were preprocessed using CLAHE, Histogram Equalization and Median Filter respectively. The performance measures discloses (shows) that CLAHE preprocessed (X-ray) along with GLCM (texture features) and SVM (classifier) gives a better/finer accuracy over other filters and serves the purpose. Hence, SVM-classification is quite acceptable for classifying X-rays (images). A bar graph (as) in Fig. 10 is opted to present a pictorial/vivid look on classification results.

Fig. 7 Represents X-rays post CLAHE

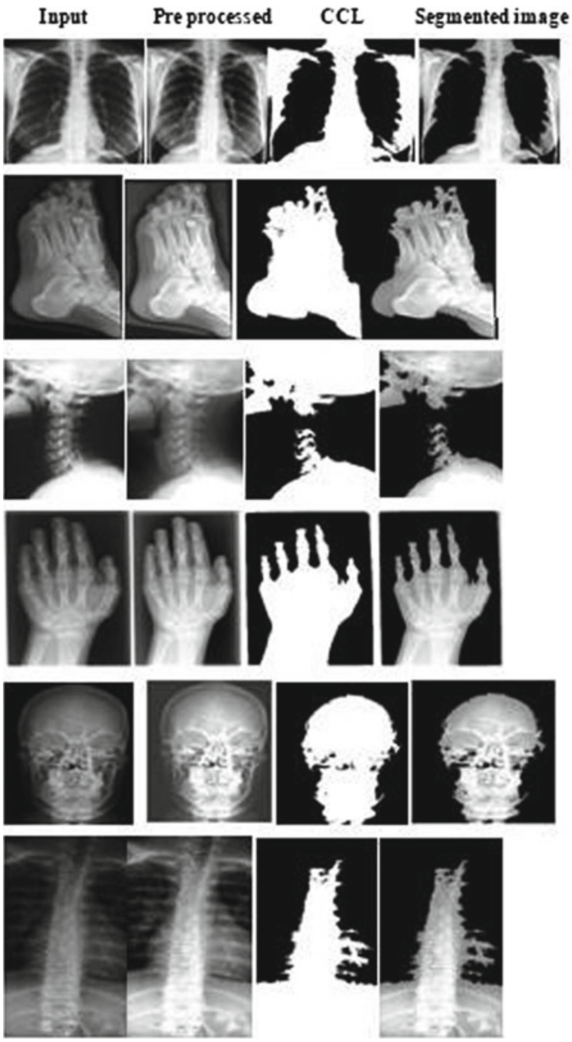

Fig. 8 Represents X-rays post histogram equalization

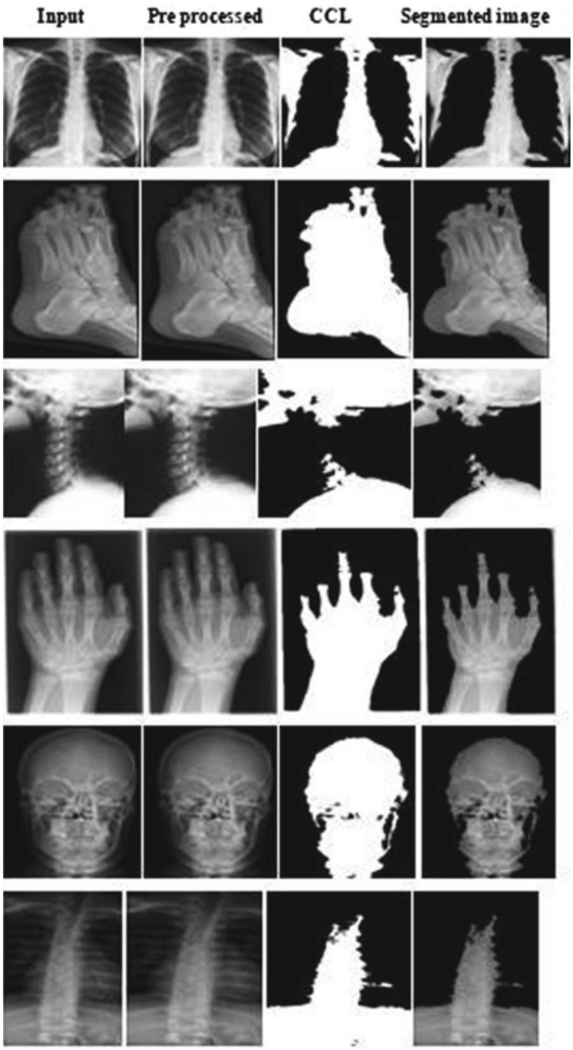

Fig. 9 Represents X-rays post median-filter

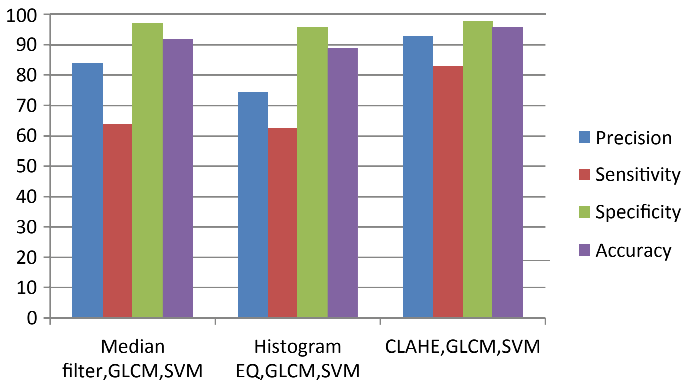

Fig. 10 Performance results (measures) for overall percentage of classified X-ray image

6 Conclusion

In Proposal described here, medical (X-rays) images of six categories namely chest, spine, palm, skull, foot, neck are acquired from IRMA medical database. These images (X-rays) are subjected to Pre-processing module wherein three different image manipulation techniques/strategies namely Median-filter, Histogram Equalization and CLAHE are implemented (or worked with) to compare their performance/results and find which Pre-processing technique works best with GLCM, SVM. Images when Pre-processed with CLAHE outshined among all three with accuracy of 96% altogether, sensitivity of 82.91%, specificity of 97.96% and precision of 92.91%. This gave a conclusion that images when Pre-processed with CLAHE gave better accuracy post classification. Future scope of this proposed work is the extension (of current work) for content based image retrieval systems (CBIR). Unlike the six groups/classes of X-rays images specified above, other parts like knee, elbow, limbs, ankle etc. can also be taken into consideration for future upgrading of medical systems. A Heterogeneous (image) types like C.T, M.R.I, U.S.G etc. can also be worked with in future.

References

1. Fang Yang, MuratHamit 'Feature-Extraction-and-classification-of-Esophageal-X-ray-images-of-Xinjiang-Kazak Nationality' Volume 2017, Article:ID 4620732.
2. Dr. M. Upender kumar, Dr. D Shravani "Novel Design of Machine Learning for Malicious Software Analysis – Malicious URL Case Study" Vol 6 Issue 4 October 2018 – December 2018 pp 292–298 International Journal of Interdisciplinary Research and Innovations (IJIRI).
3. Vaidehi, K., and T. S. Subashini. "Content- Based –Mammogram-Retrieval-based-on-Breast-Tissue-Characterization-using Statistical-Features." Research Journal of Applied Sciences, Engineering and Technology 8.7 (2014): 871–878.

4. Nooshin,jafari and Hosssein “Medical-X –ray-image-hierarchical-classification-using-a-merging-and-splitting-scheme-in feature- space” March 2013 Volume 2, Issue11.
5. R. Manavalan K. Thangaval “Evaluation-of-textural-feature-extraction-from-GLCM-for-prostate-cancer-TRUS-medical- images” ‘International Journal of- Computer Applications’ (No.0975 _ 8887), Volume :36– No:12, December2011
6. Vaidehi, K., and T. S. Subashini. "Automatic-characterization-of-benign-and-malignant-masses-in-mammography." Procedia Computer Science 46 (2015): 1762–1769.
7. V. Kaliyaperumal, S.Selvarajan “Automated-characterization- of mammographic-density-for-early-detection-of-breast-cancer risk”International-Journal-of-Simulation :Systems.Science & Technology. Feb 2014.
8. Sumera, K. Vaidehi, K., and J. Shahistha. "Automated glaucoma detection using machine learning approaches" Turkish online journal of qualitative enquiry”-2021.
9. S.Perumal1 and T.Velmurugan “Preprocessing-by-Contrast-Enhancement-Techniques-for-Medical-Images.” International- Journal -of Pure and Applied- Mathematics” Volume 118 No. 18 2018, 3681–3688.
10. Vanitha.L. and Venmathi.A.R “Classification of- Medical-Images-Using-Support-Vector-Machine” 2011 International Conference-on-Information -and-Network-Technology.
11. Usha Kumari “Lung Cancer Image-Feature Extraction- and-Classification using ‘GLCM’ and ‘SVM’ classifier” September 2019.
12. Firdaus, Syeda Aliya, and K. Vaidehi. "Handwritten-mathematical-symbol-recognition-using-machine-learning techniques." Advances-in-Decision-Sciences,-Image Processing, Security-and-Computer-Vision. Springer, Cham, 2020. 658–671.
13. Sathya, R., R. Manivannan, and K. Vaidehi. "Vision-Based Personal Face Emotional Recognition Approach Using Machine Learning and Tree-Based Classifier." Inventive Computation and Information Technologies. Springer, Singapore, 2022. 561–573.
14. Vaidehi, K., and T. S. Subashini. "Automatic classification and retrieval of mammographic tissue density using texture features." 2015 IEEE 9th International Conference on Intelligent Systems and Control (ISCO). IEEE, 2015.
15. Anjum, Nadia, and Srinivasu Badugu. "A study of different techniques in educational data mining." Advances in Decision Sciences, Image Processing, Security and Computer Vision (2020): 562–571.
16. Nenavath chander, Dr. M Upender, Machine-learning-based-Outlier-Detection-Techniques-for-IOT: A comprehensive Survey Volume 12 Issue 1 January 2021 pp 144–158 International Journal of Advanced Research in Engineering and Technology (IJARET) IAEME publication.
17. Amogh Deshmukh, Dr. M. Upender “Cyber-Security-Engineering-for-Malware-Analysis – Machine Learning for Spam detection case study” Vol 10 Issue 10 October 2019 pp 301–306 Journal of Engineering Sciences JES ISSN 0377-9254.
18. Sumathi Ganesan ,T.S. Subashini “Classification-of-medical- X-ray images-for-Automated-annotation” Journal-of-Theoretical and-Applied-Information-Technology 31, May 2014. Vol. 63, No.3.
19. Dulhare, Uma N., and Areej Mohammed Khaleed. "Taj-Shanvi Framework for Image Fusion Using Guided Filters." Data Management, Analytics and Innovation. Springer, Singapore, 2020. 419–427.
20. Dulhare, Uma, Areej Mohammed Khaled, and Mohd Hussam Ali. "A review on diversified mechanisms for multi focus image fusion." Proceedings of International Conference on Communication and Information Processing (ICCIP). 2019.