A Survey of Techniques Used in Processing and Mining of Medical Images

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Abstract. Medical image processing is the method to enhance and derive meaningful information from digital medical images. Large collection of medical images has led to the rise in some medical information retrieval system whose aim is storing images, retrieval of images, pattern reorganization etc. All of these are done so that some useful knowledge and information might be derived from them. If proper information can be retrieved from the images, it will help in diagnosis, research and education. This paper studies the various image processing and image mining techniques applied on medical images and their utility. This paper helps to understand the different techniques used in different phases of medical image processing and mining like pre-processing, feature extraction, segmentation, classification, indexing, storing and retrieval. This paper concludes by providing possible directions in future work.

Keywords: Medical images · Pre-processing · Feature extraction
Image indexing · Image retrieval · Image mining · Classification
Image processing

1 Introduction

There are various types of image data available from different domain like remote sensing, robotics vision, satellite image, computer aided visualization etc. Among all the categories of image data, medical image data is of utmost important and very sensitive. Proper methodologies should be developed for medical images processing so that it will help the healthcare stakeholders to provide better treatments and practice improved procedure in diagnosis, treatment and prevention of diseases. Medical Images are the visual representation of the organs, bones and other structure within the body for analysis relating to the observation and treatment of patients. It helps to find internal structure of the body by applying different techniques like CT images, MRI, mammography, nuclear medicines to diagnose disease and provide proper treatment. Due to advancement of technology there has been a substantial increase in the numbers of medical images of different categories. Large amount of data is now available from multiple sources. This has become a challenge for researchers for effective data acquisition, filtering, analysis and deriving meaning information. Deriving useful and timely information from the large repository of medical image data is a challenge for

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the researchers. Another challenge in processing and mining of medical image is the variety of medical image as medical images are of different types. Some of the widely used medical images are X-ray imaging, Computed Tomography (CT), Ultra-Sound Imaging (US), Magnetic Resonance Imaging (MRI), Scintigraphy (Anger camera) etc. These images are used by health practitioners throughout the world for analysis, diagnosis and providing treatment to the patient. These varieties of images provides challenges to the researcher in deriving some method for medical image mining and processing. This study is conducted to find about the various image mining and processing techniques used in medical images for knowledge discovery, prediction and proper treatment of patients. In this paper, Sect. 2 describes the processing phases of medical image data including data acquisition and storage, pre-processing, feature extraction, classification, image indexing and image retrieval. It also describes the different techniques used in medical images processing such as rough set, neural network, association rule mining [2, 3], classification [3], the k-nearest neighbour (kNN) and classification algorithm [4]. Section 2.6 describes the possible direction for future work. In the last section the conclusion of the paper is provided.

2 Medical Image Processing

Medical imaging method is a process to picture different parts of a living being. Some of the images are about the tissue, tissue composition or characteristics of bones, blood or other bodily fluids. Sometimes special substances called traces are injected into the body to image the physiological characteristics. There are various types of medical images which are applicable to many areas of healthcare domain like evaluation of MRI images, Interpretation of CT/X-Ray image etc. The main issue in image processing is to process pixel information present in an image into meaning information. Image processing is the technique of deriving a specific feature or enhancing a particular image. In image processing the main aim is to convert an image in digital form or acquire a digital image and enhance the image to identify specific feature for better analysis and interpretation. Spotting pattern, image compression, image enhancement, image restoration etc. are some techniques used for manipulating the image in image processing. Results obtained after image processing is a modified image or a report based on image analysis. The objective of image processing is extracting information from digital images. Medical image processing is supported by many medical imaging techniques like MRI, mammography, ultrasound, CT etc. These techniques are used for visualizing the internal structure of body which provides the required information to health practitioner and facilities them to provide better patient health care. The availability of huge amount of image data available from multiple sources possesses a challenge for researchers for effective data acquisition, filtering, analysis and deriving meaning information. Image processing is a combination of many different field of studies like data mining, machine learning, computer graphics, database system and artificial intelligent. There are two significant techniques in processing of image data. One of them is to process of image data only and other is to process from a combination of images and related alphanumeric characters. Medical Image processing can be divided into the following categories [5, 6]. It is depicted by the following Fig. 1.

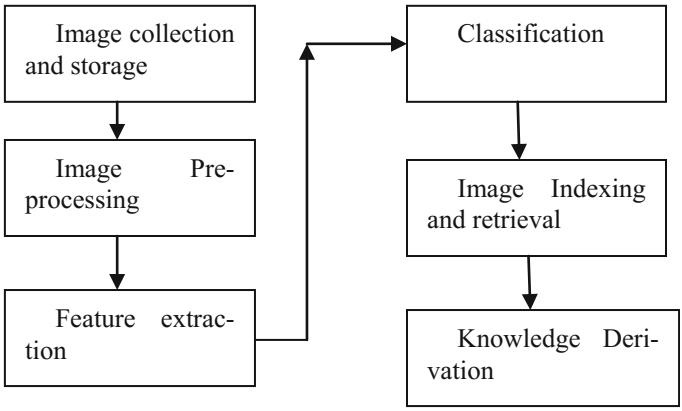

Fig. 1. Image processing stages.

2.1 Image Collection and Storage

There are several ways to store huge volume of image data. Searching for information and knowledge derivation in image database is different from traditional database because spatial information is required in image database whereas no such information is required in traditional database. Semantic values are depicted by the traditional database but in image database values are to be supported by some context. So, applying the methodology of data processing directly in images is not acceptable. This led to the rise of data management in image mining. The data management in image mining and processing is divided in two subdivisions [7]. One of category is to store images and the other one is to index and retrieve images. Storing image data cannot be done by following the rules of database because of difference in image database and traditional database as mentioned above. Many formats have been proposed for storing image data. Some of the format stores the metadata of the image in one file with the image but these have the disadvantage of using more memory and time. Another format proposes storing image metadata into separate relational database for faster and efficient image management. Object Oriented Databases are also proposed as a way for standardizing the image storage [7].

2.2 Image Pre-processing

This is an essential step required for enhancing the quality of image before proceeding to next phase [8]. Its importance ensures the quality of image data and subsequently the overall result. The main objective of analysis is to improving the image quality before applying any techniques for object detection or classification. Some of the techniques applied in image pre-processing are wavelet function, histogram equalization method, median filtering, high pass filter etc. Removal of noise or de-noising is one of the most important steps this state. It can be done by many techniques such as median filtering, wiener filtering and DWT (Discrete Wavelet Transform). Filtering of noise from images can also be done using different techniques such as Gaussian filter, high pass

filter, adaptive median filter etc. After removal of noise the focus in pre-processing shifts to recognition or enhancement of object in an image. Histogram equalization techniques, grey scale modification, thresholding and Markov random model are used to enhance different types of images so that further techniques can be applied. Enhancement of biopsy images is done by Grey Scale Modification, thresholding and interpolation. Color Image enhancement is achieved by statistical mixture model like Dirichlet and Gaussian mixture, vector direction filter and markov random model. Contrast enhancement of image can be achieved by using hybrid filter containing simple mean and fuzzy switching median. To improve the segmentation median filter, histogram equalization and normalization are used. To compress images without any loss Haar wavelet functions can be applied. CT scan brain images are pre-processed by Shape priori technique. Alteration of images for presenting them in a format which is suitable for transformation techniques can be achieved by applying wavelet functions.

The different techniques of pre-processing used in medical images are mentioned in the Table 1 given below:

2.3 Feature Extraction

This stage refers to the methods used in analyzing objects or images to extract significant information that are representative of various classes of objects. Feature Extraction basically focuses on changing the identified objects into some sets of attributes. Features are generally mathematical representation of an image which describes the object in term of shape, texture or color. Various transformation and feature extractions techniques are applied to recognize pattern. Inferring knowledge can be done by pattern interpretation which can then be used in an application. 2D Gabor feature, association rule mining, sobel edge detector, grey tone spatial dependencies, fuzzy C mean algorithm, expectation maximization (EM) algorithm are some of the methods used for extraction of useful features from medical images. To find feature which are independent of each other decision tree, naive Bayes classifier, normalized cut algorithm, PCA (Principal Component Analysis), DWT (Discrete Wavelet Transformation), nonlinear anistropic diffusion and automatic thresholding are used. Entropy based discretization; Fuzzy clustering technique and fuzzy connectedness framework are used to group objects of same type. To improve visualization of MRI data and extract feature boundary expectation maximization (EM) algorithm is used. Fuzzy connectedness framework is used to find connectedness between image elements and grouping objects of same type. To incorporate contextual information and segmentation of single and multispectral MR image Markov random field are used. A combination of texture, color and edge extraction techniques is used to improve detection process. Identifying natural cluster of patient population is done by unsupervised neural networks. Support vector machine is used to derive nuclear features from segmented nuclei. Some texture feature extraction techniques are Haralick's statistical measure, GLCM and 2D wavelet transform function. Extraction of feature set essential for classification is done by Texture Features based on gray-tone spatial dependencies, Gabor Feature, Sobel edge detector and Gabor transforms and Histogram Equalization Method.

Table 1. Techniques used in pre-processing of medical images.

References	Techniques	Utility
Sikka et al. [9]	Haar wavelet	Image compression without losses
Nikolic and Tuba [10]	Median filtering process	Detection of edge features
Zäıane et al. [11]	Histogram Equalization Method	Image Enhancement
Rajendran et al. [12]	Shape priori technique	CT-Scan brain image pre-processing
Reni et al. [13]	Contrast enhanced gray-scale conversion algorithm	Morphological filtering of the blood images to remove unwanted components
Diwakar and Kumar [14]	Weiner filtering	Removal of noises in CT images
Wang et al. [15]	Wavelet transform	Alteration of images for presenting them in a format which is suitable for transformation techniques
Trzupek and Ogiela [16]	Aggregation based on the Ferret diameter and centre of gravity	Detection of pathological changes in structure of coronary arteries automatically
Subudhi et al. [17]	Histogram partition combined with maximum entropy divergence	Extracting images of brain in MRI images
Rana et al. [18]	Statistical mixture models like Dirichlet and Gaussian	Colour image enhancement
Aina et al. [19]	First add Gaussian noise in the brain MR images and then noise is removed by Fast discrete Curvelet transform (FDCT)	Removal of noise in MRI images
Jamil et al. [20]	Hair artifact removal of dermatoscope images	Morphological and Gabor wavelet functions
Vijaya and Suhasini [21]	Different filters like-High Pass, Adaptive Medians, Alpha-Trimmed Filter, Laplacian and Gaussian	Undifferentiated noisy and fine detail pixels
Patil and Udupi [22]	Median filter and an algorithm that uses morphological operations	Reduce the over segmentation problem
Kaur and Kaur [23]	Hybrid filter containing simple mean and the fuzzy switching median	Contrast enhancement of image

Table 2 depicts the various techniques used for feature extraction with emphasis on medical images.

2.4 Image Classification

Classification means categorization of objects present in an image. Supervised classification groups the detected objects into some predefined categories. Some methods of supervised classification are support vector machine, rule based classification, decision tree, neural networks etc. Unsupervised classification or image clustering means grouping of objects based on some common factors. Hierarchical clustering, fuzzy clustering and nearest neighbor clustering are some types of unsupervised clustering.

Table 2. Feature extraction techniques used in medical images

Reference	Techniques	Utility
Sikka and Ogiela [9]	Sobel edge detector and Gabor transforms	Edge and texture features extraction
Noorazlan et al. [24]	2D Gabor Filter	Feature extraction from medical images
Zäıane et al. [11]	Histogram Equalization Method	Extracting features so that it can be organized in a database
Wang et al. [15]	Entropy-based Discretization	The majority of the values in a bin correspond to having the same class label
Trzupek and Ogiela [16]	Decision tree or Naive Bayes Classifiers	To find features which are independent of each other
Smitha et al. [25], Kaur and Wasan [26]	Association rule mining	Extraction of hidden information from medical image data sets
Kovacevic and Loncarec [27]	A receptive field (RF)	Feature extraction and normalization
Elsayed et al. [28]	Normalized Cuts algorithm, Spectral Segmentation with multiscale graph decomposition, Modified Spectral Segmentation	Application in brain MR images to extract the Corpus Callosum segment from these image
Rajani et al. [29]	PCA (Principal component analysis), DWT (Discrete wavelet transformation)	Extraction of frequency space information from non-stationary signals
Haralick et al. [30]	Texture Features based on gray-tone spatial dependencies	Extracting feature set which are essential for classification
Liu and Wechsler [31]	Gabor Feature	Extracting features of the image useful for classification purpose
Kociolek et al. [32]	Transformation by Discrete Wavelet	Texture Analysis of Digital Image
Haralick et al. [33]	Decision boundary feature extraction principal component analysis, non-parametric weighted feature extrasion, minimum noise fraction transform, discriminant analysis, analysis of spectra and transformation of wavelet	Reduce the data redundancy by feature extraction
Atkins and Mackiewich [34]	Histogram analysis, nonlinear anisotropic diffusion and automatic thresholding	(1) Removing background noises so that a head mask is left (2) Detecting irregular border of the brain image (3) Refining of the irregular brain border to a final mask
Bezdek [35]	Fuzzy C-Means (FCM) algorithm	Brain tumour extraction from brain MRI images
Boskovitz and Guterman [36]	Fuzzy clustering technique	Image segmentation by using adaptive threshold method in the input images using labels automatically
Whitey and Koles [37]	Thresholds, region growing, edge tracing	To distinguish regions with contrasting intensity levels
Anbeek et al. [38]	K-Nearest Neighbor	Generation of brain structure image for each types of tissue in cranial MR imaging

(*continued*)

Table 2. (*continued*)

Reference	Techniques	Utility
Zhang et al. [39]	EM (expectation–maximization) algorithm and HMRF (hidden markov random field) model	MR images segmentation
Udupa and Sekera [40]	Fuzzy connectedness framework	Strength of connectedness between image elements is determined connecting paths between the pairs This results in grouping of objects of same type
Wells et al. [41]	Expectation-maximization (EM) algorithm	(1) Improved visualization of MRI (magnetic resonance imaging) data (2) decision boundary feature extraction
Niessen et al. [42]	Segmentation based on edge and region	Minimum user interaction is required for segmentation of, cerebrospinal fluid, grey matter and white
Leemput et al. [43]	Markov random Fields (MRF's)	Segmentation of single- and multi-spectral MR images and incorporation of contextual information
Foschi et al. [44]	Color Feature Extraction, Texture Feature Extraction and Edge Feature Extraction	A combination of this three process to improve the detection process
Zubi and Saad [45]	Pattern recognition	A combination of a feature extraction process
Shalvi and De-Claris [46]	Unsupervised neural networks	Identification of natural clusters formation from patient populations
Tohka et al. [47]	Support Vector Machine	Extraction of nuclear features from segmented nuclei
Fayez et al. [48]	Haralick's statistical measures, GLCM and 2D wavelet transform	Texture features extraction

Supervised classification is also called as parametric or hard classification whereas unsupervised classification is also called as non-parametric or soft classification [20]. There are many different techniques used in image classification. Classification of digital mammography into two sections can be done by using association rule mining. This technique can also be used to divide CT images of brain into three groups namely benign, malign and normal. This is also used to detach corpus callosum region from the rest of brain image. Decision tree algorithms are used for mammography classification and pre-processing of CT brain images and creation of a model to segment brain images. Retrieving and classification of different medical images can be done by text based indexing and classification system, Texture correlogram, support vector machine, self-organizing map and wavelet transformation. Classification is also done by neural network or support vector machine, example is given of classification of digital image of chest X-ray into two groups: abnormal and normal. Classification of medical images based on energy, homogeneity, entropy and contrast is done by test based image classification. To reduce searching time of an image by grouping images into cluster fuzzy C-mean (FCM) may be used. Multilayer perception model are used to classify images on different criteria. Classification of breast mammography and detection of

cancerous tissue is done by genetic algorithm, branch - bound algorithm and Grey Level Concurrence matrix, Decision tree c4.5 is used to classify image samples into healthy and unhealthy. K-nearest neighbour (KNN) combined with genetic algorithm improves classification in image database. Categorization of medical images can be done by self-organising map and wavelet transformation.

Table 3 shows the different techniques of image classification with emphasis of medical images in Table 3.

Table 3. Image classification techniques in medical images

Reference	Technique	Utilities
Antonie et al. [3]	Association rule mining and neural networks	Detection of anomaly and classification
Sikka et al. [9]	Naïve Bayes and Support Vector Machine	Classification accuracy of retrieval
Zäıane et al. [11]	Association Rule based classification	Classification of digital mammography into two sections: normal and diseased
Farrugia et al. [49]	A text based indexing system	Retrieving and classification of Mammographic images
Yi et al. [50]	Texture correlogram (a new texture feature) and SVM (support Vector Machine)	High-level image classification
Zäıane et al. [11]	Association Rule based classification	Classification of digital mammography into two sections: normal and diseased
Reni et al. [13]	Nearest neighbour	Image classification
Trzupek and Ogiela [16]	Weighted Association Rule Mining (WARM)	Comparing the symptoms of patients with the existing Database
Subudhi et al. [17]	SVM. Naïve Bayes classification, Decision trees and Neural Network	To create a proto type for segmentation of brain images
Kovacevic and Loncarec [27]	Artificial neural network, radial basis function (RBF)	Classification of image regions and their labelling
Elsayed et al. [28]	Decision Trees, Support Vector Machines, Association Rule based classification	Build classifiers which will detach the Corpus Callosum region from the rest of the Brain image
Tohka et al. [47]	Classification scheme	Analyses of nuclear feature of brain into high, medium and low grade tumours
Fayez et al. [48]	K-Means clustering	Cluster images based on some feature
Kaur and Kaur [51]	Neural network and SVMs.	Classification digital X ray images of chest into two class i.e. abnormal and normal
Beevi et al. [52]	Fuzzy C-Means	Segmentation—of medical images by clustering
Abdul et al. [53]	Text based image classification	Categorization of different types medical images on the basis of energy, homogeneity, entropy and contrast
Zhou et al. [54]	Support Vector Machine	Automatic detection of brain tumour from MRI images
Matthew and Nachamai [56]	K-Means algorithm	Clustering brain MRI images

(*continued*)

Table 3. (*continued*)

Reference	Technique	Utilities
Deepa and Devi [57]	Fuzzy C-Means, Artificial Neural Networks, Support Vector Machine and Multilayer Perceptron model	Classify images based on different criteria
Devasena et al. [58], Purnami et al. [59]	Genetic Algorithm, GLCM (Grey Level co-occurrence Matrix) and fast branch - bound algorithm	Detection of cancerous tissue from mammography images of breast
Purnami et al. [59], Sathees Kumar and Anbu Selvi [60]	MKS (Multiple Knot Spline) with SVM (support vector machine)	Heart disease and diabetes diagnosis
Tu et al. [61]	Decision tree C4.5	Performance of the given method is tested to classify image samples into healthy and unhealthy
Kalaivani and Shunmuganathan [62]	K-nearest neighbour (KNN) combined with genetic algorithm	Improve classification performance in image dataset
Soliz et al. [63]	Neural network-based system	Reduction of both inter- reader variability and intra-reader variability for diagnosing chest radiographs
Thangaraju and Barkavi [64]	Neural Networks, Association Rule Mining, Apriori algorithm	Extraction of features from the database having x-ray of chest and categorizing each x-ray chest film
da Silva and Moreno [65]	Self-organizing map and wavelet transformation	Categorization of medical images
Wang et al. [66]	Combination of local binary pattern and SVMs, combination of wavelet transformation and SVMs	Compares and reveals the general characteristics for identifying of ophthalmic images

2.5 Image Indexing and Retrieval

A suitable indexing scheme is required for efficient retrieval of information from any database. In relational database, the concepts of primary and foreign key are used. This concept is not suitable for image database in image mining because image database is vastly different from relational databases. Hence several indexing techniques are developed for mining in image database. Some common techniques used in image indexing are Non Euclidean similarity measure and signature file access method for multidimensional database. X tree is used to minimizing overlap in image indexing. X tree is also used to create index structure necessary in high dimensional database. Multidimensional indexing method can be created by TV index tree, i-minmax and R* tree. An indexing scheme used for dealing with queries in high-dimensional nearest neighbour is created by using SR tree. Dynamic index structure necessary for spatial searching is created by using R tree.

Table 4 depicts the various techniques used for Image indexing.

Image retrieval system is used to browse, search and retrieve images from a digital images repository. Image retrieval methods can be divided into three categories.

Table 4. Study of image indexing techniques in medical images

Reference	Technique	Utilities
Berchtold et al. [67]	X tree	Split algorithm minimizing overlap in image indexing
Robinson [68]	The K-D-B Tree	Searching in huge multi-dimensional indexes
Gutnum [69]	R Tree	Dynamic index structure used in spatial searching.
Berchtod et al. [70]	X Tree	Index structuring used in high dimensional data
Katayama and Satoh [71]	SR-tree	An index system necessary in high-dimensional nearest neighbour queries
Dahabiah et al. [72]	TV index tree, i-minmax, R* tree, R+ tree	Multidimensional indexing method

(a) Query by Associative attribute is based on retrieval of images where attributes are stored as metadata.
(b) Query by Description is based on context associated with images.
(c) Query by Content is based on visual content such as texture, shape, color etc.

Some applications also apply a hybrid of above techniques for image. A hybrid image retrieval algorithm has been developed which include both two text model and visual features [73]. Deep learning architecture can also be used in image retrieval [74]. Fuzzy production rules are used for high level semantic image retrieval. Clustering techniques based on CBIR is used for retrieving of prominent feature of image. Retrieval of perceivable and textual information from images can be done by clustering and association rule mining. Image retrieval based on texture is done by color histogram. Weighted Euclidean distance is used to retrieve color feature. Pyramid structure wavelet functions are used for retrieval of image based on shape, color and texture. Retrieval of MRI image can be done by edge histogram and texture spectrum histogram. Unsupervised image segmentation technique based on cellular automata is used for image retrieval. Retrieving images having common pattern in medical database is done by image sequence similarity pattern (ISSP) and fuzzy retrieval techniques. Retrieving diagnostic cases similar to medical images is done by Support Vector machine.

Table 5 shows the different image retrieval techniques and their utilities

2.6 Future Directions and Discussion

The main aim of image mining and image processing is to remove loss of data and extract meaningful information as and when required by patients, healthcare providers and other stakeholder in medicine domain. The size and variety of medical image data is increasing in a very fast pace. Development in different energy source like magnetic, radio-frequency, optical and nuclear have added many forms or properties in the variety of medical images. This provides challenges to the researchers in medical images to

Table 5. Image retrieval techniques in medical images.

Reference	Technique	Utilities
Stanhev [75]	High level semantic features image retrieval	Fuzzy production rules
Kannan et al. [76]	Image retrieval on basis of prominent feature of the image	Clustering techniques based on CBIR (Content Based Image Retrieval)
Kannan et al. [77]	Optimum clusters based image retrieval	Improved CBIR with user interaction
Neethu and Wilson [78]	Clustering and association rule mining	Retrieval of visual and textual information from images
Sreelaksmi and Anil [79]	Colour Histogram	Image retrieval based on texture
Jyothi et al. [80]	Clustering technique using steerable filter and pseudo-zernike movements	Shape and feature extraction
Song and He [81]	Improving Precision Priority (IPP) algorithm	Increased precision in Content based Image Retrieval
Dong [82]	Multi-feature based retrieval	Improved retrieval in CT images of chest scan
Zhang et al. [83]	Modal shape description based search engine	Retrieve clinically similar medical images
Youssif et al. [84]	Pyramid structure wavelet	Retrieval of image based on shape, color and texture
Somnugpong and Khiewwan [85]	Color correlograms and edge direction histogram (EDH)	Improved Graphical image retrieval system by combing more than one feature
Huang et al. [86]	Ranking and multi-view learning	Retrieving image on basis of region
Kumuran et al. [87]	Edge histogram and Texture spectrum histogram	Retrieval of MRI images
Rahman et al. [88]	Classification-drive similarity matching	Biomedical image retrieval
Ghosh et al. [89]	Unsupervised image segmentation technique based on cellular automata	Image retrieval based on retrieval
Kawade and Bang [90]	Incorporation of genetic algorithm in CBIR	Image retrieval based on some defined ranked.
Enireddy and Reddy [91]	Naïve Bayes, SVM	Retrieve diagnostic cases similar to query medical images
Pan et al. [92]	Image sequence similarity patterns (ISSP)	Retrieving images having common pattern into medical image database

develop new techniques for analysis, storage, mining and retrieval of correct and timely information for helping in welfare of patients. The field of medical image Processing is in infancy and many issues remain unsolved.

- Retrieving information from fusion of unstructured heterogeneous data.
- Indexing compressed images
- Feature extraction from compressed image.
- Classification of classes into detailed higher level class.
- Improved performance in all the phases of mining process starting from image acquisition, storage, preprocessing, feature extraction, classification and knowledge derivation.

2.7 Conclusions

This paper presents the various image processing techniques that have been applied for medical image data. Fast growth in volume of medical images has made image mining techniques necessary for decision support and prediction in the area of healthcare. This paper has discussed about the various image mining technique used in medical images to provide significant outcome. According to this paper median filtering is the most commonly used technique used in image pre-processing followed by wavelet function and histogram equalization. In feature extraction decision tree model and its variation is mostly used. Other techniques used in feature extraction are Gabor feature, fuzzy techniques and GLCM (Gray-Level Co-Occurrence Matrix. For extracting common features in CT images from image transaction database a novel fuzzy association rule can be applied. For classification of images association rule mining, SVM (Support Vector Machine) fuzzy Techniques and neural network are widely used. Proper storage of medical image data can be achieved by Object Oriented database. Image indexing can be done by X tree, R tree, R+ tree and their variations. One of the main techniques used in image retrieval is CBIR (Content based Image Retrieval). This information should be produced in a way which can be used by medical practitioners and stake-holders in predicting trends in diseases. This will lead to better diagnosis and research which will improves patient care.

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