Classification of Abnormalities in Medical Images Based on Feature Transformation- A Review

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Abstract— Computer Aided Diagnosis (CAD) has become one of the major research areas in the field of medical imaging. Interpretation and analysis of medical image data is the most challenging and advanced application area of pattern recognition and computer vision. The development of medical imaging technology led to the increase in the number of parameters evolved to describe the human physiological condition, forming high-dimensional clinical datasets. Processing such a high-dimensional dataset causes high computing cost and storage that reduces the performance of the system. In this paper we made a study on different feature transformation/reduction techniques presently available in the literature and aim to propose a study on the data reduction techniques that preserve the most relevant features by providing the significance of those features. Such study will evolve a novel approach that discover optimal feature subset for real valued dataset used in building the classification model. The aim of the proposed model is to combine the features of Principal Component Analysis and Linear Discriminant Analysis, the conventional dimensionality reduction techniques commonly used in the present scenario. The reduced number of features evolved by the proposed model gives the significance of each feature in the classification and leads better performance in the classification. Further we also aim to propose feature ranking algorithm to improve the efficiency of the classification based on different methods such as Rough Set Theory, Fuzzy-Rough Set, Hybrid Genetic Algorithm, Fuzzy Rough feature selection using Support vector Machine (SVM) and filter-based feature ranking techniques.

Index Terms— *Dimensionality reduction, Feature extraction, Feature transformation, Linear Discriminant Analysis,* Medical imaging, *Principal Component Analysis.*

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1 Introduction

Recently in many areas of health care including screening, diagnosis, prognosis, monitoring, therapy, survival analysis and hospital management, machine learning classification techniques etc. provide the support of decision-making process [1]. Medical images acquired from photography (e.g., endoscopy, histology, dermatology), radiographic projection (e.g., x-rays, some nuclear medicine), and tomography (e.g., CT, MRI, ultrasound) impose unique, image-dependent restrictions on the nature of features available for diagnosis and abstraction [2]. In all these imaging modalities, input is a set of features that produce different types of outputs in many different situations. Therefore, it is very difficult to manage and provide uniform modality in the classification of abnormalities in medical images. Various studies demonstrate that researchers are still struggling a lot for devising good feature extraction techniques for analysing the different types of abnormalities to improve the accuracy and performance of classification of all these types of algorithms [3]. This is one of the major challenges in the medical image processing and it aim to devise a Computer-Aided Diagnosis (CAD) system which consists of compact set of feature extraction techniques and classification whose key feature is the ability to detect and classify pathological patterns in medical images in a unique manner [4].

Present and future researchers have to face the challenges arising from huge volume of data when applying knowledge discovery techniques in real world problems [5]. Managing this high dimensional data set for making effective classification is very difficult and the features among these set are either relevant or irrelevant for the specific situation of the classification. In situation where the relevant features set itself have redundant in nature and leads the performance degradation in final classification. Therefore, identifying and removing such redundant and irrelevant features from the set of features extracted for the classification is the one of the important challenges in the field of conventional machine learning algorithms. The way of eliminating such irrelevant and redundant features is commonly known as dimensionality reduction. There are mainly two approaches for handling dimensionality reduction known as feature extraction / transformation and feature selection / reduction. In all these dimensionality reduction methods are proposed for retaining most relevant features by eliminating all those irrelevant and redundant feature [6][3]. Feature extraction is the process of transforming input data into lower dimensional space to obtain most relevant feature/ information and feature selection reduces the input features to a minimal set by preserving the meaning of original features [7]. In order to tackle the problems like accuracy, storage, cost and time while dealing with high dimensional data, it is necessary to build a novel method for feature extraction that provide a unique model with minimum set of features for classification and learning. Therefore, the most appropriate analytical tools are to be developed for improving diagnostic accuracy and efficiency in prediction of abnormalities in medical images at early stage with which radiologists render decisions [8]. So, identifying and isolating such relevant features from the known relevant feature is a tedious job, but it makes the classification accuracy and performance much higher than the conventional feature extraction and classification methods. So, in this paper our main intension is to make a comparative study on different feature transformation methods such as Linear Discriminant Analysis (LDA) and Principal Component Analysis (PCA) and propose an efficient method for feature reduction by transformation for assessing the efficacy of automated medical imaging system for predicting and diagnosing the disease at the early stage.

The rest of the paper is organized as follows: section II describes the literature review of the related work that have been performed on different modalities of medical images to analyse various dimensionality reduction techniques. Section III, presents the dimensionality reduction approaches, to analyse how effectively these techniques can be utilized to achieve high performance of medical image classification algorithm that ultimately improves the accuracy and prediction of the abnormalities present in medical images. In section IV, the merits and demerits of existing methods followed by the proposal of effective modal to overcome the demerit that was identified during these surveys are also presented.

2 Literature Review

This literature review projects the widely used feature extraction methodologies used in different modalities of images.

Khalid et.al in [3] had presented a survey to determine how effective feature selection and feature extraction techniques can be used to achieve high performance of learning algorithms with improved predictive accuracy of classifier. Their study reveals that there is no single feature selection method that can be applied to all applications. Their studies also suggest that hybrid model of feature selection is better while dealing with high dimensional data that combines the advantages of filter and wrapper-based method. The classification accuracy achieved with different feature reduction strategies are highly subtle to the type of data that are used is shown in their study. From the experimental results it has concluded that feature selection methods that handle elimination of both redundant and irrelevant features at once are much more vigorous and beneficial for learning process as compared to methods that discretely handle feature redundancy and/or irrelevant features. Moreover, the studies suggest that, as the computation time and accuracy of the learning machine is crucial, they need to be considered as an important factor.

In [4] Huber et.al, proposed a novel approach to estimate the relevance of texture features in their ability to classify healthy and diseased lung patterns in High Resolution Computed Tomography (HRCT) images by using the Generalized Matrix Learning Vector Quantization (GMLVQ). This approach incorporates a stochastic gradient descent to determine the relevance of several input dimension for a specific classification task. The 65 texture features of real-world data extracted from Grey-Level Co-occurrence Matrices (GLCMs) are then ranked and selected according to relevance obtained by GMLVQ and for comparison to a Mutual Information (MI) criteria. The result produced shows significantly better classification performance compared with feature sets selected by a mutual information (MI) ranking. The relevance of only single feature is estimated by this approach, and they suggested a future consideration of GMLVQ should include the pairwise correlation for the feature ranking to reduce the redundancy of two equally relevant features.

The authors in [9] had proposed an image classifier to classify the mammogram images into normal, benign and malignant image. This hybrid approach of Greedy stepwise method and Genetic Algorithm uses statistical feature extraction technique to improve the accuracy of the classification algorithm for the detection of cancer. This method builds classification model that reduces or eliminate irrelevant and redundant feature and increase the performance of the system with least cost. This can be opted as a standard uniform model for building other type of image analysis application too. Initially they extracted 26 features from Mini-MIAS mammogram image and by using this hybrid approach of feature selection 75% of features was reduced. The reduced feature set is then given as input to decision tree classifier to train and test the classifier which gives an overall accuracy of 95%.

The authors in [10] developed a novel system for the diagnosis of breast masses using different feature extraction methods. Five sequential and randomized feature selection methods were applied on 159 features generated from each ROI, to select the most relevant features. As the next step, to reduce the dimensionality of the feature set and to minimize the computational complexity, Principal Component Analysis (PCA) is applied. To accumulate the advantages of three classifiers, a fusion method called Majority Vote (MV) is applied which is based on voting algorithm. As per the examination of the result they concluded that best feature performance was achieved for texture feature corresponding to Gray Level Run Length Matrices (GLRLM) descriptor.

The authors in [11] investigated different feature extraction and classification methods for identifying the abnormalities present in mammogram images. For extracting abnormal regions from a mammogram image, two different texture feature extraction methods such as Wavelet transformation and GLCM are used and it provides better classification accuracy and performance. To derive more effective and compact feature vector for classification, dimensionality reduction method called Principal component Analysis (PCA) on wavelet transformation coefficient were applied. It shows better result for reduced Wavelet transformation coefficient for mammogram images in the Mini-MIAS dataset compared to the above method. This study reveals that feature vector obtained with PCA with reduced DWT coefficients and Lazy classifiers (K*/IBL) is the best alternative for achieving high classification accuracy and performance. This work yields good results by reducing the number of features by transforming to a smaller number of features, which improve the performance and accuracy of the classification. This can still be improved, if the features are ranked by identifying the contribution of each feature's significance.

Filho et.al in [12] proposed a novel feature extraction method for medical images based on Analysis of Human Tissue Densities (AHTD). The proposed method provides a faster extraction of the required attributes and obtained best accuracy and f-score indices in the two datasets evaluated. The attributes that were extracted from lung disease images in 5.2 milliseconds obtained an accuracy of 99.01%, while the attributes obtained from the brain images were extracted in 3.8 milliseconds obtained an accuracy of 98.81% in the detection and classification of lung diseases and stroke respectively. These achievements of the proposed system show that it can be used in the classification of various diseases in medical images as well as an alternative method for real-time applications due to its fast extraction of suitable attributes and best performance.

Jothilakshmi and Raaza [13] proposed a method for the detection and classification of mass abnormalities in digital mammogram images using multi SVM classifier. The images acquired from Mini-MIAS database are segmented using region-based segmentation with split and merge technique. Texture features are extracted from the ROI samples using Grey Level Co-occurrence Matrices (GLCM) and Multi-Support Vector Machine (MSVM) are used for the purpose of classification between malignant and benign samples. The accuracy for the classification is estimated to 94%. One limitation of this proposed system is that they considered very few images and only thirteen features are extracted which can be improved by considering more data set and features by providing some feature reduction/ranking methods based on the relevance of the features under consideration.

A detailed literature survey is made on different algorithms of feature transformation techniques using various medical imaging modalities. Most of the research papers discussed in the literature review faces hurdles in building more accurate model for interpreting and analysing medical images with huge amount of data. In order to reduce the size of the input data, various reduction methods such as PCA and LDA were used. These techniques basically reduce the dimension of the data by transforming the input data as feature by representing it in a lower transformation level by retaining the most relevant features. These newly formed dataset would be a feature representation in lower dimensional which possess most of the characteristics of the original features. PCA is such an approach which reduces the dimension of the data by finding a few orthogonal linear combinations (the principal components PCs) of the original variables with the largest variance. LDA is another approach in which a supervised dimensionality reduction technique is based on a linear projection from the high dimensional space to a low dimensional space by maximizing the between class scatter while minimizing the within-class scatter by using the class information [14]. Even though all these methods had established well desired outcome but do not provide any information regarding the significance of each feature by its relevance in the form a rank or unique number that took part in building of final model for the classification. So, all these methods require further improvement that provide information about the significance of the feature chosen by the classification model. Further such a model effectively provides much more classification accuracy and performance for detecting abnormalities in medical images without changing the domain of the features. So, we aim to propose a novel approach that discover optimal feature subset by combining the features of Principal Component Analysis and Linear Discriminant Analysis to reduce the number of features by transformation for improving performance of the classification model. Further, our prime intention is to tackle these problems, by building a feature ranking algorithm which is an individual evaluation method that assigns weight for each feature according to its degree of relevance. This can improve the efficiency of classification for predicting the abnormalities in various medical imaging modalities based on different methods such as Rough Set Theory, Fuzzy-Rough Set, Hybrid Genetic Algorithm, Fuzzy Rough feature selection using Support vector Machine (SVM) and filter-based feature ranking techniques.

3 Dimensionality Reduction Approaches

The most relevant information that can be utilized for the effective classification of abnormalities present in an image can be accomplished by using different machine learning techniques. To obtain a reduced representation of the huge volume of data set or feature set, data reduction techniques are applied on the original dataset/ features extracted from the dataset by maintaining the integrity of the original dataset/features extracted [15]**.** A phenomenon called ‘curse of dimensionality’ occur when there are too many features or dimension of the dataset/features which leads to degradation in performance of the learning algorithm and takes more computational time to produce the outcome. To overcome this curse of dimensionality, feature extraction/transformation and feature selection/reduction approaches are adopted. Feature extraction/transformation methods transform the input data in high dimensional space to lower dimension space [15]. The second approach aim to identify subset of features by directly eliminating the irrelevant feature so that it can retain the original meaning of feature set [16].

3.1 Feature Extraction/Transformation

Feature extraction is usually a dimensionality reduction or data compression/reduction process that helps in reducing the number of features required to analyse an input image [17]. The dimensionality of data is reduced by retaining most of the relevant information by a process called feature extraction. The main idea behind feature extraction is to find a lower representation of the original input features. The new representation of the features is to be of lower dimensionality retaining all the relevant information of the original data set. Currently available feature extraction methods do this process by finding linear or nonlinear combinations of the input feature set and encode the representation in a set of basis functions and its weights [18]. The choice of attributes or features in extraction phase has a great influence on the accuracy, speed and performance of classification [19]. Feature extraction can be divided into four categories such as Non-transformed structural characteristics; that is applied on digital images to obtain relevant features, Transformed structural characteristics; that finds features with high information density and low redundancy, Structural descriptors; are the information regarding features given in structural form and not in numeric form, Graph descriptors; that form the basis for the model-based techniques in medical image processing [19], [20].

Features that are extracted belong to colour, texture and shape features. Colour is the most significant feature in image classification, and it is one of the most widely used visual feature in image retrieval [21], [22]. Texture features are one of the most important characteristics that is used to classify and recognize objects which have been used in finding similarities between images in multimedia databases [23], [7]. Texture determination is ideally suited for medical image retrievals [24]. Shape is an important visual feature and is considered as the main source of information used for object recognition [22]. Shape based image retrieval is the process of measuring similarity between shapes represented by their features [7].

3.1.1 Feature Extraction Methods

The high dimensional data set present new challenges for the detection and prediction of abnormalities in medical imaging. Big volume of these data is highly redundant and to be ignored the redundant nature of data while extracting features from those datasets. Some well-known techniques for reducing these high dimensional data to lower dimensional space by discarding uninformative features from dataset are Principal Component Analysis and Linear Discriminant Analysis.

3.1.1.1 Principal Component Analysis

Principal Component Analysis (PCA) is regarded as one of the most powerful tools for extracting effective features from high dimensional dataset [25]. The main goal of PCA is to reduce the dimensions of *d*-dimensional dataset into a *k*-dimensional subspace (where k < d) by retaining most of the relevant information in order to increase the computational efficiency [14]. It reduces the dimensionality of data by measuring the correlation among variables in terms of principal components. PCA finds the "principal components" in the data by calculating eigenvalue problem of covariance matrix C as follows:

$$Cv_i=\lambda_i v_i, \quad (1)$$

where 'C' is the covariance matrix of the original data 'X' and λ_i's, v_is are the eigen values and eigen vectors of the of the matrix C respectively. Then the 'k' eigen vectors that corresponds to the k-largest eigen values is to be computed to reduce the dimensionality of data [6]. It has been widely used in application areas like data compression, image analysis, visualization, pattern recognition, regression and time series prediction [3]. It is also used in a wide range of application in medical image processing such as image fusion, image registration, image segmentation, image compression, image noise reduction, image feature extraction and image classification [26].

Another type of PCA is the Kernel Principal Component Analysis (KPCA) that is used for analysing ultrasound medical images of liver cancer and another application of KPCA is the medical image classification of breast cancer biopsy image data set and 3D Optical Coherence Tomography (OCT) retinal image set. Several experiments with KPCA showed that it is more effective than wavelets, especially in the case of ultrasound medical images [26].

3.1.1.2 Linear Discriminant Analysis

The most popular Linear Discriminant Analysis (LDA) which is also known as Fisher Discriminant Analysis (FDA) is a supervised dimensionality reduction technique that transform features from high dimensional space to a low dimensional space which maximizes the ratio of the between-class variance to the within-class variance [14]. In order to achieve this, primarily three steps are to be performed. The first step is to calculate the separability between different classes (i.e. the distance between the means of different classes), which is called the between-class variance or between-class matrix. The second step is to calculate the distance between the mean and the samples of each class, which is known as within-class variance or within-class matrix. The third step is to construct the lower dimensional space which maximizes the between-class variance and minimize the within class variance [27]. The optimal transformation in LDA can be readily computed by applying an eigen decomposition on the scatter matrices. It has been used widely in many applications involving high-dimensional data [28]. In LDA two measures are defined for the samples of all the classes as follows: 1) with-in class matrix

$$s_w = \sum_{j=1}^{c}\sum_{i=1}^{N_j}\left(x_i^j-\mu_j\right)\left(x_i^j-\mu_j\right)^T \quad (2)$$

where c is the number of classes, x(i) ^ j is the i^th sample of class j, μ_j is the mean of class j and Nj is the number of samples in class j; 2) between-class matrix

$$s_b = \sum_{j=1}^{c}\left(\mu_j-\mu\right)\left(\mu_j-\mu\right)^T \quad (3)$$

where µ represents the mean of all classes. LDA method applies the linear discriminating principle, which tries to maximize the ratio determinant of the between-class matrix of the projected samples to the determinant of the within-class matrix of the projected samples [14].

4 Discussion And Conclusion

The detailed literature survey on various feature transformations techniques shows improved classification accuracy and performance in predicting the abnormalities present in medical images. Several limitations such as performance, accuracy, cost, time and storage were faced by several researchers while dealing with huge volume of data for the classification. So most of the authors restricted their study by experimenting and testing the performance of the system with limited feature set. It would be highly beneficial by proposing a classification system that can overcome the problems in the existing feature transformation and ranking techniques by developing an efficient feature ranking algorithm that determines the best feature with its significance for the classification model developed. Therefore our primary focus is on the study to devise and implement an efficient feature ranking algorithm with optimum number of features with its role of significance in classification by combining the theory of Rough Set, Fuzzy-Rough Set, Hybrid Genetic Algorithm, Fuzzy Rough feature selection using Support vector Machine (SVM) and filter-based feature ranking techniques.

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