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A Study on the Different Medical Image Processing Techniques

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Abstract— Medical images should be analysed accurately for deciding the suitable treatment plan. The major issue is that the images taken from the scanner directly will be affected by noise and othervariation. To overcome this issue, appropriate techniques should be applied to clean the data and to identify the Region of Interest. Research in the field of medical image processing has improved extensively, helping the medical practitioners to diagnose the disease undoubtedly.In this paper, different techniques such as image segmentation, image registration anddimensionality reduction are studied in detail for improving the quality of the medical images.

Keywords—*Medical image processing, image segmentation, image registration, dimensionality reduction, feature extraction, feature selection.*

I. INTRODUCTION

Medical image processing is a technique used to create visual presentations of the interior body parts for easy analysis. This technique attempts to display the internal structures concealed by the skin and bones and the acquired images are used for diagnostic and healing purposes. Some of the major modalities to acquire medical images are X-ray, Computerized Tomography (CT) scan, Magnetic Resonance Imaging (MRI), ultrasound imaging, Positron Emission Tomography (PET), Fundus images, etc.

In this paper, a study on the different image processing techniques is performed. A detailed study on the processing techniques such as image segmentation, image registration, feature extraction and feature selection is conducted. These techniques are used to improve the quality of the acquired medical images so that the symptoms can be analysed accurately.

This paper is structured into different sections. Section II gives a brief idea on image segmentation and the techniques used in image segmentation. Section III gives an idea on image registration, their classification and the steps in image registration. Section IV describes dimensionality reduction and its classification. Section V gives the conclusion.

II. IMAGE SEGMENTATION

In this process the digital image is partitioned into different components [1]. The main aim of image segmentation is to reconstruct the images into individual objectsfor easy analysis. This process is mainly used to detect objects and boundaries in an image.

A. Techniques Used in Image Segmentation

Since computers are not intelligent enough to recognize objects and boundaries, many methods have been used to partition the images into different parts. The segmentation process is carried out based on the different features that are present in an image. The most important features taken into consideration are color information, pixel information and texture information [2]. Image segmentation techniques are classified based on similarity and discontinuities. Discontinuities methods are called as boundary based methods and similarity methods are called as region based methods.

1. Region Based Techniques

This technique is used to segment the whole image into different components. Segmentation is based on certain rules like - pixels should have similargray level in a particular region. This technique depends on the similar pattern in the intensity values inside a group of neighbouring pixels. The main aim of region growing technique is to group the images into regions based on the functional or anatomical roles.

2. Split and Merge Technique

This technique is categorized into two steps. The first and the foremost step is to split the images based on some conditions and the second step is to merge them. Standard deviation is used to measure the internal similarities and thresholding is used to split the images into regions. This process is repeated till no more splits are possible. The second step is performed if any two regions are adjacent and similar, then these regions are merged and this step is repeated till no more merges are possible.

3. Normalized Cuts

Jianbo Shi et al. (2000) [3] have proposed a segmentation technique based on graph theory which is mainly used in medical imaging. The main goal of normalized cuts technique is to provide optimal division while splitting. In this technique, the vertex represents the pixel and the edges represent the adjacent pixels in the graph. Edges are weighted based on the similarities (color, texture, distance, etc.) shared by the corresponding pixels. The main advantage of this technique is that after splitting the regions, the second step (merging) is not required. This technique will calculate the total similarity that is present inside a group and the total dissimilarity that is present with the other groups.

4. Thresholding

This technique is used to categorize regions based on the range values. This value is applied to the pixel intensity of the image. This technique is inexpensive and fast and can be used in non-complex applications. Pixels are split into two groupswith respect to their range values - global thresholding and local thresholding. Global thresholding chooses one range value for the whole image whereas the local thresholding chooses different range values for dissimilar regions. Multilevel thresholding can be used to segment complex images.

5. Region Growing

This technique begins with a pixel and based on the similarity, region growing technique will group the pixels into regions. Once the similarity in a region ends, a new pixel which is not part of any other region is selected. This process is iterated till the entire pixels are owned by some region. The main disadvantage of this technique is that because of the noise in the image the selection of the new pixel can be imperfectly chosen. Region growing method is time consuming and energy consuming.

III. IMAGE REGISTRATION

Image registration is a processing technique used to merge two images the source image and the target image geometrically into one single image. In order to register these images, the transformation matrix should be determined. This process applies the geometric transformation to the target image so that this image will be aligned with the source image. Image registration is mostly used in medical imaging, computer vision, remote sensing, etc.

Classification of Image Registration Techniques

Image registration techniques arecategorized into different criteria. Brown et al. (1992) [4] has classified image registration techniques into four classes with respect to image acquisition. Barbara Zitova et al. (2003) [5] has divided the image registration techniques into area based and feature based methods. Maintzet al. (1998) [6] has proposed a nine-dimensional scheme and this scheme is mostly used in medical imaging applications.

Classification Based on Application

Brown et al. (1992) has classified image registration based on application into four groups and they are

- Analysis using different viewpoint: Images of the same view are obtained from varied viewpoints. Commonly used to create image mosaics of an inspected area in remote sensing and used to regain shape in computer vision.
- Analysis using different time: Images of the same view are obtained from varied times. It is commonly used in medical imaging to detect healing therapy, to observe tumor evolution, etc. Also used in computer vision to detect changes automatically.
- Analysis using different sensor: Images of the same view are obtained from varied type of sensors. This type of analysis is commonly used in medical imaging for collaborating the sensor recording the anatomical body structure (MRI, CT scan, ultrasound scan, etc.) with sensor observing the metabolic and functional body activities (PET, MRS, etc.).
- Scene to model registration: In this type of analysis images and model of the view are registered. The model must be a computer depiction of the map, scene, etc. It is used in medical imaging for comparing patient's image with the digital anatomical atlases.

Classification Based on Essential

Barbara Zitova et al. (2003) has classified image registration based on essential into area based methods and feature based methods.

- Area based methods: This method is used when the important information is unavailable in the local structures of an image and if these information is given by the gray levels or colors of an image.
- Feature based methods: This method is used if the local structure information of an image has more intensity.

Classification Based on Nine Dimensional Scheme

Maintzet al. (1998) has proposed a nine-dimensional scheme and this scheme gives an outstanding classification for image registration. This type of classification is commonly used in medical imaging applications.

- Dimensionality: It represents the number of geometrical dimensions in an image space (two or three dimensions).
- Nature of transformation: It denotes the propertyof a particular transformation which includes rigid, affine, curved, etc.
- Nature of registration: It refers to the characteristic of the two scenes which is used to achieve registration.
- Domain of transformation: It denotes the calculation of the transformation, whether it is done locally or globally.
- Degree of interaction: It denotes the authority over the registration algorithm specified by a human operator.
- Optimization procedure: In this scheme, the registration quality is continuously estimated during the registration procedure.
- Modalities involved: It denotes how the scenes to be registered are obtained.
- Subject: In medical image registration, this scheme denotes the patient's participation.
- Objects: In medical image registration, this scheme refers to the specific region of the body structure to be registered.

A. Steps in Image Registration

The steps involved in image registration as illustrated by Barbara Zitova et al. (2003) is as follows

1. Feature detection: This step detects the unique objects (lines, edges, points, etc.) from both the referenced image and the target image.
2. Feature matching: The similarity between the source image and the target image is noted.
3. Transform model estimation: This step will estimate the mapping function (type and parameter)that aligns the sensed image with the referenced image.
4. Image resampling and transformation: In this step, image is registered with the support of the mapping function and the sensed image is remodeled.

B. Feature Detection

Feature detection is the first step in image registration. This step is divided into -area based method and feature based method.

- Area based method

This method gives importance to feature matching than feature detection. Since features are not detected at this step, this method is eliminated.

- Feature based method

This method extracts the most important features from the image. Features like points, significant regions, lines, etc., will be extracted using this method. These features must be distinguishable in both the images and should be distributed over the entire image. The different types of feature detection methods are region features, line features, point features, etc.

Region Features: These type of features can be the protrusionin a closed boundary region of a building, water reservoirs, forest, township areas, etc. With the help of the segmentation method, region features can be detected. The final outcome of registration is influenced by the segmentation accuracy. Goshtasby et al. (1986) [7] have proposed an improved segmentation process to upgrade the quality of registration. Iteratively segmentation was done along with registration. At every iteration, an approximate similarity between the objects will betaken to enhance the segmentation parameter. The authors stated that the accuracy of the registration for the subpixel can be attained.

Line Features: These type of features represent line segments, costal lines, roads, object contours, etc. For detecting the line features, the detectors used are Canny detector, detector based on Laplacian of Gaussian, Marr-Hildreth detector, etc.

C. Feature Matching

In image registration after detecting the feature, the second step is to match them based on the intensity value of the image. This step is divided into area based method and feature based method.

- Area Based Method

This type of method combines the feature detection step with the matching step without detecting the important features from the image. The different types of area based methods are correlation-like method, fourier method, mutual information method, optimization method, etc.

Fourier Methods: This type of method is used if the images are obtained under different conditions or if the images are corrupted by noise [8]. The phase correlation method was initially proposed for matching the translated images and this method is based on the fouriershift theorem. This method calculates the cross power spectrum of the source and the target image and the position of the peak is examined in the inverse. This method decreases the computational time if the images to be registered are large in size.

Mutual Information Methods: Statistical dependency among the images are compared in this method [9]. This method was originally developed for matching multimodal medical images as this was a very difficult task. Viola Paul et al. (1997) [10] demonstrates the mutual information method for registering the MRI by combining the 3D object model to the real scene. The authors have used gradient descent optimization method to maximize mutual information. FrederikMaes et al. (1999) [11] tried to maximize the mutual information. The authors have researched on a number of multiresolution strategies and optimization methods with the goal of increasing the registration speed while registering high resolution images of large size.

- Feature Based

This method uses image features to describe the matching entities. The different types of feature based methods use spatial relations, relaxation method, pyramids and wavelets, methods using invariant descriptors, etc.

Methods Using Spatial Relations: This type of method is normally used when the features detected is uncertain. Barrow et al. (1977) [12] have presented a new technique called as chamfer matching to match images and features. Goshtasby et al. (1985) [13] have presented image registration based on graph matching algorithm. Stockman et al. (1982) [14] have presented a clustering technique which attempts to match the connected line segments or edges.

Relaxation Methods: Most of the registration methods rely on this approach as this is one of the method that gives solution to the Consistent Labeling Problem (CLP). Wang et al. (1983) [15] improved the relaxation method by considering the corner feature descriptions like slope, corner sharpness and contrast. Cheng et al. (1984) [16] have proposed a registration method which uses relational structures, that represents the images.The images are registered based on the match between the relational structures. For the matching process the authors have used star based registration structure and this is better than the conventional node structure.

D. Transform Model Estimation

Transform model estimation is done after matching the features correctly. In this step, the type and the parameter of the mapping function are created. Random Sample Consensus algorithm or [17] Maximum Distance Sample Consensus algorithm is used to remove the falsely matched features after the feature matching step and doing this will increase the robustness of the algorithm. The accuracy of the algorithm might get affected if the falsely matched features are not removed. Once the similar features are recognized, the mapping function can be created. The mapping function is selected based on the geometric distortion of the target image.

The mapping function models are classified into two groups such as global models and local models. For calculating a single set of mapping function parameters, global model uses all the control points valid for the complete image. For calculating the local mapping function, the images are treated as composition of patches and depending on the context of the image function, parameters are created.

E. Image Resampling and Transformation

The mapping function created in the preceding step is used to transform the target image and this registers the image. There are two kinds of approaches for performing transformation – forward method and backward method. Forward method can be implemented by transforming each pixel in the target image directly by using the mapping function. But this is a complex method as it creates gaps in the final image. Therefore, backward method is usually preferred. The registered data from the target image is found out using the coordinates of the target image pixel and the inverse of the mapping function which was calculated in the previous step. This method does not allow gaps in the final image.

IV. DIMENSIONALITY REDUCTION

Dimensionality reduction is a process of eradicating the redundant features from an image or a pattern, so that it becomes easier to classify them by using a proper technique. Dimensionality reduction is classified into two techniques – feature extraction and feature selection.

The main advantage of feature extraction is that without loosing much information of the primary feature space, the feature space size can be reduced. On the other hand, in feature selection, no important dataassociated to a single feature is lost, but if the required set of feature is small and if the primary features are dissimilar there are chances of losing the data as some of the features must be discarded during the selection process.

A. Analysis of Different Feature Extraction and Feature Selection Techniques.

1. Feature Extraction Methods

This method produces features that is more relevant by performing transformation on the original feature space. [18] This method is used to decrease the complexity of the feature space and to representthe data as a linear combination of primary input variable. Some of the methods used to extract features is Independent Component Analysis (ICA), Principal Component Analysis (PCA), Nonlinear Principal Component Analysis, Probabilistic Principal Component Analysis (PPCA), etc. The most widely used approach in feature extraction method is Principal Component Analysis.

Independent Component Analysis: This is a linear transformation method. The statistical dependency of the component is minimized by using the preferred representation. [19] Feature extraction is inspired by the theory of redundancy reduction.There are two fundamental types of ICA algorithm and they are – algorithms established in the minimization of mutual information and the second one is established in the maximization of non-gaussianity. The first approach helps in finding out components that are maximal independent. On the other hand estimation of independent component can also be performed by forcing non gaussianity.

Principal Component Analysis:This is an unsupervised method and the label knowledge of the data is not included. PCA is independent if the data is distributed normally. PCA is the most widely used method, this is because it is a non-complex non-parametric method which is used to extract the non-redundant data from a set of irrelevant or unclean data.

PCA discards the last principal component which is not important to the detected variables. This is done to reduce the amount of the original variables. PCA is a linear transformation of data where the redundancy is minimized and the information is maximized. Redundancy is measured using covariance and variance is used to estimate information.[20] The two main properties of PCA is that: 1) each principal component is a linear combination of the primary variable. 2) Each principal component is unrelated to each other and the information which is irrelevant is discarded.

PCA is mainly used in the fields of data compression, pattern recognition, image analysis, etc.

2. Feature Selection Methods

Feature selection is the process of choosing the most relevant information from all the extracted features that is useful in differentiating the classes. Feature selection algorithm is a computational model. Some of the feature selection methods used are Correlation-Based Feature Selection (CFS), Sequential Forward Selection (SFS), Sequential Backward Elimination (SBE), Plus-L Minus-R Selection (LRS), etc.

Correlation Based Feature Selection:This method looks for the feature subset based on the degree of redundancy between the features. The main goal of the evaluation process is to discover subsets of features that are highly correlated with the classes individually and to have low inter correlation among them. Relevance of the feature groups between features and classes increases with correlation and reduces with inter correlation. This method is usually used to decideon the best feature subset and is mostly integrated with search approaches such as backward elimination, best first search, forward elimination, etc.

Sequential forward selection: This method is a simplest greedy search algorithm. The performance of this method is best when there is small number of features in the optimal subset. The foremost disadvantage of this method is that it does not remove the old features even after the insertion of new features.

Sequential Backward Elimination: This method works in the reverse direction of sequential forward selection. The performance of this method is best when there is large number of features in the optimal subset. The major disadvantage of this method is that it does not re-evaluate the efficacy, after the feature has been removed.

CONCLUSIONS

This paper gives an idea on the different medical image processing techniques which can be applied to clean the noisy data and to select the relevant features form the image feature space. The techniques mainly discussed in this paper is as follows – image segmentation, image registration, dimensionality reduction which includes feature extraction and feature selection. The main objective of this paper is to help one understand the basic idea of the processing techniques used in medical imaging research field.

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