Research on the Image Fusion Technology Based on Redundant Contourlet Transform

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Abstract: Medical image fusion technology, as a special application field of information fusion, not only combines all kinds of medical image information organically, but also opens up new thinking and provides a new standard for clinical diagnosis of modern medicine. It is a hot research topic in recent years and also a frontier subject in the field of modern medical image processing. In this paper, aiming at the shortcomings of the existing image fusion technology, an image fusion technology based on redundant Contourlet transform is proposed.

1. Introduction

Medical image fusion refers to the technology of combining two (or more) registered images acquired from different imaging devices or at different moments and using some algorithm to organically combine the advantages or complementary information of each image to obtain new images with more information. The information provided by multiple imaging methods is often complementary, and in order to comprehensively use multiple imaging methods to provide more comprehensive information, it is often necessary to fuse the effective information. The purpose of medical image fusion is to highlight and truly show the morphological and functional information that can best reflect the physiological and pathological changes of human bodies. It mainly contains two steps: Image registration and information display. The study of fusion display method is helpful to the integration of multi-level information and the application of new modes, so it has extensive application value in basic research and clinical practice.

2. Development Status of Image Fusion Technology

Multi-mode medical image fusion is a distinctive research branch in the field of multi-source image fusion. Its development is based on the development of multi-source image fusion and is closely related to the development of medical imaging. The multi-source image fusion technology in the early days was mainly used in the military field. Different military reconnaissance means were used to repeatedly shoot a strategic area of the enemy, and the collected images were processed through filtering, correction, registration and fusion to produce a clear, accurate fusion image that can express comprehensive information. Through the analysis and understanding of the fusion image content, valuable information about the enemy's strategic area can be obtained. At present, Britain, the United States and other military powers are committed to developing an all-weather multi-source image fusion system that can adapt to the complex battlefield environment. The great motivation in military field promotes the rapid development of multi-source image fusion technology, and also accelerates the transformation of this technology into the civilian field.

In the civilian field, multi-source image fusion technology is mainly applied in two big fields which are remote sensing and medical image processing. The application in medical image processing is closely related to the development of medical imaging. Since Rontgen's discovery of X-ray, medical imaging has ushered in a period of rapid development. In particular, the appearance of CT images is of epoch-making significance in the development history of medical imaging. Until the mid-1980s, medical images of different modes came into being one after another, which

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promoted the sprout and development of image fusion technology in the field of medical imaging. In recent ten years, with the extensive application of medical images of different modes in clinical practice, multi-mode medical image fusion has developed into an important technology that cannot be replaced in the field of medical image processing. It can not only improve doctors' clinical diagnosis level, but also provide help for the aspects such as brain science research, image guided surgery and medical staff training. Its application in medicine mainly includes the following aspects: Assist doctors in diagnosis and treatment; Minimally invasive surgery and radiotherapy planning; Digital anatomy and virtual surgery teaching; Study on brain structure and function; telemedicine, etc.

The inchoate multi-mode medical image fusion algorithms are relatively simplex, most of them are directly transplanted to medical images, so the fusion effect is not ideal. With the continuous development of fusion theory, multi-mode medical image algorithms tend to use some frontier theories and methods. In addition to wavelet theory, pyramid transformation, multi-scale geometric analysis and other traditional multi-resolution analysis methods, these theories and methods also include sparse representation, group sparse representation, compressed sensing, non-negative matrix decomposition, artificial neural network, genetic algorithm, ant colony optimization, Gaussian Mixture Model and Markov Random Field. Internationally, western countries, represented by the United States, Britain and Germany, carried out special research on multi-mode medical image fusion in the 1980s, and proposed an early medical image fusion algorithm based on multi-resolution analysis. The research on medical image fusion technology in China started late, but the starting point is high. In order to catch up with developed countries, the Chinese government regards information fusion technology as a major research project in China, which includes the research on multi-mode medical image fusion technology. The government also has prioritized its development as one of the key technologies in the field of high-tech industry.

3. The Shortcomings of the Existing Image Fusion Technology

With the rapid development of computer technology and medical imaging technology, more and more medical images can be used in clinical diagnosis and treatment. Different medical images have different emphases on the image information reflected by the imaging results of the same part of a human body. Even if the same mode of imaging different physiological sections, the image content is not completely the same. Therefore, there are many new problems for medical image fusion technology. The emergence of new imaging models poses a severe challenge to the effectiveness and universality of existing image fusion algorithms. These problems are embodied in the following aspects:

3.1 Problems of medical image fusion in transform domain

For the image fusion algorithm based on multi-resolution analysis, it is the initial problem to be considered that what kind of multi-scale decomposition and reconstruction method should be chose. If the multi-scale decomposition method can provide more information about the direction of the frequency band at each decomposition level, the fusion image will perform better in detail. It should be noted that while considering multi-scale decomposition to provide more directional information, it should also take into account the source image should be represented as sparsely as possible. In this way, the complexity in time and space of the fusion algorithm can be effectively reduced while the image quality can be guaranteed. The selection of different multi-scale decomposition and reconstruction methods will produce different fusion results. Facing the large number of medical images of different modes, how to make adaptive selection of multi-scale transformation for optimal fusion processing needs further study and discussion.

3.2 The selection of fusion rules

The selection of fusion rules is also an important research content based on image fusion algorithm. With the same multi-scale decomposition method, different fusion rules for high and low frequency sub-bands will result in different fusion results. The existing fusion rules are mainly based on pixel and region. In the actual fusion algorithm, that a single fusion rule is adopted for both high and low frequency coefficients will undoubtedly bring disastrous fusion results for multi-mode medical images. Different models of medical images have their own characteristics. How to determine the most appropriate fusion rules based on the characteristics of images is a problem that needs to be solved in the research of multi-source medical image fusion.

Existing studies have shown that the selection of multi-scale decomposition levels also has a very important impact on the quality of fusion images. Too few decomposition levels will lead to fuzzy fusion results, accompanied by obvious blocking effect. On the other hand, too many decomposition levels will also lead to the degradation of fusion quality. In general, the selection of the best decomposition level should be considered comprehensively according to the specific mode of the medical image to be fused and the actual application requirements of the fused image.

3.3 Problems of medical image fusion in spatial domain

Except fusion algorithm, most of the existing medical image fusion algorithms are based on fixed model or approximate calculation. Most of the model-based methods need to select appropriate image features and the computational complexity in time and space is relatively high. The fusion method based on approximate calculation takes into account the sparsity of the source image, however, it ignores the consideration of the pixel itself and spatial adjacent relationship of the medical image in the process of solving the coefficient, which will also lead to the loss of some detailed information in the fusion result.

4. Research Methods

4.1 Standard equipment preparation for testing the accuracy of image fusion

A model which is suitable for testing the accuracy of PET/CT image fusion is prepared. The shape of the model is designed as a cylinder with an external diameter of 200mm and a wall thickness of 5mm. It is made of polymethyl methacrylate (PMMA). The model is filled with several cylindrical rods and test tubes. When collecting the image data, the solid cylindrical rods serves as the test cold area and the test tubes containing radioactive liquid serves as the test hot area.

4.2 Collecting experiment images

Taking the standard equipment for testing the accuracy of image fusion as the object to be tested, the digital image is read from the relevant diagnostic equipment through the collecting device, and transformed into image data that can be recognized and processed by the system. PET uses the mechanism of biochemical reaction which is caused by 18F-FDG tracer in the standard equipment for testing the accuracy of image fusion to determine the position of the reaction by detecting annihilation photons according to the detection principle.

4.3 Preprocessing of the source images

It includes the analysis of PET performance parameters (such as spatial resolution, sensitivity, etc.) and CT performance parameters (such as density resolution, noise, etc.). Then the two kinds of image data are processed such as denoised and enhanced. After that, the format, size and resolution of the two image data are unified. Next, the sequence tomography images are reconstructed in three-dimension and displayed. At last, the mathematical model are established according to the characteristics of the target.

4.4 Image registration

Image registration refers to mapping a certain geometric transformation of one image into another image so that the relevant points in the two images can be consistent in space. The main problem that registration solves is the geometric position differences between two images, including translation, rotation, scaling and so on. Based on the different selection of feature space, similarity criterion and search strategy, the commonly used registration methods include the method based on the global domain criterion, the frequency domain Fourier method, the matching method based on features and the matching method based on the elastic model. Based on the analysis of existing image registration methods, this project will develop an objective evaluation standard index. The specific steps include:

Extraction of segmented image features. There are basically two different methods for image segmentation: The one is to directly analyze the physiological characteristics in the region of interest (ROI) of the image. The other one is to adopt the method of feature points.

4.5 Image fusion accuracy test

The center coordinates of the objects in CT images and PET images are measured respectively.

Dealing with the CT image data. It includes image binarization and edge detection. Random Hough Transform circle detection algorithm is used to locate the center of the circle.

IDL (Interactive Data Language) is used to analyze the data of PET images. The sensitivity hatching of the objects in PET images is drawn by PROFILE in IDL, and then the center position of the object is determined.

4.6 Repeating the above steps

Simulation is carried out in MATLAB operating environment to verify the rationality of the algorithm. Based on the experiments, a more suitable objective evaluation criterion is proposed to verify the performance of image fusion.

5. Experimental Result

For the multi-resolution decomposition image fusion algorithm, the main research content should be divided into two parts, the first is the multi-resolution structure, the second is the fusion rule research. In order to achieve a better image fusion effect, it is essential to choose the appropriate fusion structure and rules. Thus, this paper proposes an image fusion algorithm based on region energy and redundant Contourlet transform. Firstly, redundant Contourlet transform is carried out on the source image. The low-frequency sub-band coefficient obtained after transformation reflects the rough contour of the image, concentrates most of the energy of the initial image, and retains the regional characteristics of the initial image. Therefore, the low-frequency fusion coefficient is determined by calculating the eight-neighborhood variance. Secondly, the high-frequency sub-band coefficient obtained by the redundant Contourlet transform reflects the details and edge features of the image. Therefore, the high-frequency fusion coefficient is determined by seeing the region energy as the measurement standard of the region correlation. Finally, the fusion image is obtained by inverse transformation. The simulation results show that the proposed image fusion algorithm has better fusion effect and better practicability.

6. Conclusion

Multi-source medical image fusion is a research subject involving a wide range and high complexity. Although this paper has done some research on multi-source medical image preprocessing and fusion, there are still many relevant theories and methods need to be further studied.

First, the preprocessing method which is more beneficial to medical image fusion should be studied. Due to the different imaging principles and image collecting methods, the different modal source images will have great differences in size, quality and spatio-temporal characteristics. Therefore, it is necessary to preprocess different source images before image fusion. Pre-processing includes aspects such as filtering, enhancement, grayscale correction and registration of the source image. The result of the preprocessing directly affects the effect of fusion algorithm. The selection of preprocessing method can not only guarantee the fusion effect but also meet the practical requirements.

Secondly, the scope of medical image fusion should be expanded. Traditional multi-mode medical image fusion is mainly aimed at grayscale images, and the fusion result is also grayscale images. However, grayscale images can only express image information through pixel gray value, which is not easy for human eyes to observe. This is very unfavorable for doctors to diagnose diseases. Therefore, in order to solve this problem, medical image fusion should be extended from the traditional gray scale image fusion to the color or pseudo-color image fusion in the future research.

Finally, the quality evaluation system of medical image fusion should be improved. The existing objective evaluation criteria for medical image fusion can only give partial information of the fusion image and sometimes even contradict the subjective visual evaluation results. Faced with a concrete example of image fusion, it is difficult to judge the fusion algorithm. How to choose a reasonable fusion algorithm has become a very difficult problem. Therefore, the objective criteria to accurately evaluate the quality of medical image fusion is the key research content in the future.

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