

Clinical Image Fusion Based on Sparse Representation and Feature Extraction

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Abstract

As a story multi scale geometric assessment contraption, meager depiction has shown various focal points over the standard picture depiction systems. Regardless, the standard deficient depiction doesn't take characteristic structure and its time multifaceted design into thought. At this moment, new blend segment for multimodal clinical pictures reliant on deficient depiction and decision direct is proposed to deal with these issues at the same time. Three decision maps are arranged including structure information map (SM) and essentialness information map (EM) similarly as structure and imperativeness map (SEM) to make the results spare greater essentialness and edge information. SM contains the local structure incorporate got by the Laplacian of a Gaussian (LOG) and EM contains the essentialness and imperativeness movement feature distinguished by the mean square deviation. The decision control is added to the common lacking depiction based methodology to improve the speed of the computation. Proposed approach furthermore improves the idea of the joined results by redesigning the distinction and sparing more structure and imperativeness information from the source pictures. The test outcomes of 36 social events of CT/MR, MR-T1/MR-T2, and CT/PET pictures display that the procedure subject to SR and SEM outmaneuvers five top tier methodologies.

1. Introduction

Medical imaging attracts more and more attention due to the increasing requirements of clinic investigation and disease diagnosis. Owing to different imaging mechanisms, medical images of different modals provide a variety of complementary information about the human body in a limited domain. For example, the computed tomography (CT) images provide better information on dense tissue, the positron emission tomography (PET) images supply better information on blood flow and tumor activity with low space resolution, and the magnetic resonance (MR) images show better

information on soft tissue. Moreover, the MR-T1 images give more detailed information about anatomical structures, whereas the MR-T2 images contain a greater contrast between the normal and abnormal tissues [1–4]. However, single multiple modality cannot satisfy the demand of images with high resolution and visualization for disease diagnosis.

In this regard, medical image fusion is a useful and powerful technique for integrating complementary information from multimodality images to improve the diagnostic accuracy. Besides, the fused images are more suitable for assisting the doctors in diagnosis and treatment planning [5]: fusing MR and CT images can generate the images which can describe the soft tissue and bone in order to concurrently represent anatomical and physiological features of the human body [6, 7]. MR-T1 and MR-T2 images are fused to segment white matter lesions and guide neurosurgical resection of epileptogenic lesions [7, 8]. In oncology, the combined PET/CT imaging is helpful to view the anatomical, physiological characteristics and the tumor activity [9, 10]. More than that, medical image fusion not only helps in diagnosing diseases but also reduces the storage cost [8]. As the most popular technique of the image fusion, the Multi scale decomposition methods have developed quickly in recent years, such as discrete wavelet transform(DWT) [3, 7],

The main contribution of this paper is as follows:

- (1) To add the local structure and energy information of the source images into the SR algorithm for medical image fusion, we design three decision maps to extract the local energy and structure features of the source images.
- (2) It is good to use the decision to reduce the number of image blocks to sparse representation, so that we can get the results in much shorter time. Using the maps to remain more structure and energy information in

fused images will also improve the quality of the results.

2. The Framework of the Proposed Method

There is the framework of the proposed approach based on SR and feature extraction as shown in Figure 1.

Firstly, we divide all source images A and B with the size of $m \times n$ into patches $y_{i,j}^1$ and $y_{i,j}^2$ through a sliding window with the size of $w \times w$ ($i \leq m-w$, $j \leq n-w$). All patches are arranged into vectors $(i-1)*(n-w)+j+1$ and $V(i-1)*(n-w)+j+2$ from left to right and from top to bottom. Secondly, we group these vectors into vector pairs according to corresponding positions of original patches and design the decision map according to their features separately. Thirdly, we use the decision map to determine which one vector of each group as the result when the map is marked as 1 or 2. It means that these groups are regarded as the input of the sparse representation system when the map is marked 0. Fourthly, we fuse the other vector pairs by the SR method. Finally, the system can generate the fused results according to the decision map. The overlaps of the patches are averaged.

2.1. SR. In SR algorithms, a signal can be expressed as a sparse combination of the fewest possible atoms of an over complete dictionary [29]. Let $V \in R^m$ denote a signal vector from the source images and let $D \in R^{m \times k}$ ($k > m$) denote an over complete dictionary whose column vectors are its atoms. The signal vector can be represented as $V = D\theta$, where $\theta \in R^k$ is a sparse coefficient vector. The sparse coefficient vector is acquired by solving the following question:

$$\begin{aligned} \hat{\theta} &= \arg \min_{\theta} \|\theta\|_0 \\ \text{s.t.} \quad &\|V - D\theta\|_2^2 \leq \epsilon, \end{aligned}$$

2.2. The Energy Map and the Structure Map. Let us regard $y_{i,j}^1$ and $y_{i,j}^2$ as mean values of $y_{i,j}^1$ and $y_{i,j}^2$, respectively. We use $\|y_{i,j}^1\|_2$ as the sign of energy and the mean square deviation $(1/64)\|y_{i,j}^1 - y_{i,j}^2\|_2$ as the sign of energy distribution for $y_{i,j}^1$, which are similar to $y_{i,j}^2$. We design the first decision map $EM \in R^{M \times N}$ (where $M = m-w$ and $N = n-w$) which called the energy map by

$$\begin{aligned} t1 &= \frac{1}{64} (\|y_{i,j}^1\|_2 - \|y_{i,j}^2\|_2), \\ t2 &= \frac{1}{64} (\|y_{i,j}^1 - \bar{y}_{i,j}^1\|_2 - \|y_{i,j}^2 - \bar{y}_{i,j}^2\|_2), \end{aligned}$$

3. Experiments

To evaluate the performance of the proposed method, three experiments are implemented. All the images are the same size of 256×256 pixels. In this paper, we train the dictionary with K-SVD using the pictures as shown in Figure 3. The error tolerance ϵ is set to be 0.01. The maximum iterations of the K-SVD are set to be 30. The initial dictionary is the DCT dictionary with the size of 64×256 . We use OMP to estimate the sparse coefficients for simplicity. The moving step of the sliding window is set to be one pixel. We use three kinds of medical image pairs including CT/MR images, MR-T1/MRT2 images, and CT/PET images to test the performances of those abovementioned methods. The DCT dictionary and trained dictionary are shown in Figure 4. The window size of LOG is set to be 5×5 , and σ is set to be 2.

For comparison, five state-of-the-art methods are evaluated in the experiments, including methods based on NSCT [1, 6], method based on JSR [12], and methods based on NSCT and SR [15, 18]. In this paper, five objective evaluation measurements parameters are adopted to evaluate the fusion performance. There is local quality index ($Q0$) [34], weighted fusion quality index (QW) [34], edge-dependent fusion quality index (QE) [34], QAB/F [35] which measures the transmission of edge and visual information from source images to fused images, and mutual information (MI) [36] which computes the information transformed from the source images to the fused images. For $Q0$, QW , QE , and QAB/F , they all lie in the interval

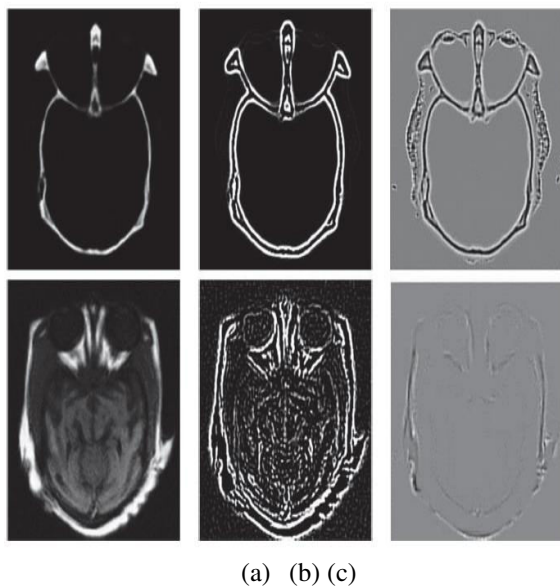


Figure 2: (a)The source images, (b) the structure information of LOG, and (c) the local structure information normalization.

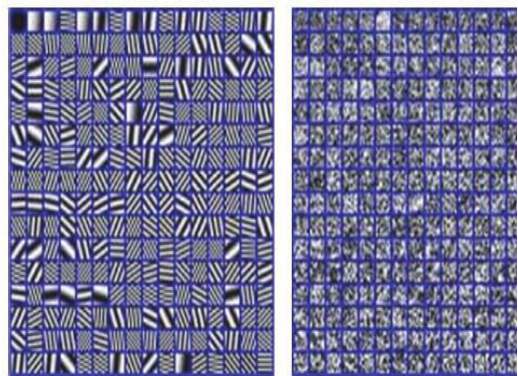


Figure 4: The DCT dictionary and the trained dictionary

experiments are carried out in the PC with the Intel i7-3770 CPU 3.40GHz and 4G RAM, operating under MATLAB R2010a.

3.1.The CT Images and MR Images Fusion. In the first experiment, the CT and MR images are fused with eight different image fusion methods listed above. We used 12 groups CT and MR images to test the performance of these methods as shown in Figure 3. Two groups of results are shown in Figure 5. It is obviously seen that the results of NSCT are fuzzy in some parts, especially in Figures 5(m) and 5(n), the results of SR + NSCT [15], SR + SM, and SR + SEM can

reserve better source image boundary information than the results of the other methods. And these results have no block effects because all the methods use the sliding window strategy, in which NSCT [1] and NSCT [6] use the window with size of 3×3 and the others use the window with size of 8×8 . And results of NSCT [1], NSCT [6], JSR [12], and SR + NSCT [18] are brighter than all source images, which will lead some dim information to be hidden by light information.

As shown in Figures 5(m), 5(n), 5(o), and 5(q), we cannot tell the tissue information between the skull and brain. In a certain extent, the proposed method can ease these problems and meanwhile remain the merits of the SR based methods. Comparatively, the results of SR + SEM can remain better image boundary and energy information, where we can get better anatomical information from CT images and soft tissue information from MR images simultaneously. More than that, the calcified meningioma in Figure 5(f) can be distinguished from background easily in Figures 5(r), 5(s), and 5(t).

3.2. The MR-T1 and MR-T2 Images Fusion. In the second experiment, we used 12 groups MR-T1 and MR-T2 images to test the performance of these methods as shown in Figure 3. To illustrate the proposed fusion method, two sets of results are presented in Figure 6. In general, the results of NSCT [1], NSCT [6], and SR + NSCT [18] look gloomy and bright, demonstrating the grey distortion happens. NSCT [1], NSCT [6], JSR [12], and SR + NSCT [18] create many bad edges and make the fused results too smoothness. Comparatively, the results of SR + NSCT [15] and proposed methods show better boundary information and energy information with fewer artifacts, so that we can get better information on adipose tissue from MR-T1 images and information on vascular and tumor from MR-T2 images. Compared to the other methods, the results of proposed methods contain more information from the source images. The proposed methods preserve both better local edge and texture information, which is the vital information for diagnosis. The sub acute premature hematoma is seen clearly in Figure 6(l), and we can see the location and contour of the intracranial hematoma in

Figures 6(r), 6(s), and 6(t). For 12 MR-T1 and MR-T2 fused results, the average scores of quantitative evaluation metrics are listed in Table 2 and the “bold” values indicate the highest values.

Table 1: The objective evaluation and running time for CT and MR image fused results of all methods.

	Q_b	Q_w	Q_e	$Q_{AB/F}$	N
NSCT [1]	0.5960	0.7511	0.5707	0.5857	4.6
NSCT [6]	0.5958	0.7554	0.5793	0.5892	4.6
JSR [12]	0.6493	0.8148	0.6296	0.5838	3.6
SR + NSCT [15]	0.6611	0.8477	0.6249	0.6447	4.0
SR + NSCT [18]	0.6527	0.8161	0.5572	0.5866	3.6
SR + SM	0.6566	0.8466	0.6992	0.6630	4.5
SR + EM	0.6643	0.8355	0.6919	0.6477	4.2
SR + SEM	0.6679	0.8477	0.7043	0.6677	4.6

Table 2: The objective evaluation and running time for MR T1 and MR T2 image fused results of all methods.

	Q_b	Q_w	Q_e	$Q_{AB/F}$
NSCT [1]	0.6311	0.8178	0.6166	0.6374
NSCT [6]	0.6316	0.8202	0.6192	0.6387
JSR [12]	0.6732	0.8369	0.6367	0.5744
SR + NSCT [15]	0.6896	0.8543	0.6313	0.6608
SR + NSCT [18]	0.6741	0.8385	0.5563	0.5774
SR + SM	0.6832	0.8520	0.7029	0.6676
SR + EM	0.6911	0.8542	0.6989	0.6577
SR + SEM	0.6991	0.8558	0.7063	0.6746

Table 3: The objective evaluation and running time for CT and PET image fused results of all methods.

	Q_b	Q_w	Q_e	$Q_{AB/F}$
NSCT [1]	0.5083	0.9442	0.7297	0.7783
NSCT [6]	0.5132	0.9475	0.7414	0.7862
JSR [12]	0.4988	0.9590	0.8095	0.7558
SR + NSCT [15]	0.4983	0.9635	0.7628	0.7863
SR + NSCT [18]	0.5046	0.9612	0.7564	0.7625
SR + SM	0.4992	0.9652	0.8337	0.8030
SR + EM	0.5234	0.9642	0.8311	0.7984
SR + SEM	0.5100	0.9652	0.8369	0.8041

3.3. The CT Images and PET Images Fusion. In the third experiment, we used 12 CT and PET image pairs to test the performance of these methods as shown in Figure 3. Two sets of results are shown in Figure 7. Comparatively, the results of NSCT [1] and NSCT [6] are best especially in energy information, so that the fused images can capture both more spatial

information in the CT images and functional information contents in PET images. However, in clinical applications, doctors need to see the position of bone and tumor to determine pathology and aid in diagnosis. The results fused by SR + SEM contain more detailed information and higher contrast but without information distortion so that we can see the outline of the kidney clearly in Figures 7(r), 7(s), and 7(t). Nasopharyngeal carcinoma can be seen in Figure 7(b), and we can use the result fused by proposed method to locate it in Figure 7 SR+NSCT[15], SR + SM, and SR + SEM easily, where are helpful to view the tumor activity, allowing physicians to better understand the effect of cancer treatment

3.4. The Time Complexity Analysis. To realize the fusion and reconstruction of 3D medical images, a lot of CT/PET and MR/PET image slices need to be fused firstly [37, 38]. Therefore, there is a need to find a faster and stronger image fusion algorithm. As shown in Figure 8, we record the average time consumption of different methods for 36 different medical image pairs listed. It is evident that the multi scale approaches including NSCT [1] and NSCT [6] are very fast while the SR based approaches (JSR [12], SR+NSCT [15], and SR +NSCT [18]) take much more time. Comparably, the time consuming of SR + SM is about 1/20, SR + EM is about 1/20, and SR + SEM is about 1/50 of the SR based approach. From the above analysis and discussion, we draw the conclusion that SR + SEM outperforms all the others in the field of medical image fusion. Because it contains more original information from source images and better local structure information, our methods are more appropriate for doctors to localize the abnormal masses and tumors in patients.

4. Conclusion

In this paper, a new medical image fusion approach based on SR and feature extraction is proposed. There are at least three major improvements compared with the conventional SR based fusion methods. Firstly, we put forward three decision maps to improve quality of the SR based image fusion methods in extracting the structure and energy features of the source images.

This strategy can help remain the original information from the source images as much as possible. Secondly, we add the decision map in to the SR based methods to improve the speed of the algorithm. It takes only 1/50 of the time that the standard SR method needs to realize the image fusion based on proposed approach. Thirdly, adding the structure and energy information of source images into the decision map improve the quality of the fused results a lot. The experiments results indicate that the proposed fusion approach can achieve better results than the conventional fusion methods in both subjective and objective aspects.

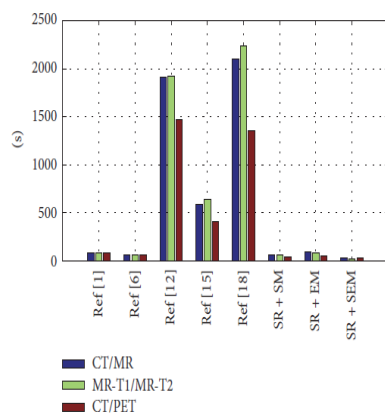


Figure 8: The time consuming of different fusion methods.

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