Image Reconstruction in Wavelet Domain Optimized by Tabu Search Algorithm

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Abstract
Image reconstruction refers to the process of conducting effective information extraction and integration on multiple images, so as to obtain more accurate, more comprehensive, more reliable description of one same scene or target information. This paper proposes the wavelet image reconstruction method based on image blocks, chooses the image block variance as the activity measure and adopts the Tabu Search (TS) optimization strategy to rapidly select reconstruction images with best effect. First of all, the wavelet transform is adopted to carry out multi-scale decomposition towards two source images to obtain coefficients of different frequencies. Secondly, different reconstruction rules are adopted towards high and low frequency respectively: the high frequency information is rebuilt by adopting the reconstruction rule of selecting the bigger coefficient absolute value, while, the low frequency information by adopting the weighted algorithm. In addition, the optimization of weighted factors is realized by using the good search performance of the Tabu search algorithm so as to make the resulting images retain as much information as possible. The ideal reconstruction effect is acquired by the effective combination of wavelet transform and Tabu search algorithm.
Key words: TABU SEARCH OPTIMIZATION, WAVELET ANALYSIS, IMAGE RECONSTRUCTION

1. Introduction

Efficient representation of visual information is the most important task in image processing [1]. The purpose of image reconstruction mainly lies in to process the complementary information of multi-source images, thus making the sharpness of the image improved and enhancing the reliability of the image by processing redundant data provided by the multi-sensor, and finally high quality images are integrated to improve the utilization rate of the image information, the spatial resolution and spectral resolution of the original image. Image reconstruction technology is widely applied in multi-source image processing and computer vision fields, etc [2].

Traditional image reconstruction method does not realize the decomposition and transform of source images, which belongs to a simpler image reconstruction method. Until the middle 1980s, scientists proposed pyramid method, the image reconstruction method based on pyramid decomposition. However, the correlation of decomposition quantity existing between layer and layer causes that the reconstruction effect is not very ideal. With the wide application of the wavelet transform theory, the wavelet transform has become a new tool in image reconstruction technology [3]. But with the deepening of the research,

there are still many problems needing to be further studied. In terms of the two-dimensional images, the direction information is a very important characteristic, but the two-dimensional separable wavelet transform has only limited direction representation, which cannot well represent the direction information of the image. These defects show that wavelet transform is not most suitable for image reconstruction method. Image reconstruction is a comprehensive theory of multidisciplinary cross, which can absorb nutrients in other new technologies, such as neural network technology, optimization technology and artificial intelligence technology, etc[4]. Tabu search is a kind of simulation of the human intelligence process, and is one extension of the local neighborhood search and one global step-by-step optimum algorithm. So far, TS algorithm has made great success in such fields as combinatorial optimization, production scheduling, machine learning, circuit design and neural network etc, and in recent years more studies are carried out in the function global optimization aspect, and its trend of development is great[5].

First, this paper introduces the related knowledge of image reconstruction, then expounds the basic idea of tabu search algorithm and introduces its components and processes. On the above-mentioned description, the image reconstruction method by combining the tabu search algorithm with the wavelet transform is introduced. Finally the simulation test and analysis are discussed.

2. Image Reconstruction

Image reconstruction is the process that effectively integrates multiple source images from different sensors ormultiple source images at different times of one same sensor and makes full usethe redundant information and complementary information of the image to produce a new image meeting specific application needs. Multi-sensor image reconstruction method based on image decomposition is one multi-scale and multi-resolution image reconstruction method, and its reconstruction process is carried out in terms of different scales, different spatial resolutions and different decomposition levels. Compared with the simple image reconstruction method, the multi-sensor image reconstruction method based on image decomposition has the characteristic of wide application occasions, as shown in Fig.1 [6].

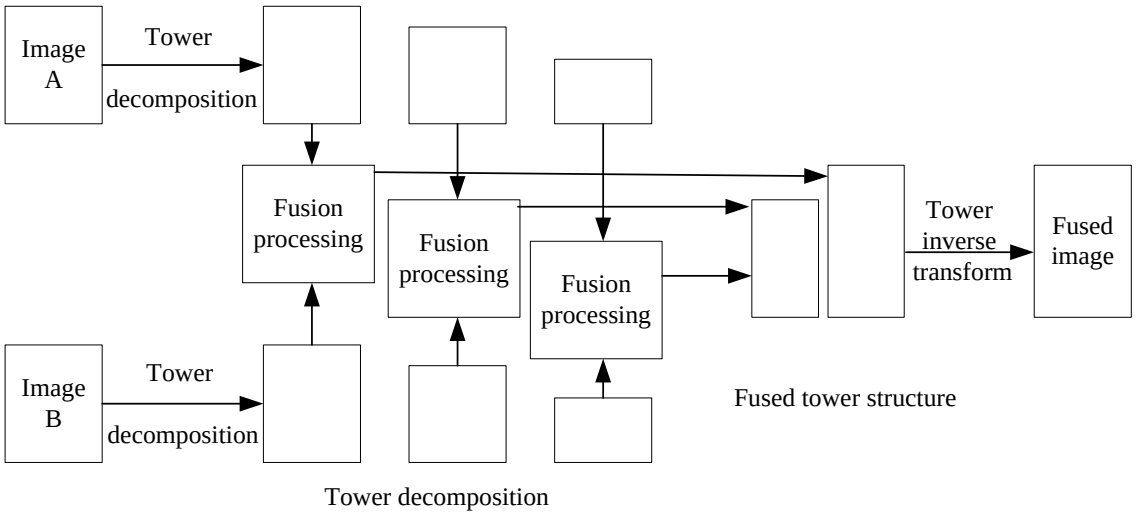


Figure 1. Image reconstruction

If follows that the purpose of decomposing images is to decompose the original images onto different spatial frequency bands respectively, adopt different reconstruction operators to carry out the reconstruction processing towards different decomposition levels with different spatial resolutions respectively by using tower structure after decomposition, thus characteristics and details from different images can be effectively reconstructed together[7].

3. Basic Idea of Tabu Search Algorithm

TS algorithm is one extension of the local neighborhood search, one global step-by-step optimum algorithm, and a kind of simulation of the human intelligence process. Based on the greed thought, local neighborhood search is the search continuously carried out in the current solution area. TS algorithm avoids detour search by introducing a flexible storage structure and corresponding Tabu rules, and also pardons some tabooed excellent states through the rule of contempt, thus ensuring the diverse effective exploration so as to finally achieve the achieve global optimization[8].

3.1. Components of tabu search algorithm

Based on the local neighborhood search, the simple tabu search taboos some undergone operations by setting the tabu list and also use rule of pardon to reward some excellent states.

Encoding mode: before using tabu algorithm to solve a problem, a kind of encoding mode is needed to select. The encoding mode can be flexibly selected according to the actual circumstances of the problem. For the same problem, there are a variety of encoding modes to choose from. Different encoding modes can be usually mutually transformed.

Fitness function: in terms of the choice of fitness function, such factors as improving the efficiency of the algorithm and being convenient to carry out the search are mainly considered.

Solution's initialization: the structure of the initial solution can be randomly generated, and one good initial solution can be also given by using other heuristic algorithm in advance. The commonly used method is to start from the characteristic information of the problem, thus the performance of initial solution can be ensured[9].

Moving and Neighborhood: the neighborhood moving rule in tabu search algorithm is similar with the crossover operator and mutation operator in the genetic algorithm, which is designed according to specific problems. Neighborhood moving is the way by which one solution is generated from another solution, which is one most important factor that ensuring the generation of good solution and algorithm search speed. Through the moving, the objective function value will change, and the difference of the objective function value generated before and after the movement is called the moving value. If the moving value is non-negative, then such moving is called the improvement moving, otherwise, the non-improvement moving. The best moving is not necessarily the improvement moving, and also could be the non-improvement moving, and this point ensures that when the search is caught in the local optimization, the tabu search algorithm can automatically help it get rid of the local optimization[10].

Tabu List: tabu list is the container used to store taboo objects and the taboo objects listed into the tabu list cannot be searched again before the ban is lifted. Tabu list simulates people's memory mechanism, and its main purpose is to prevent the circulation in the search process and avoid being caught in the local optimization, thus exploring more search space. It usually records several times of moving that are recently received and prohibited to be visited again within a certain number of times. When a certain number of times passed, these moving exits from the tabu list, and can be accessed again.Tabu list can be realized by such order structure as array, alignment, stack and linked list etc[11].

Selection Strategy: selection strategy is the method selecting a better solution from the neighborhood to serve as the next iteration initial solution. The preference strategy of the best improvement solutionis to select the moving with the best moving value from the current neighborhood to serve as the beginning of the next iteration. And the preference strategy of the first improvement solution is to select the solution generated by the neighborhood moving of the first improvement current solution as the beginning of the next iteration in the search neighborhood moving process, and a best solution shall be selected in the candidate solution set according to the nature of the problem and the form of the fitness function[12].

Ban-breakingStrategy: it usually refers to the aspiration level function selection. Under certain conditions, whether or not a certain moving is in tabu list, this moving will be accepted and the current solution and the history optimal solution will be updated. Such specific condition met by this moving is called aspiration level. There are many kinds of form for the aspiration level setting. When one taboo

moving appears again in the subsequent T times of iteration, and if it can bring the search to one area that has never been searched, this moving shall be accepted, ban-breaking, and it shall not be limited by tabu list. In addition, when it comes to the aspiration level, such strategies as the taboo length and candidate solution set shall be comprehensively considered, and the intensive search and disperse varied search shall be balanced and centralized. The ban-breaking strategy ensures that the specific solution can be released to realize the global optimization search in the search process when all candidate solutions are banned orcandidate solutions superior to the current optimal solutions are banned.

Stopping Rule: it is the standard that regards the maximum number of iterations but not the global optimization as the stopping algorithm or the stopping rule. Tabu search algorithm cannot guarantee to find the global optimal solution of the problem, and there is no rule to judge whether the global optimal solution is found. Therefore, stopping rule must be furthermore given to stop the search, and the common used rules are as follows: (1) the algorithm stops when the best solution found within the given number of iterations cannot improve or leave it. (2) In the case that objective function value of the optimal solution is smaller than the specified error. (3) In the case that the Tabu frequency of the optimal solution reaches the specified value[13].

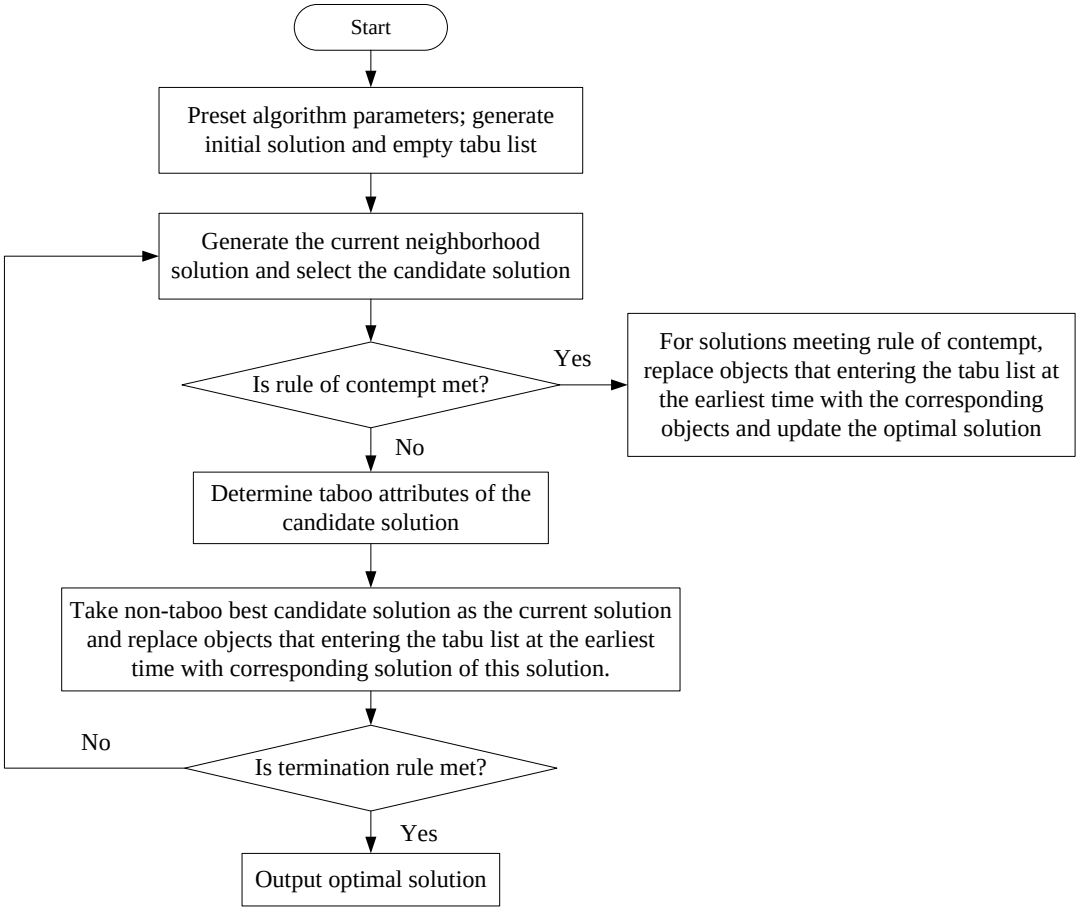


Figure 2. Tabu search procedure

3.2. Basic procedure of the algorithm

Tabu search algorithm steps can be described as follows:

(1) Preset algorithm parameters, randomly generate initial solution x and empty Tabu list.

(2) Judge whether algorithm termination conditions are met? If yes, end the algorithm and output optimization results, otherwise, continue the following steps.

(3) Generate all (or several) neighborhood solutions by using the

neighborhood function of the current solution and determine several candidate solutions.

(4) Judge whether the rule of contempt is met for the candidate solution? If met, replace x with the best state y meeting the rule of contempt and regard x as the new current solution, namely $x = y$, and replace the taboo objects that entering the Tabu list at the earliest time with the taboo objects that corresponds with y, and also replace "the best so far" state with y, and then turn to Step 6, otherwise, continue the following step[14].

(5) Determine taboo attributes of each corresponding object of the candidate solution, and select the corresponding best condition of centralized non-taboo objects of the candidate solutions the new current solution, and at the same time, replace the taboo objects that entering the Tabu list at the earliest time with the corresponding taboo objects[15].

(6) Turn to Step (2)

Algorithm procedure is shown in Figure 2 .

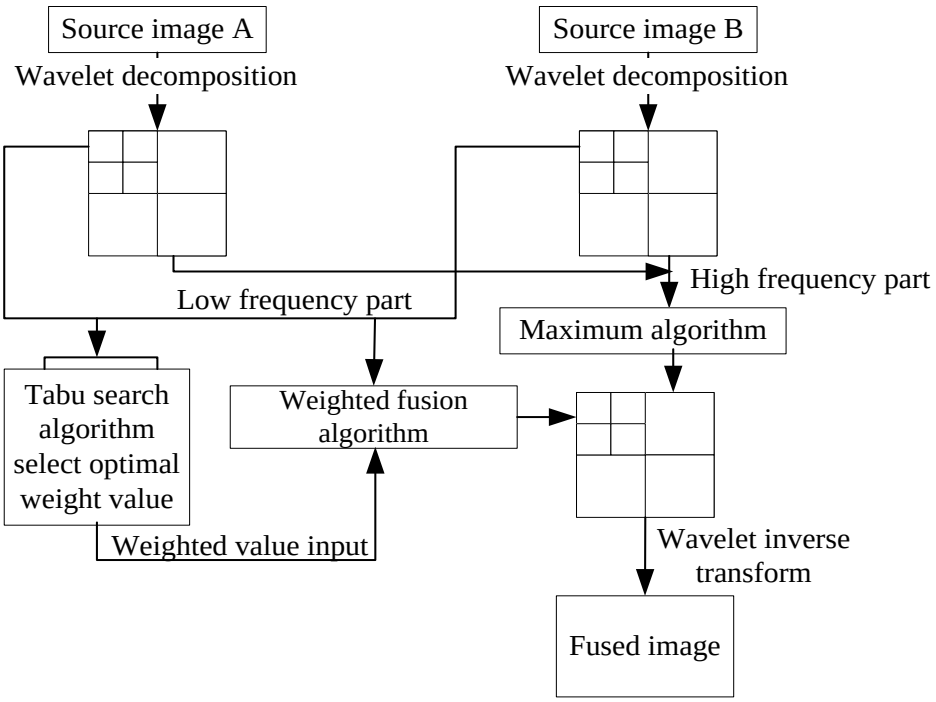


Figure 3. Image reconstruction in wavelet domain optimized by tabu search algorithm

4. Optimizing Image Reconstruction of Wavelet Domain Based on Tabu Search Algorithm

Image reconstruction scheme based on wavelet multi-scale decomposition is shown in Figure 3. Here take the reconstruction of two images for example, and the reconstruction method of multiple images can be reasoned by this way. Set A and B are two original images, and F the image after reconstruction. For searched $m \times n$ different sub-block optimum combination and then the selected the optimal reconstruction image, the most direct way is to use the method of exhaustion. Because this algorithm calculates all sub-blocks within the search window, so the optimal solution can be found, but this algorithm also has the deficiency of large calculation amount and slow speed, while, the tabu search algorithm will better achieve the rapid, fast and efficient purpose. Its basic processing steps are as follows:

(1) Carry out two-dimensional discrete wavelet transform towards each image, and establish the wavelet tower decomposition of image to get thelow frequency and high frequency components after the image decomposition and extract thelow frequency and high frequency wavelet coefficient matrix of sub-images of each layer.

(2) Reconstruct the low-frequency component with the average operator and divide the high frequency component of each image into several $m \times n$ sized sub-blocks.

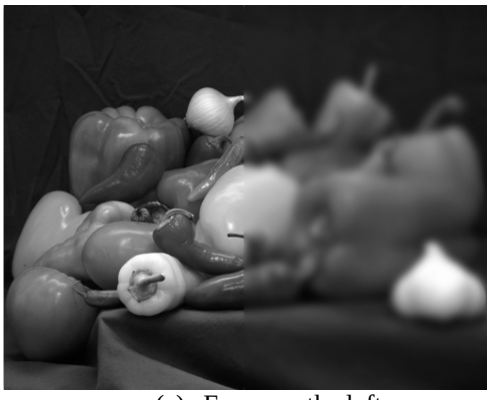
(3) Reconstruct the corresponding high frequency component and low frequency component of two images respectively: high

frequency coefficient is processed according to the rule of selecting the bigger corresponding coefficient absolute value and low frequency coefficient is rebuilt by using the weighted method, and the weighted factor is optimized withtabu search algorithm. High & low frequency coefficient of the reconstructed image obtained after the high & low frequency processing.

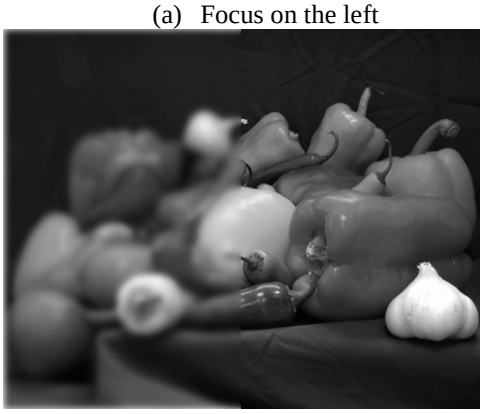
(4) Carry out two-dimensional discrete wavelet inverse transform towards the rebuilt wavelet coefficient, namely the image reconstruction, and the resulting image is the reconstructed image.

5. Experiment simulation and analysis

Integerate the method of this paper, conduct reconstruction experiment on two 512X512 clock source images. Fig.4 (a) and Fig.4 (b) are the images focusing on the left side and the right side respectively while Fig.4(c) is the ideal image. This paper performs wavelet decomposition on the images by adopting biorthogonal wavelet with 2 decomposition layers. The basic parameters of tabu search are set as follows: the maximum number of iterations is 50, the maximum number of candidate solutions is 20, the maximum number of continuous iterations is 100, the initial population size is 15 and the tabu length is 10. The 20 experiments are conducted on the computer with its CUP as Pentium G3258 3.2Ghz and with a memory of 2G and 50 iterations are performed in every experiment.



(a) Focus on the left



(b) Focus on the right

(c) Reconstructed image

Figure 4. Image Reconstruction results

Therefore, the method of this paper has preserved the useful information of the source image and manifested excellent reconstruction performance. It can be seen that the optimum selection of the low-frequency weighting coefficients of the wavelet coefficients can obtain better reconstruction result, suggesting that tabu search algorithm has certain self-adaptive ability in the search space, tabu search does not have high requirements on the initial value and it is acceptable for the initial value to produce or set as fixed value randomly. Besides, tabu search does not require too much on the setting of the parameters, instead, it has a big tolerance range. The use of tabu search algorithm can better resolve the optimization problem of the sub-blocks of the reconstructed image. Visually, the reconstructed image by the method of this paper has fantastic result without obvious indication of being cut into blocks.

6. Conclusion

This paper has systematically studied the image reconstruction of the image processing. The excellent multi-scale and multi-direction geometric analysis characteristics of the wavelet transform makes it be widely used in the field of image reconstruction. Tabu search algorithm is also caught attention because of its good properties and powerful search ability. This paper has proposed the image reconstruction method based on wavelet transform and tabu search algorithm, of image reconstruction method, and by the effective combination of wavelet transform and tabu search algorithm, from the effect of the experiment, the ideal reconstruction effect has been acquired.

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