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Pansharpening using Gravitational Search Algorithm

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Abstract: Pansharpening combines a low-resolution color multispectral image with a high-resolution grayscale panchromatic image. Multiresolution image fusion is an algorithmic approach to combine a PAN image with MS image. It combines the clear geometric features of the panchromatic image and the color information of the multispectral image. The objective of this fusion process is to enhance the spatial resolution of the multispectral images to make important features more apparent for human or machine perception. This enhancement is performed by injecting the high frequency component of the panchromatic image into the lower resolution ones without deteriorating the spectral component in the fused product. Here, gravitational search based image fusion technique is used. The fused image is essentially constructed by using the properties of panchromatic and multispectral images within a window to determine the weighting factors of the input images. To obtain accurate edge details, edge detector is used to locate the edge pixels in the initial estimate and gives better edge details in the final solution. Experimental results show the effectiveness of the proposed method.

Keywords: PAN, MS, Pansharpening, GSA.

I. INTRODUCTION

Satellite images captured by different sensors often have different spectral and spatial resolutions [1]. For example, dual sensors are widely used by some satellites such as IKONOS, Quick Bird and WorldView-2 to capture dual images, in which one is a high spatial resolution panchromatic (PAN) image (good for visualizing image details) and the other is a high spectral resolution multispectral (MS) image (good for analysing spectral features)[2].

Orbiting satellites often have two types of digital imaging sensors: First is Multispectral, i.e. different sensors for different colours (including IR), or different filters in front of the same sensor. Each individual band can be shown as a black-and-white image; multiple bands can each be assigned a colour, and combined to form an RGB colour image. Second is Panchromatic, "meaning all the colours", a single broad spectrum sensor. This is usually displayed as a monochromatic image (i.e. black-and-white). The panchromatic sensors usually have a higher spatial resolution than the multispectral. Panchromatic images can generally be collected with higher spatial resolution than a multispectral image because the broad spectral range allows smaller detectors to be used while maintaining a high signal to noise ratio. Multispectral images are designed to take advantage of the different spectral properties of materials on the earth's surface.

The objective of pansharpening is to combine the strengths of PAN and MS images for the visualization and analysis of satellite images [3]. The higher spatial resolution of panchromatic yields better detail, but with no colour. But it's possible to merge the colour data from the lower-resolution multispectral image with the luminosity data from the high-resolution panchromatic image to create a hybrid colour image with greater apparent resolution; this process is called "pan-sharpening" [4]. The need for remote sensing image fusion products is continuously growing, as it is witnessed by the increasing diffusion of commercial products using very high-resolution (VHR) multispectral images. As examples, Google Earth and Microsoft Virtual Earth exploit pansharpening fusion to yield VHR observations of the Earth, wherever possible. Google Maps and nearly every map creating company also use this technique to increase image quality.

Pansharpening uses spatial information in the high-resolution grayscale band and colour information in the multispectral bands to create a high-resolution colour image, essentially increasing the resolution of the colour information in the data set to match that of the panchromatic band. In order to incorporate prior knowledge such as the spectral response of the sensor for adaptive detail injection is also important. Detail injection-based methods show a good pan-sharpening performance because they can effectively sharpen MS images and also preserve well the large-scale spectral information of MS images. One kind of pansharpening methods is based on the injection of details from the PAN image into the MS image. However, for remote sensing images captured by satellites, the spatial details of PAN images may look quite different from those of the MS image. In this situation, detailed injection-based methods may produce serious spatial and spectral distortions. Fig.1. shows a panchromatic image and Fig.2. shows a multispectral image of the same area. Fig.3 shows a pansharpened image combining a high-resolution panchromatic image and a low-resolution multispectral image.

Fig 1. The panchromatic image of an area is shown above.

Fig. 2. A multispectral image showing the same area that is shown in the panchromatic image above

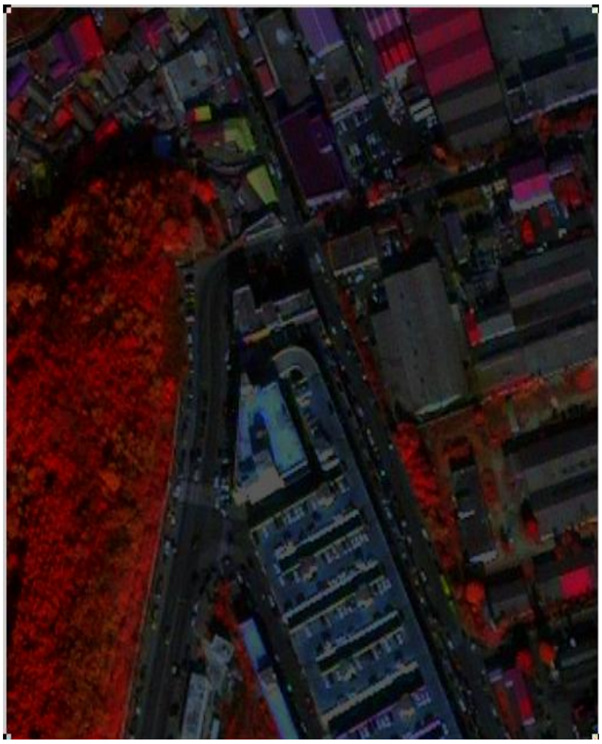

Fig.3. Pan sharpened image based on the two images shown above.

II. GRAVITATIONAL SEARCH ALGORITHM

This algorithm is based on the Newtonian gravity: ''Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of the distance between them".Gravitational search algorithm (GSA) is a population search algorithm[5]. The GSA could be considered as an isolated system of masses. It is like a small artificial world of masses obeying the Newtonian laws of gravitation and motion.The GSA is based on the law of gravity and mass interactions. The solutions in the GSA population are called agents; these agents interact with each other through the gravity force. The performance of each agent in the population is measured by its mass. Each agent is considered as object and all objects move towards other objects with heavier mass due to the gravity force. This step represents a global movements (exploration step) of the object, while the agent with a heavy mass moves slowly, which represents the exploitation step of the algorithm. The best solution is the solution with the heavier mass.

The gravitational constant G at iteration t is computed as follows.

$$G\,(t) = G_0\, e^{-\alpha t/T}$$

Where G_0 and α are initialized in the beginning of the search, and their values will be reduced during the search. T is the total number of iterations.

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The objects masses are obeying the law of gravity as following:

$$F = G\, M_1 M_2/R^2$$

Equation represents the Newton law of gravity, where
F is a magnitude of the gravitational force
G is gravitational constant
M_1 is the mass of the first object
M_2 is the mass of the second object
R is the distance between the two objects M_1, M_2

According to the Newton's second law, when a force F is applied to an object, the object moves with acceleration a depending on the applied force and the object mass M as shown in Equation.

$$a=F/M$$

There are three kinds of masses

- Active gravitational mass M_a
- Passive gravitational mass M_p
- Inertial mass M_i

The main steps of the GSA can be summarized as follows:

a) Search space identification.
b) Randomized initialization.
c) Fitness evaluation of agents.
d) Update G(t), best(t), worst(t) and Mi(t) for i = 1,2,. N.
e) Calculation of the total force in different directions.
f) Calculation of acceleration and velocity.
g) Updating agents' position.
h) Repeat steps c to g until the stop criteria is reached.
i) End.

The best optimal solution is produced.

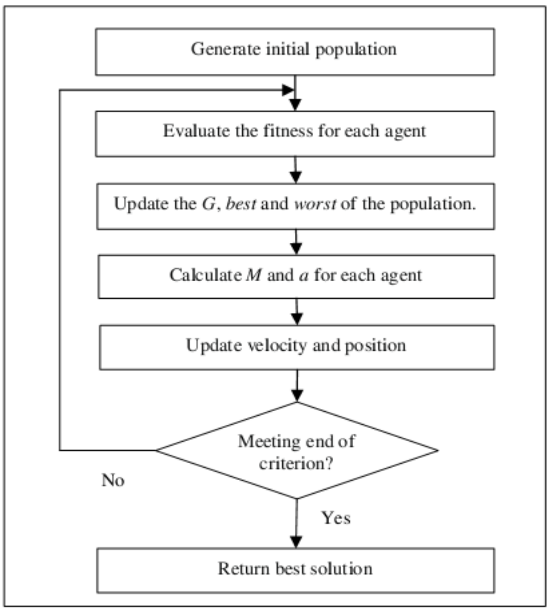

Fig.4. Flowchart of GSA

III. PANSHARPENING USING GSA

The proposed pansharpening method consists of five major steps: contrast compression, downsampling, spectral estimation, upsampling and GSA optimal fusion. Fig.5. shows the block diagram of the proposed method.

The five major steps are detailed as follows:

A. Contrast compression

Contrast compression is performed on the high-resolution PAN image (HP).

$$\widetilde{HP}_m = \frac{(1-2\rho)HP_m}{v} + \rho$$

where m means the m th pixel, ν is the maximum of pixel values in HP, and ρ is a constant which determines the bounds of pixel values in the resulting contrast compressed image.

B. Downsampling

The contrast compressed PAN image is downsampled to the resolution of the MS image.

$$\widetilde{LP}_m = \downarrow \widetilde{HP}_m$$

where ↓ refers to the downsampling operation (bicubic interpolation)

C. Spectral estimation

With the alpha channel and the low-resolution MS image the corresponding low resolution spectral foreground and background.

$$\min \sum_{m\in LM} \sum_c (\widetilde{LP}_m LF^c_m + (1 - LPm)LBm\ c)2+LPmx((LFmx\ c)2+ (LBm\ \ xc)2)+ |\widetilde{LP}_{my}|((LF^c_{my})^2 + (LB^c_{my})^2)$$

D. Upsampling

The high resolution spectral foreground, background can be approximately estimated by upsampling and low resolution spectral foreground and background respectively.

$$HF^c = \uparrow LF^c$$

$$HB^c = \uparrow LB^c$$

where c represents the c th MS band and ↑ represents the upsampling operation (bicubic interpolation).

E. GSA Optimal fusion

The compressed image, upsampled spectral foreground and background are combined together using GSA optimal fusion algorithm to obtain the output high-resolution pansharpened image.

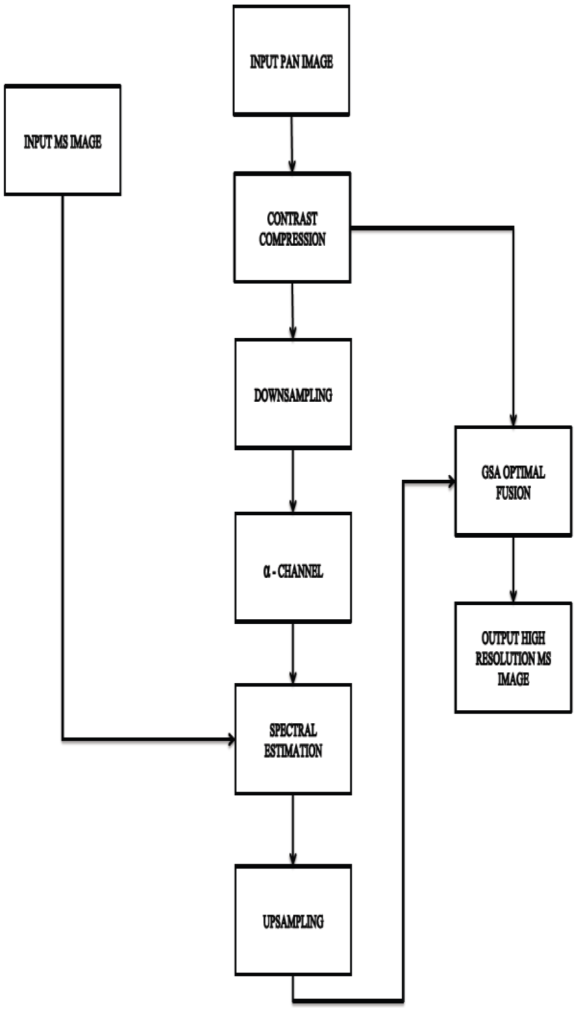

Fig.5. Block Diagram of proposed method

IV. CONCLUSION

In this paper, the proposed pansharpening method using Gravitational search algorithm is implemented. It is compared with the existing pan sharpening techniques and it gives the finer results in both visual inspection and quantitative results.

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