Forward looking infrared target matching algorithm based on deep learning and matrix double transformation

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Abstract: in this paper, infrared image target extraction is realized based on discrete stationary wavelet transform and fractal dimension. Firstly, denoising and detail enhancement algorithms are designed in stationary wavelet domain at different resolutions to preprocess infrared image. Then, on this basis, the region of interest containing the target of interest (human and vehicle) is extracted by fractal dimension. Finally, the human and vehicle targets in the infrared image are extracted by global threshold segmentation method. In the process of algorithm design, db1 wavelet is used as the mother wavelet to speed up the running speed of the algorithm. Using fractal dimension to extract region of interest can improve the accuracy of subsequent target extraction. Further work considers summarizing the fractal dimension characteristics of different targets in infrared images to realize the effective segmentation of infrared images in more complex scenes.

1. Introduction

In recent years, infrared imaging technology has developed rapidly, and its application scope has been extended to all fields of national economy, especially military fields, such as night vision imaging, guidance, search and tracking. Due to the imaging mechanism of infrared image and the reasons of infrared imaging system itself, compared with visible image, infrared image mostly has the characteristics of image blur and high noise. This is very disadvantageous to the subsequent processing, so it is essential to enhance the infrared image target and reduce the noise; Moreover, after enhancement, it is necessary to highlight some information in the infrared image, weaken or remove some unnecessary information, and then segment the infrared image appropriately to separate the target from the background image. Therefore, it is necessary to study the infrared image processing algorithm. In the research and application of image, people are often only interested in some specific and unique regions in the image, which are defined as targets (other parts are called background). Image segmentation technology is the technology and process of dividing the image into characteristic regions and extracting interested targets. It is one of the basic and key technologies in image processing and computer vision. In the field of target detection and recognition, image segmentation is often used to extract the detected target from the complex background and provide the basis for subsequent classification, recognition and retrieval. Therefore, the research on image segmentation technology is of great significance in the process of target detection and recognition.

Unmanned aerial vehicles (UAVs) are aircrafts that can fly without airborne pilots. They can control UAVs through remote control, semi autonomous, autonomous or multiple ways at the same time. UAVs can perform given tasks in many fields [1]. In order to complete these various tasks, UAV first needs to be equipped with sensor load to collect the image of the task area and realize environmental perception. The sensor load includes infrared sensor and visible light sensor. The fusion of infrared and visible images of the same scene is the basis of UAV target detection and recognition. However, the images captured by airborne sensors are dynamic, which will increase the difficulty of visible and infrared image fusion [2]. In order to obtain the situation evaluation, it is very important to extract the target information. In fact, the texture and color information in the visible image is very rich, while the target information in the infrared image is very prominent, especially the man-made target. Therefore, in order to make more effective use of the target information, the image area can be divided based on the target area.

Dynamic image fusion has its own characteristics, which requires the fusion algorithm to be consistent in time and space and have strong robustness. In order to use different regional features and obtain more effective target and background information, an infrared and visible image fusion algorithm based on frame difference detection technology and regional features is proposed. Based on dynamic target detection and target region segmentation, the information between frames is used to achieve stability and time consensus. Finally, According to the characteristics of the target area, different fusion rules are designed to realize the fusion of visible and infrared images. Finally, the fusion quality of the proposed algorithm is tested and its complexity is analyzed.

2. Motion information extraction based on frame difference

On the basis of image background motion compensation, target detection can be realized by applying frame difference algorithm to image sequence. The region with constant pixel value can be regarded as background region, and the region with variable pixel value with different points is moving target region, which includes the motion information of target [2]. Using the inverse transform parameters, the frame can be compensated and the difference $n+1$ between the previous frame and the current frame can be calculated.

$$D_n(x,y) = \left| I_n(x,y) - I_{n+1}(x,y) \right| \tag{1}$$

It refers to the frame difference of the frame at the point, and refers to the pixel value of the frame at the point. Extracting the moving target region needs to select an appropriate threshold to segment the source image, so that the moving target region and related motion information can be collected. This algorithm is easy to implement and has strong robustness to illumination. It is an appropriate algorithm for airborne image processing.

For RTS noise measurement and analysis, firstly, use the noise test platform to measure and obtain the RTS noise time series of sample devices, and quantify and store the time series; Then the RTS signal is analyzed by using the analysis methods of time characteristics and amplitude characteristics, and two groups of important parameters are obtained: one group is sum and the other group is noise amplitude. According to the characteristics of the measured RTS noise, the statistical characteristics of the interference signal are used to reduce and eliminate the influence of the interference signal on the measurement results. In the extraction of time parameters, filter processing is used to search the rising and falling edges of RTS noise. Then, the exponential distribution of time parameters is used to fit it to obtain the time constant, so as to eliminate the error caused by quantization. In the amplitude extraction, the amplitude of the filtered output is counted first, and then fitted according to the statistical distribution of the interference signal to eliminate the error caused by the interference on the amplitude extraction, so as to obtain the RTS noise amplitude parameters. When the sampling frequency is 10K, the RTS noise data automatically measured and identified by the system is shown in Figure 1.

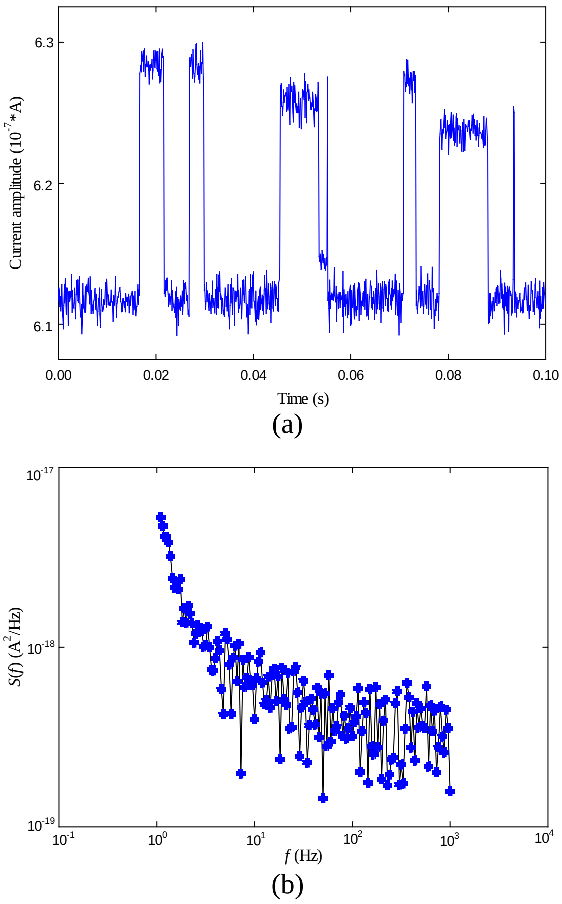


Fig.1 The measurement data of actual device

3. Complexity analysis of fusion algorithms

In order to better reflect the advantages of this algorithm, the complexity of this algorithm is compared with various advanced algorithms, including weighted average, principal component analysis, Laplace pyramid, gradient pyramid, contrast pyramid, discrete wavelet transform, global and local feature principal component analysis (glfp), enhanced Gabor feature linear discriminant analysis (egfl), The virtual sample extended 2DPCA (vse-2dpca), block Fisher linear discriminant analysis (bfld) and general Fisher linear discriminant analysis (gfld) algorithms are compared. The training time complexity, test time complexity and spatial complexity are compared respectively. The specific comparison results are shown in Table 1, where m and N represent the number of rows and columns of the image matrix, l M and N represent entropy, mutual information and edge preservation, respectively.

Table 1 complexity comparison of algorithms

algorithm	Time complexity of segmentation phase	Time complexity of fusion phase	Overall spatial complexity
weighted mean	$O(m^2n^2L)$	$O(mnL)$	$O(m^2n^2)$
principal component analysis	$O(m^2n^2L$ $+2mnN^2)$	$O(mnL)$	$O(m^2n^2)$
laplacian pyramid	$O(m^2n^2L$ $+mnN^2)$	$O(2mnL)$	$O(m^2n^2)$
Gradient pyramid	$O(m^2n^2L$ $+mnN^2)$	$O(2mnL)$	$O(m^2n^2)$

Contrast pyramid	$O(2m^2n^2L+mnN^2)$	$O(2mnL)$	$O(2m^2n^2)$
Discrete wavelet transform	$O(2m^2n^2L+mnN^2)$	$O(2mnL)$	$O(2m^2n^2)$
This paper presents a fusion algorithm	$O(m^2n^2L+2mnN^2)$	$O(mnL)$	$O(m^2n^2)$

As can be seen from table 1, compared with the weighted average algorithm, the time complexity of this algorithm in the segmentation stage is slightly higher, and others are the same; Compared with the principal component analysis algorithm, each complexity of the algorithm in this paper is equivalent; Compared with Laplace pyramid and gradient pyramid algorithm, the time complexity of the segmentation stage is slightly higher, but the time complexity of the fusion stage is half lower than them; Compared with contrast pyramid and discrete wavelet transform algorithm, the time complexity and overall space complexity of segmentation stage and fusion stage are much lower. While improving the recognition rate, the proposed algorithm can still maintain the same or even lower complexity as other related algorithms.

4. Denoising and detail enhancement of infrared image in discrete stationary wavelet domain

Discrete stationary wavelet transform (DSWT) has been proposed many times by many scholars. The application scope of DSWT mainly focuses on image denoising, compression and fusion, but the existing denoising algorithms based on DSWT use the standard variance of noise to design the threshold estimator, and are generally only effective for one kind of noise in the signal. However, because DSWT has the properties of redundancy and translation invariance, compared with the classical orthogonal discrete wavelet transform (odwt), it can give a more approximate estimation of CWT, eliminate the Gibbs phenomenon in signal reconstruction, make the signal smoother and have good visual quality.

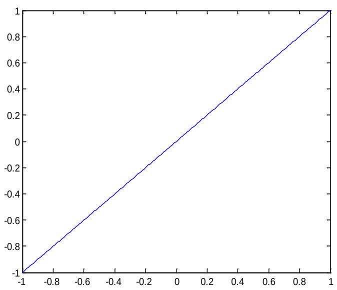
From the history of image segmentation research, we can see that there are several obvious trends in the research of image segmentation: first, the improvement of the original algorithm; The second is the introduction of new methods and concepts and the effective comprehensive application of various methods. People gradually realize that any single existing image segmentation algorithm is difficult to achieve satisfactory segmentation results for general images. Therefore, many people pay more attention to the comprehensive application of various methods while constantly introducing new methods and concepts into the field of image segmentation. Among the new segmentation methods, the image segmentation method based on wavelet transform is a good method. The third is the in-depth study of interactive segmentation. Because edge segmentation analysis of target image is needed in many occasions, such as the analysis of medical image, interactive segmentation research is needed. Facts have proved that interactive segmentation technology has a wide range of applications. Fourth, more and more attention has been paid to the research of special image segmentation. At present, there are many researches on stereo image, color image, multispectral image and multi field of view image segmentation, as well as target segmentation in moving image and video image, as well as depth image, texture image, computed tomography CT, magnetic resonance image, confocal laser scanning microscope image Research on segmentation technology of special images such as synthetic aperture radar image. Fifth, the research on image segmentation evaluation and evaluation coefficient has attracted more and more attention. I believe that with the deepening of research, the existing problems will be solved satisfactorily soon.

5. Detail enhancement

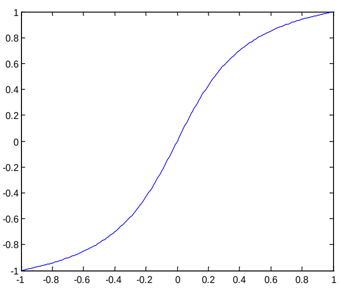
The method of image enhancement is to add some information or transform data to the original image by certain means, selectively highlight the interesting features in the image or suppress (mask) some unnecessary features in the image, so as to match the image with the visual response characteristics. In the process of image enhancement, the causes of image degradation are not analyzed, and the processed image does not necessarily approach the original image. The commonly used contrast enhancement method uses nonlinear function to map wavelet coefficients at all levels. Because the wavelet coefficients obtained by image decomposition correspond to detail components on different scales, this method can effectively improve the contrast between detail components and adjust the lifting amplitude according to the coefficient value. In this paper, the second and third layer decomposition horizontal high-frequency, vertical high-frequency and diagonal high-frequency images are nonlinear transformed to achieve the image enhancement effect. It should be noted that anti normalization should not be omitted. Low frequency images are not processed. The choice of nonlinear function is also the key. Here, we design the following nonlinear function to enhance the infrared image:

$$y = \frac{ac\tan(kx)}{ac\tan(k)} \tag{2}$$

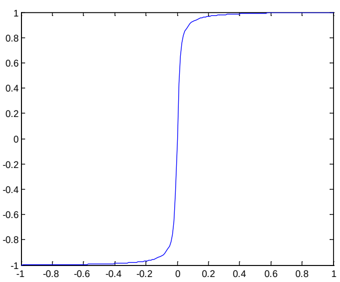
Among, $ac\tan(\cdot)$ Represents the arctangent function. The different value of K here directly affects the enhancement effect. Try to take different values of K to get the nonlinear curve, as shown in Figure 2.



(a) k=0.1



(b) k=3



(c) k=80

Fig. 2 nonlinear curve when k takes different values

6. Conclusion

This paper proposes an infrared and visible image fusion algorithm based on frame difference detection technology and regional features, which is helpful for UAV to realize environmental perception. Different from the traditional fusion algorithm based on region segmentation, this paper proposes a frame difference algorithm for target detection to segment the source image. Moreover, this paper designs different fusion rules based on the target region to fuse the visible and infrared images, which can obtain more target information and retain more background information in the source image. Experimental results verify the rationality and superiority of the proposed algorithm.

Reference

[1] Ye X, Ta Ng Y, Shu D. Large step size electromagnetic transient simulations by matrix transformation-based shifted-frequency phasor models[J]. IET Generation Transmission & Distribution, 2020, 14(15):2890-2900.

[2] Kim G, Lee K, Lee S. Linear Frequency Modulated Reverberation Suppression Using Non-negative Matrix Factorization Methods, Dechirping Transformation and Modulo Operation[J]. IEEE Access, 2020, PP(99):1-1.

[3] Li, S. , et al. "All-Optical Image Identification with Programmable Matrix Transformation." (2021).

[4] Sahani, S. K. , and V. N. Mishra . "A Study on the Behavior of Absolute Permanent Matrix Transformation." International Journal of Mathematics Trends and Technology 66.12(2020):122-127.

[5] Leal, Oes , and A. D. Conti . "Evaluation of the extended modal-domain model in the calculation of lightning-induced voltages on parallel and double-circuit distribution line configurations." Electric Power Systems Research 194.4(2021):107100.