Remote Sensing Image Change Saliency Detection Technology

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Abstract. High resolution remote sensing image target change detection technology has been widely used, and the traditional remote sensing change detection technology can not meet the requirements of high precision change detection. This paper proposes that visual saliency technology can be used for remote sensing change detection to improve the accuracy and reliability of image target change detection. First, two remote sensing images of different time are obtained, and the visual interesting region of the images are obtained by visual saliency detection. Then the difference between the region of interest is calculated, and finally binaryzation is used to get the clear changing region image, which can effectively improve the detection accuracy.

1. Introduction
In recent years, with the rapid development of digital image processing technology and the Internet, people's demand for information extraction of remote sensing images is also expanding. The region of interest (hereinafter referred to as ROI) is the most needed part of an image for users. It has the best ability to express image information. If the region can be extracted, the speed of image processing will be greatly improved. At present, there are many ROI extraction algorithms, such as edge detection algorithm (canny, soble, sift), based on statistical learning algorithm, and based on the depth of the background of selective search. The extraction method based on the visual attention mechanism has gradually developed into the mainstream. It has the characteristics of high accuracy and fast speed. Itti et al. (2002) proposed the visual attention model based on saliency, which is the most representative and which adopts a bottom-up data driven attention mechanism. Change detection, that is, through the quantitative analysis of the remote sensing data of the same area at different times, can accurately and quickly obtain the regional information that has changed in the image, which greatly improves the efficiency. At present, it is mainly used for land cover area monitoring, agroforestry monitoring, updating of geographic databases, land desertification monitoring, and rapid determination of affected areas after a disaster as well as other areas of the need for timely rapid response. Through the visual attention mechanism to determine the ROI of remote sensing images, and then detect changes in the ROI, it can obtain more accurate image change information.

2. FT Frequency Domain Visual Attention Model
Achanta et al. (2009) proposed a method based on frequency domain to calculate saliency images. It is the FT (Frequency - tuned) algorithm. The study found that an image can be divided into two parts: low frequency and high frequency in the frequency domain. The low frequency information represents the information of the entire image, including the outline of the object, and the high frequency information is the details of the image, including the noise and the texture. The basic idea is to obtain a
saliency image by bandpass filtering a number of times from low to high frequencies in an image, and then normalizing all outputs to get saliency image. Let $W_{lc}$ denote the low frequency cutoff frequency of the image, and $W_{hc}$ denote the high frequency cutoff frequency of the image. In order to obtain the entire information of the image as complete as possible, the value of $W_{lc}$ needs to be reduced. At the same time, to reduce the noise and texture of the image, we need to increase the value of $W_{hc}$. To achieve this method, we need to provide a bandpass filter $D_o$ with the following formula:

$$
D_o(x, y) = \frac{1}{2\pi} \left[ \frac{1}{\sigma_1^2} e^{-\frac{x^2+y^2}{2\sigma_1^2}} - \frac{1}{\sigma_2^2} e^{-\frac{(x-x_0)^2+(y-y_0)^2}{2\sigma_2^2}} \right] \tag{1}
$$

$\sigma_1$ and $\sigma_2$ represent two Gauss standard deviations, which determine $W_{lc}$ and $W_{hc}$ respectively. Experimental studies show that when $\sigma_1: \sigma_2=1.6:1$, the experimental results are the best.

In the actual calculation, the high frequency region is rounded off by the Gaussian filter of the template $5\times5$. The saliency image is calculated as follows:

$$
S(x, y) = \| I_{w_{hc}}(x, y) - I_u \| \tag{2}
$$

In the formula, $I_u$ denotes the average feature of the image, $I_{w_{hc}}$ denotes the feature of the image after Gaussian smoothing, and $\|\|$ represents that the Euclidean distance is calculated.

Calculation process is as follow:
1. The image is filtered by Gauss and transformed to lab space by transformation formula.
2. Calculate the luminance $l$ and the mean values $L_{m}$, $A_{m}$, $B_{m}$ representing the colors a, b.
3. Calculate the saliency image as follows:

$$
S_m = (l-L_m)^2 + (a-A_m)^2 + (b-B_m)^2 \tag{3}
$$

3. Remote Sensing Target Change Saliency Detection

By analyzing the remote sensing images of different phases, we can extract the desired regions of interest and get the change information of the region of interest. Therefore, change detection is the key. Image change detection usually includes four aspects: ①Judging whether there is a change in this area; ②Determining the location of the change; ③Determining the accurate information of the change (including the type of ground feature, area); ④Evaluating the change result and determining the change accuracy. The flow chart is as follows:

![Figure 1. Flow chart of remote sensing change detection.](image)

3.1. Image Gray Difference Method

The difference method means that the remote sensing images of two different phases are reduced directly, that is, the gray value of each pixel is subtracted, which can be used in single band image, and can also be used in multi band image processing. It can be expressed as the following formula:

$$
D_i = D_i^j(t_1) - D_i^k(t_2) \tag{4}
$$

In the formula, $D$ is the two-phase gray difference, $k$ is the image band number, i, j respectively represent the horizontal and vertical coordinates of the image, namely the row number, $D(t_1)$, and $D(t_2)$ representing the gray value of the two phase image.
3.2. Image Binaryzation

Let the image size be \( m \times n \), the number of pixel gray values in the part \( C_1 \) less than the threshold \( T \) in the image is \( p \), the average gray scale is \( \mu_1 \), and the number of pixel gray values in the part \( C_2 \) larger than the threshold \( T \) in the image is \( q \). The average gray level is \( \mu_2 \), then:

Probability of \( C_1 \):
\[
\frac{w_1}{n m} = \frac{p}{(m \times n)}
\]  
(5)

Probability of \( C_2 \):
\[
\frac{w_2}{n m} = \frac{q}{(m \times n)}
\]  
(6)

The average pixel of the entire image:
\[
\mu = \frac{w_1 \mu_1 + w_2 \mu_2}{w_1 + w_2}
\]  
(7)

Between-Cluster Variance:
\[
\delta^2(T) = w_1(\mu_1 - \mu)^2 + w_2(\mu_2 - \mu)^2
\]  
(8)

The number of \( p \) and \( q \) is determined by \( T \). When \( T \) changes, the maximum value of \( \delta^2(T) \) is obtained, \( T \) is the best threshold.

3.3. Accuracy Evaluation Binaryzation

In order to determine the accuracy of the change detection, the error matrix is used to evaluate the accuracy of the experimental results, including false alarm rate, missed alarm rate, and overall accuracy. Let \( A_m \) and \( A_n \) denote the number of pixels in the change and unchanged categories in the test result, respectively. \( B_m \) and \( B_n \) respectively represent the number of pixels in the real category and the unchanged category.

| Test results | Actual changes | Actually unchanged |
|--------------|----------------|--------------------|
| Detection of changes | \( A_m \cap B_m \) | \( A_m \cap B_n \) |
| Unchanged detection | \( A_n \cap B_m \) | \( A_n \cap B_n \) |

Table 1. Confusion Matrix

The false alarm rate (FA) refers to the ratio of the number of actually unchanged pixels detected as a change in the ground objects and the number of pixels of the entire sample detected.
\[
P_{FA} = \frac{A_m \cap B_n}{A_m} \times 100\%
\]  
(9)

The false alarm rate (MA) refers to the ratio between the number of pixels that actually changed in the ground objects and the number of pixels actually changing in the real object.
\[
P_{MA} = \frac{A_m \cap B_m}{B_m} \times 100\%
\]  
(10)

The total error rate (TE) refers to the ratio of the number of false alarm pixels and the number of false alarm pixels to the total number of pixels.
\[
P_{TE} = \frac{(A_m \cap B_m) + (A_n \cap B_m)}{A_m + A_n} \times 100\%
\]  
(11)

4. Realization of Remote Sensing Change Saliency Detection

For a remote sensing image, the saliency detection can effectively extract the region of interest in the image. The change detection can detect the saliency region of the extracted image, and improve the accuracy of the test change detection.

4.1. Experimental Results and Analysis

The experimental data is the registered QuickBird image data with a size of 540·318. The two-phase remote sensing images were September 15, 2011 and August 2, 2015, respectively, and were located in a foreign seaport.
The circles in the figure 2 and figure 3 are marked areas of change, including the moving hull, the hull resting on the shore, and parts of the ground that have changed. The rectangles are pseudo-change information, including moving vehicles and so on. Because of the long time interval between the two images, the background of the sea water also presents different colors, and the types of objects that have not changed are not considered to be significant changes in the area, and the changes of the real objects are obtained as shown in Figure 4.

4.1.1. *Traditional Remote Sensing Image Change Detection Results.* The traditional method is to treat the two images with the difference method and obtain the difference image. Then the difference image is binarized.
It can be seen from Figure 6 that the difference method has complete preservation of image information, but at the same time due to the nature of high-resolution images, the pseudo-change information in the image is also preserved intact, and the boundaries of the image are difficult to distinguish, bringing difficulties to follow-up work.

4.1.2. Saliency Detection Results. The salient features of the original image are extracted and the saliency image is obtained.
From the above figure, we can see that after the significant feature extraction, the color of the change area is more clear and distinct, and the saliency figure is processed for difference and binarization. The experimental results are shown in Figure 9 and Figure 10.

From the result graph, it is known that the saliency extraction graph can effectively extract the change part, analyze the interest area in a targeted manner, and greatly reduce the significant area, thereby improving the detection accuracy and effectively saving the time.

### 4.1.3. Accuracy Evaluation

By comparing the real-world feature image (Figure 4) and the OTSU image (Figure 6) with the salience image (Figure 10). The false alarm rate, missed alarm rate, and total error rate are used to evaluate the accuracy. The results of the experiment are shown in the following table.

| Detection method       | The Missing Alarm Rate | The False Alarm Rate | The Total False Rate |
|------------------------|------------------------|----------------------|----------------------|
|                        | Pixels | P_{MA} (%) | Pixels | P_{FA} (%) | Pixels | P_{TE} (%) |
| Traditional method     | 199    | 19.21      | 8436   | 88.12      | 8635   | 5.03       |
| Algorithm in this paper| 170    | 17.51      | 442    | 28.37      | 612    | 0.31       |

From the above table, we can see that the traditional algorithm has higher false alarm rate, false alarm rate and total error rate than this method. The main reasons are that the algorithm itself has poor performance in extracting high-resolution images, and the extracted feature pixels contain too much pseudo-variant information, making the total false detection rate significantly higher. The image processing can be more effective to highlight the edge information of the image, so that the edge and the periphery have more obvious differences. Therefore, the image can be separated well, and the
change detection can be effectively analyzed in the change detection, and the detection precision is improved.

4.2. Chapter Summary
Because of the large time difference between the two images, the difference image results obtained by the traditional difference method change detection method are not ideal, and the extracted image contains more contour information. The use of frequency domain-based FT algorithm for saliency extraction to make difference changes is more obvious. The extracted results are more accurate, and the pseudo-change information is better shielded. The result of the sea target extraction is clear and the land complex surface information is well screened. Although there are some false change information caused by the background color, shadow, and throttle, the overall results are better. The vehicles with some changes in the image are scattered in the fused image in the form of point. Obviously, there are better results for the detection of some small objects.

5. Conclusion
This paper mainly aims at the shortcomings of the traditional remote sensing image change detection, and puts forward a new idea and verified through experiments. For high resolution remote sensing images, the traditional difference method is difficult to meet the requirements. The information extracted by this method contains a large number of pseudo change information, the image contour effect is more obvious. In this paper, the region of interest in the image is extracted well through the saliency detection, and then the change detection can effectively reduce the false change information of the image, and improve the detection precision. It is of great significance to the change detection of high resolution images.

6. References
[1] Itti L, Koch C and Niebur E. 2002 A Model of Saliency-Based Visual Attention for Rapid Scene Analysis J. IEEE Trans 20 pp 1254-1259
[2] Achanta R, Hemami S, Estrada F, et al. 2009 Frequency-tuned salient region detection// Computer Vision and Pattern Recognition. CVPR 2009. IEEE Conference on. IEEE, pp 1597-1604
[3] Posner M I. 1984 Components of visual orienting J. Attention & Performance, chapter 32 pp 531-556
[4] Koch C, Ullman S. 1987 Shifts in selective visual attention: towards the underlying neural circuitry J. Hum Neurobiol, chapter 4 pp 219-227
[5] Treisman A M, Gelade G. 1980 A feature-integration theory of attention J. Cogn Psychol, chapter 12 pp 97-136
[6] Itti L, Koch C. J 2004 Computational modelling of visual attention J. Nature Reviews Neuroscience, 2(3) pp 194-203
[7] Tsotsos J K, Culhane S M, Wai W Y K, et al. 1995 Modeling visual attention via selective tuning J. Artificial Intelligence, 78 (1-2) pp 507-545
[8] Oliva A, Torralba A, Castelhano M S, et al. 2003 Top-down control of visual attention in object detection.// International Conference on Image Processing vol.1, 2003. ICIP 2003. Proceedings. IEEE, I-253-6
[9] Johnson R D, Kasischeke E S. 1998 Change vector analysis: A technique for the multispectral monitoring of land cover and condition J. International Journal of Remote Sensing, 19(3) pp 411-426
[10] Nothdurft H C. 2002 Attention shift to salient targets J. Vision research, 42(10) pp 1287-1306
[11] Li J and Gao W 2014 Visual Saliency Computation: A Machine Learning Perspective. Springer Publishing Company, Incorporated
[12] X. D. Hou, L.Q. Zhang. 2007 Saliency detection: a spectral residual approach. IEEE Conference on Computer Vision and Pattern Recognition (CVPR), pp 1-8
[13] J. R. Richard, S. Andra, O. Al-Kofahi et al. 2005 Image Change Detection Algorithms: A Systematic Survey J. IEEE Transactions on Image Processing, 14(3) pp 294-307
[14] F. Melgani, G. Moser, S. B. Serpico. 2002 Unsupervised Change Detection Methods for Remote Sensing Images J. Opt. Eng. 41(12) pp 3288-3297

[15] L. Bruzzone S. B. Serpico. 1997 An Iterative Technique for the Detection of Land-cover Transitions in Multitemporal Remote-sensing Images J. IEEE Transactions on Geoscience Remote Sensing. 35(4) pp 858-867