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Research of Anti-Noise Image Salient Region Extraction Method

Bing XU[1,*], Shiyi XIE[1] and Zhende LI[2]

[1]*Dept. of information college, Guangdong Ocean University, Zhanjiang city 524088, Guangdong province - China*
[2]*Dept. of software college, Guangdong Ocean University, Zhanjiang city 524088, Guangdong province – China*

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Abstract

The existing image salient region extraction technology is mostly suitable for processing noise-free images, and there is a lack of studies on the impact of noise on images. In this study the adaptive kernel function was employed in image salient region detection. The salient property of a region was determined by the dissimilarities between the pixels of the image region and its surroundings. The dissimilarity was measured as a decreasing function associated with adaptive kernel regression. The proposed algorithm used multi-scale fusion method to obtain the salient region of the whole image. As adaptive kernel function has strong anti-noise characteristics, the proposed algorithm was characterized with the same robustness. A numerical simulation experiment was conducted on salient region extraction of images with noise and without noise. A comparison between this study's results and two existing salient region extraction methods revealed that the proposed method in this study was superior in its extraction accuracy of image salient regions and could reduce interference of image noise.

Keywords: Image Salient Regions, Adaptive Kernel Function, Image Noise, Image Extraction

1. Introduction

Visually salient regions indicate the parts of the image that are of interest to human eyes [1], [2]. As salient regions of an image represent the main content of the image, accurately extracting the salient regions plays an important role in image recognition and image retrieval [3], [4]. Meanwhile, salient regions are also critical in computer visual tasks, as accurate extraction of salient regions allows limited resources to be used in processing regions or object of interest. In recent years, more and more studies focus on how to detect salient regions of interest in natural images. A large number of salient region extraction algorisms have been proposed [5], [6], [7], [8], which convert the image to gray scale image containing salient regions, and represent salient regions in the image with bright gray values. These algorithms obtain good results in processing sharp and high fidelity images. However, in practical applications, the captured images usually contain noise, especially images captured with infrared imaging systems. These images have low SNR (Signal Noise Ratio) and the image noise is particularly serious. The presence of noise makes image salient region extraction difficult. However, not many existing studies focus on this issue. Takeda and other researchers have proposed an adaptive kernel function [9], which has been widely used in image noise removal, face recognition and object detection [10], [11], [12].

Based on previous studies, this paper proposes a salient region extraction method with adaptive function as the key technology. As adaptive kernel function has robustness in dealing with image noise, the proposed salient region extraction algorithm has the same robustness and could reduce the jamming of image noise and improved accuracy in salient region extraction. In order to verify the effectiveness of this method, an analysis was made of the salient region extraction capacity of the algorithm in processing images with and without noise by employing the numerical simulation program. In addition, a comparison was made of this algorism with the two methods proposed in literature [4] and [5] regarding salient region extraction. The results indicate that the proposed method in this paper can effectively extract the salient regions of an image and with high accuracy in cases where the image contains a large amount of noise.

2. Image Salient Region Extraction

Judgment about salient pixel region is based on dissimilarities between this small region and the surrounding region. It defines y_i the value of dissimilarity between the centre point x_i of the observed image and its neighboring points. According to the estimation theory, each value of y_i is a potential threshold value for the salient region; however, this potential value can be erroneous. The model can be descry

$$y_i = s_i + \eta_i, i = 1, \dots, N \tag{1}$$

Where s_i is image salient region value, and η_i is the error term, N is the number of sampled image patches. By solving the following least squares problem with weights, salient region value is obtained at position x_i of the image. The problem can be described as:

* E-mail address: bingxuswcd@163.com
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$$\hat{s}(x_i) = \arg\min \sum_{i=1}^{N} \left| y_i - s_i \right|^2 K\left(y_i, y_r\right) \quad (2)$$

where y_r is the reference value, $K\left(y_i, y_r\right)$ is weight function. Let y_r be equal to the minimum value in a region with y_r as the centre, and $K\left(y_i, y_r\right)$ provides the weighting factor. Its definition is as follows:

$$K\left(y_i, y_r\right) = e^{-\frac{(y_j - y_r)^2}{h}}, j = 1, ..., n \quad (3)$$

where parameter h controls the weight of the attenuation and the fixed value $h = 0.2$ is used here. Minimization of the formula leads to the weighted average of difference, where the weighting factor is $K\left(y_i, y_r\right)$. The obtained result of minimization is:

$$\hat{s}(x_i) = \frac{\sum_{j=1}^{n} K(y_i, y_r) y_i}{\sum_{j=1}^{n} K(y_i, y_r)} = \sum_{j=1}^{n} w_{ij} y_i \quad (4)$$

Let ρ_i be defined as the similarity, indicating the degree of similarity between the value of the image point x_i and those of neighboring points. Let y_i be defined as a monotonic decreasing function on parameter ρ_i as follows:

$$y_i = e^{-\rho_i}, i = 1, \ldots, N \quad (5)$$

Where N is the number of sampled image patches. The value of parameter ρ_i can be obtained through many ways, and in this study, adaptive kernel function proposed by Takeda was adopted [9]. This function has been widely used in areas such as image de-noising, face recognition and object detection. It can self-adapt to the local information in an image, and has strong stability with images containing noise. The use of this function in the image salient region extraction and making it the core of the algorithm in this study ensures that the proposed algorithm has strong stability in handling images with noise. The definition of introducing parameter ρ_i is as follows:

$$\rho_i = \exp\{-\frac{(x_i - x)^T C_i (x_i - x)}{2d}\} \quad (6)$$

Where d is the scale parameter which controls patch size. In this study the value of this parameter was set to a fixed 3. C_i is the covariance matrix, and its specific representation is as follows:

$$C_i = \gamma_i U_{\theta_i} \Lambda_i U_{\theta_i}^T \quad (7)$$

Where U_{θ_i} is the rotation matrix, Λ_i is the tensile matrix, and they are defined as:

$$U_{\theta_i} = \begin{bmatrix} \cos\theta_i & \sin\theta_i \\ -\sin\theta_i & \cos\theta_i \end{bmatrix} \quad (8)$$

$$\Lambda_i = \begin{bmatrix} \sigma_i & 0 \\ 0 & \sigma_i^{-1} \end{bmatrix} \quad (9)$$

Therefore, the covariance matrix contains three parameters γ_i, θ_i and σ_i. Literature [9] provides a method to obtain the three parameters based on matrix singular value decomposition, as shown below:

$$\begin{bmatrix} \vdots & \vdots \\ z_{x1}(x_t) & z_{x2}(x_t) \\ \vdots & \vdots \end{bmatrix} = U_i S_i V_i^T \quad (10)$$

$z_{x1}(x_t)$ and $z_{x2}(x_t)$ stand for one step value of the image region with location x_t as the centre along the x_1 and x_2 directions, respectively. The operation of the above equation is the singular value decomposition of the matrix, and the second column of the orthogonal matrix $v_2 = [v_1, v_2]^T$ defines parameter θ_i as follows:

$$\theta_i = \arctan(\frac{v_1}{v_2}) \quad (11)$$

Parameter σ_i is determined by the value of the diagonal in the 2 × 2 diagonal matrix as shown in the formula below:

$$\sigma_i = \frac{s_1 + \lambda'}{s_2 + \lambda'}, \lambda' \geq 0 \quad (12)$$

And parameter γ_i is defined by the following equation:

$$\gamma_i = (\frac{s_1 s_2 + \lambda''}{M})^{1/2} \quad (13)$$

Where M represents the sampled number in image area and the parameter in the formula is set as a fixed value based on literature [9]: $\lambda' = 1, \lambda'' = 0.01$.

In extracting salient regions in large-scale images, salient regions are obviously concentrated on the edges of the object, resulting in loss of integrity in salient objects. To overcome this weakness, multi-scale processing was used. Sub-sampling on different scales was applied to the images, followed by the above mentioned process. Interpolation processing was then undertaken to images with salient regions extracted, so that the resulted size of the processed image was identical to the original image. Lastly, the average of the obtained images with salient regions was worked out with the expression below:

$$\hat{s}(x_i) = \frac{1}{M'}\sum_{m=1}^{M'}\hat{s}(x_i)_m \tag{14}$$

Where m represents the number of sub-sampled images. Fig.1 is a real-life example of image processing where salient regions of different sub-sampled imaged are provided. It can be seen that if the whole image undergoes direct processing, image salient regions only appear on the edges of the object. This problem is well solved using multi-scale processing of the image salient regions. Therefore, in the follow-up numerical simulation experiment, this method was adopted in extracting image salient regions.

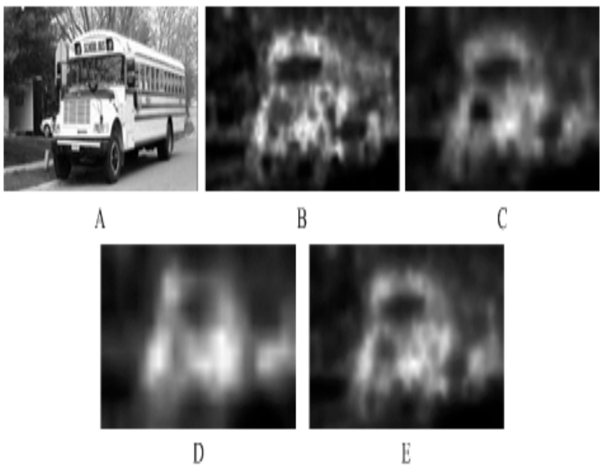

Fig.1 Image Salient Regions on Different Image Scales: (A) original image, (B) salient region of the original image, (C) image salient region after 60% sampling, (D) image salient region after 40% sampling, (E) multi- scale fused image (the two white regions are salient regions of the image)

Above all, the basic process of the image salient region extraction is described below：

Step 1: Read the original image,
Step 2: Sub-sampling the original image,
Step 3: Save the original image and the sub-sampled image, the total number is M',
Step 4: Calculate parameter ρ_i from the m *th* image,
Step 5: Get the parameter y and the weighting factor k,
Step 6: Get the salient value of m *th* image, then get consistent salient value $\hat{s}(x_i)_m$ with the original image after sampling,
Step 7: If m<M', perform Step 4, Otherwise, to the end,
Step 8: Perform the formula (14), get the final salient value.

3. Numerical Simulation Experiment

This section will present the results from processing images with or without noise. Firstly, the noise- free image salient region extraction results in various contexts will be provided. Fig.2 shows the original image and the image salient regions obtained by applying the proposed algorithm. The result indicates that although both the context and the information in the image changed, the proposed algorithm was still able to extract the salient region of the image.

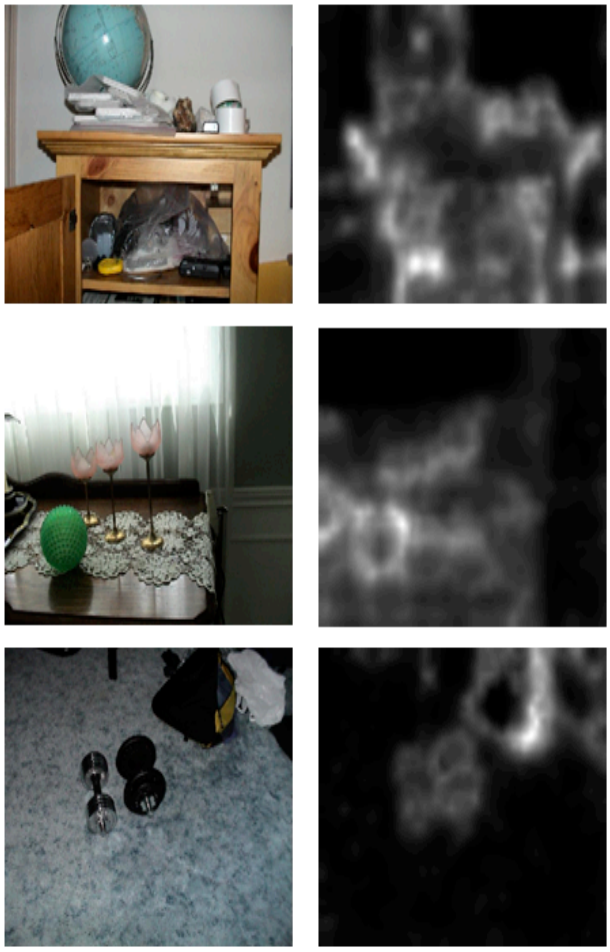

Fig.2 Noise- free Image Salient Region Extraction, (Left) Original image, (Right) Salient region of the image obtained using the proposed algorithm

Next, the performance of the algorithm on images containing noise would be studied with three real-life examples and the result of image salient region extraction is provided. In order to show that the algorithm was robust in handling noise images, two other salient region extraction methods were introduced for comparison: the algorithm introduced by Seo H. h and Milanfar P inliterature [4] , abbreviated as SM algorithm and the algorithm introduced by Rahtu E and Kannala J in literature [5], abbreviated as RK algorithm. Image capturing is inevitably interfered with Gaussian noise, therefore, the experiment conducted in this study focused on images containing Gaussian noise. Imnoise (), the noise adding function in the Matlab program, was used where the mean value was set as zero and the variance changed. Images with noise that had variance values of 0, 0.01, 0.05, 0.1 and 0.2 underwent salient region extraction.

Fig.3 presents the results of salient region extraction of an image of a single athlete, where the rows 2 and 3 show the processing results adopting SM algorithm and RK algorithm, respectively, indicating that with the gradual increase of noise, the errors in salient region extraction using these two algorithms increased. Row 4 is the result of extraction using the proposed algorithm in this study. While the algorithm was also affected by the noise, it can be seen from Fig.3 that despite the strong noise contained in the image this method was able to extract relatively accurate salient regions.

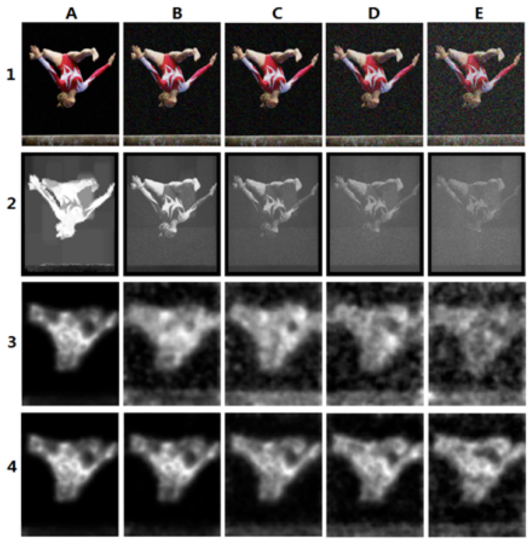

Fig.3 Results of Salient Region Extraction: columns(A, B, C, D, E) denote images with five degrees of noise and their extraction results, where row 1 indicates images with different degrees of noise, row 2 indicates the extraction results using RK algorithm, row 3 presents extraction results using SM algorithm, and row 4showsthe extraction results using the proposed algorithm

Fig.4 presents the results of salient region extraction of an image of a room with a computer. The results revealed that with strong noise in the image, large errors occurred with salient regions extracted using RK and SM algorithm. In contrast, the salient regions extracted by the proposed algorithm maintained the accuracy.

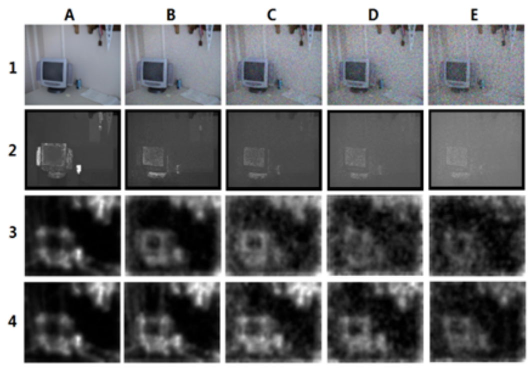

Fig. 4 Results of Salient Region Extraction: columns (A, B, C, D, E) denote images with five degrees of noise and their extraction results, where row 1 indicates images with different degrees of noise, row 2 indicates the extraction results using RK algorithm, row 3 presents extraction results using SM algorithm, and row 4 shows the extraction results using the proposed algorithm

Fig. 5 presents the results of salient region extraction of an image with a complex ranch scene. As RK algorithm was sensitive to noise, the salient woods region was impossible to extract when noise appeared in the image. SM algorithm was better in handling noise; however, with strong noise, substantial errors occurred with the extracted region. In contrast, our algorithm extracted a more accurate salient region. This was particularly the case with images in column E where the salient region extracted using our method was consistent with salient region extracted from the noise-free image.

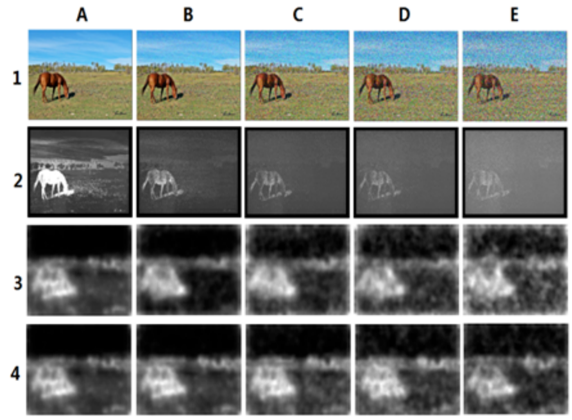

Fig.5 Results of Salient Region Extraction: columns (A, B, C, D, E) denote images with five degrees of noise and their extraction results, where row 1 indicates images with different degrees of noise, row 2 indicates the extraction results using RK algorithm, row 3 presents extraction results using SM algorithm, and row 4 shows the extraction results using the proposed algorithm

Lastly, the results of processing an image with a more complex building scene were presented in Fig.6. The results revealed that despite the complex scene and strong noise contained in the image the proposed algorithm was also able to extract accurate salient regions and keep a high accuracy.

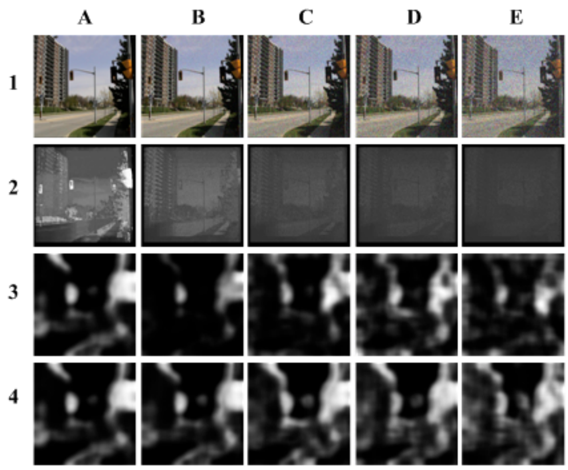

Fig.6 Results of Salient Region Extraction: columns (A, B, C, D, E) denote images with five degrees of noise and their extraction results, where row 1 indicates images with different degrees of noise, row 2 indicates the extraction results using RK algorithm, row 3 presents extraction results using SM algorithm, and row 4 shows the extraction results using the proposed algorithm

4. Conclusions

In this paper, a new algorithm that is effective in reducing image noise was proposed to address the issue of salient region extraction from images with noise. This algorithm extracted the salient region of the whole image by using adaptive kernel functions as the key technology and employing multi-scale fusion method. Because of the robustness of adaptive kernel functions in handling image noise, the algorithm proposed in this study showed the same robustness when dealing with image noise. A simulation experiment was conducted to validate the algorithm, and the comparison of this algorithm with two existing algorithms indicated that that the new algorithm was robust against image noise. Despite the robustness of the algorithm proposed, the study has its limitations. Future in-depth research is required to focus on improving the computing speed of the algorithm, multi-source noise analysis, and algorithm robustness in the area of salient region extraction of images containing noise.

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