A New Method of Object Saliency Detection in Foggy Images

Wenjun Lu^(✉), Xiaoning Sun, and Congli Li

Army Officer Academy, Hefei, Anhui, China
{wenjun.lu2013, sunxiaoning0117}@gmail.com,
lccliqa@163.com

Abstract. Aiming to saliency detection problem of degraded foggy images, a new method of object saliency detection method in foggy images based on region covariance matrix is presented. In the method, color, direction and space information are extracted to form covariance feature description matrix according to characteristics of foggy images. Then local saliency sub-map is acquired by local contrast. In the same time, Wiener filter and Sobel edge detection are used to obtain global saliency sub-map. Finally, local saliency map of color domain is optimized by edge global saliency map, and saliency map is completed. Experiments show that compared with state-of-art methods, the proposed method has better adaptability and accuracy to object saliency detection in foggy images.

Keywords: Foggy images · Region covariance matrix · Object saliency detection

1 Overview

A natural scene typically contains many objects of various structures at different scales. This complexity poses a great challenge for our visual system since, with its limited capacity, it has to analyze a vast amount of visual information at any given time. To cope with this information overload, the human visual system has developed attention mechanisms to select the most relevant (salient) parts of a scene that stand out relative to the other parts. What captures our attention depends on factors relevant to bottom-up or top-down selection processes, or a combination of those [1]. While the bottom-up visual attention is mainly driven by intrinsic low-level properties of a scene, the top-down attention involves high-level visual tasks such as searching for a specific object [2].

The existing saliency detection method for image processing is more characteristic of single feature channels to obtain through parallel processing color, direction and other characteristics of the saliency map, and then combines the feature graph linearly to form the saliency map. This approach can obtain the saliency map of high quality of natural images most speaking, because these natural images mostly have the following features: color contrasts, the outline are clear, single target object. In the fog condition, there are a large number of tiny water droplets and aerosols in the atmosphere, a serious impact on the propagation of light, resulting in a foggy day image sharpness, contrast is reduced, especially the color image, but also have serious color distortion and

dislocation. This kind of fog degraded impact distortion brought great challenges to the target image saliency detection, direct application of the existing methods are difficult to effectively solve.

Currently research on foggy image processing has focused on images defog and enhancement, quality assessment of image foggy conditions has focused on defog image [3, 4], the result of assessment is used to determine defog effect [5, 6]. But with the increase in haze weather, fog target saliency detection is widely applied and practical need in the field of military and civilian. Image based on the dense fog to construct saliency detection model, combined with the existing mature method, proposes the strategy framework of image target saliency detection for a thick fog conditions, its main characteristics are: (1) obtained using Wiener filtering and edge detection of Sobel is not related to color domain image edge fog clear the feature map and regional covariance feature graph weighted average access saliency map, reduce the color distortion on the detection effect, improves the detection efficiency; (2) combined with the classical method of mature (region covariance detection) framework construction of strong flexibility, research on image saliency detection can be extended to the rainy day, snow, cloud, smoke conditions.

The structure of this paper is as follows: Sect. 1 is the introduction part introduces the research background of detecting visual saliency detection, then puts forward the topic of this paper is the motive. The second section related characteristics of fog image is introduced in the paper, firstly analyzed the influence of the fog on the image, and then explains the significance and the existing detection methods cannot for fog image especially image fog conditions for saliency detection. The third section will be the concept of region covariance matrix into the saliency detection method, and carried on the summary to the relevant content of the concept of. The fourth section constructs the saliency detection method based on region covariance. The fifth section will be the method with the existing saliency detection method to compare the results of the analysis. The last section is the summary of this paper and the prospect of the next research.

2 Feature Analysis of Foggy Images

2.1 Fog Distortion Effects on the Image [7]

In foggy weather, there are many reflective surfaces to reflect most of the incident light. The reflection brings saturation down, hue shift and has influence on brightness and contrast. Random pattern and complex shapes are followed by fog, and dispersion and aggregation in the process continued with fog flowing, randomness of fog density is resulted. Structure similar exists in fog, if the fog is regarded as a kind of texture, the texture will flood the details of target, and shutoff outlines of target, which results in outlines splitting or abnormal. Further, fog not only affects the low frequency information of image, but also affects its high frequency information.

Based on above analysis, influence on image quality in foggy weather contains three aspects. (1) destruction of the original image information, since the structure information of an image can be interpreted as an image of high enough energy

frequency component of the fog appears in the image destruction of the structure information, and the details of the texture of the target scene is affected, at the same time blocking the edge, resulting in the loss of the color of the scene, and the loss of other visual information; (2) to add some information presence adds fog can be seen as related to the channel information, the equivalent of adding a fog of ‘mask’, increasing the overall brightness of the image visually; new information (3) derived, due to the combined effects of fog particles, fog number of days multiplied by the image information derived from, for example, fog noise, blurring the image, reducing the image contrast.

2.2 Analysis of Heavy Fog Weather Image Samples and Preliminary Experiment

2.2.1 Image Acquisition

At present there is little used exclusively for image database saliency detection foggy weather conditions, in order to make the test results more reliable, here is the use of real, real outdoor fog scene image.

Select representative (people, vehicles and buildings) 54 images of real scenes of the image, each image of the region selection using Adobe Photoshop CS4 software, select the eye that significant regional, which generates fog standard image map (Ground Truth) (Fig. 1).

2.2.2 Test of Existing Saliency Detection Algorithms

As shown in Fig. 2 (a), affected by the fog weather, a large amount of information in the image (color, contrast and edge) was mutilated target significant also have a great impact, how to use the fog image retained in the information on the fog image saliency detection becomes very important. However, from Fig. 2 (b), (c) and (d) sub graph can be seen in the saliency detection method of existing saliency detection for foggy images will have a greater error, not only can detect the target region accurately, but also error detect non significant regions. Investigate its reason, the existing detection methods are aimed at a clear image of good weather conditions, these images not only color high fidelity, and edges of the clear and obvious contrast. And this study is fog even image fog conditions, not only the color of the image information is mostly annihilation, and

Fig. 1. Foggy images and Ground Truth

Fig. 2. (a) Foggy image; (b) Saliency map by RC; (c) Saliency map by FT; (d) Saliency map by SDSP; (e) Saliency map by PCA; (f) Ground Truth

edge blur. Therefore, the introduction of the saliency detection method based on covariance matrix for saliency detection in fog image. This paper will be in the next section of the region covariance matrix are introduced in detail.

3 Region Covariances

Covariance of features was first proposed as a compact region descriptor by Tuzel [8]. Since then, it has been effectively utilized in various high-level computer vision problems such as texture discrimination, object detection, and object tracking. For the formal definition, let I denote an image, and F be the feature image extracted from I :

$$F(x, y) = \Phi(I, x, y) \quad (1)$$

Where, Φ denotes the d -dimensional function of features such as intensity, color, orientation, spatial attributes, etc.

Then, a region R inside F can be represented with a $d \times d$ covariance matrix C_R of the feature points:

$$C_R = \frac{1}{n-1} \sum_{i=1}^n (f_i - \mu)(f_i - \mu)^T \quad (2)$$

With $\{f_i\}_{i=1 \dots n}$ denoting the d -dimensional feature points inside R , and μ being the mean of these points.

Tuzel also proposed a fast way of computing covariance matrices of rectangular regions by using the first and the second-order integral image representations with $O(d^2)$ computational complexity.

Note that covariance matrices do not lie on Euclidean space. Hence, to compute the distance between two Covariances C_1 and C_2 , Tuzel suggested using the metric proposed by Foerstner and Moonen [9]:

$$(C_1, C_2) = \sqrt{\sum_{i=1}^n \ln^2 \lambda_i(C_1, C_2)} \quad (3)$$

Where $\{\lambda_i(C_1, C_2)\}_{i=1\dots n}$ and $\{x_i\}_{i=1\dots n}$ are the generalized eigen-values and the generalized eigenvectors of C_1 and C_2 , respectively, satisfying

$$\lambda_i C_1 x_i - C_2 x_i = 0, \quad i = 1 \dots d. \quad (4)$$

A covariance matrix provides a natural way of combining different visual features with its diagonal elements representing the feature variances and its non-diagonal elements representing the correlations among the features. Unlike the common practice in the existing computational saliency models that assume the responses of linear filters are independent of one another and combined linearly, incorporating second order image statistics within a single descriptor encodes the local structure exceedingly well and provides robustness and high discriminative power.

4 Proposed Detection Method

4.1 Technique Roadmap of Our Method

Similar to other bottom detection method to detect the steps, this paper follows the classical saliency detection method: (1) on single feature such as color, direction of extracting feature saliency map, (2) single feature saliency map take linear or nonlinear fitting method on single feature significant figure significant fusion into a complete map of the based on the. However, unlike other methods is the detection using local saliency detection and global complement each other, through the color domain local saliency map optimization on the edge of global saliency map, and then to improve the saliency detection effect. The strategy process is shown in Fig. 3.

In most of the existing bottom-up models, we observe the following basic structure: (a) extract some basic visual features such as color and orientation, (b) investigate

Fig. 3. Flow chart of proposed method

feature channels in parallel and extract a feature map for each dimension, and (c) integrate these maps to produce a master saliency map.

4.2 Local Color Region Saliency Detection

In our implementation, we used very simple visual features, namely color, orientation, and spatial information. Based on these features, an image pixel is represented with a seven-dimensional feature vector [10]:

$$F(x, y) = \left[L(x, y) \ a(x, y) \ b(x, y) \ \left| \frac{\partial I(x, y)}{\partial x} \right| \ \left| \frac{\partial I(x, y)}{\partial y} \right| \ x \ y \right]^T \quad (5)$$

Where L , a , and b denote the color of the pixel in $L * a * b$ color space, $|\partial I / \partial x|$ and $|\partial I / \partial y|$ are the edge orientation information, and (x, y) denotes the pixel location. Hence, the covariance descriptor of a region is computed as a 7×7 matrix.

In our model, there are three parameters related to the notion of scale: (a) the set of region sizes K , (b) the neighborhood radius r , and (c) the smoothing parameters σ . The number of most similar neighbors m is another parameter that needs be decided.

Assume that the input image, the first image reconstruction for the square form, and then decomposed into non-overlapping square block size for the collection of pixels. Through the block compared with the surrounding background are significant in the block. If the block is out of the ordinary characteristic of the block is defined as a significant. Because the characteristic of image pixel region depends on the region, so the size of the region decides to implement the scale saliency detection. Similar model contrast of local block comparison strategy and other uses, the novelty of this method is to use covariance represents visual characteristics.

In our first model, we employed covariance features to compute the saliency map of an image. It depicts that contains a rectangular region at the center whose contrast is lower than the surrounding region and so draws our attention. This rectangular region receives a low saliency value from our first model because the Covariances are the same for the center and the surrounding regions. The saliency of region R_i is given by

$$S(R_i) = \frac{1}{m} \sum_{j=1}^m d(R_i, R_j) \quad (6)$$

Where the m most similar regions to R_i is found according to the dissimilarity measure $d(R_i, R_j)$, which is defined as:

$$d(R_i, R_j) = \frac{\rho(C_i, C_j)}{1 + ||x_i - x_j||} \quad (7)$$

Here C_i and C_j respectively represent the covariance matrix of region R_i and R_j . x_i and x_j respectively represent coordinate regional and central position of region R_i and R_j . It is obvious that the impact factor of image blocks significantly decreases with the

Fig. 4. Local color saliency map

increase of the other block and the block between the distances, so the distance of space difference of introducing weight. The result of experiment is shown in Fig. 4.

Figure 4 experimental results we can see that the local color domain saliency detection can detect the location of the target in the image region of good, but vaguely. Detection methods need to be improved.

4.3 The Edge Global Saliency Detection

According to the discussion about the fog distortion effects on the image in the image above, known as compared to normal weather, fog image will lose a lot of color, orientation and location information, and will make the object contours of fuzzy. This situation will affect greatly to the saliency detection method based on color domain, in order to reduce the fog image saliency detection, this paper introduces global edge detection, to enhance the fog image saliency detection results.

In view of the existing image defogging algorithm can better restore fog image information, while also introducing to color variation noise such as fog algorithm brings, to further enhance the saliency detection. This paper only using Wiener filter to remove noise, and on this basis, using Sobel edge detection to obtain the edge of global significance. The specific results of the experiment as shown in Fig. 5.

It can be seen from Fig. 5, edge global saliency detection can be extracted from the fog the edge area of the image clear.

4.4 Local and Global Significance of Linear Fitting

Since the implementation of high quality of the above two methods are not independent of the saliency detection, this paper will be the two methods of linear fitting, to significantly improve the efficiency of detection. The linear fitting Eq. 8 as follows:

$$Sal = \alpha \times Sal_g + (1 - \alpha) \times Sal_l \quad (8)$$

Here and are respectively represent local color domain significantly and the global edge significantly, but said the weight parameters between the two, the paper will be taken as 0.3. The specific results of the experiment are shown in Fig. 6.

Fig. 5. Edge global saliency detection

Fig. 6. Significant detection method

5 Experiments and Results Analysis

In order to validate the method proposed in this paper, the first stage here proposed method (using only the region covariance method) the saliency map and 5 kinds of commonly used at this stage of the saliency detection method of obtaining and second stages (IT [10], GBVS [11], FT [12], SDSP [13], PCA [14]) test results contrast.

The experiment uses the machine hardware and software configuration: CPU as the Core i7, memory for 4 GB; Matlab R2011a; operating system is 32 bit win7 system (Fig. 7).

5.1 PR Curve

Similar to the method proposed in literature [12], according to the evaluation method of PR curve is used to evaluate the salient object segmentation saliency detection effect. The range of a given graph is significant, can set a threshold of two yuan, the segmentation of the saliency map to obtain significant target. Each of the thresholds corresponds to a more accurate rate regression data set, when the threshold changes from 0 to 255 a PR curve with the birth of. The different images of the PR curve with a saliency detection method of average can generate an average PR curve to evaluate the saliency detection results (closer to the (1,1) point the better). The evaluation results are shown in Fig. 8.

5.2 F Measure

PR curve evaluation method on different images are used in fixed threshold, and here for different test images using different threshold, usually F Measure in the evaluation of the threshold is 2 times the saliency map of the mean, the specific calculation methods such as Eq. 9.

Fig. 7. Results of comparison method

Fig. 8. PR curves of different detection methods

$$T_a = \frac{2}{W \times H} \sum_{x=1}^W \sum_{y=1}^H Sal(x, y) \quad (9)$$

Here and are respectively indicate significant figure of the length and width, said the saliency map in the point of significant value.

Using the above threshold, can be 2-division of the saliency map, find the salient object. Then for each significant method for the detection of each and every one of the saliency map, can calculate the F Measure. Specific calculation formula is as follows:

$$F_{\beta} = \frac{(1 + \beta^2) Precision \cdot Recall}{\beta^2 \cdot Precision + Recall} \quad (10)$$

F Measure can better reflect a global saliency detection method of prediction accuracy, the average results of the fog image detection in this paper, different saliency detection method is shown in Table 1.

In this paper, methods of Seen from the PR curve in Fig. 8 and Table 1 of F Measure contrast, saliency detection method is obviously better than the other in the salient region detection accuracy on saliency detection method based on region covariance matrix features. A method of detecting the optimized more significant regional positioning images accurately in the.

Table 1. F measure comparison of methods

Algorithms	F measure
IT	0.4175
GBVS	0.4062
FT	0.2317
SDSP	0.3982
PCA	0.4485
RC	0.5235
OURS	0.5467

6 Conclusions

This paper focuses on the significant target detection problem under fog conditions; we propose a novel, based on region covariance saliency detection method. The core of this method is to generate the covariance matrix, combined with foggy image features and target saliency detection visual requirements, this paper established a suitable image region covariance matrix fog conditions, combined with edge detection and Wiener filtering, the final construction of the conditions of the fog target significant detection model and method. This method not only adapt to the effects of fog environment brings to saliency detection, and the method is novel, scalability strong (extended to other domains, this paper features) strategy for the research on image saliency detection in rainy or snowy days, clouds, smoke and other conditions provided experiences for reference; due to extract more features in this paper, the high computing cost method; how to extract significant sensitive fog image features and reduce the amount of calculation is the focus of the next step.

Acknowledgement. This work is supported by the Anhui Natural Science Foundation of China (Grant Nos. 1208085MF97).

References

1. Koch, C., Ullman, S.: Shifts in selective visual attention: towards the underlying neural circuitry. *Hum. Neurobiology* **4**, 219–227 (1985)
2. Borji, A., Cheng, M.M., Jiang, H.Z., Li, J.: Salient object detection: a survey. *IEEE Transactions on Pattern Analysis and Machine Intelligence (PAMI)* (2014, accepted)
3. He, K.M., Sun, J., Zhou, X.O.: Single image haze removal using dark channel prior. In: *Proceedings of IEEE Conference on Computer Vision Pattern Recognition (CVPR)*, pp. 1956–1963. IEEE, Washington DC (2009)
4. Jing, Y.U., DaPeng, L., QingMin, L.: Physics-based fast single image fog removal. *ACTA AUTOMATICA SINICA* **37**(2), 143–149 (2011)
5. Fan, G., Zixing, C., Bin, X., et al.: New algorithm of automatic haze removal for single image. *J. Image Grap.* **16**(4), 516–521 (2011)
6. Li, C., Lu, W., Xue, S., Shi, Y.: Research on quality improvement of polarization imaging in foggy conditions. In: Sun, C., Fang, F., Zhou, Z.-H., Yang, W., Liu, Z.-Y. (eds.) *ISIDE 2013*. LNCS, vol. 8261, pp. 208–215. Springer, Heidelberg (2013)
7. Li, C., Lu, W., Xue, S., Shi, Y., Sun, X.: Quality assessment of polarization analysis images in foggy conditions. In: *Proceedings of the IEEE International Conference on Image Processing (ICIP)*, pp. 551–555. IEEE, Pairs (2014)
8. Tuzel, O., Porikli, F., Meer, P.: Region covariance: a fast descriptor for detection and classification. In: Leonardis, A., Bischof, H., Pinz, A. (eds.) *ECCV 2006*. LNCS, vol. 3952, pp. 589–600. Springer, Heidelberg (2006)
9. Förstner, W., Moonen, B.: A metric for covariance matrices. Technical report, Department of Geodesy and Geoinformatics, Stuttgart University (1999)
10. Itti, L., Koch, C., Niebur, E.: A model of saliency-based visual attention for rapid scene analysis. *IEEE Trans. Pattern Anal. Mach. Intell. (PAMI)* **2012**, 54–125 (1998)

11. Harel, J., Koch, C., Perona, P.: Graph-based visual saliency. In: *Advances in Neural Information Process Systems(NIPS)*, pp. 545–552. MIT Press, Massachusetts (2007)
12. Achanta, R., Hemami, S., Estrada, F., Süsstrunk, S.: Frequency-tuned salient region detection. In: *Proceedings of the IEEE International Conference on Computer Vision and Pattern Recognition(CVPR)*, p. 1597. IEEE, Miami (2009)
13. Zhang, L., Gu, Z.Y., Zhang, H.Y.: SDSP : a novel saliency detection method by combing simple priors. In: *Proceedings of the IEEE International Conference on Image Processing (ICIP)*, pp. 171–175. Springer, Melbourne (2013)
14. Margolin, R., Tal, A., Zelnik-Manor, L.: What makes a patch distinct. In: *Proceedings of the IEEE International Conference on Computer Vision and Pattern Recognition(CVPR)*, pp. 1139–1146. IEEE, Portland (2013)