Report Contrast-based Image Attention Analysis by Using Fuzzy Growing

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1 Contrast-based saliency map

Traditional image processing techniques usually consider an image by three basic properties, color, texture, and shape. These techniques have been successfully applied to a number of applications. However, they cannot provide high level understanding of image, because human usually do not simply understand an image from color, texture, and shape aspects separately.

They proposed a contrast-based saliency measure in this work. An image with the size of $M \times N$ pixels can be regarded as a *perceive field* with $M \times N$ *perception units*, if each *perception unit* contains one pixel. The contrast value $C_{i,j}$ on a *perception unit* (i, j) is defined as follows:

$$\mathbf{C}_{i,j} = \sum_{q \in \Theta} \mathbf{d}\left(\mathbf{p}_{i,j}, \mathbf{q}\right) \tag{1}$$

where $\mathbf{p}_{i,j}$ ($i \in [0, M]$, $j \in [0, N]$) and $\mathbf{q}$ denote the stimulus perceived by *perception units*, such as color. Θ is the neighborhood of *perception unit* (i, j). The size of Θ controls the sensitivity of *perceive field*. The smaller the size of Θ is, the more sensitive the *perceive field* is. $\mathbf{d}$ is the difference between $\mathbf{p}_{i,j}$ and $\mathbf{q}$, which may employ any suitable distance measure according to applications.

All contrasts $\mathbf{C_{i,j}}$ on the *perception units* are normalized to [0, 255] to form a saliency map. A sample of contrast-based saliency map is shown in figure 1(c). LUV space are used as stimulus on *perceive field*, and the difference $\mathbf{d}$ is computed by Gaussian distance. Their contrast-based saliency map presents color, texture and approximate shape information at the same time.

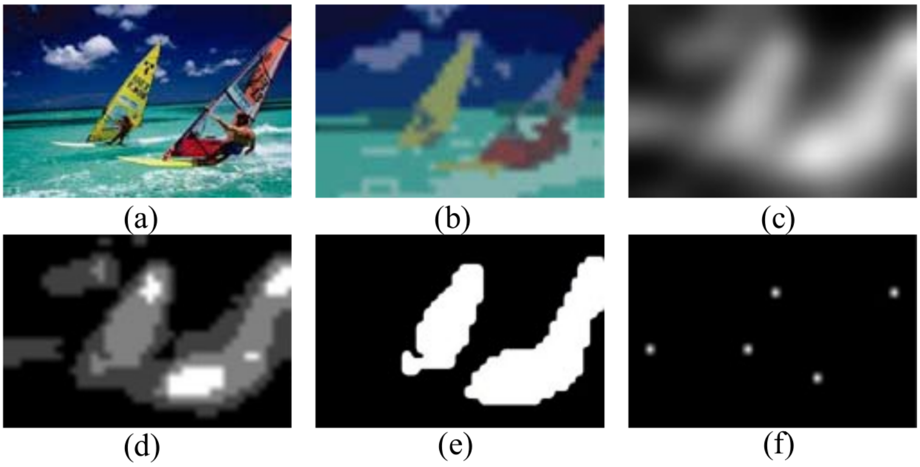

Figure 1: **Contrast-based image attention analysis** (a) original image; (b) quantized block image; (c) saliency map; (d) fuzzy growing; (e) attended areas; (f) attended points.

2 Fuzzy growing

Saliency map is a gray-level image. Therefore, a hard cut threshold is not effective for attended areas extraction, because the variation of gray-levels in saliency map are not consistent, even in one object. They proposed a method based on fuzzy theory [1] which called *fuzzy growing*. According to the definition of a fuzzy event [2], saliency map is regarded as a fuzzy event modeled by a probability space. saliency map has L gray levels from g_0 to g_{L-1} and the histogram of saliency map is $h_k,\ k = 0, ..., L-1$. Thus, the saliency map is modeled by a triplet $(\mathbf{\Omega}, k, \mathbf{P})$, where $\Omega = \{g_0, g_1, ..., g_{L-1}\}$ and $\mathbf{P}$ is the probability measure of the occurrence of gray levels, i.e., $\mathbf{Pr}\{g_k\} = h_k / \sum h_k$. They used membership function denotes the degree of attended areas and unattended areas.

$$\mu_A = \begin{cases} 1 & x \geq a \\ \dfrac{x-u}{a-u} & u < x < a \\ 0 & x \leq u \end{cases} \tag{2}$$

$$\mu_U = \begin{cases} 0 & x \geq a \\ \dfrac{x-a}{u-a} & u < x < a \\ 1 & x \leq u \end{cases} \tag{3}$$

Where x is the independent variable denoting gray level and a and u are the parameters determining the shape of the above two membership functions. By running an optimization objective function the optimal parameter for a and u are obtained.

In order to partition attended areas and unattended areas they modified Sahoo *et al* [3].

$$\Gamma(a, u) = [H_A(a, u) - H_U(a, u)]^2 \tag{4}$$

Where $H_A(a, u)$ and $H_U(a, u)$ are the prior entropies of fuzzy sets, attended areas and unattended areas, respectively. They are calculated by

$$H_A(a, u) = -\sum_{k=0}^{L-1} \frac{Pr(g_k)}{P(B_A)} \ln \frac{Pr(g_k)}{P(B_A)} \tag{5}$$

$$H_U(a, u) = -\sum_{k=0}^{L-1} \frac{Pr(g_k)}{P(B_U)} \ln \frac{Pr(g_k)}{P(B_U)} \tag{6}$$

Where $P(B_A) = \sum_{k=0}^{L-1} \mu_A Pr(g_k)$ and $P(B_U) = \sum_{k=0}^{L-1} \mu_U Pr(g_k)$ calculated this way. The global minima of $\Gamma(a, u)$ indicates the optimal fuzzy partition, i.e., optimal parameters a and u are found. This criterion can be expressed as:

$$(a, u) = argmin(\Gamma(a, u)) \tag{7}$$

With the optimal a and u, *fuzzy growing* process is performed on the saliency map. There is a number of seed are needed to be declared. The criteria for seed selection are: 1) the seeds must have maximum local contrast; and 2) the seeds should belong to the attended areas.

$$C_{i,j} \leq C_{seed} \text{ and } C_{i,j} > s \tag{8}$$

Where $s = (a+u)/2$. The probabilities of the gray-level s belonging to attended areas and unattended areas are all 0.5, see (4) and (5). Then, the new group members are used as seeds to do iterative growing. Figure 1(d) illustrates fuzzy 2-partition of saliency map. Figure 1(e) shows the result of fuzzy growing , two main objects in scene being accurately detected and segmented.

3 Evaluations

Table 1: Attended view evaluation

	Good	Accept	Failed
Corel Draw	0.85	0.14	0.01
F. Photo	0.86	0.13	0.01
Portrait	0.82	0.16	0.02
Avg.	0.84	0.14	0.02

Table 2: Attended areas evaluation

	Good	Accept	Failed
Corel Draw	0.68	0.27	0.05
F. Photo	0.60	0.31	0.09
Portrait	0.74	0.22	0.05
Avg.	0.67	0.27	0.06

Table 3: Attended points evaluation

	Good	Accept	Failed
Corel Draw	0.56	0.33	0.12
F. Photo	0.44	0.41	0.15
Portrait	0.40	0.39	0.21
Avg.	0.47	0.37	0.16

References

[1] G. J. Klir and B. Yuan, *Fuzzy Sets and Fuzzy Logic: Theory and Applications*. USA: Prentice-Hall, Inc., 1994.

[2] L. A. Zadeh, "Probability measures of fuzzy events," *Journal of mathematical analysis and applications*, vol. 23, no. 2, pp. 421–427, 1968.

[3] P. K. Sahoo, D. W. Slaaf, and T. A. Albert, "Threshold selection using a minimal histogram entropy difference," *Optical Engineering*, vol. 36, no. 7, pp. 1976–1981, 1997.