퍼지 논리 기반 HAUSDORFF 거리를 이용한 물체 인식

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Comparing object images using fuzzy-logic induced Hausdorff Distance

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요 약

본 논문에서는 쿼리 영상에 대하여 가장 정확하게 정합되는 영상을 찾기 위한 새로운 이진 영상 정합 방법인 퍼지 기반 하우스도르프 방법을 제안한다. 먼저 하우스도르프 거리를 이용하여 최소 거리 분포를 얻은 후 반경에 해당하는 집합의 개수를 이용하여 정규화하여 소속함수로 표현한다. 제안한 방법에서는 소속함수로 정의된 거리 분포에 대하여 퍼지 추론과정을 도입하여 최종적인 정합 후보를 구하게 된다. 제안된 방법을 실제 잡음이 부가된 얼굴 영상과 문자 인식에 적용하여 그 성능을 검증하였다.

Abstract

In this paper, we propose the new binary image matching algorithm called the Fuzzy logic induced Hausdorff Distance(FHD) for finding the maximally matched image with the query image. The membership histogram is obtained by normalizing the cardinality of the subset with the corresponding radius after obtaining the distribution of the minimum distance computed by the Hausdroff distance between two binary images. In the proposed algorithm, The fuzzy influence method, Center of Gravity(COG) is applied to calculate the best matching candidate in the membership function described above. The proposed algorithm shows the excellent results for the face image recognition when the noise is added to the query image as well as for the character recognition.

Keywords: Hausdorff distance, Image matching, COA, Fuzzy inference method

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1. Introduction

Proposed method is intended to present more powerful methodology to compute the optimal similarity between two images. The main idea of the our method is based on the distribution of the minimum distance computed by using Hausdorff distance between two images and combines spatial adjacency between objects and membership functions. Generally, in the recognition stage, the edges of an image play an important role in both accuracy and time-requirement. Numerous methods have been proposed to compare these edge images, such as *OCR* and the face recognition problem, using Hausdorff distance [1,7]. But the previous works suffer from the lack of robustness and hard to use in the real applications. We propose here a new similarity measure, called *Fuzzy logic induced Hausdorff Distance(FHD)* which has more robust capability. We use the fuzzy domain knowledge to handle these problems.

The remainder of this paper is organized as follows; In section 2, we briefly review the theoretical reasoning for the binary image comparison and assess the conventional methods and we introduce a new measure of object similarity, called *Fuzzy logic induced Hausdorff Distance (FHD)*. In the final section of this paper, we present the results of the testing of FHD and show the robustness.

2. Hausdorff Distance for Image Comparison

2.1 Classical Hausdorff Distance

The application of Hausdorff distance to the comparison of the binary images has been presented in [7]. We first investigate the formal description of Hausdorff distance. Given two finite point sets X, and Y, the classical Hausdorff distance is defined as

$$H(X, Y)=\max(h(X, Y), h(Y, X)) \quad (1\text{-}1)$$

$$h(X, Y)=\max_{x\in X}(D(x, y))$$

$$\forall x\in X,\ D(x, Y)=\min_{y\in Y} d(x, y) \quad (1\text{-}2)$$

In the above equations, $d(\cdot)$ is some underlying norm over the point sets X and Y. One can show that $d(\cdot)$ is a true distance and has the properties of the identity, the symmetry and the triangle inequality. $h(X,Y)$, in effect, ranks each point of X based upon its distance to the nearest point in Y and then uses the largest ranked point as the measure of the distance and $h(Y,X)$ is obtained vice versa. In the real applications, to effectively handle the noise contamination or the partial occlusions, one simply has to rank each point of X by its distance to the nearest point in Y and take the k-th quantile value. *Jain et al.* propose improved measure, called the modified Hausdorff distance, which is less sensitive to the noise because of taking the average value instead of the maximum value. *B. Takacs* proposed the doubly modified Hausdroff distance to recognize the face image under the properly normalized and non-rigid transformation being small and localized. Other modification of Hausdorff distance called the Censored Hausdorff distance has been introduced and improved its robustness [4]. They do not consider the closest neighbors of x in Y, only compute $D(x,Y)$ with the $(p+1)$th closest neighbor of x in Y. *J. Paumard* used the rates of the threshold instead of taking the min and max operations which used in the classical Hausdorff distance. Although this measure does not satisfy the property of the metric since the distance can't be nil, it provides slightly better recognition results compared with using just k-th quantile or maximum as a final similarity value. From the theoretical point of view, above modifications just provide the fixed threshold to represent the similarity and we have to manually calculate its similarity according to the quality of images. Thus it couldn't provide the optimal value of similarity, thus, to overcome this intractable problem, we propose the *Fuzzy logic induced Hausdorff Distance* to adaptively compute the similarity between two images.

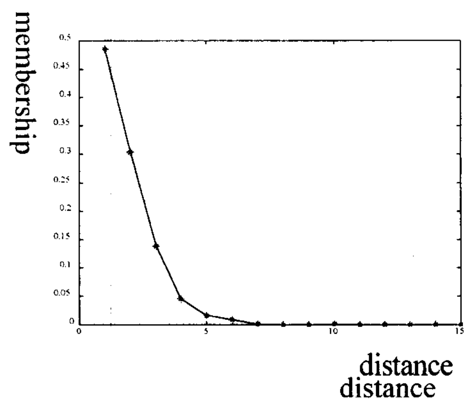
2.2 Proposed Hausdorff Distance

In this section of this paper, we propose the *Fuzzy logic induced Hausdorff Distance* which is based upon the distribution of the minimum distance between two images. Hausdorff distance was originally proposed to find the best correspondence value between two images without the preprocessing stage to find the specific feature points in the given image. To establish more stable Hausdorff distance, our method adaptively selects the best similarity value from the distribution of the distance function instead of selecting the fixed threshold value. Here we describe overall scheme of the proposed method. First, we construct the distance distribution by using the minimum distance using the Eq. (1-2). And then this distribution is normalized using the cardinality of the subset which is specified by the radius of interest. This normalization is simply processed by weighting the crisp distance and represented it as the membership function. In this method $h(\mathbf{X},\mathbf{Y})$ in the Eq. (1-1) is rewritten as follows;

$$G=\{N_{d1}/d_1,\ N_{d2}/d_2,\ldots,\ N_{dn}/d_n\} \quad (2)$$

Where, diR, di $di+1$ and N_{di} is the cardinality of subset specified by the radius R to specify the candidate region for the comparison and this membership function is depicted in the [Fig. 1]

In the intuitive sense, if two images are totally different, the distribution is the unit impulse function, but in the real images, there exists certain



[Fig. 1] The membership histogram of the distribution according to the Hausdorff distance.

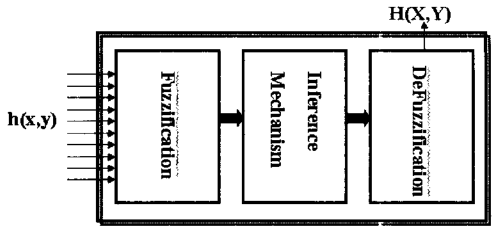
amount of the overlapping region between two images, thus it generally forms like normalized gaussian distribution function. From the fuzzy membership function *G*, we finally have to choose the optimal similarity, to achieve this goal, we compute the defuzzified value from the fuzzy membership function. There exist several defuzzification operations such as *Mean of Inversion(MOI)*, *Center of gravity(COG)* and *Mean of Maximum (MOM)*[10]. Among these, we use *COA* to handle the partial occlusion or noise contamination since it computes the crisp output which is the center of gravity of distribution of the membership function and corresponds to the final value of the agreement between two images, we define *COA* as

$$O=\frac{\sum_{i=1}^{n} G(i)\times d_i}{\sum_{i=1}^{n} G(i)} \qquad (3)$$

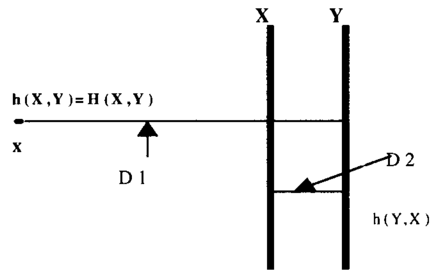
where, *G(i)* is the *i*-th membership value of *G* and *O* is the crisp output obtained from the fuzzy membership function. This defuzzified value(*O*) is adequate to represent the best matching value of two binary image when images to be compared are corrupted with the noise and partially occluded. The overall structure of the *Fuzzy induced Hausdorff distance(FHD)* is presented in the [Fig. 2]

The input variable of the *FHD* is the real distance obtained from the Eq. (1) and the output is optimized the similarity value which is adaptively computed from the distribution of the distance function. Here we present the example of bar recognition the example which is used by Paumard [4].

Intuitively, due to the noise point of *x(dotted)*



〔Fig. 2〕 The overall structure of the Fuzzy logic induced Hausdorff Distance

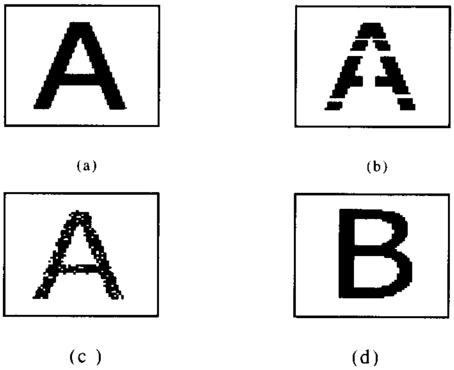


〔Fig. 3〕 Comparison between two bars

in the figure, the conventional Hausdorff distance calculates the final distance between *X* and *Y* as ***D1***, but the proposed method obviously takes the optimal distance as ***D2*** for the final value for the recognition. We verify the robustness of proposed method using the several examples in the next section and ready to present the obtained experimental results.

3. Experimental Results

In order to verify the effectiveness and robustness of the proposed recognition system, we performed the experiments on the *Optical Chara- cter Recognition(OCR)* and the face recognition examples. First we compare the similarity between the character 'A' and its two variations, i.e., the



[Fig. 4] (a) The reference image with letter A, (b) the image which is partially occluded, (c) the image which the 30% noise is added to the letter and (d) the image with the letter B.

occluded image and the contaminated with uniform noise (added 30%), to verify the robustness of the proposed method as shown in [Fig 4] The size of images in the figure is 60×60 and radius R=5 is used for the target region for the comparison.

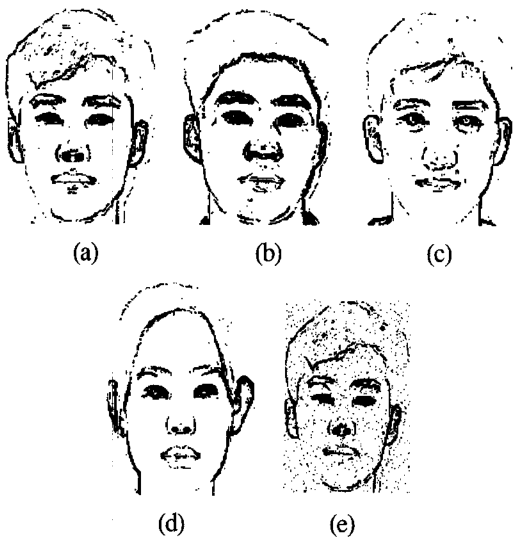
In the *OCR*, there often exists certain environment in which it is difficult to find the useful features to discern each character owing to the noise, but proposed method effectively handle this problem as shown in Fig. 4 (b) and (c). The test result is shown in [Table 1]

From the pattern discrimination point of view, we can easily know that the intra-class distance is

[Table 1] This table shows the comparison results for the character recognition problem with the images in Fig. 4.

	h(x,y)	h(y,x)	H(x,y)
Image (b)	0.04	0.03	0.04
Image (c)	0.03	0.01	0.03
Image (d)	0.40	0.60	0.60

the 10 times larger than the inter-class distance. Thus despite information loss in (b) and (c), we can easily recognize these images as same class as (a) and reject (d) for other class. To compare with conventional Hausdorff distance, we present the face recognition examples. In the [Fig 5] there are several face images obtained from the frontal view of each individual. The size of face image is 9065, and 8-bit gray level image. To more fast and stable computation, we use edge maps of each image taking sobel operation and local area thresholding is used for binarization. The value of radius R is 5 in this experiments. In the [Fig. 5], image (a) reference image and (e) is noised added models of the image (a), (b), (c), (d) are different individual of (a).



[Fig. 5] This figures is the binary images used for the face recognition. (a) is the reference image. (b), (c), and (d) is the images of the different person form the person in image (a) and (e) is the image which the 30% noise added to the image (a).

〔Table 2〕 The proposed method vs the classical Hausdorff method

	Proposed method	*Classical Hausdorff method*
Image (b)	0.27	0.8
Image (c)	0.25	0.9
Image (d)	0.30	0.9
Image (e)	0.02	0.8

The test result is shown in the Table 2 to compare the proposed method and the classical Hausdorff method. From the results, we can easily infer that the proposed method (*FHD*) has a strong capability to identify the same face and rejects different ones. But classical Hausdorff method couldn't handle this situation from the result presented in the table because there's some confusions that inter distance and intra distance are almost similar.

The time requirement and complexity of proposed method is not a big concern because we use the edge map of binary image and simple structure of reasoning procedure in the final stage of the FHD.

4. Conclusions and Future works

The enhanced performance of the proposed method dues to the inference mechanism using fuzzy defuzzification instead of the max operation used in the classical method. From the experimental results, *FHD* appears to be one of the possibilities to compute similarity measure between two binary objects. Since this method is based upon the intensity distribution of the target images, we need not to use the feature extraction tasks. This greatly lessens the operation of preprocessing

The proposed algorithm shows the excellent results for the face image recognition when the noise is added to the query image as well as for the character recognition. In the future, we should find out whether this method takes effect in detection of certain object in the scene image.

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6. References

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