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Image medium similarity measure and its applications

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ABSTRACT

Similarity measure plays an important role in many image processing fields. This paper introduces the medium mathematic systems, and establishes a novel image medium similarity measure between two pixels and that of between two image sets based on the measure of medium truth degree. Moreover, an image edge detection algorithm, an image matching algorithm and an image medium fidelity measure method governed by the medium similarity measure are discussed in this paper. Experimental results show that the proposed similarity measure is effective.

1. Introduction

Similarity measure, which is usually defined as a certain cost function or distance function, plays an important role in many image processing fields, such as image matching, image edge detection and image evaluation, etc. Correction function, covariance function, Euclidean distance, Mahalanobis distance, Chebychev distance, Minkovsky distance, Hausdorff distance are the common similarity measures used in image processing. Gray, color, texture, edge, shape and spatial relationship are the features commonly used to measure the similarity degree of images. Gray and color can be simply and directly obtained from the images, and the similarity measure based on these two features can make the most use of the information of images which also leads to high computational-complexity. Similarity measure based on texture, edge, shape, content, spatial relationship and other features has lower computational-complexity, but the accuracy depends on the extraction of the features. As a result, most of the research on similarity measure of image focuses on distance definition and feature extraction. Others studies the solution methods of similarity measure, such as absolute balance searching (ABS), sequential similarity detection algorithm (SSDA), hierarchical searching, Alpha–Beta searching and so on. As traditional similarity measures are well-established and easy for computation, they are used widely in image processing. Nevertheless, to some complicatedly and vague images, they cannot get the satisfied result. As a result, some new mathematical and computational methods such as neural network [1,2], wavelet transformation [3,4], rough sets [5] and other mathematical and computational methods [6,7] are introduced into similarity measure. Nevertheless, due to their complexities and poor portabilities, effective similarity measure methods are yet to be seen.

Because the complexity of image information and the strong relations among image pixels are evident, problems with uncertainty and inaccuracy will appear in the image processing. As a result, some scholars introduced fuzzy mathematics into image similarity measure [8–10], which have yielded excellent results. But the result of fuzzy methods is highly dependent on the membership function which is decided by subjective experience.

The medium mathematics system is another mathematical tool which deals with fuzzy and uncertain problem. This paper introduces the medium mathematics system into image similarity measure and establishes a new medium similarity measure that is governed by the measure of medium truth degree. Some properties of the proposed similarity measure are presented. Finally we present some applications of the medium similarity measure in image processing. The experimental results in these algorithms show that the proposed measure is effective.

2. Image medium similarity measure

Medium principle was established by Zhu and Xiao in 1980s who devised medium logic tools to build the medium mathematics system [11].

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In medium mathematics system [11], predicate is represented by P, any variable is denoted as x, with x completely possessing quality P being described as $P(x)$. The symbol "╕"stands for inverse opposite negative and it is termed as "opposite to". The inverse opposite of predication is denoted as ╕P. Then the concept of a pair of inverse opposite is represented by both P and ╕P. Symbol "$\sim$" denotes fuzzy negative which reflects the medium state of "either-or" or "both this-and that" in opposite transition process. The truth degree of x related to P or ╕P can be scaled by distance ratio function $h(x)$ [12,13].

2.1. Medium similarity measure of two pixels

Similarity degree between two pixels can be scaled by the difference or the radio of the gray level between pixels. This paper mainly discusses a new similarity measure based on the measure of medium truth degree [12,13].

Given: There are two pixels $x(i,j)$ and $f(i,j)$ in grey images whose range of gray level is 0–255. First, correspond the gray level of pixel to a number axis. Second, predicate $S(x(i,j),f(i,j))$ represents that $x(i,j)$ is similar to $f(i,j)$, ╕$S(x(i,j),f(i,j))$ represents that $x(i,j)$ is different from $f(i,j)$, and $\sim S(x(i,j),f(i,j))$ transition, as shown in Fig. 1. According to the measure of medium truth degree [12,13], the similarity degree between $x(i,j)$ and $f(i,j)$ can be calculated by the distance ratio function $hh(f(i,j),x(i,j))$ [12].

Definition 1. For pixels $x(i,j)$ and $f(i,j)$, we define

$$hh(f(i,j),x(i,j)) = \frac{1}{2}[h(f(i,j),x(i,j)) + h(x(i,j),f(i,j))] \tag{1}$$

where

$$h(f(i,j),x(i,j)) = \begin{cases} \frac{d(f(i,j),-1)}{d(x(i,j),-1)} & f(i,j) < x(i,j) \\ 1 & f(i,j) = x(i,j) \\ \frac{d(f(i,j),256)}{d(x(i,j),256)} & f(i,j) > x(i,j) \end{cases} \tag{2}$$

as the medium similarity measure of two pixels, where $d(a,b)$ is the Euclidean distance between a and b. Under the one-dimensional circumstance, $d(a,b)=|a-b|$. The larger the value is, and the higher the similarity degree between $x(i,j)$ and $f(i,j)$ becomes. The smaller the value is, and the lower the similarity degree between $x(i,j)$ and $f(i,j)$ becomes.

2.2. Medium similarity measure of two image sets

Definition 2. For an image $X=[x(i,j)]_{M\times N}$ of $M\times N$ pixels and an image $F=[f(i,j)]_{M\times N}$ of $M\times N$ pixels, define

$$s = \frac{1}{M\times N}\sum_{i=1}^{M}\sum_{j=1}^{N} hh(f(i,j),x(i,j)) \tag{3}$$

as the medium similarity measure of two image sets, where $hh(f(i,j),x(i,j))$ is the distance ratio function defined in (1).

The value of the distance ratio function $hh(f(i,j),x(i,j))$ reflects the similarity degree between the two pixels respectively located at corresponding position in the images X and F. So s can be used to measure the similarity degree of the images X and F. The larger the value of s is, and the higher similarity degree of the images X and F becomes.

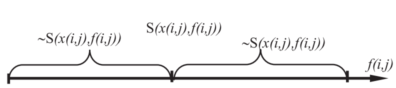

Fig. 1. Relation between the gray level of pixel $x(i,j)$, $f(i,j)$.

2.3. Properties of the medium similarity measure

Property 1. $hh(f(i,j),x(i,j)) \in (0,1]$

Proof

In gray images, $0 \le x(i,j) \le 255, 0 \le f(i,j) \le 255$.

According to expression (2), there are three cases as follows:

(1) When $f(i,j) < x(i,j)$,

$$\begin{aligned} h(f(i,j),x(i,j)) &= d(f(i,j),-1)/(d(x(i,j),-1) \\ &= |f(i,j)+1|/|x(i,j)+1| \\ &= (f(i,j)+1)/(x(i,j)+1) \end{aligned}$$

Since $f(i,j) < x(i,j), f_{\min}(i,j) = 0, 0 < x(i,j) \le 255$,

Then $0 < h(f(i,j),x(i,j)) < 1$

(2) When $f(i,j) = x(i,j), h(f(i,j),x(i,j)) = 1$

(3) When $f(i,j) > x(i,j)$,

$$\begin{aligned} h(f(i,j),x(i,j)) &= d(f(i,j),256)/(d(x(i,j),256) \\ &= |f(i,j)-256|/|x(i,j)-256| \\ &= (256-f(i,j))/(256-x(i,j)) \end{aligned}$$

Since $f(i,j) > x(i,j), f_{\max}(i,j) = 255, 0 \le x(i,j) < 255$,

Then $0 < h(f(i,j),x(i,j)) < 1$

Conclusion: According case (1)–(3), we can get. $0 < h(f(i,j),x(i,j)) \le 1$

Similarly, we can prove that $0 < h(x(i,j),f(i,j)) \le 1$

Then $0 < [h(x(i,j),f(i,j)) + h(f(i,j),x(i,j))]/2 \le 1$

That is $hh(f(i,j),x(i,j)) \in (0,1]$

Property 2. $hh(f(i,j),x(i,j)) = 1$, only if $f(i,j) = x(i,j)$

Property 3. $hh(f(i,j),x(i,j)) = hh(x(i,j),f(i,j))$

According to Definition 1, we can easily get Properties 2 and 3.

3. Applications of the image medium similarity measure

3.1. Image medium edge detection algorithm

Edge is digitally presented as a set of pixels whose neighbors are located at an orthogonal step or roof transition in gray level. Paggio stated [14] 'Edge may correspond to object boundaries or not, but it owns a great feature; it provides us reduced information required to process and preserves useful structural information about the object boundaries as well'. He defined edge detection as the operation of measuring, detecting and locating changes in gray level of the image.

In this paper, a novel image edge detection algorithm based on the medium mathematic systems is proposed. It uses the medium similarity measure to inspect the degree of similarity between a pixel and its neighbors. Then it makes use of two thresholds and applies the method of restraining the non-maxim value in domain for edge determination.

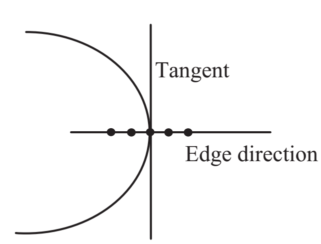

Fig. 2. Edge direction.