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Weighted-Hausdorff distance using gradient orientation information for visible and infrared image registration

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ABSTRACT

Hausdorff distance measures the distance between two sets in a metric space. The conventional Hausdorff distance is calculated by using only individual point and each point is equally weighted. The gradient orientation of each point is ignored, which limits the performance of Hausdorff distance in the image registration. Moreover, different points are of different importance and thus should be assigned different weights. This paper proposes a method to register visible and infrared images with modified Hausdorff distance measure, which uses both the position and the gradient orientation of each point. Each point is differently weighted by corner response value of each point. The experimental results demonstrate a better performance of the proposed method for registration of multi-sensor images in comparison with existing methods, which are based on conventional Hausdorff distance by the root of the mean square error (*RMSE*).

1. Introduction

Recent advances in imaging, networking, data processing and storage technology have resulted in an explosion in the use of multi-sensor images, such as visible (VIS) and infrared (IR) images [1]. Due to the different physical of principles for imaging, VIS and IR images contain different characteristics. VIS image has a higher clarity than IR image, while IR image, captured in poor lighting, smoke, and fog, can supply the information that the VIS image cannot provide [2]. For a complexed environment, fusion of infrared and visible images may lead to a better analyzing performance [3]. The one of the key technologies of image fusion is image registration.

Image registration methods can be classified into pixel-based methods and feature-based methods [1]. Pixel-based methods rely on cross-correlation and the mutual information (MI) [2]. In the cross-correlation registration methods [4], the computational complexity is high. Mutual information (MI) [5,6] needs to consider the correspondence of the gray information between the two images. However, the gray mapping relationships between the multi-sensor images are often locally different. Thus, this leads to the poor-performance of MI based methods.

However, the feature-based methods only consider some pixels, which have some obvious feature, i.e. feature points. The feature points, like edge point, SIFT, SURF, and corner, are widely used to register images. The methods based SIFT and SURF need to develop corresponding relationships between points by Euclidean distance [7–9], which does not incorporate image spatial information and is not enough discriminated in case of image deformation or noise [10]. To overcome this shortcoming, we make our centers on the Hausdorff distance (HD), which computes the similarity degree between two point sets rather than develops the corresponding relationship between points [11,12].

There have been lots of HD based methods proposed for image registration. Huttenlocher et al. proposed a partial Hausdorff distance (P-HD) [13]. It settles well in the cases, in which the image contains objects partly hidden from view. This method has a good result in estimating the similarity between two images. Dubuission et al. proposed a modified Hausdorff distance (M-HD) [14], which is robust to outlier points that might result from segmentation errors. Sim et al. proposed a Hausdorff distance based on maximum likelihood estimation (ML-HD) [15], and improved the robustness of matching. Kwon et al. presented a method named accurate M-Hausdorff distance (AM-HD) [16], to discriminate against the outliers precisely. However, these HD based methods have three main drawbacks: (1) requiring the large amount of calculation; (2) ignoring gradient orientation (GO) information of each (edge) point; (3) neglecting different importance of each (edge) point.

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By improving the three drawbacks, we propose a new method, which is called the weighted-Hausdorff distance using gradient orientation (WGO-HD). In order to reduce the amount of calculation, we use Harris corner rather than edge point. The number of corners is smaller than the number of edge points in an image, since corners are only a tiny part of edge points. This leads to a smaller amount of calculation. For exploiting gradient orientation, we divide corners into k corner subsets according to gradient orientation after extracting corners from IR image and VIS image. Then, we compute the Hausdorff distances between two corner subsets, in which gradient orientations of all corners are in the same gradient subinterval. In this paper, we call the Hausdorff distance between two corner subsets as subset Hausdorff distances. The WGO-HD is computed by the sum of subset Hausdorff distances. By this strategy, gradient orientation can be integrated into the HD. Since different corners have different importance to the WGO-HD, we assign different weights to different corners according to the response values of corners. Also, since different corner subsets have different importance to WGO-HD, we assign different weights to different corner subsets according to the number of "useful" corners, which will be defined in the Section 2.

The rest of this paper is organized as follows. In Section 2, we first present the overview of the proposed method. In Section 2.1, we describe the method of the corner extraction. In Section 2.2, the corner classification is described. In Section 2.3, we mainly present how to compute the WGO-HD. In Section 3, we describe the experimental results. Conclusions are given in Section 4.

2. Overview of the proposed algorithm

The proposed method consists of three modules: Harris corner extraction, corner set classification, and WGO-HD computation. In the first module, the Harris corners are extracted by an improved Harris corner detector. In the second module, corner set is classified into k corner subsets according to gradient orientation of each corner. In the third module, the weighted-Hausdorff distance using gradient orientation is computed by the sum of subset Hausdorff distances. The framework of the proposed method is shown in Fig. 1.

In this paper, corners are extracted by the Harris corner detector. However, the corners may be clustered in some regions, if corners are extracted by the traditional Harris corner detector. And these clusters may increase the match error [17]. To avoid the problem, we extract corner set by an improved Harris corner detector [18], which will be detailed in Section 3.

To benefit from gradient orientation, in this paper gradient orientation is integrated into the traditional HD. To do that, corner set, which includes all corners, is divided into subsets according to gradient orientation. The second module, i.e. corner set classification, is carried out by three steps as shown in Fig. 1. First, we compute the gradient orientation of each corner. Next, we divide the gradient orientation interval into k subintervals. Finally, according to the different subintervals, which the gradient orientations of different corners are in, we divide the corner set into k corner subsets. In other words, each subset consists of the corners, whose gradient orientations are in the same one subinterval. Herein, in this paper we define a new term, i.e. corner subset pair, which contains two corner subsets, the one from VIS image and the other from IR image. In the two corner subsets, the gradient orientations of corners are in the same gradient orientation subinterval. To make our explanation simple, Fig. 2 describes the definition of corner subset pair. In Fig. 2, black dots refer to the extracted Harris corners. The big circle denotes the gradient orientation interval $[-\pi, \pi]$, which is divided into k subintervals.

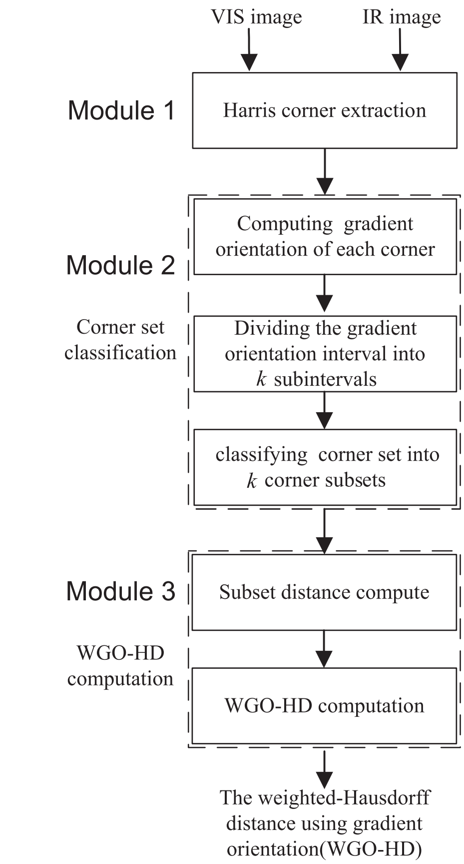

Fig. 1. The framework of the proposed method.

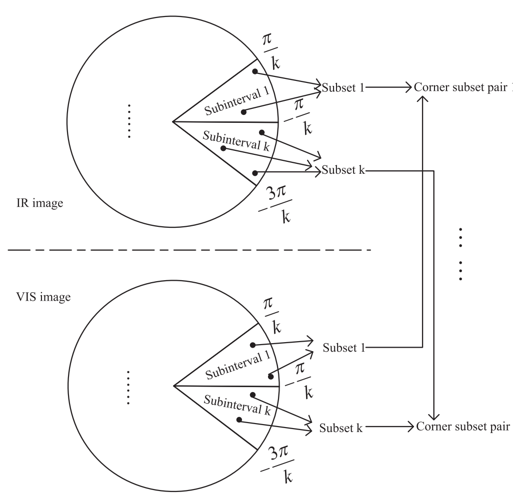

Fig. 2. The definition of the corner subset pair.

The module of WGO-HD computation is carried out by two steps: computing the subset Hausdorff distances and computing the weighted-Hausdorff distance using gradient orientation (WGO-HD). Since each subset and each corner in the subset has different contributions to image registration, in this module we introduce two weights, i.e. corner weight and corner subset weight, into WGO-HD. After classifying corners into corner sets, the subset Hausdorff distances are computed. Then, we compute the WGO-HD by the sum of the subset Hausdorff distances. The detail produce of the WGO-HD is presented in the Section 5.