A Novel Approach to Corner Matching using Fuzzy Similarity Measure

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Abstract

Corner matching in sequence images serves as a building block of several important applications of stereo vision. In this paper, we establish the corner correspondence between two images in the presence of intensity variations and motion blur by using a fuzzy theory based similarity measure. The matching approach proposed by us needs to extract set of corner points as candidates from both the frames. Experiments conducted with the help of various sequences of images prove the superiority of our algorithm over standard cross correlation and sum of absolute difference under non-ideal conditions.

1 Introduction

Feature matching from a pair of views imaging the same scene is a key component in many computer vision applications including discrete motion estimation, object recognition and localization, image registration etc. and has been studied extensively for decades. Corner points are considered as the good candidates for interesting features in the digital images. When feature points are detected for the purpose of matching, the key property of the detector is its stability: in different views of the same scene, the detector should extract the same points, despite the variations due to a change in perspective or lighting conditions. We considered corners as the local features in this paper. Corners in an image are those points of localized image structure formed at the boundaries of different brightness image regions. The matching process is an ill-posed problem. There will inevitably be some corners which cannot be matched, and there are also likely to be several candidate matches for some corners which are very similar. All of these problems lead to outliers in the set of matches.

A number of approaches have been proposed to address the theoretical and applied issues of correspondence problem, of which two approaches are more popular. One is based on some similarity / dissimilarity measures, some of which are discussed in section 2, and the other uses the feature point properties. One possible strategy is to require that the corners in a pair have similar shapes. Some matching approaches proposed must extract independently two sets of candidates from two consecutive frames, respectively. Obviously, the total time for matching process includes the cost of extracting two sets of candidates. In the matching process, the cross correlation algorithms are applied to calculate the similarity of two small regions, one of which is the template window surrounding the grey value corner in frame 1 and the other is searched in frame 2 for obtaining the maximum of similarity.

In this paper, we have used a new approach to corner matching using a fuzzy similarity measure. Since we have used a similarity measure based on fuzzy set theory to match corners between two sequence images, the algorithm proposed by us is able to match corners in the presence of intensity variations, varying illumination and noise in them.

Most of the approaches in the literature for solving the correspondence problem assume that small camera displacement and small change in camera orientation between images. Hence, pixels lying within small rectangular image windows (templates) centred on corresponding corners should have similar intensities and their disparities could be well approximated by the same 2D transformation. Considering two sets of corners detected in the images to be matched, the affinity of potential corner matches that satisfy a maximum disparity constraint is quantified with the aid of local, window-based similarity measures. Typically, the latter include metrics such as standard intensity cross-correlation, normalized (i.e. zero mean) cross-correlation and sum of absolute and squared intensity differences. Following the evaluation of the similarities corresponding to potential pair matches, actual matches are determined using various schemes that involve more global criteria. Horard and Skordas [1] identified maximal cliques in a rela-

The remainder of this paper is structured as follows. Section 2 deals with different similarity measures that are generally used for the correspondence problem. We demonstrate our new Fuzzy set theoretic approach to corner matching in section 3. In section 4, the superiority of our approach over the correlation measures discussed in section 2 is illustrated with the help of experimental results. Finally, we conclude in section 5.

2 Similarity/Dissimilarity Measures

The common approach for corner matching is to take a small region of pixels (referred to as a correlation window) around the detected corner and compare it with a similar region around each of the candidate corners in the other image. Note that all points in the region in the second image are candidate corners. Each comparison yields a score, a measure of similarity/dissimilarity. The match is assigned to the corner with the highest similarity/lowest dissimilarity score. Matches are found by evaluating the similarity between image regions and selecting as a match that pair of regions with the closest similarity. There are many possible measures of similarity, of which a few of the most popular are considered here.

1. Standard Cross Correlation Coefficient (SCCC)

\[
SCCC = \frac{\sum I_1^1 I_2^1}{\sqrt{\sum I_1^2 \sum I_2^2}}
\]  

2. Zero-Mean Cross Correlation Coefficient (ZMCCC)

\[
ZMCCC = \frac{\sum (I_1^1 - \bar{I}_1)(I_2^2 - \bar{I}_2)}{\sqrt{\sum (I_1^1 - \bar{I}_1)^2 \sum (I_2^2 - \bar{I}_2)^2}}
\]

3. Sum of Absolute Difference (SAD)

\[
SAD = \sum |I_1^1 - I_2^2|
\]

4. Sum of Squared Difference (SSD)

\[
SSD = \sum (I_1^1 - I_2^2)^2
\]

where \(I_1^1\) and \(I_2^2\) denote individual pixels from the two images \(I_1\) and \(I_2\) respectively. The correlation scores SCCC and ZMCCC are to be maximized for the best match; on the other hand, SAD and SSD must be minimized.

3 Our Approach

We have followed the first approach based on the measures of similarity/dissimilarity, but in different way. The similarity/dissimilarity measures (1 – 4) discussed in section 2 depend upon the absolute value of all intensities in windows. Therefore, they cannot properly establish the correspondence between the corners in the presence intensity variations, varying illumination as well as noise or imprecision in the images. The nature of this ambiguity (fuzziness) in the image arises from the uncertainty present. For an ill-defined image region, it is always appropriate to avoid crisp similarity measure. We have used a fuzzy similarity measure to establish corner correspondence in such regions of stereo images. In this paper, we used a similarity measure MTI (Modified Tversky’s Index) based on Tversky’s model [14], a variant of the measure a generalized Tversky’s index, that compares the saliency of the common features to the saliency of distinctive features proposed by Tolias et al. [15] as
where $\mu(A)$ and $\mu(B)$ are obtained by fuzzifying the matrices $A$ and $B$ using the Gaussian membership function with mean and variance equal to the mean and variance of intensity values of the respective matrices of size $N \times N$ respectively. The measure given above provides a set theoretic index for similarity assessment based on human perception. The higher value of the measure $MTI_{AB}$ indicates the better similarity between the sets $A$ and $B$.

### 3.1 Proposed Algorithm

The algorithm discussed below establishes the corner correspondence in the presence of intensity variations due to different camera parameters and noise in image sequence using similarity measure of fuzzy data. The steps of the algorithm are described below.

1. Corners are extracted from both the left and right images using any standard corner detector.

2. The matching is restricted to $(x', y')$ where $x - 5 \leq x' \leq x + 5, y - 5 \leq y' \leq y + 5$, where $(x, y)$ are the coordinates of the corner in the left image. $(x', y')$ are the coordinates of the corner in the right image.

3. Both left and right images are fuzzified using Gaussian membership function.

4. For each corner $(x, y)$ in the left image, repeat the step 5 to 7.

5. Consider an 11-by-11 window around the point with coordinates $(x, y)$ in the right image and the existence of corners in that window is examined.

6. If one or more corners exist within that window, then a stationary window of size $N \times N$, around the corner $(x, y)$ in the left image and around the corners $(x', y')$ within the window in the right image are defined. $A$ and $B$ are the matrices of size $N \times N$ with intensity values around $(x, y)$ and $(x', y')$ respectively. Corners are the central pixels within the windows.

7. For each window $A$ in the left image, the best possible matched window $B$ in the right image is obtained using the similarity measure given in (5) and the central points in each of these two windows are considered to be the candidates for the matched corners.

### 4 Experimental Results

To demonstrate the efficacy of our fuzzy approach, experiments are conducted on the set of three real sequence images such as Building (Figure 1(a)), Road scene (Figure 1(b)) and one indoor scene (Figure 1(c)). In each of the images of Figure 1, the brightness of the images is artificially reduced, motion blur (horizontal and vertical) is added and Gaussian noise is introduced. Improvement of our algorithm over standard similarity measures is shown in Figure 2, where along the horizontal axis we plot different image types and along the vertical axis we plot the percentage of corners matched between different types of images.
5 Conclusion

In this paper, we present a corner matching algorithm based on fuzzy similarity measure. Here we fuzzify the intensity values within the windows of the left and the right images using Gaussian membership function with the mean and the standard deviation of the intensity data of the respective windows to eliminate the effect of intensity variations between windows. The algorithm is successful to match corners between two sequence images, even in the presence of intensity variation in corresponding windows as well as noise.

References


