Computing Correspondence Based on Regions and Invariants without Feature Extraction and Segmentation *

Chi-Yin Lee , David B. Cooper, Daniel Keren
Laboratory for Engineering Man/Machine Systems
Division of Engineering, Brown University
Providence, RI 02912

Abstract

The problem addressed in this paper is matching corresponding regions in two images, even when the image intensity may be smoothly varying without distinctive edges. Corresponding small regions are assumed to be related by affine transformations. The matching is done by using a new class of low computational cost affine invariants. This approach also computes the affine transformation and is ideal for applications to 3D motion estimation and 3D surface reconstruction, image alignment, etc.. No feature extraction, segmentation or epipolar constraint is required. The very important advantage of our approach over area matching is that it handles large baselines, i.e., distance between camera positions, where the differences in orientation and linear distortion of two areas being compared is large.

1 Introduction and Problem Formulation

Common approaches to the correspondence problem involve extracting features such as points, lines and contours in the images and then establishing their correspondences between images. Both the process of feature extraction and of feature matching are often computationally expensive and noise sensitive. Besides, many methods use the epipolar constraint which does not hold when the relative positions of the camera is not known.

Two images, image1 and image2, of a scene are taken by a moving camera. Image1 is partitioned into small regions, and each region is treated as if it is a view of a 3D patch that can be well approximated by a planar patch. Each 3D patch is small compared to the patch-to-camera distance. Then the weak perspective model applies for the projection of the 3D surface into image planes, and corresponding points in a pair of images of a 3D planar surface patch are related by an affine transformation.

In this paper, we address the following two problems,

1. Given a pair of images and any region in the first image, establish its match in the second image.
2. Having found the matched regions between images, recover the associated affine transformations.

The primary contributions of this paper are introduction of a new class of easy computed affine moment invariants that are functions of the moments of both the image intensity function and of point locations in a region, and a low computational cost algorithm for matching small corresponding regions in a pair of images and recovering the associated affine transformations through the use of these affine moment invariants. The algorithm does not use the epipolar constraint. The region to be matched can be at any arbitrary position. No feature or segmentation is needed.

2 Recovering the apparent motion

The property of affine apparent motion of a region between two images, explained in section 1, enables us to use a powerful tool - ***affine invariants***. Affine invariants are functions of geometric structure which remain unchanged under affine transformation. In the following, we briefly describe the idea of 2^+D data, 2^+D affine invariants, algorithms to find 2D region correspondence between two images and to recover the associated affine transformation parameters using the invariants.

2.1 2^+D Data

Regions g and g', the projections into camera image planes 1 and 2, respectively, of the 3D planar region G are related by an affine transformation. Let (u_i, v_i), (u_i', v_i') be the i^{th} matched points pair in g and g', respectively. Then

$$\begin{pmatrix} u_i \\ v_i \end{pmatrix} = \begin{pmatrix} h_1 & h_2 \\ h_3 & h_4 \end{pmatrix} \begin{pmatrix} u_i' \\ v_i' \end{pmatrix} + \begin{pmatrix} h_5 \\ h_6 \end{pmatrix} \qquad (2.1.1)$$

Let the centers of g and g' be (m_x, m_y) and (m_x', m_y'), respectively, leading to

$$\begin{pmatrix} u_i - m_x \\ v_i - m_y \end{pmatrix} = \begin{pmatrix} h_1 & h_2 \\ h_3 & h_4 \end{pmatrix} \begin{pmatrix} u_i' - m_x' \\ v_i' - m_y' \end{pmatrix} \qquad (2.1.2)$$

Assume G is a Lambertian surface. Then, (u_i, v_i) and (u_i', v_i') appear with the intensity, say I_i, in both frame 1 and frame 2. Multiplying both sides of (2.1.2) by I_i, we get

$$\begin{pmatrix} (u_i - m_x)I_i \\ (v_i - m_y)I_i \end{pmatrix} = \begin{pmatrix} h_1 & h_2 \\ h_3 & h_4 \end{pmatrix} \begin{pmatrix} (u_i' - m_x')I_i \\ (v_i' - m_y')I_i \end{pmatrix} \qquad (2.1.3)$$

For convenience, denote the above equation as,

$$\begin{pmatrix} \alpha_{i1} \\ \alpha_{i2} \end{pmatrix} = \begin{pmatrix} h_1 & h_2 \\ h_3 & h_4 \end{pmatrix} \begin{pmatrix} \alpha_{i1}' \\ \alpha_{i2} \end{pmatrix} \qquad (2.1.4)$$

We construct two new data sets, $\{(\alpha_{i1}, \alpha_{i2})\}$ for all points in g and $\{(\alpha_{i1}', \alpha_{i2}')\}$ for all points in g'. These data sets are related by parameters h_1, h_2, h_3, h_4 and contain information about not only the locations of the image points but also about their intensities. The more interesting thing is that even with the additional intensity information, the dimension of the data set remains two and not three. So, we call them 2^+D *data sets*.

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2.2 2^+D Affine Moment Invariants

In [3], a new framework is introduced for generating affine moment invariants. The particular moment invariants developed are the eigen-values of certain matrices, whose coefficients are algebraic functions of the locations of 2D data. The computational cost of computing these invariants is low. As mentioned in the previous section, the dimension of the 2^+D data is two. Thus, we compute the 2D moment invariants directly using the 2^+D data and we called them 2^+D moment invariants. The elements of the matrices involved are functions of moments such as $\frac{1}{n}\sum_{i=1}^{n}(\alpha_{i1}-\bar{\alpha}_{i1})^j(\alpha_{i2}-\bar{\alpha}_{i2})^k$ where n is the number of image data points in region g. In our experiment, five moment invariants are used, which are the eigen-values of a 2x2 and a 3x3 matrix. Thus, little computation is involved in the evaluation of the invariants.

2.3 Region Matching and Recovery of the Affine Parameters

The idea of matching is to first compute the affine invariants for a region in the reference image, then locate the matched region in the second image such that its invariants are closest to those of the reference region. Having found the matched regions pair, the invariants also permit a trivial computation that provides a first estimate of the affine transformation. We then get an improved estimation of this affine transformation. The details of a two stages scheme to perform region matching and to recover the associated affine transformation using 2^+D affine invariants are given in [2].

3 Experiments

3.1 Experiment 1

This experiment simulates a general affine image motion, which includes rotation, translation and scaling. Fig.3.1(a) and Fig.3.1(b) show the reference image and the transformed image, respectively, and their matching results. Table 3.1 lists the mean and the standard deviation of the recovered affine transformation of all the matched region pairs along with the ground truth values , and they are in good argreement.

3.2 Experiment 2

This experiment is based on two images of a scene taken by a moving camera in our laboratory. The scene consists of a bookshelf, a table, chairs, a monitor, etc.. The matching results are shown in Fig.3.2(a) and Fig.3.2(b)

4 Conclusion

This paper presents a low computational cost approach based on moment invariants to solving the correspondence problem between two images. No feature extraction or segmentation is needed. No epipolar constraint or any camera pose information is used. Thus, this algorithm can be applied in solving for 3D surface structure and camera motion from a sequence of images [1]. The approach is well suited to large changes in camera positions from which successive images are taken.

References

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[3] G. Taubin and D.B. Cooper. Object recognition based on moment invariants (or algebraic invariants). *In Geometric Invariance in Computer Vision, Edited by J.Mundy and A.Zisserman, MIT Press,* pages 375–397, 1992.

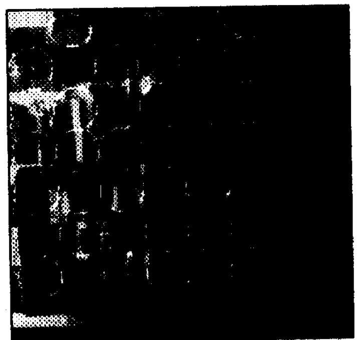

Fig.3.2(b)

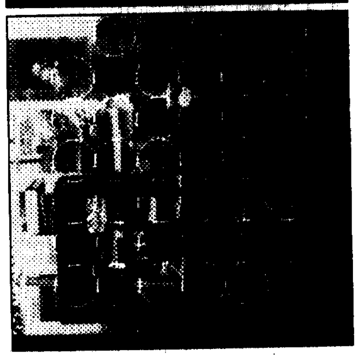

Fig.3.2(a)

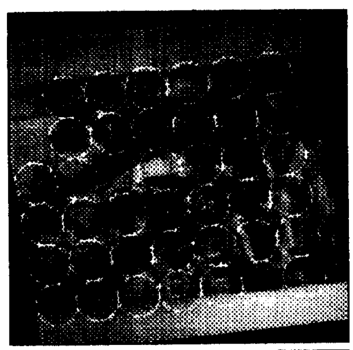

Fig.3.1(b)

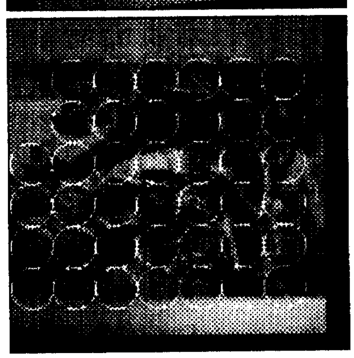

Fig.3.1(a)

	h_1	h_2	h_3	h_4	h_5	h_6
acutal values	0.985	0.152	-0.108	0.986	-8.185	-15.738
recovered mean	0.984	0.151	-0.108	0.985	-8.204	-15.678
s.d.	0.001	0.001	0.001	0.002	0.250	0.267

Table 3.1