

Finding point correspondence using local similarity and global constraint under insignificant scaling and roll

J.-H. Kao, J.-H. Chuang and M.-L. Hsieh

Establishing point correspondences is an important research topic in computer vision. Proposed is an algorithm using local similarity and global constraint to obtain point correspondence. The point correspondences are obtained by comparing their associated colour codes, which are computed by image gradients, and using spatial relationships among neighbouring feature points. The approach assumes insignificant scaling and roll, and is suitable for real-time applications.

Introduction: Extraction and correspondence establishment for image features have been areas of research in computer vision for decades. A number of constraints for feature extraction, correspondence determination, and some other assumptions, are exploited to make the problem tractable [1, 2]. Local methods can be very efficient but are sensitive to locally ambiguous regions. On the other hand, global methods are usually more robust by providing additional support, but computation is generally more expensive [3]. Feature extraction methods can in general be categorised into surrounding pixel-based methods [4–6] and edge structure-based methods [7]. Recently, SIFT was proposed and used to describe and match digital image content between views [8]. However, while the purpose is to compute features invariant to transformations, the SIFT description is typically too expensive especially when the transformation among images is not significant, e.g. between two consecutive frames of a video sequence.

In this Letter we propose a novel approach to efficient feature extraction and correspondence establishment for images. Since image transforms include mainly pan and tilt in common reconstruction scenario, we assume scaling and roll are insignificant. We first extract corner points by the Harris corner detector [4]. The by-produced image gradients are then classified into nine groups (represented by nine colours), which form a colour code for each feature point to summarise local image structure. Point correspondences are obtained by comparing the colour codes in image pairs, and by applying global constraints among them.

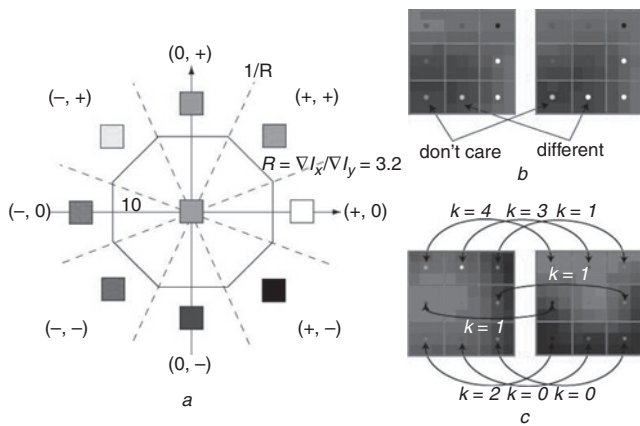


Fig. 1 Colour code transform

- a Using colours to represent eight sections of directions
- b $C_{diff} = 1$ in the local matching
- c $C_{diff} = 6$ and $C_{dist} = 12$ in the local matching

Extraction of colour codes: Denoting the image intensities as I , its gradients ∇I_x and ∇I_y motivate the idea of using them in non-parametric local transform as an additional support. Specifically, instead of exploiting local intensity values as in [9], we use local gradient directions. Fig. 1a shows a quantisation of the cotangent magnitudes of the gradient direction into eight sections, each covers 45° . We then assign each section a specific colour, e.g. white colour is specified as corresponding to $\nabla I_x > 10$ and $\nabla I_x/\nabla I_y > 3.2$. (Grey colour is used for small gradient vectors whose direction is less reliable to use.) With the above representation, we establish a colour code for each feature point by identifying local gradient directions for nearby image pixels. As illustrated in Figs. 1b and c, a window containing nine 3×3 cells is defined with the feature point at the

centre. The representative colour of each 3×3 cell is defined as the majority colour within it, and resultant 8-colour colour code consists of these colours clockwise, starting from the upper right cell.

Correspondence establishment using colour code: It is plausible to exploit local and global constraints simultaneously when computing the correspondence. Accordingly, the proposed approach uses local matching, consistency check, and iterative global matching algorithms. The local matching is similar to that of the rank transform and the census transform proposed in [9], but neither relies heavily upon the intensity of the central pixel nor performs autocorrelation; therefore higher efficiency can be achieved. The consistency check mechanism removes incorrect local matching results, which are mostly introduced owing to occlusions. The global matching uses constraints of distances and relative angular positions among feature points to establish correspondences among remaining feature points incrementally. The details are described as follows.

Local matching: Define k as the quantised angular distance between the two non-grey colours (see Figs. 1b and c). Let C_{diff} be the number of different colour pairs (grey colour is don't-care) among two colour codes associated with two corner points in two images, and let C_{dist} be the sum of relative distance between the colour code with the i th ($1 \leq i \leq 8$) term

$$C_{dist}^i = \begin{cases} k, & \text{if } k \geq 2 \\ 0, & \text{if } k < 2, \text{ or if at least one of the colours is grey} \end{cases} \quad (1)$$

Given two colour codes, if C_{diff} is less than threshold α , they are regarded as having a match. Otherwise, C_{dist} is examined to see if it is less than β , e.g. there is a match between the two colour codes in Fig. 1b but not between the two in Fig. 1c, if $\alpha = 3$ and $\beta = 8$.

Consistency check: The proposed approach also addresses the problem of ambiguity owing to occlusion and noise through a consistency check. In Fig. 2, the feature points A in the left image and A' in the right image will pass the check since they match each other, i.e. satisfy the principle of symmetric correspondence [10]. However, the correspondence between B and C' cannot be established.

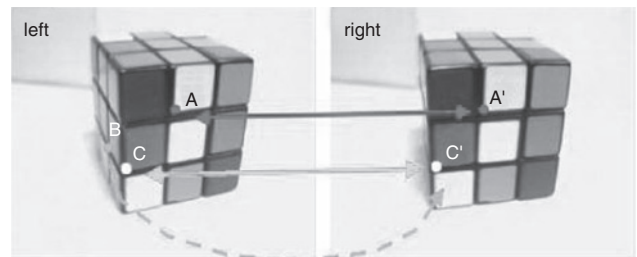


Fig. 2 Example of consistency check

Global matching: Global matching is introduced to further resolve the ambiguity due to similar local intensity gradients. It is based on geometrical relationships which are assumed to change little between two images. Assume that we want to determine the correspondence for a feature point A . Given a set of already matched feature points, $\{(P_1, P'_1), \dots, (P_J, P'_J)\}$, and a set of J candidate points $\{A'_1, A'_2, \dots, A'_J\}$. Let

$$D_j = \sum_{i=1}^J (|\overline{P_i A}| - |\overline{P'_i A'_j}|) \quad (2)$$

be the total length difference between $\overline{P_i A}$ and $\overline{P'_i A'_j}$, $1 \leq i \leq J$. In addition, we compute the sum of error in the cosine of relative angular positions,

$$C_j = \sum_{i=1}^J (1 - \cos \theta_i) = \sum_{i=1}^J \left[1 - \left(\frac{\overrightarrow{P_i A} \cdot \overrightarrow{P'_i A'_j}}{|\overrightarrow{P_i A}| |\overrightarrow{P'_i A'_j}|} \right) \right] \quad (3)$$

Besides such global geometrical information, we also incorporate the differences of colour codes between A and A_j , i.e. $CO_j = C_{diff}^j + C_{dist}^j$.

Finally, the overall score of matching can be calculated as

$$G_j = \frac{D_j - D_{\min}}{D_{\max} + D_{\min}} + \frac{C_j - C_{\min}}{C_{\max} + C_{\min}} + \frac{CO_j - CO_{\min}}{CO_{\max} + CO_{\min}} \quad (4)$$

for each A'_j , $1 \leq j \leq J$, where $D_{\max}$, $D_{\min}$, $C_{\max}$, $C_{\min}$, $CO_{\max}$, $CO_{\min}$ are maximum and minimum values of D_j , C_j , CO_j , respectively.

Experimental results: The synthesised images used in one of the experiments with readily observable ambiguities are the 'house1' images from the CMU VASC image database. Fig. 3a illustrates the global constraints used to determine the correspondence for point 5, the vicinity of which has almost identical local intensity variation as that of point 1. Fig. 3b presents the determined correspondences. The proposed approach is also applied to images of real scenes. Figs. 4a and b show the results for the 'lab' and the 'cart-alt' images in the VASC image database, respectively. Fig. 4c gives another matching result for images of a calibration grid. Table 1 provides some statistics of these experimental results.

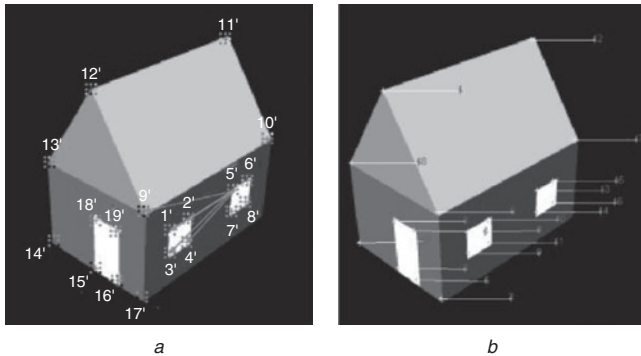


Fig. 3 Two synthesised images of 'house1' dataset

a Global constraints used to assist determination of correspondence for feature point 5
b Established correspondences

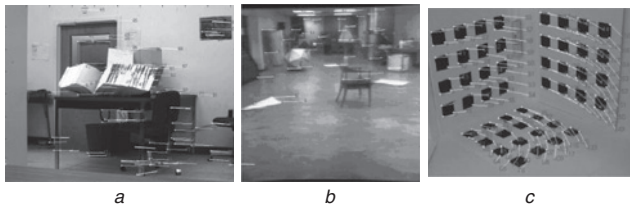


Fig. 4 Determined correspondences

a Result of CMU lab dataset
b Result of CMU cart-alt dataset
c Result of images of calibration grid

Table 1: Experimental results of real scenes

Experiment	L	R	C	I	Correct rate $(C-I)/C$ (%)
CMU house1	19	19	19	0	100
CMU lab	142	156	90	4	96
CMU cart-alt	83	42	42	0	100
Calibration grid	226	218	156	2	99

L , R , C , I denote number of feature points in left image, number of feature points in right image, number of established correspondences, number of incorrect correspondences, respectively

Conclusions: We propose an algorithm which uses local similarity and global constraints to obtain point correspondence of images taken from slightly different views. According to directions and magnitudes of gradient of its vicinity, each feature point is associated with a colour code. Correspondences are obtained by comparing these colour codes followed by consistency check and iterative global matching. Experimental results show that the proposed algorithm is efficient and very robust for finding point correspondence.

Acknowledgment: This work is partly supported by Ministry of Economic Affairs, Taiwan, Republic of China, under grant no. 95-EC17A02S1032.

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18 September 2006

Electronics Letters online no: 20062848

doi: 10.1049/el:20062848

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