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Speed Analysis of Camera Motion in Video Sequence

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ABSTRACT

This paper presents an approach to determine speed of camera motion in video sequences. The technique is based on the analysis of motion trajectories of the corners and interesting points in an image sequence. The spatio-temporal information of the feature points is a key significance in determining camera motion and speed value. The experimental results of speed analysis of camera panning, tilting, zooming, and the combination of panning and tilting are described. We also discuss the applications to help infer the higher-level semantic content and query information for the future video retrieval.

1. INTRODUCTION

Recent advances in digital technology, data compression and storage device open new opportunities and present approaches that change the way moving pictures look and are used. Digital video is now increasingly available and more pervasive. With a rich set of standardized tools to describe multimedia content of MPEG-7, the meaning and manipulation of the content have become more accessible to the users and enable the generation of new unique applications. Search and browsing performances become more effective since the detail of content that can be described using MPEG-7 is quite comprehensive. In a video sequence, motion features provide the easiest access to the temporal dimension and are hence of key significance in video indexing. When used in combination with other features such as color or texture, they significantly improve the performance of similarity-based video retrieval. They also enable motion-based queries, which are useful in contexts in which motion has a rich meaning such as sport or surveillance [1]. Camera motion is one aspect to help infer higher-level semantic content and query information in video retrieval. Several approaches have been developed to estimate camera motion. The early researches are based on the analysis of optical flow computed between consecutive images [2]-[4]. However, the estimation of optical flow, which is usually based on gradient methods or block matching methods, is computationally expensive [5]. Recent researches have moved to directly manipulate MPEG-compressed video to extract camera motion using the motion vectors as an alternative to optical flow [6]-[9]. However, the main purpose of MPEG is allowing a reasonable rendering quality at high compression rates. Therefore, the motion estimation can afford to be wrong so long as the errors to correct it are small. In the case of low-textured and uniform area, the correlation methods used to estimate motion in the first place does not work. This leads to a reason that why the MPEG encoder delivers numerous wrong motion vectors on the background when formed by large uniform regions. In addition, the accuracy in determining camera zoom operation is difficult to achieve because of noises due to independent object motions or the MPEG encoding process, such as quantization errors, and other artifacts. Moreover, the speed of camera motion still has not been focused in the previous researches.

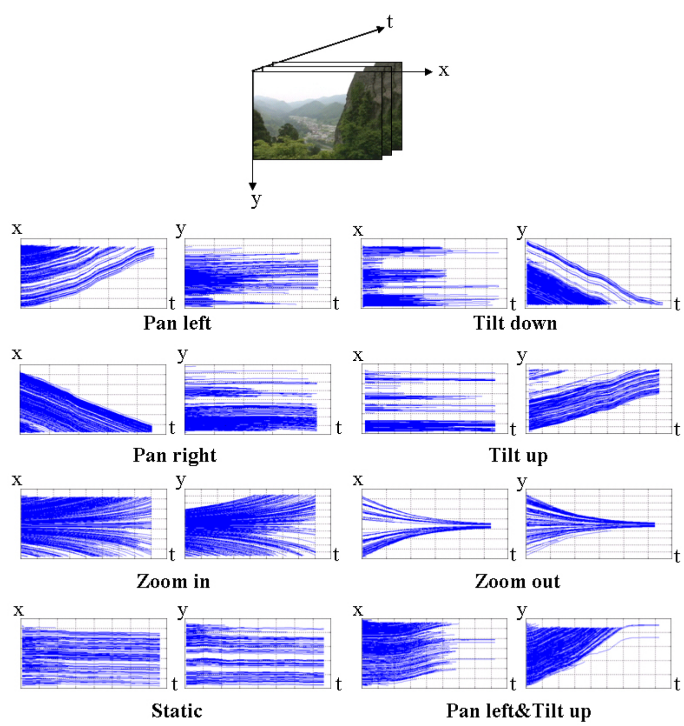
In this paper, we propose a new approach to determine speed of camera motion in video sequences which help the users to search more accurate information into the temporal domain. The technique is based on the analysis of motion trajectories of image features.0A video sequence is temporally segmented into several camera motion subunits by pattern analysis of motion trajectories of image features which is described in section 2. Section 3 presents the methodology in determining speed of camera motion. The experimental results and application are discussed in section 4. Section 5 summarizes the proposed approach and describes the future research direction.

2. CAMERA MOTION ANALYSIS

Image features are local, meaningful and detectable parts of an image [10]. They are stable even if there are some changes in image such as illumination, viewpoint, scale, rotation and addition of noise. Using local features, the most important and meaningful parts of the image can be kept, discarding all the noisy and no useful data. This lead to the motivation that if we continuously track those key locations of the image which are more rich of information than others, the motion trajectories could be sufficient to provide a description of global motion characteristic of the whole image sequence.

Edges and corners are basic features for image recognition and motion analysis. The motion is unambiguous at a corner while it is ambiguous at an edge. Therefore, we select corners as the image features for motion tracking in our camera motion analysis. By observing the motion trajectories of image features over temporal change, we envisage the

Figure 1. The spatio-temporal characteristic of various camera motions



possibilities of accomplishing the spatio-temporal characteristic of camera motion in video sequences. Figure 1 shows the spatio-temporal characteristic of various camera motions. Given a video consists of image sequence with (*x*, *y*) image dimension and *t* temporal dimension. The camera motion can be inferred directly from the spatio-temporal patterns of motion trajectories in (*x*, *t*) and (*y*, *t*) dimensions. For instance, motion trajectories of horizontal lines in both (*x*, *t*) and (*y*, *t*) dimensions depict static camera motion. Motion trajectories of slanted lines in (*x*, *t*) dimension and horizontal lines in (*y*, *t*) dimension indicate panning motion while tilting has the horizontal trajectories in (*x*, *t*) dimension and slanted lines in (*y*, *t*) dimension. For zooming, the motion trajectories are either expanded in or out for both (*x*, *t*) and (*y*, *t*) dimensions. The combination of panning and tilting has the motion trajectories of slanted lines in both (*x*, *t*) and (*y*, *t*) dimensions. The direction of the slanted trajectories indicates the direction of camera motion. We have implemented the algorithm to analysis the motion trajectories of image feature in determining camera motion. The detail can be found in [11]. Although the feature points are disappeared due to the camera movement, object motions, and scene change, the algorithm relies on the stable feature points with the longest tracking duration.

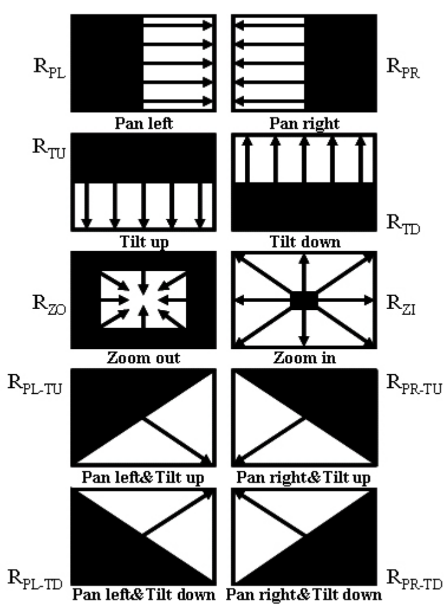
3. SPEED ANALYSIS

We determine speed of camera motion based on the slope of motion trajectories. The algorithm consists of three steps as follows.

3.1 Feature Point Selection

Since some of feature points disappear quickly due to the movement of camera, analyzing all image features might not be necessary in determining speed of camera motion. The motion trajectory of long tracking duration implies the stability of feature point tracking over temporal change, which provides more efficient analysis. Then we find the effective region that gives the longest tracking duration for each camera motion as described in Fig. 2. The magnitude and direction of arrow show the moving distance and direction of feature points in shaded area due to the camera motion. Tracking duration can be inferred directly from the moving distance, which is proportional to the tracking time. The region that gives the longest tracking duration (i.e., the largest magnitude of moving distance in the direction opposite to the camera motion) is defined as the effective region for feature selection in determining speed of camera motion. Only feature points inside shaded area are used for the speed computation.

Figure 2. The effective region for speed analysis of each camera motion



3.2 Period Selection

To make the most reliable outcome, we cut out 5 percent of total time at the beginning and at the end of period of each camera motion. Only motion trajectories in the middle part are used for the analysis. This is to filter out too short trajectories and unreliable time duration during scene change.

3.3 Speed Computation

We apply linear regression to determine the slopes of the selected trajectories from Sections 3.1 and 3.2. Then we find the average slope in (*x*, *t*) and (*y*, *t*) dimensions. Since the motion trajectories sometimes generate the groups of variety of slopes due to the object motions, we filter out the extremely great and small values of slopes including the minor groups of slopes. Only the slopes of dominant group are processed. Then the slope is normalized into the same pixel unit regardless of image size. Let the slopes of motion trajectories in (*x*, *t*) and (*y*, *t*) for image size of ($m´n$) pixels be m_x and m_y, respectively. The normalized slopes are computed as follows.

$$m_{nx} = \frac{m_x}{m} \times 1000$$

$$m_{ny} = \frac{m_y}{n} \times 1000$$

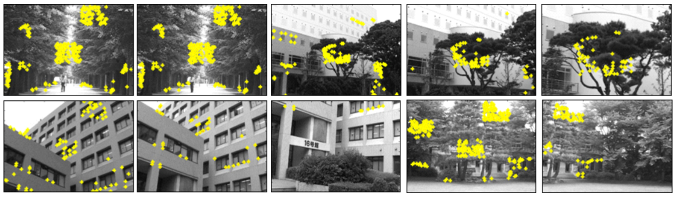
The speed of camera motion can be determined by Eq.(1). Let m_{nxy} be a set of m_{nx} and m_{ny}. The speeds of camera panning, tilting, zooming, and the combination of panning and tilting are represented as SP_{pan}, SP_{tilt}, SP_{zoom}, and $SP_{pan\ \&\ tilt}$, respectively.

$$SP_{pan} = abs(average(m_{nx}))$$
$$SP_{tilt} = abs(average(m_{ny}))$$
$$SP_{zoom} = abs(average(m_{nxy})) \qquad (1)$$
$$SP_{pan\ \&\ tilt} = \frac{\sqrt{((average(m_x))^2 + (average(m_y))^2)}}{\sqrt{m^2+n^2}} \times 1000$$

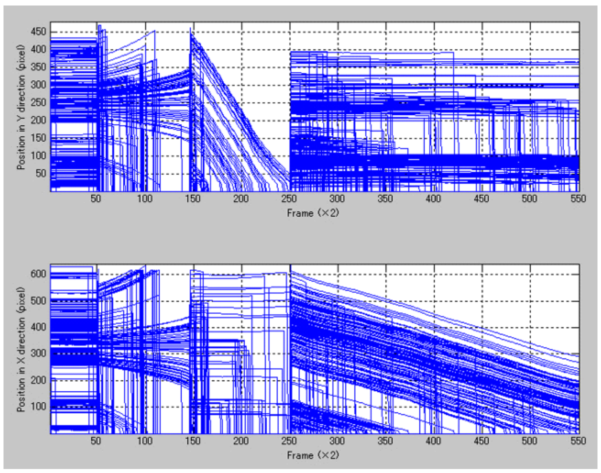
4. EXPERIMENTAL RESULTS

We conduct the experiments to determine the speed of camera motion using the real compressed videos. Fifty shots consisting of five kinds of motions (i.e., static, panning, tilting, zooming, and the combination of panning and tilting) are tested in the experiments. Figure 3(a) shows the example of video sequences and their feature points. The corresponding motion trajectories and result of speed analysis are shown in Figs. 3(b) and 3(c), respectively. The algorithm determines camera motion and its speed in time domain which leads into the interesting applications of video retrieval and scene analysis. In video retrieval, the users are possible to identify the target video with more accurate information of camera motion and its speed. Moreover, they are also possible to give the feedback of the retrieved videos in the term of speed comparison to improve the search results. In scene analysis, the relation of sequence of camera motions, speed, and time duration is possible to infer the events of sport games or the kinds of stories.

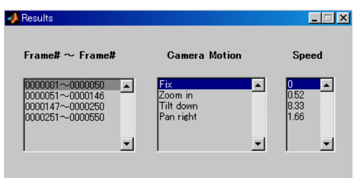
Figure 3. The example of tested videos, (a) image sequence and feature points, (b) The corresponding motion trajectories, (c) result of speed analysis



(a)



(b)



(c)

5. CONCLUSIONS

This paper presented the speed analysis of camera motion in video sequences based on the analysis of motion trajectories of image features. The video sequence is temporally segmented into camera motion subunits by using the spatio-temporal information obtained from tracking the image features along an image sequence. The speed analysis is performed by applying linear regression to the motion trajectories after filtering out unreliable trajectories and tracking period. The approach helps to facilitate the motion annotation and content description of a video particularly in the applications of video retrieval, indexing and scene analysis. The efficiency of video searching can be improved since the users can easily query more information in the temporal domain. Searching time can be reduced because the scope of targets is more specific due to the speed information. We expect to expand the application into the scene analysis of sport games in the future.

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