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MOVEMENT IMAGING

Hybrid markerless tracking of complex articulated motion in golf swings

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Summary Sports video tracking is a research topic that has attained increasing attention due to its high commercial potential. A number of sports, including tennis, soccer, gymnastics, running, golf, badminton and cricket have been utilised to display the novel ideas in sports motion tracking. The main challenge associated with this research concerns the extraction of a highly complex articulated motion from a video scene. Our research focuses on the development of a markerless human motion tracking system that tracks the major body parts of an athlete straight from a sports broadcast video. We proposed a hybrid tracking method, which consists of a combination of three algorithms (pyramidal Lucas-Kanade optical flow (LK), normalised correlation-based template matching and background subtraction), to track the golfer's head, body, hands, shoulders, knees and feet during a full swing. We then match, track and map the results onto a 2D articulated human stick model to represent the pose of the golfer over time. Our work was tested using two video broadcasts of a golfer, and we obtained satisfactory results. The current outcomes of this research can play an important role in enhancing the performance of a golfer, provide vital information to sports medicine practitioners by providing technically sound guidance on movements and should assist to diminish the risk of golfing injuries.

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Introduction

The study of human motion is the interpretation of human activity for the description, analysis and assessment of human movement (Blake and Shiffrar, 2007; Luo et al., 2003; Castrodad and Sapiro, 2012). The application of human motion analysis is limitless and can be categorised into three major fields: surveillance, control and analysis (Moeslund and Granum, 2001; Moeslund et al., 2006; Couceiro et al., 2012). The increasing technological advancements in medicine have drawn attention to the development of human motion analysis in the fields of sports and biomedicine. In addition, human motion analysis can also be used as a training database that athletes can use to compare their techniques with a particular professional athlete who executes the same movement in a similar sport. Motion analysis can also be used in the rehabilitation phase of an injured athlete. Hence, incorrect movements of injured athletes can be used to recover the correct movement pattern with the help of a concerned athlete. To solve this problem, many researchers are attempting to develop a motion tracking system. The main challenge of this work is to retrieve important information of human trajectories from video content and to properly configure each articulated limb to mimic the human pose shown in the video. Thus, the majority of the existing approaches rely on videos with certain conditions, such as a constant moving camera and a static background (Gouwanda and Senanayake, 2008; Erp et al., 2006; Ali et al., 2012). However, most sport activities are captured from pre-recorded sport broadcasts with many unknown parameters. As a result, the athletes might present unexpected movements and extensive body articulations that may rapidly effect changes, self-occlusion and heavy motion blur. The cluttered background in sports videos also increases the complexity of the tracking process. These challenges make the results of the direct application of the existing tracking algorithms unsatisfying. Hence, the detection and tracking of players in broadcast sports videos remains an unsolved problem.

One of the most popular types of video processing methods for the extraction of independent foreground motion is background subtraction (Liu and Sarkar, 2004; Moeslund et al., 2006; Sim and Sundaraj, 2010; Gall et al., 2010). However, the problem associated with this method is the acquisition of an instantaneous reference image, especially when a large part of the background is occluded by the moving background objects or by parts of the background that were never observed and identified. To solve this problem, a single cue or feature is not sufficient to perform human motion tracking, and studies have shown that combining evidence from difference sources yield better tracking results compared with the single cue approach (Ruixuan, 2004; Yang et al., 2005; Tony and Matsuyama, 2008; Karliga and Hwang, 2007). The common approach used to track human body poses uses an a priori human model to guide the tracking process (Urtasun et al., 2005; Park et al., 2006). However, this method requires that the motion data library learn different types of motion patterns. To avoid the use of a human model, model-free approaches were introduced to perform direct human body posture estimations from a single image (Moeslund et al., 2006; Wang et al., 2003; Karliga and Hwang, 2007; Ruixuan, 2004). This method can build a simple model to represent the pose in the initialisation stage as an interpretative guide for the tracking process.

Even though golf has not been familiar as a game related with injuries, scientific studies related to golf state that back and elbow injuries are most frequent in male recreational golfers (McCarroll, 1996; Meira and Brumitt, 2010). In addition, wrist and lower back injuries occur in male and female golf professionals. On the other hand, the elbow and the lower back are the most common areas of injury associated with female amateur golfers. These injuries are mainly associated to poor conditioning, overuse, lack of technical information and improper swing mechanics. Therefore, we envisage that this study, which embarks on the use of a hybrid markerless tracking approach, will produce outcomes that will contribute to prevention of golf-related injuries.

The primary goal of this project was to develop a human motion tracking system that is able to track the motion of a professional golfer performing a full swing from a sports broadcasting video. The tracking process was performed using a genuine sports competition video; hence, video-related problems, such as the complexity of the background, illumination changes and shadows, were our main concern. In addition, no special markers were attached to the subject's body to aid the tracking. We wanted our tracking system to track the major body parts, including the head, body, hands, shoulders, knees and feet, as the golfer performed a full swing. Therefore, we combined both motion and feature cues by introducing a hybrid tracking approach to track the subject's points of interests in each consecutive frame. The tracking outputs are represented in an articulated human skeleton that mimics the exact pose of the subject during the execution of the motion.

Materials and methods

In this work, we used an unconstrained sports video as our input data. The video was obtained directly from the broadcast and contains several types of sports actions with a cluttered background (Reddy, 2010). In fact, one of the most challenging problems related to the tracking of the golfer concerns the occlusion of the body movements and the rapid movements of the swing. Our human motion analysis follows the functional taxonomy summarised in the survey work by Moeslund and Granum (2001), which is shown in Fig. 1.

Initialisation

In our work, we utilised the initialisation stage to determine the location of the golfer's body parts. This allowed us to separate the foreground human subject from the background and provided useful information for the tracking. The LK algorithm was then used to track the motion of the body parts over time. However, this algorithm yields a very poor result when problems, such as occlusion and rapid changes of the swing speed, arise. To solve this problem,