Markerless Human Motion Tracking For Golf Swing Application

By

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To my friends and family, for their love and support.

"*Rejoice with your family in the beautiful land of life*!" By Albert Einstein

ACKNOWDGLEMENT

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LIST OF ABBREVIATIONS

2D	2 dimensions
3D	3 dimensions
AVI	Audio Video Interleave (multimedia container format)
FPS	Frame per seconds
GB	Giga bytes
HMI	Human machine interface
IR camera	Infra red Camera
LK algorithm	Lucas-Kanade optical flow method
OpenCV	Open source computer vision library
ROI	Region of interest
TV	Television
USD	United States Dollar
W4 system	Who? When? Where? What? Surveillance system

Pengesanan Pergerakan Manusia Tanpa Penanda Untuk Aplikasi Ayunan Golf

ABSTRAK

Penjejakan video sukan adalah satu topik baru yang telah mencapai banyak perhatian disebabkan potensi komersialnya yang tinggi. Pelbagai jenis sukan termasuk tenis, bola sepak, gimnastik, larian, dan golf telah digunakan untuk mendemonstrasikan idea-idea baru dalam penjejakan gerakan sukan. Cabaran utama dalam kerja penyelidikan ini adalah pengekstrakan pergerakan bersendi pemain golf yang amat kompleks dalam mempersembahkan aksi sukan daripada adegan video. Kerja penyelidikan ini bertumpu pada pembangunan satu sistem penjejakan usul manusia tanpa penanda yang menjejak bahagian-bahagian badan utama seorang atlet secara langsung daripada siaran sukan. Satu hibrid kaedah pengesanan telah dicadangkan dalam kerja penyelidikan ini iaitu aliran optik Lucas Kanade, korelasi ternormal berdasarkan templat sepadan dan pengurangan latar belakang. Algoritma ini digunakan untuk mengesan kepala, tangan, bahu, lutut dan kaki seorang pemain golf semasa dia mempersembahkan buaian penuh. Akhirnya keputusan output dijejak dan dipetakan ke atas satu 2D model orang lidi untuk mewakili gaya pemain golf. Kerja penyelidikan ini telah diuji di siaran video seorang pemain golf pada pelbagai jenis kerumitan latar belakang.

Markerless Human Motion Tracking For Golf Swing Application

ABSTRACT

Sports video tracking is one of the emerging topics that have grabbed a lot of attention due to its high commercial potential. A variety of sports, including tennis, soccer, gymnastics, running, and golf have been utilized to demonstrate new ideas in sports motion tracking. The main challenge for this research work concerns the extraction of a highly complex articulated motion of a golf player performing sports action from a video scene. This research work focuses on developing a markerless human motion tracking system that tracks major body parts of an athlete directly from a sports broadcast video. A hybrid tracking method is proposed in this research work which consists of a combination of three algorithms namely the pyramidal Lucas-Kanade optical flow, normalized correlation based template matching and background subtraction. These algorithms are used to track the head, body, hands, shoulders, knees and the feet of a golfer while the individual is performing a full swing. Finally, the output results are tracked and mapped onto a 2D articulated human stick model to represent the pose of the golfer. The research work has been tested on a broadcast video of a golfer on various background complexities.

CHAPTER 1

Introduction

1.1 Project Overview

The study of human motion is the interpretation of human activity that describes, analyzes and assesses human movement. The application of human motion analysis is limitless where it can be categorized into three major fields of surveillance, control and analysis. In the field of surveillance, one or more subjects are being tracked over time and serves as a monitoring tool to identify suspicious individuals. Another application area for human motion analysis is in the control area where the captured motion is used to provide controlling functionality for game interfaces in virtual reality and human machine interfaces (HMIs). Lastly, the third application is concerned about the precise and detailed human motion analysis for clinical studies where it can be used as a tool to perform an accurate assessment of the human motion's ability.

The increasing technological advancement in medicine has drawn a lot of attention to development of human motion analysis in the field of sports and biomedicine. Today many researchers use human motion analysis as a tool for athletes to enhance their skills, movement correction, and provide extra visualization for coaches to identify good and bad movement techniques. With the aid of computational power, athletes may fine tune their techniques where minor correction of error made might lead to better performance. In addition, it can also be used as a training database for athletes to compare their techniques with a particular professional athlete who executes the same movement in a similar sport. Another important aspect for this type

of motion analysis is that it can be used in the rehabilitation phase of an injured athlete. Incorrect movement of the injured athlete can be pointed out to help the concerned athlete to recover back his proper movement pattern. Numerous tools and techniques of tracking and accessing human motion have been developed. However, they require a laboratory environment and the attachment of markers onto the human's body to access the motion data. In order to solve this problem, many researchers now attempt to develop a motion tracking system which can be easily accessed anytime and anywhere from variety of receiving devices of various sports events. With the increasing involvement of technology in computer and multimedia, this has led to a tremendous growth in the research of the human motion analysis from sport videos' content.

In this project, a sports motion tracking system based on prior recorded videos of experienced athletes in various competitions is proposed. From the video, the points of interests of the subjects are tracked consecutively and the outputs of the results are represented in an articulated human skeleton model. From the movements of the skeleton, the tracking system will be able to identify the optimum movement performed by experienced athletes. The overall goal of this research is to enable athletes to have proper sports training in order to obtain optimum sports performance results. It should be affordable to any general user and not just limited to professional athletes, hereby increasing the sports competitiveness among our local Malaysia athletes again our foreign counterpart.

1.2 Motivation of Studies

In many high competitive professional leagues, the research for athletic perfection has become essential for athletes to keep up with their rivals. This has led to

the increase demands for tools to measure and analyze their performance accurately in terms of position, orientation, turning angle, speed and trajectories (refer to Figure 1.1). This is due to the fact that it is impossible for the coaches and athletes to gain access to their movement techniques precisely without any instrumental aids. Furthermore, it is also very difficult for the coaches to keep track of subtle changes in movement over a period which might require more eyes and memory. Recently with the advance in computer systems, sports motion analysis tools can assist the athletes and coaches in the above aspects. For this purpose, two types of databases can be utilized where the first database consists of extracted body movements of experience athletes, while the second is movements created by the user himself. From this, athletes can make a direct comparison in their trajectory's points of interests with a database made for this particular athletic activity. They can pay close attention to fine tune their techniques with several repetitions until the desired performance level is reached. For example, the system may suggest that the player needs to extend the elbow more in order to deliver maximum power or lower the body centre point to gain more stability. Another important aspect for this type of motion analysis is that it can be used in the rehabilitation phase of an injured athlete. Strategies and proper training programs can be used as an important part of this treatment. By using motion analysis, it allows frame by frame observation of the joint motion, kinetics and kinematics. This information can be used to determine surgical intervention, and physical therapy recommendations.

To date, there are numerous commercial sports motion analysis systems available in the market (refer to Table 1.1). However, such systems are expensive and only suitable for general applications which require a laboratory environment and the attachment of reflective markers or sensors onto the human’s body to access motion

data. Moreover, some of the sports motion analysis system often lack of intelligence in the system where the users are required to specify the type of analysis desired manually.

Thus, it is clearly shown that there is still a need to develop an affordable sport motion analysis system as a tool to enhance athletes' sports performance due to its high marketable potential.

Figure 1.1: Sports motion analysis tools used to enhance athletics' performance (Van, Saturday & Jansen, 2006).

Table 1.1: Commercial sports motion analysis system.

Name of the product	Price in USD
MotionPRO! ™	**2199.99**
AmTrainer3D™	**1964.00**
Elite motion coach ™ EMC 3000	**2895.00**
T2motion ™	**5995.00**

1.3 Problem Statement

The main challenge of this work is to retrieve important human trajectories information from the video content and configure each articulated limb in a properly manner to mimic the human pose. Majority of the existing approaches relied on the videos with certain conditions such as constant moving camera and static background.

However most of the sport activities were captured from pre-recorded sport broadcast videos with many unknown parameters. Athletes may perform abrupt movements and extensive body articulation that may result in rapid appearance changes, self-occlusion and heavy motion blur. In some cases, not only one subject is considered as the tracking subject, but multiple players in a shot of broadcast video where they might move at various directions in a scene. As for cameras used to capture sports games, they are not fixed and always moving around to keep track of the field players. Last of all, the cluttered background in sports videos also increase the complexity of the entire tracking process. These challenges make the result unsatisfying with direct application of the existing tracking algorithms. Often, solutions based on a single cue or features is not sufficient to perform human motion tracking and studies have shown that combining evidence from difference sources yield better tracking results compared to a single cue approach. This is due to the fact that not all humans' poses are of the same type of motion at the same time. Hence, detection and tracking of players in broadcast sports videos still remain as an open subject to be solved.

1.4 Scope of Work

Human motion analysis is a very wide field of study. In this project, the goal is to develop an affordable markerless human motion tracking system. The system is expected to perform motion tracking on a professional golfer while the individual is performing a full swing from a sports broadcasting video using a markerless approach. Several research challenges such as rapid motion, body occlusion and complex background are the issues that needed to be solved. Different types of tracking algorithms will be investigated to find the optimum solution that yields the best tracking

result. Single cue solutions are not reliable to perform robust tracking hence the proposed work is to combine 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 of the results are represented in an articulated human skeleton that mimics the exact pose of the subject during execution. This project is developed entirely using a C language platform with an additional aid from the OpenCV library.

1.5 Research Objective

The main goal of this project is to develop a markerless human motion tracking system which is capable to perform motion tracking on a professional golfer while the individual is performing a full swing from a broadcast sports video. It can be achieved by the objectives as follows:

i. To perform object identification on various parts of the subject body like head, shoulder, knees, feet, hands and golf club.
ii. To track the point of interests of the subject's body over time with a suitable markerless tracking algorithm
iii. To map a resultant output on 2D articulated human stick model to represent the pose.

1.6 Project Milestone

The main target of this project is to develop a tracking system which is expected to track the major body parts of the golfer which include the head, body, hands, shoulder, feet and the golf club while the individual is performing a full swing. The

tracking process is performed using a genuine sports competition video. Additionally, no special markers were attached onto the subject's body as an aid for tracking. The system is also expected to yield promising tracking results on different athletes with various heights and skin colours, and also with various background complexities using the proposed hybrid tracking techniques. Lastly, the system should be able to map the tracking results onto a 2D articulated model to represent the pose of the golfer.

1.7 Thesis Organization

This thesis begins with an overall introduction which includes a brief explanation on the field of motion tracking followed by its contribution towards sports science. The current state of sports technologies that are used to enhance sports performance encourages us in developing a motion tracking system. In addition, in this chapter, the level of expectation of the proposed motion tracking system is described here.

Chapter 2 presents the literature review of this project where this chapter present an overall study on the previous research and methodology that is related with this project. This chapter begins with the study of motion tracking systems, focusing more on sports applications. A detail review on the widely used methods for tracking an articulated human motion is presented. The limitations of each approach are also highlighted.

Chapter 3 explains the methodology of this project. It starts with the detailed description of the proposed motion tracking system. The setup of the system setup is explained in this chapter and the entire initialization process is introduced. Then a full description on the proposed hybrid tracking algorithm is explained in the following

section. Some preliminary results are also presented in this chapter to demonstrate and prove the effectiveness of the proposed algorithm.

Several experiments are conducted in Chapter 4 to validate the robustness of the proposed motion tracking system ranging from simple exercise movements to complex golf swing motions. Various degrees of background complexity are also used as part of the experiment criteria to validate the performance of the tracking system.

The last chapter will conclude this thesis with the summary and the recommendations for future work.

CHAPTER 2

Literature Review

2.1 Introduction

The beginning of studying human motion was by analyzing human and animal movement from photographs. Since then, the evolution of electronic technology and computers science has reduced the complexity of accessing human motion by increasing the number of tools available for tracking and acquisition. From the computerized input data of the sensor, scientists can be now able to access each individual's upper and lower extremities in real-time basis. This chapter represents an overview of tracking human motion, focusing more on tracking complex articulated motion, especially in sports.

2.2 The Study of Human Motion Tracking in Sports

Sports performance has a direct link to the study of human motion. Athletes or coaches can use motion analysis as a tool to enhance techniques, correct movement errors and built-up physical fitness. And in some cases, to help those injured athletes to have a proper rehabilitation exercise. Sports motion tracking tools can be classified into a contact or non-contact type, which depends on the sensing device used.

As for the contact based, it uses sensors or devices that are attached to the human body and transmit data to the computer for further analysis. Accelerometer, force