Human Motion Reconstruction using Wearable Accelerometers

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Abstract

We address the problem of capturing human motion in scenarios where the use of a traditional optical motion capture system is impractical. Such scenarios are relatively commonplace, such as in large spaces, outdoors or at competitive sporting events, where the limitations of such systems are apparent: the small physical area where motion capture can be done and the lack of robustness to lighting changes and occlusions. In this paper, we advocate the use of body-worn wearable wireless accelerometers for reconstructing human motion and to this end we outline a system that is more portable than traditional optical motion capture systems, whilst producing naturalistic motion. Additionally, if information on the person's root position is available, an extended version of our algorithm can use this information to correct positional drift.

Categories and Subject Descriptors (according to ACM CCS): INFORMATION INTERFACES AND PRESENTATION [H.5.1]: Multimedia Information Systems —Animations COMPUTER GRAPHICS [I.3.7]: Three-Dimensional Graphics and Realism—Animation

1. Introduction

For a number of years, optical motion capture systems have provided sports scientists, coaches and athletes with important data about an athlete's performance that is difficult to elicit with the naked eye or even via high speed video capture. Although very accurate, optical motion capture systems are cumbersome for capturing precise, complex and rapid athletic movement in some scenarios. Athletes, in particular, often move very quickly through large spatial volumes that may be difficult to densely and safely populate with cameras. They also often perform outdoors where the lighting conditions cannot be easily controlled. Additionally, occlusion of markers, due to sports equipment or other players, can cause tracking difficulties. Artifacts in reconstructed motion due to occlusions may be overcome by manual intervention and correction, but for time-critical applications, such as instant replays of the athlete's 3D motion for sports broadcasting purposes, manual interventions may be unfeasible.

In this paper, we outline a system to address these limitations. Our goal is to produce a portable system that can operate in large sporting areas such as outdoor arenas, where traditional motion capture systems would have problems. In addition, we would like to make the system relatively cheap, unobtrusive to wear and, of course, obtain reconstructed motion to as high a degree of accuracy as possible. The focus of this work is on the specific application of novel visualisation of athlete performance within sports broadcasting scenarios.

2. Overview

Figure 2 illustrates an overview of the different stages of the proposed system: (a) an offline stage, (b) a pre-capture stage and (c) the motion reconstruction stage. In the offline stage, a motion capture database is created that contains a sample set of the types of motions that we expect a player to perform at capture time. Using this, a motion graph is constructed, encoding how captured clips may be reassembled in different ways. Novel motions can be obtained by traversing the graph. The pre-capture stage of the system tailors the motion graph to different placements of accelerometers on players, using *virtual accelerometers* to generate accelerometer data for each motion in the motion graph The online stage of the system reproduces novel motions by finding paths in the mo-

Figure 1: *Tennis reconstruction from six accelerometers.*

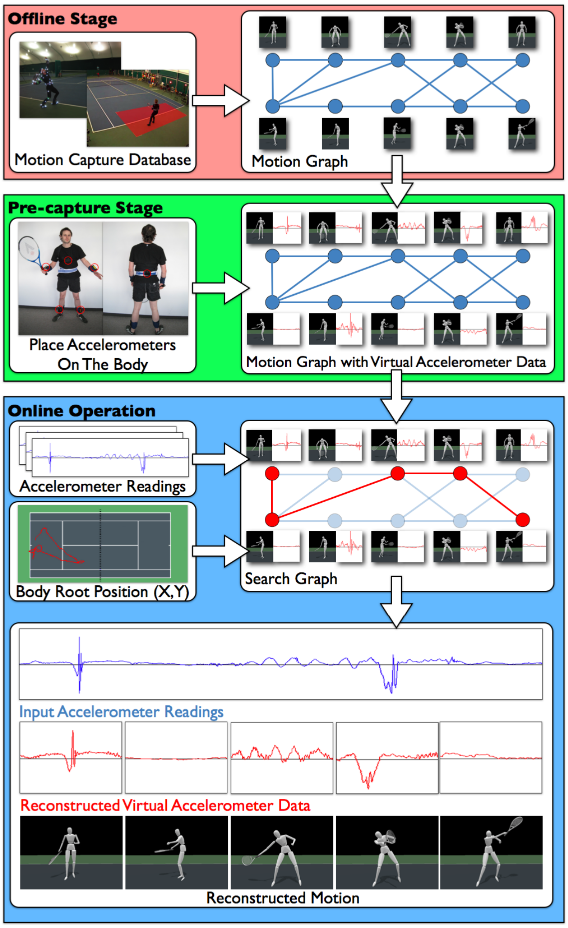
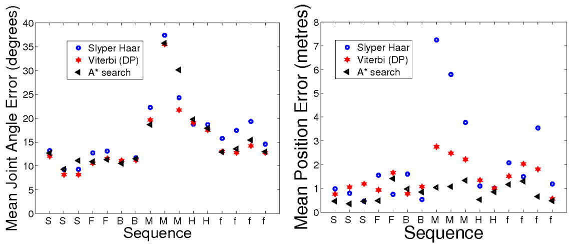


Figure 2: *System Overview.*

tion graph that would produce similar acceleration readings to those measured at capture time. Using a dynamic programming (DP) solution to find the optimal path through the graph, this results in a sequence of poses whose accelerations most closely match the recorded accelerometer values. Noting that the root position in the motion produced by this method can *drift* away from the correct body position and orientation, an alternative approach can also be applied in the online stage, that attempts to correct this using player



(a) (b)

Figure 3: *Joint angle error and positional error comparison.*

position information from an external source. Any localisation method can be used to supply this positional information (e.g. image-processing from calibrated cameras [CKCO09], GPS, UbiSense, etc). For this second graph search technique, the proposed framework temporally segments a capture session into *action* and *non-action* segments. The DP solution reconstructs motion during *action* segments, resulting in highly accurate motion at important times, and a second search strategy, using A* search, attempts to correct the position and orientation drift of the actor during *non-action* times.

3. Experimental Results

For quantitative evaluation of the proposed technique, we benchmarked the two search algorithms – using 16 tennis motion sequences of 6 different types (S=Serve, F=Forehand, B=Backhand, M=Motion, H=move and Hit, f=Freestyle) – against prior work in action capture using accelerometers [SH08] and ground truth motion capture data – see Figure 3. The results show that our DP approach outperforms Slyper in almost all cases (or is very close), while the $A*$ search manages to keep a relatively low error, while also improving upon the positional error of both DP and Slyper.

References

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