A New Illuminated Contour-Based Marker System for Optical Motion Capture

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Abstract

Motion capture has been developed with the aim to track and/or reproduce complex movements. This paper will mainly focus on the optical marker based approach to tracking and will present a new type of marker identified as an Illuminated Contour-Based Marker. This new marker has been developed in order to solve the problems identified with current standard sphere-type markers, such as the need to wait through a whole "flash sequence" in order to automatically identify individual markers, ambiguities related to current color cues and problems associated with missing information in data streams. Experiments indicate that the new markers support active marker extraction and robust tracking across time steps.

1. Introduction

Motion capture has been developed with the aim to support accurate capturing of complex movements. These captured movements can be used in applications related to movies, animations and games industries, where high quality presentations of movements are required in order to support suspension of disbelief. As reported in the literatures [1]-[4], motion capture data can be used in vast areas of applications, such as in technologies that aim to facilitate movement enhancements and/or analysis. In these applications, motion capture data is used as input to control systems that use the human body as an interface between man and machine, or to construct databases of realistic movements for use in virtual motion capture.

A range of different technologies has been developed with the aim of capturing motion. These technologies span from optical, magnetic, mechanical, structured light and acoustic systems to wearable resistive strips or a combination of these [5]. In general, these approaches can be divided into Marker-based and Marker-less tracking systems. This paper will mainly focus on the Marker-based Optical approach to motion capture.

Optical systems commonly utilize cameras as sensors to capture movements. Some of the central issues with the current standard spherical markers used in most optical systems are that they suffer from occlusion problems and are sensitive to noise. Further, most of these systems are high-end and therefore quite expensive, which makes it hard for many individuals and small companies to acquire this type of technology. The aim of this research is therefore to develop a marker that can minimize and/or solve these problems.

2. Markers

In general, a marker can be defined as a data structure that contains two primary pieces of information: what an object is in terms of its role in the current task and where the object is located in the coordinate system [6]. In order to do this, each marker must have properties that enable them to be continuously identified and tracked over time. Passive and active systems are currently the two main categories of markers used in optical motion capture that possess these qualities.

Passive markers are in general constructed of spheres 2.5 cm in diameter and covered with a highly reflective material that often are over 2000 times brighter than a normal white surface [7]. A standard passive marker is shown in Fig. 1. The material covering the marker reflects light projected from light sources positioned around each camera. These reflections give the markers distinct color values compared to the rest of the image, which in turn enable extraction markers from the background of captured images. One of the main problems with passive

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markers is that either a trained human operator or a specific startup position of the performer is required to recognize, label and track each individual marker.

Fig. 1 A standard spherical marker [8]. Reflects light projects light reflected from light sources.

Active markers, which usually consist of flashing LEDs, can be automatically labeled through the use of an external computer connected to the markers through wires.

This computer transmits individual electric pulses to each marker in order to make each of them "flash" in distinct patterns, which in turn enables the motion capturing system to identify each marker without human interference. A problem with this technique is that the cabling restricts the user's freedom of movement [9, 10], which will make the captured movement appear un-natural. This is highly undesirable because constraining the performers movements contradicts with one of the central aims of motion capture, which is to capture realistic motion, and movement. It is also found that this approach to automatic marker identification delays processing time, as the system need to wait through a whole flash sequence in order to identify each individual marker [9].

An other problem with current standard spherical markers is that they can create holes in incoming data streams. These holes are results of occlusions, limited field of view or sensing errors and makes straight forward capturing of 3D motions hard, because the holes can make the captured motion data appear staccato [2], [6]. One way to minimize this problem is to use "spatial memory" and linear interpolation between known values, to estimate some of the missing data inter-frame. Adding more cameras or markers to the capturing system may also ease the problems associated with missing data. However, this makes the tracking procedure more complex, which results in a higher processing time, while adding more markers may cause an exponential increase in the "confusion factor", which can make it harder to distinguish between each of the individual markers [11]. A better approach might, therefore be to develop more alternative methods for estimating missing data.

It has been pointed out in literatures that it is important to find suitable positions for the markers on the body, as failing this, might affect the accuracy of the motion capturing due to secondary motions in soft body tissue [7]. Further, it is indicated that noise must be expected in the captured data when using optical sensing systems due to the continuous fluctuation of light. Noise can be defined as unwanted data that will complicate further processing and should therefore be removed from the data set [12].

In order to reduce and/or solve the above-mentioned limitations associated with the current standard spherical markers, the authors have developed a new marker system based on intersecting illuminated line segments.

3. The new marker system

The new Illuminated Contour-Based Marker system supports active tracking through the use of a battery-driven low power color marker and is ideal for tracking non-rigid motion. A set of the new markers is shown in Fig. 2. These markers are attached to a tightly fitted body suit at key areas of the body where the skin is close to the bone. This is done to avoid secondary motions from soft body tissue to introduce noise to the motion data. To allow for calibration of the bodysuit, the markers are attached to the suit using patches of Velcro, as this makes continuous fine adjustment of marker positions possible.

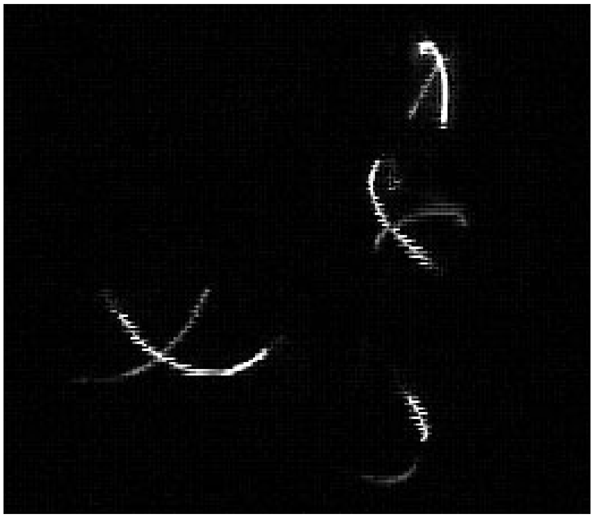

Fig. 2 The new markers. Each pair of line segments illuminates a set of distinctive colors.

The new markers consist of intersecting thin (3mm), flexible illuminated line segments of different colors. The manufacturer [13] specifies that the line segments are made up of copper wire with a phosphorus powder coating protected by PVC, and operate on alternating current using an inverter. It is also stated that, when current is applied to the copper wire, the phosphorus reacts by giving of a distinctive static electro luminescent glow. In the new marker system, these wires are assembled in a way that provides every marker on the bodysuit with a distinctive ID based on two different colors. This gives the Illuminated Contour-Based Marker system an advantage over systems that use one single color to generate each marker ID, such as [14]. This advantage is gained because there naturally is a larger range of individual markers available when using combinations of colors in each ID, compared to using ID's based on single colors.

Since static colors are used to identify markers rather than the individual "flash" sequences used by standard active markers, problems associated with standard active markers such as, the need to connect to a complex external computer and having to wait through a "whole" flash sequence before a marker can be identified, is removed.

An additional strength of the new marker system is that it indicates a way of solving one of the current problems associated with using color cues in tracking. This problem is related to the fact that colors change when they are exposed to different lighting, which in many cases is the reason why the color cue is unable to support tracking by itself. Therefore, as has been reported in the literature [see 15, 16], it is necessary to combine the color cue, with a motion cue. However, this second cue also has problems with tracking human motion due to severe discontinuities in human movement and delays in frame processing. The new markers solve the color cue problem by generating its own internal light, which is less affected by changes in external lightning. Another benefit of using a marker with an internal light source is that tracking can be performed in a semi-dark room. This is because it limits the interference of noise artifacts from the background and therefore simplifies the tracking process.

The new marker system may also support more robust estimation of data missing due to occlusions, than traditional spherical markers. This is because the new marker allows for intra-frame interpolation of missing data, as well as inter-frame regression of the individual line segments. This in turn, can support accurate motion capturing and reproduction by minimizing linearisation of non-linear data in the case of occlusions. Further, as the line segment based markers are designed to be larger than traditional ball markers, the new marker is more likely to be only partially occluded. The benefit of this is that the marker (due to its size) will have a greater chance of retaining enough data to estimate missing marker positions inter-frame in the case of occlusions.

It should be noted that different cameras might produce different color values for the same line segment. This can confuse the capturing process if multiple cameras are used for the tracking process. It is therefore essential that all cameras used are of the same type in order to support accurate determination of intrinsic parameters. Further, there are currently ten different glow wire colors available on the market, but several of these have color attributes that are too similar to be separated into distinct classes. Hence, only five distinctive colors have been ultimately incorporated into the new marker system. These colors are: Red, Orange, Green, Purple and Yellow.

4. The skeleton model

A virtual skeleton is used to reconstruct and present captured human movement to the user of the motion capture system. Fig. 3 portrays the virtual skeleton rigged with spherical markers, while Fig. 4 show the same skeleton equipped with the new type of markers.

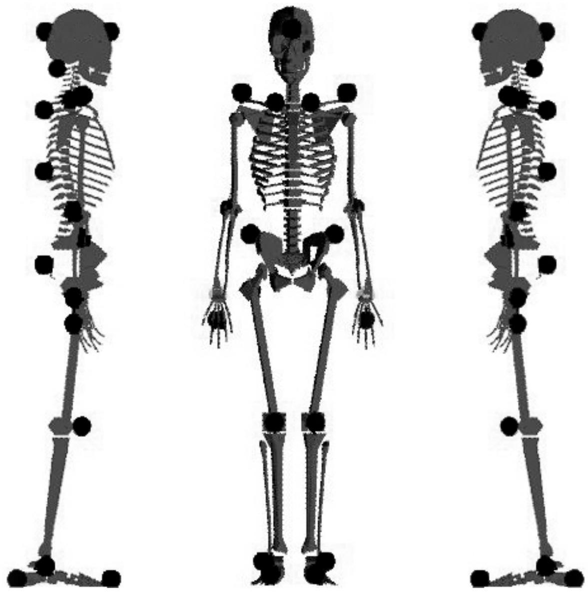

Fig. 3 Skeleton rigged with spherical markers. All of the markers reflect the same color projected from the light sources surrounding the camera lenses that have captured the motion data.

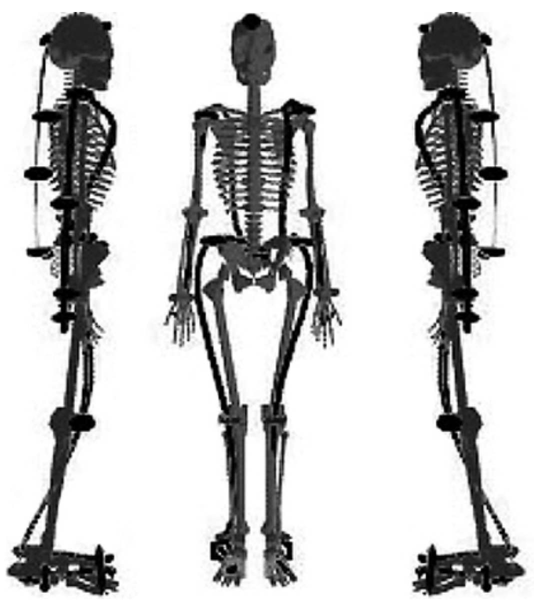

Fig. 4 Skeleton rigged with line segment based markers. Each line segment illuminates a distinctive color.

5. Conclusion

A new marker system based on intersections of static thin illuminated line segments has been developed. These new markers are attached to a tightly fitted body suit at key areas of the body where the skin is close to the underlying skeleton. This prevents the individual markers relative position to the key tracking points from being influenced by "secondary motions" in soft body tissue. As these new markers have clearly distinctive color attributes, they support "ease of extraction" from the background images. They also facilitate robust tracking over time steps by minimizing noise caused by background objects in the capturing environment. Furthermore, problems identified with using color cues in tracking across time steps, have been reduced. This is because the new markers are less affected by changes in external lightning, due to their internally produced colored light.

The new markers also support automatic marker identification without the need to be wired to a complex external computer device, as the separate markers can be recognized by their constant color values rather than individual "flash sequences". This allows for both unrestricted body movement of the user and the markers to be continuously identifiable. As the new markers do not depend on "flash" sequences for identifying individual markers, they do not suffer from delays in active marker identification the way the traditional flashing LEDs based active markers do.

Furthermore, the new Illuminated Contour-Based Markers facilitate accurate reproduction of non-linear data by allowing linear inter-frame interpolation of missing data as well as intra-frame regression. Here, intra-frame regression can assist in retaining non-linear characteristics of motion data by making it possible to perform initial estimations of missing information, which in turn can minimize the need for assuming inter-frame linearity.

6. Future work

One of the limitations facing the new marker system is related to the number of glow wire colors available on the market (five clearly separable distinctive colors), as this constrains the possible number of markers. Further research may therefore involve manipulation of glow wires in order to produce more distinctive colors.

Research is currently underway to find algorithms for automating marker midpoint estimations. Ways of removing noise that is pertinent to motion data captured with optical systems, due to the continuous fluctuations of light are also being investigated.

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