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# Fully Wireless, Full Body 3-D Motion Capture for Improvisational Performances

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## ABSTRACT

This paper describes a framework for exploring the boundaries of interactive whole-body improvisational performances using the Orient-3 Wireless Motion Capture System in collaboration with composers and musicians. The requirements for improvisational performances are explored and the choice of the Orient-3 motion capture system is justified from among mechanical, acoustic, magnetic, optical and inertial motion capture methods.

## Categories and Subject Descriptors

C.2 [Computer-Communication Networks]: Network Architecture and Design – Wireless Communication.

H.5 [Information Interfaces and Presentation]: Multimedia Information Systems – Animations; User Interfaces – Input Devices.

J.5 [Computer Applications]: Arts and Humanities – Performing arts (Dance and Music).

## General Terms

Design, Experimentation, Human Factors, Measurement, Performance.

## Keywords

Wireless Motion Capture, Full-body Motion Capture.

## 1. INTRODUCTION

Motion capture is the recording of motion for either real-time or delayed analysis, and playback. Subsequent analysis of the data is used in a wide range of applications including clinical studies, i.e., gait analysis, sports science, i.e., biomechanical studies in skill acquisition, and computer animation. A number of classical motion capture methods ranging from mechanical, acoustic, magnetic, optical and inertial methods are described in Section 2. A full body, fully wireless, 3-D motion capture system is described in Section 3 and its choice for interactive improvisational performances is justified in Section 4, with early results and plans for future research described in the rest of the paper.

## 2. MOTION CAPTURE METHODS

Classical motion capture techniques [2] are distinguished by the location of the sensors - either external to, or on the subject, and the nature of the transducers employed – mechanical, acoustic, magnetic, optical or inertial.

Prosthetic or mechanical motion capture methods require the subject to wear an external structure or exoskeleton, and the posture is determined by detecting changes in the optical or electrical transducers at the joints. The main disadvantage is the cumbersome external structure, whereas the many advantages are the direct computation of rotation, simultaneous capture of multiple subjects without problems of occlusion, portability and relatively low cost.

In the acoustic motion capture method, audio transmitters are attached to the performer and the external receivers measure the time to receive the signal, and compute the position of the transmitters using triangulation. As in the previous method, the principal advantage is the lack of occlusion in the case of multiple performers, whereas the many disadvantages include unwieldy wires, limited size of the capture area, reflections of sound compromise accuracy, and the low rate of transmission only supports limited number of transmitters.

Magnetic motion capture method uses a large central magnetic transmitter to compute the position and orientation of the receivers attached to the person. The lack of occlusion is the principal advantage; disadvantages include the cabling which inhibits movements, interference from metal in the vicinity, and the limited capture volume.

Optical motion capture (Vicon [3], Qualisys [4], Motion Capture [5]) is probably the most widely used method in which either passive reflective markers or active markers are attached to a performer, and a system of fixed cameras record the position of these markers. This approach allows the performer greater freedom of movement, and achieves faster sampling at a high resolution than the previous methods, in a capture area which is normally larger in comparison to the acoustic and magnetic methods. This method is by far the most expensive and suffers from problems of occlusion. Extensive post processing is required in order to locate and identify the markers and account for any crossovers.

A typical optical motion capture session is both a time-consuming and expensive process with well-defined phases: planning, setting-up and calibration, capturing of performance, post-processing for the identification and location of markers,

and the final editing of the data. There are intrinsic problems in using markers, mainly the inconvenience of attaching them to the body and failures in tracking them, and the requirement for special lighting conditions. Techniques in software have been developed to understand the motion in the images from the cameras by extracting the silhouette of the subject [6][7], without using on-body markers. Commercial marker-less optical motion capture systems have appeared on the market recently [8].

Motion capture suits [9] using inertial sensors are aimed at alleviating some of the problems of the optical method. The sensor devices, each with a gyroscope and accelerometer, are embedded in the suit which also contains the wires connecting them together to a base unit. The advantage over the optical method is the lack of cameras and can therefore be used anywhere, and with no concern about lighting conditions and occlusion.

### 3. WIRELESS MOTION CAPTURE

#### 3.1 Orient Motion Capture System

The Orient Motion Capture System [1] developed by the Research Consortium in Speckled Computing [11] at the University of Edinburgh demonstrated for the first time, fully wireless, full-body, 3-D motion capture in real time using on-body network of fifteen custom-designed Orient inertial sensor devices (Figure 1). The system is free of infrastructure such as cameras, magnets, or audio receivers, nor does it require special suits to be worn to contain the wires as in the case of Xsens's Movens and Animazoo's IGS-190.

The compact Orient device measuring 36x28x11mm and weighing 13gms contains 3-axes gyroscope, magnetometer and accelerometer. The sensors are sampled at up to 512 Hz, and a positional update rate of up to 64 Hz is achieved over the wireless network for full-body motion capture using a modest low-power 250 kbs radio. This is achieved thanks to an efficient local orientation estimation algorithm in the device firmware running on a 16-bit dsPIC, which reduces the communication data by 79% compared to existing methods [1].



Figure 1: (Clockwise bottom-right) Orient-3 device; Mobile Phone; Orient Base-station.

Its onboard ADC is used to sample the inputs of the analog sensors: rate gyroscopes, magnetometers and accelerometers in each axis, plus temperature monitoring to allow compensation of the thermal response of the sensors. When multiple Orient devices are used together, their measurements are synchronised and their results transmitted across the radio channel in sequence, so that a complete frame's data can be assembled at the base-station (Figure 1, top-right) within milliseconds. The base-station has USB, Bluetooth and WiFi interfaces which can bridge to a mobile phone (Figure 1, left).

The Orient-3 device captures full-body motion data at the maximum update rate of 64 Hz for around 150 minutes from a full charge. The whole device can be placed into a low-power, sleep mode for weeks at a time, whilst being ready for use within a couple of seconds of being woken by a radio signal. The 120mAh lithium polymer battery and charger are integrated into the device, with charging as simple as plugging in a lead, even when the device is held in a strap for use.

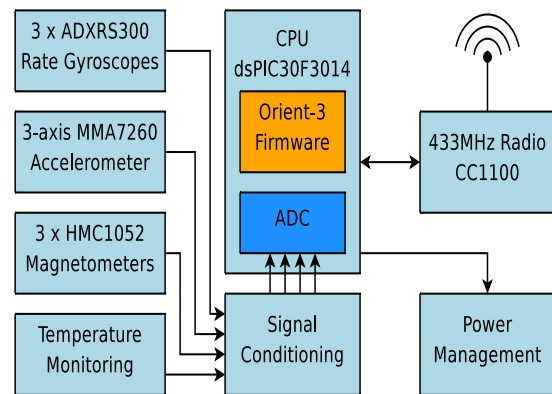


Figure 2: The system block diagram of Orient-3

#### 3.2 MotionViewer Software

The MotionViewer software provides a user-friendly interface (Figure 3) for the performer to interact with a network of Orient-3 devices. The software comprises of five main subsystems: Device Interface, Forward-kinematic rigid-body model, Project Management, Real-time visualisation, and a Plugin API.

The Device Interface is used to configure individual Orient-3 devices and set up a network to perform motion capture. The base-station with its USB, Bluetooth and WiFi interfaces acts as a bridge between the Orient-3 devices and the host which could be a PC, PDA or a mobile phone. The interface is designed to be usable as a library for stand-alone applications, in addition to its use in MotionViewer.

A simple calibration process requires the performer to hold briefly, just for a few seconds, a pre-determined stance which enables the alignments between the Orient-3 devices and the performer's body segments to be automatically accounted for.

The Rigid-body Model provides the translation from the orientation data gathered by the network of Orient-3 devices to a real-time 3D model of the performer. The model consists of a number of joints connected by rigid rods to form a simplistic model of the performer's skeleton. The proportion of the sizes of the rods in the model should correspond to the relative sizes of the limbs of the performer. Rotation data from each Orient-3 device is mapped uniquely to a joint, and after each frame of data the full state of the model is updated using a forward-kinematic method.

The Project Management feature in MotionViewer allows several takes of motion capture to be amalgamated as a project. Each take of the performance can have its own set of Orient devices, complete with their own calibration data and joint

mapping. Joint mappings can be changed after captures are completed allowing mistakes to easily be corrected.

A real-time Open-GL visualisation of the body-model is provided which enables the capture performances to be monitored. The full 3-D model is viewable with the performer able to move freely around the body to inspect it from different angles.

The Plugin API allows the MotionViewer application to be extended. Two types of Plugins are supported: Live and Export. Live Plugins run all the time, even during live motion capture, whereas Export Plugins allow for high-speed, off-line export of motion capture data for use in other applications. Plugins are given access to the body model and are free to manipulate it. A generalised annotation mechanism allows for Plugins to add data to the model without requiring sub-classing of the main software. Annotations can be used to pass data between Plugins. Examples include a Live Plugin for real-time data graphing, which allows sensor data such as acceleration to be monitored along with the 3D model, and a BVH Export Plugin, for integration with existing animation software, such as Motion Builder.

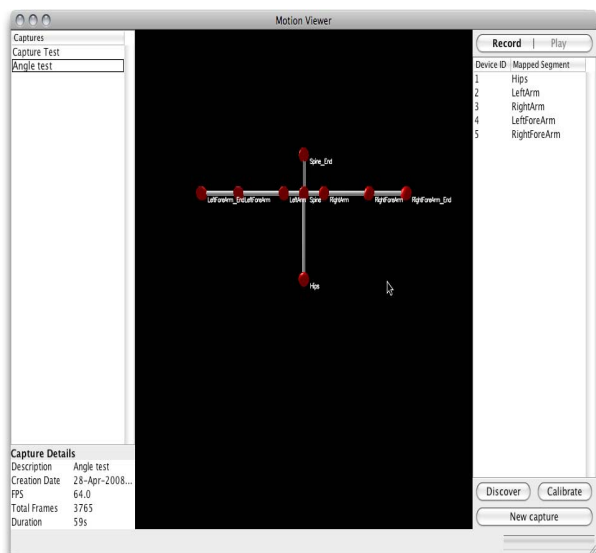
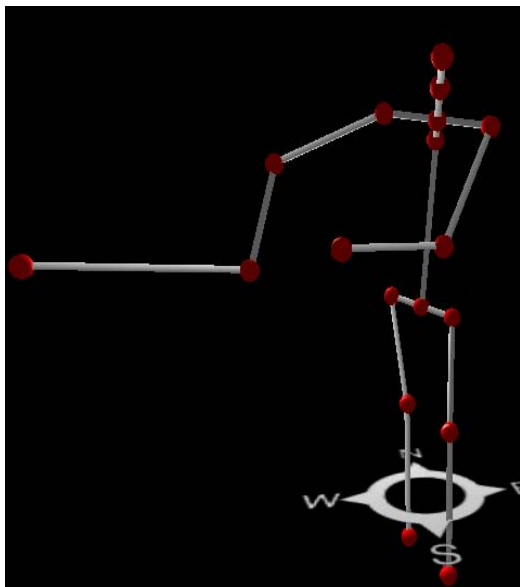


Figure 3. MotionViewer user interface

#### 4. IMPROVISATIONAL PERFORMANCE

The sonification of gestures using wireless motion capture for interactive virtual instruments had been explored in a previous work [12] using on-body wireless network of Orient-2 devices, and interpreting the gestures as sounds in MaxMSP. The current research extends this further by exploring the transcription of whole body movements, such as in dance, into sound. The aim is to create a system for relating human movement with sound within a specific context, i.e., to explore the potential and limitations of whole-body improvisational performances using wireless motion capture systems by interfacing the output of Orient-3 with a set of sound modules and customizable algorithms for adapting to different cultural and artistic contexts.

The Orient-3 is eminently suited (as compared to the traditional motion capture methods outlined in Section 2) for the purpose of creating a framework for bringing together dancers, composers and musicians to explore the different creative processes and their interconnections. It is small, lightweight and unobtrusive and does not interfere with the dancers. It is easy to use with minimal calibration and does not require technical knowledge to operate it. The full-body motion capture data is available in real time which is a critical requirement for improvisational performances. There is no danger of problems due to occlusion when several performers dance in a limited space. The Plugin API in MotionViewer allows easy interfacing to software such as MaxMSP, which is favoured by composers and musicians for its graphical programming environment for algorithmic development. This is particularly important for the task at hand. For instance, within the context of dance, it functions as a virtual musician, whereas within the context of a musician's requirements, it functions as a virtual instrument. These two aspects require the manipulation of different parameters, different algorithmic structures and different compositional techniques. The lack of physical resistance is counterbalanced by the audiovisual feedback.

The framework realises a virtual representation of the postures of the different parts of the body based on the sensor data. The movement of the performer is represented in the virtual space, which in turn powers the engines responsible for audio and visual outputs. Examples of movement data include the velocity of the body parts and the angles between the different limbs.

The framework was tested extensively at a workshop at Dance Base in Edinburgh in June 2008, where the limitations of interactive performances were explored when a dancer digitally manipulated the acoustic musical gestures from a cello and a saxophone [13]. A computational structure was defined in MaxMSP for different sound qualities. The next workshop in November 2008 in Lisbon, aimed to create a more dynamic virtual space and concentrated on the interaction between the physical and virtual elements with concepts such as time and memory were guidelines for the dialogue between the physical bodies and virtual performers, and between a digital composition system and the analogue musical instruments.

#### 5. CONCLUSION

In the first instance, the research focuses on the sonic-compositional element; a future development will realise three-dimensional graphical content based on the interactive relationship between the performer with this virtual space. Initially, the virtual space is limited to a cube surrounding the

body. This will be extended to situate the performer in a more dynamic virtual world with translational movement derived from a camera or step tracking software which are provided as Plugins for MotionViewer. Another extension will be to integrate a pair of wireless datagloves in the Orient-3 Motion Capture System which will capture the expressions of the fingers in tandem with the actions of the hands to provide richer interactions in the virtual world.

Future research will explore the notions of posture and stillness in the context of yoga and meditation practices. Another area for experimentation and validation of research findings will be the application of this framework in a contemporary Japanese dance practice called Butoh which has influenced western dance in a new understanding of body and space.

In the proposed research the movement manifests itself through sonic and visual feedback. The area that has to be better understood and explored is the neutral ground where the exchange takes place between the physical and virtual worlds.

Such interactive system introduce a new reflexive relationship of the body with itself that is revealed through the virtual body: the body becomes both a subject and an object by affecting and being affected by its virtual environment.

## 6. ACKNOWLEDGMENTS

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