# Integration of kinematic Analysis into Computer Games for Exercise

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## Abstract

*This paper incorporates a review of current methods for integrating body movement or physical activity into computer games and a rationale for a new approach in this genre. Computer games are frequently implicated in the increasing sedentary nature of modern lifestyles and associated problems such as childhood obesity. Any measures that help to incorporate physical exercise into computer games will help to advance the notion that they can be used to promote rather than hinder health. Current approaches to integrating physical exercise into games can be divided into 2 categories: (1) camera based tracking of gross 2-D body movement and, (2) sensor based tracking of 2 or 3-D kinematics of regional body segments. These approaches are appropriate for their means yet they do not permit integration of whole body 3-dimensional kinematics into a computer game. Such a system should have the capability to monitor 3-D kinematics from all body segments and reconstruct the body's movement in real-time on screen. Integration of physiological sensors could augment the kinematic data to add features to the game. This approach to gaming could be used to guide and analyse a user while performing a series of exercises such as Yoga or Pilates and give feedback both during and after the exercise regime to help improve future performance.*

## Key Words

Computer Game, Serious Games, Exercise, Motion Capture, Biofeedback

## 1. Introduction and Background

Regular physical activity is associated with enhanced health and reduced mortality [1-4]. Along with the impact on preventing mortality, physical activity has many disease prevention benefits, including reduced risk of cardiovascular disease [5-6] and stroke [7-9]. Despite these benefits of regular physical activity many people still fail to engage in the recommended amounts of physical activity (30 minutes of moderate-intensity activity on 5 or more days per week, 20 minutes of vigorous-intensity activity on 3 or more days per week) [10].

Playing computer games has been associated with many health problems particularly among children and adolescents. The sedentary nature of using only the movement of fingers and thumbs to manipulate hand held controllers or keyboards while playing computer games results in hours of inactivity usually spent sitting. Studies outlining some of the problems associated with playing computer games in the past include wrist pain [11], hand arm vibration syndrome [12], neck pain [13], and repetitive strain injuries [14]. However, computer games for exercise where the players' own body actually takes the place of the mouse or joystick are now being developed and can instead lead to many health benefits.

These exercise games such as the EyeToy: Kinetic or Dance Mat Revolution for the Sony Playstation®2 (PS2) console encourage players to perform physical exercise in an enjoyable fashion. These games capture the players' body movements and use it as input control during virtual exercise games and classes. Virtual reality-type games are typically employed where the player can see themselves or an animated avatar mimicking their movements on-screen in a computer-generated environment. Engaging with a game in this fashion makes the exercise experience more enjoyable therefore increasing their motivation to participate [15]. Inadequate knowledge of how to perform exercise may often limit people from taking part but these games demonstrate how to perform the exercise so the player can copy the movements. O'Connor [15] in a study involving wheelchair users using a purpose built roller system interface (GAME$^{Wheels}$) to play Need for Speed II (Electronic Arts, Inc) showed a significantly higher level of exercise intensity was achieved during the computer game compared to the control condition of exercising without any game. There was also a self-reported increased motivation to partake in wheelchair propulsion exercise shown in participants. This suggests that such systems can provide a very engaging and motivating form of physical exercise training.

Section 2 will give an exposition of current technologies in use for such integration while Section 3 proposes a more advanced method of motion capture in that could be implemented in gaming.

## 2. Existing Approaches to Integrate Exercise and Computer Games

There are many movement based human computer interfaces on the market. These include camera-based systems and position sensor systems. Position sensor systems include systems with a single sensor worn on the body at a key reference point (usually worn on a belt around the waist) or dance mats. All approaches work well in achieving instantaneous feedback and interaction with onscreen objects.

In camera based computer games the player can view themselves in a virtual environment as they interact with on-screen objects in real-time. Games are quite simple and usually involve the tracking or evasion of on-screen objects. For example the Sony EyeToy for the PS2 employs a single USB camera to place the player in an on screen environment. Games such as EyeToy: Kinetic feature a host of fitness exercises ranging from combat games where players must use their limbs to hit specific moving targets to exercise programmes where the player must copy the on screen virtual personal trainer. Performance rating scores can be recorded for games where on screen targets have to be hit.

GestureTek Inc™ have produced many camera-enabled computer control systems. The Gesxtreme system is a virtual reality-type game where the player can also see their virtual body on-screen and interact with objects to play the games. The IREX exercise system, by the same company, is used as a tool in physical rehabilitation and is also a camera-based system. While these sorts of camera-based systems are very engaging from an interaction point of view the problem is that they can only track gross body movements in a single 2-dimensional (2-D plane (up-down and left-right). It lacks a sense of 3-dimensional (3-D) immersion. The addition of this depth dimension would allow far more realistic and challenging physical interaction with the gaming experience.

The Cybex Trazer® (Cybex International, Inc.) employs a single infrared beacon mounted on a belt worn around the waist of the player. The position of this sensor is monitored by the tracker bar of the system to capture motion of the player which can move an on-screen avatar as one rigid block to play various drills and games. Heart rate is also monitored through sensors located in the belt in this system and information relayed to the computer.

Dance mats are used in games have a number of sensors located at specific sections. These are used sense pressure and therefore identify when the foot is placed over them. During these games such as, Dance Factory for the PS2 or Dancing Stage Unleashed™ for the XBOX Live, the player must step on an arrow on the mat to match the on-screen directional arrow while listening to music and press the feet on the correct area of the dance mat controller at the correct time. Speed and timing are important and increase through the difficulty levels.

Although these systems meet the goals of each game successfully they lack the capability to capture detailed human movement and administer accurate biofeedback on individual body segment. All human motion is 3-D therefore requiring some form of discreet motion tracking. These systems are only useful for cardiovascular type exercise as they have no discreet movement analysis capability and therefore they cannot be used in games where accurate measurement of body alignment and posture is required in order to judge player performance. This means that games based on movement therapies or martial arts cannot have an accurate scoring system based on full body movements with current approaches. For this to be achieved a method of quantitatively tracking the different limb segments must be employed.

## 3. A More Expansive Approach: Whole Body Kinematics

Advanced motion capture technologies that analyse discreet body movements have been continuously developed and improved in recent years. These are utilised to study the biomechanics of the human body and investigate clinical problems, as well as to provide realistic animation for the entertainment industry. This has usually taken place in a laboratory setting but technologies are increasingly being employed in peoples' natural environments at home, at work and during sporting participation.

The most commonly used method for accurate capture of 3-D movement require attachment of markers or fixtures on the skin's surface of the segment being analysed [16] (Figure 3.1). These are used to derive data on position and orientation of joints. Physiological sensors could also be utilised to monitor heart rate or breathing rate during the exercise.

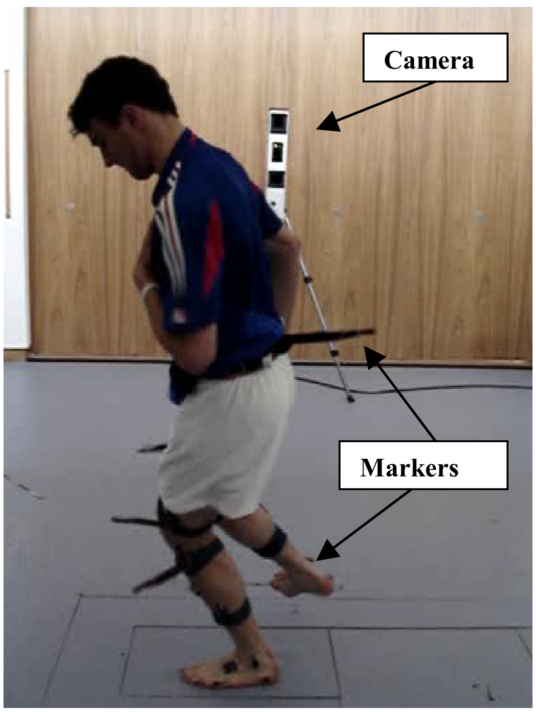


Figure 3.1 Laboratory based Motion analysis.

Integrating kinematic analysis technology into computer games for physical activity would bring this type of gaming to a higher level. Detailed analysis of joint movement would allow a virtual personal trainer to give more effective instantaneous feedback on the postures and movements achieved during the gameplay. Users can be guided through a series of exercises and receive immediate and accurate feedback regarding the quality of their performance based on a combination of their movement and physiological indicators. The system could then serve as an educational tool for learning movement based exercise techniques. Objective measures of performance over successive sessions with the game could be recorded and progression of performance0 mapped over time. It could be argued that such a system is preferable to a personal instructor as it offers a greater level of accuracy in judging the quality of movement and physiological control than would be visible to the naked eye. It also allows the user to be less self-conscious in their engagement with the exercise as they can play the game in the privacy of their own home.

All human motion is 3-D therefore requiring some form of discreet motion tracking. This means that games based on movement therapies or martial arts are not possible with current approaches. Obviously, extending the scope of the computer gaming spectrum to include this type of exercise would be beneficial to encourage greater levels of participation in exercise designed to improve mind and body function as well as the cardiovascular aspects of fitness that are catered for in existing gaming technology.

## 4. Design Features

From the afore-described discussion it is apparent that whole body tracking is perhaps the next step forward for physical movement controllers. To this end then we tentatively suggest some basic components and specifications for such systems and how the game will be designed.

### 4.1. Motion and Physiological Sensors

For robust 3-D motion tracking, an orientation sensor is preferable as it can easily be applied to a body segment and will produce continuous movement data without the need to be 'in-view' of a camera at all times as some marker systems require. In selecting a sensor it is important to mention the difficulties that may be encountered such as tolerance, fidelity or noise with the data. From work others and ourselves have done previously we would suggest the use of 3-D accelerometers for this purpose [17]. A body sensor network of one sensor on each of the shin, thigh, forearm and upper arm along with one on the back and head is the minimum requirement. Physiological sensors to monitor heart and breathing rate may also be included in the system.

The sensors can be embedded in a lycra garment which will be worn by the player during the gameplay. The continuous development of smart fabrics, which are have sensing materials either coated on or woven in the textile structure, may eventually lead to the possibility of using textile-based sensors.

### 4.2. Wireless Interface

A tetherless controller would in our opinion be more suitable for such a device that current wired systems such as GameTrak have not achieved. This would allow freedom to perform exercises without the restrictive wires or cables. Indeed controllers for all the next generation games consoles (Xbox 360, PS3, Revolution) are all wireless. Clearly this is what we want to see then in any sensor based kinematic controller.

### 4.3. Software

Software will process sensor data in real-time to administer audio and visual biofeedback to the users along with recording data for post game analysis. This will be based on their performance in the game (i.e. how close the player is to the correct postures throughout the exercise programme) against pre defined expert level of performance. Modifiable programmes to meet the goals and capabilities of all ages can be included. Games designers can incorporate this into the games using their own creativity.

### 4.4. Playing the game

Playing the game will require wearing the sensor-based garment as the human computer interface. Initial calibration of the sensors will be required before the game begins and screen display will instruct the player to calibration position. Progression mapping of performance over time will be used to generate short-term goals for players. Applications for such a game include training to improve cardiovascular fitness and endurance, reaction time, spatial awareness, physical rehabilitation and injury prevention programmes.

### 4.5. Obstacles and Limitations

With the large amount of input data from sensors a large amount of real-time processing will be required by the system. Cost effective hardware must be producible so an affordable system can be reproduced. Also, performance data must be generated from analysing experts performing the exercises for the games to be designed.

## 5. Conclusion

Detailed motion capture and physiological monitoring technologies employed to give real-time visual and audio feedback could be employed to design the next generation of computer games for exercise. Such a system could accurately progress a player through increasing difficulty levels and eventually be used as a training device during movement rehabilitation.

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## Author Biography

Mr. Diarmaid Fitzgerald is a postgraduate researcher at the School of Physiotherapy and Performance Science at University College Dublin. Mr. Fitzgerald is currently involved in a research project aimed at producing a virtual reality-based computer game to teach a player an exercise programme. This involves using motion and physiological sensors to analyse the player and give instantaneous feedback on the players' performance. Mr. Fitzgerald holds a BSc in Physiotherapy from University College Dublin.