Whole Body Interaction: Literature Review of Whole Body Tracking

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ABSTRACT
Sensors such as Kinect and Leap Motion have made whole body tracking a lot easier which opens up many possibilities of using the technology, such as exergaming which can help improve physical fitness by combining video games with exercise. However, current generations of applications using full motion tracking are inaccessible to elderly and those with mobility disabilities due to them not having full range of motion of their bodies. Part of this problem can be solved by designing dynamic interfaces that change depending on the user abilities. This paper looks at literature on the research of whole body interaction and the accessibility available to all types of users as well as making physically active video games and the effectiveness of them.

Author Keywords
whole body interaction; body tracking; human computer interaction; exergame; exergaming; game design

INTRODUCTION
Gorilla-arm is a condition when mid-air interactions lead to a feeling of heaviness in the upper limbs[5]. This condition can often be found when using technology such as the Kinect or Leap Motion due to them having whole body tracking. Applications which use such technology do not consider the accessibility issues that come with using such input. There are many different considerations that need to be made in whole body tracking, this paper looks at some of those considerations and why they are important.

RELATED RESEARCH
Exertion Interfaces
Problem
Exertion interfaces are meant to engage users by providing an entertaining experience. Issues[6] in designing such interfaces need to consider flow and engagement issues where flow is the mental state of ‘optimal experience’, induced by a focused and successful activity. Obvious methods of obtaining exertion interfaces is to connect exercise machines (treadmills and exercise bikes) to a virtual environment. This device can then be used to navigate through the application. However, performing actions on a physical device reduces the amount of engagement felt by users as they are not distracted away from the fact that they are doing physical activities. Current commercial applications fail to adapt the interface to individual users, instead going for a one-size-fits-all approach. There have been attempts of modeling flow and immersion in movement-based interfaces but the study found that there are few models of the gaming experience.

Solution
A solution for an adapting interface is to measure mental states of users. This can be done by using sensors to automatically measure experiences which can help in improving the design. Some of the existing sensors are cameras and microphones that allow visual and audio processing of user activity. These sensors can provide information about location changes (skeletal body structure movement and face tracking), frequency and expressiveness of movements. Other sensors can detect touch, pressure or proximity. One of the issues with using these sensors is that some users may not be willing to let information about them be given away despite the information being used by a system to provide a positive experience.

Future Work
By allowing to measure mental states, the interface will be able to change according to how the current user experience is. Future development of exertion interfaces should embed sensor technology in game designs and game experience research. Although sensors have made whole body tracking easier, more effort needs to be placed in designing interfaces that provide a positive user experience.

Exergaming Energy Expenditure
Concept
Due to the increase in ease of detecting full body movements, one of the recent areas of research is the development of exergames. An exergame is a video game that is also a form of exercise, such as the Wii Fit. Previous research in exergaming has focused on evaluating consumer products as a potential replacement for traditional seated game play. The focus of a research[1] looks to determine the relative effect of interactive digital exercise that features player movement on energy expenditure. With the prevalence of over-weight children and adults increasing over the past few decades, the use of exergames has the potential to combine the entertainment aspect of games with the health benefits of performing exercise. Previous research in exergaming has focused on
evaluating consumer products as a potential replacement for traditional seated game play.

**Methods**

Thirty-nine boys and girls (with a mean age of 11.5 and varying body mass indexes) from local schools and after-school programs participated in the study. This comparative study involved testing six different exergames and treadmill walking with 3 games being commercial products (Cybex Trazer, LightSpace, and Sportwall) and 3 being consumer products (Sony Playstation [DDR], Nintendo Wii, and Xavix). Each of these systems have various game modes and levels within them, so the levels tested were based on their potential effect on energy expenditure and potential enjoyment. The primary measurement in the study was energy expenditure during rest and exergame play while enjoyment and body composition were also assessed.

Measurement of energy expenditure was done by using indirect calorimetry during physical activity and using of a CosMed K4B2 portable metabolic cart during rest. Participants, on arrival, were required to rest for 15 minutes to measure the energy expenditure of seated rest. The activities were performed for a duration of 10 minutes with 5 minutes of seated rest between activities. After each exergame, user enjoyment was measured using a 10-point discrete analog scale. The question asked to the users was How much did you enjoy this activity?, with answers ranging from “not at all” to “very much”.

**Results**

As seen in Table 1 below, all of the exergames tested had increased energy expenditure above resting with five of the exergames having more energy expenditure compared to treadmill walking at 4.8 kilometers per hour. Enjoyment results, seen in Figure 1 below, showed that all of the participants generally enjoyed the games but the highest enjoyment was for children with body mass indexes in the highest percentiles.

![Figure 1. Mean (SD) enjoyment ratings by exergame and sex](image)

**Future Work**

All of the games used in the study elevated energy expenditure to moderate or vigorous intensity and suggests that exergaming has the potential to increase physical activity and be a viable alternative to traditional fitness activities. Future work could include advertising and releasing exergames as an alternative to getting healthier.

![Table 1. Energy Cost of Exergaming Activities by Body Mass Index Classification](image)

**Application Design**

**Concept**

One of the considerations of whole body tracking improving is the ability to incorporate other methods of input which combines to create a full immersion-based experience. With mobile phones becoming smarter and more powerful, more functionality is able to be performed by them. Sensor components in phones are able to detect movement, actions and intentions to enhance the human-computer experience. Exergames have been created for helping rehabilitating patients without needing direct supervision from physiotherapists[3]. It incorporated the use of a single mobile device, such as an iPhone, to act as a single sensor input to the game. It used the 3-axis accelerometer in the iPhone to measure the angle of the phone with respect to gravity. A physiotherapist interface is included so they can observe the performance and gather results of the patients. Observations of patients using the game showed that it should be easy to add or remove feedback based on user preferences and a one-size-fits-all approach is not recommended. So despite the application being useful, results show an adaptable design should be used. In order to design applications with these considerations in mind, a conceptual framework[7] was designed that identifies the core elements of interfaces that use body interaction.

**Methods**

The framework is as follows:

- At least one device with one or more built-in sensors, and an operating system that supports the development of custom applications
- A client application that runs on each device, interacting with the operating system to read sensor data, and communicate the data through a wireless network
- A host application, which receives data from the application(s) and interfaces with the videogame in question to convey the desired action to the game.
- A wireless communication infrastructure to support communication between device and host applications.
A proof of concept implementation of the framework was made which involved using a mobile phone to capture additional input. A user experience evaluation of the demo application was performed after implementation and unit-testing of the framework.

Results
Participants found the technology enjoyable and showed a clear intention of using such technology. The testing performed validated the use of the framework and that it is able to make no assumptions of the technology used while still working correctly with varying changes in design.

Future Work
The framework developed would need to be further evaluated using a broader scope as it be able to make better conclusions as to how effective the framework is.

Accessibility
Problem
Full-body motion-control games using technology, such as the Kinect, provide an opportunity for people to remain active and engaged. However, these games are not designed for use by the elderly and those with age-related impairments. FitForAll[2] was created to help elderly patients entertain themselves while they do their workout. It makes use of both body tracking and a platform to depict movement patterns on a screen. Further investigation from them wanted to look at enhancing the elderly user experience and suggest that adaptation of an interface based on user abilities would result in a more effective training exercise. So while full body tracking is easier, no consideration is given to those that don't have full body movement. There are no guidelines for designing gesture-based games for elderly, and applying HCI principles is difficult because games require consideration to balance the difficulty needed to bring challenge and ease of use. Two studies[4] were performed to explore full-body motion control for elderly. The first study evaluates various gestures in terms of how older persons could perform them. Results from the first study were used to design a game which was evaluated by participants in the second study.

Study 1: Methods
Four static and four dynamic gestures were used in a tool which helped to evaluate the feasibility of gesture based interaction. The tool[4], which utilises the Kinect, prompted users to perform the following gestures:

Static
1. Hands together
2. Raise one arm
3. Arms to the side
4. One-leg stand

Dynamic
1. Clap hands
2. Wave arm

3. Pretend to fly
4. Walk in place

Instructions were provided to the user through descriptions such as "Put your hands together" while a stick figure performed how the gesture should be done. Upon successful completion of the gesture, the user is notified and performance metrics (gesture completion, tracking quality) were recorded.

15 participants were used (mean age of 73.72). 13 of them were in a wheelchair, 1 used a cane for walking support and 1 able to walk independently. Only 8 participants had played video games before, 7 of them having used a Wii.

Study 1: Results
Participants rated their interaction experience using a 5-point Likert scale. Results show that there was a positive experience overall with respect to the amount of fun users had performing the gestures. The difficulty overall for completing the gestures was relatively low with 67% not being afraid of losing balance.

Hand gestures were highlighted as the easiest gesture to perform while gestures that required movement from impaired parts of the body were the most difficult, being leg-based input and gestures using both arms.

Completion rates for each gesture, seen in Figure 2 below, show high completion rates static hand-based gestures while dynamic gestures had lower completion rates. This matches with what the participants observed.

Figure 2. Completion results for gestures in percent (CI: 95%)

The first study found large differences in participant abilities due to the differing ranges of motion for each user and their strengths affecting the ability to perform and hold a gesture. Games for the elderly need to consider the issue of wheelchair tracking by using space that isn’t affected by the chair.

Study 2: Methods
Based on the results of the first study, a gesture based game for elderly was created[4]. The gesture system was designed to provide adaptable interaction paradigms that accommodated age-related changes, such as not being able to raise arms over a certain degree or allowing slower steady movements.

To test the game, 12 older adults (mean age 76.7) were used as participants. Each had the opportunity to freely play with the game. After the session, a questionnaire was completed...
which gave feedback about the gestures and game mechanics.

**Study 2: Results**

The questionnaires revealed that gestures were perceived as suitable, and the game was perceived as easy and fun. Some participants noted an increase in their alertness and suggested that more feedback and options would improve their experience. Researchers also noticed that participants could not perform free play on their own.

From the results of this second study, a set of design guidelines were created for the design of whole-body gestures of the elderly. The guidelines are as follows:

1. Age-Inclusive Design
2. Range of Motion Adaptability
3. Exertion Management
4. Dynamic Game Difficulty
5. Easy Gesture Recall
6. Continuous Player Support
7. Simple Setup Routines

**Future Work**

Results[4] indicate that future research should explore on-screen instructions for institutionalised adults and that the effect of their guidelines in game design for older adults should be evaluated.

**CONCLUSION**

Despite the improvement of body tracking, there is still a while to go until proper design considerations especially designed for body tracking applications are made. Research shows that headway is being made into making it more accessible and that everyone is considered in the human-computer interaction.

**REFERENCES**