Ambient videogames for health monitoring in older adults

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***Abstract*— Ambient videogames can be used for frequent continuous monitoring of older adults in order to detect early signs of frailty. In this paper we propose a general architecture for health monitoring through ambient videogames and illustrate its instantiation with the development of two ambient casual games that have been designed to measure arm muscle strength utilizing a custom-designed interaction device that provides a natural user interface for the games. The games are designed to be used frequently and for short periods of time. We conducted a formative evaluation of the games with 5 older adults to assess ease of use and their interest in playing them. We compare the results of traditional measures of muscle strength using a clinical dynamometer with those obtained using the videogame.**

Keywords- Game design, ambient games, embodied interfaces.

I. INTRODUCTION

Ageing is one of the major social and economic issues facing modern society. It is estimated that by 2030 more than 50 countries are expected to have at least 20% of their population over 65 and according to the United Nations Population Division, 1 in 5 people are expected to be 65 or older by 2035 [1]. This demographic shift is becoming particularly acute in developing countries that have seen their fertility rates drop sharply in the last few decades and which have more limited resources to cope with the problem.

One of the main issues related to the care of elders is the diagnosis of their physical state. One way to detect functional decline in an older adult, and therefore, the increase of dependency, is through the measure of their frailty. Rockwood et al [2] described the concept of frailty as a multidimensional syndrome which involves loss of physical and cognitive reserves and ultimately an increase of vulnerability.

Recent studies reveal that more than 65% of households in the USA play videogames [3] and the numbers are growing. More surprising is the fact that there are more people over 50 that play games than children [3]. When Nintendo launched its Wii console, introducing a simplified controller with a unique and intuitive control scheme, it opened the door to a new class of players. These types of games have been referred to as “ambient games”, games that incorporate a new paradigm of interaction, which allows an embodied, physically active way of engaging with the game. Some authors suggest that this new form of gaming brought back the game play from the 3D space used by many conventional games to the physical user space [4]. Also this kind of interaction style could be used as a persuasive technology to provide incentives for a healthier life [5] or to promote social engagement. In fact, popular consoles like the Nintendo Wii have been introduced in community centers and old people’s homes where they are being used as an alternative leisure activity to help in physical and cognitive stimuli [6][7].

The purpose of this study is to design and evaluate ambient videogames that allow the measurement of muscle strength to assist in the detection of early signs of dynapenia, without waiting for a visit to the physician for a clinical assessment. We propose that the continuous unobtrusive assessment performed by the video game interface could be equal or more effective than the assessment performed in a clinical environment. The continuous use of the games may reveal a complete picture of the measured strength and its evolution, motivating the patient to participate and eliminating the stress induced by these tests, while increasing the ecological validity of these measurements.

The rest of the paper is organized as follows: Section II discusses the use of videogames among older adults. In Section III we introduce a general framework for ambient videogames for healthcare. Section IV presents the design and development of two videogames to measure muscle strength as well as results from a preliminary evaluation of the system.

II. VIDEO GAMES AND OLDER ADULTS

There is a growing body of evidence indicating that video games can have a positive impact on the elder’s mental and physical condition. One of the first or these studies focused on the improvements of the perceptual abilities of the elders using the first generation console games like “Pacman” and “Donkey Kong” which recorded reductions in the reaction time and improvements in cognitive performance of the test subjects [8]. In another study, subjects over 60 years-old played the game “Tetris” for a period of five hours a week over a five week period. The results suggested that the use of games enhance the attention, hand-eye coordination, fine-motor skills, short-term memory, and problem solving and speed reactions [9]. Another kind of study focused on the diagnosis of illnesses associated with age like Alzheimer’s [10]. Video games have also been used for occupational therapy or to bring a sense of accomplishment and improve self esteem in a long-term care facility [7].

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With the arrival of the ambient games, movement base interaction is now possible, enabling the user to employ active body movements as a way of interaction. Muller et al [11] defined the term “exertion interface” to highlight the physical activity that this games can afford, which later followed the appearance of a new kind of games called “exergames”. Pasch et al. [12] studied some of these benefits and the means to engage the player in physical activity in order to fight obesity or sedentary habits. Liberman et al. [5] discussed the implications of the use of this active-play technology to possibly change the sedentary behavior and at the same time provide motivation to be more physically active, and preventing diseases derived from a sedentary life such as cardiovascular diseases or strokes.

Finally, videogames have also been observed to promote social interaction with peers of the same age and strengthen intergenerational relationships [13].

2.1 The emergence of embodied interfaces

Most of the success of the new generation of game consoles and, particularly, the Nintendo Wii and Kinect are due to the physical interfaces that mimic the action in the games. Watt [14] proposed the term “video game embodied interfaces” as “…an interface which draws on players’ spatial and physical skills, and leads players to express themselves through physical actions which have an intuitive and meaningful relation to the game they are playing”, a definition based on the concept of embodiment advanced by Dourish [15] and Ishii’s tangible bits [16]. Another definition of this kind of interfaces is given by Juuls [4] who referred to them as “mimetic interfaces”. Both definitions highlight the benefits to players and game developers:

1. Embodied interfaces provide more accessibility than generic interfaces
2. The operation of this type of interfaces is more visible and easy to grasp to the outside observer
3. This type of interfaces provides a more social environment.
4. The use of these interfaces creates the possibility for new types of game play.

III. Towards a Framework for Ambient Videogames for Health Monitoring

Our aim is to provide a general framework to facilitate the development of personalized ambient videogames that monitor health and wellbeing. By continuously monitoring the health status of individuals, particularly of elders, we might be able to detect early signs of increased frailty such as a sharp decrease in weight or loss of muscle strength.

Figure 1 shows a general scheme of our framework. At the bottom layer are the different sensors that measure physical variables. These include commercially available devices such as the Wii Remote and Kinect sensor, as well as custom-made devices as the one presented in this paper to measure muscle strength. These devices generate signals, in some cases directly, in other cases by the fusion of data from different sources. These are then connected, through a component-based architecture to game play abstractions that provide high-level constructs for the development of videogames. The device and games discussed in this paper provide initial evidence of the feasibility of such a framework to facilitate the development of ambient videogames for healthcare monitoring.

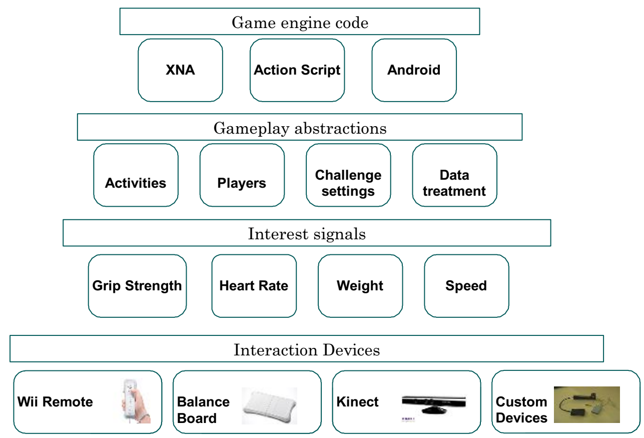

Figure 1. A Framework for ambient videogames for health monitoring

IV. Design of Videogames to Measure Muscle Strength

This section describes the design and implementation of two video games to assist the early diagnosis of dynapenia. Following a user centered methodology, the development started with an initial case study in which the research team gathered insights to inform the design of the games in order to make them engaging and easy to use.

4.1 Initial case study

The purpose of this initial case study was to gain an understanding of the elder’s perceptions about games and identify what types of games would be entertaining for them and easy to learn. With that in mind we selected a few games for two popular commercial game consoles: the Xbox 360 and the Nintendo Wii. The games chosen included exergames like *Wii fit* or *kinect Sports* and casual games like *Kinect Carnival*.

4.1.1 Participants

A group of 11 elders was selected from a local community center. Their age ranged from 65 to 85. The majority of the participants were active and none of them suffered from dementia or other cognitive impairments but most of them suffered age-related impairments to their mobility. One participant suffered from a hearing impairment. Although some of the members of the group had contact with video games none of them had significant experience playing them.

4.1.2 Protocol of the intervention

The protocol for the evaluation was as follows:

1. The purpose of the study was explained to the group.
2. Participants were asked to complete a survey to gather demographic data and information about their experience using technology and video games in particular.
3. The 11 participants were divided in two groups. One group gathered for a playing session in a room with an Xbox 360 using the Kinect sensor, while the other group played with the Wii console using the Wii remote sensor. After the first play test session both groups were interchanged to allow all participants to experience the use of both consoles. Each session with one of the consoles lasted approximately 45 minutes.
4. Finally, after the play test session a focus group took place to obtain the user's preferences and to reveal what particular traits in the games were more appealing, their perceptions about the game played, and the difficulties they experienced trying to complete the game tasks.

4.1.3 General Observations

Even though all the participants reported that they enjoyed playing both Xbox 360 and Wii games, most of the players had problems performing adequately during the game sessions which can be attributed to a lack of experience, ignorance about game conventions and age-related impairments. All participants reported feeling anxiety and insecurity at the beginning of each new activity presented and that they needed guidance mostly to help in the complex menu structure navigation of the games and to clarify the activities introduced like button sequences, movements, etc. The familiarity of the activity helped to engage the player. For example, one of the female participants suffered of hearing impairment and refused to actively participate in the game sessions at the beginning, but when the game of yoga was introduced she asked to participate since she used to practice yoga a few years ago, and actually performed quite well in the activity.

4.1.4 Focus group discussion

Despite the difficulties encountered during the game sessions, the comments made by all participants during the focus group suggests that playing these videogames was a pleasant experience and a valuable alternative to the real physical activity. For instance, one of the participants observed:

"I like these games because most of us have difficulties to leave home and do any kind of exercise, and this is wonderful".

They specially liked those games that were more familiar to them, even when they did not performed so well. Games like baseball or tennis that brings simple and well known rules are highly usable even for an elder, which highlights the need for an intuitive and simple interface with familiar mechanisms:

"It really seemed so nice because these are the movements that we are familiar with or at least we've seen like baseball".

The participants claimed to have experienced difficulties at the beginning of each game but that the assistance of the facilitator helped them better assimilate the activity:

"When the assistant came to me I felt more secure, it's like it gives more security, doing it alone would be stressful".

Also they reported that, surprisingly the challenge of some games was encouraging:

"I liked the games that require movement and also the challenge of hitting the ball".

Playing the games in a group of people of the same age was perceived as an important factor in making the session a positive experience:

"The younger people go so fast and learn too fast, being with people of the same age, the same way of speaking, of move, all that gives me more confidence and then I feel that I can do it".

The participants also discussed that their anxiety and insecurity diminished when they started to score points in the game:

"At first I felt that I didn't know what to do, but when I knocked a bomb I started to feel all right".

Finally the participants experienced emotional bounding with each other:

"We felt closer… for example I got up and hugged my partner to help her in hitting the thing".

Another interesting result is that the physical interaction demanded from these games was well appreciated not only because it encouraged social interaction but also because most elders in the study were conscious of the importance of keeping physically active. Finally, the participants felt more confidence when they started to obtain positive feedback while playing the game.

4.2 Development of the interaction device

A crucial aspect of this work is the development of a device capable of measuring the user's grip strength as he plays the videogames. For that purpose a Vernier Hand

Dynamometer [17] was chosen as the core element of the interface along with additional electronic circuitry to augment the interface with more interaction affordances to the player such as an accelerometer, digital buttons and a heart rate sensor to gather bio signal feedback during the engagement. A schematic representation of the device's interface general architecture is presented in the Figure 2. The interface consists of a Digital Signal Controller (DSC), an accelerometer, a ZigBee radio chip to allow wireless communication and a sensor receiver [18] for a Polar heart rate transmitter [19]. In the prototype the DSC is a Microchip dsPIC33f64GP802 [20], the accelerometer is a MMA7455 [21] and we used an XBee [22] module for the ZigBee network implementation. The DSC regularly (around 20 times a second) gathers the reading of all the sensors and then structures the data in a packet format to be transmitted through the Zigbee network. Another ZigBee module acts as a receptor connected to a PIC18F2550 [23] microcontroller to gather the sensors' data through a USB interface. In this way we can reprogram the controller firmware over the air to make adjustments of the data or calibration. The interface implementation is showed in Figure 3.

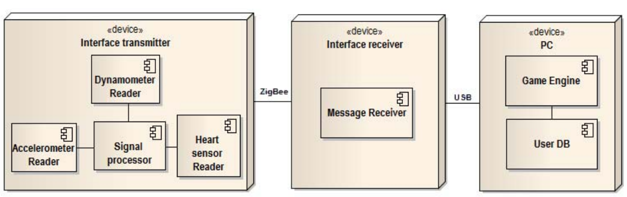

Figure 2. Interface architecture

Figure 3. Interface devices

The interaction with the game controller begins when the user performs an action which can be to press a button, exert a force on the dynamometer or move the arm. As shown in Figure 4 the transmitter device reads the sensors and establishes a link with the receptor which then requests the data to further transmit it through the USB connection. A communication manager is provided to handle these low level messages to process the user response, record it and later generate events in the game engine providing visual feedback to the player.

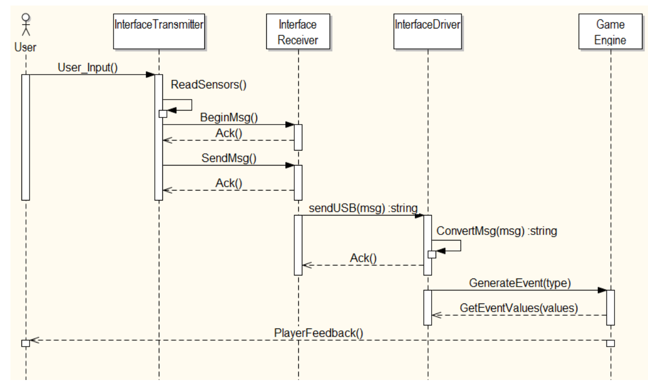

Figure 4. Sequence diagram for the interaction device

4.3 Comparison with the clinical dynamometer

To test the precision of the video game interface we conducted a test to compare the measurements of a clinical dynamometer with those of the interface developed for this project. Measurements were taken from 10 participants using both devices and both hands. The correlation coefficient obtained is 0.98. Thus, the interface device properly measures grip strength.

4.4 Design and development of the games

For the game design we followed an iterative design process. In this development methodology, the designers conceived the game concepts through brainstorming. In our case we tried to provide a game play with intuitive mappings between the interface device and the game mechanics. Later, we tested the games starting from early concepts followed by low fidelity sketches, which provides a basic impression of the design, and later with the initial functional prototypes. In this process the designers become active participants in order to find possible flaws in the design concepts and the game play, making possible a special form of research and experimentation defined as "playcentric" approach [24]. The Figure 6 illustrates this process.

4.5 The game Concepts

During the design process, the designers proposed several game concepts during the brainstorming sessions and two concepts were selected based on the design insights obtained from the focus group session. The first videogame was based on a game of pool given that most aged players are familiar with this concept and requires the user to throw a white ball using the measured strength. The ball must be directed strategically to hit other balls of different color placed on a table in order to insert them in a hole marked with the same color. In that way, the player needs to figure out how to hit the balls to match the color patterns from the balls and the holes. When this happens a sound is played, giving positive feedback to the player.

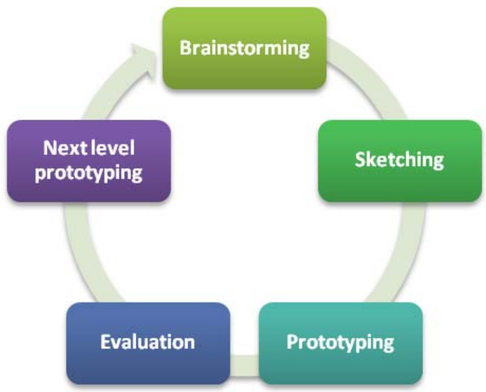

Figure 6. Iterative game design process.

Several affordances are included to give feedback of the amount of strength used in the controller like a sliding bar and a sound indicating an increase of the strength with which the ball will be hit. Once the player releases the pressure in the controller it will throw the ball with the amount of power registered in the bar. We decided to add strategy and physics based reaction of the game elements to deliver a more engaging experience. Figure 7 shows the screen of the interface of this game.

The games were developed using action script 3 and the physics engine Box2D to provide the visual elements and C# and the .NET 3.0 framework to handle the low level interaction with the devices.

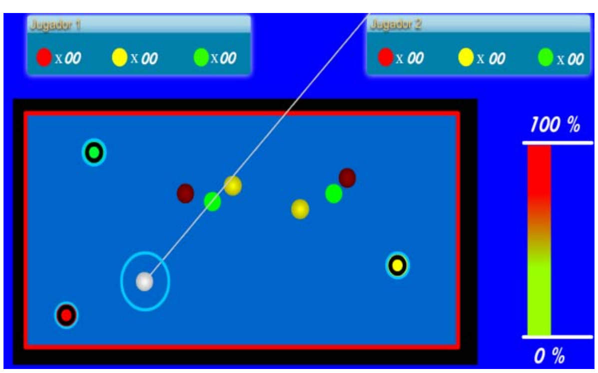

Figure 7. Pool Game screen.

The second game was selected for simplicity so as not to provide a complicated plot for inexperienced players that are not familiar with the common conventions of current games. This game was based on the old platform games and requires the player to control a bird utilizing hand strength. When the player presses the controller, the bird will gain height and speed trying to avoid the planes flying randomly on the screen and at the same time enabling the player to collect items. If the bird collides with a plane an explosion will occur and the player will lose points. On the other hand if the player hits the items, he will earn score points. The use of these items was intended to give a sense of motivation and a defined goal.

Figure 8. Bird game screen.

Figure 9. A user playing the games with the video game interface.

4.6 Preliminary Evaluation of the game

After several iterations within the design team we conducted a formative evaluation with the target audience. We invited five participants from the same community center of those who participated in the initial case study. The group's mean age was 71 years old and only one had experience playing video games before. After inquiring demographic data, the prototypes were presented to the participants in a 30 minutes play session. The purpose of the session was to find out if the game play devised was intuitive enough and verify if the difficulty settings were appropriate for the elders. For that purpose we conducted observations during the game play and asked them several open questions after they played.

After the play sessions the participants revealed that the pool game was more appealing to the male participants, maybe because of previous experiences, while the female participants preferred the bird game. Both games were easy to understand but the pool game needed more time to master because it required more skill and strategy than the other game but kept most players trying to improve their performance. In contrast, the bird game was very easy to learn but some of the players found it little engaging after a few minutes of playing it. So we found that adding more depth to a game play in general results in a more engaging experience when the rules are simple so that no significant cognitive effort is required to learn to play them.

Further refinement and play testing with older adults is planned in order to adjust the appropriate level of difficulty and to improve the usability of the game interfaces.

V. CONCLUSION AND FUTURE WORK

In this paper we presented the design and development of two casual ambient games that involved the use of a prototype of an embodied video interface. We found that this device accurately measures the grip strength to assist in the detection of early signs of dynapenia. We also conducted a preliminary usability test and found that these games resulted appropriate and can be played by older adults although the results revealed differences in perception about difficulty based on gender and past experiences. This suggests that several game concepts need to be explored in order to attract a broader audience of older adults. Further evaluation tests and refinements of the user interfaces and game play need to be performed to adequately address the elder's usability needs.

Future directions may involve a better organization and treatment of the data gathered by the game to assess possible abnormal physical conditions. Another interesting improvement could be to introduce game play auto adaptation based on the signals received from the sensors to balance the difficulty presented with the skills perceived or the physical condition to provide better incentives for player engagement.

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