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Design of a Computer Vision Based Exercise Video Game for Senior Citizens

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***Abstract*—**There are numerous changes, both mental and physical, taking place when people age. We need to understand the different aspects required for healthy living, including meeting nutritional needs, regular physical activities to keep agility, sufficient rest and sleep to have physical and mental well-being, social engagement to avoid the risk of social isolation and depression, and access to healthcare to detect and manage chronic conditions. Promoting physical activities for an ageing population is necessary as many may have enjoyed sedentary lifestyles for some time. In our study, we evaluate the considerations when designing a computer vision video game for the elderly. We need to design some low-impact activities, such as stretching and gentle movements, because some elderly individuals may have joint pains or mobility issues. The exercise game should consist of simple movements that are easy to follow and remember. It should be fun and enjoyable so that they can be motivated to do some exercise. Social engagement can keep the elderly motivated and competitive, and they are more willing to engage in game exercises. Elderly citizens can compare their game scores and try to improve them. We propose a computer vision-based video game for the elderly that will capture and track the movement of the elderly hand pushing a ball on the screen into a circle. It can be easily set up using a PC laptop with a webcam. Our video game adhered to the design framework we employed, and it encompassed ease of use, a simple graphical interface, easy-to-play game exercise, and fun gameplay.

***Keywords*—**Computer vision, video games, gerontology technology, caregiving.

I. Introduction

HEALTHY living is important for the ageing population and the key factors for evaluating a healthy lifestyle include maintaining sufficient physical activity that include low impact exercises, balanced nutrition consumption, adequate sleep, social engagement with family and friends, and access to healthcare and screening. Technology such as computer vision is used for helping elderly to recognise fall detection, identify different postures and motions, and monitor sleep quality by detecting tossing and turning.

There are pilot studies conducted on interactive computer vision systems for home-based physical therapy [1]. ExerciseCheck, an interactive computer vision system, is designed to work with different sources of human pose estimates using traditional and deep learning models. It can customise exercises and perform evaluation of patient performance based on captured exercise information. The patient's progress can be tracked by the patient and the therapist to support the patient during the therapy duration. Computer vision is also used in fall detection of elderly in a room environment using extraction method of human motion by an analysis of motion process of a human body [2]. Oumaima et al. [3] had performed a literature review of work related to elderly fall detection and discussed about the main methods to recognise human postures, and the paper recommended work on new algorithm that can predict people's behaviour with partial occlusion and to work on more real-world falls in all environments. There is an increase of using human body gesture-controlled in gaming applications as discussed by Metkar et al. [4].

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A. Use of Technology to Help Elderly Maintain Fitness

There are numerous technologies that can assist elderly people to maintain fitness. Fitness apps on smartphones and tablets can be used to track fitness progress and learn exercise routines. Seniors can set their goals and monitor their activity performance. There is a growing number of wearable devices such as smartwatches and fitness trackers that can monitor vital health statistics (such as heart rate, number of steps taken, number of stairs climbed and other physical movements). There are different virtual classes provided by different fitness companies and they may be live-streamed lessons or recorded fitness classes (such as yoga, aerobics) which elderly can sign up to do at home. There are numerous exergames which are video games that can engage elderly people to do exercise activities such as bowling and dancing. Human pose estimation using artificial intelligence in virtual gym tracker can be implemented [5] and OpenCV libraries allow key points on a human body to be tracked (for e.g., wrist, knee) so they can be monitored to check if the individual is doing the exercise correctly. In this paper, we will focus on encouraging elderly people to do more physical activity to improve their wellbeing and we explore the use of computer vision in the development of applications for elderly. Discussion will be made on the development of an exercise application.

B. Considerations for Designing an Exercise Game for Elderly People

Before we go into designing an exercise game using computer vision. It is good to gather some insights on how video games are designed for elderly people. There are significant differences in game experience and preferences among young and elderly. Wang [6] discussed about the experimental result gathered and it showed that no matter if the game is for training for speed, training for memory or both, the young people achieve better performance than the older adults. Their survey result showed that most of the older

people love shooting game because it is easy to play and control and no other psychological burden. This alludes to having no memory pressure as well as no time limit being considerable factors in designing games for elderly people. When designing games for frail elderly people, the game features had to be drastically reduced in complexity so that elderly people with no prior gaming experience can engage in playing regardless of their physical or cognitive impairments [7]. Ljsselsteijn et al. [8] have listed four main areas for design opportunities for digital game: (1) for relaxation and entertainment, (2) socialisation with other people, (3) sharpening one's mind, and (4) new ways to interact with new technologies (affordances and engage whole body). Numerous studies including some using the Nintendo Wii platforms have shown that exercise games for older adults have positive effects on the social well-being and the three social outcomes identified are emotion-related, behaviour-related and attitude related [9], [20], [21]. Findings had shown that the exercise games could reduce loneliness for some older adults since they provided an increase in social interaction for the older adults with their peers and family members. There are imitations of the studies including impact of cultural context (e.g., Western and Asian people) on social-based outcomes is not examined in depth. Gerling et al. [10] provided a summary of game design considerations and showed that the age-related changes in player's cognitive and physical abilities would influence how they respond to games and making it necessary to look at games mechanics when designing for older adults.

Clemenson et al. [11] had conducted studies to show that playing video games like Angry Birds or Super Mario 3D World on Nintendo Wii U can produce a positive effect on older adults and their four-week video intervention with low daily commitment of around 30 minutes per day resulted in an improved hippocampal-based memory and improvements on the MST (Mnemonic Similarity Task) (recognition memory task) and Rey-O (neuropsychological test which assess several cognitive functions such as attention and concentration). A review was on done physical activity and exergames among older adults and it was found that exergames improved balance and cognitive function [12]. Another study done by Sunwoo et al. [13] indicated that mobile healthcare games for elderly are feasible to be used as a rehabilitation and exercise tool, however, they still have limitations of their study due to small sample size and demographics at that time.

Pyae et al. [14] had conducted a usability testing of Finnish Skiing Game on 24 Japanese elderly participants in Japan and they observed that the game was suitable because it consists of simple interface, easy game action and sociable game context. Saari and Hynninen [15] discussed usability observations from user tests, game design observations and testing environment observations of a digital puzzle game. From usability observation, it is apparent that users preferred a more intrusive animation (in-game tutorial) to understand the objective of the game and how to play it, rather than relying on built-in detailed instructions buttons that had to be read. From game design observation, users may be confused with real-life rules versus games rules. For e.g., can we drive over a passenger to get them or must we avoid knocking into obstacles by driving around them. From testing environment, it may be hard for users to see the screen properly due to issues with reflections, lightings, and its effects on graphics. Theng et al. [16] conducted an exploratory study on senior citizens' perceptions of the Nintendo Wii in Singapore and they had concluded that findings did not show that perceived usefulness presented a significant influence for senior citizens' intent to use the Wii to improve their health, exercise, and social interaction. Rather it was ease of use that would convince the elderly to accept Wii usage.

The effects of familiarity design for use in wellness games by the elderly were discussed by Pan et al. [17] and their studies showed that familiarity in design improved adoption likelihood significantly among the elderly surveyed. Rienzo et al. [18] evaluated playability and player experience for older adults and had concluded that techniques for assessing and designing games on older adults are lacking and they have identified some factors that affect playability and experience.

Fun element is of paramount importance. The player must find the game enjoyable and increase their motivation to participate more. The game must have elements to allow the elderly people to engage and interact more with others. As elderly players may have some health conditions such as joint pains, it is necessary to develop games that are low impact with gentler movements. Simple and repetitive movements without a lot of complexities or overly challenging physical fitness will be more suited. Though it may be good for an exercise game to allow customisation of game to match an individual's physical fitness and abilities, it may be more tedious to add in that feature.

There is another perspective to game design and that is to provide older adults the opportunity to come up with ideas of game content as well as the gameplay of the game by Havukainen et al. [19] and they suggested looking at the similarities and differences in the assets of the designers of different age, gender, and cultural background for their future work.

C. Advantages and Disadvantages in Implementing Computer-Vision Games for Elderly People

There are many advantages in computer vision games. It allows for much greater immersion and realistic experience because the players use body movements, hand gestures, facial expressions and eyes to control the game. It promotes physical activity, and it is beneficial for the players to engage in some physical movements in a game because they may be leading a sedentary lifestyle due to their health conditions or personal choice. Physical movements can motivate the players to engage more in exercise. It may provide accessibility to audiences with certain mobility issues. Some games require hand movements and even wheelchair bound players can participate in the gameplay. Computer Vision offers new gameplay experiences with augmented reality (AR) and virtual reality (VR) elements.

There exist some limitations in using computer vision for gaming especially when it concerns elderly people. Hardware

limitation such as camera used is a factor. Other factors that can affect the technical performance of the system include lightings conditions, image or visual quality captured and occlusions. The reliability and accuracy of algorithms can be impacted by these factors. If the game must be played in a low-lighting condition, the choice of algorithm and/or camera may be very different. When it comes to capturing visual data such as images or video of a person, there are privacy concerns. Users may not be keen for personal information to be recorded and/or stored. It is necessary to have transparency in data privacy of users. In terms of cost and accessibility, some computer vision games may involve the use of VR headsets and higher end computer devices (PC, mobile phones) and some players may not have access to such devices or equipment. The learning curve may be steeper for elderly people because they may need to try out different gestures and movements to interact effectively in the game. Physical fatigue and injury may occur when playing exercise games with hectic physical movements for elderly people with limited physical capabilities or inherent health issues.

II. Research Methodology

The objectives of research are as follow:

(1) To provide an engaging video game for elderly individuals.
(2) To develop a computer vision game design framework for elderly.
(3) To develop a computer vision exercise game for the elderly.

Experimental methodology is adopted. The game is developed and tested to ensure that there are good game play components (such as no significant delay and logical responses) and the functionalities of the game worked according to the specification.

III. Proposed Framework for Computer Vision Game Design for Senior Citizens

To have a more immersive experience, computer vison games allow the players to interact with the game in a more natural and intuitive way and they can be in the forms of gestures (e.g., raising arm), facial expression (e.g., blinking eye) and eye tracking (e.g., gaze to the left).

In this paper, we would like to propose a computer vision game design framework that is tailored for elderly people. It will detail all the components necessary to give this demographic an engaging game experience. Broadly, we evaluate the physical needs of the elderly people, the physical movements required by the game, cognitive stimulation and brain training, personalised game experience, social interaction and engagement, user interaction design, accessibility, user safety and ethical considerations.

In developing a game, the comprehensive framework allows us to check if we have missed out on any critical design features but at the same time, a game may not need to meet all the requirements. Some games are deliberately designed for a broad group of users while others are designed for a certain selected group with certain interests or needs.

A. Physical Needs

Identifying the physical needs and limitations of the player is of paramount importance; e.g., we need to know if the game needs to cater to people who are wheelchair bound or may not be able to raise their hands.

B. Physical Activity

There is a need to assess the suitability of game activity for the target audience. Selecting the type of physical activity for the game and the extent of the range of movements required in the game is part of game design; e.g., player needs to be able to stand up and squat down for a game feature. If the player has severe mobility issue and cannot squat down, this game may not be suitable for him

C. Cognitive Simulation and Brain Training

Games can be designed to increase cognitive simulation and provide brain training. Computer Vision can use captured cognitive responses by tracking the player's gestures (e.g., waving hand), eye movements and gaze patterns.

D. Personalised Experience

It is necessary to decide if the game is required to provide a personalised experience for each player by being adaptable to different needs of the player and adjusting the difficulties of the game according, or a more generic gameplay experience for all players. Personalised experience will more time and efforts in coding and designs.

E. Social Interaction and Engagement

To help to combat loneliness and isolation, we can design games that encourage more social interaction for elderly individuals. It may be in different forms. In a game, there may be a facilitator (e.g., caregiver) to guide the elderly individual players. It can be an individual game, but it can allow a group of people to take turns playing it and cheering you on. Computer vision games may increase social engagement if it is a multi-player game, have online communities and in virtual reality space, where the player must interact with other players. The game can incorporate game elements such as emotional cues to evoke positive emotions.

F. User Interaction Design

There are essential user interface design considerations for individuals with visual impairments such as font sizes, colour contrast and more intuitive menus. For those with hearing impairments, audio cues and visual captions are important. It may be good if there is customisation for players to adjust game settings to align to their preferences or their abilities.

G. Game Experience

To achieve a good game experience for the player, it is necessary to design the game with the fun element, the engaging experience and motivation factor in mind.

H.Accessibility & Inclusivity

Accessibility to the equipment is a consideration for game developers. VR/MR games will recover use of VR headsets which may be not accessible and pricey for some. Some video games also require high computing and bandwidth usage, which some people may not have access to.

Inclusivity allows for a larger audience including those with disability and special needs. It will require the game to be programmed to be adaptable to different audiences and adjust the challenges accordingly and this will cost more in terms of design and programming resources.

I. User Safety

In terms of user safety, it is good to examine if the game will cost the player severe discomfort or safety concerns (e.g., losing balance and fall down).

J. Ethical Concerns

There are ethical considerations when it comes to designing computer vision games because it involves capturing visual data for analysis. If player data are collected and stored, there must be transparency in handling the data and consent should be obtained for data collection. It is necessary to ensure that there are no biases in computer vision algorithms that may give unfair gameplay experiences.

TABLE I
COMPUTER VISION GAME FRAMEWORK FOR ELDERLY PERSONS

Key Aspects	Components	Questions
Physical Needs	Mobility	What is the mobility range that the player must have?
	Vision	What is the visual level the player must have?
Physical Activities	Simple Movements	Do the players need to use hand gestures, move their hands or legs?
	Physical Intensity	Will this activity be overly strenuous for the player? In this game increasingly strenuous?
	Adaptable	Can this game adapt to the player's physical level?
Cognitive Stimulation & Brain Training	Cognitive Stimulation Task	Does this game require the player to do memory challenging task?
	Brain Training	Is the task/ game/ puzzle pitched at the right level for brain training?
Personalised Experience	Adaptable	Is this game able to adapt to player's cognitive ability?
	Appropriate level of challenge	Is this game able to provide appropriate level of challenge to the player?
	Configurable	Can the player configure their game preference?
Social Interaction & Engagement	Interaction with other players inside the game	Does the player need to interact with other players in the game?
	Interaction with facilitators, family and/or friends	Does the player need to interact with facilitator? Does the game bring family and friends together?
User Interface Design	Visual Elements	Are the text, 2D & 3D graphics, visual effects, & animation sufficiently big enough, enough contrast & aesthetically pleasing?
	Audio elements	Are the audio elements suitable and loud enough?
	User Interface	Is the user interface intuitive? What are the visual cues? Are the visual cues obvious enough?
Game Experience	Fun	What is the fun element for the player?
	Engaging	Is the game engaging that can keep the player from coming back to play the game?
	Motivation	Does the game motivate the player to perform better in the game?
Accessibility	Cost of Accessibility	Is the cost of acquiring the equipment for this game reasonable for the player?
	Accessibility of Equipment	Is the player able to access the equipment?
Inclusivity	Inclusive Games	Does this game cater to different individual needs (including those with disabilities or special needs)?
User Safety	Discomfort Level	Does this game cause motion sickness or physical discomfort?
	Physical Safety	Will this game cause people to lose balance or trip easily?
Ethical Concerns	Data Collection	Does the game collect and store player's data?
	Biases	Will the game form bias actions towards the player?

IV. COMPUTER VISION BALL GAME CASE STUDY

A sample of prototype requirement is presented. As shown in the prototype requirements, we take note of the request of not using VR headset or have complicated and expensive equipment setup. The target audience is for above 65 years old elderly people who may be frail, and wheelchair bound. We look through the computer vison game framework for elderly to make sure we have considered all the key components and questions in our development. In our scenario, the caregiver can facilitate the session and explain to the elderly persons how this game works. We have decided to design a very simple exercise game that can motivate the elderly player to make some hand movements. Family and friends can be around and take turns to play the game with the elderly player and motivate the player to make some hand movements. This simple prototype does not store the player's personal and game information so there are no data security concerns. The game can be run as an exe file on any PC laptop with a 2D webcam.

The program is written in Java Processing environment and motion detection of hand movement is coded using a comparison of the RGB of the individual pixels of previous and current video image frame to check if they exceed a certain threshold and to check if the movement of hand pushing the brown circle touches the green circle.

TABLE II
SAMPLE OF PROTOTYPE REQUIREMENTS

Prototype Requirements	
Target Audience (Age Group)	Above 65 years old
Physical Needs (Mobility & Vision)	Most have mobility issues. Wheelchair bound for many of them.
Facilitated by (Elders/Caregivers/Both)	Yes
Simple Movements Requirement (Hands)	Yes
Simple Movements Requirement (Legs)	No
Type of Games (Exercise Game/Cognitive Stimulation/Brain Training)	Exercise Game
Equipment Requirements	Simple Setup (Ease of Setup with laptop with a built-in 2D web camera)
Use of VR Headset	No
Any Other Considerations	No

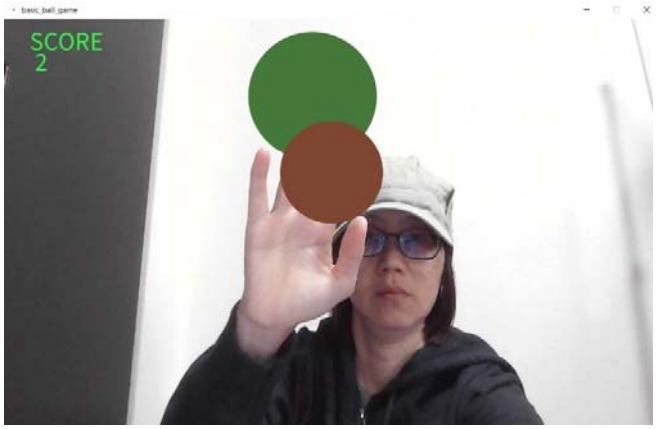

Fig. 1 Player pushing brown ball into fixed position green circle

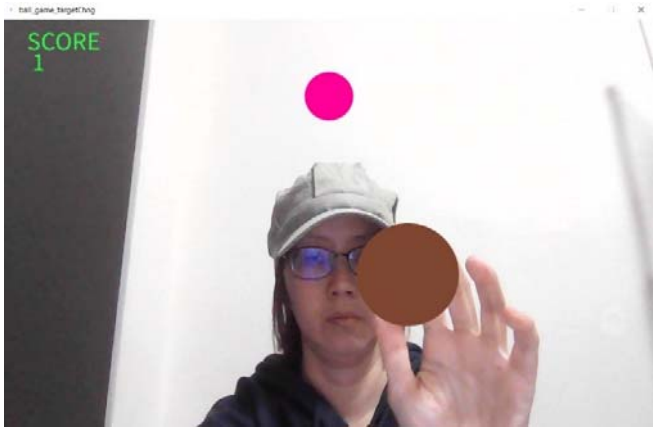

Fig. 2 Player pushing brown ball into constantly changing size of pink circle

In the first game prototype, the game is designed for the player to push the hand (i.e., brown ball) into the green circle area. Every time the player lands the brown ball into the green circle area, the score will be increased by 1 and there will be a loud buzzer sound.

In the second game prototype, the game is designed for the player to push the hand (i.e., brown ball) into the pink circle area (which is constantly changing its size, growing, and shrinking the pink circle). Every time the player lands the brown ball into the pink circle area, the score will be increased by 1 and there will be beeper sound. In this game, there is also background sound that makes the exercise game more exciting.

V. FUTURE WORK

For our next steps, we would propose to improve the current game prototype by giving more options for the elderly to exercise more specific parts of the body. Apart from raising their right hand higher than their right shoulder, raising their left hand higher than their left shoulder, we can design games for those who are not wheelchair bound and let them exercise their legs by lifting their right knee higher or left knee higher in the game to score a point.

We would like to let different groups of people evaluate our game using different screen sizes to better understand the effectiveness of our prototype exercise game.

VI. CONCLUSION

To sum up, we have proposed a computer vision game framework for elderly people. This provides certain pointers on things to remember when designing a game for this demographic. It does not mean that all the components are to be fulfilled to make this a good game. The clients' requirements may be specific, and they may require ease of setup and simple interface and less features.

We have used the computer vision game framework when designing our exercise game for the elderly. This is to ensure that we can meet the needs for this group of players. In game development, we usually run a few iterations of tests with the client to ensure that the game meets their needs and we will change the appearance of the graphics and tune the response time and reaction of the game assets accordingly.

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