Computer Vision Based Video Game to Enhance Agility for Elderly Individuals

June Tay, Singapore University of Social Sciences, Singapore
Ivy Chia, Singapore University of Social Sciences, Singapore

The European Conference on Aging & Gerontology 2023
Official Conference Proceedings

Abstract
Staying physically and mentally healthy is important for the elderly individuals. In this paper, we propose a computer vision video game that allows the user to exercise their hands by raising their hands above their shoulders. The video game we designed uses a laptop with a webcam and employs computer vision to track the elderly wrist's to be above the shoulder and it has a counter that keep track of the number of times the user raises the hand. This type of game is suitable for elderly individuals with legs mobility issue and are home-bound. The users can sit down to play the game and that can help to improve the agility of the hands by making hand movements. This paper discusses the special specifications required by elderly individuals and that encompasses usability, accessibility, and engagement. A simple and easy to navigate interface is necessary. The font size and a high visual contrast page with recognisable objects should make it more accommodating for ageing eyesight. There should be clarity in the game audio. The game control options (such as mouse, keyboard) should be easy to use. The game content needs to be engaging and not too complicated for the elderly. For exercise game that requires spatial awareness keeps the agility in the elderly. By taking turns to play this game, the elderly individuals can better connect and socialise with their friends and family. Players can try to improve on their game scores and outperform one another.

Keywords: Computer Vision, Exercise Games, Gerontology

Introduction

Markerless motion capture can perform movement analysis with reduced data collection and processing time. According to Wade et al (2022), the pose estimation algorithm error rates are like marker-based capture, but it still pales in comparison with the gold standard bi-planar video radiography in terms of accuracy. The current open-source estimation algorithm is not really designed to do biomechanical application. Nonetheless, many applications including games use open-source estimation algorithms such as human pose landmark, hand landmark and gesture recognition, because they are sufficiently accurate for their usage. Metkar et al (2022) had developed some human gesture-controlled gaming applications and some of the examples included a quiz game where player can use the tip of index and middle finger to select the MCQ answer, a racing car game can be controlled by the index finger, a bubbles game where bubbles appeared on the screen, and the player can use the tip of their finger to pop it. Metkar et al (2022) had use whole body tracking in a red light green light game. Faujdar et al (2023) use human pose estimation for their virtual gym tracker. The gym trainer tracker can assist in counting repetitions of any exercise done during weightlifting or CrossFit events. The pose estimation can be used to identify key points and measurements of angles between key points (such as elbows and shoulders) can be measured.

In our research, we seek to develop a computer vision exercise game for elderly people using human pose estimation algorithm. Before we look at the general guidelines on video game development and how we look at the suitability of the key guidelines for designing computer vision applications for elderly people. In this paper, applications of pose estimation and use of pose estimation models will be discussed. The development of our game prototype is presented and discussed.

Applications of Pose Estimation & Use of Pose Estimation Models

There are numerous applications we can use markerless human pose estimations to determine the human body posture by processing the images or videos. It tracks human body landmarks also known as keypoints which include the face (ears, eyes, mouth and nose), the upper body (hip, shoulder, elbow, wrist), lower body (knee, ankle), foot (heel, big toe, small toe) and hand (tip and 3 joints of each finger). Human activities estimation can be performed for surveillance, security, and monitoring purposes. These activities may range from walking, running, sitting, and sleeping.

In healthcare, pose estimation is used to monitor motor and non-motor development of infants, human performance optimization, injury prevention, and safety, and clinic motor assessment (Stenum et al, 2021). In sports, movements can be monitored to help athletics to achieve optimal performance and not relying on personal trainers and equipment which may be costly (Sharma et al, 2022). Bridgeman et al (2019) presented a full-body 3D pose estimation and allowed the tracking of multiple players in highly dynamic sports scenes such as table-tennis, boxing, karate, and soccer. For robotics, human pose estimation can be used to train the robot's joint movements. Wang et al (2019) performed human-robot retargeting which let a robot follow the movements of a human subject. In VR gaming, the pose is estimated by the camera and the game character can move in accordance with the human's pose. Anvari et Park (2022) conducted a survey on doing 3D human body pose estimation in virtual reality and they had discussed different methods for human motion estimation. In movie or game, 3D rendered graphics can be animated by human's movements. Tous (2023)

described Pictonaut, an approach to perform movie cartoonisation using 3D human pose estimation and GANs.

Design Considerations & Research Methodology

Our design considerations include identifying if there are any specific frameworks related to the design of video games for elderly people. Any guidelines to address unique needs and preferences of elderly people. What about the cognitive, physical and sensory abilities of elderly people. We also question what the guidelines for designing a computing application for elderly people are. Most importantly, we would like to know if there is any specific guideline on computer vision games for elderly.

The objectives of the research are as follow:

(1) To design a computer vision exercise game for 2 groups of elderly people above 65 years old (wheelchair bound and non-wheelchair bound)
(2) To develop computer vision game design guidelines for elderly people

The game is developed and tested to ensure that it is used computer vision to capture player's actions and responses to and from the game system. The game is tested to ensure the game specifications are met. Experimental and iterative methodology is used.

General Guidelines That Can Be Applicable to Video Game Design

In this section, we look at some general guidelines that can be applicable to our video game design and they include universal design principles, ISO 9241-210 Ergonomics of Human-System Interaction, Gerontology and Gamification frameworks. Universal Design aims to create products, systems and environments that can be usable by as many people as possible, despite their age, ability, or conditions (Steinfeld & Maisel, 2012). It encompasses key concepts which include equitable use, perceptible info, flexibility, simple and intuitive design, and tolerance for error. Adopting these principles makes the game more inclusive and accessible. While it may not be suitable for all video games because some games are targeted for a specific audience.

International standard ISO 9241-210 Ergonomics of Human-System Interaction provides guidelines for interactive systems which includes video games. It consists of accessibility, usability, and user experience. Though it may not be addressed specifically to elderly people, these key principles are incorporated since it should help to improve the design of games for elderly people.

Gerontology is the study of the different aspects of aging ranging from social, cultural, cognitive, biological, and psychological. A sub-field of gerontology focuses on the use of technology to address the needs of elderly people. The principles and frameworks in gerontology on user-centred design, age-appropriate design and suitable technology are beneficial in guiding design process to develop games for older demographics. Singh (2002) has presented recommendations of suitable exercise for elderly people. It is useful to understand how certain movements may benefit them so that we can incorporate them into our computer vision exercise game.

Gamification frameworks may provide some insights on game design elements that can improve player motivation and engagements. Chou Yu-Kai (2013) has proposed an

octanlysis framework that looks at 8 core aspects (such as epic meaning, empowerment, social influence, unpredictability, avoidance, scarcity, ownership, and accomplishment) that can provide intrinsic motivators and improve positive user experiences. Mora et al (2015) presented a review of the literature on gamification design frameworks, and the paper categorised existing approaches and showed an assessment of the main features which can be useful to developers of gamified solutions. Hunicke et al (2004) proposed the MDA framework (Mechanics, Dynamics and Aesthetics) as a formal approach to understanding games to build the gap between game design and development, game criticism and technical game research.

Key Guidelines for Designing Computer Vision Applications for Elderly People

We examine the needs of elderly people, their abilities, and their preferences when we design a computer vision game for them.

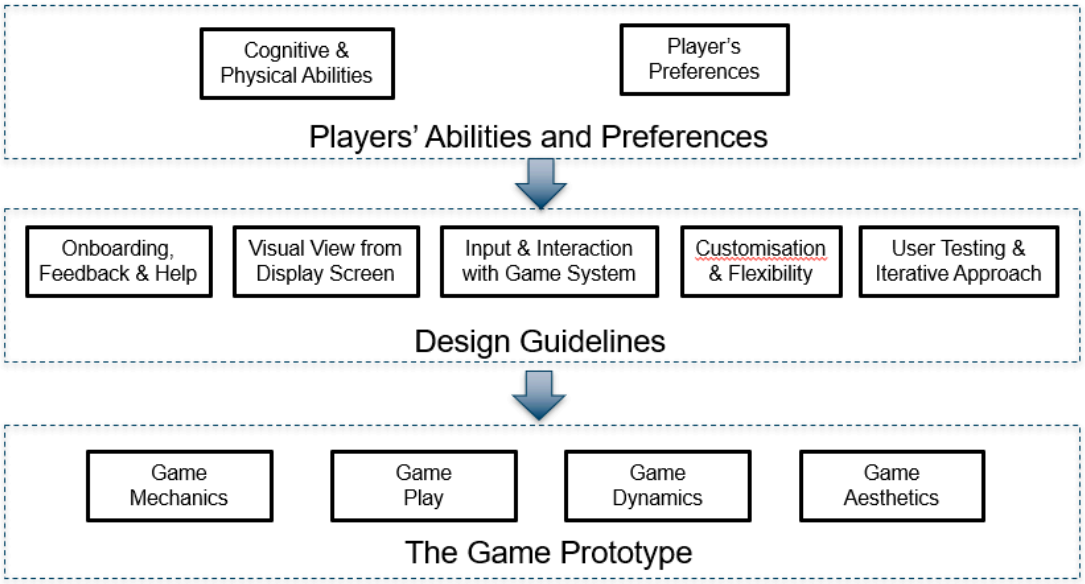

Figure 1: Key Guidelines for Designing Computer Vision Applications for Elderly People

Cognitive and Physical Abilities

It is important to identify what the targeted group of players could and could not do. It is necessary to consider the cognitive abilities of elderly and that includes their memory retention and attention span. It would be useful to provide concise instructions, prompts and design features that can support recalling. It may be necessary to avoid complex tasks. The physical abilities of the elderly include the type and range of movements they can cope with and safety in carrying out the movements. Design games that are within the physical limits of the intended audience and avoid complex and dangerous moves would be a consideration. Another factor is the vision of the elderly, and they may not have sharp vision as compared to people who are younger.

Players' Preferences

It is crucial to find out the elderly players' preferences and that includes the genre of the game, the type of game, the complexity level, the onboarding requirements, and other visual and audio needs.

Onboarding, Feedback & Help for the Game Application

Design application or games with gentle learning curve would make it easier for elderly to try out the game. It is beneficial to provide guided session, some tips and video tutorials for onboarding new players. There should be clear and accessible resources which include tutorials. It should be straightforward to get support and assistance information. It may be necessary to provide context sensitive help information for specific questions or people.

Visual View From the Display Screen

The screen of the application or game could be a monitor screen, laptop or mobile screen. The user interface is required be simple and intuitive. The fonts are to be legible and in high contrast. The graphics, icons and buttons must be large and highly distinguishable. For navigation and layout, there should be clear labels and visual cues. The content should be organised in a structured and well-organised manner. When giving instructions, they are to be clear and concise and complex information are to be expressed in digestible chunks. Acronyms and technical jargons are to be avoided. For a computer vision game, we need to be more specific in defining to the audience how much they are to be positioned away from the device (for e.g., the laptop) so that they can capture the human pose landmarks clearly.

Input and Interaction With the Game System

If there is a need for user to interact with the screen display, the buttons and interactive elements should be large, clear, and well-spaced. The input methods include keyboard, mouse, touch screen, VR tools and computer vision gestures. In our game, the player's human pose landmarks are captured by computer vision to be input into the system for analysis and feedback. It is important to note the range that the player must stand away from the screen display for the human pose landmarks to be captured by the web camera to achieve good accuracy of the vision capture which will impact the game play.

Customisation and Flexibility

We can consider allowing setting to be changed to accommodate individual's preferences and needs. There may be options to adjust font sizes, contrast level, audio setting and other relevant parameters. The customisation features should be easy to use and accessible.

User Testing & Iterative Approach

User testing should be conducted on targeted audience to gather feedback. The iterative design process can help to improve user's game experience.

Development of a Game Prototype

In a game system that interacts with our game model in memory, we have the following components:

(1) Graphics as Output (projected onto the laptop screen or monitor screen)
(2) Sounds and Music as Output (projected out from speaker on laptop)
(3) User Inputs (from keyboard or mouse)
(4) AI as Input and Output (Computer Vision from webcam and projecting onto the screen)

In our game prototype, we use deep computer vision algorithms in Processing. The library we have chosen is Deep computer vision algorithm for Processing by Florian Bruggisser (2022). This Deep Vision library can support object detection using different known models (such as YOLOv5, SSDMobileNetV2, Ultra-Light-Fast-Generic-Face-Detector), object segmentation, object recognition, keypoint detection (which includes facial landmark detection and single human pose detection based on lightweight openpose), classification, depth estimation and image processing.

In video games, game mechanics are rules of the games, and what are the player's actions and the game response to it. The game mechanic of this game is to encourage the player to make hand movements. In response to the player's action, the response would be adding a point to the player's score and sounding the buzzer.

The player is supposed to raise their right hand where the right wrist should be placed higher than the right shoulder. In this simple prototype, we programme to check if the player raises her right hand (i.e., Y coordinate of the right wrist is placed higher than the Y coordinate of the right shoulder). If so, the buzzer will ring.

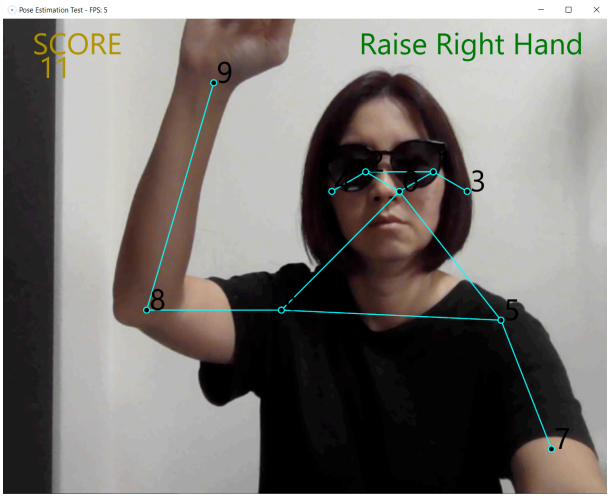

Figure 1: A demonstration of a player raising her right hand and scoring a point

Gameplay is a combination of different elements in a game. A basic gameplay refers to the core game mechanics which determines the features of the game. The basic gameplay of this game is to raise the hand as much as possible to reach the highest score within a predetermined time frame.

The game can be further modified to let the player move different parts of the body to exercise. This can include raising the left hand, raising the left leg, and raising the right leg as instructed by the game instruction. A point can be awarded for doing the correct action as instructed.

As the target audience of our game is elderly people and some of them may be wheelchair bound, we have two versions of the game with one requiring the player to move both arms and another version requiring the player to move both arms and legs.

Some of the dynamic game elements we can change include how frequently we can change the instruction of what the player should do (for e.g., raise right hand, raise left hand) and the duration of the gameplay experience. Dynamic game difficulty balancing is a process where

we can automatically change parameters or behaviour in the game depending on the player's ability to keep the player's from feeling too frustrated or bored. The game's difficulty can be increased by increasing the frequency of different movements the player has to be made. We can allow the player to pick a difficulty level to start the game or start at the beginning stage but to be subject to dynamic difficulty as the player progresses in the game.

Game aesthetics is an important focus. In this prototype, we show the score of the game and instructions from the game. We need to shortlist a few colour schemes and layouts, and conduct a user survey before finalising on the game aesthetics.

Challenges & Discussion

There are numerous challenges we can identify when developing a prototype exercise game for the elderly.

Since this is a computer vision game, we should discuss some of its issues. In terms of accuracy of the game, the height of the male and female are different, and the physio of male and female are different. The game may need to be calibrated for different groups of players. Low lighting is an issue because the game may not be able to detect human poses if the lighting is not optimal and the game cannot be played. Different thresholds may have to be set when it comes to movement of arms and legs, and this may impact the difficulty of the game. There may be too many design considerations and it is important to prioritise the design considerations that are important, and bear in mind what are the "must-have" features to be implemented.

For the prototype, we still need to fine tune the game play, game mechanics, game dynamics and game aesthetics through a more comprehensive user testing of game experience.

Future Work

Moving forward, we would like to modify our prototype to different versions to cater to broadly 2 different groups of elderly people (wheelchair bound and non-wheelchair bound). Conducting more computer vision mechanics testing can be carried out to increase our understanding on the algorithm and mechanism limitations. It is important to improve the accuracy of the game for different groups of elderly people. A more detailed user testing will be conducted. Using the results, this would help in crafting a new framework which focuses on designing computer vision applications for elderly people.

Conclusion

The general design principles for universal design, human factor principles, gamification and gerontology are good to serve as references when designing a computer vision game for elderly people. It is not necessary to have a game that meets all the design principles but rather design a game that meets the needs of the intended audience. In our paper, we have developed a simple computer vision game prototype in Java to allow elderly people to exercise their arms.

It is useful to explore and evaluate computer vision algorithms and libraries that are available and decide if they are suitable to be used in your game design. The prototypes can be fine-

tuned to achieve a more engaging gameplay. It is an iterative process in design to improve gameplay.

References

Anvari, T. and Park K. 3D Human Body Pose Estimation in Virtual Reality: A survey. *2022 13th International Conference on Information and Communication Technology Convergence (ICTC)*. Jeju Island, Korea, Republic of, 2022, pp. 624-628, doi:10.1109/ICTC55196.2022.9952586

Bridgeman L., Volino M., Guillemaut J. -Y. and Hilton A. (2019) Multi-Person 3D Pose Estimation and Tracking in Sports. *2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition Workshops (CVPRW)*. Long Beach, CA, USA, 2019, pp. 2487-2496, doi:10.1109/CVPRW.2019.00304

Bruggisser F. (2022) Deep Vision Processing. Library for Processing. (https://github.com/cansik/deep-vision-processing)

Chou Y.K. (2013). Octalysis: Complete gamification framework. (https://yukaichou.com/gamification-examples/octalysis-complete-gamification-framework/) (last accessed: 13 Aug 2023)

Faujdar, N., Saraswat, S. & Sharma, S. (2023) Human Pose Estimation using Artificial Intelligence with Virtual Gym Tracker. 6th International Conference on Information System and Computer Networks (ISCON).

Hunicke R., Leblanc M. & Zubek R. (2004). MDA: A Formal Approach to Game Design and Game Research. *AAAI Workshop - Technical Report. 1*.

Metkar, S., Mahajan, J., Adsul, J. & Chavan, B. (2022) Human body gesture-controlled gaming application. Second International Conference on Next Generation Intelligent Systems. (ICNGIS).

Mora A., Riera D., Gonzalez C. and Arnedo-Moreno J. (2015). A Literature Review of Gamification Design Frameworks. *2015 7th International Conference on Games and Virtual Worlds for Serious Applications (VS-Games)*, Skovde, Sweden, 2015, pp. 1-8, doi:10.1109/VS-GAMES.2015.7295760

Sharma P., Shah B.B., & Prakash C. (2022). A Pilot Study on Human Pose Estimation for Sports Analysis. In: Gupta, D., Goswami, R.S., Banerjee, S., Tanveer, M., Pachori, R.B. (eds) *Pattern Recognition and Data Analysis with Applications*. Lecture Notes in Electrical Engineering, vol 888. Springer, Singapore. https://doi.org/10.1007/978-981-19-1520-8_43

Singh M.A. F. (2002). Exercise Comes of Age: Rationale and Recommendations for a Geriatric Exercise Prescription. *The Journals of Gerontology: Series A*, Volume 57, Issue 5, 1 May 2002, Pages M262–M282, https://doi.org/10.1093/gerona/57.5.M262

Steinfeld E. & Maisel J. (2012) Universal Design: Creating Inclusive Environments, Wiley, Apr 2012, ISBN: 978-0-470-39913-2.

Stenum J., Cherry-Allen K.M., Pyles C.O., Reetzke R.D., Vignos M.F., & Roemmich R.T. (2021). Applications of Pose Estimation in Human Health and Performance across the Lifespan. *Sensors 2021*, 21, 7315. https://doi.org/10.3390/ s21217315

Tous R. (2023). Pictonaut: movie cartoonization using 3D human pose estimation and GANs. *Multimed Tools Appl 82*, 21101–21115 (2023). https://doi.org/10.1007/s11042-023-14556-1

Wade, L., Needham, L., McGuigan, P. & Bilzon, J. (2022). Applications and limitations of current markerless motion capture methods for clinical gait biomechanics. PeerJ. 2022 Feb 25;10:e12995. doi:10.7717/peerj.12995. PMID: 35237469; PMCID: PMC8884063

Wang S., Zuo X., Wang R. and Yang R. (2019). A Generative Human-Robot Motion Retargeting Approach Using a Single RGBD Sensor. *in IEEE Access*, vol. 7, pp. 51499-51512, 2019, doi:10.1109/ACCESS.2019.2911883

Contact emails: junetayhm@suss.edu.sg
ivychiasm@suss.edu.sg