Design and Evaluation of an Interactive Game-Based Exercise System Using Pressure Mat and Kinect for Elderly Body Training

HASAN IMADUDDIN[1], QINGWEI SONG[1], MAHIRO TAKANO[1], CHYAN ZHENG SIOW[1], FERNANDO ARDILLA[2], NAOYUKI KUBOTA[1]

[1]Graduate school of Systems Design, Tokyo Metropolitan University, Tokyo, Japan
[2]Department of Information and Computer Engineering, Politeknik Elektronika Negeri Surabaya, Surabaya, Indonesia
E-MAIL: hasan-imaduddin@ed.tmu.ac.jp, qingwei-song@ed.tmu.ac.jp, takano-mahiro@ed.tmu.ac.jp
siow-zheng@tmu.ac.jp, nando@pens.ac.id, kubota@tmu.ac.jp

Abstract:

As the global population ages, maintaining physical and cognitive health in older adults becomes a growing concern, especially since traditional exercise and rehabilitation programs often suffer from monotony and low engagement. This study presents the development and evaluation of an interactive game-based system that integrates a pressure-sensitive mat with LED indicators and a Kinect Azure motion sensor to deliver a stimulating platform for physical and cognitive training. The game comprises three sessions—two involving stepping on numbered tiles based on auditory instructions, and one focused on upper-body posture imitation using MediaPipe pose estimation. Two participants, a healthy young adult and an elderly adult, were tested to compare mission completion times. Results demonstrate that the elderly participant required significantly more time to complete tasks, highlighting age-related differences in perception and flexibility. These outcomes underscore the system's potential as a fun, low-cost, and accessible tool for motor-cognitive assessment and training in elderly care, rehabilitation, and home-based therapy.

Keywords:

Data, Sensor, Kinect, Sensor, Elderly

1. Introduction

As global life expectancy continues to rise, improving the quality of life for elderly individuals has become a growing concern in both healthcare and recreational domains. Regular physical activity and cognitive stimulation have been shown to play a key role in mitigating the decline of physical and mental functions associated with aging [1]. However, conventional approaches such as physical therapy and mental exercises are often perceived as repetitive and unengaging, leading to poor adherence among older adults [2].

To address this issue, serious games—digital games designed for educational or therapeutic purposes—have emerged as a promising solution. These games combine entertainment, motivation, and rehabilitation into a unified, interactive platform [3]. Research has shown that serious games can improve motivation and promote cognitive and physical engagement among the elderly, making them a compelling alternative to traditional rehabilitation programs [4].

This study is motivated by the urgent need to design engaging and meaningful interventions that can keep elderly individuals mentally and physically active. In particular, we focus on developing a game-based tool that not only supports training but also provides enjoyment, thereby increasing long-term participation and user satisfaction [5].

Recent advances in interactive technologies, including pressure-sensitive surfaces and depth-sensing cameras such as the Microsoft Kinect, have opened new opportunities in rehabilitation, education, and movement training [2]. These technologies have been successfully applied in stroke rehabilitation and balance training, where motion tracking and real-time feedback enhance user involvement and therapeutic outcomes [1].

Despite the promising potential of these systems, their application as immersive physical games targeted specifically at elderly users remains underexplored [4]. By integrating a pressure sensor mat with Kinect-based gesture recognition, the system developed in this study enables users to follow visual movement instructions and respond physically, stepping on numbered tiles and performing gestures as prompted by the game interface.

The system not only assesses response speed and accuracy but also provides a fun, game-like experience that encourages continued use and participation (Agres et al., 2019). This aligns with the concept of "playful rehabilitation," where engagement is a key factor in achieving successful physical and cognitive outcomes [5].

The primary objective of this study is to develop and evaluate an interactive game tool that combines a pressure-sensitive mat and a Kinect motion-tracking camera. This system is designed to present users with random, visually guided tasks requiring a combination of cognitive interpretation and physical action. Through this mechanism, the tool serves as both a training platform and an evaluative instrument to assess user responsiveness and coordination.

Moreover, the study aims to compare performance between a younger adult and an elderly adult to demonstrate the system's potential for detecting motor-cognitive differences across age groups [3][4]. Ultimately, the system strives to serve as an engaging tool for promoting physical and mental activity in elderly populations—beyond traditional rehabilitation—by leveraging the power of interactive gaming.

2. Related Work

As the aging population continues to grow, older adults face a progressive decline in both physical and cognitive functions, which can increase the risk of falls and reduce overall quality of life. In response to these challenges, researchers have explored the use of interactive technologies, such as pressure sensors and motion-sensing cameras, to support physical and cognitive rehabilitation in elderly populations.

One notable study by Kamnardsiri et al. introduced an interactive exergaming system that integrated cognitive and physical training using the Kinect motion sensor. The system was designed with a user-centered approach to enhance balance and executive function in older adults, demonstrating improvements in engagement and usability across sessions [6]. Similarly, Ayed et al. evaluated the feasibility of Kinect-based games for balance rehabilitation among the elderly. Their findings indicated a positive impact on balance scores and high levels of acceptance among participants, although the study was limited to a small sample size and short-term application [7].

Despite the promise of such systems, several limitations remain. A systematic review by Webster and Celik highlighted that many Kinect applications in elderly care and stroke rehabilitation are still in early developmental stages. Key challenges include limited motion tracking accuracy—especially for fine movements—and the need for larger-scale studies to validate their long-term effectiveness [8]. Additionally, many existing systems are designed for individual use and fail to incorporate features that foster social interaction or multiplayer engagement, which are important for sustaining motivation. Complex user interfaces can also pose barriers for older adults who may have limited technological familiarity [9].

In light of these limitations, the current study offers a novel contribution by developing an interactive game tool that integrates a pressure-sensitive mat with Kinect-based gesture detection. Unlike previous research that primarily focused on clinical rehabilitation scenarios, this system emphasizes playfulness and user motivation. It provides a gamified environment where users respond to visual instructions by stepping on numbered tiles and performing body movements that are tracked in real time.

Moreover, this study evaluates the performance differences between a younger adult and an older adult using the system, shedding light on age-related variations in perceptual processing and motor responsiveness. The tool thus serves both as a training platform and an evaluative system capable of distinguishing functional capabilities across different age groups. This dual-purpose design enhances its applicability in both recreational and therapeutic settings for older adults.

3. Method

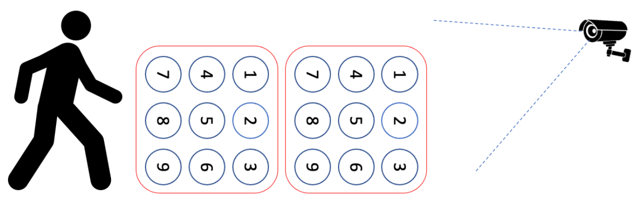


FIGURE 1. Proposed Game Device

This study presents the development of an interactive game device aimed at enhancing physical and cognitive engagement, particularly for older adults. The system combines a pressure-sensitive mat with visual LED indicators and a Kinect Azure camera for full-body motion detection.

The core component of the game is a pressure-sensitive mat configured with nine active zones. Each zone corresponds to a number from 1 to 9, arranged in a 3x3 grid. An LED light is installed above each zone to display visual cues, while a pressure sensor is mounted underneath to detect and confirm the player's foot placement. Similar configurations have been implemented

FIGURE 2. Session 1 and 2

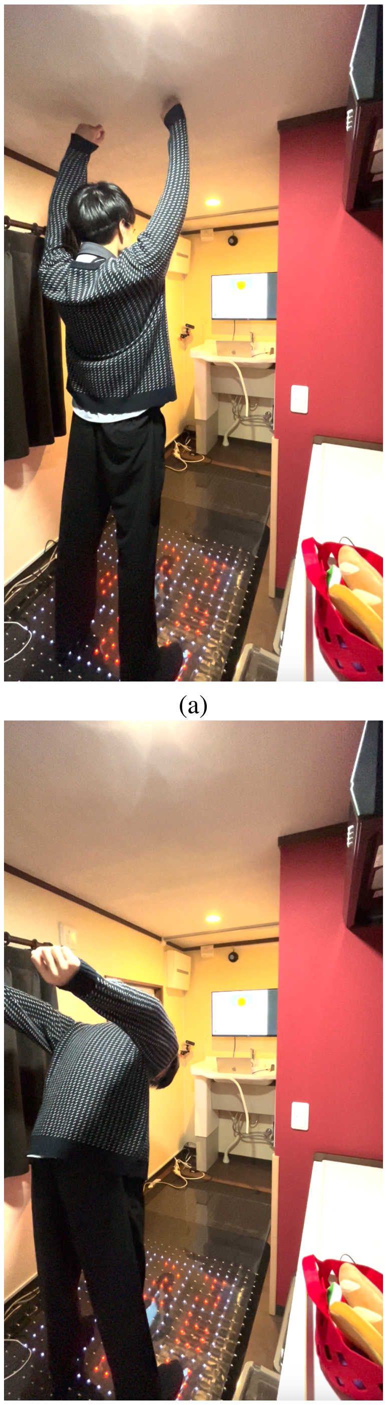
in interactive rehabilitation tools to promote balance training and motor coordination [10][11].

Placed approximately 3 meters in front of the mat, the Azure Kinect DK camera captures real-time body motion. This device, which integrates a depth sensor and an RGB camera, allows precise tracking of human joints in three dimensions. The skeletal data is processed using the MediaPipe framework to extract pose landmarks and assess the accuracy of body movements [12][13]. Previous research has demonstrated the potential of combining Kinect and MediaPipe in evaluating upper-limb movement in rehabilitation settings [14].

The gameplay is divided into three sessions. In the first and second sessions, the system plays an audio cue instructing the player to step on a randomly selected number between 1 and 9. The corresponding LED illuminates to reinforce the instruction visually. The player's foot placement is verified via the pressure sensor beneath the activated zone. For Sessions 1 and 2 (step-based tasks), the system randomly generates a sequence of target positions $T = \{t_1, t_2, ..., t_5\}$ where each $tk \in \{1, 2, ..., 9\}$ corresponds to a zone on the pressure mat. The random selection follows a uniform distribution with constraints to avoid immediate repetition:

$$P(t_k = i) = \frac{1}{8} \forall i \in \{1, 2, ..., 9\}/\{t_{k-1}\} \tag{1}$$

For the third session, after completing the stepping tasks, the system transitions to a gesture-based activity. A display screen shows a predefined hand or body movement. The player is expected to replicate the movement, which is monitored and evaluated by the Kinect Azure and MediaPipe system. For Session 3 (posture tasks), the system presents a sequence of upper-body postures $P = \{p_1, p_2, ..., p_7\}$ where each posture p_m:



(a)

(b)

FIGURE 3. Session 3 (a) First move (b) Second move.

$$p_m = \{\theta_{shoulder}, \theta_{elbow}, \theta_{wrist}\} \tag{2}$$

This dual-phase design targets both cognitive processing (by interpreting instructions and gestures) and physical response (through stepping and movement replication). By integrating multimodal feedback—auditory, visual, and tactile—the system intends to improve motivation and user experience, particularly for elderly users who may be less engaged by conventional therapy [5].

4. Result

The experiment was designed to include three distinct game sessions using two interactive sensor mats. Each mat was embedded with pressure sensors and LED indicators, and the Kinect Azure camera was used for motion detection. The participants performed the game sessions individually under the following structure:

Session 1 (Mat 1 – Step Tasks): 5 missions requiring the participant to step on numbered positions as instructed by the system.

Session 2 (Mat 2 – Step Tasks): 5 additional missions with a similar step-based structure on a second mat.

Session 3 (Upper Body Posture Tasks): 7 missions requiring upper-body gestures including raising both arms in front and behind the body, tracked by the Kinect camera.

Each session was initiated with a verbal instruction from the system, and the participants responded either by stepping on the designated area (Sessions 1 and 2) or performing the specified arm posture (Session 3). The system automatically recorded the time taken to complete each mission.

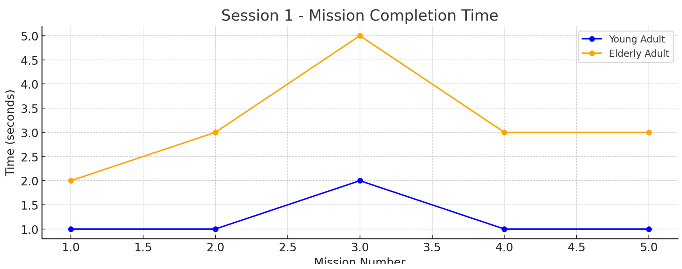


FIGURE 4. Session 1 Result

The data clearly illustrates a performance gap between the young and older participants. The young adult completed most step-based tasks in 1–2 seconds and posture tasks in 2–4 seconds. In contrast, the older participant consistently took longer across all sessions, averaging 3–5 seconds for step tasks and up

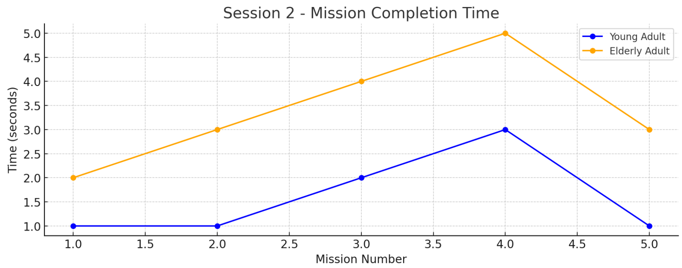


FIGURE 5. Session 2 Result

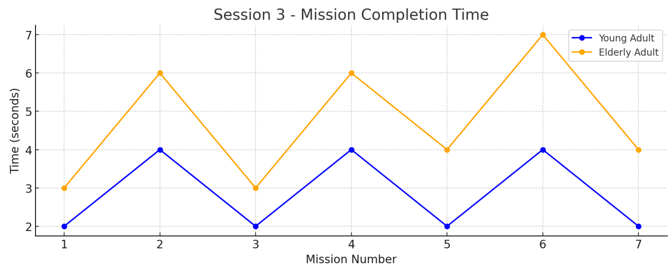


FIGURE 6. Session Result

to 7 seconds in the more cognitively and physically demanding posture tasks.

These findings are consistent with previous research indicating that older adults generally exhibit slower reaction times and reduced motor control due to age-related changes in sensorimotor function [16][17]. Additionally, the increased completion times in posture-based tasks suggest that upper body coordination and cognitive-motor integration are more challenging for elderly participants [18].

The experiment demonstrates that the developed system successfully differentiates physical and cognitive responses between age groups, validating its potential use in physical-cognitive training scenarios. Furthermore, the gameplay format helped maintain participant engagement, a benefit also reported in prior studies utilizing serious games for elderly users [19].

5. Conclusions

This research presents the development and preliminary evaluation of an interactive game-based system using a pressure-sensitive mat and Kinect Azure camera, designed to enhance physical and cognitive engagement—particularly for elderly users. The system was constructed with two sensor mats embedded with LEDs and pressure sensors, combined with a Kinect camera to track body posture using the MediaPipe framework. The game comprises both step-based tasks and upper-body movement imitation to stimulate multiple motor and cognitive functions simultaneously.

Through experimentation with two participants—a young healthy male and an elderly male—the system successfully differentiated performance based on task completion time. The younger participant consistently completed all game missions faster than the older participant, highlighting the potential of the system to assess perceptual and motor differences across age groups. This aligns with existing literature showing that aging affects reaction time, flexibility, and cognitive-motor processing.

In addition to its evaluative function, the system offers a playful and motivating experience that may encourage consistent physical activity in older users. This dual purpose—assessment and training through gamification—marks the system's primary contribution. As such, this research demonstrates the feasibility and benefits of integrating low-cost sensors and motion tracking into serious games for elderly care and rehabilitation.

6 Future Work

Future experiments should include a larger and more diverse sample size to validate the consistency of the observed trends and allow for statistical significance. Age, gender, mobility level, and cognitive condition should be considered to broaden the system's applicability. Then, the evaluation metrics can be expanded beyond time-based performance to include the accuracy of movement and balance stability. And also, the game scenarios can be diversified to maintain user engagement and address various therapeutic goals.

Acknowledgements

The authors would like to acknowledge this work was partially supported by the Japan Science and Technology Agency (JST), Moonshot RD, with grant number JPMJMS2034.

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