SUGISAKA MASANORI

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Research Article

Interactive Beating Drum Unity Game

Chung-Wen Hung[1], Cheng-Lung Ko[1], Wen-Huei Chou[2]
[1]*Department of Electrical Engineering, National Yunlin University of Science & Technology, 123 University Road, Section 3, Douliou, Yunlin 64002, Taiwan, R.O.C*
[2]*Department of Digital Media Design, National Yunlin University of Science and Technology, 123 University Road, Section 3, Douliou, Yunlin 64002, Taiwan, R.O.C.*

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ABSTRACT
In this research, we introduce an interactive beating drum game built on the Unity game engine. Our objective is to address the social and mental health impacts of the pandemic, particularly among older individuals. Using the Unity engine, we have developed a sports and social platform. And we employed Bluetooth Low Energy (BLE) chip to transmit drumming signals to the Unity engine following the Bluetooth (BT) protocol. Then, the user interface on the tablet in our game will show the drum locations beat by user. Our game offers single player mode and multiplayer mode. The multiplayer mode provides social network features. Players need to strike the falling icons on the drum in conformity with the rhythm of the music. The game will assess precision and give reward points at the end of the game. In accordance with experimental findings, the elderly participants considered that the system is user-friendliness.

1. Introduction

With advances in medical technology and declining birth rates, there has been an increase in the elderly population. This trend has caught the attention of the United Nations (UN) and the World Health Organization (WHO). The growing number of elderly individuals has become a development trend. The geriatric health is seen as the important factor to evaluate the contribution of elders for family or community. The physiological degeneration, dementia and poor physical coordination caused by aging process affect the daily life of elders. Therefore, to postpone senility and improve the quality of life become an issue. The first international congress on gerontechnology is held on August 1991, trying to provide some solution for growing population of elderly and improve the life of elder by proposing geotechnology-related applications [1]. In the last few years, the application of gerontechnology are most used as an assistive devices to help elders keep their normal life. For example, the health monitoring on wearable device which can let the elders and their family member trace data of body and enable the basic warning and prevention. In addition, many papers propose that communication technology can enhances the elder's knowledge and technical ability. The pandemic changes people's way to live, making people have to spend most of their time staying at home. However, it also accelerates the development of information technology and family entertainment such as PS5, Switch and Xbox rich our free time during the pandemic. Among these items, Taiko no Tatsujin: Drum 'n' Fun and Ring Fit Adventure in Switch can not only let players have fun but also help people do the exercise at home. These interactive games allow people in different times and environments connect with each other online, increasing the opportunities for developing digital play and digital learning. There have other researches propose that digital games are good at improving the elder's wellness, enhancing social bond and generating a sense of happiness [2], [3], [4]. It is also considered as an effective way to do exercise [5].Compare with online games or console games, portable gaming console market share has steady increased, which shows the potential of creating social relation by playing games.

The benefits of drumming is mentioned from [6]. In addition to single-player mode, users can drum with

Corresponding author's E-mail: m11012073@yuntech.edu.tw, wenhung@yuntech.edu.tw, cris@yuntech.edu.tw

other people and then create the interpersonal relationships in multiplayer mode. Moreover, the upper limb muscles which are usually used during drumming could become stronger after operating the system frequently, helping prevent Sarcopenia effectively. The Fig.1 shows a player who was playing the system proposed by this paper.

Fig.1. The player is drumming

2. System Architecture

The system architecture is showed in Fig. 2. This research uses Laser-engraved drumhead with piezoelectric devices, releasing the wireless transmission through Bluetooth Low Energy (BLE) and user interface is developed based on Unity environment on the tablet. The application of sensing device can show the drumming location effectively. First, mechanical energy causeing by drum hitting is converted into electrical energy by piezoelectric sensors. The generated voltage is received by ADC of the Bluetooth module, and then this signal is transferred into data in binary format. The position code is transmitted by the Bluetooth module and the user interference constructed by Unity decodes the position and display on user interface at the same time. This online rhythm game allows elders to interact and play with others over the internet.

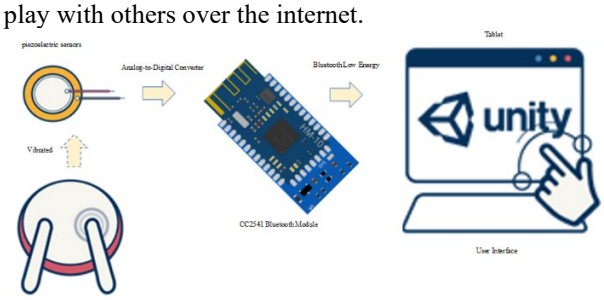

Fig.2 System architecture diagram

3. System Development

3.1 Unity

Unity offers a full set of tools and features for creating 2D and 3D games, simulations, and other interactive experiences. Developers can easily design scenes, create game objects, and manage resources using Unity's visual editor. Additionally, the Unity engine works on multi-platforms, including Windows, MacOS, Linux, iOS, Android, and various game consoles. This wide platform compatibility provides developers with highly flexible development choices. Developers use the C# language for code development and can take advantage of Unity's GUI interface, making it accessible even for beginners.

In Unity, developers can also extend application functionality by using a variety of resource packages. These packages include 3D terrains, network, sound systems, animations, and etc [7]. They enable developers to quickly build high-quality games and interactive experiences. Unity provides a platform with various resources. Developers can access plenty of pre-made assets, scripts, plugins, and tools through Unity's Asset Store. With this, we can accelerate the development process. Moreover, Unity provides collaboration, version control, and performance optimization tools to enhance team efficiency and improve game experiences.

This research is based on the gameplay of the game "Taiko no Tatsujin: Drum ‘n’ Fun". And we chose Unity 2D as the development environment for interactive design. By receiving signals processed through a Bluetooth module on a Unity tablet, the Unity engine generates visual patterns representing the beats. These patterns are generated according to the music's BPM (Beats Per Minute). Players can follow the rhythm and strike the falling patterns, including actions such as left-side, left face, right face, right-side, both faces, and both sides. By combining all the relevant information, coupled with controlled user interfaces and game feedback, we successfully developed an interactive drumming application suitable for home use.

3.2 Bluetooth Low Energy (BLE)

Bluetooth Low Energy(BLE) is developed by Bluetooth Special Interest Group (SIG). The performance of BLE are completely compared by [8]. BLE optimizes the transmission of small data and has been widely utilized on various occasions. The advantage of BLE lies in its ability to connect with mobile devices such as smartphones and tablets, providing real-time data transmission. It is currently being applied in various fields such as wearable device, automotive application [9], [10], medical environment and home automation [11], [12], [13], [14]. It uses Generic Attribute Profile (GATT) to send and receive application data. GATT encapsulate the Attribute Protocol (ATT) use service, characteristic and property to establish the link, to organize data, to read and to write data [15].

Due to the flexibility of the definition, the server and characteristic definitions can be freely implemented by users based on their own data structures and application requirements. , BLE is an ideal solution for sensor devices that only require data status transmission.

In our research, we employ BLE technology to convert voltage signals collected from sensors into data. Next, this data is transmitted to the Unity game engine on a tablet device through the Bluetooth module.

3.3 Piezoelectric sensors

Piezoelectric sensors are made of a piezoelectric material, which is a transduction element [16]. This research installs piezoelectric sensors at the interlayer of the drum body in Fig.19 and Fig.20, determining the position of the drum by using this component's piezoelectric characteristics. When there is an external force hitting the component, its internal electric dipole moment will be shortened by the pressure. At the same time, piezoelectric element generates voltage in order to resist the change caused by external pressure. If user need to generate electrical energy continuously, the user will need to vibrate the sensor. Eq. (1) is the piezoelectric effect process that the piezoelectric converting mechanical energy into electrical energy. In this paper, we divide the beat position into four position like left side, left head, right head, right side to avoid the vibration effect of beating. Fig.3 shows the piezoelectric elements change the mechanical energy to electrical energy. Where P is the polarization intensity of crystal, d is the piezoelectric constant, σ is the stress.

$$P = d\sigma \quad (1)$$

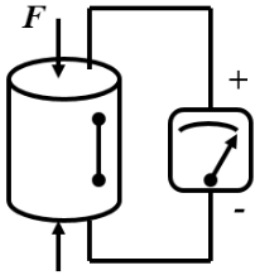

Fig.3 Inverse piezoelectric effect

3.4 Operational Amplifier (OPA)

3.4.1 Voltage follower

The voltage follower is a type of OPA circuit. It is designed with a unity voltage gain, meaning that the output voltage is equal to the input voltage. The voltage follower also shows the characteristics of high input impedance and low output impedance. The voltage follower's frequency response is determined by the OPA's open-loop gain and gain-bandwidth. And it is limited by the bandwidth of the OPA, which is inversely proportional to the open-loop gain.

3.5 Analog-to-Digital Converter (ADC)

The 12bits ADC in CC2541 Bluetooth module was used for the sampling of time domain data. The ADC is main convert the continuous time into stimuli to discrete time and represent the data in binary format [17]. It is widely employed in instrument measurement applications, such as converting signals from temperature sensors into digital signals. we used the four-channel 12-bit ADC of the CC2541 module to convert the obtained pressure values from the piezoelectric sensors into corresponding voltages, representing the positions of left side, left head, right head, right side. So, we can set a threshold range. Determine the drumming position when the ADC value over the setting threshold. However, each sensor is interconnection with the base of the drum that can affect each other. Therefore, we revise the ADC threshold to avoid the influence of the four positions on each other.

4. Result

In this research, we make use of the Unity game engine for the creation of interactive game content. Unity is recognized for its strength and flexibility as a development environment, leading game developers to prefer it for creating their projects. The platform offers a wide variety of content, including games, simulations, virtual reality experiences, and augmented reality applications. Additionally, it supports cross-platform applications on Windows, MacOS, Linux, iOS, Android, and several next-generation gaming consoles. We chose to apply the Samsung Tab A7 tablet running on the Android system to meet the needs of the primary users who are elderly individuals and require a larger screen size to reduce visual strain. In this paper, The Unity platform plays a key role in facilitating Bluetooth connectivity and multiplayer game networking within this environment. The tablet is capable of receiving drum position data through Bluetooth connection. Additionally, it supports internet connectivity for multiplayer gaming, enabling elderly population to establish connections with the community even when staying at home due to the pandemic. The laser- engraving drum incorporates striking functionality, allowing the elderly to increase their strength and maintain basic physical fitness.

The user interface in this research considers that elder's visual weakened. The game's user interface is designed with larger fonts and simplified composition of images, because the elderly usually cause visual fatigue. Fig.4 to Fig.7 are screenshots in this unity game. Fig.4 is the game start interface, Fig.5 is the game home interface, Fig.6 is the game single-player mode playing screenshot and Fig.7 is multiplayer mode playing screenshot.

Fig.4 Start interface

Fig.5 Home interface

Fig.6 Single-player mode playing

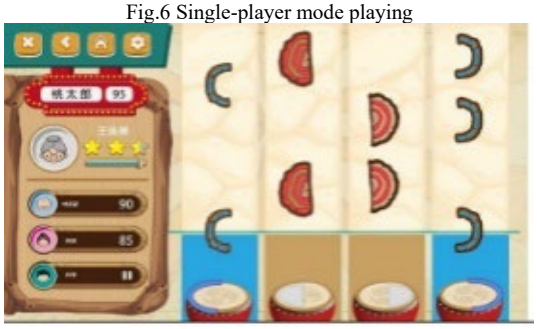

Fig.7 Multiplayer mode playing

This research employs the voltage follower mentioned in Section 3.4. Fig.8 shows the circuit design of the voltage follower. We use the left position as an example, the piezoelectric sensor converts the mechanical energy from the drumming into a voltage input to the OPA. The OPA converts and outputs the signal while reducing the loading effect. An RC filter circuit is added at the output of the OPA to reduce the mutual interference between waveforms. And we used the same method to the other three positions.

Fig.9 to Fig.12 display the voltage waveforms at the input from left side to right side. It is obvious that the channels influence each other by vibrations. Fig.13 to Fig.16 represent the voltage waveforms at the output terminals from left side to right side. Obviously, with the inclusion of the amplifier and the filter circuit, the waveforms become more discernible, making it easier to determine the position. Finally, the output of the filter circuit is connected to the ADC channel of the CC2541 Bluetooth module.

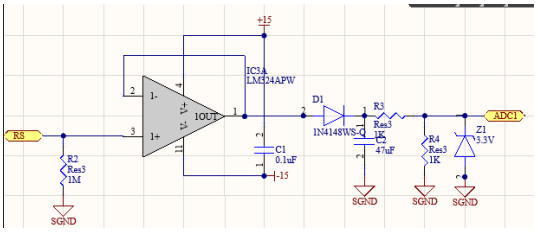

Fig.8 The voltage follower layout design

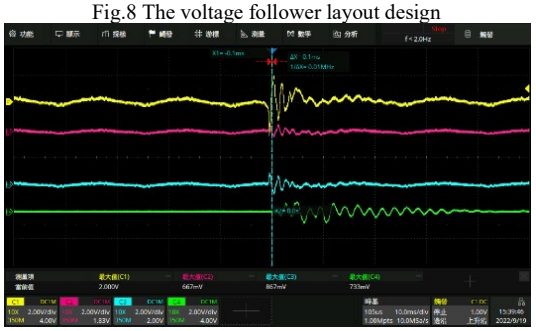

Fig.9 Left side voltage waveform

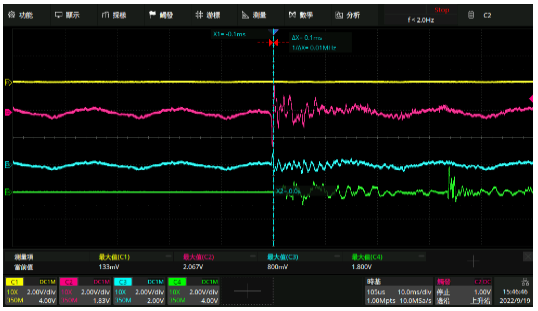

Fig.10 Left head voltage waveform

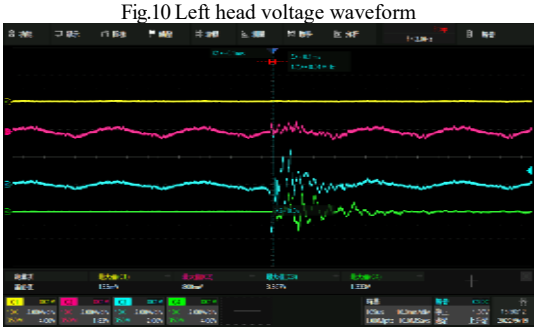

Fig.11 Right face voltage waveform

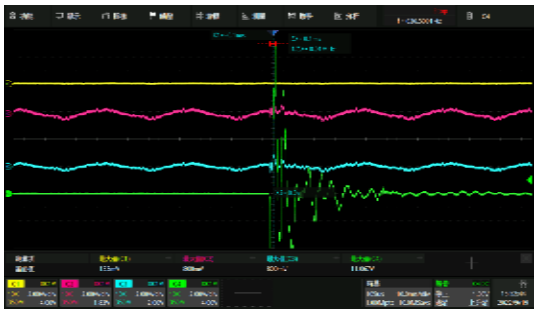

Fig.12 Right side voltage waveform

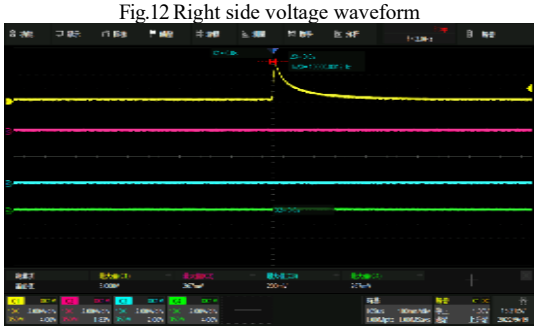

Fig.13 Left side voltage waveform

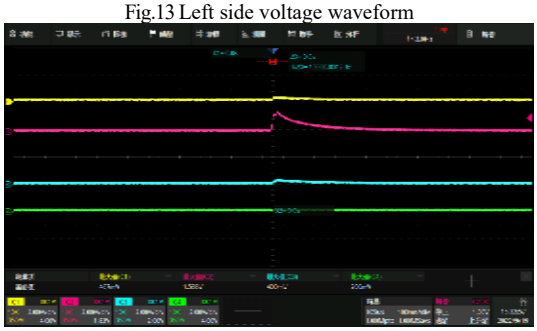

Fig.14 Left face voltage waveform

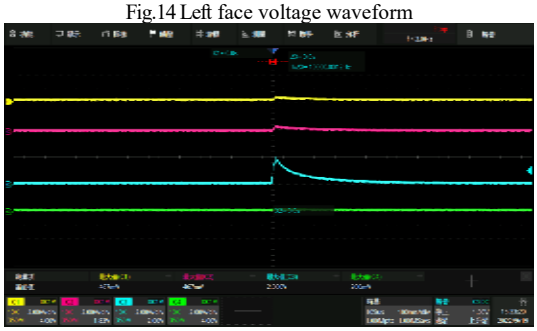

Fig.15 Right face voltage waveform

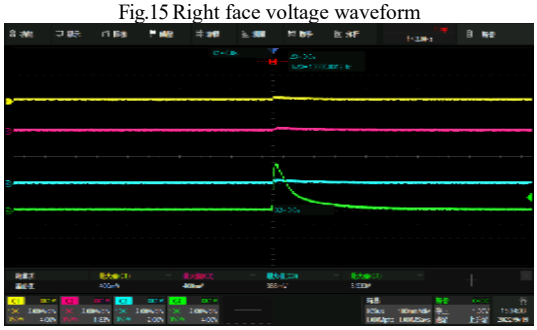

Fig.16 Right side voltage waveform

This study refers to drums of different types, including traditional drums and electronic drums with augmented noise-reducing drumheads. After evaluation, a drumhead design was developed using laser-engraving. Initially, a layer of foam padding was included in the middle section of the drum body to assess its performance in Fig.17. However, the development and testing phase, it was found that the positions were easily misjudgment and mutual interference. Therefore, taking inspiration from the construction method used in the game " Taiko no Tatsujin: Drum ‘n’ Fun " the foam padding in the middle layer in Fig.17 was removed. As shown in Fig.18, holes were drilled at each position and screws were used to reduce the contact area between the striking position and the bottom of the drum. The side structure is shown in Fig.19. Additionally, the original piezoelectric sensors were replaced with black piezoelectric devices in Fig.20. This replacement was done to prevent them from falling off during impacts caused by the structural changes. Through Multi-person testing, the experimental results demonstrated a significant improvement in the accuracy of position feedback with the modified drum body structure.

To verify the user-friendliness and usability of the proposed application, we recruited 5 users to test this application. The mission table, shown as Table 1 and Table 2, are also designed for users to reply the questions. The System Usability Scale(SUS) can be build based on Table 1 and Table 2, which becomes a objectively metrics to determine the usability and learnability of system, as indicated in Table 3.

Users evaluated the application according to Table 1 and Table 2, and the evaluated result table as Table 3 was also inserted in this paper. Table 3 shows the System Usability Scale (SUS) of the proposed system. The average score is 71, the usability score of system is 72.5 and the learnability score of system is 70.6 after the evaluation of 5 users’ response. According to the standard defined for interface assessing [18], the evaluated results of proposed system are above 70, which can be considered as a user-friendly system.

Table 1 Single-player mode missions

Mission number	Mission contents
Mission 1	Entered username and selected an avatar after watching the introduction video.
Mission 2	Pressed the button (e.g., volume key, button size key) and completed the BLE connection.
Mission 3	Entered the single-player mode and selected a music from list
Mission 4	Played the drum with music in single-player mode.
Mission 5	Watched the evaluation after the music finished.

Table 2 Multiplayer mode missions

Mission number	Mission contents
Mission 1	Entered username and selected an avatar after watching the introduction video.
Mission 2	Pressed the button (e.g., volume key, button size key) and completed the BLE connection.
Mission 3	Selected the multiplayer mode and entered the game room.
Mission 4	Player 1：Waited for player 2 to enter the room. Player 2：Waited for player 1 to enter the room.
Mission 5	Player 1 and player 2 operated the drum in multiplayer mode.
Mission 6	Watched the evaluation after the music finished.

Table 3 Evaluated results

Evaluate item	Average	Max	Min
Usability score	72.5	100	50
Learnability score	70.6	84.4	53.1
Total score	71	82.5	52.5

Fig.17 The drum interface with hollow

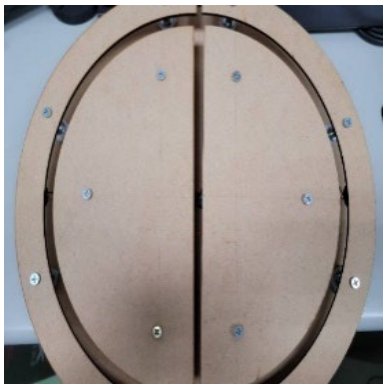

Fig.18 Laser engraving

Fig.19 The drum side view

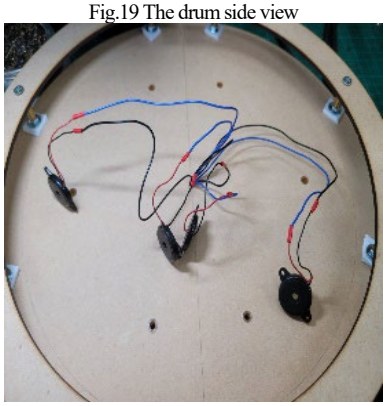

Fig.20 The Drum with piezoelectric sensors

5. Conclusion

In this paper, a simple user interface is used to decrease the elder's learning burden. Elder can play online game with other players though the connection technology between Unity and BLE even at home. Moreover, we designed the simplified gaming interface to reduce the elderly visual fatigue. With this simple playing way at home, elder can not only prevent Sarcopenia but also communicate with other players.

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Authors Introduction

Prof. Chung-Wen Hung

He received the Ph.D. degrees in Electrical Engineering from National Taiwan University in 2006. Currently he is a Professor in National Yunlin University of Science &Technology. His research interests include the IoT, IIoT, and AI application.

Mr. Cheng-Lung Ko

He is a graduate student at department of Electrical Engineering, National Yunlin University of Science & Technology.

Wen Huei Chou

She is a professor at the Digital Media Design department in National Yunlin University of Science and Technology in Taiwan. She holds a BA in Art education in National Hsinchu Education University, an MA in Applied Art (major in Design) in National Chaio Tung University, and a doctorate degree in Design in Swinburne university of Technology. She dedicates herself in the field of design research; especially in the innovation and integration in new media deign domain. Her current research interests include innovative and transdisciplinary design research, social and service design for social practice.