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Using Google MediaPipe to Develop an Innovative Motion-Sensing Game

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Abstract

This paper combines AI, motion-sensing games, and healthcare to propose an innovative motion-sensing game framework based on AI technology. We aim to address the current issue of people's lack of exercise. In this paper, we use the multimedia machine learning tools developed by Google MediaPipe to transform the once-popular arcade game Breakout into a motion-sensing Breakout game.

In our experiments, we found that MediaPipe can misjudge in complex scenarios. However, to ensure a smooth experience with the motion-sensing Breakout game, we proposed an improved algorithm to resolve MediaPipe's misjudgments. To enhance user engagement, we also developed a two-player mode and incorporated calorie consumption estimation during the gameplay. This aims to motivate people to exercise more and improve their health. From our experiences, the motion-sensing Breakout game indeed sparks people's interest in exercise and helps them achieve physical activity through the gameplay.

Keywords: Google Mediapipe, Breakout game, Motion-Sensing Game, motion-sensing Breakout game.

1. Introduction

In this chapter, we will introduce the origin and purpose of this research. We will first explore the causes and consequences of the current lack of exercise among

people. Next, we will introduce motion-sensing games and discuss the reasons for incorporating them. Finally, we will introduce the multimedia machine learning tool Google MediaPipe, along with its advantages and disadvantages.

1.1 Lack of exercise[11, 12, 13, 14, 15]

In this era of Industry 4.0, people's work has not decreased but has become increasingly heavy. Because everyone has to bear more work, many people are almost constantly sitting for long periods without moving. Coupled with other reasons, people's daily exercise is also decreasing, gradually leading to the emergence of Metabolic Syndrome, which is a warning sign for health.

According to the World Health Organization (WHO),[15] insufficient physical activity is one of the four major risk factors affecting global mortality rates. Those who lack exercise have a 20-30% higher risk of death compared to those with regular exercise habits. Metabolic Syndrome is a warning sign of health issues, and a lack of exercise is one of the main causes of this syndrome. The harms of insufficient exercise to the body include: 1) cardiovascular diseases and strokes; 2) osteoporosis; 3) diabetes; 4) high blood pressure and high cholesterol; 5) obesity; 6) cancer. Therefore, exercise can improve health and reduce the risk of death. Multiple scientific studies have shown that among school-age children, adults, and the elderly, those who exercise or have higher activity levels have better cardiopulmonary function and overall health, and a lower risk of cardiovascular and chronic diseases. Hence, more exercise can reduce the risk of death, and even a small amount of exercise is beneficial for both physical and mental health.

The most common reasons people give for not exercising are as follows: 1) no time to exercise or poor time management; 2) too tired from work; 3) laziness; 4) lack of motivation or interest; 5) health or psychological issues; 6) lack of facilities or inconvenient transportation; 7) lack of support from exercise partners; 8) economic factors.[14] Based on these reasons, we conclude that home exercises, which do not require expensive equipment and allow for enjoyment with family or partners, might be a good option. However, it is still necessary to spark people's interest in exercising, and thus motion-sensing games are a choice that meets these criteria.

1.2 Motion-Sensing Game

Motion-sensing games are electronic games that utilize players' physical movements to control gameplay. These games employ various sensing technologies such as infrared, cameras, accelerometers, and gyroscopes to capture players' movements and translate them into game commands. The main feature of motion-sensing games is that players interact with the game through body movements, gestures, or other actions, rather than using traditional keyboards or joysticks. They may even forego traditional screens, opting instead for head-mounted virtual reality (VR) displays to provide a more immersive experience in the virtual world.[10] Common motion-sensing games on the market include Nintendo Wii, Microsoft Kinect, Sony PlayStation Move, Oculus Rift, and HTC Vive.[4, 8]

Motion-sensing games have wide applications in physical and occupational therapy. These games can help patients with limb function rehabilitation training, enhancing muscle strength and coordination.

However, these commercially available motion-sensing game consoles require a significant number of sensors (such as infrared, cameras, accelerometers, gyroscopes, and force sensors), making them quite expensive. Additionally, the game software must be purchased separately, and it is also not cheap. Therefore, is there a more affordable and accessible alternative? Can laptops or computers be used to achieve the same effects as commercially available motion-sensing game consoles?

In this paper, we propose an innovative motion-sensing game that requires only a webcam, allowing us to experience the game using a laptop. The game in question is the famous Breakout, which we have transformed into a motion-sensing game. Instead of using a keyboard or mouse, we use body movements to simulate the directional keys of the keyboard or the mouse's tracking function. This way, players no longer need to sit while playing the game. They must stand in front of the webcam and move quickly from side to side as the game progresses, trying to earn more points or survive longer. This approach enables people to exercise at home or indoors, requiring only easily accessible equipment—a laptop. Exercising at home can alleviate psychological burdens, allowing people to exercise comfortably,

significantly reducing issues of low self-confidence and exercise anxiety. Additionally, to encourage participation, we have also introduced a two-player mode, addressing the issue of lacking support from exercise partners.

Our proposed motion-sensing game can address several reasons why people are reluctant to exercise, but how can we experience it using only the webcam on a laptop? Can the webcam track the player's body movements as smoothly as controlling a mouse? Will there be frequent misjudgments? Next, we will introduce how to solve these problems, with Google MediaPipe playing a key role.

1.3 Google MediaPipe

MediaPipe is a multimedia machine learning model application framework developed by Google Research. MediaPipe offers cross-platform, customizable ML solutions for live and streaming media. MediaPipe Solutions provide a series of libraries and tools that allow you to quickly apply artificial intelligence (AI) and machine learning (ML) technologies in your applications. You can immediately integrate these solutions into your applications, customize them according to your needs, and use them on multiple development platforms. Currently, MediaPipe is available on Windows, Android, iOS, and can also be used for web development.

The solutions provided by MediaPipe include object detection, image classification, hand landmark detection, face landmark detection, and pose landmark detection. MediaPipe is a very powerful AI tool that allows for the rapid development of AI applications. With the addition of innovative ideas, it can become a novel AI application. In this paper, we will use MediaPipe, incorporating new ideas, to create a motion-sensing Breakout game.

In the motion-sensing Breakout game, we will use the pose landmark detection solution from MediaPipe to detect and track the position of the human body in the camera's view. The pose landmark detection solution can detect and recognize whether a human body is present in the image, and then use AI functions to identify key landmarks on the body (as shown in Figure 1). The illustration shows that MediaPipe identifies a total of 33 body landmarks (numbered 0-32). With these body

landmarks, we can easily recognize the current posture of the human body and develop many AI applications.

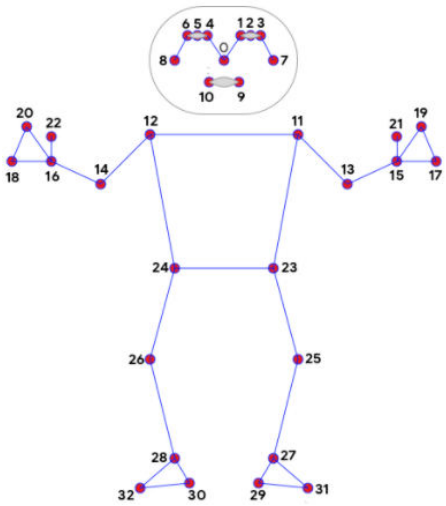

Figure 1. The illustration shows that MediaPipe identifies a total of 33 body landmarks (numbered 0-32).

Can MediaPipe detect and recognize the human body with high accuracy? In what situations might MediaPipe misjudge? If misjudgments occur, how can we ensure that the Breakout motion-sensing game runs smoothly without errors? In the next section, I will discuss how to replace mouse operation with body movements and ensure that the control is as smooth as using a mouse.

2. methodology of research

In this chapter, we will first introduce the traditional Breakout game. Next, we will explain how we used Google MediaPipe to transform it into a motion-sensing Breakout game. We will then discuss the experience results and propose an improved algorithm.

2.1 Breakout game[1, 2]

Breakout is an arcade video game developed by Atari, Inc. and released in 1976.[1, 2] Although Breakout has very simple game rules, it caused a sensation upon release, driving many players crazy and becoming a highly successful classic game.

What exactly is Breakout like? In the Breakout game screen, there are several bricks arranged at the top of the screen. A moving ball bounces between the bricks, the top wall, the left and right walls of the screen, and a movable paddle at the bottom of the screen(as shown in Figure 2). When the ball hits a brick, it bounces back and the brick disappears. Players control the movement of the paddle at the bottom of the screen using a joystick, keyboard, or mouse to keep the ball bouncing back up to hit and clear all the bricks. If the ball reaches the bottom of the screen without hitting the paddle, it disappears, and if all the balls disappear, the game ends in failure. If the player manages to clear all the bricks before all the balls disappear, they pass the game.[1, 2]

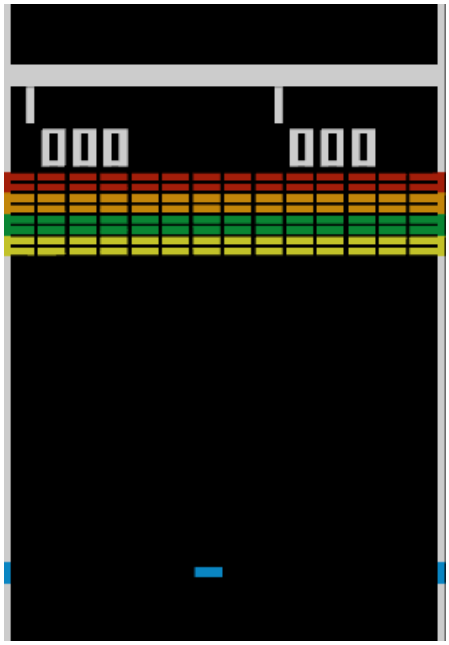

Figure 2. The Breakout game.[1]

Due to the success of Breakout, many game software companies have produced imitations, resulting in numerous versions of Breakout games on the market today. Currently, brick-breaking games can be played on arcade machines, computers, and smartphones, as well as on various internet platforms. In this paper, we propose a motion-sensing Breakout game based on Google MediaPipe. We aim to replace the traditional control methods of joysticks, keyboards, or mice with motion-sensing

technology, thereby enhancing people's willingness to exercise and improving the quality of their recreational activities.

2.2 Our motion-sensing Breakout game

In this chapter, we introduce how we improved the traditional Breakout gameplay to create a motion-sensing Breakout game. We used Google MediaPipe's multimedia machine learning model framework, implementing motion-sensing functionality through MediaPipe's pose landmark tracking feature. By tracking players' bodies with MediaPipe, we use their movements to control the paddle in the Breakout game, eliminating the need for joysticks, keyboards, or mice. In the Breakout game, the paddle can only move left and right, meaning its X-axis position changes with the player's movements while its Y-axis position remains fixed.

Additionally, we use MediaPipe's pose landmark tracking feature to recognize players' poses in real time, enabling control over game functions such as starting and pausing the game with different body poses. The motion-sensing Breakout game is written in Python. In addition to the AI technology MediaPipe, we also use OpenCV for image processing and Pygame to show the game's graphical interface.

In the motion-sensing Breakout game, we use the player's body movements to control the paddle, eliminating the need for joysticks, keyboards, or mice. The ball and brick mechanics are identical to those in the traditional Breakout game, so we will not reintroduce them in this chapter.

We first use OpenCV to read the camera feed and perform preliminary image processing. Then, we use MediaPipe's pose detection model to detect and mark the player's body, identifying the corresponding nodes and skeleton of the head, hands, limbs, and torso. From the results processed by MediaPipe, we can obtain 32 body landmarks (landmarks[0] ~ landmarks[31]) of the player in the image, as shown in Figure 1.

Among these 32 landmarks, we use the nose (landmark[0]) to represent the player's current position, with coordinates (landmark[0].x, landmark[0].y). The coordinate values obtained after MediaPipe processing range between [0, 1):

$0 \leq$ landmark[0].x, landmark[0].y < 1

However, we only need landmark[0].x because the paddle's Y-axis coordinate is fixed, so landmark[0].y is not needed. Next, we convert the nose's X-axis coordinate (landmark[0].x) to screen coordinates and set this X-axis coordinate as the paddle's X-axis coordinate (X, $\bar{Y}$), as shown below:

X = landmark[0].x * Screen horizontal resolution

The paddle's Y-axis coordinate $\bar{Y}$ remains fixed. By continuously performing camera capture, detection, paddle coordinate setting, and screen updating, we can simply achieve player-controlled paddle movement in the game.

However, during experiments, we found that the paddle sometimes malfunctions and does not fully follow the player's movements. While playing the game, the paddle exhibits erratic jumping. Therefore, we need to investigate the causes of paddle malfunction and make improvements based on the identified issues to make the game more robust.

3. Improved motion-sensing Breakout game

In this chapter, we will propose several improvement strategies to enhance the game's stability and usability.

3.1 More robuster algorithm

In our experiments, we found that the paddle sometimes malfunctions and fails to follow the player's movements accurately. While playing the game, the paddle exhibits erratic jumping. This issue is caused by MediaPipe misjudging the player's body position during tracking. We observed that MediaPipe misjudgments typically occur when the background behind the player is complex or the player's body posture is unusual. When the background is complex and the player is in an awkward posture, MediaPipe may occasionally mistake part of the background for the player or fail to detect the player altogether. To solve this issue, we propose an improved algorithm to handle misjudgments, ensuring the game runs smoothly even when MediaPipe misjudges.

Let $(x_t, \bar{Y})$represent the paddle's coordinates at time t, and $(\Delta x_t, 0)$ denote the paddle's movement speed and direction at time t:

$$\Delta x_t = x_t - x_{t-1}$$

The predicted coordinates of the paddle $(\hat{x}_{t+1}, \bar{Y})$ at time t+1 are given by:

$$\hat{x}_{t+1} = x_t + \Delta x_t$$

Let $(\bar{\bar{x}}, \bar{\bar{y}})$ be the coordinates of the player detected by MediaPipe at time t+1. The paddle's coordinates $(x_{t+1}, \bar{Y})$ at time t+1 are:

$$x_{t+1} = \hat{x}_{t+1} \quad if\ |X - \hat{x}_{t+1}| \geq \theta$$
$$x_{t+1} = \bar{\bar{x}} \quad if\ |X - \hat{x}_{t+1}| < \theta$$

If at time t+1, the predicted X-axis coordinate of the paddle and the X-axis coordinate detected by MediaPipe differ by more than a threshold θ, it likely indicates a MediaPipe misjudgment. In this case, the paddle's X-axis coordinate is set to the predicted coordinate. Otherwise, it is assumed that MediaPipe has correctly tracked the player's position, and the paddle's X-axis coordinate is set to the coordinate tracked by MediaPipe. The paddle's Y-axis coordinate $\bar{Y}$ remains fixed. This approach significantly mitigates the issue of paddle malfunction due to MediaPipe misjudgments.

Of course, this method relies on a fast computer execution speed. We use the number of frames processed per second (FPS) as a measure of the computer's processing speed. Most modern computers can easily handle over 30 FPS, so the time interval between consecutive frames is very short. In such a short time, the movement speed of the human body can be assumed to be constant or nearly constant. We can use this characteristic to reduce the impact of MediaPipe misjudgments on the game, thereby greatly enhancing the game's stability.

3.2 Two-player mode

To enhance the interest and entertainment value of the motion-sensing Breakout game, we modified it to include a two-player mode, allowing players to experience the game with an exercise partner. This setup encourages mutual competition and support, increasing players' willingness to engage and have fun.

In the game screen, most configurations are the same as in single-player mode, but there are two sets of balls and paddles, with each set having the same color. Each player controls one paddle to hit back the ball of the same color, aiming to destroy as many bricks as possible with their respective balls. Since MediaPipe can only track a single player from the image, we need two cameras for the two-player mode, with each camera capturing the image of one player.

The algorithm for the two-player mode in the motion-sensing Breakout game is the same as that of the single-player mode, but it requires approximately double the computational power. Given that modern computers have high processing capabilities, adapting the motion-sensing Breakout game to a two-player version is entirely feasible, and the gameplay experience remains smooth.

3.3 Energy expenditure

Motion-sensing games have broad potential applications in healthcare, helping patients improve treatment outcomes, increase engagement, and enhance overall health. For a motion-sensing game user, knowing how much energy is consumed during gameplay is very important. Quantifying the energy expenditure allows players to plan their daily exercise and manage their diet effectively. Therefore, we calculate and inform players of their energy consumption at the end of the game.

To calculate the calories burned during daily activities and exercise, we need to consider not only the exercise intensity but also the individual's weight and activity duration. The formula for energy expenditure (kcal) is as follows:[3, 4, 5, 6, 8]

Energy expenditure (kcal) = Metabolic Equivalents (METs) × weight (kg) × time (hours)

In this formula, Metabolic Equivalents is abbreviated as METs[3, 4, 5]. One MET is defined as the energy expenditure of sitting quietly, which is 1 kcal per kilogram of body weight per hour. According to the common MET values for various activities, the MET value for the motion-sensing Breakout game is approximately 8.[3, 4, 7, 9]

For example, a person weighing 70 kg who plays the motion-sensing Breakout game for 30 minutes would have an energy expenditure of approximately 70 kg x 8 METs x 0.5 hr = 280 kcal. The provided energy expenditure is an estimate and may not accurately reflect the actual energy consumption, as it varies between individuals based on factors such as age, gender, body fat percentage, and fitness level.

In summary, we hope that players can understand their calorie consumption through the game, which will aid in exercise planning, health management, diet management, and the formulation of weight loss plans.

4. Experiments and Discussions

To demonstrate the playability and exercise potential of the motion-sensing Breakout game, we arranged for many players to experience both single-player and two-player modes. The laptop specifications for running the game are shown in Table 1.

CPU	Intel CORE i7-8750H
Graphics card	Nvidia GEFORCE RTX2070
Main memory	DDR III 32G
Hard disk	512GB NVMe PCIe SSD
Integrated development environment(IDE)	Anaconda 3
Programming language	Python 3.9
Screen	12 inches

During the gameplay, we observed that most players felt somewhat tired, such as faster breathing, increased body temperature, flushed faces, and sweating. However, their faces showed expressions of joy, and they reported feeling refreshed after playing, similar to post-exercise relaxation. Players also found it very enjoyable to experience the game with friends. At the end of the game, players were surprised by the amount of energy they had expended during the session.

From the player experiences, we identified two main drawbacks of the game. The first drawback is the high spatial requirement. Players need a large area to move left and right, and the space required is even larger for two-player mode, as players cannot overlap. Additionally, the playing area should be relatively simple to minimize the chances of Google MediaPipe misjudgments. The second drawback is the small screen size of computers or laptops. To enhance the player experience, it is recommended to display the game on a large LCD screen or project it using a projector.

5. Conclusions

In conclusion, this paper integrates AI, motion-sensing games, and healthcare to propose an innovative motion-sensing game framework based on AI technology, aiming to address the prevalent issue of insufficient physical activity in modern society. By leveraging the multimedia machine learning tools developed by Google MediaPipe, we transformed the popular arcade game Breakout into a motion-sensing Breakout game.

Our experiments revealed that MediaPipe may misjudge in complex scenarios, and to address this, we proposed an improved algorithm to ensure a smooth gaming experience. To enhance user engagement, we developed a two-player mode and incorporated calorie consumption estimation to motivate people to exercise and improve their health.

Through experiments and user experiences, we found that the motion-sensing Breakout game effectively stimulates interest in exercise and helps players achieve physical activity through gameplay.

In summary, this innovative AI motion-sensing game not only provides an enjoyable way for gamers to exercise but also helps to mitigate the widespread issue of insufficient physical activity in modern life. In the future, we hope to further optimize this game to expand its applicability and benefit more people.

Although Google Research has not disclosed the internal details and technology of MediaPipe, we can consider it a valuable tool for developing AI applications. By

incorporating new ideas and innovations, we can easily develop enhanced AI applications.

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