Article

Robotics Project Amphawa Floating Market Board Game

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Abstract. This report details the engineering development of an interactive board game inspired by the vibrant atmosphere of the Amphawa Floating Market. The project leverages a Raspberry Pi 5 microcontroller and advanced sensors to create a gameplay environment that fosters self-expression, critical thinking, and social interaction. By integrating these technical elements, the game aims to instil a sense of achievement and pride within the target audience.

The system utilizes an RFID scanner as the primary sensor, which coordinates with a suite of actuators including speakers, vibration motors, LEDs, and servo motors. The Raspberry Pi 5 serves as the central hub, mapping objectives from physical playing cards to specific sensory outputs. These components work in unison to simulate the dynamic movements and environmental conditions of the floating market. Testing results confirmed high functional cohesion, demonstrating synchronized servo movements, accurate audio output, and timed LED sequences. Furthermore, the vibration motors and actuators successfully responded to localized "weather" data triggered by the RFID cards, ensuring a responsive and engaging physical computing experience for all players.

1. Introduction

As technology advances, teenagers are becoming increasingly dependent on and addicted to their screens. This is leading to a decline in attention span, as well as a decrease in successful critical thinking. Teenagers often choose to text or interact online rather than in person, which is negatively impacting their people skills and communication skills.

In the initial design phase, our team collaborated with the ID group to create a smart toy that not only encourages teenagers to interact but also promotes problem-solving skills. To achieve this, we had to create a game that was both interactive and strategically challenging.

Considering usability, cost efficiency, and system reliability, our team's final design for the Amphawa Floating Market Boardgame included an RFID scanner, speaker, LED, servo motor, and vibration motor. The system integrates all these sensors and actuators using a Raspberry Pi 5 microprocessor.

This final report outlines the development process, design modifications, and testing results of the combined system. The effectiveness of the system will be evaluated in terms of accuracy, usability, and reliability.



Figure 1 Displays the final Amphawa Floating Market Board Game.

2. Literature Reviews

A study (2019) conducted on secondary school science students investigated the relationship between problem-solving skills, working memory, and attention span. The findings suggested that attention span and working memory can influence students' ability to think critically and solve problems effectively. The study also recommended the use of activities that encourage creative problem-solving and cognitive engagement to help improve students' learning and thinking skills [1].

Another study, conducted by A. Gauthier (2019), found that nondigital board games can positively impact knowledge, behaviors, social functioning, anxiety, and executive functioning, demonstrating their potential to promote learning, interaction, and cognitive development [2].

Studies (2024) have shown that board games can help develop communication, teamwork, problem-solving, and social interaction skills while also increasing engagement and motivation among players. However, traditional board games may not always appeal to modern teenagers who are more attracted to technology-based entertainment [3]. Therefore, this project aims to create a smart interactive board game that combines traditional social interaction with technologies such as sensors, microcontroller and actuators to make gameplay more engaging and encourage teenagers to participate more actively.

3. Methodology

The function of the Amphawa Floating Market Board Game's internal engineering is to translate the RFID weather tags into the correct output: the speaker, to play the correct sound according to weather; the vibration motors, to shake the boats during stormy weather; the LEDs, to light up the high scoring points according to the weather card; and the servo motors, to reveal the spots covered by umbrellas during rainy weather.

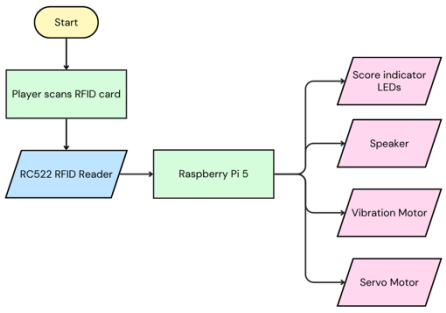


Figure 2.1 Illustrates the flow of the components and features of the board game system.

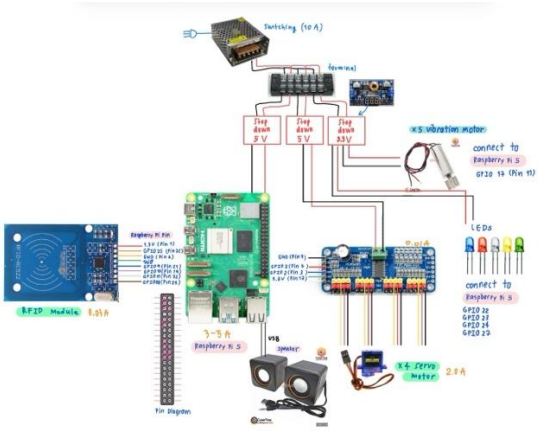


Figure 2.2 Illustrates the final circuit connection of the game.

The UID of the RFID tags are read by the RFID scanner and provided to the Raspberry Pi 5 which results in the correct output by the actuators. The system is powered by an AC to DC power system using 3 different step-down buck convertors. Each component requires different levels of voltages and current which requires special consideration as the gameplay is about 45 minutes.

The vibration motor is connected to the Raspberry Pi 5 through the GPIO 17 and 8 pin using a 1 kΩ resistor, a 2N2222 transistor, and a diode. The team tested the operation of the vibration motor using two RFID cards that corresponded to a short buzz and a long buzz, while all five motors were connected through one common pin. Both testing conditions operated successfully and could be attached to a spring mechanism to oscillate the boat when the stormy weather card was scanned.

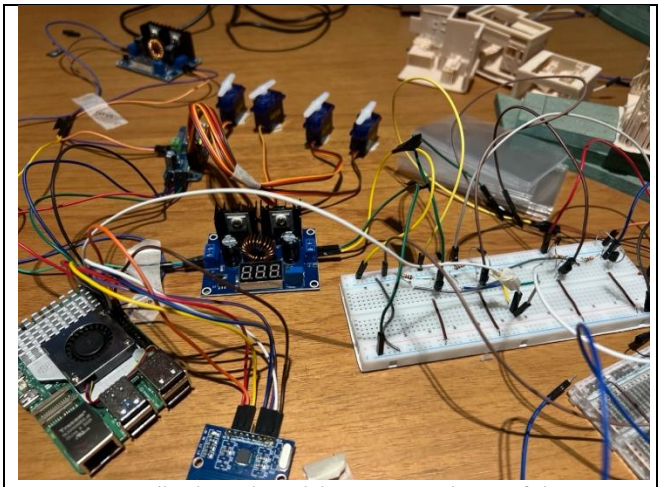


Figure 2.3 displays the wiring connections of the RFID scanner, servo motors, and vibration motors.

The servo motors were connected to the Raspberry Pi 5 using a common PCA9685 driver board. GPIO pins 1, 3, 5, and 6 were used to complete the connection for the four servo motors. The team tested the motors using three RFID tags that corresponded to different rotation angles and successfully achieved the desired movements. Covers were then attached to the servo blades and placed through the roofs of the shops to create an umbrella reveal effect when the rain RFID cards were scanned.

The RFID scanner (RC522) was connected to the Raspberry Pi 5 using SPI communication pins, including GPIO25, GPIO8, GPIO11, GPIO10, and GPIO9, along with the 3.3 V and GND connections. The team tested the RFID scanner using three sets of RFID cards corresponding to sunny, rainy, and stormy weather conditions. The scanner successfully detected each card and transmitted the corresponding signals to the Raspberry Pi 5, allowing the appropriate game responses and actuator actions to be triggered.



Figure 2.4 displays the final umbrella mechanism using the servo motor.

The LEDs are split into 4 objective groups: monk, boat, fireflies, and rain. These objective lights are to guide the players towards to highest scoring point areas for corresponding phase of day and weather card. Our group used 4x 2N2222 transistors and 4x 1 kΩ resistor and corresponding GPIO pins 22,23,24, and 27 to connect to the Raspberry Pi. The lights were successful in testing to only light up to their corresponding RFID weather card.



Figure 2.5 Displays the objective LEDs when the stormy weather card is scanned.

Our group used the NS44 desktop speaker to connect to our Raspberry Pi using 2 USB ports and downloaded 3 weather sounds: sunny weather, rainy weather, and stormy weather. During testing, the audios successfully played when the correct RFID weather card was scanned. We were also able to successfully code the Raspberry Pi to loop the audio until the next weather card was scanned.

After the LEDs were connected to the same buck converter and ground as the vibration motors, the vibration motors experienced electrical noise and current disruptions that caused them to halt their working.

Similarly, our RFID stopped working due to electromagnetic noise that clashed with the RFID logic.

4. Results

After the initial engineering designs were completed, the sensor was tested with each desired actuator. During the testing phase, the vibration motor accurately corresponded to the UID of the weather cards. Based on when the stormy weather card was scanned, the vibration motor and spring mechanism would allow the boats to shake.

The speaker was installed with 3 sounds saved: sunny, rainy, and stormy. According to the weather card scanned, the corresponding sound was played. Similarly, the objective LED lights worked by lighting up around the highest scoring area depending on the weather card scanned.

Similarly, the objective LED lights that were grouped into 4 main objective groups also worked as intended by relating to the scanned weather card. Due to the LEDs taking up a lot of current, our group chose to not use the vibration motor on the boats.

The servo motors were fitted with an umbrella covering designed by the ID group and would rotate 180 ° when the rainy weather card was scanned, allowing for "safe score spots" to be revealed when it rained.

To evaluate the gameplay experience, the Amphawa Floating Market Board Game was play tested by a group of three seniors and one 5th-grade student. The senior testers specifically commended the interactive mechanics, and the engaging sensory elements integrated into the design. Additionally, the younger participant remained captivated by the game's dynamic environment, which evolves every round based on the specific weather cards scanned, ensuring a fresh and responsive experience for players of all ages.

5. Discussions

During the development of the Amphawa Floating Market Board Game, the team encountered several challenges that required adjustments to ensure the gameplay operated effectively and safely. An important adjustment was made to the features of the board game: the LED strip was removed from the hardware requirements as it was used as a design aesthetic and required a large amount of current. Instead, the project was simplified to keeping only the 4 respective LED groups for objective lights.

The first issue was related to the system's power distribution. Since the system required approximately 10 A of current with varying voltage requirements for different components, a stronger power source along with multiple buck converters had to be introduced to operate the components safely. To ensure proper power distribution, terminal blocks and brackets were also added to the system. These additions resulted in extra wiring and modifications to the original design.

The second challenge was due to the electrical and electromagnetic noise from the large use of LEDs. This stopped our vibration motor and RFID scanner from operating the way they should. For future projects, isolating the RFID power source and connecting a capacitor will result in greater reliability. Similarly, isolating the LEDs and vibration motor mechanism will ensure smooth operation.

Another challenge was related to the intricate layout of the board game. The game pieces were small and spread across a large area, while much of the wiring had to be placed underneath the board with certain components mounted above it. This made the wiring process difficult, as wires could easily be pulled out or exposed from the housing. The team communicated this issue with the ID group and developed a solution by creating hatch-like sections with hinges on each side of the board, allowing easy access to the internal wiring. Additionally, holes were drilled into the board to route wires through for components such as the speaker and power supply.

For future improvements, we could design a custom PCB that would reduce the number of wiring we had to make the design more compact. We could also optimize the power distribution to use a chargeable and portable system so the game can be played without being plugged in.

Although several challenges were encountered during the development of this smart toy, the team was able to successfully create and test the Amphawa Floating Market Board Game. Overall, the project demonstrates the potential of a smart toy controlled by a Raspberry Pi 5 and integrated sensors and actuators. With further improvements in power management and system design, the Amphawa Floating Market Board Game could become a practical and effective way to encourage critical thinking among teenagers while also improving their social skills and promoting a sense of self-achievement.

6. Conclusion

In conclusion, the project successfully developed and tested a smart toy that can increase social skills and

promote critical thinking skills. The final board game included an advanced sensor, the RFID scanner, the Raspberry Pi 5, and these actuators: servo motor, vibration motor, LEDs, and speakers. These components worked together to create an interactive gameplay.

The smart toy system demonstrated the ability to accurately correspond to the sensor's readings and carry out the correct responses from the multiple actuators. Although several challenges were encountered during the development of this smart toy, the team was able to successfully create and test the Amphawa Floating Market Board Game.

Overall, the project demonstrates the potential of a smart toy controlled by a Raspberry Pi 5 and integrated sensors and actuators. With further improvements in power management and system design, the Amphawa Floating Market Board Game could become a practical and effective way to encourage critical thinking among teenagers while also improving their social skills and promoting a sense of self-achievement.

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