Sensor Module Application in the Design of an Automatic Tabletop Hockey Product Prototype for Leisure Activities and Mental Fitness

Li-Shiue Gau[1] [a], Chung-Wen Hung[2], Chia-Jui Yang[2], Tzu-Ling Liu[1] and Shiou-Ling Lin[1]

[1]Department of Business Administration, Asia University, Taichung, Taiwan
[2]Department of Electrical Engineering, National Yunlin University of Science and Technology, Yunlin, Taiwan

Keywords: Hockey, Signal, Leisure Activity, Mental Fitness, Device Engineering.

Abstract: With the fast-paced modern lifestyle and increasing work pressure, the demand for leisure and entertainment is rising. Traditional tabletop hockey has been a popular leisure activity, primarily providing relaxation and enjoyment while promoting interpersonal interaction. However, modern needs have evolved, transforming games that once required multiple participants into formats suitable for solo play. This evolution has led to the emergence of the automatic tabletop hockey product, creating new business opportunities. Despite its immense potential, there are currently no automatic tabletop hockey products available in the market. Therefore, the purpose of this study is threefold. First, sensor module applications were used to design an automatic tabletop hockey product prototype. Second, this study also conducts an in-depth practical investigation to assess the commercial feasibility of automatic tabletop hockey product in the perspective of leisure activities. Third, an experimental design was conducted with young elementary school children to see the experiential value of this product prototype, referring to the mental fitness. The anticipated contribution of this study not only aims to satisfy the modern demand for leisure and entertainment but also has the potential to open new business prospects.

1 INTRODUCTION

In response to the fast-paced modern lifestyle and the accumulation of work pressure, the demand for leisure and entertainment has become increasingly significant. Modern individuals seek convenient, enjoyable, and effective ways to relieve stress and keep mental fitness. Currently, tabletop hockey has been a popular leisure activity in hotels, entertainment venues, night markets and households, providing a pleasurable and relaxing form of entertainment while promoting interpersonal interaction. However, the COVID-19 pandemic has necessitated social distancing, increasing the trend toward individual leisure. Consequently, games that previously required multiple participants have evolved into formats suitable for solo play. Despite this evolution, there are currently no automatic tabletop hockey products available on the market, warranting an investigation into this product's potential market and commercial feasibility.

Therefore, this study has three primary purposes. First, it utilizes signal and sensor module applications to design an automatic tabletop hockey product prototype. Second, it conducts an in-depth practical investigation to assess the commercial feasibility of the automatic tabletop hockey product prototype from the perspective of leisure activities. Third, it employs an experimental design involving young elementary school children to evaluate the experiential value of this product, with a focus on mental fitness. The anticipated contribution of this study is not only to satisfy the modern demand for leisure and entertainment but also to potentially open new business prospects.

1.1 An Automatic Tabletop Hockey Product Prototype with a Sensor Module

To reduce costs, an infrared positioning sensor module was used along with a self-built XY platform

---

[a] https://orcid.org/0000-0002-6976-6640

to control the striker. The infrared positioning sensor module receives infrared data and transmits it to the MCU (Microcontroller Unit) via I2C (Inter-Integrated Circuit) communication. After processing the data through a coordinate transformation algorithm, stepper motors drive the XY platform to adjust the position of the striker, enabling striking and defensive actions.

An available small air hockey table (70 centimeters long, 36 centimeters wide) was purchased online to be modified for this project. The installation height for the infrared positioning module was calculated based on this module's resolution of 1024×768 pixels and its field of view of 33 degrees horizontally and 23 degrees vertically (Figure 1). To capture the entire table, the module needs to be mounted at a height of at least 118 centimeters (Figure 1). Each pixel corresponds to approximately 68 millimeters on the tabletop surface, allowing for precise tracking of the puck's movement.
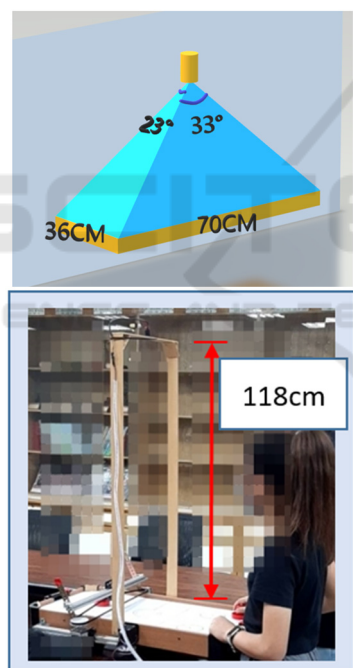

Figure 1: The installation for the infrared positioning module.

The infrared positioning system exhibits several limitations and calibration requirements. First, it needs to be calibrated after installation to ensure accuracy, as potential sources of measuring errors can arise from obstructions or interference from other infrared sources. Additionally, because the infrared tracking puck requires the module to be installed above the table, signal interference from the player can occasionally occur. Despite these challenges, the

system's high refresh rate of up to 26Hz minimizes dynamic response limitations, enabling accurate tracking of fast-moving pucks during gameplay.

To enable the infrared positioning module to detect the puck's position, an infrared light and a button battery were added above the puck as a tracking point. Due to the added weight, a 110V fan was used as the air source through the holes in the table to ensure the puck can float properly. In terms of battery autonomy, using a CR2032 battery with a 220-ohm resistor can power the infrared LED for approximately 17 hours, providing sufficient energy for extended playtime. However, switching to a lighter CR1620 battery enhances the puck's hovering effect due to its reduced weight but limits the playtime to around 5 hours, offering a trade-off between performance and battery longevity.

The infrared positioning module tracks the puck's position, sending signals to the microcontroller, which calculates the puck's position in terms of movement direction and speed. The microcontroller then commands the carriage motor to move the striker. When the puck approaches, its path is predicted, and the striker is moved to the strike point (Figure 2).
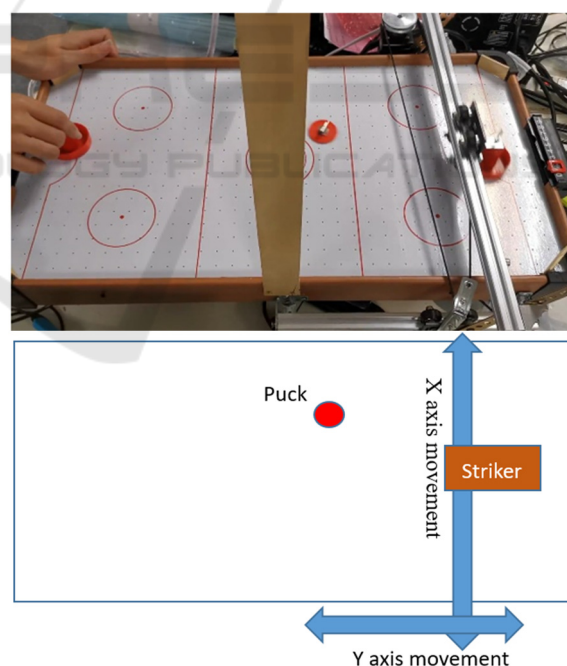

Figure 2: Signal communication for the puck position to the striker movement.

The microcontroller used is the Renesas RX62T6DDFM from the RX600 series, with a maximum operating speed of 80MHz (Renesas, 2014, 2010). It features a 32-bit processor with Floating

Point Unit (FPU), effectively handling the high-speed algorithms required for motor control, making it suitable for computing the position of the puck and controlling the motor. The RX62T's built-in Serial Peripheral Interface (SPI) and Inter-Integrated Circuit, I2C, are used for communication between the infrared positioning module and the stepper motor driver.

The striker is mounted on the XY platform and can move freely, allowing it to engage in defense, striking, and attacking the puck that is about to stop. Unlike a passive pad that merely reflects the puck, the striker actively performs a "strike back" action. It has a range of motion of approximately 22 centimeters along the Y-axis and can reach speeds of up to 75 centimeters per second. In this game, the player's objective is to send the puck in such a way that it passes the striker and reaches the opposite end of the table.

1.2 Leisure Experiences in Playing Tabletop Hockey

A traditional tabletop hockey game is typically played by two people as a fun leisure activity. An automatic tabletop hockey device with a sensor module, if introduced to the market, could provide a new and varied experience. This innovation has the potential to enhance the overall enjoyment and experience of playing tabletop hockey in multiple ways.

The concept of the "Experience Economy," introduced by Pine and Gilmore in 1999 (Gilmore & Pine, 2007), suggests that economic development has evolved through four stages: Agrarian, Industrial, Service, and now, Experience Economy. This latest phase focuses on the user experience, emphasizing the creation of memorable and immersive experiences. The Experience Economy categorizes experiences into four realms: Entertainment, Education, Esthetic, and Escapist (4E). These realms vary in the level of customer engagement and their connection to the surrounding environment, ranging from passive absorption to active participation. In the context of tabletop hockey, this leisure activity primarily falls within the Entertainment and Education realms, offering both enjoyment and active learning experiences.

Experiential Marketing (Schmitt, 1999) is a strategy that emphasizes the sensory, emotional, cognitive, and relational dimensions of consumer experiences. It involves creating memorable experiences that resonate with consumers, often through engaging activities. For tabletop hockey, players experience joy and a sense of achievement,

which strengthens their emotional bond with the product. Additionally, the game's strategic and skill-based elements engage players cognitively, promoting problem-solving and creative thinking. This blend of emotional and intellectual engagement not only makes the game more appealing but also provides educational value. Together, the leisure experience and experiential marketing create a rich, multifaceted consumer experience, enhancing mental fitness and life quality.

In comparing traditional and automatic tabletop hockey, the experience theory highlights distinct differences in user engagement and experience. Traditional tabletop hockey relies on manual control and real-life opponents, emphasizing interpersonal interaction. In contrast, automatic tabletop hockey integrates advanced technology, such as infrared sensors and stepper motors, to automate gameplay (Mena, Ruiz, Ortiz, & Andaluz, 2018). This technological integration enhances the entertainment value by introducing a unique, interactive element that simulates competition against a machine, suitable for solo play. While the automatic version requires more maintenance and incurs higher costs, it provides a distinct, modernized experience that could appeal to tech-savvy consumers seeking innovative leisure activities, then potentially increasing user engagement through novelty and excitement.

2 RESEARCH METHODS

This study employed a mixed-method research design to evaluate the effectiveness of the potential automatic tabletop hockey product, incorporating interviews, observations, and surveys. Interviews with potential users, such as night market vendors, explored commercial potential, user interest, and market challenges, while elementary school students participated in observational and survey-based experiments comparing traditional and automatic versions of the game. The experiential value of the product was measured using a tailored experience value scale, assessing dimensions like entertainment, escape, education, self-esteem, and social interaction, supported by qualitative observations of gameplay dynamics and engagement.

2.1 Research Design

This study employed multiple research methods to evaluate the effectiveness of the automatic tabletop hockey product prototype, including interviews, observations, and surveys. Interviews with potential

users such as night market vendors were conducted to assess the feasibility of this innovative product. The semi-structured interviews were guided by a set of questions focusing on the commercial potential, user interest, and market expectations. Additionally, the interviews explored opinions on the appropriate pricing range and potential market challenges.

2.2 Observational and Survey Data Collection

Observations and surveys were integral components of an experimental design involving ten elementary school students, with parental consent. The students participated in playing both traditional and automatic versions of tabletop hockey (Figure 3). Observational notes were taken as students took turns playing. Specifically, during the sessions with the automatic product prototype, observations focused on capturing data related to product features, gameplay dynamics, user engagement, and interaction patterns. After the play sessions, all ten students completed a valid questionnaire and were divided into two groups of five for interviews, where they provided feedback on their experiences.

Figure 3: Play both traditional and automatic versions of tabletop hockey.

2.3 Measurement Tools

Drawing on the theories of experience economy (Gilmore & Pine, 2007) and experiential marketing (Schmitt, 1999), the experiential value of playing the automatic tabletop hockey product prototype was measured using a tailored version of the experience value scale. This scale, based on previous research (Bouchet, Bodet, Bernache-Assollant, & Kada, 2011; Brakus, Schmitt, & Zarantonello, 2009; Gau, Dung, & Huang, 2015), assesses five dimensions of user experience: Entertainment, Escape, Education, Self-Esteem, and Social Interaction. The questionnaire used a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) to measure responses.

Additionally, observation sheets were designed to document specific aspects of gameplay and interaction during the study. Separate sheets were used for manual and automatic gameplay, recording the number of matches, techniques or strategies used, player interest levels, and interaction patterns. These observations provided qualitative insights into the product's performance and user engagement, offering a comprehensive view of the product's experiential value and market potential.

3 RESULTS AND DISCUSSIONS

This study evaluated the performance and feasibility of an automatic tabletop hockey product prototype, focusing on its lateral movement, reaction speed, and accuracy. While the product showed strong potential, challenges related to portability and incomplete automation were identified. Interviews with night market vendors revealed mixed feedback: some saw market potential in the game's novelty, while others raised concerns about cost, maintenance, and limited social interaction. Surveys and interviews with upper elementary students compared the manual and automatic versions, with the manual version favoured for its interactivity and social engagement, and the automatic version appreciated for its novelty and strategic elements, fostering mental fitness and creativity. The following sections provide further details.

3.1 Product Performance Observation

3.1.1 Movement Speed

The movement speed highlights efficiency of the striker's X-axis and Y-axis movements. The device covers a distance of 34 centimetres among the X axis

movement in approximately 0.47 seconds. It has a Y-axis range of 22 centimetres and can reach speeds of up to 75 centimetres per second.

3.1.2 Response Times of the System

This section explains device response time to puck movements. The system starts predicting and reacting 0.15 seconds after the puck is hit. In other words, it takes approximately 0.15 seconds for the system to "take a decision" and to generate corresponding control signals. An additional 0.3 seconds (at most) is required for the striker to reach the demanded defensive position. In total, the system responds and moves the striker within 0.45 seconds.

3.1.3 Accuracy Rate

The accuracy rate refers to the proportion of successful hits by the striker when attempting to make contact with the puck. A successful hit means the striker prevents the puck from bypassing it and reaching the end of the table. In actual tests, the machine achieved an accuracy rate of about 77% per minute, meaning that, on average, the striker successfully intercepted the puck in 77% of attempts during a one-minute interval of continuous gameplay. This method measures performance over time, reflecting the striker's effectiveness in ongoing, timed gameplay rather than being based on the number of strikes or reaching a specific score.

3.1.4 Market Potential and Design Limitations

In terms of commercial viability and installation, the sensor module's signal application in the device design of an automatic tabletop hockey is workable, engaging the participants into playing involvement. The current design of the automatic tabletop hockey product prototype shows promising market potential. However, due to the requirement of installing the infrared positioning module at a height of 118 cm (Figure 1), the product may need to be fixed in a specific location, such as a recreation room, rather than being portable. Additionally, the costs associated with installation and maintenance could be a concern for potential buyers.

3.1.5 User Experience

The playing experience offers a sense of novelty, achievement, and the convenience of being able to play alone. However, the automation of the game is not fully comprehensive. For instance, if the puck

bypasses the striker, it must be manually repositioned, indicating that the product's automation level is not yet complete at the current situation of the device.

3.2 Interviews About the Feasibility of the Automatic Tabletop Hockey

3.2.1 Supportive Perspectives

Several vendors believe that automatic tabletop hockey has potential market feasibility, particularly in night markets, which attract a diverse range of tourists and visitors. The novelty of the game could draw interest, especially from those seeking new and unique experiences. Vendors noted that night market visitors often look for engaging activities beyond food, and an automated game could offer a fresh entertainment option. Some vendors highlighted that the introduction of such a unique game might stand out in an environment typically filled with traditional offerings, potentially appealing to families and tech-savvy individuals. This innovation could enhance the marketability of their stalls and attract a broader audience.

3.2.2 Skeptical Perspectives

Conversely, some vendors expressed reservations about the product's suitability for night markets, which traditionally feature games and food with a more classic appeal. They argued that the automated aspect might not resonate well with the typical night market atmosphere, which thrives on interactivity and communal experiences. Concerns were raised about the game's lack of social interaction, as many visitors come to the night market with friends and prefer activities that facilitate group participation. Additionally, there were worries about the cost and maintenance associated with such a product, which could outweigh its potential benefits and fail to attract enough interest to justify the investment.

3.3 Survey and Interviews About the Experiential Values

3.3.1 Preference for Manual Tabletop Hockey

The manual tabletop hockey generally received higher ratings from participants from upper elementary school students. The key factors contributing to this preference include the game's high level of interactivity, which allows for direct, face-to-face competition with peers, enhancing the

fun and challenge of the game. Additionally, the manual version requires players to react quickly and develop real-time strategies, aligning with the cognitive development stage of these children and enriching their gameplay experience. This age group also values social interaction, preferring activities that allow them to engage and bond with their peers, making the manual version particularly appealing as it fulfils their social needs.

3.3.2 Preference for Automatic Tabletop Hockey

On the other hand, the automatic tabletop hockey version intrigued the students with its novelty and the opportunity it provided for strategic thinking and learning. The newness of the automated game sparked curiosity and encouraged students to cognitively explore strategies to beat the machine, fostering a sense of creative thinking. One student noted the uniqueness of the experience, highlighting how it prompted them to think about overcoming the automated opponent. Additionally, while some students mentioned a preference for the social interaction offered by the manual version, they also expressed interest in sharing their experiences in the automatic version with friends and family, suggesting that the novelty of the game provided a fresh topic for social interaction. This novelty factor, combined with the technological aspect of the game, made the automatic tabletop hockey an exciting new experience for the children.

3.3.3 Mental Fitness

The survey and interviews reveal that both manual and automatic tabletop hockey games contribute to mental fitness among upper elementary school students, albeit in different ways. The manual version enhances mental fitness by fostering real-time strategic thinking and quick reflexes, which align with the children's cognitive development stage. In contrast, the automatic version stimulates mental fitness by introducing novelty and requiring students to devise strategies to compete against an automated opponent. This element of technological novelty encourages creative thinking and problem-solving. Furthermore, the excitement of experiencing something new promotes social interaction, as students are eager to share their unique experiences with peers and family.

4 CONCLUSIONS AND FUTURE WORK

This study successfully achieved its three primary objectives. First, the design of an automatic tabletop hockey product prototype using sensor module's signal applications demonstrated its potential for enhancing gameplay through automation. Second, the investigation into the product's commercial feasibility highlighted its appeal in the leisure market. Third, the experimental evaluation with young elementary school children revealed that the product offers significant experiential value, particularly in fostering mental fitness through strategic thinking and interactive play. Overall, the findings suggest that the automatic tabletop hockey product has both the technical and market potential to succeed, provided that the challenges related to production costs, difficult installation, and complete automation level are effectively managed.

An important area for future research or future work is the potential to introduce remote multiplayer functionality, allowing two players to compete over the internet. In this mode, one player could control offensive strikes while the other manages the movement of the defensive striker. This option could enhance the game's appeal by providing a more interactive and social experience, even for players who are not physically together. Implementing this feature would require networked control systems and additional software development to synchronize actions between remote players. This enhancement could significantly boost the game's appeal and expand its market potential by enabling a wider range of gameplay options for users who are not physically in the same location.

REFERENCES

Bouchet, P., Bodet, G., Bernache-Assollant, I., & Kada, F. (2011). Segmenting sport spectators: Construction and preliminary validation of the sporting event experience search (SEES) scale. *Sport Management Review, 14*, 42-53. doi:10.1016/j.smr.2010.02.001.

Brakus, J. J., Schmitt, B. H., & Zarantonello, L. (2009). Brand experience: What is it? How is it measured? Does it affect loyalty? *Journal of Marketing 73*, 52-68.

Gau, L. S., Dung, Y., & Huang, P. J. (2015). Asymmetrical analysis of sport spectator experiences for senior high school students in Taiwan. *Journal of Sport & Exercise Psychology: NASPSPA 2015 Conference Abstracts, 37* (supplement), S114.

Gilmore, J. H., & Pine, B. J. (2007). Authenticity: What consumers really want? *Harvard Business Press*.

Mena, M. J., Ruiz, C. M., Ortiz, J. S., & Andaluz, V. H. (2018). Autonomous control technique for an air hockey table. *Advanced Science Letters, 24*(11), 8944-8950.

Renesas (Jan. 2014). RX62T Group, RX62G Group, RX62T Datasheet.

Renesas (Oct. 2010). RENESAS 32-Bit MCU RX Family, RX62T User's Manual.

Schmitt, B. H. (1999). *Experiential marketing*. New York: The Free Press.