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DEVELOPMENT AND RESEARCH OF AN INTELLIGENT SYSTEM FOR CREATING BOARD GAMES

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Abstract. The article discusses creating an intelligent system for board games that combines physical and digital interaction. The study aimed to develop a solution capable of automatically tracking the position of game pieces on the board, transmitting data to a mobile application, and highlighting certain sections according to a scenario in physical and virtual formats. The basis of the development was the integration of modern technologies, including contactless data reading devices and real-time interaction algorithms. The methodology included modeling a physical board using PLA plastic, creating a display system based on addressable LEDs, setting up wireless communication to synchronize components, and developing a mobile application to visualize gameplay. The innovation of the solution lies in the hybrid approach to integrating physical and digital gaming environments, which creates a new experience for users. The practical value of the system lies in its adaptability and scalability. The solution will allow for the future creation of new game scenarios, including procedural generation of the arrangement of pieces and the realization of various types of events supported by visual indication. The proposed system can be applied in entertainment and education, contributing to increased motivation and user engagement. Further research can be aimed at implementing artificial intelligence algorithms to personalize the game and analyze player behavior.

Keywords: interactive system, board games, visual display, mobile technologies, entertainment, educational games.

Introduction

Board games are essential for developing logical thinking, social interaction, and creative skills. They combine entertainment and educational value, reaching audiences of all ages. In the modern world, their potential is actively used in education, where games help to model real-life scenarios, promoting critical thinking, collaboration, and decision-making.

Digital technologies are transforming board games, opening up new opportunities for interactivity by integrating physical and virtual components. Such games provide a personalized experience, adapt to users' needs, and create favorable conditions for learning and entertainment by combining the best aspects of traditional and digital solutions.

Problem Statement

Despite the active development of digital technologies, board games continue to be an essential part of the entertainment industry. They create a unique atmosphere of social interaction and facilitate live communication, which is not always possible with fully digital games. However, modern consumers increasingly expect new interactive features from board games that integrate traditional experiences with

the benefits of digital technologies. This demand creates the need for innovative solutions to make board games more attractive, accessible, and technologically advanced.

One critical aspect of relevance is the use of interactive and augmented realities. The ability to physically and virtually highlight the available moves greatly simplifies the gameplay for beginners while opening up new opportunities for experienced players. It also makes board games more accessible for people with special needs, such as players with limited vision or motor skills. In addition, such technologies allow for integrating automation elements such as scoring or hints, significantly improving the overall experience.

The growing popularity of hybrid platforms that combine physical and digital components confirms the relevance of such developments. Products such as ChessUp or apps for HeroQuest demonstrate the market demand for integrated solutions that add a technological element to traditional games. In addition to the entertainment aspect, a system that tracks the position of pieces and integrates with a mobile application creates new opportunities for learning, data collection, and analysis, which is essential in educational and professional contexts [11].

It is important to understand that the development of an intelligent system for creating board games promotes innovation in this area, allowing you to create your own educational and entertainment products. This intelligent system not only meets users' needs for convenience and interactivity but also lays the foundation for the further development of new-generation games that integrate physical and digital experiences.

Review of Modern Sources of Information on the Subject of the Publication

The article considers the potential of using large language models (LLMs), such as GPT, to adapt board games for learning. The researchers analyze the possibility of personalizing the learning process with the help of intelligent systems that consider users' individual needs and learning styles. The main goal is to integrate LLMs to create adaptive learning content in games, allowing users to maintain interest and improve their learning experience. The methods discussed in this article include:

- Tracking player behavior.
- Analyzing their decisions in the game.
- Applying machine learning algorithms to generate personalized tips.

Such approaches ensure the creation of adaptive content that corresponds to the player's current level of knowledge and learning style. For example, using emotional and behavioral analysis helps improve player interaction and motivation during the game

The study's results indicate the effectiveness of adaptive learning games using artificial intelligence, especially for subjects with abstract concepts such as math or programming. The study demonstrates that the use of AI approaches can significantly increase student engagement and performance and contribute to the development of more complex game-based learning systems [1].

The article investigates the impact of board games on the development of multiple intelligences in primary school students. The results showed that board games positively affect all aspects of multiple intelligences, except for musical and physical intelligence, where improvements were observed in the control group. This indicates that factors other than board games also influence these types of intelligence. The study's conclusion shows the potential of using board games as a learning tool to increase students' interest and motivation.

The study methods included a sample of primary school students attending after-school centers, dividing students into experimental and control groups, measuring levels of multiple intelligences before and after the introduction of board games, and comparing the results between the groups. The revealed statistically significant difference between the groups demonstrates the increased effectiveness of board games in developing students' intellectual abilities [2].

The article explores the use of board games as a tool for collecting data and analyzing algorithmic influence in academic social media. The authors build on the tradition of studying board games in the educational community but approach the issue from a new perspective by using games as a research

method. As part of the study, they created a severe board game to analyze users' perceptions of algorithmic mediation. The authors used SGDA (Serious Game Design Assessment) to develop the game. This framework provides a structured approach to creating severe games, focusing on content, mechanics, narrative, and aesthetics.

An essential part of the work was the challenges faced by the authors during the game's development, in particular, the balance between the simplicity and complexity of the game, the need for quality narration, and the risks of distorting the results due to the participants' strategies. The article also discusses approaches to addressing these challenges and the types of data obtained through the game. In conclusion, the authors emphasize the importance of choosing the target audience for testing, ensuring simplicity of design and a strong narrative that allows for engagement and relevant data while minimizing distortions due to "playing to win" [3].

The article explores students' creation of educational board games as a teaching method. The author proposes a theoretical model of GEC (Games as Educational Challenge) to help understand how students develop game tasks and solve specific dilemmas and difficulties in creating such games. The model is based on previous research but adapted to analyze student design processes.

As part of a large project, GBL21 (Game-Based Learning in the 21st Century, 2017-2022), Danish students in grades 5-8 from 19 schools used a design thinking approach to create game tools that solve specific learning problems in such disciplines as math, Danish language, and science. The study pays special attention to the task for the 5th grade, where students created a board game on the topic of combating toxicity in online communication. The analysis through the lens of the GEC model revealed three key aspects:

- Student involvement in the selection and development of game challenges
- The balance between game elements and educational goals
- The legitimacy of using board games in the context of academic subjects

The article highlights challenges and learning opportunities, contributing to a better understanding of the complexity of educational processes through game design [4].

Objectives and Problems of Research

The main goal of this study is to create an intelligent system that combines the physical and digital components of board games. The system should automatically track the positions of pieces on a physical board, transfer this data to a mobile application, and highlight the available sections for movement both in the virtual environment and on the physical board. This will simplify the gameplay for beginners and increase the interactivity and engagement of experienced players. Additionally, the study aims to analyze the impact of this approach on user interaction with games and assess the possibilities of integrating physical and digital gaming experiences.

Among the key issues to be addressed is technological complexity: developing a reliable mechanism for accurately tracking the movement of pieces and synchronizing data between the physical board and the mobile application without delays. There is also the task of creating an intuitive interface that will not overwhelm the user while keeping the game understandable for beginners and enjoyable for experienced players. It is equally essential to ensure the system's adaptability to different types of board games, taking into account their rules and mechanics, which requires flexibility in the design of algorithms.

Particular attention should be paid to the system's accessibility. It must remain financially accessible to a wide range of users. In addition, a balance between automating the process and preserving the strategic element of the game must be found to avoid oversimplifying the gaming experience. Solving these problems is critical to successfully implementing a system that integrates the latest technologies into the traditional format of table games.

Main Material Presentation

Developing an intelligent system for board games usually involves integrating physical and digital components to create a modern interactive solution [5]. The main task is to ensure accurate tracking of the

Development and Research of an Intelligent System for Creating Board Games

movements of pieces on a physical board and integrate this data into a mobile application for further visualization and interaction. The main stages of the work included modeling the board, selecting hardware, developing a mobile application, and implementing algorithms that ensure the system's interactivity.

The process of creating the system relied on modern approaches to design and the use of available technologies, such as 3D printing for manufacturing components, RFID readers for tracking the positions of objects, and the ESP32 microcontroller for processing data and transferring it to the mobile application (Fig. 1). These solutions were selected based on their functionality, reliability, and ability to provide real-time integration of physical and digital components [5].

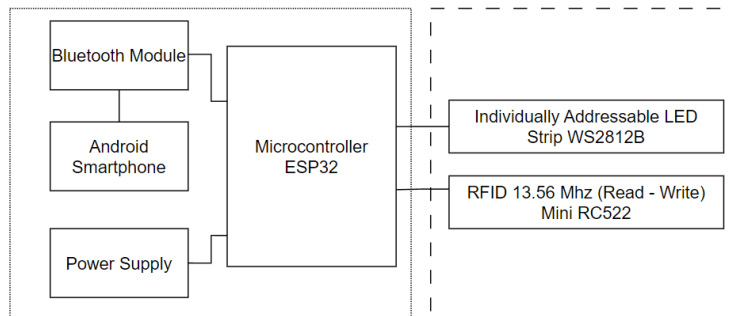


Fig. 1. Block diagram of the system

One of the first steps was to model the physical board. A round shape with seven sections was chosen to ensure versatility and ease of design. This structure was necessary to integrate RFID-RC522 mini readers, which measure 25×37.3 mm (Fig. 2.1). The height of the lower part of the board was set at 1.5 cm, and for the middle part, disks with a thickness of 0.4 mm and 1 mm were printed, which have different effects on the level of light transmission.

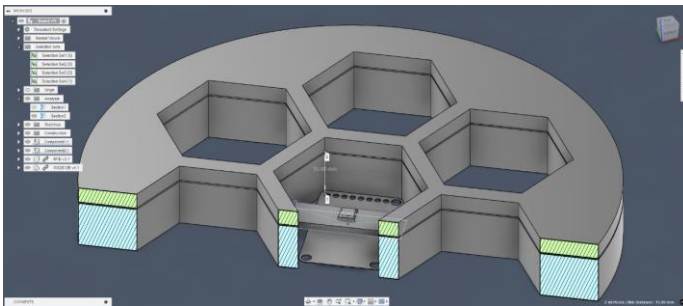


Fig. 2.1. Prototype whiteboard in Autodesk Fusion 360

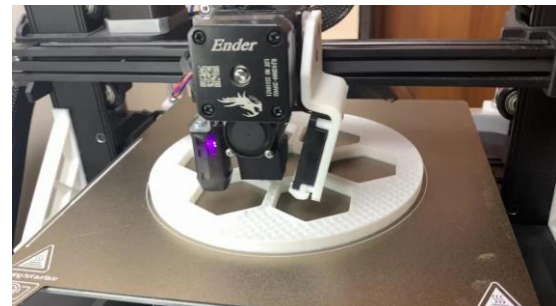


Fig. 2.2. The process of printing a part

3D printing was used to manufacture the board, which ensured precision in production and quick verification of experimental models (Fig. 2.2). The upper part of the structure was created to reproduce the depth of the playing field and, thanks to the walls for each section, a specific concentration of light emitted by the LEDs during illumination was achieved. This enabled the players to achieve the required level of display visibility.

The system's effective operation depended on the right choice of hardware. The key requirement was to ensure communication between the physical board and the mobile application. The ESP32 was chosen as the microcontroller, which is characterized by built-in Wi-Fi and Bluetooth modules. These features provide data transfer directly to the mobile device, making the system more flexible and easily integrated with additional software solutions [6].

RC522 mini RFID readers were chosen to track the board's status. These devices work with ISO14443A tags at a frequency of 13.56 MHz, providing a reading range of up to 5 cm. The use of Ntag215 tags with 512-byte memory allowed it to store additional data for each game piece, allowing for a

flexible approach to identification and interaction in the system [7].

The WS2812B LED strip was used to visually indicate the board's state: each LED corresponds to a separate section, which simplifies the recognition of potential moves during the game. All components were assembled into a single system that ensures full integration of physical and digital elements [8].

To work with several RFID readers in the system, you can provide for the use of a multiplexer (for example, CD74HC4067) in cases where the number of free microcontroller pins to control SPI devices is not enough. The multiplexer allows you to switch SS lines between several readers, which makes it possible to connect up to 16 devices through a single set of pins. This approach ensures the system's scalability, allowing you to quickly expand the number of readers without significant changes in the structure (Fig. 3).

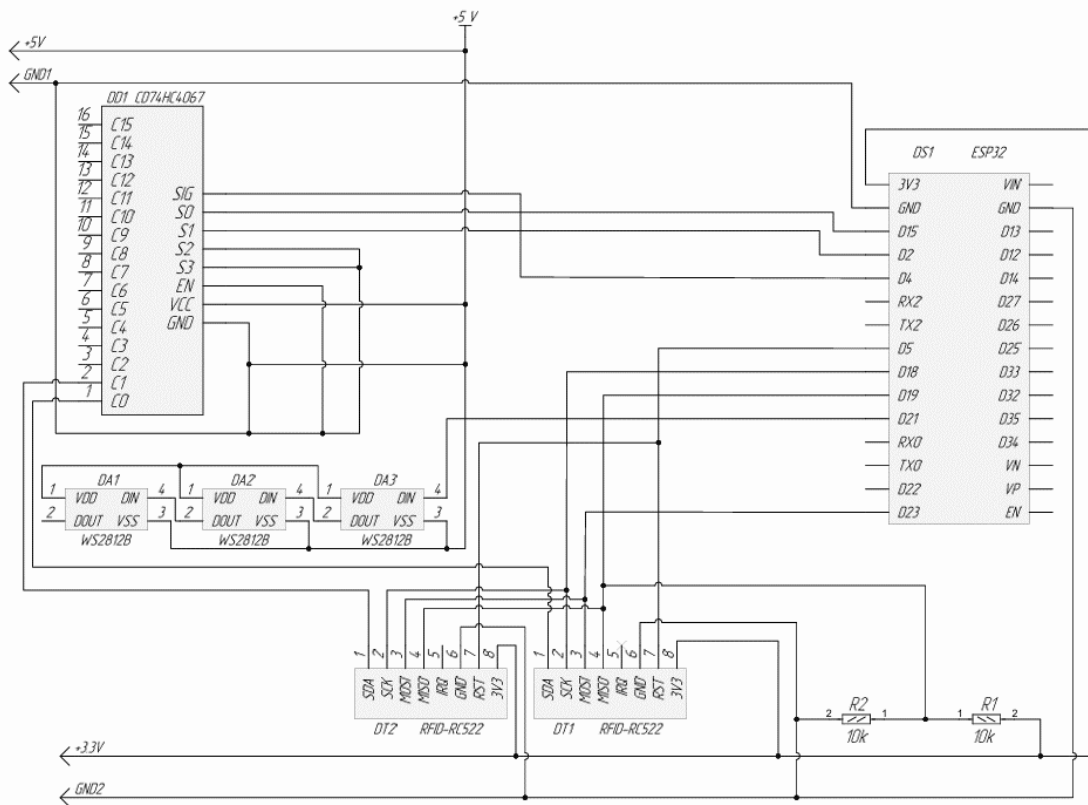


Fig. 3. Schematic diagram of the prototype using a multiplexer

Integrating physical and digital components in hybrid board games provides new opportunities to improve user interaction with gaming systems, mainly through two-way communication between physical game sets and digital platforms. This allows automating and adapting game processes following real-time and game conditions, essential for interactive games with high-accuracy rules and mechanics. In this context, an essential component is ensuring synchronization between the game's physical elements and the digital interface, which allows for effective feedback and adaptation of game actions [9].

We developed a mobile application that provides interactivity between a physical board and digital objects to implement this approach. The application is built on the Kotlin programming language for the Android platform, which allows the use of the specific functionality of this platform to optimize the user experience [10]. The central function of the application is the creation of a "label-image" pair, which allows you to link physical figures to virtual representations using NFC and RFID technologies (Fig. 4). This makes it possible to scan the tags both through the built-in NFC module in the mobile device and through RFID readers on the board, which allows the system to be adapted to different user hardware

configurations.

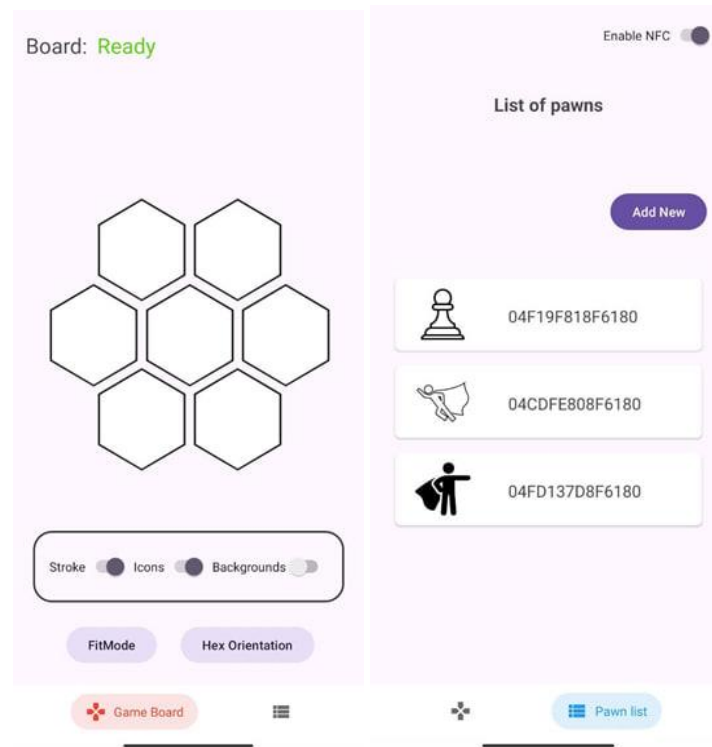


Fig. 4. The developed application for interaction with the physical field

Results and Discussion

To test the prototype's functionality, we assembled it and tested the interaction between the physical board and the mobile application (Fig. 5.1). After selecting a piece in the application; the system activated an algorithm for determining the available moves for a given piece. The result was displayed in two ways: in the application, the virtual board highlighted the available sections, and on the physical board, the WS2812B LEDs highlighted the corresponding zones in red (Fig. 5.2). This synchronized visualization provided easy navigation for users.



Fig. 5.1. View of the prototype in the disassembled version



Fig. 5.2. Synchronization between the application and the physical system

Conclusions

During the work, a prototype of an interactive system for board games was created, which uses RFID technology to accurately track the position of game pieces on a physical board. The physical board sections are illuminated with LEDs according to the allowed moves, and the mobile application displays this in a virtual form, ensuring synchronized interaction between the components. The interactivity supported by LED indication can significantly increase player engagement, providing visual support for beginners and new strategies for experienced players.

The developed system has a high potential for scaling. Thanks to procedural generation, creating unique game scenarios, such as dynamic placement of pieces, integration of random events, or customization of rules for specific game conditions, is possible. The system, combined with the capabilities of the mobile application, can be helpful in entertainment and education, particularly in teaching algorithmic thinking and financial literacy or developing teamwork skills. This approach opens new prospects for integrating digital technologies into next-generation board games.

References

- [1] Andrea Tinterri, Federica Pelizzari, Giordano Vignoli, Francesco Palladino, Marilena di Padova, Towards: AI-assisted Board Game-based Learning: Assessing LLMs in Game Personalisation, Proceedings of the 18th European Conference on Games Based Learning, 18(1), 2024, pp. 1107-1115, <https://doi.org/10.34190/ecgbl.18.1.3055>.
- [2] Jiwon Kim, Yunkyung Au, Towards: The Effects of Board Game Activities on the Improvement of Multiple Intelligence of Elementary School Students, The Korean Journal of the Human Development, 31(3), 2024, pp. 73-89, <https://doi.org/10.15284/kjhd.2024.31.3.73>.
- [3] L. Monteiro-Krebs, D. Geerts, K. Sanders, S. Caregnato, B. Zaman, "Board Games as a Research Method: A Case Study on Research Game Design and Use in Studying Algorithmic Mediation," Proceedings of the CHI Conference on Human Factors in Computing Systems (CHI EA '24), Honolulu, HI, USA, May 2024, <https://doi.org/10.1145/3613905.3637116>.
- [4] T. Hanghøj, "Students as Educational Board Game Designers: Learning Opportunities and Design Dilemmas," Proceedings of the 17th European Conference on Games Based Learning (ECGBL 2023), Enschede, October 2023, <https://doi.org/10.34190/ecgbl.17.1.1741>.
- [5] G. Fabris, L. Scalera, A. Gasparetto, "Playing Checkers with an Intelligent and Collaborative Robotic System," Robotics, 13(1), article 4, 2023, <https://doi.org/10.3390/robotics13010004>.
- [6] N. Cameron, "Electronics Projects with the ESP8266 and ESP32", Building Web Pages, Applications, and WiFi Enabled Devices, Berkeley, Apress, USA, 2021, ISBN: 978-1-4842-6335-8, <https://doi.org/10.1007/978-1-4842-6336-5>
- [7] V. S. Velmurugan, "RFID Technology in Library and Information Science," The International Journal of Social Sciences and Humanities Invention, 11 (8), pp. 8238–8241, 2024, <https://doi.org/10.18535/ijsshi/v11i08.02>.
- [8] A. D. Ardiatma, B. Soewito, "IoT-Based Indoor Lighting Performance of LED with Different Color Temperatures System Based on Human Activity," Jurnal Syntax Admiration, 4(7), pp. 1007–1024, 2023, <https://doi.org/10.46799/jsa.v4i7.788>.
- [9] J. W. Park, "Hybrid Monopoly: A Multimedia Board Game that Supports Bidirectional Communication between a Mobile Device and a Physical Game Set," Multimedia Tools and Applications, Springer Nature, vol. 76, no. 1, August 2017, <https://doi.org/10.1007/s11042-017-4589-x>.
- [10] Kotlin-first Android development, 2024. URL: <https://developer.android.com/kotlin/first>.
- [11] Rubens Anderson de Sousa Silva, Rossana Maria de Castro Andrade, João Bosco Borges Aragão Filho, Ismayle De Sousa Santos, Joseane Paiva, Bruno Aragão, "Design and Evaluation of a Mobile Application for an Educational Card Game," Journal of Interactive Systems, 11(1), 2020, pp. 110-124, <https://doi.org/10.5753/jis.2020.763>

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**РОЗРОБЛЕННЯ ТА ДОСЛІДЖЕННЯ ІНТЕЛЕКТУАЛЬНОЇ СИСТЕМИ ДЛЯ СТВОРЕННЯ
НАСТІЛЬНИХ ІГОР**

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Анотація. У статті описано створення інтелектуальної системи для настільних ігор, яка поєднує фізичну та цифрову взаємодію. Дослідження мало на меті розробити рішення, здатне автоматично відстежувати положення ігрових фігур на дошці, передавати дані в мобільний додаток і виділяти певні ділянки відповідно до сценарію у фізичному та віртуальному форматах. Основою розробки стала інтеграція сучасних технологій, включаючи пристрої безконтактного зчитування даних і алгоритми взаємодії в реальному часі. Методологія включала моделювання фізичної плати з використанням PLA-пластику, створення системи відображення на основі адресних світлодіодів, налаштування бездротового зв'язку для синхронізації компонентів і розробку мобільного додатку для візуалізації ігрового процесу. Інновація рішення полягає в гібридному підході до інтеграції фізичного та цифрового ігрового середовища, що створює новий досвід для користувачів. Практична цінність системи полягає в її адаптивності та масштабованості. Рішення дозволить у майбутньому створювати нові ігрові сценарії, включаючи процедурну генерацію розташування фігур і реалізацію різних типів подій, що підтримуються візуальною індикацією. Запропоновану систему можна застосовувати в розвагах і освіті, сприяючи підвищенню мотивації та залученості користувачів. Подальші дослідження можуть бути спрямовані на впровадження алгоритмів штучного інтелекту для персоналізації гри та аналізу поведінки гравців.

Ключові слова: інтерактивна система, настільні ігри, візуальний дисплей, мобільні технології, розваги, навчальні ігри.