Developing an Open Hardware RFID Architecture for Electronic Board Games

Samuel Vitorio Lima, Victor Travassos Sarinho
Universidade Estadual de Feira de Santana (UEFS)
Laboratrio de Entretenimento Digital Aplicado (LEnDA)
Feira de Santana, Bahia, Brazil
samvlima10@gmail.com, vsarinho@uefs.br

***Abstract*—RFID is a technology that allows the integration among virtual and real world in smart environments, augmenting physical games by tagging game tokens, pieces and cards during the gameplay. Focusing on RFID for board games in an open hardware initiative, this paper presents the development and evaluation of an open hardware architecture for electronic board game structures based on low cost components and RFID sensors. For this, the construction of integrated units with RFID sensors, microcontrollers and LEDs was performed, together with the definition of a communication protocol for reading/writing multiple connected RFID devices, and the development of a Tic-Tac-Toe game to validate the proposed architecture with board game mechanics and dynamics.**

***Keywords*-RFID; open hardware; electronic board games;**

I. Introduction

RFID (Radio Frequency IDentification) is a technology for automated identification of objects and people [1]. It increased the integration of the virtual world and real world in smart environments [2], providing means of computer applications to keep tracking changes in the physical world to reflect them in the virtual world [2].

Regarding board games, some of them need to know the location and orientation of the piece in the game to perform certain actions [3]. In this sense, RFID tags are used to augment the physical game by tagging all the game pieces. As a result, they improve the proposed game play by: working as a guide for beginners, helping them with tips to know the pieces that the player has [2] [4]; calculating the score provided by tag values; and increasing social aspects by physics interactions in the game [2] [4] [5].

Open hardware initiatives, like Arduino, NodeMCU and Raspberry PI, are an easy way to develop and understand how to work with hardware devices without advanced electronics knowledge [6]. They also provide several libraries to assist developers in using desired actuators and sensors, such as accelerometers, WiFi and RFID, for IoT projects in a DIY perspective [6].

Focusing on RFID for board games in an open hardware initiative, this paper presents the development and evaluation of an open hardware architecture for electronic board game structures based on low cost components and RFID sensors. The intention is to provide an integrated and dynamic approach (according to hardware limits) able to be extended from the current evaluation developed structure to a generic electronic board game platform.

II. Related Work

Some development initiatives have been provided to apply the RFID technology to the game board domain. As an example, Deshmukh, Sonal and Baru [5] created a software and hardware architecture to play chess in an augmented real-world by putting a RFID tag in each piece of the game. The main objective is to help people that do not know how to play chess, as well as control a professional chess gameplay. To control the game logic, for each player movement, the player needs to move the piece to the RFID reader. The movement verification is performed by comparing the last piece position with what kind of movement the piece can do.

An RFID-based infrastructure, to automatically determine the position and orientation of game objects in tabletop games, was also developed as a project to build a war game [3]. It provides a n-tags system, where each object contains more than one tag to be located by several antennas distributed over the table as a grid. As a result, they are able to define the item position and orientation based on each individual tag location of the game object [3].

An activity created by Bohn [2] had the objective to make a smart jigsaw game with RFID resources. It suggests to put a tag in each piece of the puzzle and makes the detection of each piece, together with the discovery of which piece fits into a location chosen by the player.

Finally, the design created by Miriam Konkel et al. [7] had the purpose of building a wearable radio frequency identification technology. They proposed a pocket to put tags distributed among the players, and a glove equipped with a RFID reader to get them. The objective of the game is to find tags as much as the player can with the glove, encouraging a physical activity in children by playing hide and seek with the game tags.

III. Methodology

A. RFID Device

Focusing on the positional usage of RFID readers to detect multiple RFID tags representing tokens/pieces in board games, it is necessary to integrate open hardware resources in a low-cost perspective to provide electronic board games.

In this sense, in order to create an electronic grid structure to detect player tags used in board game mechanics, some independent *RFID devices* were designed. Each one is composed by 2 RFID RC522 S50 with 13.56 MHz frequency range for user inputs, 4 LEDs (red and yellow) for user outputs, and 1 LoLin NodeMCU 1.0 to integrate and manage them.

Each tile of the electronic game grid will be represent by a RFID reader, being able to get current tags applied in game elements such as tokens, pieces or cards of the proposed game. Each set of 2 LEDs are used by the game to send a feedback to the player about the current status of the game tile. Finally, the microcontroller is responsible to manage the low/high signals of the LED lights, to receive tag IDs by the RFID reader, and to connect the developed RFID device to an associate server broker via Wifi and MQTT protocol.

The connection between NodeMCU and the RFID reader is performed by a SPI (Serial Peripheral Interface) communication, which uses the D4, D5, D6 and D7 pins that represent respectively Reset (RST), Serial Clock (SCK), Master Input Slave Output (MISO) and Master Output Slaver Input (MOSI) (Figure 1). D1 and D2 pins represent the Slaver Select (SS) of each RFID reader (Figure 1), which is responsible to verify if there is a card with tag on the RFID reader. The D0, D3, S2 and S3 pins are responsible to control the low/high signals of each connected LED.

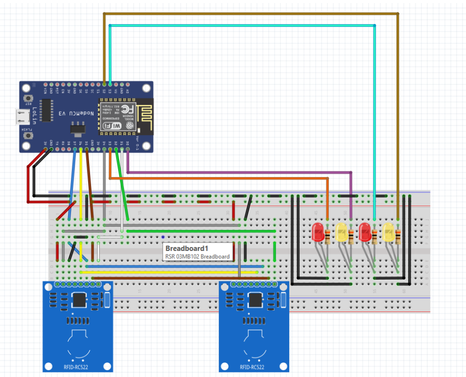

Figure 1. RFID device architecture connecting 2 RFID readers and 4 LEDs with respective microcontroller pins.

Only 2 RFID readers were connected and used with success by the microcontroller, detecting and reading player tags without compromising the device performance and functionality. The total LEDs that can be used by the microcontroller are limited only by the number of pins available on RFID readers. The final prototype is illustrated at Figure 2, showing the microcontroller connected with the LEDs and RFID readers.

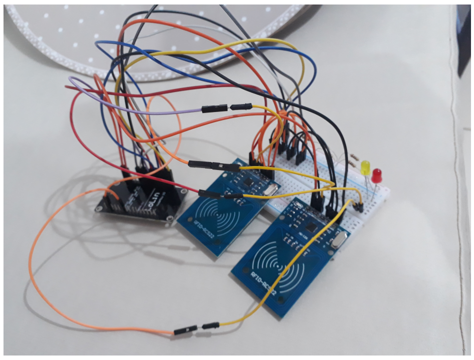

Figure 2. RFID device prototype with 2 RFID readers, 4 LEDs and 1 microcontroller.

B. Communication Server

The protocol MQTT was used to establish a communication between RFID devices to implemented electronic board games. Each RFID device can be defined as a MQTT client-server, establishing connections among them via WiFi (library *ESP8266WiFi.h*) and message-request service (library *PubSubClient.h*).

The Eclipse Mosquitto was used as a message broker server for the RFID devices, being executed in a Raspberry Pi 3 for portability purposes. It allows each RFID device to subscribe the LED topic to be informed about which LED of a specific coordinate should be on/off, as well as to publish to the RFID topic the coordinate of the RFID reader where an RFID tag was detected.

Each RFID device has a personalized ID, which is sent to the communication server when the login service is performed (Figure 3). Next, for each tag detected by a RFID reader, a message is sent to the server in the RFID topic with the respective RFID device coordinate. An RFID coordinate is defined by the combination of the RFID ID and the RFID reader number (1 or 2). Published RFID coordinates are sent to the subscribed game, which performs the current game logic and send all necessary messages to the LED topic as a gameplay response for the player (Figure 3).

C. Evaluation Game

A *Tic-Tac-Toe* game was created using the Python language as a game example to evaluate the RFID devices over the message broker server according to proposed game mechanics and dynamics. In this sense, the library *"paho.mqtt.client"* was applied to connect the developed game with the message broker via MQTT protocol, getting messages from the RFID topic and sending turn on/off information to the LED topic according to game rules.

Regarding the game logic and implementation, a matrix structure was declared to store player movements during the gameplay. When the game starts, each cell value in the matrix is set to zero. The *currentTurn* variable controls the

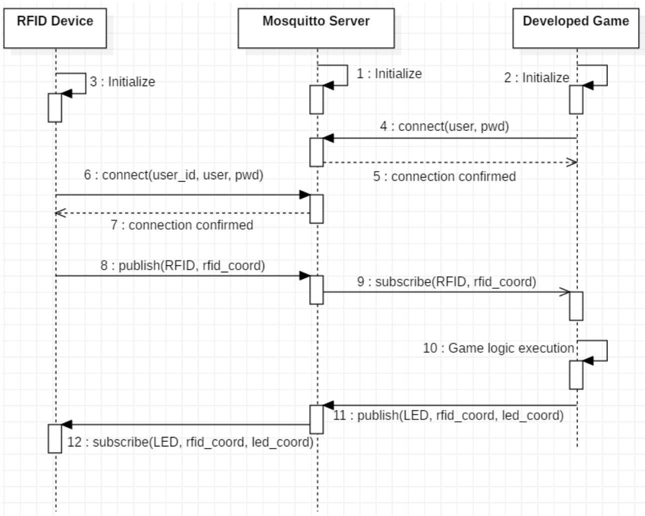

Figure 3. Sequence diagram of the communication process among RFID devices, the message broker server and the developed game.

game turn, ranging between even or odd values to set the current turn player. When a RFID device detects one tag, it sends to the server the respective RFID coordinate associated with the RFID reader. When the Tic-Tac-Toe game receives the RFID coordinate, it stores a negative/positive value into the respective matrix cell (if it has a zero value yet) according to detected coordinate and currentTurn value. As a game response, if the matrix value was updated, one LED color is sent for the RFID coordinate by the LED topic, indicating the current tile state that represents am *"X"* or *"O"* status.

The game loop also performs a continuous verification of the matrix structure, looking for a player winner to perform a blink behavior with the correspondent game color. By this process, the matrix cell and currentTurn values are set to zero again, all LEDs of the game board are turned off, and the game goes to an idle state, waiting for a new message in the RFID topic to restart the game.

IV. Results and Discussion

Five RFID devices were developed (4 with 2 RFID readers and 1 with 1 RFID reader) and integrated with the message broker to represent an electronic board structure for the Tic-Tac-Toe game. The mapping among RFID coordinates and game tiles was directly configured by the developed game code, being necessary a previously identification of the RFID readers and device IDs to provide a correctly game logic. Figure 4 shows the RFID devices organization for each matrix cell representing a hypothetical Tic-Tac-Toe board game grid.

Considering the Tic-Tac-Toe gameplay, Figure 5 illustrates the current status of the "O" and 'X" players represented by distinct LED colors (red and yellow), which

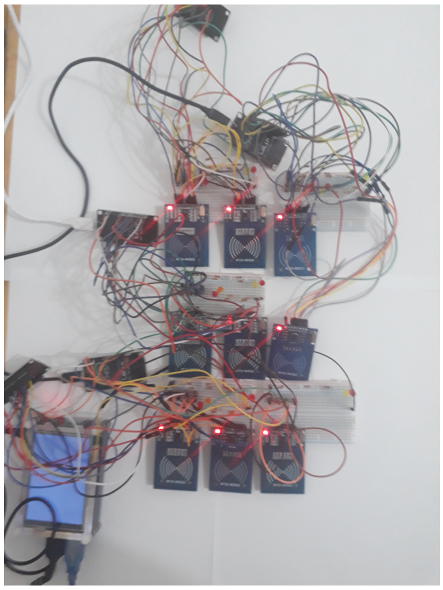

Figure 4. RFID devices distribution representing a hypothetical Tic-Tac-Toe board grid.

are selecting the *(1,2)*, *(2,2)* and *(3,2)* coordinates. When a winner combination with the same LED colors is obtained in the board grid, a blink behavior is performed over this winner combination and the game restarts for another match.

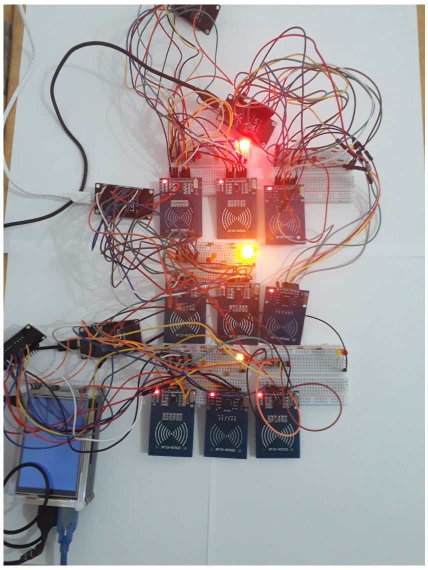

Figure 5. Gameplay example of the RFID Tic-Tac-Toe board game.

Regarding the Tic-Tac-Toe game production, 9 RFID readers were used to cover the 9 tiles of this board game. Each RFID device costs about U$ 6.35 when considering only the open hardware components, having U$ 2.12 for one RFID reader and U$ 2.11 for a microcontroller LoLin NodeMCU. Therefore, a total of U$ 31.75 was spent to build the Tic-Tac-Toe game prototype.

Table I describes the expected costs for the construction of hypothetical board game examples with the proposed RFID architecture. As a result, by the usage of available open hardware components, is not viable to build an electronic board game with more than 30 tiles in a low cost perspective. As workarounds, a RFID antenna or a more powerful microcontroller could be applied to reduce the number of electronic components required, but increasing the necessary money to acquire them, maintaining as a result the difficult of providing an low cost electronic platform to support designed board games.

Table I
EXPECTED COSTS FOR THE CONSTRUCTION OF BOARD GAMES WITH THE PROPOSED RFID ARCHITECTURE.

Board Game Examples	Number of Tiles	Total Cost
Chess[8]	64	U$ 203,20
Draughts[9]	32	U$ 101,60
Nine Men's Morris[10]	24	U$ 76,20

V. CONCLUSIONS AND FUTURE WORK

This paper presented a hardware/software architecture proposal to build electronic board game structures. It describes the construction of integrated units with RFID readers and LEDs, the definition of a communication server for reading/writing multiple connected RFID devices, and the development of a Tic-Tac-Toe game able to communicate with RFID devices via communication protocol and to validate the proposed architecture with game mechanics and dynamics capable of implementing interesting board games.

In fact, with each RFID reader representing a game tile, as exemplified in the integration of 5 built RFID devices, it is possible to extend this concept to create different types of grid/path boards for desired electronic board games. Therefore, in a brief comparison with described related work, the proposed architecture can be used to provide: a RFID chess game to help novice player [5]; a RFID puzzle to assist the player in locating the pieces [2]; a RFID-based exergame with wearable resources [7]; and a war game by using more tha one RFID reader to determine token/piece positions and orientations [3]. Moreover, with the possibility of a rapid inclusion of new RFID devices in the proposed communication service, it is possible to confirm that the proposes architecture represents a flexible and dynamic open hardware solution for the construction of electronic board games based on RFID devices.

However, due to the open hardware limitations, few RFID readers could be integrated simultaneously into a single controller unit, thus requiring a larger number of microcontrollers to perform the integration of desired RFID sensors in a desired game board configuration (8x8 in a chess game for example). As a result, it is possible to build electronic board games with the proposed architecture, but with a relatively cost for medium-large boards when compared with the standard costs involved in the construction of DIY devices according to the open hardware philosophy.

As future work, it is intend to develop an edge computing architecture based on built RFID device architecture, but in this case with multiple I/O sensors to support different types of game applications, such as joysticks for the monitoring of physiological signals and positional interfaces for activities with exergames. A development tool to facilitate the mapping configuration among RFID device coordinates with tile positions in developed games also needs to be constructed. For stress testing purposes of the proposed communication architecture, performance validation with multiple simulated RFID devices will also be performed. Finally, the construction of printed circuits in order to eliminate the volume of used wires in RFID devices will also be carried out in the near future.

REFERENCES

[1] A. Juels *et al.*, "Rfid security and privacy: A research survey," *IEEE journal on selected areas in communications*, vol. 24, no. 2, pp. 381–394, 2006.

[2] J. Bohn, "The smart jigsaw puzzle assistant: Using rfid technology for building augmented real-world games," in *Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive*, vol. 2004, 2004.

[3] S. Hinske and M. Langheinrich, "An rfid-based infrastructure for automatically determining the position and orientation of game objects in tabletop games," *Concepts and Technologies for Pervasive Games-A Reader for Pervasive Gaming Research*, vol. 1, pp. 311–336, 2007.

[4] K. Römer and S. Domnitcheva, "Smart playing cards: A ubiquitous computing game," *Personal and Ubiquitous Computing*, vol. 6, no. 5-6, pp. 371–377, 2002.

[5] S. Deshmukh and V. Baru, "Applications of rfid in interactive board games," *International Journal of Electronics, Communication and Soft Computing Science & Engineering (IJECSCSE)*, p. 87, 2013.

[6] M. McRoberts, *Arduino Básico-2ª edição: Tudo sobre o popular microcontrolador Arduino.* Novatec Editora, 2015.

[7] M. Konkel, V. Leung, B. Ullmer, and C. Hu, "Tagaboo: a collaborative childrens game based upon wearable rfid technology," *Personal and Ubiquitous Computing*, vol. 8, no. 5, pp. 382–384, 2004.

[8] "Chess," https://en.wikipedia.org/wiki/Chess, accessed: 2019-06-25.

[9] "Draughts," https://en.wikipedia.org/wiki/Draughts, accessed: 2019-06-25.

[10] "Nine men's morris board game rules," https://www.thesprucecrafts.com/nine-mens-morris-board-game-rules-412542, accessed: 2019-06-25.