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PARKING LOT ACCESS CONTROL SYSTEM BASED ON RADIO FREQUENCY IDENTIFICATION

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This article intends to present the construction and operation of a scale model of a car parking whose access control system is based on RFID (Radio Frequency Identification). Centred around the control access system and the functioning of RFID components, this paper does not go into detail about other aspects of car parking and seeks to simplify them as much as possible. RFID (radio frequency identification) is a type of wireless communication that includes the use of electromagnetic or electrostatic coupling in the radio frequency portion of the electromagnetic spectrum to uniquely identify an object, animal or person. We believe that understanding the access control system can later help an authorized person to implement it in any real parking system, the differences being given by the number of parking spaces, access/exit gates, complexity, layout, etc. The model is composed of an Arduino Nano 3.0 board and other Arduino components. These modules are controlled by a code written in Arduino IDE language. The proposed system aims to create an easy to use and easy to implement paid card car parking and featuring 4 parking spots with IR sensors and 2 gates, one gate for entrance and one gate for exit. Each gate has its own RFID control access plus one card/tag recharging simulated machine.

Keywords: RFID, Arduino, ID, access control, car parking, tag.

1. Introduction

According to an article published by the World Economic Forum in april 2016, „The number of cars worldwide is set to double by 2040”.[1] According to Hedges & Company, „There are 1.474 billion cars in the world in 2023.”.[2] Considering the constant increase of the population, these statistics are no surprise. This translates in our daily lives in an increased wait time in traffic and an increased time spent searching for a parking spot.

The ParkMan Team considers that unorganized parking is the main problem when it comes to finding a parking spot. Furthermore, they have collected the most troubling facts about unorganized parking that result from failed parking management. They concluded that unorganized parking is a waste of time, burns a

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lot of money, causes traffic jams, steals our living space, pollutes the environment, is a massive stress factor for drivers and poses dangers.[3]

An easy to implement and low-cost solution to this would be the arrangement of parking lots with RFID based control access system. This way, everyone would have their own secured parking space, because the number of users and parking spots can be balanced by giving access by means of an RFID tag/card to an exact number of people. Being low cost, easy to replace if lost, compact and resistant, these tags/cards are easy to use and to not require prior use instructions. They can be nominal or not and have different levels of security, as needed.

Therefore, we believe this parking access system to have the advantage of flexibility and simplicity when implemented in a real parking. Other popular parking access systems need a person on site to grant access and collect fees or use a costly ticket/pay machine. Furthermore, the ones using tickets are bad for the environment as the tickets are made from paper covered in harmful substances such as bisphenol A and end up as litter.

RFID control access systems come with a variety of flexible parameters, making them easy to adapt to different environments and situations. According to MARKETS AND MARKETS, the RFID market in control access systems is forecasted to triple in revenue by 2030 in comparison to 2021 for Asia Pacific countries.[4] Thus, we consider that a specific RFID based control access system in a parking lot is one of the most advantageous solutions.

This article intends to exemplify the implementation of an RFID control access system in a parking, by constructing a miniature model and simulating the actions of cars using it.

2. Hardware components required for parking simulation

In short, RFID-based access systems have four main components:

• RFID Tag(s) - installed in a card or keychain, which residents use to gain access to the building;

• RFID Reader(s) - installed near the door it manages access to. It contains antennas that receive data transmitted by RFID tags. Depending on the RFID system's state, active or passive, it can also emit an electromagnetic field that powers the RFID tag;

• Control Panel - a computer server that reads and interprets the data transmitted by the RFID reader;

• Electric Door Opening Mechanism/Gate Lifting Mechanism - if the control panel verifies a resident's credentials, it sends instructions to the electric lock of the building's door or to the gate lifting mechanism. These instructions unlock the door/lift the barrier and allow the person to enter.[5]

For the physical miniature model, the following hardware components with their specific tasks were used:

- 1× Arduino Nano 3.0; 4× Infrared Sensors;
- 2× RFID Card Reader Module RDM6300 125kHz (2 readers and 5 tags);
- 2× SG90 Servo Motors; 2× 16x2 LCD Display Modules with I2C Interface;
- 4× Buttons, 1× Breadboard; 2× PVC Board 50×50 cm, 3 mm thickness;
- Dupont Jumper Wires, 1× 5V Battery.

Fig. 1 shows the circuit created in Fritzing, detailing the connections of the physical assembly.

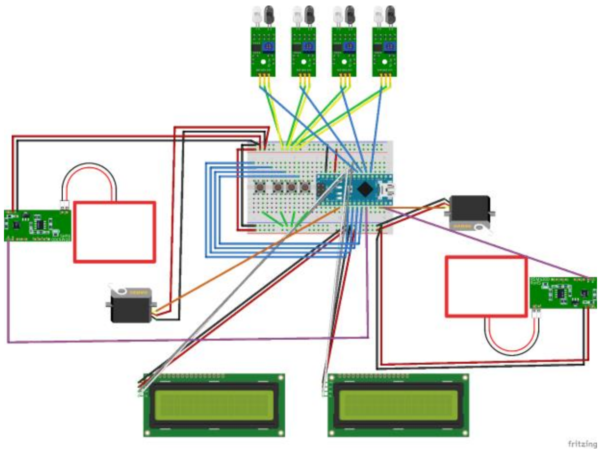

Fig. 1. The wiring diagram of the system components

The appearance of the physical model is presented in Fig. 2.

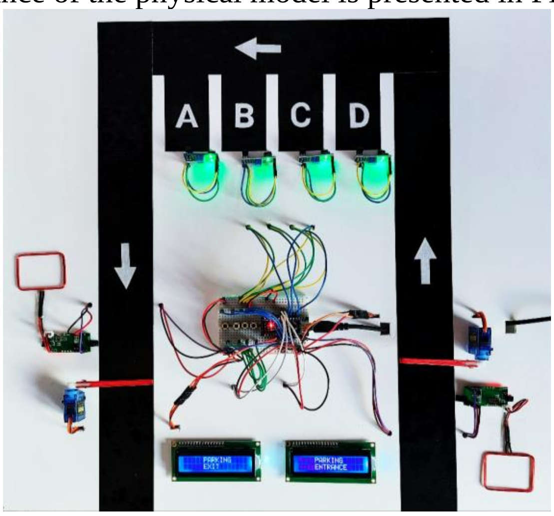

Fig. 2. The final physical assembly form

The parking spaces have been intentionally named with letters to emphasize that any car can park anywhere.

To simulate the authorized parking users, I used 4 cars, each with their assigned RFID card (they are marked numerically for this purpose). These elements can be seen in Fig. 2. I also used 1 card that is not registered in the database to simulate an entry attempt of an unauthorized person.

Fig. 3. Elements belonging to users

3. Parking access control software

Arduino IDE software we was used, and the code was written in the C++ language. We simulate a parking lot with 4 parking spaces, labelled from A to D. Four cars, numbered from 1 to 4, will park in these spaces. Each user of one of the 4 cars is assigned an RFID card, numbered from 1 to 4. These cards have an ID on the back, which we will extract using the RFID reader, and it is entered into the system to provide access to the user. For the demonstration, we also consider a card of the same type that is not in the database.

We have two servo motors simulating two barriers. When entering the parking lot, the car advances to the barrier, the user brings the card close to the reader, the reader extracts the card's ID along with other data, recognizes it in the database, and activates the servo motor for 4 seconds to allow passage. Then, it marks that the respective car is in the parking lot by changing a parameter from "0" to "1" in its status. Simultaneously, the time elapsed since the microcontroller started when the car entered the parking lot is stored in a variable. Below, you can physically see the entrance to the parking lot and the LCD display.

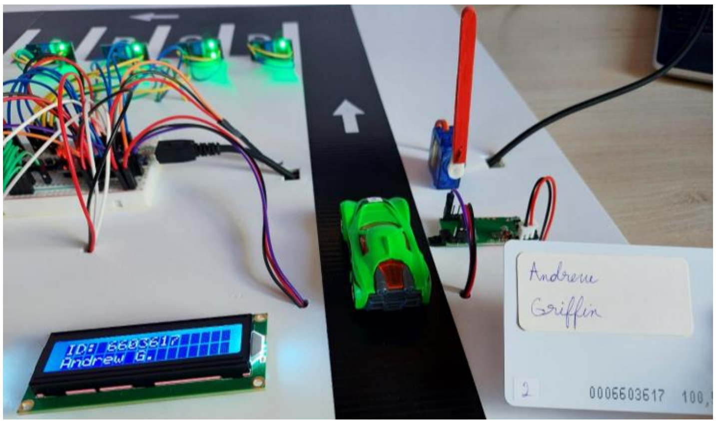

Fig. 4. Example of a user entering the parking lot

The car occupies a parking space, as indicated by the status of the infrared sensor at that location. The sensor statuses are checked to display on the LCD which spaces are available, and which are occupied at the entrance, as shown below, using checkmark and "x" symbols. These symbols were defined previously in a 5x8 matrix, with "0" or "1" representing an off or on pixel. We labeled these symbols as "0" for an empty parking space and "1" for an occupied parking space to facilitate use in the code below.

```
void available_spots(){
lcd1.clear();
if (digitalRead(Sensor_A)==0){lcd1.setCursor(0,0);lcd1.print("SPOT A");
lcd1.write(1);lcd1.print(" ");}
 else {lcd1.setCursor(0,0);lcd1.print("SPOT A");
lcd1.write(0);lcd1.print(" ");}
 if (digitalRead(Sensor_B)==0){lcd1.setCursor(8,0);lcd1.print("SPOT B");
lcd1.write(1);lcd1.print(" ");}
 else {lcd1.setCursor(8,0);lcd1.print("SPOT B");
lcd1.write(0);lcd1.print(" ");}
 if (digitalRead(Sensor_C)==0){lcd1.setCursor(0,1);lcd1.print("SPOT C");
lcd1.write(1);lcd1.print(" ");}
 else {lcd1.setCursor(0,1);lcd1.print("SPOT C");
lcd1.write(0);lcd1.print(" ");}

 if (digitalRead(Sensor_D)==0){lcd1.setCursor(8,1);lcd1.print("SPOT D");
lcd1.write(1);lcd1.print(" ");}
 else {lcd1.setCursor(8,1);lcd1.print("SPOT D");
lcd1.write(0);lcd1.print(" ");}
}
```

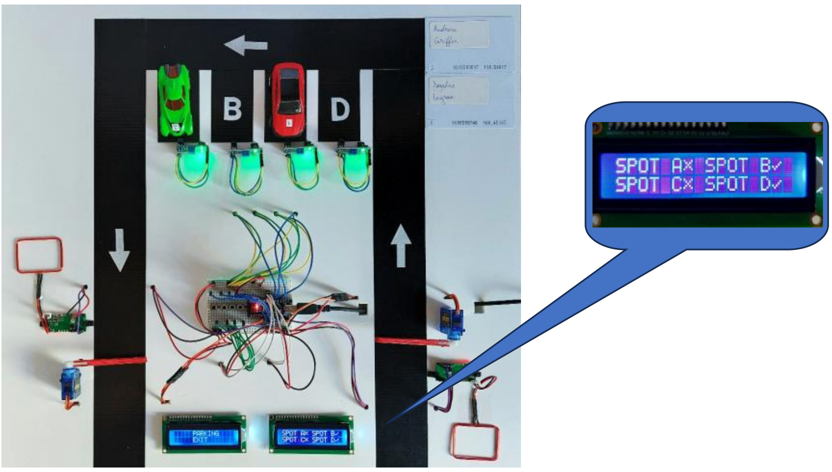

Fig. 5. Intermediate Status

Meanwhile, other cars can enter/exit the parking lot in any order.

After a time x, the car leaves the parking space and moves to the exit barrier. To calculate time x, we check how much time has passed since the microcontroller started and subtract the time recorded when the car entered the parking lot. Then, this time is converted into hours, with parking fees calculated per hour. Now, there are two cases:

a) The user has enough money on the RFID card to pay for parking which costs 1 euro per hour. They simply bring the card close to the reader, the amount is deducted from the card, and the barrier is lifted for 5 seconds to allow passage. This case is presented in Fig. 6.

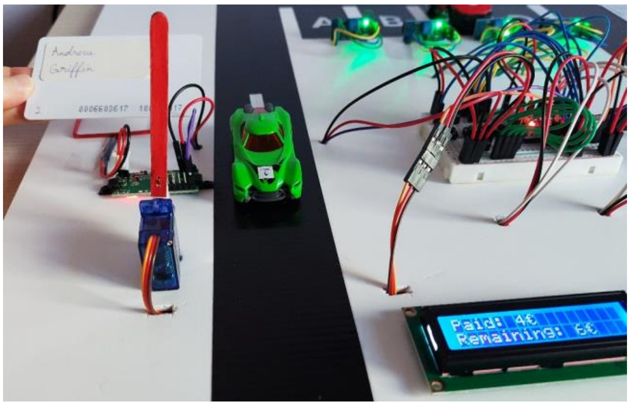

Fig. 6. Payment at exit with sufficient balance

The calculations performed at this step can be seen below:

```
Parking_Duration = millis() / 1000 - TIME[Val - 1];
// Difference between the current moment and the time when the car entered
// the parking lot, result is in seconds
Parking_Duration = Parking_Duration / 3600;
```

//the result is converted in hours
Payment = Parking_Duration * Price;
//The payment is calculated according to the price

b) The user does not have enough money on the RFID card to pay for parking, so they receive an appropriate message, and the "barrier" does not open to allow passage.

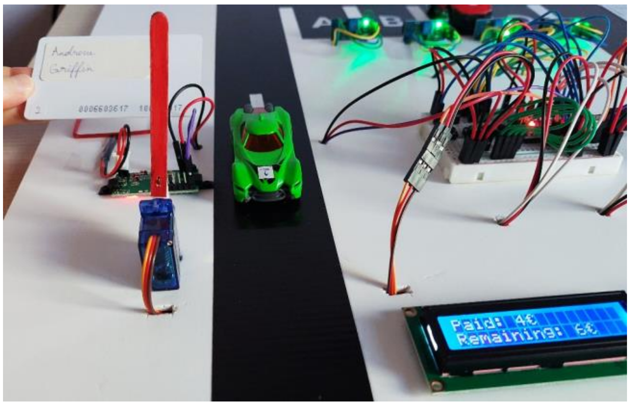

Fig. 7. Insufficient Balance

We simulate a card charging machine with 4 buttons and the exit reader. The user presses the first button to start the payment process, brings the card close to the reader, the card is read, and the user is asked to choose the amount to recharge the card with.

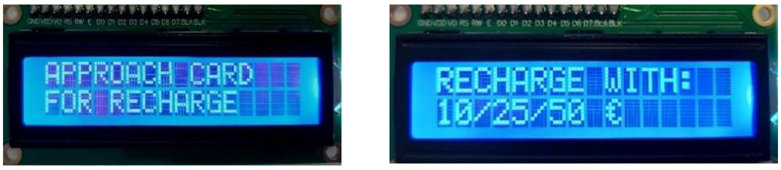

Fig. 8 Card recharge amount options

The remaining 3 buttons represent 3 different recharge amounts, as shown in the code below.

```
Choose:
 if (digitalRead(Buton_2) == LOW) { Add_Balance = 10; goto Chosen; }       aaaaaaaaaelse if
(digitalRead(Buton_3) == LOW) { Add_Balance = 25; goto Chosen; }
aaaaaaaaaelse if (digitalRead(Buton_4) == LOW) { Add_Balance = 50; goto Chosen; }
else goto Choose;
Chosen:
        BALANCE[ID - 1] = BALANCE [ID - 1] + Add_Balance;
```

The user presses one of these buttons (and theoretically enters the cash/card amount at the machine), and the card is recharged. In Fig. 9, a confirmation message appears, and the user is asked to bring the card close again to exit the parking lot.

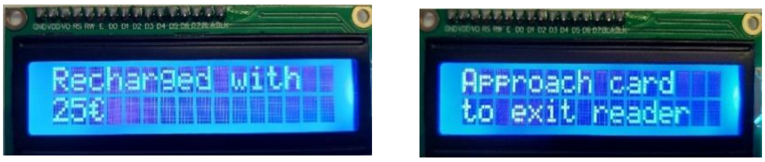

Fig. 9 Messages after card recharge

Now, the user theoretically returns to the exit barrier, brings the card close, and the process from point a) is repeated.

If someone tries to enter/exit the parking lot with an unauthorized card, the reader will read the card but not recognize it, and the servo motor will not be activated. The LCD will display the message "Unknown User," as in the Fig. 10.

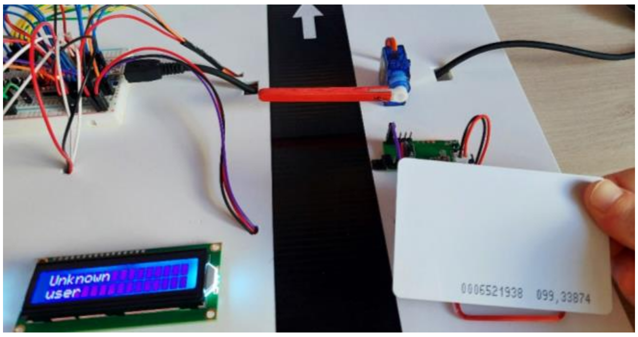

Fig. 10. Unregistered User

Considering that this paper focuses on RFID, let's take a separate look at what the user doesn't see in this operation, namely the communication between the tag and the RFID reader. First, the reader continuously emits the signal that powers the tag and "listens," waiting to receive a response from a tag. Once the tag comes close to the reader and is powered, it begins to send the stored data, specifically 14 numeric values, one by one. Their significance is defined by order. In the serial monitor of the program, we display these values read for card 1, for the user Ingram Daphne, and then we explain the process for extracting the ID, which is also physically inscribed on the card.

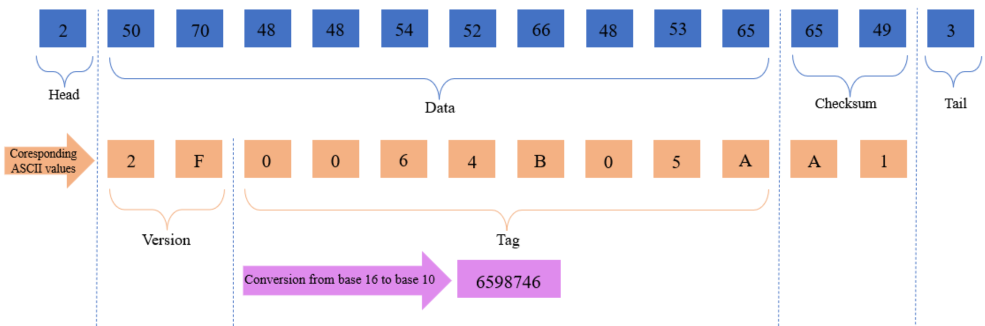

Fig. 11. Data read by the RFID reader

Above, in blue, we have the 14 values read. Values 2 and 3 can only be found exclusively at the ends, indicating the start and end of the data sequence. Thus, they do not contain any other information. The next 10 values represent tag data. The following 2 values represent a method for checking the correct reading of tag data.

The first step is to convert each value containing data, including the checksum for verification, into the associated characters according to the ASCII code. We can see the results in orange in the Fig. 11. The first 2 values form the hexadecimal number 2F, representing the tag version. The next 8 values make up the hexadecimal number 0064B05A. This is converted to decimal, thus obtaining the ID of the tag. Finally, we have the hexadecimal value of the checksum.

The second step is to verify that we obtained the correct ID and version, as reading errors can occur. We will perform an exclusive OR (XOR) operation between groups of 2 hexadecimal values read, i.e., between 2F, 00, 64, B0, and 5A. Through this calculation, we obtain the hexadecimal value A1, which corresponds to the checksum, ensuring that the reading was correct.

The specific functions used for this part are found in the SoftwareSerial.h library. Using the functions below, we check if the tag sends a signal to the reader, and if the response is positive and there are bytes that can be read (currently stored in the reader's buffer memory), they are extracted for processing.

```
mySerial.listen();
if (mySerial.available() > 0) {…}
```

This system and its operation mode are very flexible; the code can be easily modified for other functionalities, such as adding/removing a new card to/from the system, granting privileges to certain cardholders, adding new parking spaces, or changing the charging system for specific implementations, such as a mall parking lot where the first 3 hours of parking are free. The used cards have a price of only 0.80 euros each and offer a medium level of security.

In addition to the card reading mode and details about the connection of the assembly elements, we decided to include a flowchart that captures the main cases and decisions made in formulating the code. The main variants in reading a card are: the user is at the entrance or exit of the parking lot, the user is known or unknown, at the exit, they have or do not have enough money on the card for passage. In addition, the associated value in the k vector is checked to prevent exit at the entrance or entry at the exit. The flowchart is presented in Fig. 12 and 13 respectively.

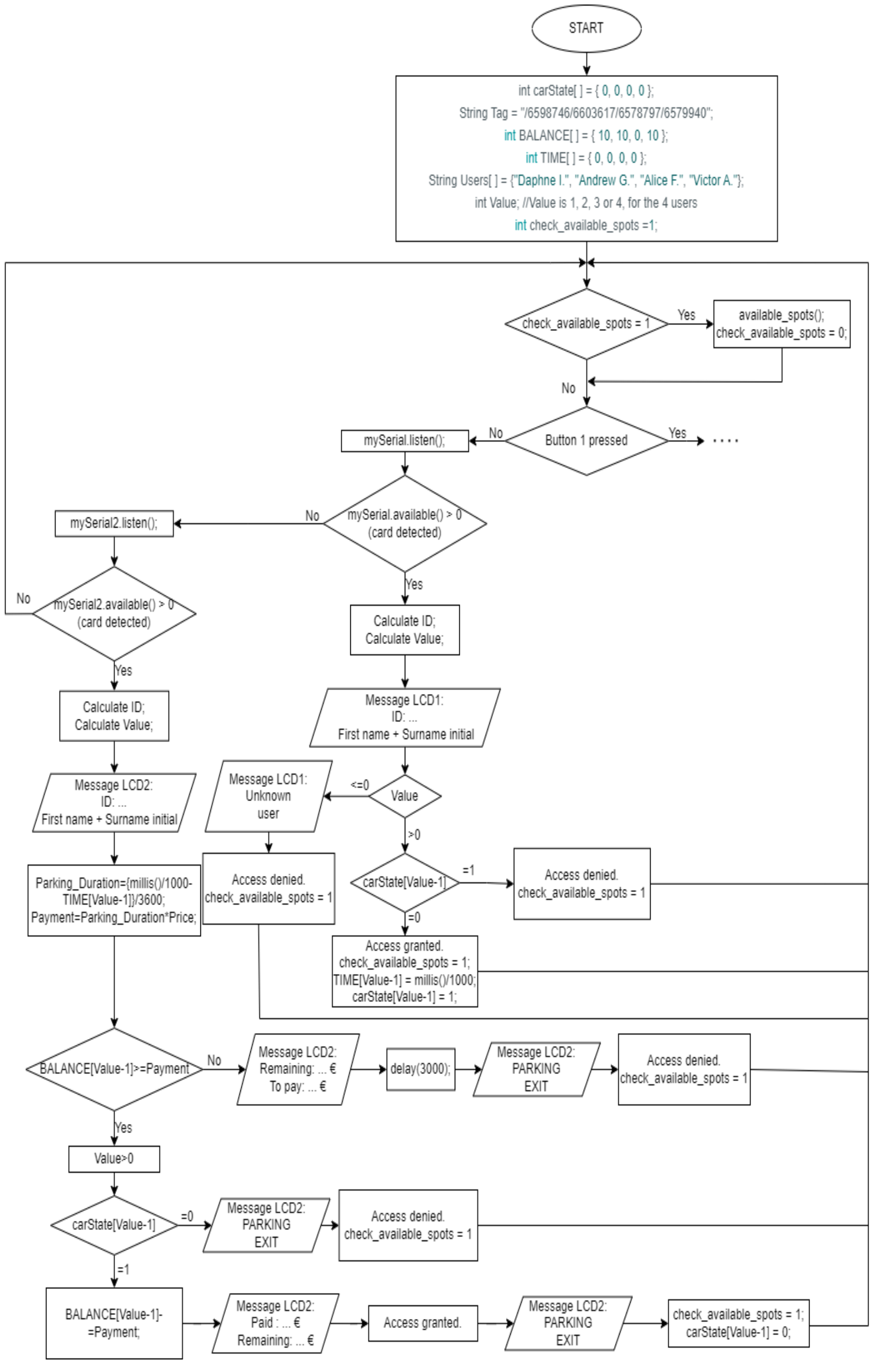

Fig. 12. The flowchart of the parking lot

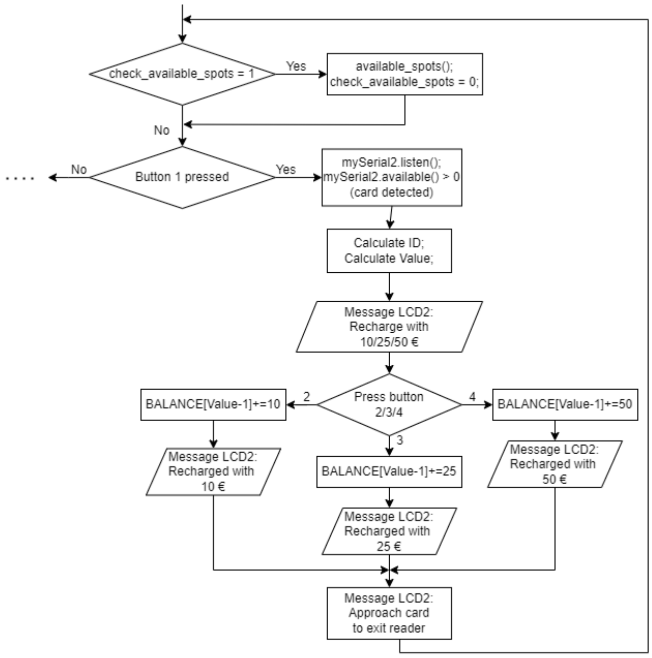

Fig. 13. The flowchart of the parking lot - continuation

4. Conclusions

In this paper was presented a simulation of a possible implementation of a paid car parking based on parking cards controlled thru RFID. The emphasized element of this system is the control access system based on RFID that consists of an RFID reader that opens a barrier at the entrance of the parking and another one at the exit. The authorized users have access to the parking based on a nominal RFID tag, which they also use to pay for parking. The practical implementation of the scale model presents an attractive didactic level. Although, these RFID solutions are already in use, in comparison, this simulation has certain advantages such as:

- the license plate number must not be read upon entry by a license plate scanner;
- the human operator is eliminated in terms of tax collection and barrier control;
- the card can be loaded automatically using a GSM application;
- the driver does not have to open the window and park very close to a contactless card reader.

Furthermore, RFID technology is an innovative and practical solution used in access control systems. RFID offers many advantages such as low implementation and maintenance costs, relatively low complexity, and adaptability to various environments and situations. It is also beneficial the fact that most people are familiar with how to use these RFID cards, eliminating the need for training of a new user.

In the future, this simulation can be implemented in a real parking environment, such as a residential parking lot, an office building, a commercial complex, and so on. The main advantages lie in the adaptability of the code and the flexibility of the project itself. The functionality is not affected if the parking configuration or the billing method is modified. Plus, this modern RFID technology is intended to be an important part of the artificial intelligence (AI) used in any automation future projects.

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R E F E R E N C E S

[1]. *** The number of cars worldwide is set to double by 2040; https://www.weforum.org/agenda/2016/04/the-number-of-cars-worldwide-is-set-to-double-by-2040

[2]. *** How Many Cars Are There In The World in 2023?; https://hedgescompany.com/blog/2021/06/how-many-cars-are-there-in-the-world/I.

[3]. *** 7 Worrying Facts That Prove the Parking Industry Needs Fixing; https://blog.parkman.io/http-blog-parkman-io-worrying-facts-about-parking-problems/J.

[4]. *** RFID Market Size, Share & Industry Growth Analysis Report by Offering (Tags, Readers, Software & Services), Tag Type (Passive, Active), Wafer Size, Frequency, Form Factor (Card, Implant, Key Fob, Label, Paper Ticket, Band), Material, Application & Region – Global Growth Driver and Industry Forecast to 2030; https://www.marketsandmarkets.com/Market-Reports/rfid-market-446.html

[5]. *** RFID Access Control Guide: 4 Best RFID Access Control Systems; https://butterflymx.com/blog/rfid-access-control/

[6]. *Mingjun Tang, Renwen Chen*, Study and implementation of a tunnel personnel and materials management system based on RFID technology, Scientific Bulletin, University POLITEHNICA Bucharest, Series C: Electrical Engineering, vol. 1, 2023.

[7]. *Liqian Zhang, Xueliang Fu, Honghui Li, Buyu, Wang*, Algorithm based priority (ABP) mechanism for decreasing tag loss in mobile rfid systems, Scientific Bulletin, University POLITEHNICA Bucharest, Series C: Electrical Engineering, vol. 2, 2023.

[8]. *Irani, Z; Gunasekaran, A., and Dwivedi, YK,* " Radio frequency identification (RFID): research trends and framework" , 2010 *International journal of production research*, pp. 2485-2511.

[9]. *Wei, YB and Liu, P.*, " A Development Research of Self-guided Robot Based on Radio Frequency Identification", *2023 13th China Academic Conference on Printing and packaging and Forum of Collaborative Innovation of Industry-University-Research,* pp. 405-411.

[10] *V. Daniel Hunt, Albert Puglia, Mike Puglia*, RFID-A guide to radio frequency identification, 2007; www.researchgate.net/publication/362581874_An_Introduction_to_RFID_Systems;

[11]. *Patrick J. Sweeney II*, RFID for dummies, 2005, https://www.pdfdrive.com/rfid-for-dummies-e166874016.html;

[12]. *Klaus Finkenzeller,* RFID Handbook Fundamentals And Applications In Contactless Smart Cards, Radio Frequency Identification and Near-Field Communication, Third Edition, 2010, https://www.pdfdrive.com/rfid-handbook-fundamentals-and-applications-in-contactless-smart-cards-radio-frequency-identification-and-near-field-communication-e176912261.html;