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Research Article

RFID Cartesian Smart Parking Lot System

Sabri UZUNER[a] Fatih Mert CELEBİ[b]

[a]Duzce University, Engineering Faculty, Mechatronics Engineering, TÜRKİYE
[b]Duzce University, Engineering Faculty, Mechanical Engineering, TÜRKİYE
ORCID[a]: 0000-0002-9099-1324
ORCID[b]: 0000-0002-1945-9343

Corresponding Author e-mail: sabriuzuner@duzce.edu.tr

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ABSTRACT: In recent years, smart products in different fields that have come to the market continue to exist and increase. Smart products, which we hear about in every sector, allow us to make life easier, save time, and even allows us to protect nature. In this study, the smart parking lot system aims to provide security, save space, save time, and reduce the carbon emitted while searching for a parking space with the vehicle. In the present study, Arduino MEGA 2560 was used as the controller, DC motor with reducer to provide movement, encoder to count the steps of the moving motors, servo motor to place the cars on the shelves, MFRC522 card reader to read RFID cards, 20x4 LCD screen for information and 12V DC adapter to provide the power required by the system. The car park has 3 rows and 4 columns and 12 parking spaces. The vehicle arriving at the car park is parked in the car park by reading any RFID (13.56MHz) card. If there is no free space, the warning "There is no space in the parking lot!" is given. In the realized system, integrating RFID security standards into parking lot automation may provide advantages in terms of security and time.

KEYWORDS: Arduino, Smart parking lot, Encoder, RFID, Automation

1. INTRODUCTION

Technology has entered almost every aspect of human life today (Anli and Taş, 2018; Meral, 2018). The innovations brought by technology facilitate people's daily lives and contribute to their adaptation to changing world conditions (Davey et al., 2018; Yam and İlhan, 2020). New inventions from the past to the present have brought new problems, such as where these inventions will be used (Seferoğlu, 2015), the areas where they will be stored (Sağlık, 2021), the storage conditions, and so on. For example, the telephone was invented and brought features such as a battery for carrying (Beyzanur, 2020; Şükran and Güngör, 2021), a charger for charging, and even wireless charging, which has recently become widespread (Aydın, 2020; İspir, 2020).

As the invention of the car has added many requirements to the car, parking lots have become widespread as safe areas where the car will be kept. With the increase in city life, parking lots were not enough and were replaced by multi-story parking lots (Haldenbilen et al., 1999). The disadvantages of multi-story parking lots include being unable to find the car due to many floors, theft of valuables in some parking lots without cameras, and, of course, the time lost while parking and picking up the vehicle (Cheng and Nian, 2021). These disadvantages of parking garages have pushed parking lots to become smart (Güngör and Öztürk, 2017).

There are many different automation systems integrated into parking lots. Bingöl et al. (Bingöl et al., 2010) studied a PLC-controlled automatic parking garage system. In their study, a three-story, three-row parking lot system with a total capacity of nine vehicles was designed. In a study by Yardım and Ağrıklı (Yardım and Ağrıklı, 2005), automatic parking garages used worldwide were examined, and their contribution to the solution of the parking problem in Turkey was evaluated. A study by İçer (İçer, 2019) aimed to develop smart car parks with controlled charging stations that are centralized and collected at certain points instead of individual or scattered uncontrolled charging stations. By calculating the power requirement for vehicle charging in the parking lot, an effective PLC-based energy control automation has been developed to ensure efficient use of energy resources by considering the grid power demand density. Can and Ilıcalı (Mesut and Ilıcalı, 2019) introduced the mechanical lift, which is a semi-automatic and fully automatic parking system which have been used for a long time in developed countries where the construction of traditional open or closed parking lots is inefficient or does not meet the needs in terms of capacity and operating conditions.

There are RFID systems used for different purposes in parking lots. Pala and Inanc (Pala and Inanc, 2008) carried out parking lot entrance and exit controls with RFID readers, tags, and barriers. In the study by Winter and Goel (Winter and Goel, 2021),

an RFID tag is attached to the vehicle for parking lot occupancy detection, and information about the vehicle, such as brand, model, and license information, is stored in the memory of this tag. Moreover, when the vehicle enters the range of the reader placed in the parking lot, the reader detects the tag, reads the stored data, identifies the vehicle, and determines whether it is parked.

In the present study, an automation system for smart car parks that can be entered and exited with an RFID system has been developed. The developed system is presented as a solution to the problem of finding a parking space, which is one of the problems experienced in urban parking. At the same time, the vehicle can be dropped off and picked up with any RFID-enabled card used in daily life (bus card, student card, credit card, etc.) without requiring an RFID card registered in the car park. paragraph.

2. MATERIAL and METHOD

Arduino MEGA 2560, geared DC motor, encoder, servo motor, MFRC522 card reader, 20x4 LCD screen, and 12V DC adapter were used in the present study. The system is designed to provide automatic parking management and layout.

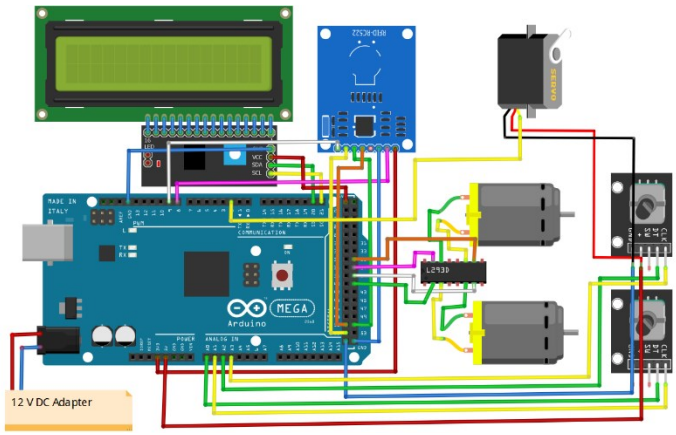
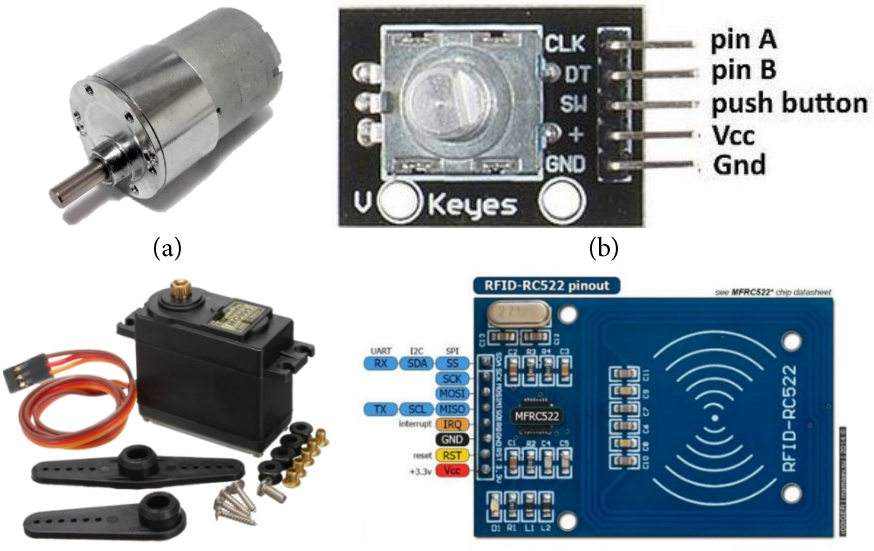


Figure 1. Experimental Setup

Control and management were coordinated through the Arduino MEGA 2560 microcontroller. Arduino Mega 2560 is an electronic control board with Atmel's ATmega2560 microcontroller. There are 15 PWM outputs among the 54 input-output pins on it. It also has 16 analog inputs on it (Kayaalp and Özkorucuklu, 2015).



(a) (b)

(c) (d)

Figure 2. (a) Geared DC Motor, (b) HW-040 Encoder, (c) Servo Motor, (d) MFRC522 RFID Module

Preferred DC motors with gearboxes that transmit motion ensured smooth and precise movement of parked vehicles. Gearboxes are gear systems that change the speed-to-torque ratio of a rotary motion with the help of gears. They are closed-gear assemblies designed to convert the high rotational speeds of motors into the torque required for machines (Erkan, 2014). The Gearmotor DC motor consists of a reducer and a motor (Figure 2a). HW-040 encoders accurately tracked these motors' movement steps to determine the parked vehicles' position. The encoders in question, shown in Figure 2b, a rotary encoder, also called a shaft encoder, are electromechanical devices that convert the angular position of an axle into analog or digital output signals (Salur et al., 2021). The HW-040 model encoders used in this study can count 30 steps in 1 circular revolution. The task of shelf arrangement and placement of vehicles in the car park was undertaken by servo motors. MG995 servo motor, shown in Figure 2c, was used in this study. The servo was an automatic device that controlled the functioning of any mechanism with the help of a feedback device by detecting errors and eliminating errors. It is the most widely used motor type in robot technology. As the DC motor in the servo moves, the potentiometer rotates, and the control circuit compares the motor's position with the desired position and drives the motor (Sarıaltın, 2017). MFRC522 card reader is used to read RFID cards in the system so that vehicles and parking spaces can be uniquely identified. The MFRC522 RFID Reader module shown in Figure 2d generates a 13.56MHz electromagnetic field to communicate with RFID tags (Süzen and Taşdelen, 2018). The RFID reader comprises a Radio Frequency module and an antenna that generates a high-frequency electromagnetic field. The RFID tag is a passive RFID device. The feature that allows it to operate without energy is that it contains a microchip that stores and processes information and an antenna for receiving and transmitting a signal. The tag is placed within range of a reader, and the reader generates an electromagnetic field that allows electrons to pass through the tag's antenna and then power the chip to read the information encoded on a tag (Karakoç et al., 2021). The system is directed according to the information in the read RFID card. In addition, a 20x4 LCD screen was integrated into the system to provide users with operational status and instant information presentation. This screen instantly displayed the parking spaces' status, occupancy rates, and guidance information. As a result, users can quickly and easily obtain information about the car park's status. A 12V DC adapter supported the system to provide uninterrupted and sufficient power. This adapter was selected considering the energy requirement of the Gearmotor DC motors that provide movement in 2 axes. The car park has a 3x4 matrix structure and has 12 parking spaces. Incoming vehicles are directed to empty parking spaces by reading their RFID cards. However, when all parking spaces are full, the system warns the users, "There is no space in the car park!". This feature aims to help prevent time loss for vehicle owners and optimize car park management.

3. RESULTS and CONCLUSION

Initially, it was planned to arrange the shelves in a cylindrical arrangement. As a result of the research, it was determined that when the cylindrical parts are arranged side by side, there are gaps between them, which cannot be used. Since one of the most important goals of this study was to save space, geometric shapes that are compatible with each other were emphasized. Hexagonal parts can be arranged side by side like a honeycomb without leaving any space between them. However, the corners cannot be used since the motor will move the system from the center to the middle during the usage phase.

The square and rectangle were emphasized. Since it will be an example, the number of parks was determined as 12, and the design was started to be made accordingly. The design was made in 3x4 (3 rows, 4 columns). Then, the shelves were converted into a Cartesian (x,y) system. Using 2 motors, the mechanism movement was realized in x (vertical) and y (horizontal) planes. DC motors provided this movement. At the end of the DC motor is a 20-tooth pulley and an encoder with the same axis as this pulley. The pulley at the end rotates the encoder, and the position information of the encoder is transmitted to the Arduino. In this way, the position control of the DC motor can be easily done.

A demonstration study was conducted to assess the system's performance. Initially, the encoder lacked positional information when the system was first initiated due to the absence of a zero setting. A limit switch was employed to determine the zero positions of the motors responsible for moving the axes to address this issue. In the software developed for this purpose, all motors automatically align with the predefined zero point upon program initiation. This zero point is also where vehicles are picked up and placed.

When considering inter-axis movements, we initially opted for a double steel bar layout but subsequently realized that a single bar could effectively resolve the issue. The drawback of using double rods lies in the additional compressive load imposed on the system, resulting in a doubled weight. Instead of the bolt initially used to transmit linear motion for vehicle parking, we explored the possibility of employing the 3D printer Z-axis bolt as a more favorable alternative. However, this would necessitate using a

more powerful motor, presenting a trade-off between time and cost. If speed is a priority, opting for the 3D printer bolt with a higher-powered motor is advisable, with cost considerations taking a secondary role. When contemplating axis movements, one can envision a configuration where the motor and steel rods responsible for the x-axis motion are mounted on the y-axis. This approach may offer advantages in terms of aesthetic design and expedited results.

In conclusion, this study successfully developed an RFID-based smart car park automation system to alleviate urban parking issues. It accommodates various RFID-enabled cards for vehicle access, eliminating the need for dedicated cards. The design evolved from cylindrical shelving to a space-efficient 3x4 grid, controlled by DC motors with encoders in a Cartesian system. A limit switch ensured zero position alignment for motors. The choice between single and double steel bars, as well as the consideration of a 3D printer Z-axis bolt, balanced speed and cost factors. The study's innovative axis configuration proposes mounting x-axis components on the y-axis for potential efficiency and aesthetics. This work provides valuable insights for future automated parking projects and optimization efforts.

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