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Design and Fabrication of an Intelligent System to Control Use of Water Shower and Chlorine Pond by Swimmers in Pools According to the Hygiene Protocols

Mohammad Khalilakbar [1], Shirin Nasresfahani [2] *

1. Department of Electrical Engineering, Science and Research Branch of South Khorasan, Islamic Azad University, Birjand, Iran.
2. Department of Electrical and Computer Engineering, Golpayegan College of Engineering, Isfahan University of Technology, Golpayegan, Iran.

ABSTRACT

The growing demand to benefit from swimming and swimming pools highlights the need for automated monitoring and control of swimmers' hygiene. Because hygiene protocols noncompliance results in infection transmission and disease spread, as well as a threat to swimmers' health. This paper presents an intelligent system for monitoring, identifying, and announcing non-compliance of hygiene criteria by swimmers in the pool and preventing accessing the pool. Radio frequency identification (RFID) technology, which is based on the detection of electromagnetic signals and radio frequencies, has been applied for automatic recognition. The system monitors the information written on the MIkron FARE (MIFARE) intelligent tags by the ATMEGA32 microcontroller and the MFRC522 interface module as swimmers pass through the water shower and chlorine pond before entering the pool. Then the electrical gate is opened using a relay. Another technical highlight of this system is the ability to define the desired number of tags without the need for a computer, which will reduce costs. We investigated the performance and reliability of the system in an experimental environment.

Corresponding Author: Shirin Nasresfahani, Department of Electrical and Computer Engineering, Golpayegan College of Engineering, Isfahan University of Technology, Golpayegan 87717-67498, Iran. Email: Sh.nasresfahani@iut.ac.ir, Tel: +98 9132066376

INTRODUCTION

Nowadays, swimming as a sport and recreational activity is spiritually and physically popular and the number of people who use swimming pools and enjoy swimming is rising all year. Therefore, it is very important to pay attention to the hygienic aspects of swimming pools to protect the health and well-being of swimmers. One of the most significant important hygiene issues in this field is swimmers' hygiene. In the pool, the body is in close contact with the water, and while the swimmer is immersed in the water, water may enter the mouth, eyes, nose, and ears; As a result, in the case of microbial or chemical contamination of the swimmer, the possibility of spreading diseases such as eczema, gastrointestinal diseases, and ear infections is very high (1). Transmission and outbreaks of infection to swimmers from pool water have been reported in recent studies (2-4). Since pools are used simultaneously by a vast number of swimmers for a short period of time, the amount of contamination is constantly increasing. Hence, hygiene protocols noncompliance in swimming pools turns this fun and healthy sport into a source of a variety of diseases. Hygiene protocols that must be followed by swimmers are: 1) The swimmer must wash his body with soap and water before entering the pool. 2) The swimmer must cross the chlorine pond before entering the pool (the required duration in the chlorine pond is 20 seconds) (5). Short-term foot contact with a chlorine pond may not be adequate to achieve disinfection, but the high concentration of chlorine in the pond has reduced the time required. It is worth noting that it is difficult to monitor the execution of processes 1 and 2 with limited staff.

In recent decades, a broad category of technologies has been introduced to identify objects, humans, and animals, known as automatic identification (6). Bar codes, smart cards, voice recognition, biometric technologies, as well as radio frequency identification (RFID) technology are some of these technologies that have been designed and applied for automatic identification (7,8). Among these modern technologies, RFID technology has the ability to capture object data automatically and accurately, as well as it provides instant traceability and visibility (9). Tag or card, reader, controller, and software (data collection and management system) are the main components of any RFID system. A tag or automatic transmitter is composed of an electrical circuit (chip, antenna, and, in some cases, a battery) enclosed in a plastic cover, protecting it from common damage and ambient humidity. Each tag contains a unique identifier (ID) as well as other data. Tags are attached to the product or person to indicate the product or person's characteristics as well as their access level. Radio waves are used to send and receive information data between tags and readers continuously. The RFID antenna is responsible for propagating and receiving waves within a certain range, allowing the reader to recognize RFID tags. Moreover, the antenna provides the energy required by the tag to communicate. A reader is an electronic device that generates a magnetic field to read tags' information through radio waves and retrieves the data stored in tags. The magnetic field produced by the reader activates the tag when it is near to or within the range of the reader (10). The controller and related software process data received from the reader. In addition to managing the processing, storage, and retrieval of data, RFID software is responsible for monitoring and providing commands to exchange data from the reader to the tag or vice versa. On the other hand, software controls the access of people based on time and distance. Therefore, software plays an essential role in an RFID system, and without software, the RFID system hardware will be useless.

The MIkron FARE Collection System (MIFARE) is a contactless smart tag that uses RFID technology to wirelessly communicate with a card reader. These tag work at the carrier frequency of 13.56 MHz, receiving power from near-field inductive coupling (11). The tags are small enough to embed in plastic cards, silicon wristbands, and spring wristbands. The intelligence of MIFARE tags is attributed to their ability to read and write more than 10,000,000 times with reading and writing distance up to 10 cm and the type and capabilities of chip used in them. They are equipped with a security module to prevent unauthorized access to their information. Furthermore, they are capable of withstanding adverse environments such as humid or harsh (12). By exploring RFID characteristics and capabilities, this technology finds applications in a broad spectrum of fields including person identity, libraries, warehouses, logistics and retail, access control, enterprises, parking services, medical centers, prisons, public environment, indoor localization, etc (13-17). However, to the best of our knowledge, there is no study to monitor keeping hygiene in swimming pools using MIFARE tags and RFID technology.

Accordingly, in this paper, we present an intelligent system for monitoring, identifying, and announcing non-observance of hygienic protocols (crossing the shower and chlorine pond) in the pool by swimmers, which has been designed and developed for the first time. The system consists of some electronic boards that can read and write data on MIFARE tags, as well as define and register a vast number of them without the use of a human agent or a data server. The system was implemented in an experimental environment and its functionality (performance and reliability) was evaluated. The results were completely satisfactory. Deploying the RFID system in the pool provides real-time monitoring and control of keeping hygiene by swimmers.

MATERIAL AND METHODS

The system is composed of hardware and software which operate together to provide the system's desired function. The hardware includes three electronic boards and an electrical gate. The circuit schematic of the first and second electronic boards, which include the MFRC522 module, ATMEGA324P microcontroller, LCD, and dipswitch is shown in Fig. 1. The electronic boards are powered by the Lf33 regulator IC along with the diode and capacitor. The microcontroller inputs are the MFRC522 interface module and dipswitch. The outputs of the microcontroller are LCD, buzzer, and MFRC522 interface module. The MFRC522 module, as an interface circuit, is responsible for communicating with the microcontroller and the MIFARE tag. It provides the required power of the tag, identifies, reads, and writes data on the tags, and sends data to the microcontroller. To read and write the data on a MIFARE tag, it is placed close to the MFRC522 interface module. The LCD monitor displays system notifications. The buzzer is used to provide an audible warning. For simplicity of design and also to distinguish the boards, a dipswitch is used. On the first electronic board, the first dipswitch key is in position one, and on second electronic board, the second key is in position one. The first electronic board is located next to the faucet in the shower. The second electronic board is located on the wall of the chlorine pond.
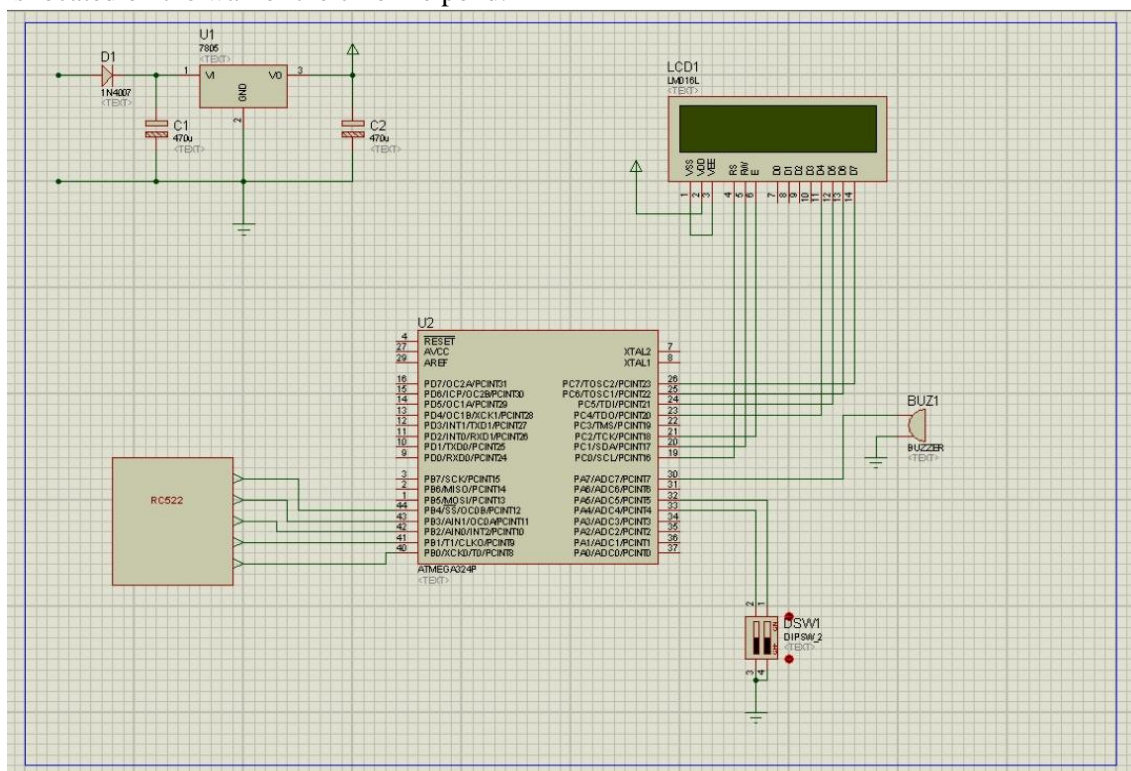

Fig. 1. Schematic of the first and second electronic boards, which includes MFRC522 modules(RC522), ATMEGA324P microcontroller(U2), LCD, dipswitch

The schematic diagram of the third electronic board is shown in Fig. 2, which includes the MFRC522 module, ATMEGA324P microcontroller, LCD, dipswitch, relay, and keys for registering and deleting tags. Defining,

authorizing, and resetting MIFARE tags to the initial state, opening and closing the electrical gate is accomplished by the third electronic board. Each electronic board has been placed in a waterproof plastic enclosure. Electrical gates composed of electric motor and mechanical parts available on the market.
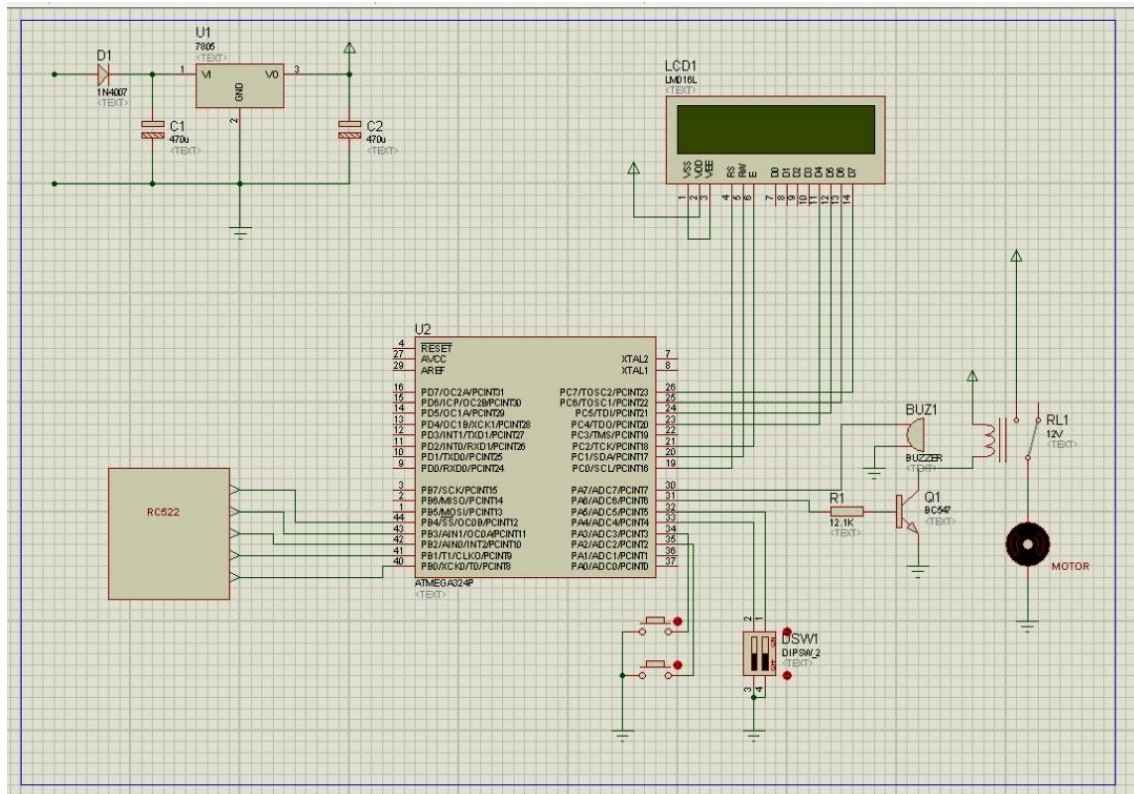

Fig. 2. Schematic of the third electronic board which includes MFRC522 modules(RC522), ATMEGA324P microcontroller(U2), LCD, dipswitch (both keys are in the same position), buzzer, relay, key (to register and delete tags)

The flowchart of the system's operation is shown in Fig. 3. The microcontroller has been programmed by Code Vision software according to this flowchart.
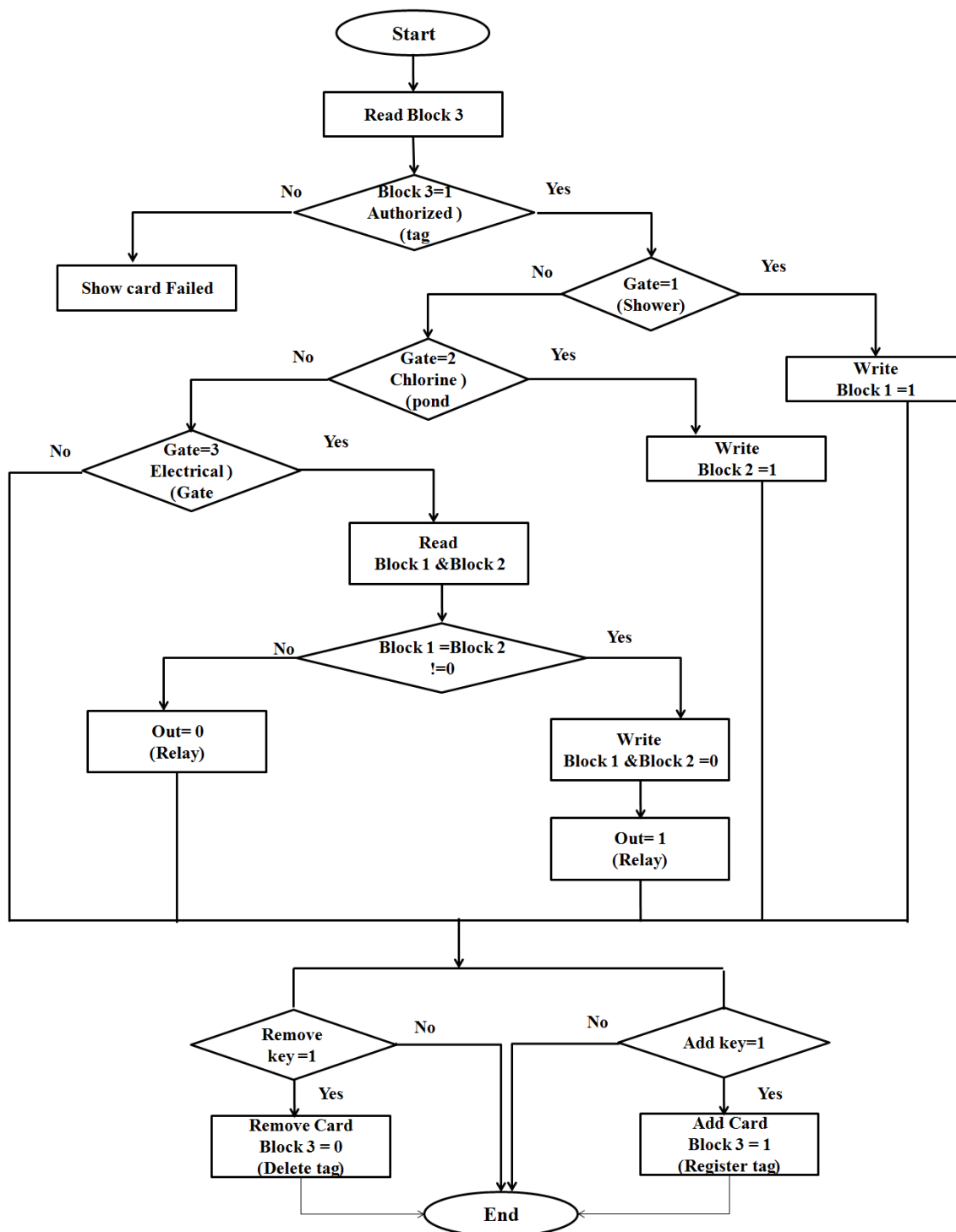

Fig. 3. Flowchart of system performance

RESULTS

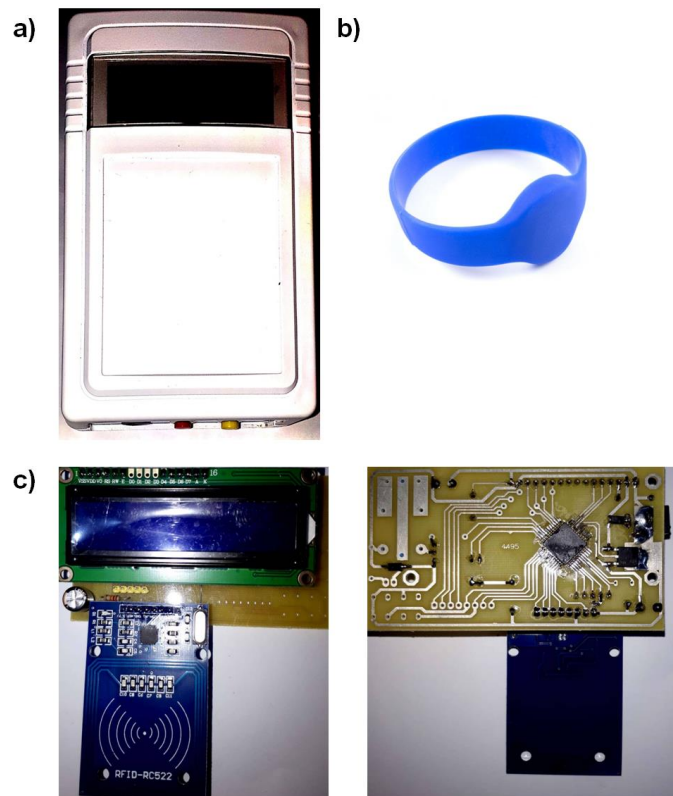The images of the fabricated device and board are shown in Fig. 4.

Fig. 4. Images of a) fabricated device, b) tag, c) electronic board

The system block diagram is shown in Fig. 5. To access the pool, each swimmer must wear a MIFARE tag that has been registered in the system and embedded in the wristband. Therefore, following the installation of this system in the pool, MIFARE tags are first registered and authorized by the third electronic board installed in the barrier section and then distributed to swimmers. The system is capable of authorizing an unlimited number of tags. Without the use of a computer, the system can authorize the desired number of tags. In so doing, the registry (delete) key is pressed after each tag is placed in front of the third electronic board.

When the swimmer opens the shower (faucet), the tag is placed near the first electronic board (reader) and it is identified by the MFRC522 interface module and microcontroller, and data string is written on it. The pools can be completely mechanized with the use of electric steering valves in the shower. Moreover, the tag does not need to be in the direct line-of-sight of the reader to be tracked, so there is flexibility in where these instruments are placed. The second electronic board recognizes the tag and writes data string on it when the swimmer is located in the chlorine pond for 20 seconds. The third electronic board then reads the data written in the previous two steps. The electrical gate is allowed to open if the swimmer passes through the shower and chlorine pond. At the same time, the tag is reset and all data is erased, after which it can be given to other swimmers for later use.
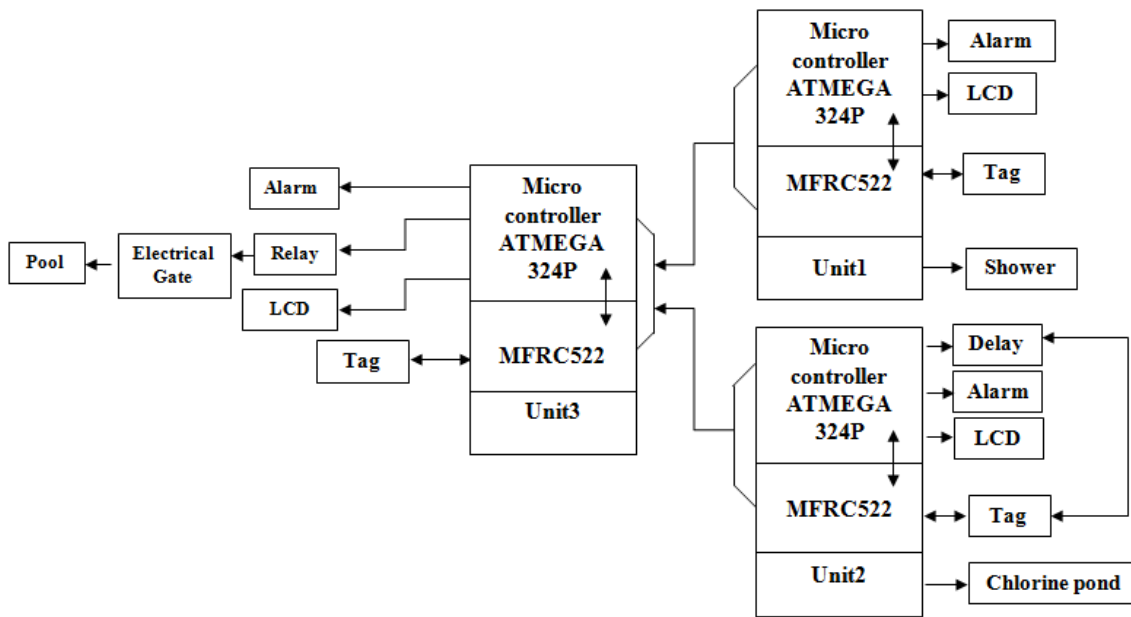
Fig. 5. Block diagram of the system

Due to the lack of human intervention, the discussed system is extremely reliable, with a very low percentage of error. Moreover, system maintenance costs are reduced as a result of contactless readers.

CONCLUSION

With the advent of RFID technology, the idea of applying this unique and cutting-edge technology to a variety of fields arose. In this paper, we develop an intelligent system based on RFID technology and MIFARE tags for automatic monitoring and control of the use of water shower and chlorine pond by swimmers before entering the pool. Software along with the hardware was implemented to read, write and recognize data without the assistance of a person. The desired number of tags can also be easily added to the system. The implementation of RFID is linked with significant improvement in operating efficiency (reducing costs and increasing speed), reducing human errors, decreasing employees, and affordability.

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چکیده فارسی

طراحی و ساخت سامانه هوشمند برای کنترل استفاده از دوش آب و حوضچه کلر توسط شناگران در استخرها مطابق پروتکل های بهداشتی

محمد خلیل اکبر[۱] شیرین نصراصفهانی[۲]*

۱. کارشناسی ارشد مهندسی برق گرایش قدرت، دانشگاه آزاد اسلامی، واحد علوم و تحقیقات تهران- خراسان جنوبی، ایران

۲. گروه مهندسی برق و کامپیوتر، دانشکده فنی و مهندسی گلپایگان، دانشگاه صنعتی اصفهان، گلپایگان، ۶۷۴۹۸-۸۷۷۱۷، ایران

تقاضای روزافزون برای بهره مندی از شنا و استخر شنا نیاز به نظارت و کنترل خودکار بهداشت شناگران را افزایش داده است. زیرا عدم رعایت پروتکل های بهداشتی منجر به انتقال عفونت و گسترش بیماری و همچنین تهدیدی برای سلامت شناگران می گردد. این مقاله یک سامانه هوشمند برای نظارت، شناسایی و اعلام عدم رعایت پروتکل های بهداشتی توسط شناگران در استخر و جلوگیری از دسترسی آنها به استخر را ارائه می دهد. فناوری رادیو شناسه (RFID)، که بر اساس تشخیص سیگنال های الکترومغناطیسی و فرکانس های رادیویی است، برای تشخیص خودکار استفاده شده است. این سیستم اطلاعاتی را که بر روی تگ های هوشمند مایفر(MIFARE) توسط میکروکنترلر ATMEGA32 و ماژول رابط MFRC522 هنگام عبور شناگران از حوضچه آب و حوضه کلر قبل از ورود به استخر نوشته شده ، بررسی می کند. سپس گیت برقی با استفاده از رله باز می شود. یکی دیگر از ویژگی های فنی بارز این سیستم، امکان تعریف تعداد مورد نظر از تگ ها بدون نیاز به کامپیوتر است که هزینه ها را کاهش می دهد. عملکرد و قابلیت اطمینان سیستم را در یک محیط آزمایشی مورد بررسی قرار گرفته است.

واژه‌های کلیدی: فناوری RFID ، تگ مایفر، پروتکل های بهداشتی ، شناگر، استخر