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Design and Implementation of Intelligent Automatic Door System

Saurabh S. Badave [1], Makrand N. Kakatkar [2], Moreshwar K. Dani [3]
[1] *Student, Sinhgad College of Engg., Pune, India, saurabh2052@gmail.com, +91 9423682868*
[2] *Asst. Professor, Sinhgad College of Engg,. Pune, India, mnkakatkar@gmail.com, +91 9420495358*
[3] *Director, Dani Data Systems Ind. Pvt. Ltd, Pune. India, mkdani@danidatasystems.com, +91 20 25675530*

Abstract: Conventional automatic door systems use fixed settings for various door parameters such as opening widths, opening timings, opening and closing speeds, etc. These settings generally cannot be altered by end user. If the door settings need to be changed, the end user has to call a technician to fix it. A new approach is proposed in this paper which enables the end users to do the changes by themselves by means of a handheld device. This device communicates with the door system to do the necessary changes, thus avoiding the need of reprogramming the whole system. This paper also introduces security mechanism to the door system using access control through RFID smart cards, and safety of door users by using combination of multiple human presence sensors. Cost and energy saving during the operation can be achieved by minimizing the unnecessary opening cycles occurred due to false detections.

Keywords – Automatic door system, access control, NFC, PWM, GPRS

1. INTRODUCTION

Automatic door systems are installed at many places such as shopping malls, airports, office places, etc. Typical automatic sliding door is as shown in Fig. 1. These doors open automatically when presence of one or many people is detected. If the door is installed at public places, the door opens for everyone, and if it is installed at private places with restricted access, then some form of access control mechanism is employed.

Fig. 1 : Target environment

The presence sensors are generally placed at the top of the doors, which continuously scan the detection region.

When the system is installed at the user's space, various settings of the door such as door opening width, opening time, opening and closing speeds are fixed. If the user wants to alter the door settings, the user has to call a technician to do the necessary changes. Problem with this is that the user has to bear the expenses of technician's visit, every time the door settings need to be altered.

This paper presents an intelligent automatic door system, in which the users can do the changes by themselves. This can be achieved by means of a handheld device which can be operated by the user, and the handheld device communicates with the automatic door system to do the necessary changes.

The rest of the paper is organized as follows. Section 2 describes overview of the system. Sections 3 and 4 describe the hardware design of the system and the software design of the system. Section 5 concludes the paper.

2. SYSTEM OVERVIEW

As explained in the previous section, the user can be benefitted by using a handheld device which can communicate with the door system in wireless manner.

Access control mechanism can be implemented to allow only authorized persons to enter through the door. This can be achieved through various techniques such as voice recognition, face recognition, iris recognition [3], password-based systems, smart cards [4], etc. We have used NFC smart card based approach as it provides necessary access control with computational needs very less than voice and iris recognition type of systems [1]. Only the users with valid and authorized cards can pass through the door. This is useful to keep a track of employee's attendance record within an institution [5]. The designed system is able to operate both as a public

place door (without authentication), and as a private place door (with authentication).

Some of the conventional door systems use infrared sensors for detecting a human presence, while other use Doppler Effect sensors for detecting motion. Infrared sensors cannot detect motion [2], while Doppler Effect sensor cannot detect a stand still person. In the designed system, we have combined both of these sensors so that even if a person walks towards a door and stands right below the door frame, the door will not collide. Thus user's safety can be increased by combining multiple sensors together.

Power can be saved if false opening cycles of the door are minimized. A Doppler Effect sensor is a directional sensor, meaning that it can detect if a person is walking towards a door or walking away. If the door gets less frequently opened for false detections, the drive mechanism and the rollers in the door frame will require less frequent maintenance. Thus maintenance costs get reduced. If the door gets frequently opened, it creates a huge burden on the air conditioning facilities inside a building. So cost saving can also be achieved through cheaper electricity bills.

3. HARDWARE DESIGN OF THE SYSTEM

The detailed block diagram of the system is as shown in Fig. 2.

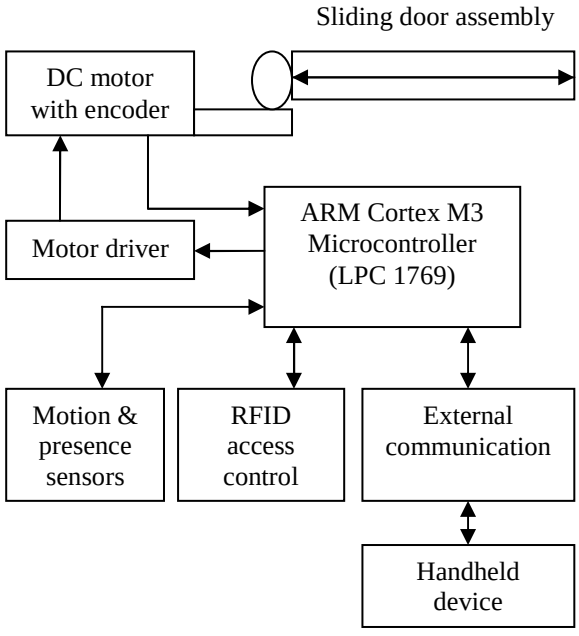

Fig. 2 : Block diagram

The sliding door assembly is coupled with the DC motor shaft through a belt drive. As the motor rotates, the circular motion of motor shaft is converted into linear motion of sliding door. The positioning of the door system is detected through limit switches, and the feedback signal received from the motor. For generating a feedback signal, the motor is equipped with an optical quadrature encoder mounted on its shaft. As the motor rotates, it generates a signal in the form of two identical square wave signals, which are phase shifted by 90 degrees. These two signals can be used to derive the direction of rotation of the motor, depending on which of the two signals is leading over the other.

The microcontroller LPC 1769 has a special peripheral known as Quadrature Encoder Interface (QEI). This block can decode the quadrature encoded feedback signal from the motor, and derive the direction of rotation of the motor. The motor driver used is L298 which can operate up to 46 volts at 4 ampere current. The maximum DC voltage to be applied to DC motor depends on the total load on the drive shaft e.g. weight of glass door panel, belt drive, etc. The speed control of the motor is achieved through PWM signal generated by the microcontroller. The acceleration and deceleration rates need to be set properly, since the door panels used in sliding doors are very fragile, and may get shattered if the door does not stop at right moment.

For detecting motion and presence of a person, a Doppler Effect sensor and an infrared light sensor is used as explained in previous chapter. The combination of sensors makes the overall system safer.

Access control is provided through NFC smart cards. The readers installed at the door emit an electromagnetic radiation to read NFC cards in the vicinity. The NFC smart cards are protected by special passwords so that only authorized card holder will be granted an entry.

A separate handheld device is designed, which is used to change the current settings of the door. This device communicates with the door system via GSM. A message, in a predefined format, is sent via the handheld device which contains the desired new door settings. This handheld device is designed using 89V51RD2 microcontroller which has an 8-bit CPU. The handheld device can also communicate via any of the wired protocols such as I2C, SPI, etc. The device is equipped with an LCD display, matrix keypad, GPRS module, battery, and notification LEDs.

There are other facilities such as daily record tracking, displaying current status of door, etc. The total counts of people passing through the door (in either of the directions), entry and exit times of a particular person (in case of entry through NFC smart card), can be stored and uploaded to a database via GPRS. This is useful to keep a record of attendance reports at a particular institution.

The door system is also equipped with an LCD display, which is used to display the current status of the door. This includes current count of people passed

through the door, time, error warnings, maintenance schedule warnings, etc.

4. SOFTWARE DESIGN OF THE SYSTEM

When powered up, the door system first undergoes a learning procedure to analyze the length of the total track it has to cover. Workflow of the learning procedure is as shown in Fig. 3. The learning procedure is carried out at a very low door speeds, for pre-decided number of iterations. If the door does not move, extra power is applied to the motor drive by increasing width of PWM signal. The feedback from the encoder is observed and stored in memory. Now the system is ready to work at higher door speeds.

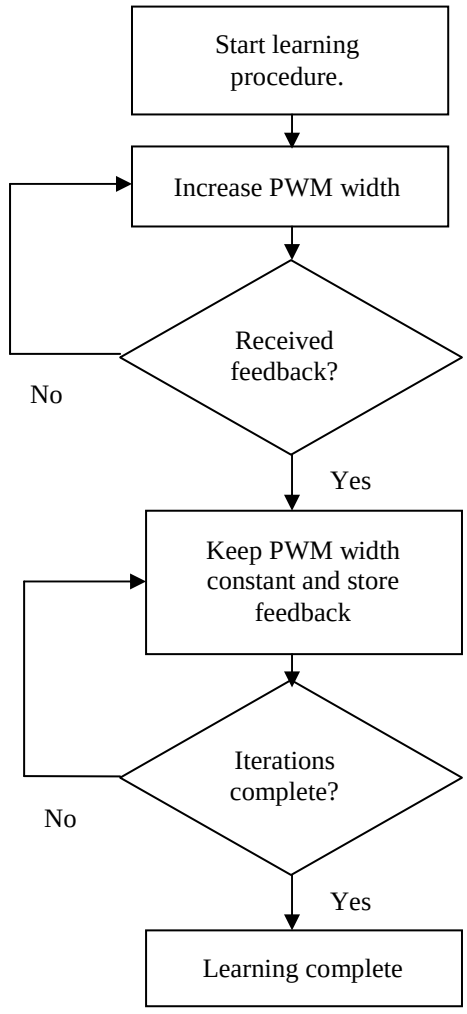

Fig. 3 : Workflow of learning procedure

When the learning procedure is complete, the system now enters a normal operation mode. Depending on the state of the access control, door opens and closes after a certain time, automatically. If the access control is switched on, the door will open only when a valid identity is shown to the reader. If the access control is switched off, the door will open for everyone as if it is installed at a public place.

When settings of the door need to be changed, the data received through GSM module is used. The received message, in a predefined format, contains new settings of the door.

5. CONCLUSION

The designed system is safer, efficient and easy to be adjusted. The main advantage is that the end user can do the settings by himself. This saves large amounts of time and money. The new settings can be sent via GSM which is not limited by distance of the handheld device from the door system. The conventional system is made safer by combining multiple sensors together. This overcomes the possible danger of colliding of door with a person standing beneath the door frame. Energy and maintenance costs can be saved by minimizing false opening cycles.

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