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A Smart Door with Web Controllable Door Motion and Window Transparency

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ABSTRACT: *A smart home allows homeowners to control appliances, thermostats, lights, and other devices remotely using a smartphone or other networked devices. Smart home technology provides homeowners with ease and better accessibility. In this paper, the design of a smart door is proposed – that will increase privacy and convenience. The proposed smart door has a door window – that can be made opaque or transparent by the user - using a touchscreen-based wall display panel or using a smartphone. The door can be opened and closed utilizing a servo motor - using the display panel or the smartphone. The system has a Raspberry Pi microcontroller with a local webserver built inside it. A prototype of the proposed smart door is developed and tested successfully.*

KEYWORDS: *Graphical User Interface (GUI), Webserver, Raspberry Pi, Servo Motor, Smart Home, Smart Tint Film.*

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I. INTRODUCTION

In the context of technology, the word 'smart' is recently used to refer an intelligent web-connected electronic device or system which may function alone or in a network with other devices. Some form of user interaction is usually involved with smart systems. Low cost and low power microprocessors, sensors, actuators, and wireless devices are enabling the creation of smart homes - integrating devices to make the home a better place to be in terms of safety, privacy, comfort, productivity, and well-being. The smart home market was valued at about $24 billion in 2016 and it is expected to grow about $53.5 billion by 2022 [1][2]. In this paper, we developed a smart door where the user can open and close the door; and turn on and off the door window's opacity with a wall-mounted touchscreen panel and from a smartphone. These will allow for easy access to the outside world while maintaining the user's privacy. The smart door will help to reduce annual heating and cooling costs with the ability to tint the door window that prevents sun rays from entering the home. The tint-able door window glass is beneficial for privacy - as it protects the user from unwarranted interference at their homes while also allowing them to turn off the setting should they want a viewable window or to see someone at the doorway. The proposed smart door is considered part of home automation, creating a system that can be controlled from anywhere inside one's house, which could potentially be added to the Internet of Things [3].

II. SYSTEM ARCHITECTURE

The architecture of the system is shown in Fig. 1. The Raspberry Pi will activate through the smartphone app or liquid-crystal display (LCD) as chosen by the user to open/close the door through the servo motor or turn the glass transparency on/off through the relay acting as a switch.

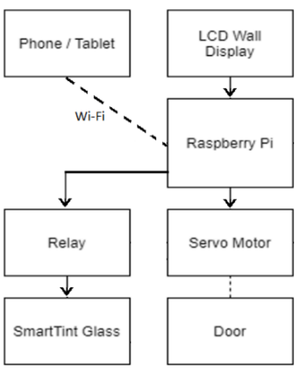


Figure 1: System architecture of the smart door.

2.1 Hardware

2.1.1 Raspberry Pi and LCD

A Raspberry Pi (RPi) v4 [4] single-board computer is used as the main processing unit. It containing a 1.5 GHz 64-bit quad-core ARMv8 microprocessor, 1 GB of RAM, micro SD card slot supporting up to 32 GB, 40 general-purpose input-output (GPIO) pins with two pulse width modulation (PWM) module, onboard Wi-Fi module, and other built-in hardware peripherals such as universal asynchronous receiver/transmitter (UART), I2C, serial peripheral interface (SPI), universal serial bus (USB), audio output via 4-pole 3.5mm connector, LCD interface (DSI), etc. A 7-inch capacitive touch LCD [5] is interfaced with the RPi using the DSI and the I2C port as shown in Fig. 2. The LCD has a 24-bit color depth and a screen resolution of 800 × 480 pixels.

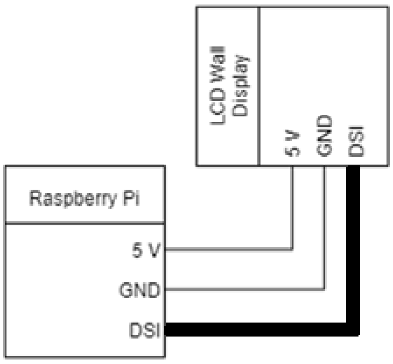


Figure 2: Interfacing LCD with the Raspberry Pi.

2.1.2 Relay and Smart Tint Film

Smart Tint [6] film is used to make the door window either transparent or opaque. The relay connection with the smart tint film was simulated using Multisim [7] - as shown in Fig. 3. - before integrating into the circuit. When 3.3 volts from the Raspberry Pi go to the normally open (NO) pin of the relay, it closes the connection for the film sending the high voltage to the film to polarize.

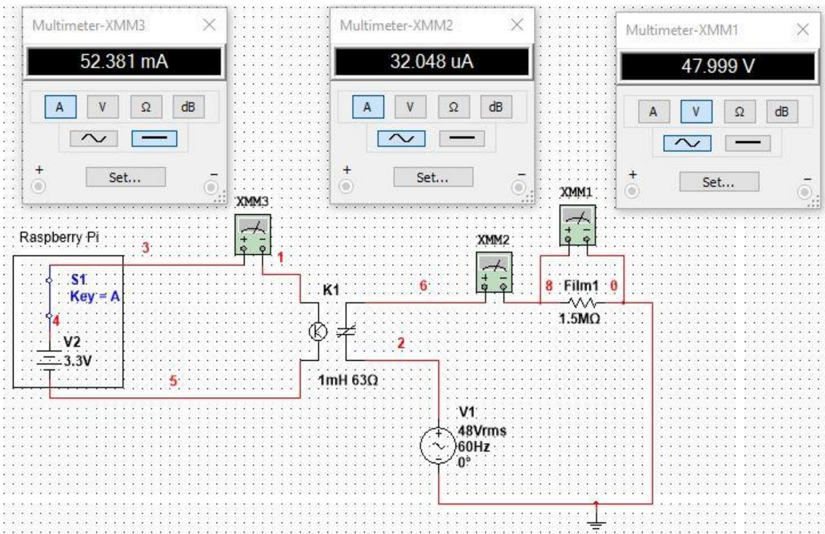


Figure 3: Multisim simulation of the relay with the smart tint film

The relay [8] was wired in series with the Smart Tint film and its power supply as shown in Fig. 4 to create the switch needed from the Raspberry Pi while still providing the appropriate power to the smart tint film. The required power to the relay is 3.3V and the signal is 3V. This was met by the Raspberry pi using a 3.3V power pin (for the relay power) and GPIO pin 17 (for the relay signal).The smart tint film was tested physically within the constructed door. The relay, as shown in Fig. 11, was soldered using a soldering iron and flux. The NO and COM connections were used, so when the Raspberry Pi sends a 3.3V signal to the relay, it will close the connection of the relay and complete the circuit. This switches on the smart tint and polarizes the liquid film crystals, turning the film from opaque to transparent.

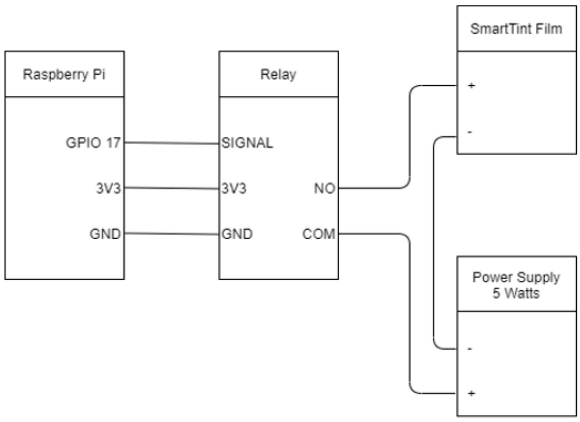


Figure 4: Interfacing of the Smart Tint film with the relay and the Raspberry Pi.

2.1.3 Servo Motor

A high torque servo motor [9] is used for the angular motion of the door. As shown in Fig.5, a constant 6V power supply is used for the motor. The ground of the servomotor and power supply was reconnected to the Raspberry Pi. Using pin GPIO 18, a 3.3V pulse width modulation (PWM) signal [10] is sent to the servo motor to adjust the angle and open-close the door.

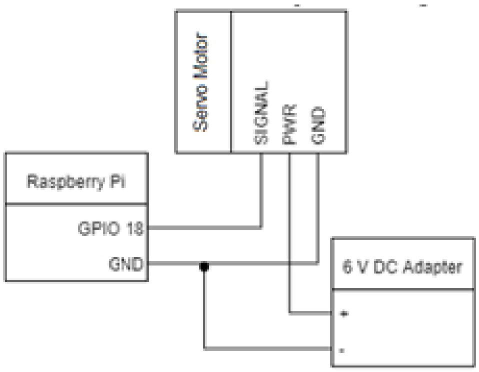


Figure 5: Interfacing servo motor with the Raspberry Pi

2.1.4 Prototype Door Construction and Hardware Assembly

A prototype door was constructed out of three layers of ¼ " plywood with a 0.5' × 0.5' hole cut for the smart tint window externally with a 1.0' × 1.0' hole internally to fit the Plexiglas as shown in Fig.6. The Smart Tint was cut to match the external window following the safety procedures as the Smart Tint film should have a ⅛" gap from the glass edge [11].

(a) (b)

Figure 6: Plywood door assembly: (a) Three layers of plywood; (b) Hole cut for the smart tint window.

The LCD and Raspberry Pi were mounted to the frame using adjacent sides of a metal plate and zip ties as shown in Fig.7.

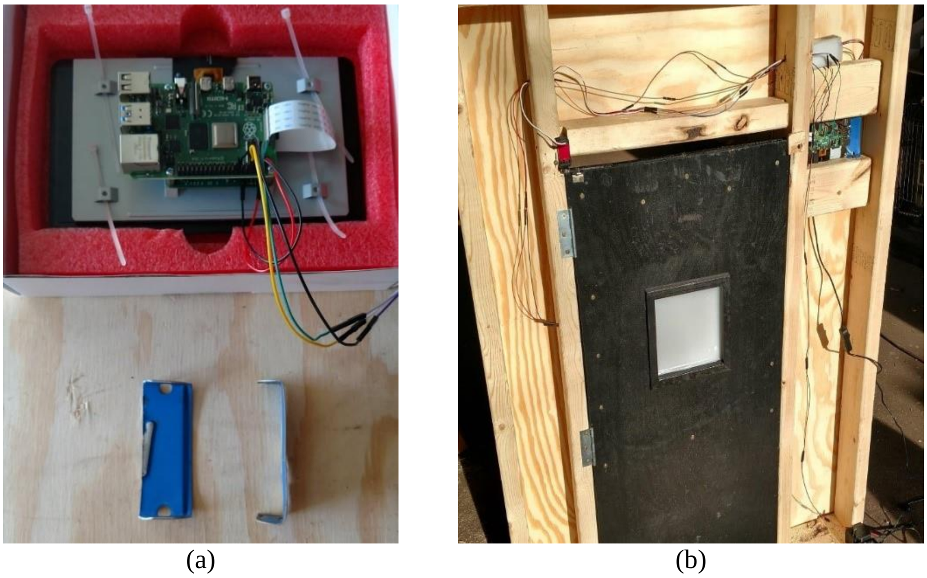


Figure 7: Mounting the display panel (a), and wire-management (b) at the backside of the door.

2.2 Embedded Firmware

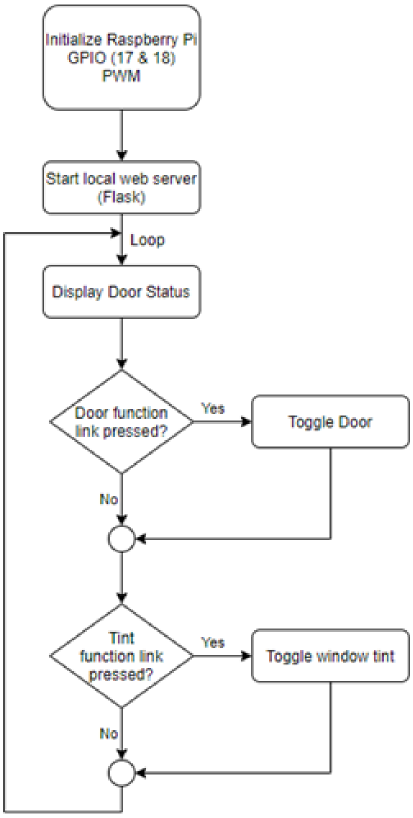


Figure 8: Flow chart of the firmware

The firmware first sets up the GPIO pins that will be used by the system. In this case, they are GPIO 17 and 18. It does so by setting them as output. It then starts the PWM service, which will be used to control the servo. Then it starts the local web server that runs using *Flask*. *Flask* is a lightweight Web Server Gateway Interface (WSGI) web application framework. It is designed to make getting started quick and easy, with the ability to scale up to complex applications. It has become one of the most popular Python web application frameworks [12].

That ends the setup of the system and then it goes on an infinite loop that updates the door status (open/close) and window tint status (on/off) every run. If the link to open/close the door is pressed, then it toggles the door by operating the servo. If the link to turn on/off the tint is pressed, then it toggles the window tint by toggling the relay. The flowchart of the firmware is shown in Fig.8.

2. 3 Web-based Graphical User Interface

A local web server using Flask was used in the Raspberry Pi. To access the server, all that is needed is a device that is connected to the same network and writes the Internet Protocol (IP) address to the web browser. The local IP was set as `192.168.0.7`. A web interface of the server is made using Hypertext Markup Language (HTML)and Python. The HTML consists of status updates and links to toggle the door or tint. The links then run the Python code in the background which performs the desired action: turn on/off the tint on the window or close/open the door.

III. RESULTS

A prototype of the proposed smart door system is developed and tested successfully. The door is 1.5' wide and 3' tall with a window of 0.5' × 0.5' and the total project dimensions of 4.0' × 4.0' as shown in Fig. 9. Using the LCD panel or the smartphone - the door can be opened or closed; and the window can be made either transparent or opaque. Screenshots of the GUI of the display panel and the smartphone are shown in Fig.10. The door open/close function is shown in Fig.11 and the window transparency on/off are shown in Fig.12.

(a) (b)

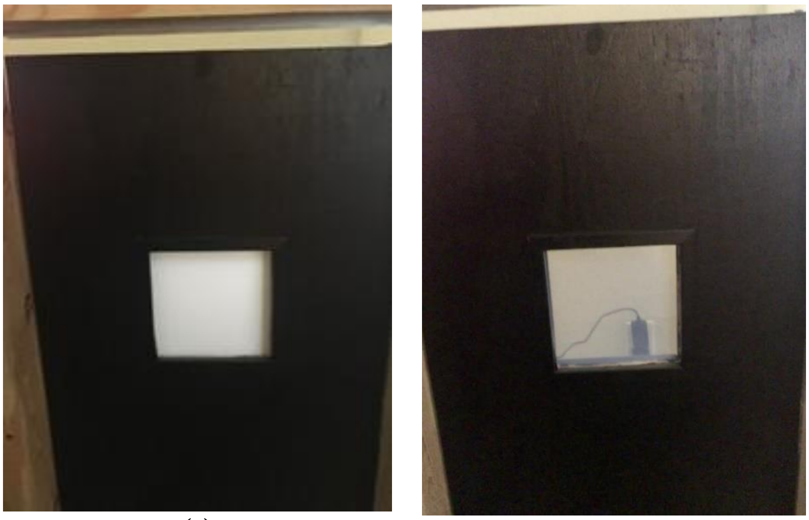
Figure 9: The smart door prototype: (a) front view showing the LCD panel and the door with controllable opacity windows; (b) back view showing the other hardware assembly.

(a) (b)

Figure 10: Screenshot of the web-based GUI: (a) LCD panel; (b) Smartphone

(a) (b)

Figure 11: The angular motion of the smart door using servo motor: (a) door closed; (b) door opened.



(a) (b)

Figure 12: Opacity control of the smart door's window: (a) window opaque; (b) window transparent.

IV. CONCLUSION

In this paper, a smart door is designed, developed, and tested. The proposed system uses a touchscreen or a smartphone –to control the angular door movement and the transparency of the door window. The door met the two project aspects: ease-of-use by automatic door movement and user privacy by the opacity changeable window. This project could be taken multiple steps further depending on the needs of the user. A low-voltage relay to control an electromagnetic component could be used to lock the door while being integrated into the code for opening and closing the door. Voice recognition through Google or Alexa could be added through the Raspberry Pi. For the local server, making it accessible through the Internet, to be able to open/close doors and tint/clear from a longer distance, while safeguarding security issues.

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