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Contact-Free Operation of Epidemic Prevention Elevator for Buildings

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Abstract: The COVID-19 pandemic broke out in early 2020, and the infection rate of COVID-19 variants is considerably higher than that of the original virus. The pandemic is still spreading globally. In June 2021, two families living on different floors of a building in Fongshan, Kaohsiung, were simultaneously infected with COVID-19. Investigation results suggested that an elevator in buildings was the most likely place where the virus transmission occurred. Building elevators are a necessary vertical transportation facility for residents or workers in high-rise buildings, and people touch elevator buttons while operating elevators. When a passenger carrying the virus touches elevator buttons, subsequent passengers may be easily infected if they touch those buttons and then touch their mouth, eyes, or nose by accident before sanitizing or washing their hands. In this study, we developed a contact-free elevator ride system by applying smart speech recognition, contact-free perceptual buttons, gesture recognition sensors, and a web page browser activated by quick response codes to operate an elevator. This system reduces the risk of virus infection caused by contact during an elevator ride, effectively enhancing pandemic prevention and protecting people's health.

Keywords: COVID-19; contact-free perceptual button; epidemic prevention elevator; smart speech recognition; building

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1. Introduction

Coronavirus disease 2019 (COVID-19) [1] is a global pandemic of severe infectious pneumonia caused by severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) [2].

1.1. Research Background

The first known patient of the disease was identified in Wuhan, Hubei Province, the People's Republic of China in late 2019 [3], and the disease then rapidly spread to many countries around the world in early 2020, gradually becoming a global pandemic [4]. As of 10 March 2022, more than 451 million confirmed cases have been reported worldwide, of which more than 6.02 million have died [5], and the case fatality rate is about 1.34% [6]. It is one of the large-scale epidemics in human history. Estimates of the case fatality rate of the disease vary widely around the world, and the observed case fatality rate of the disease is between 0.5% and 5.0% in most countries [7].

In late 2002, a severe acute respiratory syndrome broke out in Guangzhou, China [8–10]. In March 2003, the first confirmed case was reported in Taiwan [11,12]. Thereafter, nosocomial infections occurred at the Taipei City Hospital Heping Branch, and an emergency hospital lockdown was implemented, which severely strained Taiwan's medical system. After this event, the Taiwanese government strengthened its epidemic prevention medical organizations by addressing the deficiencies of the original epidemic prevention system and preparation efforts and dividing the health command structure into three levels (i.e., central, regional, and local government levels) [12–14].

As an active epidemic prevention measure, the Taiwanese government promoted the amendment of the Communicable Disease Control Act and passed it on 24 May 2018. Through the newly established National Health Command Center (which is under the central command system) and the Central Epidemic Control Center (which was established under legal authorization), resources, equipment, and manpower can be integrated to facilitate consistent decision-making with respect to epidemic prevention. The Bureau of Communicable Disease Control was upgraded and renamed as the Taiwan Centers for Disease Control, and highly professional technical, educational, and medical personnel were recruited to build a robust inter-unit coordination mechanism. Taiwan also enhanced its system and training for epidemic prevention specialists, stockpiled epidemic prevention supplies (e.g., face masks, and protective suits), and proactively invested in the research and development of epidemic prevention technologies for emerging communicable diseases. In addition, the government amended the law to establish the Communicable Disease Control Medical Network, which comprises isolation, responding, and supporting hospitals. After experiencing the outbreak of the severe acute respiratory syndrome and the H1N1 pandemic, the Taiwanese people have also developed hygiene habits such as frequent hand washing, mask wearing, and temperature taking.

1.2. Research Purposes

COVID-19 is spread by virus-containing droplets and diminutive particles exhaled by infected individuals. These droplets and particles may be inhaled by other individuals; come into contact with their eyes, mouths, or noses; or even contaminate surfaces [15]. Individuals who are less than 2 m away from an infected individual are most likely to be infected. The space in an elevator is typically small; therefore, maintaining effective and safe social distancing in an elevator is difficult. In addition to the wearing of masks, avoiding unnecessary contact with objects is a crucial means of preventing infections. To provide passengers with a safe building elevator operating mode and ride, we took the following steps to develop a contact-free epidemic prevention elevator:

1. We collected relevant information about COVID-19 and discussed the major transmission modes of the virus and effective pandemic prevention strategies;
2. We explored the possible control mechanisms for developing a contact-free epidemic prevention elevator, including the use of contact-free perceptual buttons, gesture recognition and smart speech recognition for building elevator car calling, quick response (QR) codes for app development, and web browsers for operating an elevator;
3. We purchased a scale-down elevator and used an Arduino control panel, smart speech recognition technology, contact-free perceptual buttons, a gesture recognition sensor, and a building elevator control program to build a prototype of the contact-free epidemic prevention elevator. After we completed wiring, testing, software development, and integration processes, we could control the elevator through speech commands, contact-free perceptual buttons, gestures, and a mobile building elevator control software.

The remainder of this paper is organized as follows: Section 2 details the relevant literature on COVID-19, Internet of Things, smart buildings, elevator and other related studies; Section 3 outlines the research methodology; Section 4 presents the research design such as software and hardware devices, and the introduction to the epidemic prevention elevator; Section 5 describes the results of the study; Section 6 concludes the discussion; and finally, Section 7 makes the conclusion of the manuscript.

2. Literature Review

2.1. COVID-19

2.1.1. Background Information of COVID-19

The first confirmed case of COVID-19 was reported in Wuhan City, Hubei Province, China [12], in late 2019. COVID-19 later spread throughout the world, becoming a pandemic and one of the most fatal epidemics in human history. The common symptoms of COVID-19 are fever, cough, hyperventilation, and loss of taste and smell [16,17]. Its incubation period from infection to symptom onset is generally between 1 and 14 days. It is most contagious during the first three days following symptom onset, although it can still be spread prior to symptom onset and by asymptomatic individuals [18]. A study even indicated that approximately 40–45% of patients with COVID-19 infections were asymptomatic [19].

The COVID-19 virus is mainly transmitted through the droplets produced by patients' coughs or sneezes. Although these droplets generally do not travel far in the air [20,21], individuals who are standing close to an infected individual may still be infected by inhaling these droplets or by touching their faces after contacting surfaces contaminated by these droplets. Pathogens may also be transmitted through aerosols, and they can survive for several days in an aerosol state [22].

Air transmission is an effective means of spreading a virus, and this typically occurs in crowded and poorly ventilated indoor spaces, particularly restaurants, nightclubs, public transportation, and funeral venues [23]. Phlegm and saliva carry numerous viruses [24]. Although COVID-19 is not a sexually transmitted infection, the virus can be spread by kissing and close contact [14,25].

2.1.2. Scientific and Technological COVID-19 Prevention Measures

During the COVID-19 outbreak, the Taiwanese government took full advantage of smart technologies for pandemic prevention. The Executive Yuan integrated the databases of various governmental units and established a smart pandemic prevention system [12] and a pandemic prevention big data team, facilitating pandemic investigation and epidemiological analysis through the utilization of big data, artificial intelligence (AI), and data analysis. The National Health Insurance card and cloud system has become the basis of the COVID-19 prevention network, playing an essential role in face mask distribution, access to medical records, quarantine implementation, and the provision of information about entry into Taiwan [12]. The National Health Insurance Administration applied the existing Health Insurance Medical Information Cloud-based Inquiry System to develop the Instant Alert System, enabling front-line medical personnel to look up an individual's international travel history, identify high-risk occupations, and track down potential contacts through a medical database.

With the assistance of the five major telecommunications companies in Taiwan, governmental units can verify the locations of quarantined individuals through the positioning function of the Pandemic Prevention Tracking System and the Electronic Fence System [12]. To keep track of the health conditions of quarantined individuals, the Central Epidemic Command Center launched an integrated LINE Bot and two-way messaging health report system [26]. After the remaining quantity of face masks at pharmacies was released as open data, Audrey Tang, the Digital Minister of Taiwan, coordinated the government and private sector's joint efforts to develop a face mask inquiry platform (i.e., map of face mask stock) for the convenience of the public [12]. According to the positioning information provided by the telecommunications companies, the government sends public warnings to certain individuals to advise them on the implementation of self-health monitoring.

The U.S. Centers for Disease Control and Prevention made the following statement: "The best way to prevent illness is to avoid being exposed to this virus." The precautions people can take include frequent hand washing, maintenance of respiratory hygiene, quarantine measures, social distancing, implementation of indoor ventilation, wearing of masks in public places, and vaccination. These measures can effectively reduce the risk of COVID-19 transmission [27].

2.2. Internet of Things

The Internet of Things (IoT) consists of all types of items or devices that can be connected to the Internet, which range from factory equipment and automobiles to mobile devices, including smart phones and watches [28,29]. Today, the term IoT specifically refers to interconnected equipment that combines sensors, software, and other technologies and can transmit and receive data from other devices. Conventionally, IoT connectivity is dependent on Wi-Fi. Nowadays, fifth generation and other network platforms are gradually able to process large datasets quickly and reliably. Collected data are not only stored but also used. The ultimate goal of collecting and transmitting data through IoT devices is to analyze such data and accelerate strategy formulation, and AI technology excels in this regard. With the help of advanced analysis and machine learning, an Artificial Intelligence of Things network can be established.

IoT devices can become people's eyes and ears, and equipped sensors can collect visual, auditory, and perceptual data. These data can also be shared according to instructions [30,31]. The information obtained through analysis can facilitate subsequent operations or automate decision-making. The entire process can be divided into four key stages, namely data retrieval, data sharing, data processing, and data-based automated decision-making [32].

2.3. Smart Buildings

A smart building is a building that "endows the building with life, allows the building to actively perceive people's needs and changes in the environment, and provides more natural, healthy and humanized services". The Building Automation System (BAS) is installed in buildings and their bases [33]. With the building space and building elements, the ergonomics, physical environment, operation type and management type are integrated. The BAS automates the operation, maintenance and management of electrical, telecommunications, water supply and drainage, air conditioning, disaster prevention, anti-theft and transportation equipment systems and space usage in buildings. This can improve the function and quality of the building, so as to achieve the purpose of building safety, health, energy saving, convenience and comfort [34]. Its basic elements include building automation system devices, building use space and building operation management systems.

Smart buildings include the integration of information and communication (ICT) technology into buildings to enhance the efficiency of building management and the quality of living for users [35]. The goal is divided into two major aspects, that is, people and the environment. In terms of "people", it is the use of network technology to provide intelligent services, which are beneficial in providing safe, healthy, convenient and comfortable life assistance functions. In terms of "environment", it is to make good use of sensing technology and automation equipment to improve the efficiency of sustainable energy saving, safety and disaster prevention, and facility management [36]. In Taiwan, smart building evaluation indicators are divided into eight categories, including: integrated wiring, information communication, system integration, facility management, safety and disaster prevention, energy saving management, health and comfort, and smart innovation [37].

2.4. Elevator

The building elevator is a type of vertical lift powered by motors; it consists of a box-shaped car and is used in multi-story buildings to carry people and goods [38]. The car runs between two or more rows of vertical, rigid guide rails, and its size and structure are designed to facilitate the entry and exit of passengers and the loading and unloading of goods. Regardless of its driving method, the elevator is the customary term for a vertical transportation vehicle in a building [39]. Building elevators can be classified by speed into three categories, namely low-speed (<1 m/s), fast (1–2 m/s), and high-speed elevators (>2 m/s) [40].

Building Elevators as a Transmission Medium for COVID-19

The cluster infection that occurred in a building in Fongshan, Kaohsiung involved two families who lived on the third and seventh floors and did not know each other or have direct contact with each other. However, they were simultaneously infected with COVID-19. A possible explanation for the cluster infection is that a member of one family pressed an elevator button that was contaminated by the virus through transmission from the nasal mucus to eye, nose, and mouth [41]. A recent study indicated that in an elevator used by patients with COVID-19, the likelihood of the COVID-19 virus existing on the buttons of the elevator is 43%. If elevator users press the elevator button contaminated by the virus and eat with their hands, rub their eyes, or pick their nose shortly afterward, the virus is likely to enter their bodies through the mucosa in their eyes, nose, and mouth, resulting in non-droplet transmission from the nasal mucus to the eye, nose, and mouth. The COVID-19 virus may exist in the nasal mucus, saliva, skin, urine, and feces of patients. When patients sneeze and cover their nose and mouth with their hands, their nasal mucus may contaminate their hands. If they touch objects such as elevator buttons and doorknobs afterward, the virus in their nasal mucus may contaminate these objects. Recent research on the contamination of the daily necessities of patients with COVID-19 revealed the contamination rate of mobile phones (78%), telephones (40%), bathrooms (81%), doorknobs (16%), keyboards (40%), computer mice (33%), and elevator buttons (43%). Therefore, in areas where COVID-19 is prevalent, people are at risk of being infected by the virus when they press elevator buttons and hold doorknobs [42].

2.5. Related Study

In "Design of the overall epidemic prevention system for the healthy operation of elevators", which was published by Wang and Li [43], a contact-free elevator with gesture and mobile phone car calling features was developed. The gesture for activating car calling is the waving of one's palm, and the building elevator automatically recognizes a passenger's gesture, determines whether they want to go up or down, and sends the car to the floor that the passenger is on (Figure 1). A mobile phone car call was made through a dedicated app (Figure 2), which can preset the passenger's destination floor. When the passenger enters the lobby or the elevator car, signals can be sent manually or automatically by mobile phone to call the car or set the destination floor. Floor selection in the car can be performed through contact-free methods, such as face recognition, smart card calls, QR code calls, voice calls, and infrared induction buttons (Figure 3). Face recognition is conducted using a camera, and it enables the instant completion of floor selection. Smart card calls are made by swiping a card in the car; the smart card controller is connected to the corresponding floor button according to the authorized floor set in the smart card. QR code calls are made by sending QR codes through mobile phones (Figure 4); after the codes are scanned, car calling or destination floor settings are automatically completed. Voice call floor selection is performed through simple communication with the passenger. Infrared induction buttons are designed using infrared digital coding technology, and a passenger can trigger the buttons with finger gestures to select their destination floor without touching the buttons.

Figure 1. Gesture car calling.

Figure 2. Mobile phone call floor App.

Figure 3. Infrared sensor button.

Figure 4. Mobile phone QR code to call elevator in a building.

3. Research Methodology

This study used the following steps to develop a contact-free epidemic prevention elevator, the process of which is shown in Figure 5:

1. Purchased a miniature elevator with half the length and height. It only had an elevator hall door and no elevator car to simulate the operation of the actual elevator.
2. Installed a control panel that simulated a seven-story building in the elevator car, and installed contact-free perceptual buttons (including 1F–7F, opening and closing doors), voice recognition device, elevator operation display and the connection of the wires on the control panel.
3. Installed the control panel in the elevator hall, and installed the contact-free perceptual button (including up and down), gesture recognition sensor, elevator operation display panel and its circuit connection on the control panel.
4. Constructed the prototype of contact-free epidemic prevention elevator, and connected each contact-free perceptual button, relays, light display of each button, voice recognition device and displays, etc. to the Arduino Mega 2560 control board.
5. Developed control software, and tested the actuation function of each component, the response to being touched, the function of the voice recognition device and the display content of the elevator operation display panel.
6. Connected the ESP8266 communication module with the Arduino Mega 2560 control board, and developed the operation webpage of the two-way control interface between the elevator and the mobile device. Posted the QR Code in the boarding hall and elevator box for scanning to open the elevator control screen.
7. Verified the functionality of the system, including:
    (a) Approaching each contact-free perceptual button with a finger to test the relevant response of the system, including the setting of the destination floor, the command to open/close the door, and the function of calling a car up/down.
    (b) Issuing voice control commands to verify the functionality of the destination floor setting.
    (c) Scanning the QR Code with a mobile device, opening the elevator control screen, and touching the icons on the screen to verify the function of synchronously controlling the elevator.

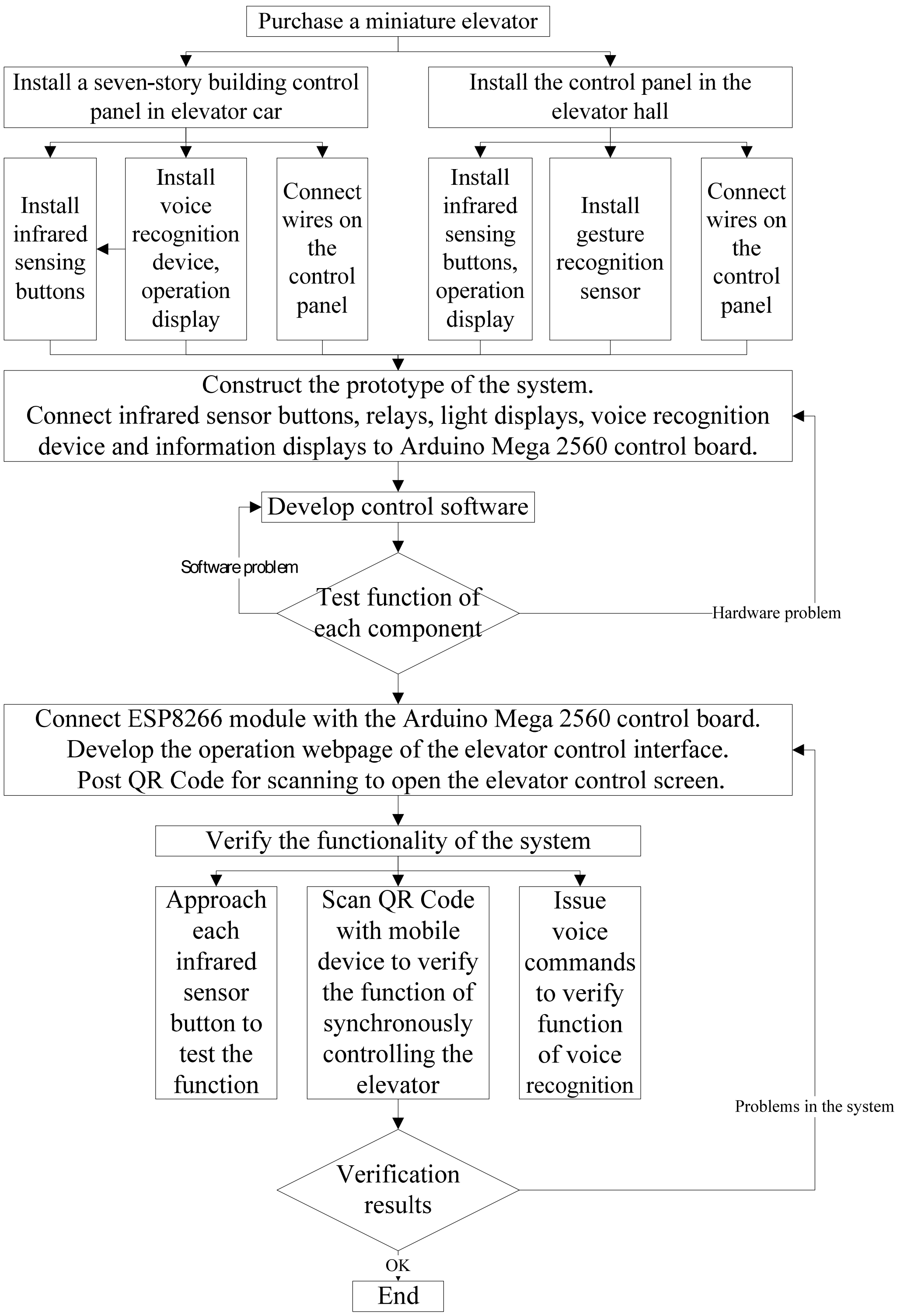


Figure 5. Flow chart for developing the contact-free epidemic prevention elevator.

4. Research Design

4.1. Software and Hardware Devices

In the development of the application system of IoT, Arduino-related components are a relatively easy-to-use environment for the personnel of the College of Architecture to design the apps of smart buildings. Because the control of a seven-story elevator requires a lot of connection points, the Arduino Mega 2560 is the control board with the most connection points, so it was selected in this study. The relays are used to receive the signals from each button, and then turn on/off the button's light after processing. The gesture sensing device is used to call the up/down function of the elevator. Voice recognition devices are used to parse human voice commands and perform related elevator control tasks. The ESP8266 is connected to the Internet by Wi-fi, so that the operation of the elevator can be controlled by the mobile device. Arduino Software IDE is the best tool for writing Arduino-related component control software.

4.1.1. Hardware

Arduino Mega 2560 Control Panel

The Arduino Mega 2560 (Figure 6) is a microcontroller panel designed using Mega 2560. It contains everything that is required to support a microcontroller, and it can be connected to a computer through a Universal Serial Bus (i.e., USB) cable or be powered by an AC/DC power source or batteries [44,45].

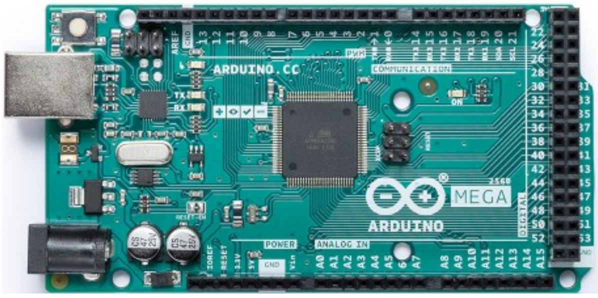


Figure 6. Arduino Mega control panel.

Relay

A relay (Figure 7) is an electrical control device; it consists of a control system (also referred to as an input circuit) and controlled system (also referred to as an output circuit), and it is typically used in automatic control circuits. Specifically, a relay is a type of automatic switch that is operated by using a smaller current to control a larger one, and it handles automatic adjustment, safety protection, and circuit conversion in circuits [31,46].

Figure 7. Relay.

Gesture Recognition Sensor

A gesture recognition sensor (Figure 8) is an extremely small sensor that performs ambient light and color measurements to detect contact-free gestures. Through gesture recognition sensors and gestures, items such as computers, microcontrollers, and robots can be easily controlled. The detection range of such sensors is generally between 10 and 20 cm [47].

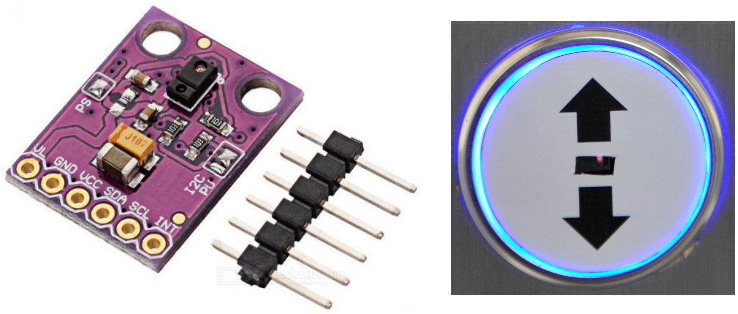


Figure 8. Gesture recognition sensor.

Infrared Contact-Free Perceptual Buttons

During the detection process, an infrared sensor (Figure 9) is not in direct contact with the detected object; hence, contact-based transmission cannot occur. An infrared sensor, comprising an optical system, detection elements, and a conversion circuit, also has high sensitivity and a fast response time. The optical systems used in infrared sensors can be categorized by structure into transmission-type and reflective-type sensors. The detection elements can be divided into thermal detection elements and photoelectric detection elements according to their operational principles. The most widely used thermal detection element is the thermistor. When a thermistor is exposed to infrared radiation, its temperature increases, and its resistance is then altered through a conversion circuit and output as an electrical signal. The characteristics of infrared contact-free perceptual buttons are as follows: (1) They have an embedded installation design with a slim and visually appealing appearance and an LED frame; (2) the infrared sensor enables a passenger to open an elevator door in a building without touching any buttons; (3) the infrared detection distance can be adjusted within the range of 0.5 and 20 cm depending on requirements; (4) elevator buttons can also be operated by touch; hence, they can be used to open the elevator door in the event of a power outage [48].

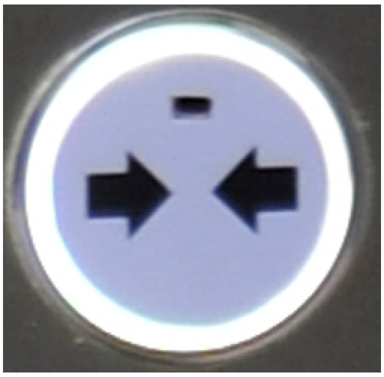


Figure 9. Contact-free perceptual button.

Arduino Wi-Fi Esp8266

The ESP8266 (Figure 10) is an ultra-low power consumption UART-Wi-Fi transmission module. It utilizes an extremely small package size and ultra-low energy consumption technology and is specially designed for mobile devices and IoT applications. Furthermore, it can connect a user's devices to a Wi-Fi network to enable Internet or local-area-network communication and realize networking functions. The ESP8266 can be packaged in various formats, and its antenna can support three types of interfaces, namely printed circuit board (i.e., PCB) onboard antennas, IPEX interfaces, and stamp hole interfaces. It is widely applied in various networks, including smart grids, smart transportation networks, smart furniture networks, handheld devices, and industrial control networks [49].

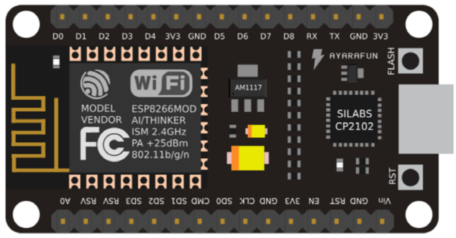


Figure 10. ESP8266 Wi-Fi communication module.

4.1.2. Software

Arduino IDE

Arduino Software IDE uses a programing language that is similar to C/C++ and provides a Wiring library with common input/output functions [50]. After the completion of the compilation and connection processes through a GNU toolchain, Arduino Software IDE provides an executable file for conversion that can be written into the firmware of the Arduino hardware. Each sketch in Arduino IDE has two major components as follows. (1) Void setup (): This is the first function used when Arduino starts running. The function is executed only once during the entire operation of the program. The setup function contains the initialization of the pins in the project that are intended for input and output. (2) Void loop (): This comprises the continual execution of parts of codes. The Arduino language comprises core electronic design libraries (including Digital I/O and Analog I/O) that are based on Wiring.

4.2. Introduction to Epidemic Prevention Elevator

4.2.1. Elevator System Architecture in Buildings

The architecture of the contact-free epidemic prevention elevator that we developed is illustrated in Figure 11. In Figure 11, the upper section shows the input devices (comprising various contact-free perceptual buttons, a QR code, speech recognizer, and smartphone app). The middle section of the figure shows the Arduino Mega 2560 control panel and Arduino Wi-Fi ESP8266 transmission module. Specifically, the middle-left section shows the display module, which consists of the display panels in the elevator car and elevator hall and a mobile elevator control system app that can be synchronized with the system; the middle-right section shows the editing environment. The lower section of the figure shows the control mechanism, which contains relays, speakers, and the opening and closing mechanism of the elevator door.

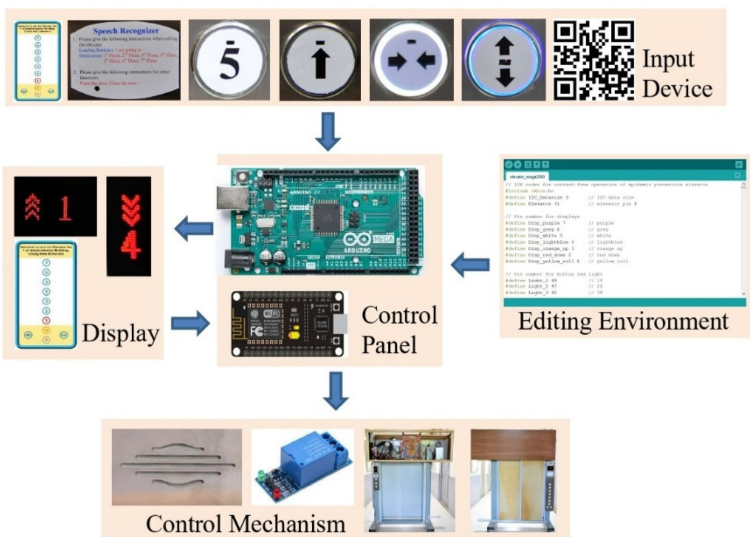


Figure 11. Architecture of contact-free epidemic prevention elevator.

4.2.2. Prototype of the Elevator System

Figure 12 shows the prototype of the epidemic prevention elevator system, which comprises the Arduino Mega 2560 control panel (middle section), Arduino Wi-Fi ESP8266 (right section), and prototype relays (left, top and down sections). Figure 13 shows the purchased scale-down elevator prior to the installation of control elements. Figure 14 shows the rectangular box that we secured to the top of the elevator and placed the prototype in. We installed multiple perceptual buttons, a voice recognizer, display panels, and QR codes in the elevator car and hall in buildings.

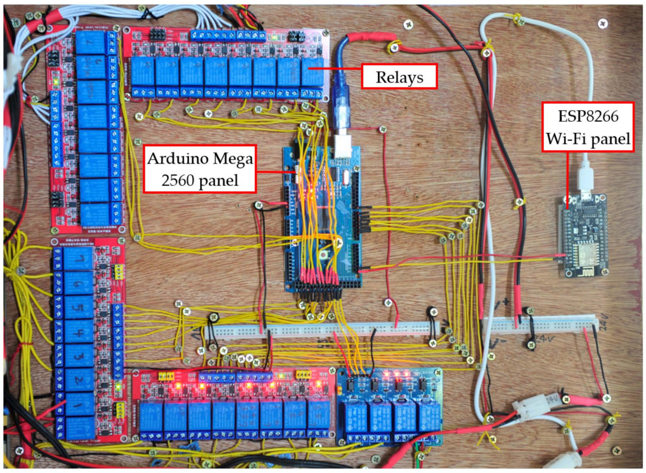


Figure 12. Prototype of contact-free epidemic prevention elevator system.

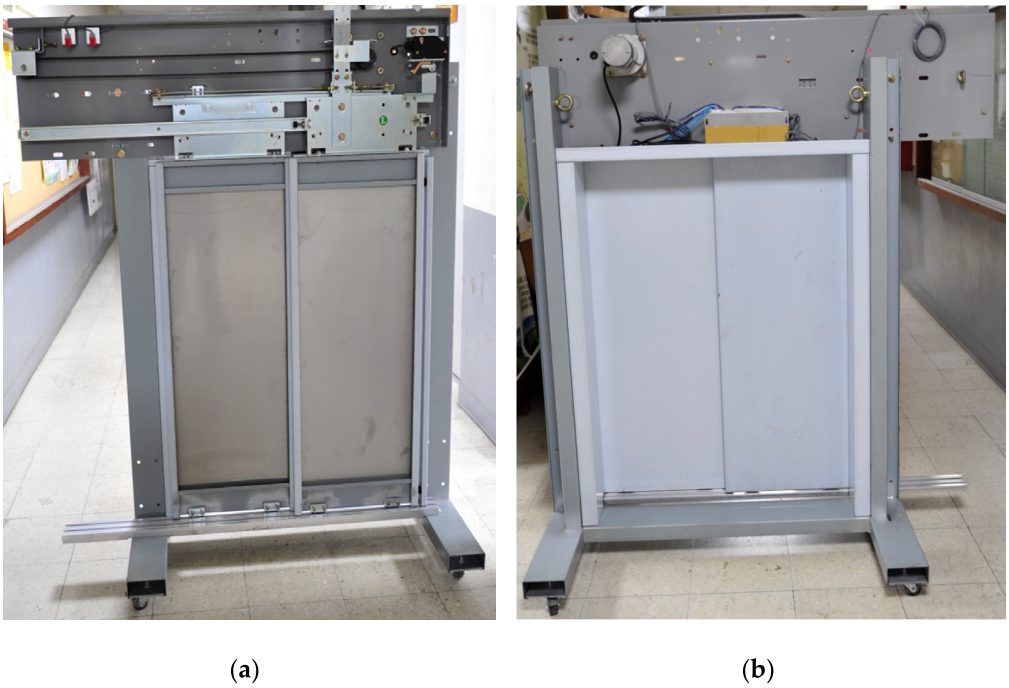


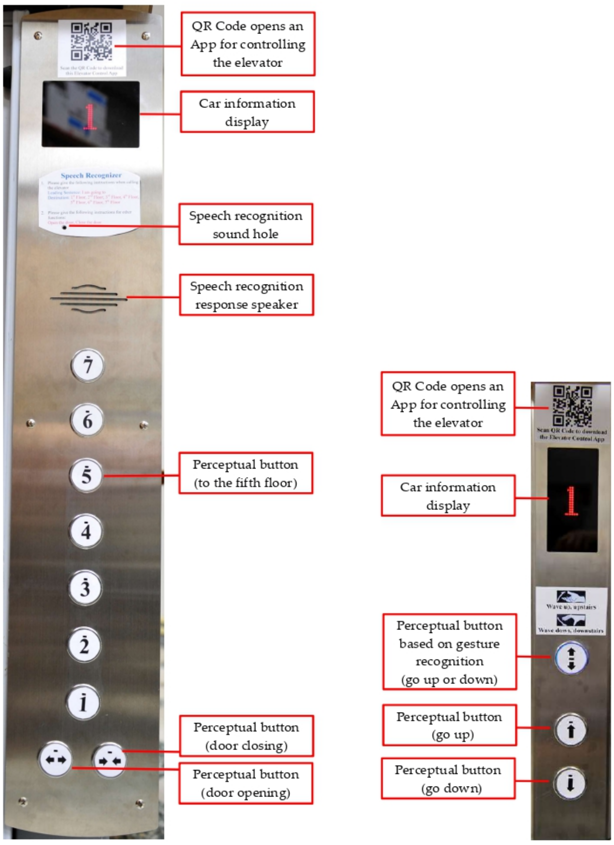
Figure 13. Elevation view of the elevator before installation. (**a**) Elevator car; (**b**) elevator hall.

(**a**) (**b**)

Figure 14. Elevation view of the elevator after installation. (**a**) Elevator car; (**b**) elevator hall.

4.2.3. Console

We installed a console in the elevator car; drilled holes in the console panel to install perceptual buttons, a floor display panel, and a speech recognizer; and attached a QR code sticker on the console panel. Figure 15 shows the console in the elevator car and the console on the wall of the elevator hall in buildings.



(a) (b)

Figure 15. Elevator consoles. (**a**) Console in the elevator car; (**b**) console on the wall of elevator hall.

4.2.4. Display Panel

The display panels show the current floor that the elevator car is on and the direction of the elevator's movement (up/down). Figure A1 shows the images of the display panel that indicates the floor the elevator is on (i.e., second floor, going up from the second floor, and going down from the second floor). Figure A2 presents the images of the display panel on the wall of the elevator hall in buildings that display car information.

4.2.5. Speech Recognition

Automatic speech recognition is a function that enables programs to process human speech in written form. The operational principle of automatic speech recognition is to extract features after the input of speech, place the extracted feature values into a model library for continual training and matching, and finally decode and obtain results. AI and machine learning are the more advanced solutions. They integrate the composition of grammar, syntax, language structure, speech, and voice signals to interpret and process human speech. The so-called model training is performed to obtain the model parameters with the most features from the known speech forms in accordance with specific principles. By contrast, form matching is performed to identify the most satisfactory match between an unknown speech form and a model in the library in accordance with specific principles [51].

We used a speech recognizer to identify the passenger's destination floor. Figure 16 shows the instruction label of the speech recognizer. A passenger provides instructions by saying a leading phrase and his destination floor. The leading phrase is "I am going to", and the destination floor is "the first–seventh floor." The other special functions were "open the door" and "close the door."

Figure 16. Instruction label of speech recognizer and sound hole.

4.2.6. Development of Wi-Fi Control Interface

The elevator prototype has a built-in web server that enables web page operation for elevator control. The WebSocket communications protocol enables real-time data transmission with a passenger. In addition, the building elevator is equipped with a dedicated Wi-Fi access point, which enables a passenger's mobile device (e.g., smart phone or tablet) to access an elevator operation web page without an Internet connection. The operational steps are as follows:

1. Connect the mobile phone Wi-Fi to the name of the Wi-Fi access point (service set identifier);
2. Scan the QR code sticker on the console in the elevator car or the elevator hall in the building (Figure 17) and open the web browser to access the entry page of the elevator control web page;
3. Click to enter the web page to receive real-time elevator information, that is, the floor on which the elevator car is stopping and the direction of the elevator's movement;
4. Tap the icons on the touch screen to control the elevator synchronously.

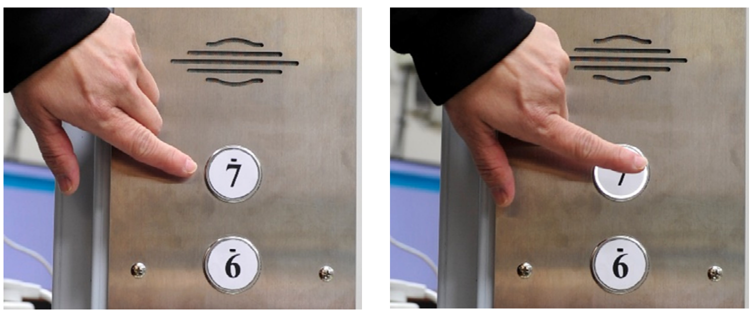
Figure 17. QR code that opens a web browser.

5. Results

The contact-free epidemic prevention elevator is installed with a wooden frame, panels inside and outside of the elevator car, contact-free perceptual buttons, a speech recognizer, and display panels. QR code stickers and a speech recognizer instruction label are put up. The circuit connection, prototype system, buttons, and button circuits were tested. After the elevator control system was programmed, tested, and revised, and the synchronization and interaction tests for mobile devices were conducted, the contact-free epidemic prevention elevator system was finally completed. After the program was uploaded to Arduino Mega 2560, the system became operationally functional.

5.1. Operation of Contact-Free Perceptual Buttons

To test the contact-free perceptual buttons, we pointed a finger at a given button. From a distance of between 10 and 15 mm, the button could detect an approaching finger and activate. At this moment, the relay in the prototype system plays an activation tone, and the button lights up (Figure 18). Figure A3 demonstrates the operation of the contact-free perceptual buttons).



(**a**) (**b**)

Figure 18. Activation and deactivation of contact-free perceptual buttons. (**a**) Finger not approaching the sensory button; (**b**) ginger close to sensory button.

5.2. Operation of Destination Floor Setting through Speech Recognition

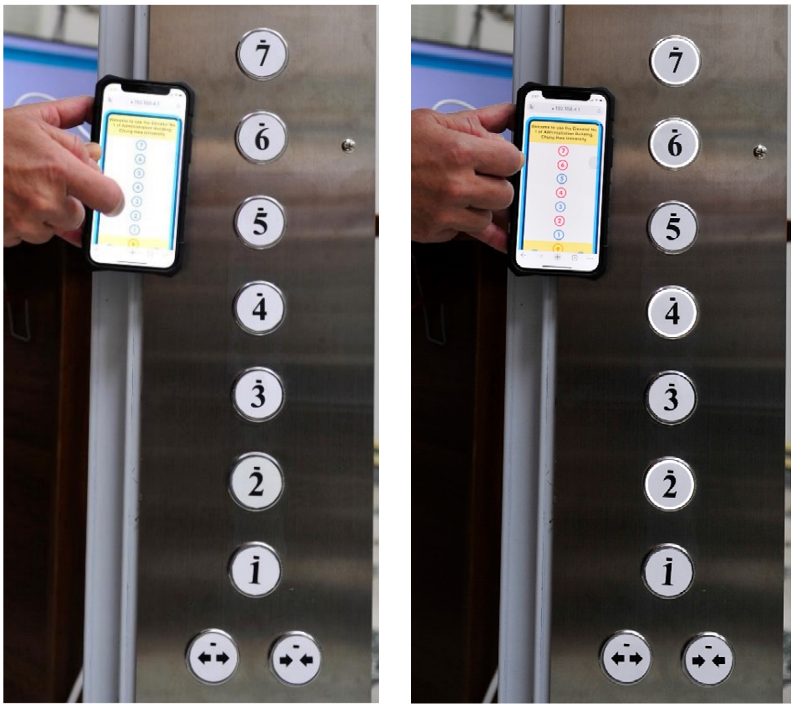
After entering, the passenger can control the building elevator with speech by following the instructions presented in Figure 16. When the passenger says, "I am going to the sixth floor", the sixth-floor contact-free perceptual button on the console in the car lights up (Figure A3e). Based on the current location of the car and other elevator operational settings, the elevator then schedules the transportation of the passenger to the sixth floor. In addition to setting the destination floor, the passenger can verbally command the elevator door to open or close.

5.3. Display of Car Information

The consoles in the car and on the wall of the elevator hall in buildings are equipped with liquid-crystal display monitors that display car information. Figure A4 shows the panel in the car indicating the floors that the car has stopped on (the 1st row) and the direction of the car's movement (i.e., going up (2nd row) or down (3rd row) from the current floor). Figure A5 shows the panel on the wall of the elevator hall in buildings indicating the floors that the car has stopped at and the direction of the car's movement (i.e., going up or down from the current floor).

5.4. Elevator Control App Operated through QR Codes and Mobile Devices

When a passenger scans the QR codes (Figure 17) on the consoles in the car and on the wall of the elevator hall in buildings with their mobile phone, the passenger can connect to a web browser (http://192.168.4.1 (accessed on 17 March 2022)) and operate the elevator control software that we developed. When the elevator control system app is opened, a welcome screen (Figure A6a) first appears. When the passenger selects the destination floor with a mobile phone, the corresponding button on the console in the car lights up. This creates an ideal situation in which the passenger can remotely control the elevator through a mobile phone without touching any elevator buttons. Figure A6b–h demonstrates use of a mobile phone to synchronously activate the first to seventh floor buttons. Figure 19 shows the actual scene of the floors to be reached by using the mobile app to control it. The picture on the Figure 19a is the screen of the mobile phone button that has not been touched. The picture on the Figure 19b shows touching the buttons 2F, 4F, 6F and 7F of the mobile phone to simultaneously activate the buttons 2F, 4F, 6F and 7F of the elevator cabin control panel.



(**a**) (**b**)

Figure 19. Control the floor to be reached with the mobile browser. (**a**) The floor button of the mobile phone has not been touched; (**b**) 2F, 4F, 6F and 7F of the mobile phone are touched.

5.5. System Validation

When the elevator stops at 1F, the buttons of 3F, 5F–7F are activated to verify the function of the elevator. Figure A7 shows the process of the elevator ascending, stopping at 3F, 5F–7F, and turning off the original button lights in sequence. As shown in

Figure A7, it can prove that the contact-free operation of epidemic prevention elevator is functioning normally.

6. Discussion

The innovations of the contact-free epidemic prevention elevator that we developed are as follows: (1) Application of speech recognition and use of verbal instructions to command the elevator in buildings to stop at a destination floor and to open or close the elevator door; (2) use of infrared contact-free perceptual buttons that can detect and convey a passenger's instructions, allowing for the elevator to move to and stop at the passenger's destination floor and open or close its doors; (3) operation of car calling through the use of a gesture recognition sensor to determine the direction of the car (i.e., up or down); (4) development of an elevator control app that allows a passenger to scan QR codes to open a web page browser, operate a control software, and synchronously operate the elevator through the icon on a mobile phone touch screen.

Compared with the study conducted by Wang and Li, the advantages of the present study are as follows. Although we developed a contact-less gesture-activated elevator that is similar to that developed by Wang and Li, they used a recognizer with an external screen that was large in size and easily damaged. By contrast, the gesture detection devices that we used were small buttons embedded in the consoles. Furthermore, the mobile phone call function of the elevator system required the installation of a specific app, and a passenger's destination floor must be preset. The app that we developed can be activated after a passenger completes scanning; hence, we did not have to spend time setting each passenger's destination floor in advance. Speech recognition and infrared perceptional buttons were used in Wang and Li's study and our study. In their study, mobile phone calls, face recognition, smart card calls, and QR code calls were also used. Nevertheless, in their study, the error rate of face recognition became considerably high when passengers wore face masks in the elevator. Smart cards are a preferable tool but the situation will be inconvenient for passengers who forget their smart cards. The use of QR code calls can also be inconvenient because such codes must be issued by the residence or building management center. The mobile phone in Figure 2 has 15 floors, while the elevator control panel has only 12 floors. The mobile app is different from the elevator box scene, and it is obviously just a schematic diagram. The approach of the finger in Figure 3, and the touch of the up button (which turns red), look more like a composite image than a real button at all. The QR Code in Figure 4 is quite different from what we obtained using the QR Code generator. On the whole, Wang's research is more like a descriptive method and a composite drawing method for illustration. All the mechanisms in this study are based on a real physical elevator, control panels, buttons, voice recognition, and the development of a mobile app to illustrate the concept and implementation of an epidemic prevention elevator for buildings.

7. Conclusions

Under specific circumstances, the COVID-19 virus can survive on a surface. The space in an elevator car is small, and the virus is likely to survive on the surface of elevator buttons (after they are touched by a passenger with the virus) and spread to subsequent passengers in buildings. To provide a safe elevator operation model, we developed a contact-free epidemic prevention elevator, as follows: (1) We gathered relevant information about COVID-19 and discussed the major transmission modes of the virus and effective pandemic prevention strategies; (2) we explored the control mechanisms of the contact-free epidemic prevention elevator, including the use of contact-free perceptual buttons, gesture recognition and smart speech recognition for elevator car calling, speech recognition destination floor setting, and elevator control software; (3) we purchased a scale-down elevator and used an Arduino control panel, smart speech recognition technology, contact-free perceptual buttons, a gesture recognition sensor, and an elevator control program to build the prototype of the contact-free epidemic prevention elevator. After we completed the wiring, testing, software development, and integration processes, the elevator could be controlled through speech recognition, contact-free perceptual buttons, gestures, and a mobile elevator control software. The building elevator that we developed has the following characteristics and contributions:

1. The elevator buttons are perceptual buttons that can be activated through finger gesture detection from a distance of 1.5 cm;
2. Speech recognition was applied. After a passenger says, "I am going to" and the destination floor, the system then automatically sets the destination floor as requested;
3. To call the elevator car in a building, the passenger can wave his palm upward or downward to trigger the sensor and command the car to go up or down;
4. Through QR code scanning, a web page browser can be accessed and a mobile elevator control software can be activated. By tapping the icons on their mobile phone, a passenger can synchronously set their destination floor, call the elevator car, and open or close the elevator door;
5. With the integration of the aforementioned technologies and the elevator control system, a passenger can perform the functions of the elevator through contact-free operation, which reduces the risk of virus transmission through contact with contaminated surfaces.

Because of its continual evolution, the COVID-19 virus has spread quickly. Therefore, avoiding unnecessary contact in public facilities is an essential pandemic prevention measure. Taiwan has more than 30 thousand building elevators in total. According to the three principles of COVID-19 prevention (i.e., direct elimination, filtering and blocking, and contact avoidance), the use of the contact-free epidemic prevention elevator can effectively reduce the risk of infection through contact with contaminated surfaces.

Although this research has successfully developed a contact-free epidemic prevention elevator with IoT components, it still has the following limitations: (1) Use of a miniature elevator to simulate the operation of the physical elevator function; (2) because the Arduino Mega 2560 control board has limited connections, we cannot simulate the operation of the elevator for high-rise buildings; (3) the elevator in this study is only equipped with the door of the elevator hall, and the elevator car and its door are not installed; (4) because this study is a simplified version of the elevator, the control panels of the elevator car and elevator hall can only be installed on the vertical C-shaped steel of the elevator.

Face recognition and RFID recognition can be added to the future research direction of this study. After the facial feature value is captured, it is compared with the registered face feature value. The system also verifies the correctness of the RFID. After the verification, the set floor of the passenger can be retrieved from the database. The system can automatically set the floor to which the passenger wants to go through these verifications, saving the work of calling the elevator car and setting the destination floor.

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Appendix A

Figure A1. Display panel in the elevator car that shows the elevator reaching and leaving the second floor.

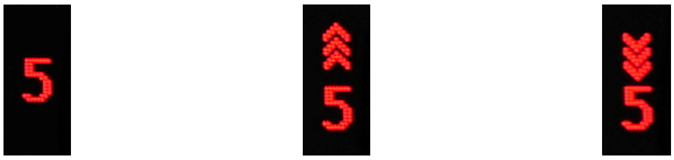
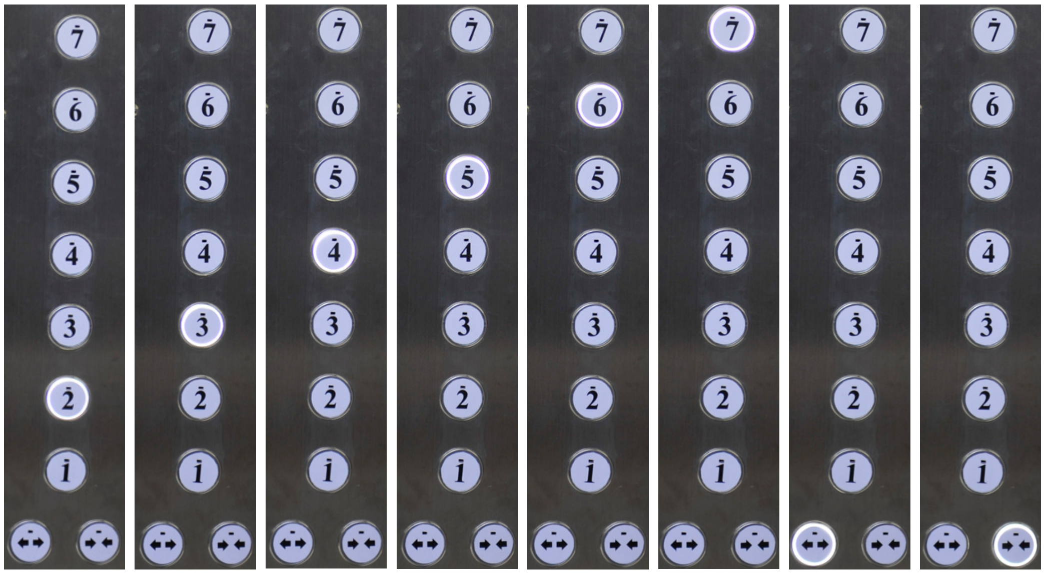


Figure A2. Display panel on the wall in the elevator hall that shows the elevator reaching and leaving the fifth floor.



(**a**) (**b**) (**c**) (**d**) (**e**) (**f**) (**g**) (**h**)

Figure A3. Operation of contact-free perceptual buttons in the elevator car. (**a**) 2F button lights up; (**b**) 3F button lights up; (**c**) 4F button lights up; (**d**) 5F button lights up; (**e**) 6F button lights up; (**f**) 7F button lights up; (**g**) Open button lights up; (**h**) Close button lights up.

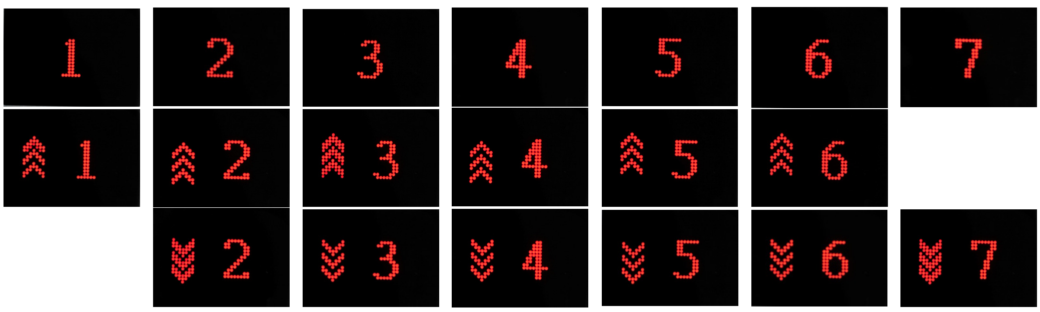


Figure A4. Images displayed on panel in the elevator car.

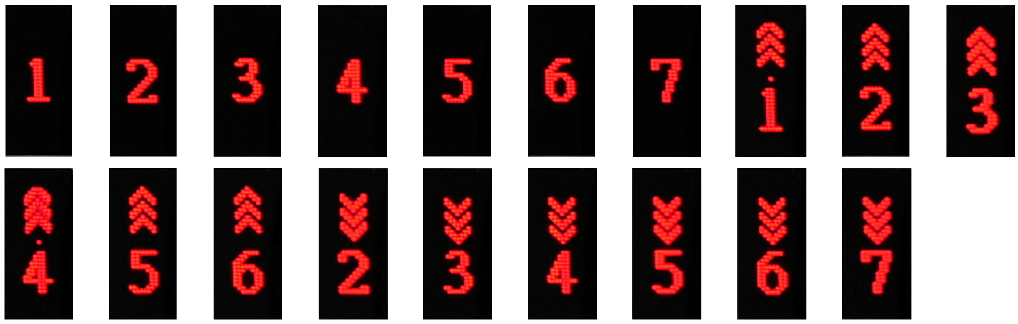


Figure A5. Images displayed on panel in the elevator hall in buildings.

Figure A6. Synchronized images of elevator control software app. (**a**) Welcome screen of elevator control software app; (**b**) synchronized image of activation of 1F button; (**c**) synchronized image of activation of 2F button; (**d**) synchronized image of activation of 3F button; (**e**) synchronized image of activation of 4F button; (**f**) synchronized image of activation of 5F button; (**g**) synchronized image of activation of 6F button; (**h**) synchronized image of activation of 7F button.

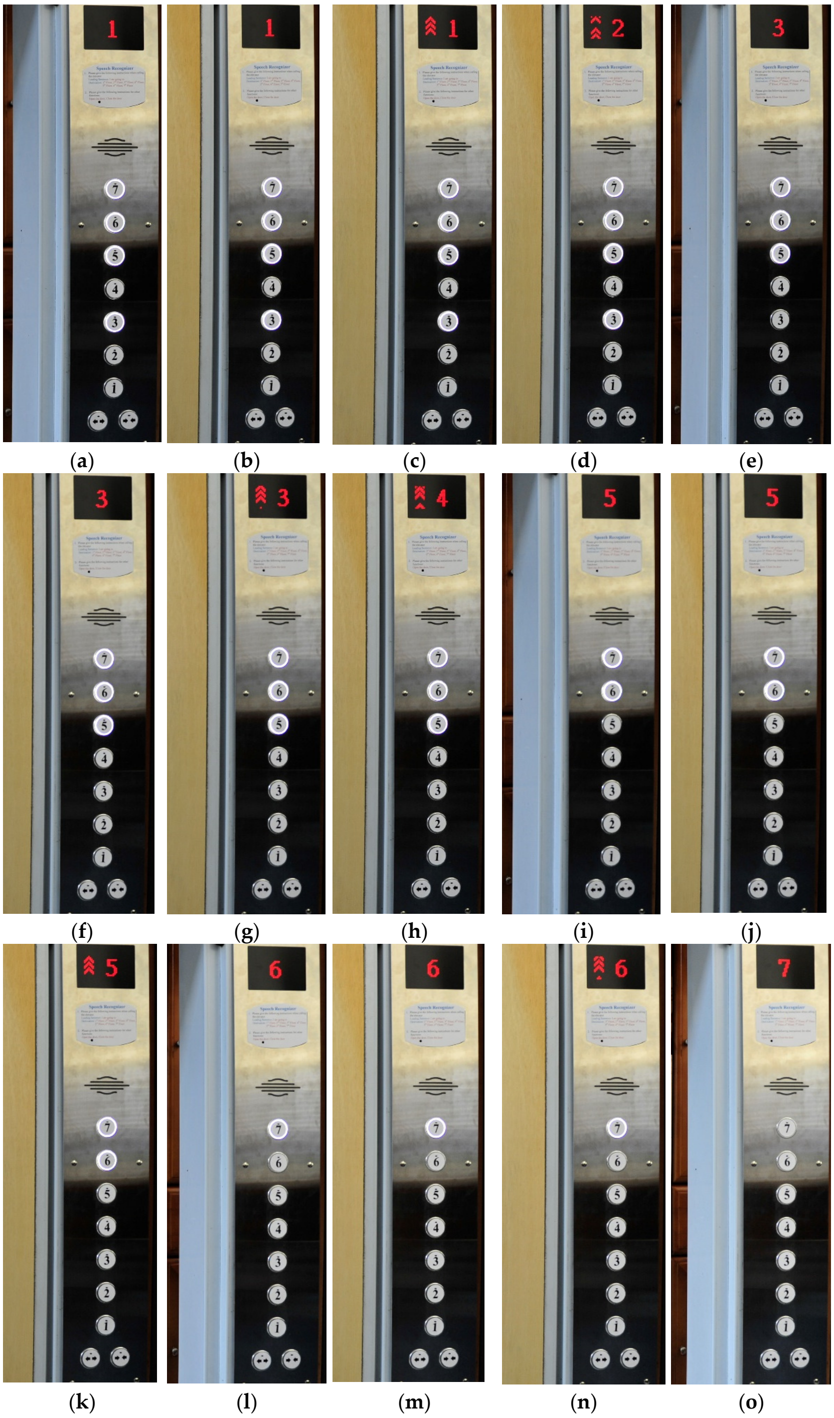


Figure A7. The system verification process of the contact-free epidemic prevention elevator. (**a**) The elevator stops at 1F (the elevator door is open), and the buttons 3F and 5F–7F are activated (the button lights are on); (**b**) the elevator door is closed; (**c**) the elevator starts to ascend; (**d**) the elevator continues to ascend through 2F; (**e**) the elevator stops at 3F, the elevator door opens, and the button light of 3F goes out; (**f**) the elevator door is closed; (**g**) the elevator starts to ascend; (**h**) the elevator passes through 4F and continues to ascend; (**i**) the elevator stops at 5F, the elevator door opens, and the button light of 5F goes out; (**j**) the elevator door closes; (**k**) the elevator starts to ascend; (**l**) the elevator stops at 6F, the elevator door opens, and the button light of 6F goes out; (**m**) the elevator door is closed; (**n**) the elevator starts to ascend; (**o**) the elevator stops at 7F, the elevator door opens, and the button light of 7F goes out.

References

1. Coronavirus Disease (COVID-19). Available online: https://www.who.int/emergencies/diseases/novel-coronavirus-2019/question-and-answers-hub/q-a-detail/coronavirus-disease-covid-19 (accessed on 10 March 2022).
2. Coronavirus: Death Toll Passes 3000 Worldwide as Second Person Dies in US, The Guardian for 2000 Years. Available online: https://www.theguardian.com/world/2020/mar/02/coronavirus-death-toll-passes-3000-worldwide-as-second-person-dies-inus (accessed on 10 March 2022).
3. Hui, D.S.; Azhar, E.I.; Madani, T.A.; Ntoumi, F.; Kock, R.; Dar, O.; Ippolito, G.; McHugh, T.D.; Memish, Z.A.; Drosten, C.; et al. The continuing 2019-nCoV epidemic threat of novel coronaviruses to global health—The latest 2019 novel coronavirus outbreak in Wuhan, China. *Int. J. Infect. Dis.* **2020**, *91*, 264–266. [CrossRef]
4. Coronavirus Map: How COVID-19 Cases Are Spreading across the World. Available online: https://web.archive.org/web/20200326042444/https://www.theguardian.com/world/ng-interactive/2020/mar/25/coronavirus-map-how-covid-19-cases-are-spreading-across-the-world (accessed on 10 March 2022).
5. COVID-19 Dashboard by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU). Available online: https://gisanddata.maps.arcgis.com/apps/dashboards/bda7594740fd40299423467b48e9ecf6 (accessed on 10 March 2022).
6. Taiwan Centers for Disease Control. Available online: https://www.cdc.gov.tw/?r=989826461 (accessed on 10 March 2022).
7. Mortality Analyses. Available online: https://web.archive.org/web/20210124160327/https://coronavirus.jhu.edu/data/mortality (accessed on 10 March 2022).
8. Zhong, N.S.; Zheng, B.J.; Li, Y.M.; Poon, L.L.M.; Xie, Z.H.; Chan, K.H.; Li, P.H.; Tan, S.Y.; Chang, Q.; Xie, J.P.; et al. Epidemiology and cause of severe acute respiratory syndrome (SARS) in Guangdong, People's Republic of China, in February, 2003. *Lancet* **2003**, *362*, 1353–1358. [CrossRef]
9. The Source of SARS Is in Shunde. Available online: https://news.boxun.com/news/gb/china/2003/04/200304281012.shtml (accessed on 27 January 2021).
10. Ding, Y.; Wang, H.; Shen, H.; Li, Z.; Geng, J.; Han, H.; Cai, J.; Li, X.; Kang, W.; Weng, D.; et al. The clinical pathology of severe acute respiratory syndrome (SARS): A report from China. *J. Pathol.* **2003**, *200*, 282–289. [CrossRef] [PubMed]
11. Chen, K.-T.; Twu, S.-J.; Chang, H.-L.; Wu, Y.-C.; Chen, C.-T.; Lin, T.-H.; Olsen, S.J.; Dowell, S.F.; Su, I.-J. SARS in Taiwan: An overview and lessons learned. *Int. J. Infect. Dis.* **2005**, *9*, 77–85. [CrossRef] [PubMed]
12. Ministry of Health and Welfare Republic of China. *On the Road in Fight against COVID-19: All the Critical Moments in the Combat*; Ministry of Health and Welfare Republic of China: Taipei, China, 2020; pp. 8, 65.
13. Lee, S.-H.; Juang, Y.-Y.; Su, Y.-J.; Lee, H.-L.; Lin, Y.-H.; Chao, C.-C. Facing SARS: Psychological impacts on SARS team nurses and psychiatric services in a Taiwan general hospital. *Gen. Hosp. Psychiatry* **2005**, *27*, 352–358. [CrossRef] [PubMed]
14. Nguyen, T.T.; Johnson, G.R.; Bell, S.C.; Knibbs, L.D. A Systematic Literature Review of Indoor Air Disinfection Techniques for Airborne Bacterial Respiratory Pathogens. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1197. [CrossRef]
15. Hung, C.-H.; Fanjiang, Y.-Y.; Lee, Y.-S.; Wu, Y.-C. Design and Implementation of an Indoor Warning System with Physiological Signal Monitoring for People Isolated at Home. *Sensors* **2022**, *22*, 590. [CrossRef]
16. Grant, M.C.; Geoghegan, L.; Arbyn, M.; Mohammed, Z.; McGuinness, L.; Clarke, E.L.; Wade, R.G. The prevalence of symptoms in 24,410 adults infected by the novel coronavirus (SARS-CoV-2; COVID-19): A systematic review and meta-analysis of 148 studies from 9 countries. *PLoS ONE* **2020**, *15*, e0234765. [CrossRef] [PubMed]
17. Loss of Sense of Smell as Marker of COVID-19 Infection, Ear, Nose and Throat Surgery Body of United Kingdom. Available online: https://www.bbc.com/zhongwen/simp/chinese-news-51540821 (accessed on 27 January 2022).
18. How COVID-19 Spreads. Available online: https://chinese.cdc.gov/coronavirus/2019-ncov/prevent-getting-sick/how-covid-spreads.html (accessed on 27 January 2022).
19. Oran, D.P.; Topol, E.J. Prevalence of Asymptomatic SARS-CoV-2 Infection: A narrative review. *Ann. Intern. Med.* **2020**, *173*, 362–367. [CrossRef] [PubMed]
20. Stadnytskyi, V.; Bax, C.E.; Bax, A.; Anfinrud, P. The airborne lifetime of small speech droplets and their potential importance in SARS-CoV-2 transmission. *Proc. Natl. Acad. Sci. USA* **2020**, *117*, 11875–11877. [CrossRef]
21. Aristei, L.; D'Ambrosio, F.; Villani, L.; Rossi, M.F.; Daniele, A.; Amantea, C.; Damiani, G.; Laurenti, P.; Ricciardi, W.; Gualano, M.R.; et al. Public Health Regulations and Policies Dealing with Preparedness and Emergency Management: The Experience of the COVID-19 Pandemic in Italy. *Int. J. Environ. Res. Public Health* **2022**, *19*, 1091. [CrossRef] [PubMed]
22. Van Doremalen, N.; Bushmaker, T.; Morris, D.H.; Holbrook, M.G.; Gamble, A.; Williamson, B.N.; Tamin, A.; Harcourt, J.L.; Thornburg, N.J.; Gerber, S.I.; et al. Aerosol and Surface Stability of SARS-CoV-2 as Compared with SARS-CoV-1. *N. Engl. J. Med.* **2020**, *382*, 1564–1567. [CrossRef]
23. Kohanski, M.A.; Lo, L.J.; Waring, M.S. Review of indoor aerosol generation, transport, and control in the context of COVID-19. *Int Forum Allergy Rhinol.* **2020**, *10*, 1173–1179. [CrossRef] [PubMed]
24. To, K.K.-W.; Tsang, O.T.-Y.; Yip, C.C.-Y.; Chan, K.-H.; Wu, T.-C.; Chan, J.M.-C.; Leung, W.-S.; Chik, T.S.-H.; Choi, C.Y.-C.; Kandamby, D.H.; et al. Consistent Detection of 2019 Novel Coronavirus in Saliva. *Clin. Infect. Dis.* **2020**, *71*, 841–843. [CrossRef]
25. Berger, I.; Mooney-Somers, J. Smoking Cessation Programs for Lesbian, Gay, Bisexual, Transgender, and Intersex People: A Content-Based Systematic Review. *Nicotine Tob. Res.* **2017**, *19*, 1408–1417. [CrossRef] [PubMed]
26. Face Mask Registration System Goes Online, Three Ways to Check the Stock in Pharmacies. Available online: https://www.rti.org.tw/news/view/id/2058885 (accessed on 27 January 2022).

27. Help Stop the Spread of Coronavirus and Protect Your Family. Available online: https://www.fda.gov/consumers/consumer-updates/bangzhuzuzhiguanzhuangbingdudechuanbobaohunidejiaren (accessed on 27 January 2022).
28. Hsu, W.-L.; Tsai, H.-H.; Yang, M.-L.; Lai, S.-C.; Ho, M.-C.; Shiau, Y.-C. Development of Smart Residential Environment Control System. *Sens. Mater.* **2021**, *33*, 3361–3377. [CrossRef]
29. Lavric, A.; Petrariu, A.I.; Mutescu, P.-M.; Coca, E.; Popa, V. Internet of Things Concept in the Context of the COVID-19 Pandemic: A Multi-Sensor Application Design. *Sensors* **2022**, *22*, 503. [CrossRef]
30. Hsu, W.-L.; Chen, W.-T.; Kuo, H.-H.; Shiau, Y.-C.; Chern, T.-Y.; Lai, S.-C.; Fan, W.-H. Establishment of Smart Living Environment Control System. *Sens. Mater.* **2020**, *32*, 183–195. [CrossRef]
31. Hsu, W.-L.; Ho, C.-Y.; Liang, C.-K.; Shiau, Y.-C.; Hsieh, H.-N.; Lai, S.-C. Application of IoT in the Prevention of Carbon Monoxide Poisoning. *Sens. Mater.* **2019**, *31*, 3465–3482. [CrossRef]
32. What Is Internet of Things (IoT)? Available online: https://www.sap.com/taiwan/insights/what-is-iot-internet-of-things.html (accessed on 2 June 2021).
33. Al Dakheel, J.; Del Pero, C.; Aste, N.; Leonforte, F. Smart buildings features and key performance indicators: A review. *Sustain. Cities Soc.* **2020**, *61*, 102328. [CrossRef]
34. Hsieh, M.-H. The Application Trend of Smart Sensing Technology in Home of Building: An Example of a Green and Smart Building for the Seniors Citizens Offered by Farglory Land Development. *Int. J. Autom. Smart Technol.* **2011**, *1*, 3–5. [CrossRef]
35. Plageras, A.P.; Psannis, K.E.; Stergiou, C.; Wang, H.; Gupta, B.B. Efficient IoT-based sensor BIG Data collection–processing and analysis in smart buildings. *Futur. Gener. Comput. Syst.* **2018**, *82*, 349–357. [CrossRef]
36. Peña, M.; Biscarri, F.; Guerrero, J.I.; Monedero, I.; León, C. Rule-based system to detect energy efficiency anomalies in smart buildings, a data mining approach. *Expert Syst. Appl.* **2016**, *56*, 242–255. [CrossRef]
37. Liao, H.-Y.; Chen, B.-H. *Smart Building Evaluation Manual*; Institute of Architecture, Ministry of Interior, Taiwan: Taipei, Taiwan, 2016.
38. McKeen, P.; Liao, Z. The Influence of Building Airtightness on Airflow | in Stairwells. *Buildings* **2019**, *9*, 208. [CrossRef]
39. Al-Kodmany, K. Tall Buildings and Elevators: A Review of Recent Technological Advances. *Buildings* **2015**, *5*, 1070–1104. [CrossRef]
40. Now Let Us Take a Closer Look at Elevators. Available online: https://read01.com/zh-tw/O3A4P60.html#.YbXUnb1Bw2w (accessed on 27 January 2022).
41. Going Back to the Office after the Restriction Lift? Doctors Warns about Places Most Seriously Contaminated by COVID-19. Available online: https://health.udn.com/health/story/120952/5595046 (accessed on 27 January 2022).
42. COVID-19 Nasal Mucus–Eye, Nose, and Mouth Infection That Must Not Be Ignored. Available online: http://www.tmanh.org.tw/NewsInfo/NewsArticle?no=2007 (accessed on 27 January 2022).
43. Bo, W.; Zheyi, L. Design of the overall epidemic prevention system for the healthy operation of elevators. In Proceedings of the 2020 5th International Conference on Mechanical, Control and Computer Engineering (ICMCCE), Harbin, China, 25–27 December 2020; pp. 311–315. [CrossRef]
44. Play Robot. Available online: https://shop.playrobot.com/products/arduino-mega-2560 (accessed on 27 January 2022).
45. Hsu, W.-L.; Wang, W.-K.; Fan, W.-H.; Shiau, Y.-C.; Yang, M.-L.; Lopez, D.J.D. Application of Internet of Things in Smart Farm Watering System. *Sens. Mater.* **2021**, *1*, 269–283. [CrossRef]
46. How Relays Work. Available online: https://www.doyouknow.wiki/a/202103/116118.html (accessed on 27 January 2022).
47. Lu, S.-Y.; Lo, C.-C.; Syu, J.-Y. Project-based learning oriented STEAM: The case of micro–bit paper-cutting lamp. *Int. J. Technol. Des. Educ.* **2021**, 1–23. [CrossRef]
48. Infrared Sensors. Available online: https://www.newton.com.tw/wiki/%E7%B4%85%E5%A4%96%E7%B7%9A%E6%84%9F%E6%B8%AC%E5%99%A8 (accessed on 27 January 2022).
49. ESP8266. Available online: https://www.taiwaniot.com.tw/product/esp8266-esp-01s-%E4%B8%B2%E5%8F%A3wifi-%E7%84%A1%E7%B7%9A%E6%A8%A1%E7%B5%84/ (accessed on 27 January 2022).
50. Course for Arduino Preprocessor Commands. Available online: https://micro.rohm.com/tw/deviceplus/how-tos/arduino-guide/arduino-preprocessor-directives-tutorial/ (accessed on 27 January 2022).
51. Automated Speech Recognition Technology. Available online: https://codertw.com/%E7%A8%8B%E5%BC%8F%E8%AA%9E%E8%A8%80/583362/ (accessed on 27 January 2022).