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Design and Evaluation of Noncontact Elevator Control Mode and User Interface

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In response to the global coronavirus disease 2019 (COVID-19) pandemic, the use of short-term confined spaces has attracted widespread attention, and elevators have become a major pathway for pathogens. This study uses video recognition technology to develop a contactless elevator operating system, which can be operated by hand gestures of the user. This design can solve current elevator usage problems by integrating human and spatial aspects into the control mode and user interface. By observing and analyzing operational interfaces and behaviors in current hospital elevators, specifications for the new interface were developed. A video motion recognition sensory system was applied to formulate the design and planning principles of the noncontact elevator. Gesture images were combined with simulations to create experimental tasks, in which users were timed and interviewed to evaluate the acceptability and efficiency of the designed interface. The results of this study show that the planning and design of noncontact elevator control modes and user interfaces are advantageous, intuitive, and easy to learn. The control interface of the elevator was displayed in an electronic panel using colors, shapes, and sizes to show operational information, enabling a quick search and high learnability.

1. Introduction

In 2020, the sudden outbreak of coronavirus disease 2019 (COVID-19) severely affected the health and lives of people worldwide and caused major damage to the global economy. The outbreak affected education systems around the world, resulting in the almost complete closure of schools, universities, and colleges, accompanied by worldwide panic buying of personal protective equipment to combat the outbreak. The impact of the pandemic has been enormous both culturally and politically. In response, innovations in service design and medical equipment have flourished.

Elevators are indispensable in hospitals to allow the free movement of large amounts of medical equipment and hospital beds. However, hospitals are public places with high infection rates, and the medical staff and patients are the most direct sources of infection. Dr. Nicholas Moon of the University of Arizona pointed out that the buttons on an elevator control panel are

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covered with bacteria. During the severe acute respiratory syndrome (SARS) and influenza epidemics, the Centers for Disease Control and Prevention (CDC) promoted a set of "elevator etiquettes", emphasizing that it is not necessary to touch the elevator operation buttons and interface with bare hands in a crowded elevator. A noncontact mode of operation, such as using a pen or key, should be developed to reduce the risk of infection. In addition to personal mask protection and diligent hand washing, interrupting transmission from button contact in elevators is a method of interrupting transmission learned from previous experience with SARS.

Speech recognition, gesture control, and virtual reality have provided channels for human–computer interactions (HCIs). Touch screens (tablets) and games (using body gestures to change actions) based on HCIs can be adopted for the design of noncontact elevator operating systems to develop an intuitive and publicly acceptable elevator operating mode.

In this study, we explore the development of a noncontact mode for operating hospital elevators, whereby human factors and cognitive principles are employed to design a new noncontact user interface (UI) with the aim of improving sanitary conditions in hospitals, reducing the spread of disease, and improving the convenience of elevator use. We analyze the usability of HCIs and interface applications to understand their potential impact on efficient noncontact elevator design.

2. Literature Review

Elevators are important equipment for transporting patients within hospitals; however, they are also environments that can easily carry pathogens and infections. Improving the operating environment of an elevator is an important way to reduce infections. HCIs supported by advanced technology have been widely used. In the absence of direct touch, recognition technology assists communication in HCIs.(1) Therefore, in this study, we aim to use video recognition technology to develop dynamic models for the contact-free control of elevators and thus improve the sanitation of hospitals. This study focuses on the ergonomics design, which requires an understanding of the development of sensor applications in motion perception systems, and the operation interface has to further meet the user's cognitive needs. Therefore, we examined the basic literature on human motion perception with the aim of designing a feasible system for the noncontact control of elevators. The following literature review focuses on motion control, operation interfaces, and touchless interfaces.

2.1 Basic research on motion-aware operation

The UI of an elevator console should be simple and intuitive to ensure operability while using limited computer memory. To achieve simple operation, visual feedback is regarded as a link between the control methods and UI design.

Some scholars of cognitive psychology believe that the main theoretical framework of how humans think, reason, and learn is based on information processing models,(2) as human beings are stimulated by various sensory organs. Through analysis, interpretation, and understanding, information becomes "conceptualized sensory perception" through a chain reaction. In this process, the information is encoded, stored, transformed, and contemplated. Finally, people can choose to react to the information, where the response is used as a processing stimulus,[3] as shown in Fig. 1.

The design of an interface that provides sensory stimulation is complicated by the diverse ages of users. Therefore, we incorporate the concept of universal design into the design of human gestures and a noncontact control UI with the aim of providing convenient and unrestricted actions for different users. A universal design was proposed in 1974 by Professor Ronald L. Mace of North Carolina State University. The goal of universal design is to ensure that everyone can live freely and comfortably when designing and creating new products. Product design should be based on the basic principle of being "available to everyone".[5] The ultimate goal of universal design is to bring the convenience and comfort of products and the environment into social consciousness and attitudes.[6]

The seven most typical universal design principles were formulated by the Universal Design Center in 1995 and revised in 1997 (version 2.0) and are further adjusted in this study on the basis of the design. These design principles are expressed as follows:[5]

Principle 1: Non-discriminatory use.
Principle 2: Flexible to use.
Principle 3: Simple and intuitive to use.
Principle 4: Perceivable information.
Principle 5: Low physical exertion.
Principle 6: Error tolerance.
Principle 7: Proximity in use of space.

Particular emphasis is placed on Principles 3 and 4.

Nielsen, an expert in ergonomic engineering, pioneered research on usability. He used inquiry, inspection, and testing technology to describe and evaluate usability. User-focused evaluation methods, including interviews, observations, questionnaires, discussions, cooperation, and experiments, were used to evaluate user responses. Das and Pandit pointed out that existing level of service (LOS) benchmarks for public transport are based on expert judgments and proposed that a user-perception-based LOS benchmark be developed for public transport services using the continuous interval scale method.[7]

To understand the various perceptions of users after operating our proposed noncontact elevator, users were evaluated on the use of the noncontact elevator on an evaluation scale after

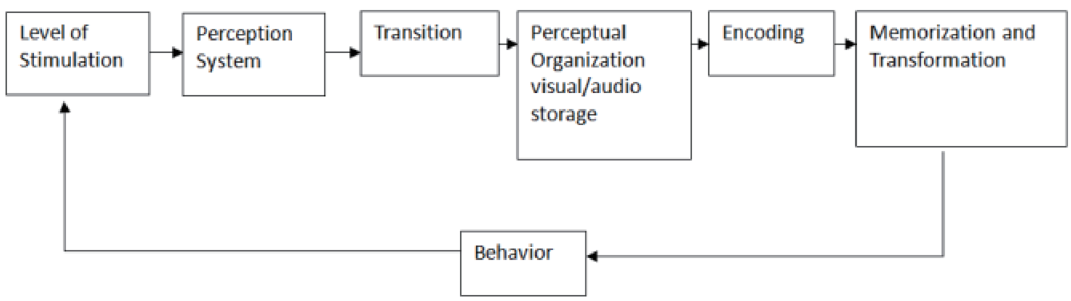


Fig. 1. Information processing model.[4]

completing two experimental tasks to assess the suitability of the elevator interface in this study. The survey included the sanitation of the interface, convenience of functions, visibility of information, adaptability of operation, and applicability of technology.

2.2 Research on motion control and operation interface

We aim to develop a sensor-based noncontact elevator control operating system whose design makes operations intuitive and easy to learn. The first item we considered is the control methods of current technology products, including touch gestures for tablet computers and video recognition for sports equipment. Data were collected and analyzed, and the results were used as a basic reference for noncontact elevator control design.

2.2.1 Current development of remote control methods

Gesture recognition provides a new environmental interface. For example, a computer allows users to touch an interactive interface with their fingers (or pen), replacing the traditional mouse and keyboard to realize HCIs. Operation with gestures is a popular trend in end-user industries such as the automotive, healthcare, consumer electronics, gaming, aerospace, and defense industries. One of the its functions is to input information directly from a screen. This touch-based input method replaces traditional mouse and keyboard input methods and creates new operating modes. The most common gestures on touch-screen panels involve touching, pressing, and dragging, with different combinations corresponding to different operations. With the progress of technology, HCI UIs have been popularized and updated. Speech recognition and synthesis, handwriting and gesture recognition, virtual reality, and other technologies have become the main methods used with HCIs.(1) Control methods for consumer electronic products have been developed, from 2D touch control to 3D dynamic control, with a wide range of applications. Users interact with the well-known gaming equipment Xbox 360 Kinect, smart TVs, and gesture-controlled noncontact search systems through body gestures. Dynamic recognition uses images from a webcam for image recognition. Figure 2 illustrates the operation mode of a noncontact touch search system.

Fig. 2. (Color online) Operation mode of noncontact touch search system.

2.2.2 Mode of operation

In the design and planning of controlling gestures, in addition to using a variety of gestures in different games, such as by the Xbox 360 Kinect, kinesthetic systems also coordinate with interfaces when selecting games or controlling a smart TV. The gestures are simplified to avoid the burden of remembering new gestures. When using a recognition system similar to that of Kinect, the user is required to be 1.5 to 4 m from the system for good recognition.

On the basis of the collected information, the controlling gestures and visual feedback from interfaces can be summarized as follows:

- Controlling gestures
  - · Moving the pointer: Raise and wave arms in any direction, and place the palm to cover the desired link or function key. A cursor will appear on the screen corresponding to the position of the palm.
  - · Making a selection: Pause in the same position for a while; the corresponding cursor on the screen will change from a palm to a fist (grabbing act).
  - · Returning to the interface: Turn the hand counterclockwise, and the user will be directed to the previous page. However, this function is often implemented as a function key that users can see on the screen.
- Visual feedback from interfaces
  - · Modes of movement
  - · When a user's palm is detected, an arrow or palm appears on the screen as a cursor. When the user moves the palm, the arrow/hand cursor moves according to the movement of the user.
  - · A light round spot may appear to provide a highlighting effect. When the user moves the palm, the circular spot tracks the dragged movement to indicate the direction and movement of the user.
  - · Modes of selection
  - · When the user pauses the palm at one location, the round spot turns into a circle and shows the process of drawing a circle (in about 1 s), indicating the selection process.
  - · The object being selected blinks or changes in size slightly, indicating that such an object is selected successfully.

2.2.3 Touchless (contactless) interfaces

Touchless technology can be defined as interactions that do not require physical touch to operate, that is, controllable interfaces that enable user–technology interactions through voice, gestures, hand interaction, eye tracking, and biometrics, such as facial recognition and contactless fingerprints. To protect as well as be protected from infected workers returning to the workplace, different operating interfaces are being developed using noncontact IoT devices to comply with new pandemic-related health policies.[8]

Eye tracking is the process of measuring eye movements using an eye-tracking device. Eye-tracking technology is reasonably mature and is now an important tool in many fields. The eye-tracking technology used by Tobii Rex is a noncontact technology that uses a pair of IR sensors to track the user's eyes to interact with a computer similarly to a mouse cursor. Windows eye control was released via a Windows update on October 17, 2017. This is the first implementation of eye control in Windows and is intended to provide a basic UI that can be manipulated by users with limited limb movement capabilities and unable to effectively use the keyboard and mouse. Instead, it partly relies on eye tracking as the primary input when using the computer. Vasisht *et al.* proposed an HCI system designed for amputees and people with hand problems. The system is an eye-based interface that acts as a computer mouse by translating eye movements such as blinking, gazing, and squinting into mouse cursor actions.[(9)]

Li *et al.* proposed a dynamic gesture recognition method based on hidden Markov models (HMMs) and Dempster–Shafer (DS) evidence theory. On the basis of the original HMM, it transforms the tangent angles and gestures of palm trajectories at different times into features of complex motion gestures, and the number of trajectory tangents is reduced by quantifying the code. Finally, DS evidence theory is combined with combination logic for dynamic gesture recognition to obtain better recognition results.[(10)]

Gestures have been widely recognized as a promising method for HCIs. Recognizing human gestures using surface electromyography (sEMG) applications is an important research topic. Qi *et al.* solved the technical problems of unsteady signal processing in feature extraction and pattern recognition using sEMG signals. The proposed method was implemented to extract the feature map slope in a gesture recognition system with linear discriminant analysis and an extreme learning machine, which can reduce redundant information in sEMG signals, improving recognition efficiency and accuracy.[(11)]

Since the outbreak of the COVID-19 pandemic, innovations that can provide a more germ-free environment are highly desirable for public use. Even before COVID-19, in the design of public spaces, there was a trend toward touchless and motion-sensing equipment, notably in sinks and light switches. In recent years, there have been many achievements in the development of noncontact elevator buttons. U.S. Patent No. 4044860 is an elevator traffic demand detector, which is mainly used for collecting large, extremely complex data by sensors and software, although it has the drawback of high installation and maintenance costs.[(12)] U.S. Patent No. 5149986 is an electronic control button operated by an acoustic controller. This invention is the first known use of ultrasonic waves with elevator buttons.[(13)] U.S. Patent. No. 6161655 is a contactless elevator call button employing an IR beam with a fixed reflection point in an unprotected space 3 inches from the surface of the device.[(14)] However, a disadvantage is that it requires user training. Even with motion sensing, there are problems with people inadvertently activating a button when passing the device. U.S. Patent No. 8872387 B2 is a noncontact selector switch. This invention utilizes an interrupted beam in a confined space. To meet Americans with Disabilities Act (ADA) requirements, the device is combined with a conventional push button.[(15)] A disadvantage of this device is that special user training is required to achieve the desired results. Moreover, the narrow opening of the device, allowing the use of one finger for operation, results in limited space, making contactless activation difficult for most users. Neither of these connections (methods of pressing the control button) have the capability of cleaning a user's hand or collecting advanced traffic data.

U.S. Patent No. 9463955 B2 (2016) is an elevator operating interface with virtual activation[16] and U.S. Patent No. 10618773 B2 (2020) is an elevator operating control device and display method.[17] Both inventions use a vision system to integrate the spatial recognition of a finger placed in one of the control keys on a keypad. These systems then activate a button on the keypad when the finger is located above the keypad but not in contact with it. However, there are several practical problems, the main one being that for this system to work, there is a defined finger dwell time on a button. If this dwell time is too short, it will result in false activation. In addition, when the finger is moving above the keypad, a too long dwell time can lead to frustration and button contact. Therefore, a high degree of user training is required.

Trong *et al.* presented an integrated approach and system applicable to smart homes for implementing gestures using several depth models and mobile sensors. They mainly used gesture recognition methods and systems for mobile sensors in smart watches, smartphones, and home appliances. Their system consisted of three components of actual smart home configurations: (i) a smart watch worn on the user's wrist for capturing gesture patterns, (ii) a recognition application that runs on a smartphone and sends corresponding commands to a home automation platform, and (iii) a home automation platform with connected smart devices instrumented with ambient sensors.[18] The gesture sets employed in their study can be used to control appliances in smart homes. Vaish *et al.* proposed a system based on an IR light field that used two types of gestures to call an elevator or open a door. However, the control range of the proposed operating instructions was limited and the accuracy of the proximity sensors used in the system was low.[19] Katti *et al.* used a convolutional neural network to define gesture and control devices using particular hand gestures.[20]

The above-mentioned research results have led to breakthroughs in gesture recognition. However, the definitions of gestures and actions have not been discussed in detail or in terms of application validation and usability evaluation.

Many current designs focus on the development and application of functionality, seemingly solving the interface operation problem in virus transmission. However, design solutions without usability evaluation may cause operational problems for users. Therefore, in this study, not only is a design solution proposed, but also its usability is evaluated.

3. System Construction and UI Design

3.1 Conceptual construction of the system

The innovative design of the elevator control mode is different from that of traditional elevator control interfaces. The main purpose of the system is to integrate not only technology, information, and space through the use of a noncontact interface, but also gesture recognition technology into user operations to meet the needs of users. When operating in the noncontact control mode, the user behavior is first recognized by a video recognition system and then transferred to the buttons on an electronic panel to operate the elevator. The structure of the noncontact elevator control system is shown in Fig. 3.

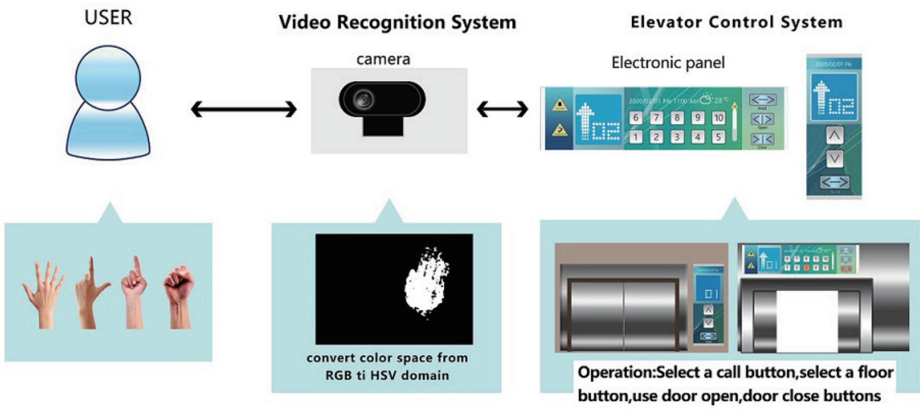


Fig. 3. (Color online) Structure of noncontact elevator control system.

3.2 Noncontact elevator control mode and UI design

In this study, we designed a noncontact elevator control interface utilizing the design requirements and suggestions obtained during heuristic evaluations. The interface is shown on an electronic panel, allowing the colors, shapes, positions, and functions to be redesigned. Visual feedback and audio support were provided to replace the sense of the traditional touch control mode in operations.

3.2.1 System control UI design

Regarding the style of UI presentation suitable in a hospital, green is regarded as lowering the anxiety of patients, while blue provides a relaxing effect, calming nervousness.[21] The information presented on the electronic panel should be grouped functionally and distinguished using various shapes, background colors, and sizes so that users can scan and absorb the information quickly. The selection of buttons should be coordinated by a control mode and visual feedback. The control panel interfaces designed in this study are as follows:

(1) UI of outer control panel [Fig. 4(a)]

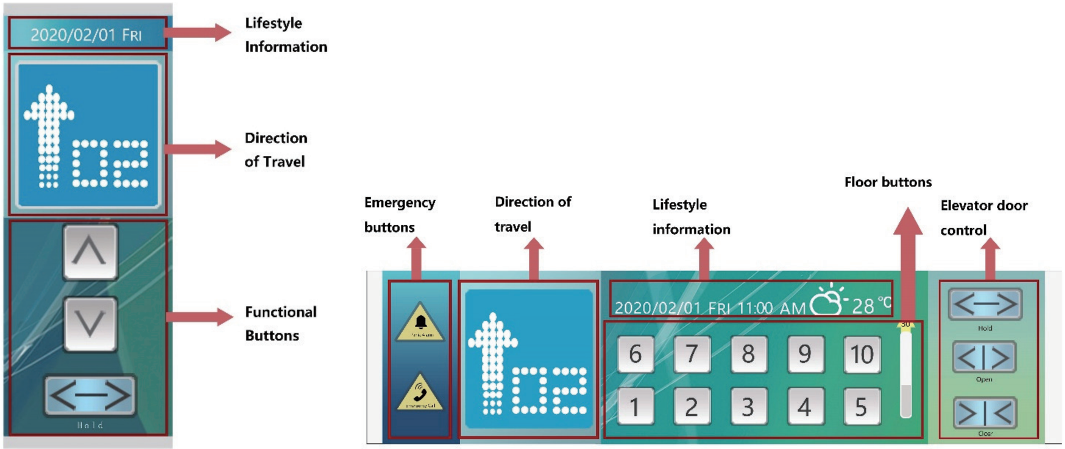
The outer control panel displays information including:

1. Number of located floor and direction of travel
2. Lifestyle information
3. Operational functions (including floor button, door open and door close buttons, hold button, and call button)

(2) UI of inner control panel [Fig. 4(b)]

The inner control panel displays information including:

1. Number of located floor and direction of travel
2. Lifestyle information
3. Floor button (numbers) to indicate the floors of the building: if the building is relatively high, the floor buttons may be presented in a menu, reducing the density of buttons on the panel and the error rate in operations



(a) (b)

Fig. 4. (Color online) (a) Outer control panel. (b) UI of inner control panel.

4. Door opening, closing, and hold buttons (the buttons are designed as larger rectangles, with different buttons having different colors and shapes for easy identification)
5. Emergency buttons (the two buttons for emergency use are touch-controlled and are not part of the noncontact operation mode)

3.2.2 Planning of system control mode

In a noncontact design, the sense of press and touch is not used during elevator operations. Therefore, the incorporation of visual feedback, corresponding to hand gestures, is particularly important. When operating a touch control interface, users are usually unaware of their gestures and actions before pressing the buttons. However, in a noncontact system, recognizing each behavior is important and meaningful. The detection of the hand is used as a trigger to initialize the system in a noncontact elevator control UI. The steps for using the noncontact system are next described in detail.

Step 1. Image recognition. When a hand appears in front of the camera, the image is recognized and a hand-shaped pointer appears on the elevator operation panels, and the system is tolerant to different lengths and thicknesses of the fingers. The hand shown in the panel is visual feedback indicating to the user that the system has been initialized.

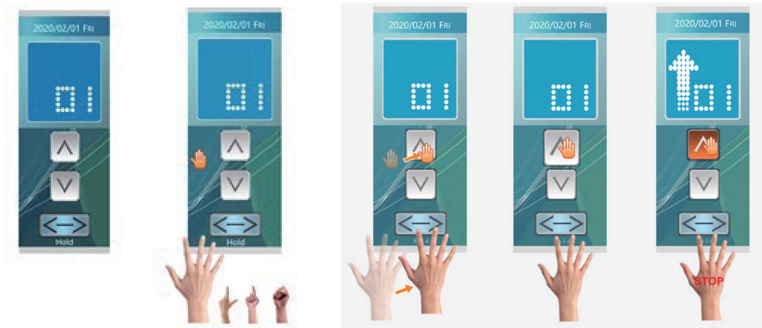
Step 2. Motion tracing. The user can move the pointer to any location or select a function button.

Step 3. Select a function. When the user moves the hand pointer to a function button, the button is enlarged, providing visual feedback to inform users that the selection has been made successfully.

Step 4. Confirm the selection. Because hand gestures are used to control the pointer in the noncontact elevator control panel, the selection and its confirmation should be distinguished. When the pointer moves to select a function, users only need to pause the hand movement for a short period to confirm the selection.

All the function buttons can be operated in the same manner. Consistency in the operational modes may reduce the difficulty of learning and memorization. Details of the operational procedures are shown in Tables 1–3.

Table 1
(Color online) Usage of outer control panel.



1. System idle.
2. Camera detects hand gestures and cursor appears.
3. Cursor moves corresponding to motion of hand.
4. When cursor is directly above button, visual feedback is given by showing enlarged button.
5. Button selected by pausing hand while cursor is on button, and color of button changes.

Table 2
(Color online) Usage of interior control panel (selecting a floor).

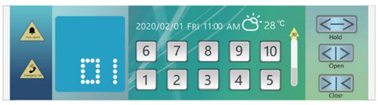
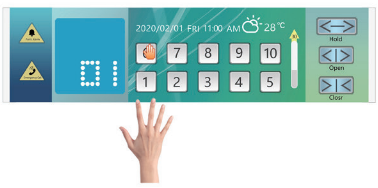
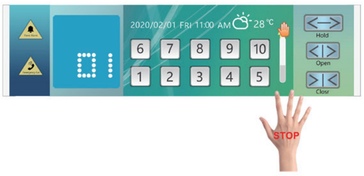
	System idle.
	Camera detects motion of hand and cursor appears (any gesture detected).
	Cursor moves corresponding to motion of hand.
	When cursor is placed on floor button, visual feedback is given by showing enlarged button.
	Floor selected by pausing on floor button, and color of floor button changes.

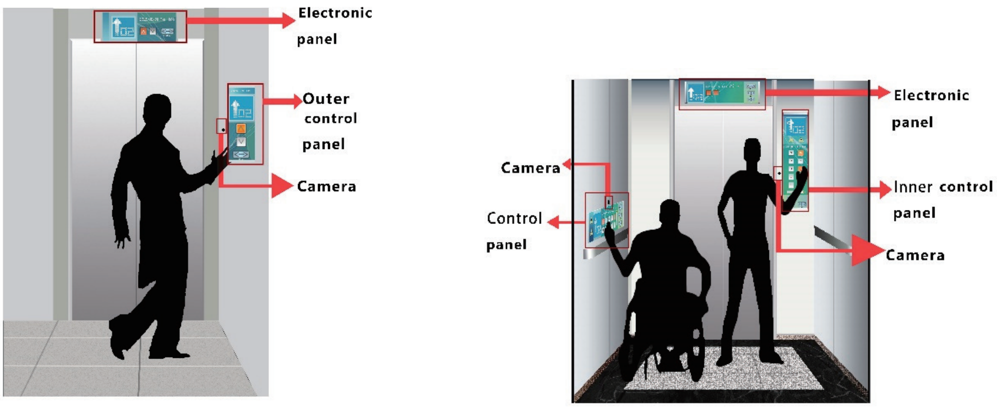
Table 3
(Color online) Usage of interior control panel (selecting floor with higher or lower number).

	To select floor with higher (lower) number, scroll up (down) to corresponding page of menu.
	Scroll on side indicates relative position on menu.
	When one end of menu is reached, reminder is given.
	Move hand to desired floor button to select floor.
	Pause on button of desired floor to select floor, and button changes color.

Ergonomics should be considered in the layout of spaces (including the operational interface and camera). Considering the limited space in an elevator and the possible number of users, the camera is set 130 cm above the floor to capture the motion of the user's shoulder to elbow. An electronic panel is placed at the top of the elevator doors to increase visibility. Figure 5(a) shows the location of the outer control panel and Fig. 5(b) shows the layout of the interior space.

3.3 Video recognition system

The noncontact elevator control system incorporates a video recognition technique and can be operated in the kinesthetic mode. The program was written in C language using Visual Studio with the OpenCV package. The image processing procedure is shown in Fig. 6, where



(a) (b)

Fig. 5. (Color online) (a) Outer control panel. (b) Layout of interior space.

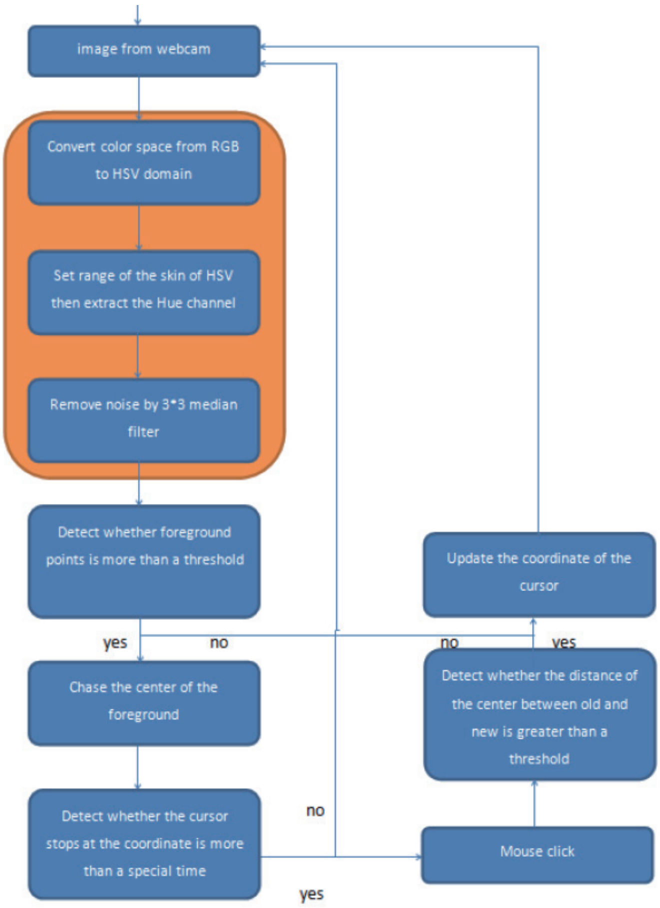


Fig. 6. (Color online) Process of video recognition.

yellow is used for the preprocessing of images and blue is used for processing actions. This system first recognizes the hand shape by transforming captured images into an RGB system, then performs the following steps.

1. Distinguishing the skin color and hue saturation value (hsv) of the hand. The skin color in this range is extracted as hsv, cvScalar (0, 58, 89), and cvScalar (25, 173, 229).
2. Establishing the number of sensor points for foreground detection. The sensing area is set to 10000 dpi, and motion tracking is initiated only when the detected points are above a threshold. The location of the pointer indicates the main location of most of the sensor points.
3. Confirming the selection. The detection range is set to 1000 dpi. At the user's target position, the rate of gesture motion is relatively low, and the pointer pauses at a specific position.

4. Analysis Using Noncontact Elevator Evaluation Scale

In our experiment, users operated the noncontact elevator, and the user operating times were measured to evaluate the usability of the system. In addition, evaluations of the noncontact elevator were conducted using a seven-point Likert scale to record the perceptions of users to assess the suitability of the elevator interface in this study.

4.1 Basic information of test takers and survey

This study involved 30 test takers with previous experience of using elevators in any setting. The test takers were mostly medical staff in the hospital from various work fields and age groups (between the ages of 14 and 65). Most test takers understood the functions and concept of kinesthetic systems, but only half of the test takers had actual experience of them.

The test takers were categorized according to whether they had experience of kinesthetic systems (for example, Xbox 360 Kinect or Wii) to determine whether previous user experience affected their perceptions and evaluation of the noncontact elevator control system. This comparison was used to evaluate the universality of the operation mode and UI.

4.2 Results of timed tasks and analysis

Two tasks were completed in the experiment. 1. Test takers rode the elevator with the noncontact control system from the first floor to the ninth floor with the purpose of exposing them to the noncontact operation mode; 2. test takers moved three chairs from the twelfth floor to the third floor using the elevator with the purpose of ensuring that they experienced the hold button, increasing the difficulty of the task.

From the descriptive statistics of task 1 (Table 4), the shortest time taken to complete the task among the experienced users was 13.03 s and the longest time was 16.80 s, with an average completion time of 14.40 s for the task. Among the test takers with no previous experience of kinesthetic systems, the shortest completion time was 15.14 s, the longest time was 19.39 s, and the average time was 16.75 s.

From the descriptive statistics of task 2 (Table 5), the shortest time taken to complete the task among the experienced users was 41.14 s and the longest time was 54.98 s, with an average completion time of 49.74 s. Among the test takers with no previous experience, the shortest completion time was 46.12 s, the longest time was 56.93 s, and the average time was 53.12 s. This

Table 4
Descriptive statistics of experimental task 1 (unit: s).

	N	Minimum	Maximum	Mean	Std. deviation	Variance	Skewness
Experienced	15	13.03	16.80	14.4027	1.02032	1.041	.783
Non-experienced	15	15.14	19.39	16.7507	1.29000	1.664	.783
Total	30	13.03	19.39	15.5767	1.65280	2.732	.501

Table 5
Descriptive statistics of experimental task 2 (unit: s).

	N	Minimum	Maximum	Mean	Std. deviation	Variance	Skewness
Experienced	15	41.14	54.98	49.7473	4.81180	23.153	−.937
Non-experienced	15	46.12	56.93	53.1247	3.91054	15.292	−.821
Total	30	41.14	56.93	51.4360	4.63788	21.510	−.896

data shows that the gap between average time taken increases as the difficulty of the task increases. The results for the two tasks showed little difference between the times taken by test takers with and without experience of kinesthetic systems, showing the operability of the noncontact elevator by both types of users.

4.3 Analysis of noncontact elevator evaluation scale

The scale employed for noncontact elevator evaluation allowed users to evaluate the applicability of the tested elevator interface upon completing the experimental tasks. The evaluation included the sanitation of the interface, convenience of functions, visibility of information, adaptability of operation, and applicability of technology to determine whether any parts of the design could be modified to increase convenience and operability. A seven-point Likert scale was used in the evaluation.

Before using the scale for analysis, a reliability test was conducted on the scale. We employed Cronbach's alpha value to test interior coherence (Table 6) and obtained a value of 0.615 (>0.5), implying good reliability. The test results of single items showed that item 1 (sanitation of interface) had an alpha value of 0.670 and that the deletion of this item would increase the overall alpha value. However, because the deletion of item 1 would not significantly increase the reliability, it was kept in the scale for further analysis.

(1) Sanitation of interface

This item describes the situation that users avoid coming into contact with the elevator control panel when operating the interface to reduce the possible spread of diseases. As shown in Table 7, the average of this item was 6.97, close to the maximum possible score of 7. It is inferred that most users believed that the noncontact elevator control interface had better sanitation than a traditional elevator, as indicated by the positive evaluations.

(2) Convenience of functions

This item describes whether the tested interface could assist users in operating the elevator faster with convenience. This included comparing the hold button on the operation panel (both inner and outer panels) with that of a traditional touch-controlled elevator to evaluate whether such a design decreases the frequency and length of time used to push the door open button. The

Table 6
Reliability statistics of noncontact elevator evaluation scale obtained with Cronbach's alpha.

Cronbach's alpha		Number of items		
.615		5		
Item – total statistics				
	Scale mean if item deleted	Scale variance if item deleted	Corrected item – total correlation	Cronbach's alpha if item deleted
1.	20.6000	3.007	−.044	.670
2.	21.5333	2.051	.410	.540
3.	21.6667	2.299	.452	.540
4.	24.6333	1.551	.571	.429
5.	21.8333	1.661	.422	.544

Table 7
Descriptive statistics of noncontact elevator evaluation scale (N = 30).

	Minimum	Maximum	Mean	Std. deviation	Variance	Skewness
1. Sanitation of interface	6.00	7.00	6.9667	.18257	.033	−5.477
2. Convenience of functions	5.00	7.00	6.0333	.55605	.309	.022
3. Visibility of information	5.00	7.00	5.9000	.40258	.162	−.883
4. Adaptability of operation	200	4.00	2.9333	.69149	.478	.087
5. Applicability of technology	4.00	7.00	5.7333	.73968	.547	−.067

average score for this item was 6.03 and the standard deviation was small (0.556), meaning that the users shared similar views on the convenience of the functions on the tested interface. It is inferred that the majority of users believed that the tested interface was advantageous over touch-controlled elevators, rating it with more positive evaluations.

(3) Visibility of information

This item describes the visibility of information displayed on the operation interfaces and electronic panel, including lifestyle information and advertisements. In comparison with current touch-controlled elevators, the information can be easily recognized by elevator riders. The average score for this item was 5.90 with a small standard deviation (0.403). This means that the test riders shared similar views on the visibility of information. Skewness was less than zero, meaning that data scores were distributed closely above the average, with more high than low scores. It is inferred that most users believed that the tested interface was advantageous over touch-controlled elevators.

(4) Adaptability of operations

This item describes the overall opinion of the users on the tested interface regarding user friendliness as well as difficulty, intuitiveness, integration, learnability, confidence, and efficiency of operation. The average score was 2.93, lower than a neutral opinion of 4, with a small standard deviation. This means that the test riders shared similar views on the adaptability of the operation. It is inferred that the majority of users believed that the touch-controlled traditional elevators had more advantages over noncontact elevators. According to comments made by users in post-task interviews, the change required in their customary elevator operation reduced the score for this category. Users would like to operate the elevator more simply but are willing to adapt to their operation method through practice to improve hygiene.

(5) Applicability of technology

Video recognition was employed to detect hand gestures when users moved their hands to move the pointer to a symbol to select a function button. Our aim was to investigate user opinions on the applicability of video recognition for elevator operations and determine whether there are more suitable methods of operation. The average score for this item was 5.73 with a relatively small standard deviation (SD = 0.739). This means that test takers shared similar views on the applicability of the technology. Skewness was less than 0, indicating that the data scores were distributed above the average, with more higher than lower scores. It is inferred that most users positively evaluated the video recognition system for use in noncontact elevators.

5. Conclusion

This study integrates video recognition technology into elevator technology to develop a noncontact elevator control system that can be operated using intuitive hand gestures, thus solving the virus transmission problem of traditional touch operation systems. In particular, the interface for operational control may be redesigned by enhancing the organization of visual elements to remind users of the sequence of behaviors necessary for operation, while the additional value of medical alert messages or commercials may be added to the functionality of the new interface. This system may be applied in public hospital elevators to improve hygiene by reducing contact with pathogens while making the elevator more efficient. Our interface has the following features.

1. The buttons on the inner panel change color to provide visual feedback to users in order to compensate for the loss of the sense of touch. Audio is used to assist users in recognizing commands.
2. The function buttons are aligned horizontally for ease of operation because during the experiment, we noticed that the operators' hands were mainly used for horizontal movements.
3. The operational interface is presented on an electronic panel. Using appropriately designed icons and changing their colors to help users quickly scan and process the functional information on the panel increases the ease of recognition of the interface. The color, shape, and size of the buttons were designed according to functionality groups. For example, the hold button is larger than the door open button to indicate the time delay in closing the door. Visual differences may also assist in the search and memorization of functions.
4. To enhance the efficiency of operation, functional buttons were placed at a distance from the edge of the sensor area to maintain some distance between each function button and reduce the error rate during operation. The number of floors displayed may be adjusted to the actual number of available floors in the building.
5. Hold buttons are implemented both inside and outside the elevator to reduce the number of times the door open button is operated. After the experimental tasks, the users expressed high satisfaction with this design.

This study integrates the engineering design and industrial design of the UI with color design and image construction to increase visual recognition in addition to aesthetics; these designs may vary according to the location and functionality of the elevator, thereby increasing user awareness of the functional organization. The design is not only concerned with the functional design of the operation, but also with the aesthetic design and ease of operation. Furthermore, this study also evaluated the usability of this system. The results of experiments and validations demonstrated that the designed noncontact elevator control mode was indeed intuitive, with an operational interface allowing users to specify the necessary steps through gestures. All users considered the newly designed system to have high universality. They also expressed their willingness to use such a design in elevators as a means of improving hygiene. In the future, we plan to optimize the design of the system on the basis of the results of post-interviews of users.

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