Integrating motion sensing technology in radiographic examination

Christopher Lai, Chun-Fai Ellis Li

Background: In the daily operation of X-ray machine, radiation technologists need to have direct close contact with patients with known or potential infectious disease, resulting in environmental contamination by pathogens if hand hygiene was not properly observed. In the last 15 decades, the method for inputting computer commands has evolved from using keyboard, mouse and to touchscreen and a touch-less method: motion sensing technology. Therefore in the present study, we aim to explore the feasibility of using motion-sensing technology to replace several computer-inputting commands that were frequently used during radiographic examination in order to reduce the chance of pathogen contamination to the radiographic equipment and accessories.

Method: In this study, two sets of gesture commands that can encompass the most frequently used computer commands for image manipulation and x-ray acquisition during radiographic examination were carefully designed. Then, the proposed gesture commands were detected by the Leap Motion Controller using motion sensing technology under a controlled experimental environment. Using Leap Motion Diagnostic Visualizer, the recognition performance, practicability and feasibility of the gesture commands were assessed by 4 different trained operators.

Results: In our proposed gesture commands**, t**he horizontal movement of the thumb (when performing right click and exposure release command) and the vertical movement of the index finger (when performing left click, scrolling up and scrolling down command) were the key sensing component that govern and trigger the gesture command. In general, the magnitude of these key sensing fingertip movement was consistent within an operator, but was varies from operator to operator because each of the operator was allowed to achieve the proposed gesture commands with certain extent of flexibility.

Discussion and conclusion: Motion-sensing technology could practicably for image manipulation and making X-ray exposure. As a high variability exists among different operators, the application of an individual operator dependent threshold value rather than

a single threshold value in the magnitude of key sensing fingertip movement of gesture commands is recommended. Also, although the implementation motion sensing technology in radiographic examination may inevitably slow down the examination throughput, it could possibly reduce pathogen contamination to the radiographic equipment and accessories, in particular under nosocomial outbreak of epidemic diseases.

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Integrating Motion Sensing Technology in Radiographic Examination

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Abstract

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Conclusion: Motion-sensing technology could practicably for image manipulation and making X-ray exposure. As a high variability exists among different operators, the application of an individual operator dependent threshold value rather than a single threshold value in the magnitude of key sensing fingertip movement of gesture commands is recommended. Also, although the implementation motion sensing technology in radiographic examination may inevitably slow down the examination throughput, it could possibly reduce pathogen contamination to the radiographic equipment and accessories, in particular under nosocomial outbreak of epidemic diseases.

Keywords: Motion-sensing technology; Radiology department; Pathogen contamination; Leap Motion Controller

Manuscript

Introduction

The radiology departments characterized by a high patient's turnover and the necessity of direct contact between patients and radiation technologists during radiographic examination contribute significantly to an increased chance of environmental contamination by pathogens. Today, radiographic examination is an important clinical step in the management of many acute disease conditions. During the outbreak of epidemic diseases such as Severe Acute Respiratory Syndrome(SARS) in 2003(Peiris et al. 2003), the differential diagnosis for suspected SARS cases relied heavily on the radiographic features of lung infiltrations similar to pneumonia or respiratory distress syndrome (RDS).Also, in the first case of Middle East Respiratory Syndrome (MERS), a chest X-ray was immediately taken once the 60-year-old Saudi man had admitted to a private hospital in Jeddah, and a follow-up chest X-ray was performed two days after his admission(Zaki et al. 2012).In 2014, Assiri group pointed out that MERS coronavirus was capable to transmitted from person to person(Assiri et al. 2013), and the latest data from WHO revealed its relatively high mortality rate that reach up to 30.5 %. Therefore, the risk of pathogen contamination to radiographic equipment and accessories is substantially high in the radiology department.

Apart from the issue of epidemic disease outbreak, the overcrowding environment, insufficient healthcare professionals and relatively undesirable management in the public hospitals also alarm the world about the effectiveness of hospital infection control measures (Defez et al. 2008). A study conducted in Nigeria during March to July 2012 reported that pathogens such as *Staphylococcus aureus*(76.9%); *Pseudomonas aeruginosa* (48.4%); *Coliform spp* (44.0%); *Streptococcus* (28.6%)and *Proteusspp* (15.4%)were identified on the surfaces of radiographic examination couches, x-ray tube handles, chest stands, control panels, exposure buttons, anatomical markers and x-ray cassettes(Eze 2013).Even in the developed countries like Korea, *Methicillin*-resistant *Staphylococcus aureus* (MRSA) still be found on the surface of x-ray cassettes (Kim et al. 2012). Therefore, the implement of infection control measures remains challenging in the radiology department.

Today, observing the principles of infection control is regarded as the most reliable way to prevent the spread of pathogens in radiology department (Lowy 1998), but the major challenge seems to be the impracticable to change contaminated gloves or sterilize the hands, and disinfect the control panel and exposure release button after every single radiographic examination. Hand washing with detergent is promoted to be an important step to prevent pathogen contamination to the environment. However, MRSA still could be found on the surfaces of subjects' hands even after 10-second of hand washing with soap and water (Larson et al. 1992), and on the surface of X-ray cassettes after disinfection procedure (Lai, Leung and Law 2014).Moreover, environment disinfection by spraying and wiping disinfectants was found unable to inactivate bacteria activity completely because of the chance of introducing human error at each disinfection process (Eze 2013).Therefore, apart from killing the bacteria by disinfection, infection control measures that can block the transmission routes such as using a touch-less computer-inputting command during radiographic examination may serve as an alternative way for the enhancement of infection control measure in radiology department.

The Leap motion controller (San Francisco, United States) is one of the motion-sensing devices available in the market for the accurate fingertips motion tracking. The Leap motion controller consists of three infrared light emitters and two infrared light cameras, and hasan excellent sensitivity to detect very fine movements of finger tips at up to over 200 frames per second. By comparing the points in the two 2D images that acquired by the two infrared light cameras, it can track the 3D movements of any moving parts. The Leap motion controller has been using in the operating theaters to assist surgeons on viewing radiographic images. In fact, before the introduction of it in surgical procedures, the self-manipulation of medical images by surgeon was limited due to the concern of sterilization. Therefore, surgeons usually require the help from circulating nurse to handle medical images. This kind of motion-sensing technology, however, has not been implemented in the radiology department yet. Therefore, in order to minimizing the chance of pathogen contamination to X-ray equipment and accessories, we aim to explore the feasibility of using touch-less motion-sensing technology to replace several computer-inputting commands during radiographic examination.

Methodology

This study was approved by the panel for summer research studentship, Faculty of Health and Social Science, The Hong Kong Polytechnic University. A standardized and controlled experimental environment that consist of a chair, a table, a notebook and a Leap Motion controller was designed to simulate the working environment of using x-ray control panel for image manipulation and x-ray acquisition (figure 1).The positions of the chair, the table, the notebook and the Leap Motion controller were all fixed during the whole study. Then, we carefully designed two sets of gesture commands for 1) mouse cursor manipulation during image manipulation (Moving the cursor, Left clicking, Right clicking, and Scrolling up or down the mouse wheel) and 2) making an X-ray exposure like holding a typical x-ray exposure releasing device (usually in tubular shape with an end-plate button designed for x-ray anode rotation and X-ray release when the button is half pressed and full pressed respectively). Also, by simply extend all fingers and thumb at any time will exit the cursor manipulation mode and X-ray exposure mode function. A summary of the two sets of gesture command was listed in Table 1.

In this study, the motion tracking data was monitored and captured by Leap Motion Diagnostic Visualizer (LMDV, Leap Motion Inc.) and PicPick software (a full-featured screen capture tool own by NTeWORKS, software available at www.pickpick.org) respectively for offline analysis. The 3D coordinates of the fingertips track data were instantly displayed on the upper right corner of LDMV, and the speed of the fingertips motion were displayed next to the coordinates (Fig. 2). The capability of the proposed gesture commands for image manipulation to be differentiated and detected correctly by the Leap Motion controller was assessed using "Touchlesss for Windows" program (Leap Motion Inc.). After verbal consent was obtained, and a 30-minute of training and rehearsal in performing gesture commands, the fingertips tracking data from four volunteers (operators A, B and C were males while operator D was female) were analyzed. Although all gesture commands and the equipment settings were fixed, in order to simulate a practical and real working environment, operators were allowed to perform the gesture command naturally with certain degree of flexibility. At each measurement, the operator was instructed to repeat each gesture command by four times, and the key sensing component that govern and trigger each gesture command will be defined. Finally, the repeatability and variability of gesture commands were assessed by analyzing the magnitude of these key sensing fingertip movement within an operator and among difference operators respectively.

Fig. 1.The setup of the chair, the table, the notebook and the Leap motion controller in the present study. Their positions were all fixed during the whole study.

Fig.2. In the present study, Leap Motion Diagnostic Visualizer was used to monitor the motion tracking data that generated by fingertips movement of each gesture command. In this figure, several color lines and dots were used to indicate the coordinates of the fingertips relative to the Leap motion controller, and their value and speed of change were instantly displayed at the top right corner of the program under x-axis, y-axis, z- axis and speed column.

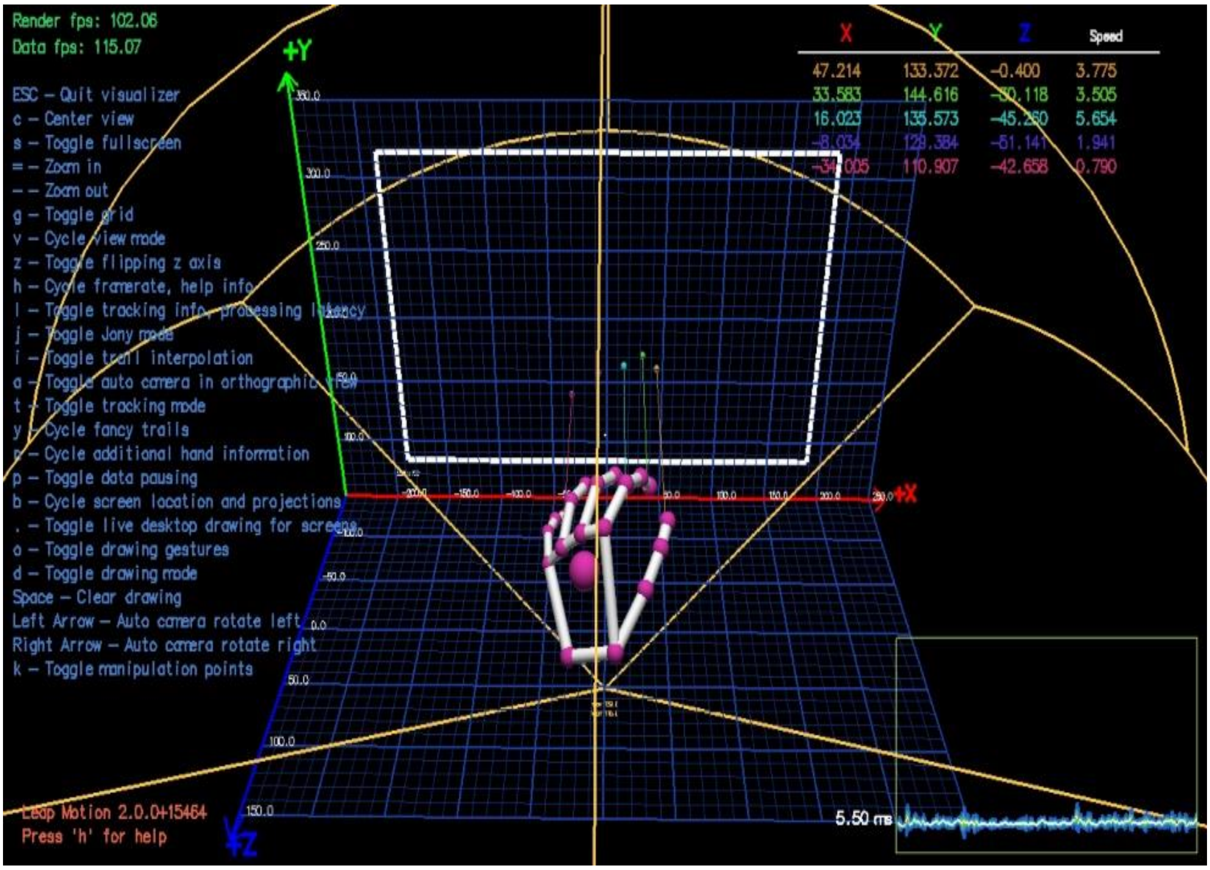


Table 1.Gesture commands to simulate different mouse cursor manipulations (Moving the cursor, left clicking, right clicking, and scrolling up or down the mouse wheel) for image processing.

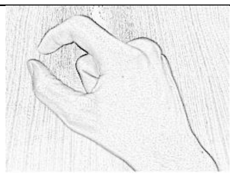
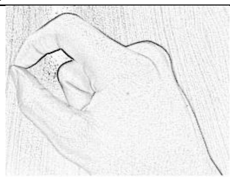
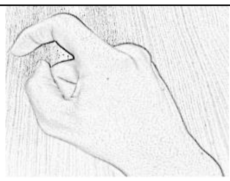
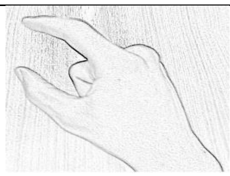
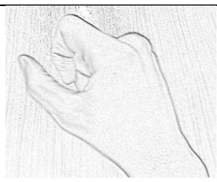
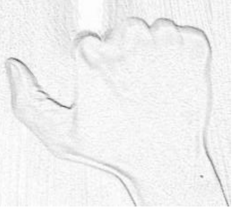
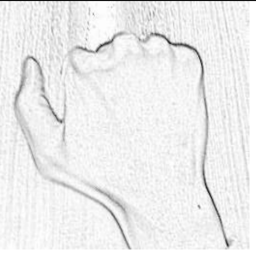
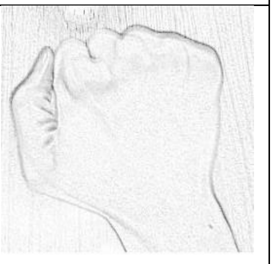
Task	Conventional commands using computer mouse	Suggested gesture commands using Motion-sensing device	Graphical illustration of the gesture command
A. Simulating the manipulation of cursor for image processing		To trigger the mouse cursor manipulation mode, the operator should opposing the tips of thumb and index finger with a gap about 2cm meanwhile other fingers are fully flexed for 1 second. (*Gesture A)	
	A1.Moving the cursor	A1. Once you entered the mouse cursor manipulation mode, you can "**move the cursor**" while holding the gesture A and move the hand.	
	A2.Left click	A2. Once you entered the mouse cursor manipulation mode, you can perform "**left click**" while holding the gesture A by opposing the tips of thumb and index finger.	
	A3.Right click	A3. Once you entered the mouse cursor manipulation mode, you can perform "**right click**" while holding the gesture A by flexing the thumb towards the lateral surface of the index finger.	
	A4.Scrolling up the mouse wheel	A4. Once you entered the mouse cursor manipulation mode, you can perform "**scrolling up**" function while holding the gesture Aby extending the index finger.	
	A5.Scrolling down the mouse wheel	A5. Once you entered the mouse cursor manipulation mode, you can perform "**scrolling down**" function while holding the gesture A by Flexing the index finger.	

Table 2.Gesture commands for making an X-ray exposure simulate the use of a typical x-ray exposure releasing button.

Task	Conventional commands using X-ray releasing button	Suggested gesture commands using Motion-sensing device	Illustrations of the gesture commands
B. Making exposure		To trigger the x-ray exposure mode, pronate the hand, and flexed all fingers except the thumb.	
	B1. Pressing the exposure release button to half the way to trigger the rotating of X-ray anode.	B1. Once you entered the x-ray exposure mode, slightly flex the thumb a little (preferably by more than 3 mm) to trigger the rotation of X-ray anode.	
	B2. Completely press the exposure button for irradiation.	B2. Once you entered the x-ray exposure mode and activate the rotation of X-ray anode, flexing the thumb so that the thumb touches the lateral surface of the index finger will trigger the release of X-ray.	

Result

Table 3 to table 7 summarized the magnitude of the motion change of thumb and index finger tips movement when performing image manipulation gesture commands (left click, right click, scroll up and scroll down) and executing X-ray exposure release gesture commands. Negative value of fingertips movements in x-, y- and z-axis correspond to a left side, downward (towards the table) and backward (away from the operator) shift respectively (Figure 2).For repeatability of gesture commands, we performed coefficient of variation (CV) test on each measurement, and a value of more than 50 % was considered as highly variable and marked with a (*).

Table 3. The thumb and index finger tips movement when performing "Left click" gesture command as detected by Leap Motion Diagnostic Visualizer. The key sensing fingertip movement is highlighted in red.

	Thumb and index fingertips movement (mm)					
	X-axis		Y-axis		Z-axis	
Operator	Thumb	Index finger	Thumb	Index finger	Thumb	Index finger
A	10.2 ±2.1	-3.6±1.5	-1.0 ±1.7 *	-5.1±3.4*	-0.2 ±3.1 *	12.5±2.8
B	11.4 ±1.7	-8.2±1.7	1.3 ±4.4	-16.2±3.0	3.1 ±2.3	23.5±5.0
C	13.9 ±1.2	8.6±1.6	-8.5 ±2.0	-9.4±2.6	-9.5 ±1.1	22.8±2.3
D	7.4 ±2.3	-0.4±1.6	1.7 ±2.7	-6.8±6.0	-1.4 ±3.4	23.5±5.4

* denotes the Coefficient of Variation (CV) was equal or greater than 50%.

Table 4. The thumb and index finger tips movement when performing "Right click" gesture command as detected by Leap Motion Diagnostic Visualizer. The key sensing fingertip movement is highlighted in red.

	Thumb and index fingertips movement (mm)					
	X-axis		Y-axis		Z-axis	
Operator	Thumb	Index finger	Thumb	Index finger	Thumb	Index finger
A	26.4±3.5	0.3±1.7 *	-11.7±2.7	1.7±3.3*	-5.5±1.7	0.6±2.2*
B	25.8±5.1	-2.2±4.7*	-8.6±4.8*	-2.5±3.5*	-0.1±4.2 *	4.0±2.8*
C	18.0±5.8	-1.2±2.4 *	-11.9±6.0*	-4.2±3.0	-15.3±3.9 *	-0.1±1.8 *
D	17.0±2.6	-1.8±1.2 *	-12.4±2.9	-0.9±2.5 *	-2.2±3.5 *	0.5±0.7 *

* denotes the Coefficient of Variation (CV) was equal or greater than 50%.

Table 5. The thumb and index finger tips movement when performing “Scroll up” gesture command as detected by Leap Motion Diagnostic Visualizer. The key sensing fingertip movement is highlighted in red.

	Thumb and index fingertips movement (mm)					
	X-axis		Y-axis		Z-axis	
Operator	Thumb	Index finger	Thumb	Index finger	Thumb	Index finger
A	-1.2±1.7 *	9.1±6.9 *	-1.3±1.7 *	25.1±2.6	-1.6±1.9	-33.2±6.6
B	-2.0±1.8 *	12.8±5.5	18.3±8.3	29.2±5.5	-1.8±3.7	-35.4±7.4
C	-9.1±15.9*	31.4±18.6 *	-1.7±9.7 *	66.4±4.7	-16.6±6.1	-34.5±16.2
D	2.0±1.3 *	9.8±2.0	0.7±2.2 *	28.7±3.6	-1.1±2.2*	-19.0±5.0

* denotes the Coefficient of Variation (CV) was equal or greater than 50%.

Table 6. The thumb and index finger tips movement when performing “Scroll down” gesture command as detected by Leap Motion Diagnostic Visualizer. The key sensing fingertip movement is highlighted in red.

	Thumb and index fingertips movement (mm)					
	X-axis		Y-axis		Z-axis	
Operator	Thumb	Index finger	Thumb	Index finger	Thumb	Index finger
A	2.4±0.5	20.7±3.7	-0.4±0.8 *	-3.3±4.1 *	-1.2±1.0 *	22.9±6.9
B	2.4±3.0 *	8.5±6.9 *	-2.7±1.6 *	-19.6±6.6	-1.4±2.0 *	34.9±10.3
C	8.3±3.2	15.8±3.1	-4.6±3.7 *	-2.7±4.2 *	-0.7±4.0	47.6±6.0
D	6.9±5.7 *	25.2±13.7	-5.1±5.2 *	-24.4±6.5	-4.1±2.6 *	51.2±10.3

* denotes the Coefficient of Variation (CV) was equal or greater than 50%.

Table 7.Comparisons of the average values of thumb movement when executing the x-ray exposure commands (half pressed and full pressed of the exposure release button) as detected by Leap Motion Diagnostic Visualizer. The key sensing fingertips movement is highlighted in red.

	Thumb tip movement (mm)					
	X-axis		Y-axis		Z-axis	
Operator	Half pressed	Full Pressed	Half pressed	Full Pressed	half pressed	Full Pressed
A	19.8±1.5	15.8±1.8	-4.5±1.2	-1.1±0.7 *	-7.0±2.8	-2.5±2.5 *
B	27.3±4.0	35.2±9.0	-6.4±4.6 *	0.3±5.1 *	-13.2±-3.9	-1.6±2.6 *
C	33.7±3.7	19.3±2.3	-11.7±3.6	-0.1±2.4*	-21.0±4.2	-4.8±2.3
D	28.1±5.3	26.8±3.5	-8.7±5.5 *	-2.6±1.3*	-23.8±3.9	-13.6±3.4

* denotes the Coefficient of Variation (CV) was equal or greater than 50%.

Discussion

Gestures commands should be user-friendly, as simple as possible and easy to recall. Therefore, each command should be executed by a simple or coherent gesture such as supinating the one single hand from pronating position rather than combination of several gestures. For the purpose of being easy to remember, it should be designed as intuitive as possible. Take the suggested gesture for making exposure as an example; it is designed to mimic the conventional manner – pressing the exposure button. Since the workloads of general X-ray departments in majority of the hospitals are heavy, for the benefits of patients and shortening the time of waiting for the general X-ray examinations, the duration of executing the commands or performing the gestures should be as short as possible. Minimal physical risk is also essential for preventing or lowering the strain of the radiographers due to long-term use of motion-sensing technology. It can be objectively quantified by considering the degree of movements and the times of repeating the movement for a single command. Ideally, the degree of the movements should be as little as possible and preferably using one hand for each gesture. Finally, the limitations of movements at certain joints level should be considered when designing a new gesture command

In the present study, in order to evaluate the recognition performance, practicably and feasibility of each gesture manner by Leap Motion Controller, we identified the key sensing fingertip movementin each gesture commands, and assessed whether 1) our proposed gesture command can be correctly determined, 2) an operator can repeat the command consistently, and 3) a threshold on the magnitude of the motion change of fingertips can be defined. Due to the fact that the integration of Leap Motion controller to the X-ray machine was prohibited by vendor at the time when this study was performed, we cannot check whether our proposed command could be differentiate and detected correctly to trigger irradiation by the Leap motion controller. However, we found the gesture commands for image manipulation (cursor movement, left click, right click and cursor scrolling) works well in "Touchlesss for Windows" program by all operators.

We found the thumb movement in X-axis (in right click and exposure release) and the index finger movement in the Y-axis (in left click, scrolling up and scrolling down) were the key component for the success of the implementation of our proposed gesture commands. They all have a low coefficient of variation, and therefore an operator is able to repeat the gesture command consistently. However, because we allowed certain extent of flexibility for operator to achieve the proposed gesture commands, the magnitude of the fingertips movement was varies from operator to operator, resulting in a high variability in many finger tips motion when performing different gesture commands. In this regard, a single threshold value was not recommended in a particular gesture command. We therefore suggest usingindividual threshold for each particular gesture command for each operator. When taking into the consideration of the least sensitivity for the Leap motion controller in dynamic situation of 2.5mm (Weichert et al. 2013), and the amplitude of physiological tremor in healthy people ranged from 0.04mm to 0.09mm(Sturman et al. 2005), the individual threshold for each gesture command should also be preferably not less than 2.75mm (as estimated by 95% CI of the sum of equipment error (2.5mm) and human error (0.09mm)) to avoid mistaken commands.

Another motion-sensing device, Kinect^{TM}, has been applied for motor recovery in a cost-effective, interactive and home-rehabilitation manner. The research project called Stroke Recovery with Kinect^{TM} conducted by Microsoft Research Asia and Seoul National University aimed to investigate how to measure and evaluate patient's progress by using the Kinect^{TM} sensor's three-dimensional cameras to track the trajectories of the skeletal movements and the variations in movements of the patients. Other applications in clinical settings including automatically open the door in operating room and infrared sensor embedded into faucet for the purpose of infection control.

Although both the Kinect^{TM} and Leap motion controller provide Software Development Kit or designing tailor-made application for research and experimental purposes, the present study employed Leap motion controller instead of Kinect^{TM} because of two reasons. First, regarding sensitivity of the fingers and hands, Leap Motion Controller is able to tracks all 10 fingers accurately up to 1/100thmillimeterat a rate of over 200 frames per second with150° field of view. Weichert group quantified the accuracy of the Leap motion controller in 2013 by using industrial robot in accordance to ISO 9283(Weichert et al. 2013). The results suggest that although the actual overall average accuracy of 0.7mm is not as accurate as the theoretical accuracy of 0.01mm and accuracy in dynamic scenario, namely, the object was moving, is less than 2.5mm while in static setup, i.e., the object was static and be measured over time, is less than 0.2mm. In contrast, the random error of depth measured by Kinect^{TM} was 4cm within 5m distance between object and the sensor (Khoshelham & Elberink 2012). Second, the vertical distance allowing for operating the Leap motion controller is ranged from 50mm to 400mm(Weichert et al. 2013). However, the vertical distance of operation for Kinect^{TM} are 0.4 – 3.0m and 3.0 – 8.0m in close distance mode and long distance mode respectively(Khoshelham & Elberink 2012). Considering the situation of using the computer in general radiography room, the Leap motion controller is much more desirable than the Kinect^{TM} in terms of the coverage of detection.

Conclusion

Gesture commands should be worked as an alternative manner for operating the computer, but not replacing the conventional control manner. The integration of voice control can further enhance and supplement the weakness of the implementation of gesture commands in the radiology department. The undesirably low efficacy might be one of the major concerns hindering the applications of motion-sensing technology in clinical settings. However, it can prevent pathogen contamination to the radiographic equipment and accessories, especially during outbreaks of epidemic disease.

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