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Finger-based gestural interaction for exploration of 3D heart visualization

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Abstract

Interaction with medical visualization is one of attractive research topics in human computer interaction and medical visualization. Controlling the volume visualization for 3D heart is one of the useful applications for clinician to produce an efficient ways on analysing the behaviour of heart. In this paper, we use some scenarios to develop a gesture control system using finger gesture to give more natural way to interact with the 3D cardiac model besides helping to reduce user cognition in using the system. We had proposed several gesture techniques that only require the user to move their finger in interacting with model. This paper also will focus on how to interacting with the cardiac model with finger gestures and advantages of using finger gestures in helping the diagnosis part besides having several drawbacks that can be solved in the future.

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Keywords: 3D Visualization; finger gesture control; medicine application

1. Introduction

Heart diseases are one top major death causes in Malaysia. Early diagnosis of this disease can helps saving patient lives. In recent years, many non-invasive imaging techniques such as that been developed by Narici [1] which can be used to help diagnosis process of analysing data generated such as CT, MRI, PET and ultrasound. The common method that always been used to view these data are using DICOM Viewer. Usually, these data been visualized from slices of set images and it allows the user to explore the surface of 3D model generated. It also the reason why 3D visualization techniques is important and needed by many clinician in their daily routine tasks.

One of the main challenge in visualization the dataset is to provide clinicians with a more realistic view of patient's body anatomy especially for the heart. In order to give users a deep sense of presence into the virtual scene and experience similar to the real situation, more advanced and natural human-computer interaction interface are required. In facts, the 3D visualization with gesture interaction helps the clinician in exploring the data especially in critical medical environment such as in operating room where it can replaces 2D images that commonly used to assist the surgeons to navigate the patient heart. Other problem that arises from the situation is the surgeon needs to

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browse the scans images without having any physical touch since they cannot leave the sterile field around the patient. The time duration also need to be considered where the surgeon needs to browse safely during the operation being done where the time very critical in saving the patient lives. Moreover, time-consuming for learn the interface also other main factor needed to be considered in development new solution especially for the clinical uses.

Apart from that, there are growing interest in system interface with controller-free same as in Gallo, Placitelli, & Ciampi [2] study that very efficient and easy to use for medical data exploration especially for cardiac data. The basic idea is to use medical imaging technology to create a virtual heart model that uses Microsoft Kinect to enables hand-finger gestures. By interacting with the heart model, its can helps to give better understanding of heart function and helps in diagnosis the diseases as it complement to medical imaging information. It also give an opportunity for heart model modification, simulating cardiac disease or other treatment options such as choosing between different mechanical heart valves. Not only that, it also offers a tool for decision support in planning surgery or other treatment. Gesture control interface that recognize the hand finger gestures made by the user seems to be suitable for operating rooms. However, there is still no exists really mature technology for effective gesture control.

In this context, the choice and the integration of input devices as the fundamental components for developing immerse 3D user interfaces are very important where it must be simple and non-obstructive that freeing the user from any cables and equipment that provide intuitive ways of interaction with medical data. In this paper, we present a 3D interaction techniques developed for manipulating and selecting three-dimensional heart model by using Microsoft Kinect camera that to be used in semi-immersive environment. These 3D interaction techniques have been implemented by using the Visualization Toolkit (VTK) library that integrated with open-source Kinect library which is using OpenNI library.

2. Related Work

About more than a decade, keyboard, mice, wands joystick has been the most common and dominant devices uses to interact with the machine. However, all these device seem inconvenient and unnatural ways especially in human computer interaction (HCI). By using human movement especially hand gesture, it can give others alternative method to interact with machine and had become quite popular research topic in human computer interaction (HCI) area. Moreover, it also had become a motivation force for research in modelling, analysing and gesture recognition. Many of these techniques developed in HCI area had been extended to other areas such medical imaging.

Nowadays, most medical imaging software application that being developed are capable to provide a three-dimensional visualization of volumetric data with high degree of accuracy such as Robb [3] study. Recent studies had showed that Immersive Virtual Reality (IVR) technologies had being used to enhance the performance of clinician tasks such as Narayan, Waugh, Zhang, Bafna, & Bowman [4] study. However, most of VR facilities for 3D visualization do not provide natural interaction that necessary in order to get most of benefit in IVR environment. In order to enhance the usability of the old method, it should be replaced with more user-friendly human-computer interaction interface.

In medical imaging, Tuntakurn, Thongvigitmanee, Sa-Ing, Makhanov, & Hasegawa [5] had proposed a natural interaction on 3D medical image viewer software by combining both hand and body gesture to control mouse cursor. Meanwhile, Kipshagen, Graw, Tronnier, Bonsanto, & Hofmann [6] had demonstrated a touch free input device for controlling the medical viewer. They had used 3D hand position generated from stereo camera that combined with open-source medical viewer and named it as OsiriX DICOM viewer that uses OpenCV library for hand gestures. Wachs et al. [7] in their studies had implemented a real-time hand gesture interface to manipulate objects within medical data visualization environment by using one-handed gesture. They used both dynamic and static navigation gestures and had used haar-like feature to represent the shape of hand. The gesture recognition system was used in sterile medical data-browser environment. Unfortunately, due to lack of training and testing set, there are some user confusion during doing the gesture and had suggested to use both hand to control the gesture rather than only one hand gesture and testing their system with more gesture vocabularies.

Another framework was proposed by Soutschek, Penne, Hornegger, & Kornhuber [8] where gesture-based user-interface had being used for the exploration and navigation through 3-D data sets using a time-of-flight (ToF) camera. In their studies, they had achieved high successfully rates for most of gestures their proposed using ToF camera. For the extension of their work, they had recommended an enhancement by integrating virtual button and hand gesture for selecting the volume of interest and do evaluation in clinical environment.

In cardiac visualization, human gesture also being used to give a real-life situation in diagnosis the heart disease. Ioakemidou et al. [9] in their studies had demonstrated a 3D heart visualization with hand gesture and haptic interaction to enhance the understanding of heart function while simulating it. To interact with the heart simulation, they had used open and closed hand as an input to user interface of the system. But still in medical visualization area, there are still no existing system that uses finger gesture interaction as an input to the user to interact with virtual heart. Taking account from this drawback, we want to propose a framework that uses finger gestures as an input to interact with the 3D cardiac visualization that can helps enhancing the way human interacting with device especially such critical environment.

3. Finger Gestural Tracking

Finger gestural tracking is a techniques that being employed to know consecutive position of the finger and also to represent object in 3D environment. Hence, a framework had being purposed to able the system to track the user finger in 3D environment. In purposed framework, the user are only allows to use their finger as an input to manipulate the 3D model. To interact with 3D heart visualization, all the commands were attached based on the hand finger gestures command which being executed without touching the display or the viewing screen. Therefore, before the system can recognize the user hand finger gestures that been done, there are several preliminary process that needs to be executed first in order to system work correctly. Figure 1 shows the hand finger tracking and gesture recognition of proposed system.

Fig. 1. System Framework

3.1. Hand Segmentation

Before the process of hand segmentation being done, the system will extracts the depth data from the Kinect sensor. After depth data being processed then the segmentation process will be executed. The aims of hand segmentation process is to separate the hands images from background images. It being done by setting a specify depth range where the hand gesture images will recognized. The depth range distance that being set into the system was 0.5m to 0.8m which an optimize distance for the segmentation process. The segmentation process will store the entire depth pixel between the specified ranges to be used for next process.

After that, the next process is to partition all the pixels into two groups of hand pixels data by using K-means clustering algorithm. K-means clustering is a method to partition all pixel data into two separated hand that being recognized same as implemented in Li [10] study. After the clustering process finish, the next process is to compute the hand contour by using Graham Scan that was developed by Graham [11] and a modified Moore-neighbour tracing algorithm that will be used to detect the hand contour. All the process being accomplished by using group of hand point that being stored from the previous process.

3.2. *Fingertip Identification*

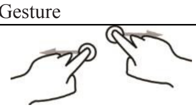
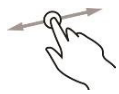
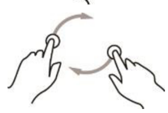
In order to identify the hand fingertips, there are several process and algorithm that being used in order to identify each fingertip that being used. The first process that need to be done is to scans all the pixels around the user hand by using contour tracing algorithm same as implemented in Li [10] study until the hand contours are detected. After the hand contour are detected, the next process are to detect the centre of the hand which is the user palms where is used for normalizing the fingers point direction. Finding the hand palms also is important in deciding whether the user hand is open or closed states and whether the fingers are bending or not. To detect user fingertips, the three-point alignment algorithm is being used where the data pixel are came from convex hull and hand contour data pixels that came out from the previous process. After successful detects the user hand fingertips, the next process is the gesture recognition where it will calculate the total number of hand fingertips that being recognized by the Kinect in order to decide gestures command to interact with 3D heart visualization.

3.3. Gestural Identification

In order to specific gestures that being done by the user, all the previous process must be successful conducted. The gestures that had being developed was specific by counting the number of fingertips that recognized by Kinect camera and then the system will executed the gesture commands to move or manipulate the 3D heart visualization. Meanwhile, Turk [12] had said that the primary goal of virtual environment (VE) is to provide natural and flexible interaction. Having using gestures as an input modality can helps meet those requirement. He also stated that human gestures are certain natural and flexible and often efficient and powerful especially compared to with the alternative interaction modes. Although sometimes interaction technologies are overly obtrusive, awkward or constraining, the user experience is degraded and also imposes high cognitive load on the user where it became burden to a successful VE experience. But all this can solved by given more user training on the system and introduced be more specific and natural gestures where it can helps improve the user cognition to use the system.

To meet all the requirement, the system had introduced a new gestures by using hand finger where it is key activities in designing touch less interface besides having only using hand palm that may higher user cognition to interact to the system. When choosing specific gesture for the interaction, it must takes both consideration the hardware characteristic of the input device and the application domain where the action takes will takes place. There several fingertips gestural that being included inside the system such as in the Table 1.

Table 1. Finger Gesture Identification

Finger Gesture	Hand Detection	Description	Gesture
Zoom In/Out	Using one-finger from both hand	To gain better focus of a region with large scale factor	
Spread/Pinch	Using two finger from one hand	To gain better focus of a region with small scale factor	
Drag	Using a finger from a hand	To point out the area of volume and drag in or out the volume of the displays region	
Rotate	Using a finger from each hand	To rotate the 3D volume in 3D space	

4. Result and Discussion

In this section, it will explains more details about the implementation for each gesture and it effects to the rendered 3D cardiac volumes. Each gestures has its own specification and commands to the cardiac model in the system. There are six gestures that able to be used by user to navigate to the cardiac visualization. Before we described each gesture, this section first will described about the environment details of the project development and then about the result of project.

4.1. Environment details

The interface has been written using C++ language and had being built on open-source and cross-platform libraries, which had combined and extended to support medical imaging processing and interaction functionalities. To able Kinect to generate raw depth image, OpenNI library had been used which is an open-source framework for natural interfaces together with middleware component NITE, which provides a closed-source that being used to communicate with the Kinect device.

For the gesture control interface was described in the paper, it was integrated with VTK which open-source visualization toolkit that being developed for visualization uses especially for medical purposes where they need to correct represent and navigate the data at different spatial and temporal scales. Besides that, VTK had being developed allows new module to be added to support computer-aided medicine application together with the gesture interaction to 3D visualization of cardiac data. In order to test functionality of system work accordingly, the project was divided into several type of scenario which based on hand finger gesture that being specific into the system to interact with volumetric data.

4.2. Scenario A

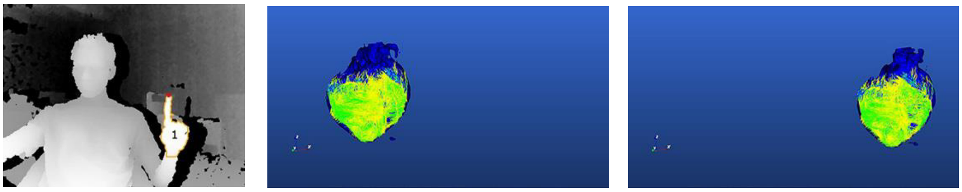


Fig. 2. Drag gesture scenario

For the first scenario, the finger gesture that being used is drag gesture. The drag gesture allows the user to drag the model from the initial position to a new position. In the order to allow the users to move the model, only one finger needed to do the process. The cursor or the point of user hand needed to touch the surface of the model to move it. To drag the model, the hand of the user must be at valid distance that already being set to 500mm to 800mm. At this distance, the system can recognize the user hand gesture.

4.3. Scenario B

Fig. 3. Zoom gesture scenario

For the second scenario, the gesture that introduced is zoom-in and zoom-out gesture. For zoom gesture, it allows the physician or research to look more detail inside the 3D cardiac model. Not only that, it also helps the give better understanding about the patient heart. In order to use gesture, the users must use one finger from each hand to able the cardiac model to be zoom. The zoom-in and zoom-out also allows the researcher to analyse the symptom inside the patient heart where they able to see up to cell inside it.

4.4. Scenario C

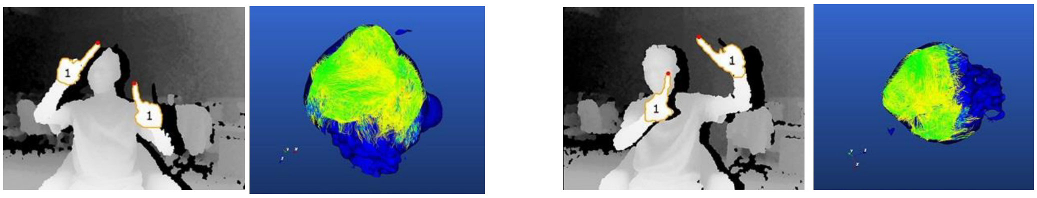


Fig. 4. Zoom gesture scenario

Meanwhile, another gesture is rotate gesture. The rotate gesture will helps the researchers to see the part that not see in view where by rotating it, the researcher can the hidden part of the 3D model. To use this type of gesture, the researcher also must one finger from each hand and then rotates it to up and down.

4.5. Scenario D

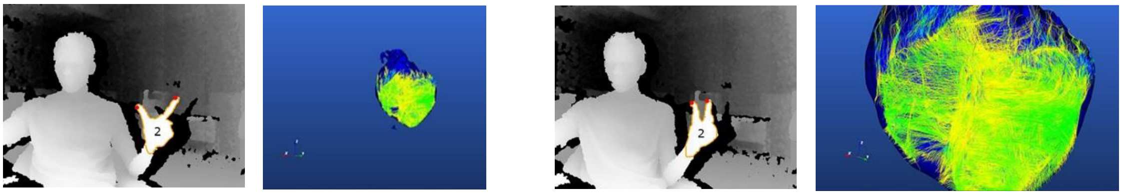


Fig. 5. Spread and Pinch gesture scenario

The last gesture inside the system is spread and pinch gesture where it same capability same as the zoom gesture. The different from zoom gesture, it's only required the user to only use two fingers from a hand. Besides that, for spread and pinch gesture the zoom scale that being done are in small scale different from zoom-in and zoom-out gesture.

By allowing the researchers to use the finger gesture to manipulating the cardiac model, it not only can helps the researchers to gain more insight about the patient heart but helps to prevent the spreading of the unwanted virus by touching any physical device when the surgeon in operation room where its free from any physical device. Moreover, the use camera sensor like Microsoft Kinect also does not requires special lighting condition where as we know in the surgery room the lighting condition are swallow and only focusing on the patient.

5. Conclusion

As conclusion, the new proposed system had being developed that uses non-touch based gestures for semi-immersive 3D virtual medical environment. The sensor camera technology was used to enable gesture that had specifically design and developed by considering the user skill and needs of the clinician when doing diagnosis where they need to interact with 3D virtual heart in order to detect symptoms of the disease.

As mentioned early, the aims of this research is to enhance the performance and to give new interaction way to daily clinician tasks by giving them to manipulate and examine the three-dimensional heart that reconstructed from the scan data by using hand finger gesture. Besides that, it is also a strong belief the medical experts especially the cardiologist can obtain great advantages by the virtual technologies where it easy their works by providing them with natural and intuitive manner to interact in 3D space not only by using their hand but only also their fingers.

Lastly, we also conducts a formal usability evaluation of the proposed solution that involved the user. By doing that, the data that we collects will be further analysis to validate the proposed finger gesture and to get better understanding of usability issues that not yet being recognized. For the future works, we planning to add more finger gestures to interact with volumetric data. Finally, in order to provide a usable tool for computer-assisted education and trainings for clinicians, a semi-immersive multi-user interaction approach can be proposed where the system can detect more than one user.

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