User-defined Gestures for Virtual Heritage in Three-Dimensional User Interface: Motion Gestures

Normala Rahim, Tengku Siti Meriam Tengku Wook, Nor Azan Mat Zin

Abstract: Natural User Interface (NUI) is the 4th paradigm in the user interface after Command Based Line (CBL), Graphic User Interface (GUI) and Windows, Icon, Menu &Pointer (WIMP). NUI allows users to make movements and displays on the virtual world resembling human movements in the real world. There are two components in NUI: surface gestures and motion gestures. Device development in surface gestures involves input in touch (taps, swipes, press and drag) and motion gestures (hand, arm, eye, body and head). Hand-tracking technology has been widely used in the field of Virtual Reality (VR).It allows users to use hand gestures to interact with the virtual environment. Research on acquiring the hand gestures of real user's needs is still lacking and so is the implementation. This paper presents results of a guessability study of actual user hand-gesture movements in command development for virtual heritage. A total 312 gestures were obtained from 13 respondents for 24 selected tasks. This study proposes a list of specific gestures set by the actual users. The implication from the study is relevant to the design of hand gestures for virtual heritage interactions.

Keywords: Human Computer Interaction; Natural User Interface; Virtual Heritage; Gestures-based interaction; Guessability.

I. INTRODUCTION

VR technology has thrived with a variety of advanced devices that require users to wear them on limbs such as HMD, glove and body tracker, or do not require users to wear them besides advanced technology that can recognize human gestures such as Kinect and Leap motion. All of these devices can be used by users to interact with the virtual environment, giving users a sense of immersive experience like being in the real world. The immersive concept can increase the sense of user presence and provide intuitive and responsive technology. This study focuses on the field of VR in a virtual heritage domain. Motion gestures or gesture-based interactions are integrated to allow users to interact with virtual heritage system which takes hand gestures via leap motion device. This device has the advantage of allowing users to interact naturally and is cost-effective. Fig.1 shows the leap motion device.

Fig. 1 Leap motion
Source: (Amazon, 1996)

Two input modalities supporting NUI are the touch through display and set of motion that the sensor can recognize(Ruiz, Li, & Lank, 2011). They are two different types of signals where the user can gesticulate in two dimensions. The first dimension is when the user interacts with the system via touch. This is recognized as the gesture on a two-dimensional surface. The second dimension is when the user uses the movement to interact, or be known as a gesture through motion. The main focus of this study is on the second dimension which is the motion gestures.

The purpose of this study is to identify what and how natural hand inputs are required by real users for virtual heritage. To achieve this, there are two questions to be answered: (1) What is the appropriate gesture set for the user to interact with the virtual heritage system? (2) Is the gesture appropriate and easy to carry out for specific tasks?

This study was conducted based on Wobbrock et al., (2005) study that used guessability technique. The guessability technique is implemented to obtain a set of gestures from real users of virtual heritage system. Each task is briefly described to the respondent. Then they are asked to choose an appropriate gesture related to the given task. A total of 24 tasks were selected, including the task of controlling the video simulations. The results of this study are a list of special gestures set for virtual heritage and the subjectiveevaluation by actual users on the designed gestures based on two aspects: ease of use and easy to remember.

II. RELATED WORKS

Technology becomes a state-of-the art where it can accommodate input recognition for human gestures. This computer vision technology allow humans to interact more naturally without depending on the device that needs to be attached to the human body(Vatavu, 2011).

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It offers ease in humans interactions by using any parts of the human body such as hands, legs, head, eyes and so forth.

Human Computer Interaction (HCI) has the same characteristics as interaction among humans. Unnoticedly, the interpretation of human interaction with the machine has occurred much the same as human with humans interaction(Vatavu, 2011). According to Sharmaand Kurian(1989)“Verbal and non-verbal human behaviour form the events for human communication. Verbal behavior makes use of language, while the nonverbal behaviour employs body postures, gestures and actions of different kinds”. Therefore, gesture-based interaction is the nonverbal behavior category where humans employ touch and motion through gestures to communicate.

Gesture-based interaction

Gesture interaction has long been considered as an approach that provides a more natural and intuitive interaction method in HCI. The first gesture interaction started from PhD research by Ivan Sutherland (1963) which produced the Sketchpad. Sketchpad is an early gesture designed interface founded on stroke-based signals by using pen for manipulation of graphic objects on tablet displays.

This gesture designed interface has been widely accepted in the HCI community. It began with the inspiration of stroke-based signal interaction which uses text media as inputs to personal digital assistants (PDAs), mobile computing and pen-based devices (Buxton et al., 1983;Cohen et al., 1997). Since then, the implementation of this interface design has greatly facilitated users to interact intuitively and more expressively. In the field of HCI, it has gained popularity among researchers to constantly search for new interactions that promotes ease of use for users to interact with computers.

Researches about gesture interactions are in the context of NUI. The common question that appears in NUI research is on how the five human senses can be utilized to interact with electronic devices. The idea is to achieve the level of user experience in the context of daily use without having to learn ways to handle complex devices. According to Norman(2010),NUI is a non-natural but human way of interacting with computers, similar to natural interaction between human beings. Since the use of NUI has become widespread in literary studies(Arbeláez-Estrada & Osorio-Gómez, 2017; Kaushik & Jain, 2014a, 2014b; O‘Hara et al., 2013; Wigdor & Wixon, 2011), NUI is also used in a context that is synonymous with "natural".

Karam (2006) and Karam andSchraefel (2005)proposed a taxonomy of the interaction of gestures from technological aspects; two different forms of input interaction namely perceptual and non-perceptual. Perceptual is an input that can recognize gestures without using any additional electronic device. Non-perceptual input interaction requires the electronic device to be employed by the user so that the interaction process can be executed. These devices can be electronic gloves, optical devices and many more. Fig. 2 shows the gestures interaction classification.

Gesture interaction has been widely implemented in various application domains such as virtual reality, e-learning (Hussain, Wook, Noor, & Mohamed, 2018), real estate, games(Salihan, Rahman, Ali, & Mohd, 2018;Shapi’i & Ghulam, 2016), rehabilitation games (Shapi’I et al., 2015) entertainment, communication and so forth. Chen, Chen and Wu, (2013)conducted research on the effects of using signaling interactions in the form of perceptual input by utilizing camera technology for recognition and implemented in the digital leather puppet application (Chen, Chen, & Wu, 2013).

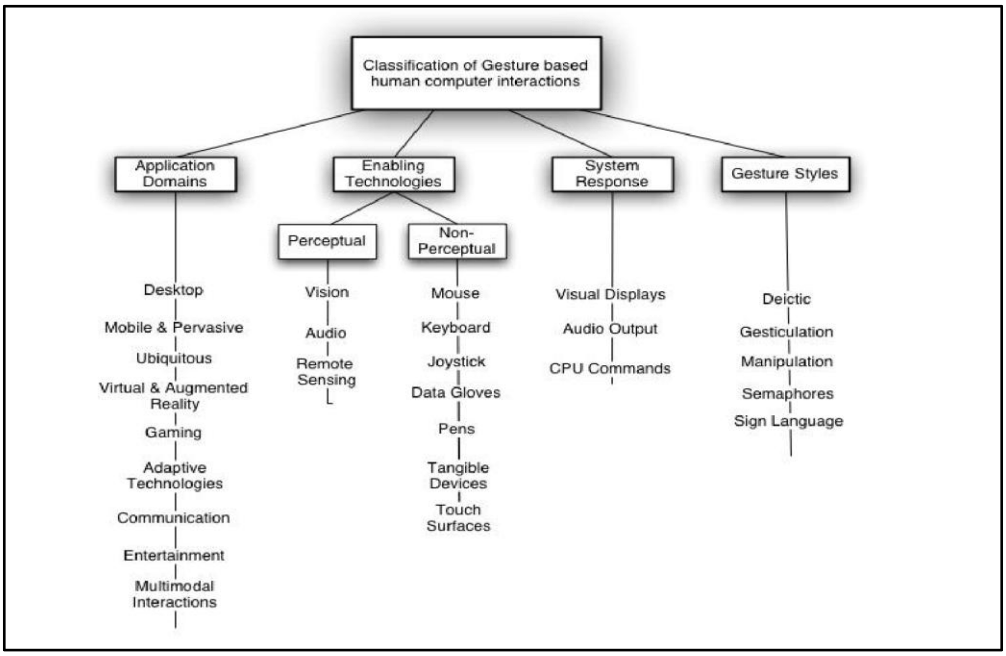

Fig. 2 Classificationof gesture-based interaction
Source: (Karam, 2006)

In addition, Rautaray, Kumar, & Agrawal, (2012) claimed that implementation of the hand-gesture technology allowed user to interact with intuitive, natural, powerful and easy to learn. Thus, user's cognitive load can be reduced.

Gesture interaction is implemented through Human gesture modalities. Human gesture modalities are divided into two: surface gestures and motion gestures. Surface gestures are interactions that require human touches on the surface of the device. Motion gestures are human-system interaction by utilizing the body gestures recognition technology. Research in motion gestures focuses on the interaction techniques using motion inputs and tools to design human movement motion(Ruiz et al., 2011). Table 1 lists the variety of research that has been implemented for various different motion gestures modalities such as body, head, fingers, hand and eye or gaze.

Motion gesture in virtual heritage

Research in gesture-based movement domains, also known as motion gestures, is gaining momentum and has grown rapidly with the help of various sophisticated, inexpensive and easily available technologies such as Microsoft Kinect and Leap Motion devices. Motion gesture is an approach towards interactive systems, intelligent computing and efficiency in interactions between machines and humans. According to Kaushik and Jain (2014a, 2014b),gestures are the movement of the body used to communicate with each other. Gestures are expressive movement of the body including physical action of fingers, hands, arms, head, face or body(Sagayam & Hemanth, 2016). To ensure effective and successful communication, both entities, presenter and receiver, need to obtain the same set of information for each gesture. There are two categories of different gestures static and dynamic. Static gestures are permanent gestures such as stop signals while dynamic gestures are fluctuating or moving movements repeatedly like hand-waved gestures(Pavlovic, Member, & Sharma, 1997). The design and development of hand gesture-based interfaces must comply with the gesture design features such as low cognitive load, user friendly, flexible and user natural (Thewsuwan & Chiracharit, 2015). The wsuwan and Chiracharit (2015) conducted studies using device such as Microsoft Kinect. This device is an example of an ideal and yet inexpensive device for whole or part of body gestures recognition. However, since the device has a low resolution of only 640 x 480 pixels, fine motors recognition such as hand gestures become inaccurate. This affect the system manipulation.

Table. 1 Human gestures input modalities in gesture-based interaction

Num.	Author	Surface gesture					Motion gesture				
		Body	Head	Fingers	Hand	Eye	Body	Head	Fingers	Hand	Eye
1	(Rozado, Moreno, San Agustin, Rodriguez, & Varona, 2015)					/					
2	(Leng, Norowi, & Jantan, 2017)				/						
3	(Manresa-Yee, Varona, Perales, & Salinas, 2014)		/								
4	(Ding & Chang, 2016)	/									
5	(Long, Fu, Zhu, & Ge, 2015)			/							
6	(Rautaray et al., 2012)									/	
7	(Dontschewa, Rosmann, Marinov, & Overview, 2016)						/				
8	(Manresa-Yee et al., 2014)							/			
9	(Rozado et al., 2015)										/
10	(Long et al., 2015)								/		

Gesture-based technology has been implemented in various applications such as system developments for disables in hearing impairments. It allows children to interact with computers, design forensic identification systems, communicate through gesture recognition for navigation and controlling virtual environments and communicate in video conferencing.

According to Sagayam and Hemanth (2016), in gesture-based input technology, sensory approaches require recognition and interpretation of head movements, eyes, face, hands, arms or even the entire body. However, among the body part, hand is the most effective because of its consistent function and power.

Lu et al., (2014)developed a prototype for mobile devices where users can interact with hand gestures. Users are required to wear sensing devices on the arm. Through this device, users use hand gestures to interact with mobile. Findings have shown that interactions based on gestures is feasible and works better when used by experienced users. However, its efficiency requires improvement. The results on user-based experience shows that the developed prototype is accepted by user. The signal-based interaction is intuitive and easy to learn which promotes its acceptance among mobile device users.

Research conducted by Rautaray et al., (2012) is an application design that uses visual recognition and handheld gesture detection techniques. In this study, inexpensive input devices were developed to enable users to interact with virtual games. The application utilized seven gestures which are move backward, pause, move forward, grab, throw, punch and jump. These gestures are used to manipulate the virtual game.

The remainder of this paper is organized as follows: Section 3 discusses the methodology which includes research participants, procedures and the set of tasks examined. The results of guessability study based on aspects of ease of use and easy to remember will be presented in Section 4. Section 5 sums up the paper with discussions and conclusions.

III. METHOD

To get user-defined gestures, the researchers demonstrate the selected task list to respondents for interacting with the existing system of Terengganu Virtual Museum(Tengku Wook et al., 2016).Then, respondents are required to perform all the tasks and choose the appropriate gestures for each task. Respondents need to follow the think-aloud protocol and also evaluate every gesture for ease of use and easy to remember aspect.

Developing a user-defined set

The objectives of this study are (1) to produce a set of gestures acquired and determined by users for virtual heritage and (2) to assess gesture sets in terms of ease of use and easy to remember. Hand gestures were obtained from 13 respondents. Respondents were required toprovide suggestions on how to design appropriate gestures to interact with the virtual museum system. Then, respondents perform the gesture assignment. Finally, each respondent assessed the implemented task using afive-point Likert scale instrument based on the following criteria:

- The selected gestures are easy to use
- The selected gestures are easy to remember

Each session takes about 1 hour to complete. Each performed task is recorded using the camera and video camera. The approach is based on the computational methods proposed by Wobbrock et al., (2005) and Wobbrock, Morris, & Wilson, (2009)for assessing the score of consent for every task. The value obtained means that the higher the score, the higher the level of consent for each of the suggested gestures. The approval score is calculated based on the following equation:

$$A = \sum_{P_s} \left(\frac{|P_s|}{|P_t|} \right)^2$$

Where,

- Pt = total number of gestures within the task
- t = a task in the set of all tasks T
- Ps = a subset Pt containing similar gestures,
- A = agreement score in range between zero to one.

Selection of task

The total number of tasks in this study is 24, 19 tasks are based on Piumsomboon & Billinghurst(2013)and 3 tasks are based on Wobbrock et al. (2009). In addition, 2 tasks are related to the functionality of virtual heritage. The total number of these 24 tasks are compiled into 5 categories: environment navigation, object manipulation, menu, browsing and simulation. Each category of group is classified according to the same tasks. Table 2 shows a list of the 24 selected tasks for the 7 categories.

Table. 2 List of selected tasks for virtual heritage interaction

Num	Gesture tasks group categories		
	Task categories	Tasks code	Tasks
1	Environment navigation	EN1	Go
		EN2	Back
		EN3	Pan left
		EN4	Pan right
		EN5	Tilt up
		EN6	Tilt down
		EN7	Zoom in
		EN8	Zoom out
2	Object manipulation	OM1	Grabbing
		OM2	Rotate left
		OM3	Rotate up

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		OM4	Rotate right
		OM5	Rotate up
		OM6	Rotate down
			Release
3	Browsing	B1	Next
		B2	Previous
4	Menu	M1	Close
		M2	Select
5	Simulation	S1	Play/resume
		S2	Pause
		S3	Stop/reset
		S4	Volume up
		S5	Volume down
		S6	Mute

Participants

Thirteen respondents (7 females and 6 males) were involvedas volunteers. Range of respondent age is 21 to 35 years (mean = 25.2years and SD = 4.85 years). Respondents must have minimal knowledge of experiencing gesture-based interface such as touchscreen and air-gesture based devices. All participants used PC regularly with average usage in a day of 7.54 hours (SD = 3.4). The study was conducted in computing research laboratory. All respondents owned touchscreen devices and used them for an average of 8.3 hours (SD = 4.09) daily. Six respondents had some experience with gesture-based interface devices such as Microsoft Kinect, Leap Motion, webcam and Xbox 360.

Procedure

The researchers provided a brief explanation on the implementation of the experimental method. First, researchers demonstrate how to interact with the system and explained the main purpose of the experiments. This is to simplify and give a clear understanding of the experiment to respondents. Each respondent is given a paper that describes all selected tasks. Respondents are required to follow a think-aloud protocol and then provide a level of rating for each proposed gesture based on easy to use and easy to remember aspects. This method is performed to observe the unrevised behaviors, in accordance to Wobbrock et al. (2009)'s study.

Respondents are required to map the gestures performed accordingly to their demand and preferences. Respondents are then instructed to rate the gesture using five point Likert scale in term of easy to use and easy to remember.

IV. RESULT

At the end of the study, a total of 312 suggestion of gestures were collected from 13 participants who performed 24 selected tasks. The collected data includes video recordingsofthe front facing participants doing their tasks and a sheet of subjective ratings for each gestures. From this data, a consensus set of gestures for virtual heritage application was identified.

Designing user-defined gesture set

The user defined gesture consists of two sets which are consensus set discarded set (Ruiz et al., 2011; Wobbrock et al., 2009). Consensus set is the user's preferred gesture with total score of 1(all agreed) while the discarded set isthe one which gets a lower score of less than 1. For this study, gestures score 0.8 to 1 are used while score less than 0.8 are discarded.

In this study, gestures that are more or less similar or have the same direction are consistently categorized in the same category. For example, go and back tasks, respondents use open hand, holding hand, point finger, hand to move forward or backward. Although this gesture has various poses but the important features of the gestures that distinguish between go and back with the same direction are categorized in the same group.

From 312 gestures, 234 gestures are the consensus set gestures which denotes 75% from the total gestures. Gesture setconsists of a navigation environment (22.2%), object manipulation (38.9%) and video simulation (38.9%). Gesture score below 0.8 which are discarded sets totalled78 gestures.

Level of agreement

The consensus scores for all 24 tasks are shown in Figure 3. The result indicates that 13 gestures obtainedgood consensus scores with a maximum value of 1. These gestures are EN1, EN2, EN3, EN4, OM1, OM2, OM3, OM4, OM5, OM6, M2, S2 and S3.The gestures of M1, S1, S4, S5 and S6 are chosen because the score value is more than 0.8.The result also shows that6 tasks from navigation environment and browsing categoryhave the lowest consensus score.

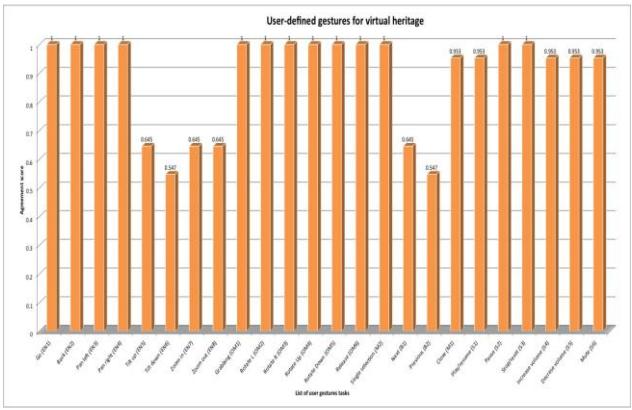

Fig. 3 Agreement score for 24 tasks

A user-defined gesture set

Out of 24 gestures tasks, only 18 gestures are selected where these gestures exceeded the scorepoint of 0.8. Gestures with low score indicates the low level of user agreement which implies that the respondents are not confident with the gestures. Therefore, gestures that get a low score are categorised into the discarded set. Gestures to be used for virtual heritage are the static hand-gestures. Static hand-gesture is a permanent gesture without repeating motions. This static hand-gesture gained high score due to the ability of the system to recognize user's hand motion, compared to the dynamic hand-gesture. Dynamic hand-gestures are moving gestures such as pan left or pan right and tilt up or tilt down.

The complete virtual heritage hand gesture set is shown in Fig. 4 while the function of each gesture is described in Table 3.

Table. 3 List of selected tasks for virtual heritage interaction and gesture style clarification

No.	Gesture tasks group categories			
	Task category	Task code	Task	Gestures style
1	Environment navigation	EN1	Go	To move forward, you need to hold your right hand then point your hand forward slightly. To pause, you need to open the palm of your hand in a state of five-fingers open facing down.
		EN2	Back	To move backward, you have to grasp the right hand in the fingertips to the top. To pause, you need to open the palm of your hand in a state of five-fingers open facing up.
		EN3	Pan left	Use the right hand for pan-left or move your right hand from left to right to view the environment.
		EN4	Pan right	Use the right hand for pan-right or move your right hand from right to left to view the environment.
2	Object manipulation	OM1	Grabbing/pinch	Use the left hand to manipulate or pinch the artifacts using thumbs and index finger together to pinch 3D artifacts.
		OM2 OM3 OM4 OM5 OM6	Rotate left Rotate up Rotate right Rotate up Rotate down	Use the right hand in the pinching the artifacts then turn to the right, left, up and down to view the 3D artifact as a whole position or 360 degree.
			Release	Use thumb and index finger by positioning them to release artifacts that are held.
4	Menu	M2	Single Selection/point	Point the right index finger to the artifact or button, then point the index finger forward for the purpose of activating artifacts, buttons or videos.
		M1	Close	Use single selection or point gesture and point to the video control button to activate or disable the button.
5	Simulation	S1 S2 S3 S4 S5 S6	Play/resume Pause Stop/reset Volume up Volume down Mute	

The subjective rating - ease of use and easy to remember

The study finds that there are two sets of gestures: consensus set and discarded set. comparing both sets, subjective ratings on 'ease of use' is higher than the discarded set with average scores of 4.39 (± 0.54) and 4.21 (± 0.32) respectively. For 'easy to remember', consensus set also yields higher rating than the discarded set with mean value of 4.40(± 0.53) and 4.25 (± 0.29) respectively. The results show that the user-defined gestures set is easy to use and easy to remember compared to the discarded set

V. DISCUSSION & CONCLUSION

In this section, the implications of the findings on the design of hand gesture interaction for virtual heritage are discussed and conclusion made. Hand gesture design includes the gestures for virtual environment interaction navigation, virtual object manipulation and information display or video simulations.

The designed hand gestures obtained from this study can help designers and application or software developers to determine the hand gestures. Gestures for different users are dissimilar for distinct tasks. The results obtained in this study can aid designers and developers to provide a library-codes for virtual heritage. Additionally, the hand gestures designed 00areeasy-to-use, and easy-to-remember gesture design obtained from real users. These hand gestures will help users to interact more naturally and reduce their cognitive load considerably. According to The wsuwan and Chiracharit (2015), to develop the design of the hand-based gesture interface, it is important for the designers to be more concerned on the low cognitive load aspects, friendliness, flexibility and re-designed element for users.

In this study, even though pan-left and pan-right gestures are rated the score of 1, these gestures are not used in developing the virtual system to avoid system inefficient performance which may cause discomfort to user. In addition, go-pause and back-pause gestures are proposed for users to stop for a while when they explore the virtual environment.

In this work, guessability results for virtual heritage interactions are presented. The results show that the appropriate gestures are required by real users. Hand gestures obtained are easy to use and easy to remember by users. Hence, the contribution of this study is the design of natural hand gestures comprising the consensus set for virtual heritage, as illustrated in Figure 4.

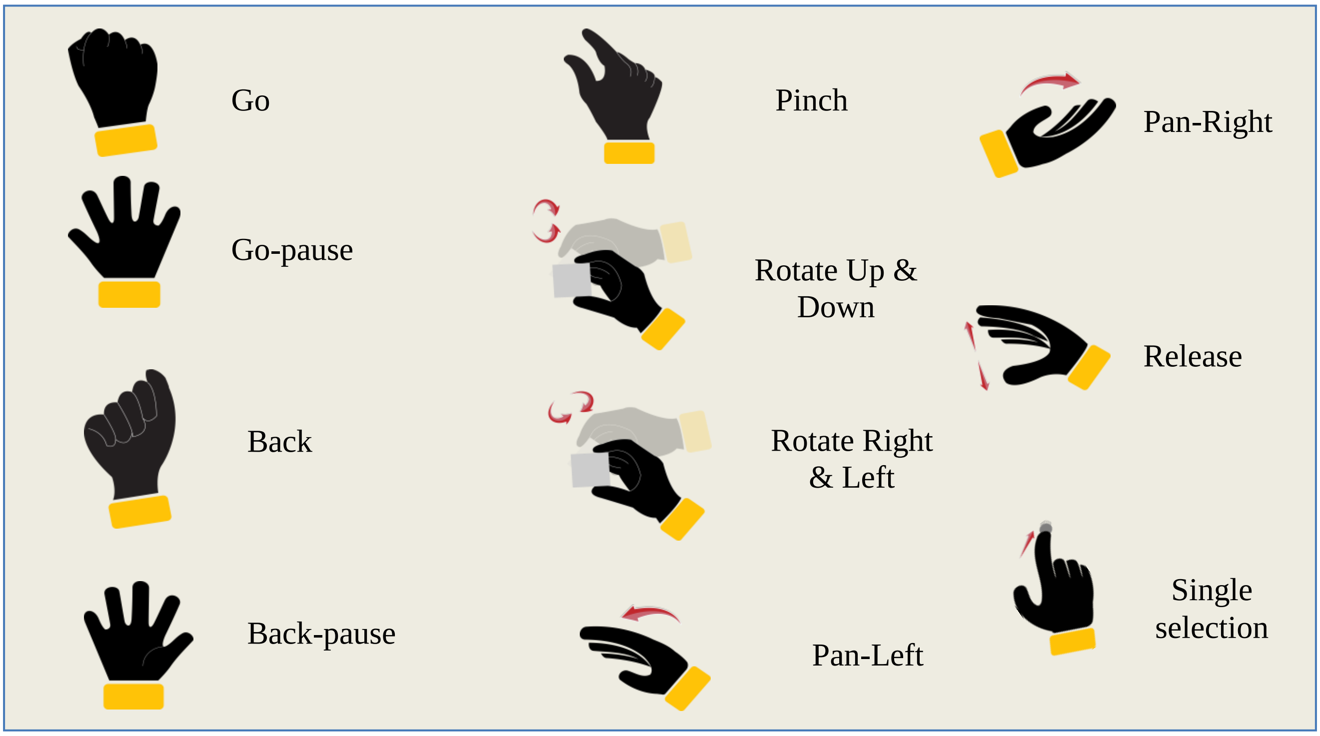

Fig. 4 The user-defined gesture set for virtual heritage.

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