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Research paper



Head Gesture Recognition and Interaction Techniques in Virtual Reality: a Review

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Abstract

This paper presents a review of head gesture recognition using specific models by year timeline. The related minor topics of this project also mainly discuss (a) Virtual Reality interaction techniques, (b) Virtual Reality head gesture interaction, and (c) Mobility Impairments using Virtual Reality (VR) System. This study contributes to an exploration of a different body part of the gestural input, which is the head gesture as the main interaction approach in virtual reality (VR). This review also prepares new insights of head gesture from how the model theoretically recognizes the gesture and implemented as input modality and interaction in virtual reality (VR) environment.

Keywords: *Head Gesture Recognition; Mobility Impairments; Virtual Reality Interaction Technique; Virtual Reality*

1. Introduction

Uprising virtual reality (VR) in numerous industries like entertainment and education had forced the production of various virtual reality system. Many discoveries nowadays exist to make the virtual world as close as possible to interact.

Head gesture is one of body interaction approaches discovered and used as an input modality. By using 3-dimensional (3D) interfaces as an interaction platform, the gestural input recognized by the yaw, pitch, and rolls of user's head movement [6-9]. Other interaction techniques include hand pointing gestures, eye-gaze selection based, gaze-pinch interaction and leap motion. The head gesture interactions generally classified into several types: being Idle, rotating left, rotating right, tilting upward, tilting downward, leaning left, leaning right, shaking and nodding [10].

Through virtual reality devices like Oculus Rift [1] and HTC Vive [2], the interaction between real and virtual world becomes possible to communicate including mobility impairments user. However, the VR interaction also faced problem in functions limitation such as misunderstand head gear's gestures commands, object-point selection, that mostly leads to weaknesses like motion-sickness and dizziness. Therefore, the study of head gesture recognition and virtual reality interaction techniques has been created in this review to support the issues. Besides, to identify the limits of VR System and its interaction functions in Human-Computer Interaction (HCI) perspective, a few insights into mobility impairments is used to help understand and address the issues.

Recently, the world is eyeing 3D virtual reality training simulations including surgery procedure simulation [3]. The simulation appointing safety measures and highly effective way as the critical aspects. The system provides a variety of scenarios, randomized conditions of visibility and perfect situational awareness for observers or controllers to coach. In surgery procedure simulation, the patient's metrics displayed inside the virtual reality headset employed, allowing the surgeon to keep track of heart rate, brain function, and blood pressure [4]. Furthermore, with an uprising of the entertainment industry, the motion sensors including Microsoft Kinect Sensor [5] have become more recognized for facilitating natural Human-Computer interactions at low cost in virtual reality. Besides being driven by Kinect that uses motion tracking to track the motions of an object, the users' body motions and voice commands used as the input in Kinect to control navigation and operation within the Virtual Environment. Although the studies available are mostly focusing on the vision-desktop monitor as the leading platform devices, the survey on eye-tracking sensors in wearable devices also hugely explored.

Despite the massive interaction discoveries applied in virtual reality application, the head gesture interaction approach is still newly employed. It expected that this study review could maximize the head gesture interaction and get access to real-time virtual reality platform.

In this paper, the report on how head gestures are recognized using theoretical models and algorithm by year timeline proposed. Aside from head gestures, related topics reviews on this proposed project: Virtual Reality Interaction Techniques, Mobility Impairments using virtual reality system also discussed.

2. Related Works

2.1. Head Gesture Recognition

Many researchers have previously examined the recognition of body gestures including head using Markov Models as the main reference approach starting from early 1990 until now. In the year 1996, a study on head gestures has done by Morimoto [6]. The study was extensively carried out using Hidden Markov Models (HMMs), an extension of discrete Markov chains theory to recognize subsets of body-parts gestures (head gestures). Using optical flow algorithm to estimate image rotation axis of yaw, pitch, and a

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roll of user's head, the authors estimated the angles specified into seven observation symbols. These observation symbols then converted and processed by HMMs to correspond to four output gestures: Yes, No, Maybe and Hello. In placing more emphasis, Kapoor claimed that head movements (nods and shake) with pupils-position based are important as observations and can detect by the discrete Hidden Markov Model-based pattern analyzer [7]. Furthermore, Tan performed face detection and eye-tracking to produce a direction [8], which acts as an observation to be translated into consecutive frames [6-9]. This study can be supported by Terven [9] through their research conducted in 2014. By using the same model (Hidden Markov) [6-9] with the presence of a new system, the recognition of head gestures increased into six types: nodding, shaking, turning right, turning left, looking up, and looking down. By breakthrough, which was the limitation of head movement, the authors benefit using a robust method to estimate motion based on SIFT features (detecting and tracking the face) [11]. Since previous works [6-8] only focused on making use of HMMs with different states, this study works with a system that uses fixed position. The fixed position commonly used in applications such as robotics and Human-Computer Interaction.

Following a similar study with slightly different methods (Cascaded Hidden Markov Models structure), Zhao findings [10] presented an approach to recognize real-time head gestures. Compared to past study that mostly used computer vision based system [6-9], the authors potentially used Head-Mounted Display (HMDs) as specific assistive tools that can generally be adapted to work with virtual reality system and track user's head motions. With the proposed Cascaded Hidden Markov Model (CHMM), the system recognized another three head gestures: Being Idle, rotating left, rotating right, tilting upward, tilting downward, leaning left, leaning right, shaking and nodding.

As previously stated, the head gestures have been recognized by the abundant studies [6-9] using Hidden Markov Models as the main gesture technique recognition. This paper seeks to review head gesture recognition techniques while discussing the analyzed topics regarding virtual reality interaction approach of head gestures interaction focusing. The figure 1 below shows a timeline of head gesture recognition presents by years published and authors involved.

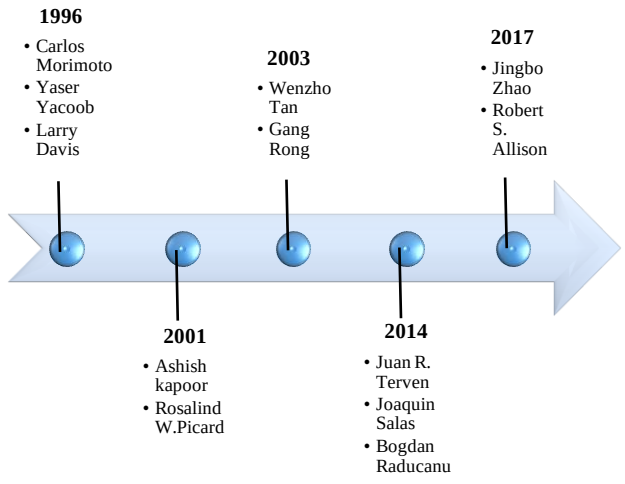

Fig.1: Head Gesture Recognition Timeline with Authors' Names

2.2. Virtual Reality Interaction Techniques

A tremendous increase in virtual reality had overcome the limitations and covered much more controllers and techniques used in virtual reality interaction. Virtual reality systems including Oculus Rift uses virtual pointers as controller [1]. Meanwhile, leap motion has hand tracking capability that enables conscious control entirely based on physical world gesture manipulation without controller [12]. This show how the assistive devices are driving their function to integrate well with virtual reality.

The past publications on the techniques to interact with virtual reality also hugely presented. According to the study by Piumsomboon on different natural eye movements, three novel interaction techniques were proposed [13] based on eye movements consisting Duo-Reticles (DR), Radial Pursuit (RP), and Nod and Roll (NR). The study was evaluated using HTC Vive on laptop PC and Pupil Labs eye tracker to stream eye-gaze data input to the laptop over Ethernet. The Duo-Reticles (DR) simply used spatiotemporal based on selection techniques where reticle alignment is needed to trigger the selection. Meanwhile, radial pursuit used eyes lock onto moving object (smooth pursuit) to select the cluttered object target. Lastly, Nod and Roll (NR) utilized the alternate input of eye gaze and head gesture as interaction approach where natural vestibular-ocular reflex (VOR) acts in providing gaze stabilization during selection.

In placing more emphasis, Suen Pai claimed that eye-gazed-based also uses interaction technique in virtual reality application [14]. The authors used eye-gaze focus depth as an input modality and determined the usability of proposed system by comparing two different methods: scroll-based and gaze-based. Furthermore, the findings from Pfeuffer explored the combination of gaze and pinch (freehand input) for 3D interaction in virtual reality [15]. The study had brought direct manipulation gestures such as pinch-to-select or two-handed scaling to any target seen by the user. Besides, a recent study has used navigation as the main approach to interact with virtual space. As stated by Suen Pai in their second study, orbital motion technique is used for navigation and interaction in computer-aided design (CAD), data visualization, and for virtual tours [16]. This claim can be supported by the similar study done by Sargunam using head-mounted display device to help navigation and virtual view as the user rotates his head. The study examined two semi-natural techniques for seated viewing: Amplified guided head rotation and guided rotation techniques [17]. However, these findings reported users having sickness problems because of constant adjustment during the preliminary test.

2.3. Virtual Reality Head Gestures Interaction

Head gestures generally discovered from eye-gazed-based inputs and tracking device exploration in virtual reality research. As mentioned by Piumsomboon, head gestures act as discrete inputs for tasks involving controlling [13]. By using eye-gaze indication, the object of interest is targeting while head nodding detected by vertical direction of head acceleration, which is measured using Head-Mounted Display's (HMD) head orientation changes. This study seeks to discover more detection of head rolls and nods (RN) input commands: nod, roll left and stay, roll right and stay, roll left and return, roll right and return, roll left then right, and roll right then left. This can be supported by a similar study done by Zhao using six Degree-of-Freedom (DOF) hybrid optical-inertia tracker of Oculus Rift DK2 for head motion tracking at 75 Hz [10]. The angular velocities of head motions used as angular velocities (yaw, pitch and roll) that directly reflect the user's head movement and direction. In another study conducted by Gandrud on predicting destination using head orientation and gaze direction, nVisorST 50 optical see-through head-mounted display equipped with Arrington Research ViewPoint eye tracker was utilized [18]. Table 1 below shows the overview of head gestures recognition while table 2 shows virtual reality interaction techniques.

Table 1: Head Gestures Recognition

Research Title		Year	Techniques	Evaluation overview
Recognition of head gestures using hidden Markov		1996	Hidden Markov Models (HMMs)	1. Collect a database of head gestures from ten video clips of different peoples 2. Using a static webcam and

models				head wearable glasses 3. Translate gesture training by a sequence of 20 digits from consecutive frames
A Real-Time Head Nod and Shake Detector		2001	Hidden Markov Models (HMMs)	1. Using an infrared sensitive camera synchronized with infrared LEDs 2. Processed by the feature extraction 3. Directions of the head movements in consecutive frames used as a sequence of observations
A Real-Time Head Nod and Shake Detector using HMMs		2003	1. Hidden Markov Models (HMMs) 2. AdaBoost algorithm	1. Face detection and eye-tracking performed 2.The direction of face's movement based on the coordination of eyes 3. The directions used as observation sequences to perform head gesture recognition
Robust Head Gestures Recognition for Assistive Technology		2014	1. Hidden Markov Models (HMMs) 2. Supervised Descent Method (SDM)	1. Extract 2D facial features 2. 3-D anthropometric head model 3. Head pose estimation using POSIT algorithm from the face and head extracted
Real-Time Head Gesture Recognition on Head-Mounted Displays using Cascaded Hidden Markov Models (CHMMs)		2017	Cascaded Hidden Markov Models (CHMMs)	1. 6 Degree-of-Freedom (DOF) hybrid optical-inertia tracker using Oculus Rift DK2 2. External camera with an infrared filter to track infrared LED array

Table 2: Virtual Reality Interaction Techniques

Research Title	Techniques	Evaluation overview
Exploring Natural Eye-Gaze-Based Interaction for Immersive Virtual Reality	1.Duo-Reticles 2.Radial Pursuit 3.Nod and Roll	1. Tested Duo-Reticles (DR) and Radial Pursuit (RP), respectively, for their performance and usability against a baseline method, Gaze-Dwell (GD) 2. In the third part, participants tried Nod and Roll and gave their impressions
Transparent Reality: Using Eye Gaze Focus Depth as Interaction Modality	Eye-gaze based interaction technique	1. The proposed system compares two methods: scroll-based and gaze-based 2. Scroll-based -the user is required to obtain scores by touching a sphere, which is control with a mouse 3. Gaze-based -the scroll wheel's function of depth control substituted with eye-gaze
Gaze + Pinch Interaction in Virtual Reality	Eye gaze-insights based interaction technique	1. Users are sitting on a swivel chair during the study and calibrated to the eye tracker at the beginning 2. Conducted an informal evaluation to get insights into the usability of Gaze + Pinch interaction
GazeSphere: Navigating 360-Degree-Video Environments in VR Using Head Rotation and Eye Gaze	Orbital motion technique	System: GazeSphere; a navigation system (developed to limit the overall input devices and create a hands-free solution to navigation between stationary positions represented to the user through 360-degree video)
Guided Head Rotation and Amplified Head Rotation: Evaluating Semi-Natural Travel and Viewing Techniques in Virtual Reality	1. Amplified guided head rotation technique 2. Guided rotation technique	Participants use a wireless Xbox One controller for additional input; an analogue thumbstick is used for virtual travel, while buttons are used to confirm responses in the application

2.4. Mobility Impairments Using Virtual Reality System

Any case or condition involving difficulty of a person to do everyday activities without any help is called mobility impairment. Mobility aids like the crutches, canes, walking frames, wheelchairs, orthotic appliances, and artificial limbs are usually used to obtain mobility [19]. According to World Report on disability (2011) produced by the World Health Organization (WHO) - The World Bank joint, there are more than a billion of people experiencing disabilities, representing 15% of the world's population [20]. The main health domains include mobility, dexterity, affect, pain, cognition, vision, and hearing.

Numerous researchers have previously studied the interaction between human and computer and how it works as an assistive medium tool for disabled people. For example, according to Wenhao, an HCI system does not only observe its users passively but also enable them to take control of the system actively using eye movement from eye gaze analysis [8]. Thus, the recent eye gaze analysis [13] helped in remote and contactless interaction by giving an ideal channel for older adults (elder) and those with motor disabilities to access HCI system. The findings have shown that virtual reality can offer those with mobility impairment with new advanced devices like the Head-Mounted Devices and Oculus, which are affordable enough to keep but also focusing the more significant opportunity towards students especially for those who use a wheelchair. The virtual reality system enables wheelchair users to navigate a virtual world. For instance, in a scenario where the user is currently in a busy street or shopping centre, the virtual reality system enables him/her to learn how to move around and avoid obstacles in a virtual setting before putting these into the real world's practice [21]. Despite the difficulty to handle interactions with such devices, using just one key of the virtual mouse directly enables users to control their access to virtual reality application with ease as an excellent training environment [22]. This claims that virtual reality is not only limited to be experienced through the images from Oculus and such but also gives a grab on interacting virtual world to engage the users more than the usual wide view. The Table 2 below shows the overview of virtual reality interaction techniques.

3. Conclusion and Future Works

This study generally focuses on the exploration of head gestures starting from methods used to recognize the gestures and how they act as interaction techniques applied in the virtual environment. Industry nowadays offers a tremendous opportunity to discover as many uses of virtual reality as possible whether in learning space or in improving skills and not only limited to normal people but also those with mobility impairments. With the already-have advanced virtual assisted devices and tools like Oculus, head-gear, VR-supported hardware and software, users can be able to experience an immersive virtual world. To better understand whether or not the techniques need to maximized and well-accessed, more studies and the broader range are required to explore. For example, it would be good to study other methods to improve the head gesture interaction such as the discovery of tilting at specific angle or combination of other body parts gestural.

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