Bimanual Gestural Interface for Virtual Environments

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Abstract

In this paper, a 3D bimanual gestural interface using data gloves is presented. We build upon past contributions on gestural interfaces and bimanual interactions to create an efficient and intuitive gestural interface that can be used in immersive environments. The proposed interface uses the hands in an asymmetric style, with the left hand providing the mode of interaction and the right hand acting at a finer level of detail.

Index Terms: H.1.2 [Models and Principles]: User/Machine Systems—Human Factors; H.5.1 [Information, Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

1 Introduction

This paper presents the design of a bimanual gestural interface. Our goal is to exploit currently available technology for developing a two-handed *gestural* interface for immersive virtual environments.

The proposed interface was designed for IMAGE (Figure 1), an application exploiting simulation and scientific visualization for improving user performance in understanding complex situations [4].

In the proposed interface, hand gestures are captured by data gloves, rather than computer vision, for increased efficiency and reliability, but future work could study the use of recent technology advancements in bare-hand gestural interfaces like the Microsoft Kinect. The interface uses *static* gestures, i.e. static hand configurations or hand postures (e.g. clenched fist), not to be confused with *dynamic* gestures (e.g. waving hand).

It should be noted that as a means of simplifying the task of designing and evaluating the interface, it is assumed that users are right-handed - similarly to the previous work surveyed in the next section.

2 Previous Work

A major contribution in the domain of bimanual interactions is Guiard's "kinematic chain model" [2], which implements three principles that can be used to describe bimanual interactions : 1) the right hand operates in a spatial frame of reference that is relative to the left hand, 2) the left and right hands operate on different spatial and temporal scales of motion and 3) the left hand usually precedes the right hand in action. Hinckley et al. have developed a bimanual interface for 3D visualization that uses Guiard's right-to-left reference principle with great efficiency [3]. Veit et al. also developped a 3D bimanual interface that uses Guiard's reference principles [6].

Nielsen et al. extensively covered the design and selection of gestures for an interface, providing ergonomical insight as to what type of gestures should be used in gestural interfaces [5].

3 Gestural Interface Design

In the proposed interface design, users perform hand gestures to interact with the environment. Gesture recognition is achieved by a support vector machine with good accuracy and precision for a set composed of around 10 gestures.

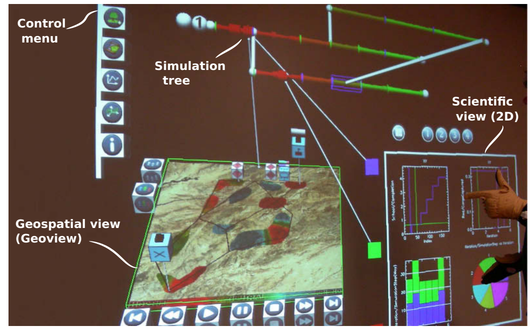


Figure 1: The proposed bimanual gestural interface in action.

The interface is based on Guiard's kinematic chain model, not in the way that objects are manipulated, but rather in the way interactions are initiated and completed by the hands.

The following guidelines were used in the design of the interface:

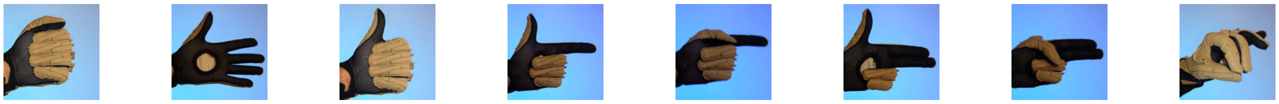
- Guiard's principles for bimanual interactions are respected.
- The right hand executes the interactions demanding the best precision.
- The number of gestures to be used is kept to a minimum, since there is a learning curve imposed on users for remembering all gestures.
- Whenever possible, actions should be mapped to gestures that are semantically related. It is also important to give users proper instructions (cues as to why a given gesture was chosen) and training.
- The hand gestures used in the interface reuse some ergonomic guidelines found in [5], e.g. avoiding outer positions and relaxing muscles as much as possible.
- The beginning of interactions is associated with muscle tension and the end with the release of the tension (as proposed in [1]).
- The interface is designed for expert users.

The left hand plays the role of a mode switcher while most of direct manipulations are executed by the right hand. Hand gestures are executed by the left hand to select interaction modes, while the right hand performs the interaction itself, e.g. pointing, moving or scaling the desired object. The gesture set to be used in the environment is presented in Table 1.

4 3D Interactions

The actions available to the user have been divided into four categories: 1. Selection and designation of objects, 2. Generic manipulations, which group all interactions for moving and positioning objects, 3. Specific manipulations, which is a mode of interaction for specific objects, 4. System control, which represents all actions related to menus and to how the environment behaves. Interactions and their corresponding gestures are presented in Table 2.

Designation and selection. Designation is active: users need to maintain a gesture with their left hand for designation to be activated in the environment. Designation is then based on ray-casting. Once designation ends (by switching to a different gesture), an object becomes selected if it was designated. Objects are circum-



Clenched-fist	Open-hand	Thumb-up (or down)	Index pointing, thumb-up	Index pointing, thumb-down	Index and middle pointing, thumb-up	Index and middle pointing, thumb-down	Pinch (Index, middle and thumb)

Table 1: Hand gestures used in the environment.

	Action	Left hand	Right hand
Selection	Designation and selection	Index pointing, thumb up	-
Generic manipu-lations	Move	Index pointing, thumb folded	-
	Resize	Index and middle pointing, thumb up	-
	Rotate	Clenched fist	-
Specific manip.	Object specific	Pinch (thumb, index and middle)	Various.
System Control	Circular menu, numerical value modification	As needed, accept: Thumb up, cancel: Thumb down	Browsing: Pinch (thumb, index and middle)

Table 2: Interactions and corresponding hand gestures.

scribed in boxes of different colors according to their status. The use of an active designation should help the user focus on the data and information in front of him and not be distracted by the visual ray. Once an object is selected, the user can then perform any of the other available actions on that specific object, with no need for reselection between interactions.

Generic manipulations. Generic manipulations are relevant to positionning and orienting objects:

- Moving an object: A selected object is moved using a metaphor that attaches it to a ray cast from the user's right hand. The distance from the hand to the object remains constant throughout the whole interaction and the object's orientation is adjusted so the object always faces the user.
- Resizing an object: Objects can be resized using the right hand's distance to the object once the interaction is initiated. Bringing the hand closer to the body enlarges the object, while moving it towards the object makes it smaller.
- Rotation of an object: For users to adjust all 3 degrees of freedom in rotation of a given object, an isomorphic rotation interaction was added which maps the user's right hand relative rotations (from the beginning of the interaction) on the selected object without scaling.

Specific manipulations. To further improve the usability of IMAGE, object-specific interactions were added to the environment. Such manipulations were only added to the one object which has playback capabilities, allowing for control of the playback using the right hand's gestures and or pose while the left hand maintains the mode.

Interactions could be provided for more objects should such needs arise. The same left-hand gesture is to be used for all objects, thus allowing the user to easily remember this mode.

System control. System control is achieved through two different elements in the environment: control and circular menus.

Control menus (Figure 1) are a set of icons that represent actions that can be either selected or dragged onto targets. A control menu is typically used for the creation of objects, while deletion of objects is achieved by throwing the object behind the head of the user.

Circular menus (Figure 2) are hierarchical menus that can be attached to objects for additional configuration capabilities. These menus expand once selected and the right hand's orientation can

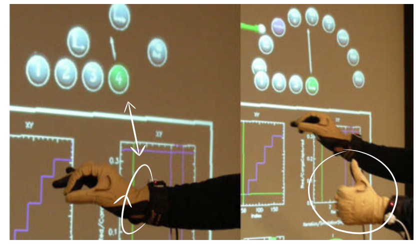


Figure 2: Circular menu. Left: Selection. Right: Confirmation.

then be used to select a menu option. The user confirms or cancels a selection with his left hand by pointing his thumb up or down respectively. To limit fatigue, the thumb-down gesture must not point all the way down but only half-way.

Symbolic input of numerical values is also implemented through a behavior similar to that of circular menus, i.e., by rotating the right hand and accepting or cancelling with the left hand.

5 Conclusion

The design of a 3D gestural bimanual interface was presented. It is built upon past contributions on gestural interfaces and bimanual interactions to create an efficient interface to be used in immersive environments. The interface uses the hands asymmetrically, assigning the mode switching to the left hand and the role of manipulation to the right hand.

To validate the efficiency of this interface design, a comparative study between the proposed two-handed interface and a one-handed variant was conducted on a group of right-handed users. In the experiment, users were requested to complete a series of tasks both unimanually and bimanually after a short training period. The results of the experiment demonstrate that the bimanual gestural interface is more efficient and less demanding than the unimanual one.

This interface is an example of a state of the art 3D bimanual gestural interface design. It is hoped that it will guide other researchers in the construction of future interfaces by providing a sound starting point as well as insight on bimanual gestural interfaces.

References

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[3] K. Hinckley, R. Pausch, D. Proffitt, and N. Kassell. Two-handed virtual manipulation. *TOCHI*, 5(3):302, 1998.

[4] M. Mokhtari, E. Boivin, D. Laurendeau, S. Comtois, D. Ouellet, J. Levesque, and E. Ouellet. Complex Situation Understanding: An Immersive Concept Development. In *VR' 11*.

[5] M. Nielsen, M. Storring, T. Moeslund, and E. Granum. *A procedure for developing intuitive and ergonomic gesture interfaces for HCI*, pages 105–106. Springer, 2004.

[6] M. Veit, A. Capobianco, and D. Bechmann. Consequence of Two-handed Manipulation on Speed , Precision and Perception on Spatial Input Task in 3D Modelling Applications. *Universal Comp. Science*, 14(19):3174–3187, 2008.

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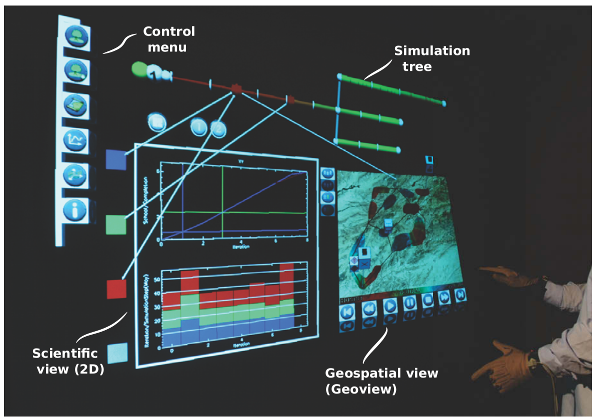
Introduction

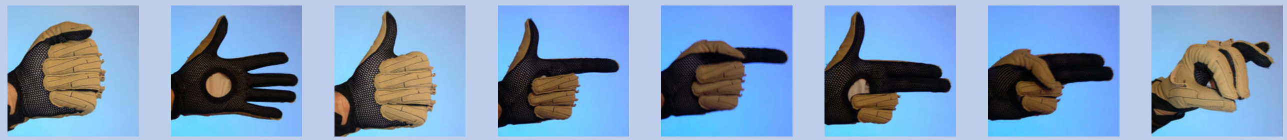
- Exploit currently available technology to develop a *two-handed* gestural interface for virtual environments using data gloves (CyberGloves™).
- Developped and designed for IMAGE, an application using simulation and scientific visualization for improving user performance in understanding complex situations [Mokhtari, 2011].
- The interface uses *static* gestures, i.e. static hand configurations or hand postures (e.g. clenched fist), not to be confused with *dynamic* gestures (e.g. waving hand).
- To simplify the task of designing and evaluating the interface, users were assumed to be right-handed.



The proposed bimanual gestural interface in action.

Gestural Design

- Users perform hand gestures to interact with the environment.
- Gesture recognition is achieved by a support vector machine, with good accuracy and precision for a set composed of about 10 gestures.
- The interface is based on Guiard's kinematic chain model [Guiard, 1987], not in the way objects are manipulated, but rather in the way interactions are initiated and completed by the hands.
- The left hand plays the role of a mode switcher while most of the direct manipulations are executed by the right hand. Hand gestures are carried out by the left hand to select interaction modes, while the right hand performs the interaction itself, e.g. pointing, moving or scaling the desired object.



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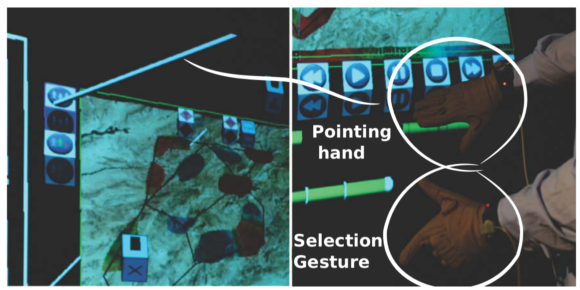
Hand gestures used in the environment.

3D Interactions

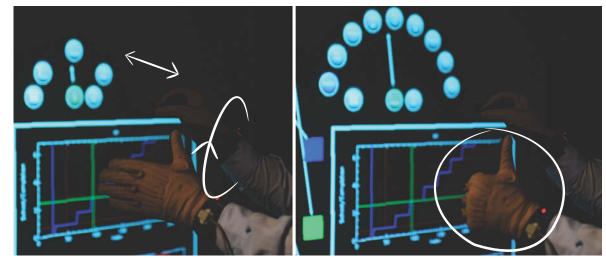
- **Designation and selection**. Designation is active: users need to maintain a gesture with their left hand for designation to be activated in the environment. Apart from this particularity, designation is based on ray-casting.



Designation of an object.

- **Generic manipulations**. Generic manipulations are relevant to positioning and orienting objects.
  - Moving an object: A selected object is moved using a metaphor that attaches it to a ray cast from the user's right hand.
  - Resizing an object: Objects can be resized using the right hand's distance to the object once the interaction is initiated. Bringing the hand closer to the body enlarges it, whiling moving it towards the object makes it smaller as if it was pushed away.
  - Rotation of an object: For users to adjust all 3 degrees of freedom in rotation of a given object, an isomorphic rotation interaction is present.
- **Specific manipulations**. Object-specific interactions aiming to further improve the usability of IMAGE. For example, such interactions were added to one object which has playback capabilities, allowing for control of the playback using the right hand's gestures and or pose while the left hand maintains the *specific interaction* mode.

3D Interactions



Circular menu. Left: Selection. Right: Confirmation.

- **System control**. System control is achieved through two different elements in the environment:
  - Control menus: A set of icons representing actions that can be either selected of dragged onto targets. A control menu is typically used for the creation of objects, while deletion of objects is achieved by throwing the object behind the head of the user.
  - Circular menus: Hierarchical menus that can be attached to objects for additional configuration capabilities. These menus expand once selected and the right hand's orientation can then be used to select a menu option.

Conclusion

- 3D gestural bimanual interface which uses the hands asymmetrically.
- The interface was tested against an equivalent one-handed interface to validate the efficiency of the interface design. Users were requested to complete a series of tasks both unimanually and bimanually after a short training period. The results of the experiment demonstrate that the bimanual gestural interface is more efficient and less demanding that the unimanual one.
- Further work could consist of extending the methods to the field of bare-hand interfaces and compare performance with different types of commonly used physical input devices such as wands.

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				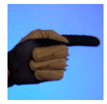	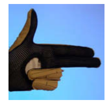	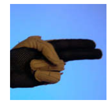	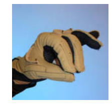
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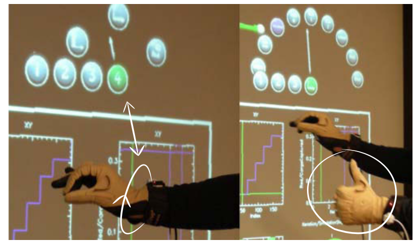

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[3] K. Hinckley, R. Pausch, D. Proffitt, and N. Kassell. Two-handed virtual manipulation. *TOCHI*, 5(3):302, 1998.

[4] M. Mokhtari, E. Boivin, D. Laurendeau, S. Comtois, D. Ouellet, J. Levesque, and E. Ouellet. Complex Situation Understanding: An Immersive Concept Development. In *VR' 11*.

[5] M. Nielsen, M. Storring, T. Moeslund, and E. Granum. *A procedure for developing intuitive and ergonomic gesture interfaces for HCI*, pages 105–106. Springer, 2004.

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