The Go-Go Interaction Technique:
Non-linear Mapping for Direct Manipulation in VR

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ABSTRACT
The Go-Go immersive interaction technique uses the metaphor of interactively growing the user's arm and non-linear mapping for reaching and manipulating distant objects. Unlike others, our technique allows for seamless direct manipulation of both nearby objects and those at a distance.

KEYWORDS
Virtual reality, 3D user interface, user interface metaphor.

INTRODUCTION
The human hand is an ideal direct manipulation input device for virtual reality (VR) [1]. Equipping the hand with a 6 degree-of-freedom sensor, such as the Polhemus Fastrak, we can map its position onto the position of a virtual hand in an immersive world and create the illusion that participants can touch, grasp and manipulate virtual objects using their own hands. This allows for natural and intuitive interaction with immersive worlds. However, using the hands as an input device imposes a significant constraint: users cannot interact directly with objects out of their reach [2].

We present a new interaction technique which significantly expands the user's reach and provides a natural way to grasp and manipulate objects located both far away and close to the user. The technique is based on the metaphor of being able to change arm length at will. We name it the Go-Go interaction technique, after the cartoon character Go-Go Gadget, who had a powerful ability to extend his arms much further than normal. In contrast to other approaches [1, 3, 6] the Go-Go technique is a single interaction method which allows for modeless and seamless direct manipulation of both close objects and those at a distance.

RELATED WORK
The most straightforward method of accessing remote objects in VR is to allow the user to "fly" around the virtual environment. However, the current absence of adequate flying tools makes navigation in VR difficult [4]. Presets, which are predefined locations where the user can move instantly [4], can be used to overcome this problem. The problem with presets is the absence of natural ways to address existing and create new presets from within the environment. Ray and cone casting have also been used to extend the user's reach [1, 3], but this approach typically re-quires two separate interaction techniques: one for distant and one for local manipulation. It also permits only line-of-sight object selection and manipulation [3] and there are no intuitive ways to rotate remote objects or bring them into the area of the local manipulation. Finally, the Worlds-In-Miniature technique (WIM) [3, 5] allows manipulation of objects by interacting with their representations in a miniature model of the virtual world. Although proven to be useful, the WIM approach does not provide direct manipulation of objects and precise positioning can be difficult [3].

DESCRIPTION OF THE TECHNIQUE
Having an arm to grow at will is a compelling prospect. However, implementing this metaphor in VR poses three major challenges: first, how to enable users to tell the system when they want to expand their virtual arm; second, how users can control their virtual arm length; and third, how to make the implementation of this metaphor intuitive, seamless and easy to use.

Our implementation solves all these problems by using a non-linear mapping between the controlled motion of the user's hand in the real world and the effected motion of the virtual hand in the immersive environment. Using two Polhemus Fastrak sensors we calculate the position of the human hand in polar coordinates $\{R_r, \phi, \theta\}$ in a user-centered coordinate system with the origin at the chest of the user. R_r is the length of the vector $\bar{R}r$ pointing from origin to the user's hand, and ϕ, θ its orientation. The virtual hand is rendered in position $\{R_v, \phi, \theta\}$ within the virtual environment. R_v is the length of the "virtual arm" - a vector $\bar{R}v$ pointing from the origin to the virtual hand (Fig. 1). We calculate R_v using the non-linear mapping function F:

$$R_v = F(R_r) = \begin{cases} R_r & \text{if } R_r < D \\ R_r + k(R_r - D)^2 & \text{otherwise} \end{cases},$$

where k is a coefficient: $0 < k < 1$. Vectors $\bar{R}r$ and $\bar{R}v$ have the same orientation and different magnitude.
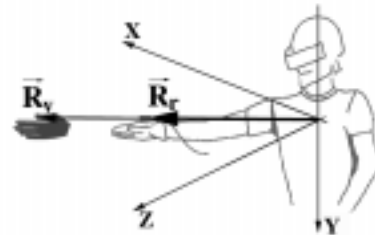

Fig. 1: Position of real hand is defined by vector $\bar{R}r$; position of virtual hand is defined by vector $\bar{R}v$.

The mapping function F divides the space around the user into two parts: one with linear and one with non-linear mapping (Fig. 2). As long as the user operates on nearby objects ($R_r < D$) the mapping is linear and the movement of the virtual hand matches movement of the real hand. We chose the value of D as 2/3 of the user's arm length, as our observations showed that this is a distance within which people can work most comfortably. To reach and manipulate remote objects the user simply extends the hand further than D ($R_r > D$); the mapping becomes non-linear and the virtual arm grows. To return to the conventional manipulation the user just brings the hand within the distance $R_r < D$. The C^1 continuity of the function F at point D ensures a smooth transition between the linear and non-linear parts.
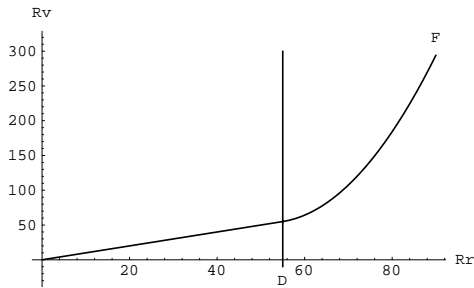

Fig. 2: Mapping function F (k = 1/6) consists of linear ($R_r < D$) and non-linear parts ($R_r > D$).

The non-linearity of F means that as the user moves the hand, R_v increases or decreases faster than R_r so the virtual arm appears to grow or shrink as the user extends the hand further or closer. The technique thus provides an intuitive way to interactively control the length of the virtual arm - by stretching the real hand further or bringing it closer. We render a small white cube in position $\{R_r, \phi, \theta\}$ to provide a visual reference about the real hand position (Fig. 4).

EVALUATION
To evaluate the Go-Go interaction technique we developed an immersive medical environment and a virtual art museum (Fig. 3, 4). Users could not translate but could select and manipulate objects using the Go-Go technique. A boundary box was drawn around objects when selected to provide visual feedback and minimize overshoot. Preliminary usability tests show that the Go-Go interaction technique is highly intuitive and easy to use for at least two reasons. First, it imitates real world human behavior - when we want to reach a remote object we stretch an arm toward it. Second, our technique is modeless and allows direct manipulation with both close objects and those at a distance, unlike other techniques which require the user to switch between local and remote manipulation modes. The Go-Go technique thus simulates conventional techniques in the space close to the user and uses the remainder of the space for accessing and manipulating remote objects.

CONCLUSIONS AND FUTURE WORK
The Go-Go interaction technique implements the metaphor of interactively growing the user's arm to reach farther in the virtual world. Our technique is unique in allowing for seamless direct manipulation of both close objects and those at a distance. Using a non-linear control-display (C-D) gain for immersive hand input is also a novel approach. Although it has been used for navigation [2, 6], we have found no reports of using a non-linear C-D gain for immersive hand input. We view our technique as a supplement rather then a replacement for existing techniques. Ray casting could be more effective when only selection is required and the WIM technique when precise manipulation is not important. Our future research will study and compare alternative selection and manipulation techniques to provide guidelines for developing effective immersive interfaces.
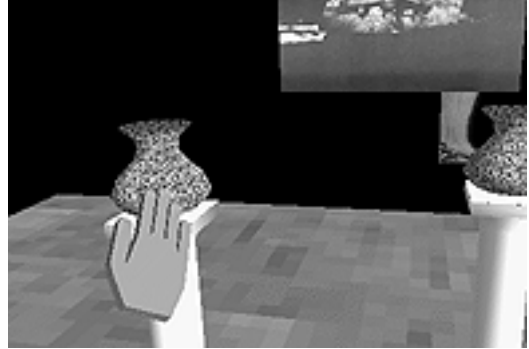

Fig. 3: With traditional VR manipulation techniques the user cannot reach the vase; reach is limited by arm length.
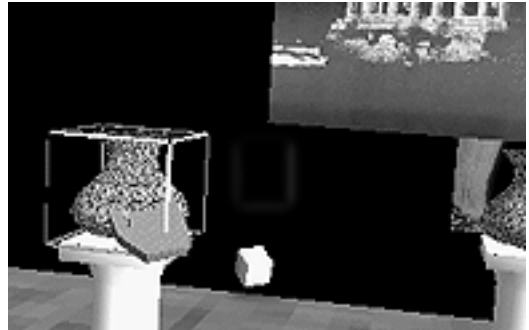

Fig. 4: The Go-Go technique allows users to expand their reach. The white cube shows the real hand position.

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