A Natural Pointing Technique for Semi-Immersive Virtual Environments

Luigi Gallo[1]
ICAR-CNR
Via Pietro Castellino 111
80131 Napoli, Italy
+390816139517
gallo.l@na.icar.cnr.it

Aniello Minutolo
ICAR-CNR
Via Pietro Castellino 111
80131 Napoli, Italy
+390816139507
minutolo.a@na.icar.cnr.it

ABSTRACT
Several interaction metaphors and techniques have been proposed to allow a natural interaction in virtual environments. Usually all these techniques are designed to be used with input devices such as wands, 3D mice or gloves. However, the availability of a new generation of auto-stereoscopic displays now makes it possible to exploit virtual experiences in new scenarios. In this paper we propose a variation of the ray-casting technique suitable for use with a standard mouse. With this proposed technique, users can move a 3D cursor in the virtual world without worrying about the third dimension and without losing the level of immersion provided by the 3D display.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies*; I.3.6 [**Computer Graphics**]: Methodology and Techniques – *Interaction techniques*; I.3.7 [**Computer Graphics**]: Three Dimensional Graphics and Realism – *Virtual reality*.

General Terms
Design, Human Factors.

Keywords
Pointing, Virtual Reality, Interaction Techniques, Mouse, Wiimote.

1. INTRODUCTION AND BACKGROUND
In recent years, Virtual Reality (VR) technologies have progressively gained new fields of application. The availability of new powerful auto-stereoscopic displays now makes it possible to exploit the benefits of a 3D visualization almost everywhere.

In the past, Immersive Virtual Environments (IVEs), such as CAVEs or large stereo walls, were widely used, particularly in 3D design and modeling tasks. This kind of display gives a high level of immersion, but not always all that is required. As Bowman outlined in [1], in most applications, using a semi-immersive environment, instead of a full one, does not affect performance. On the contrary, it significantly reduces the costs.

Figure 1. Visualization of an anatomical part on a 3D display.

New generation 3D displays are able to bring an adequate immersion level to places where a full immersive virtual environment is not a practical solution. Instead of immersing the user in a virtual world, this kind of device makes it possible for the user to look inside a virtual window. Banks, hospitals, shops are all places where it is difficult to install a CAVE, but not a glass-free auto-stereoscopic display.

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[1] Luigi Gallo 2nd affiliation: University of Naples Parthenope, Centro Direzionale Isola C4, 80143 Napoli, Italy. Tel. +390815474893, e-mail: luigi.gallo@uniparthenope.it

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With the proliferation of these displays, 3D interaction becomes a primary issue. If it is an easy task to exchange a traditional display with an auto-stereoscopic one, it is not so easy to change the traditional input devices: mouse and keyboard. Several devices have been designed to allow a usable interaction in VEs, but most of them require a long training time, are inconvenient or very expensive.

In this paper we mainly consider the pointing task, the basic one in the 2D interaction. In traditional 2D GUI, the mouse is certainly the most commonly used device to perform the pointing task.

In [2], the authors have performed a comparison between mouse, direct tablet and indirect tablet in terms of pointing time, accuracy, mental work load and psychological ease of operation. Their experiments revealed that the pointing time is slightly lower with the direct tablet, probably because the mouse movement is different from that of the pointer, so users need to coordinate eyes and hand. Despite this, the mouse has proved to have a higher psychological ease of operation.

This is not a surprise, since the mouse is widely used in 2D interaction. As Johnson et al. reported in [3], up to 65% of computer operating time involves use of the mouse in windows-type environments. This experiment was performed in 1993. Today this estimate percentage has probably increased.

Although the pointing could be considered a problem solved in 2D interaction by using the mouse, this is still an open issue in virtual environments.

Usually the pointing task is performed by using the virtual pointer metaphor. This consists in visualizing a pointer in the 3D scene, the position of which can be controlled in different ways. The Ray-Casting technique is the best known implementation of this metaphor. In this technique the direction of the virtual pointer is defined by the orientation of a virtual hand. As an example, to select a 3D object we can point at it with the virtual hand, that is an avatar of our real hand.

A different approach is to use the virtual hand metaphor, which is based on a virtual representation of the user hand. Different implementations of this metaphor address the problem of the inaccessibility of distant objects. In the Go-Go technique [4] the virtual arm can be extended following a non-linear mapping with the real one.

Other pointing techniques can be found in [5], [6], [7] and [8].

All these pointing techniques share one characteristic: they all make use of an input device expressly designed to be used in a VR context. When implementing these techniques, Wands, 3D mice, data and pinch gloves, tracking and inertial devices are used to move a pointer in the 3D space.

We propose in this paper to use a standard mouse to perform the pointing task. As Bowman indicated in [9], in the design of 3D interaction techniques, the application scenario should be expressly kept in due consideration. Our idea is that, if the user is not immersed in a virtual environment but is using a 3D display, the mouse could be a suitable 3D user interface.

The technique we propose consists in a variation of the ray-casting implementation of the virtual pointer metaphor. The proposed technique is particularly suitable for the VROM [10] operating method, in which there is only one data object to examine and manipulate and it is already within touching distance.

2. THE PROPOSED POINTING TECHNIQUE

The use of an indirect input device, the traditional mouse, in order to perform the pointing task in a semi-immersive virtual environment, brings some benefits:

- the mouse moves on a flat surface, so allowing users to perform more accurate movements with less fatigue;
- there is a common knowledge about the use of the mouse;
- it is a less expensive device.

However, in a stereoscopic visualization context, using the classical mouse pointer is not the best choice. Firstly, a mouse pointer is a 2D object that during a virtual world manipulation does not change its shape and its perspective, so that the user will always feel it as an out of place object. Furthermore, a mouse pointer can move only along a fixed plane, while the other displayed objects extend in the 3D dimensions in accordance with the three dimensional stereoscopic perception. Therefore, when the mouse pointer crosses a 3D object, the stereoscopic perception of the object is damaged. In fact, the user sees the different object parts on the same plane as the mouse pointer, losing de facto the three dimensional perception of that object (see Fig. 2).

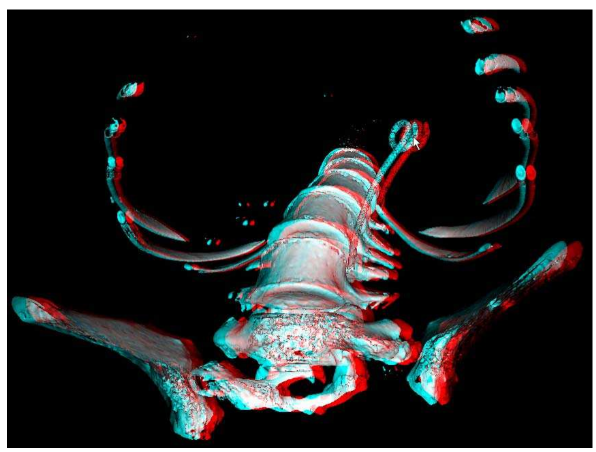

Figure 2. The traditional mouse pointer on an anaglyph stereo pair.

To remove the inconveniences of the mouse pointer, we have to use a three dimensional pointer, so that it can be completely absorbed in the virtual environment and benefit from its stereoscopic visualization. This solution gives the pointer used a way of moving in a 3D world like the other 3D objects of the scene.

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This new spatial freedom raises new questions in the task of pointer navigation. To move a 3D object in a 3D world with a 2D interaction device (a mouse) is not simple. The mouse allows you to move the pointer only along 2D positions, for example along parallel planes to the screen, and so, to add the third dimension, we have to develop a *fishing reel* based technique to change the plane on which the pointer can move [11]. This solution is not simple to control, and the technique requires a long time to learn.

Furthermore, it is very simple to lose the pointer and to hide it behind other 3D objects. A fundamental feature of a pointer, instead, is that the pointer must always be visible.

Our aim is to make it very easy to interact in the 3D world simply using a common mouse without losing the opportunity of using a 3D pointer. This work has been inspired by the idea that users are interested in pointing only at objects that they can directly view. If the user can view several overlapped objects, we speculate that he may wish to point always at the visible parts of the objects. Whereas, if he wants to reach the hidden parts of objects, the user has to change the point of view of the camera.

Therefore, our idea is to free the user from the necessity of selecting the pointer depth (fishing reel technique). The pointer instead, has to be bound to the visible surfaces of the objects.

This solution takes away from the pointer one of its degrees of freedom. Now, with this technique, users have only to indicate the pointer display coordinates (x,y) by using the mouse, and the pointer depth will be automatically determined from the user's point of view. If in the selected display coordinates the user can view an object surface, then the pointer depth will be the same as that of the particular visible zone. Otherwise, if no object surfaces are observable, the pointer depth will be a prefix value like the camera focal point depth.

3. IMPLEMENTATION DETAILS

The built system provides 3D interactions via a mouse and the pointer is represented by a three-dimensional sphere. The sphere has a stereoscopic representation which makes it completely integrated in the virtual environment. Moving around a pointer in this way does not interfere with the three-dimensional perception of the other objects.

When the pointing interaction starts, the pointer depth is fixed at the same depth as the camera focal point. Using the mouse, the user can change the pointer display coordinates, via a simple two-dimensional mapping.

The pointer depth is automatically determined by a ray casting based technique. In particular, the current pointer display position is used to calculate the leaving point from which a virtual beam starts to go through the virtual scene. The virtual beam generated goes across the scene along the camera direction of projection. The beam starting point and the beam ending point are calculated in accordance with the camera view frustum in such a way that the beam crosses the entire visible scene and intersects any visible objects.

If this beam intersects a 3D object surface, the pointer depth will be the same depth as the point of intersection. Otherwise, the pointer depth will be the same depth as the camera focal point.

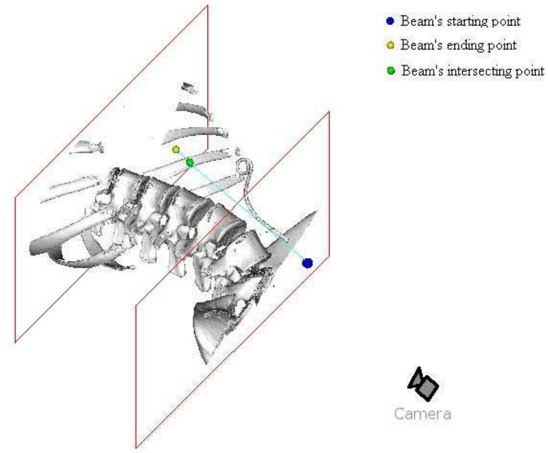

Figure 3. The beam's intersecting point calculus.

In the built system, the user can change the pointer display position via the mouse, and so alter the starting point of the virtual beam used to determine the pointer depth. The pointer moves around like a classical mouse pointer but it lies on a dynamic plane that automatically changes its depth in accordance with any 3D objects that the virtual beam meets.

In order to evaluate the pointing technique developed, we have implemented it in a medical imaging application. In this application, the physician can interact with three dimensional medical anatomical models inside a semi-immersive virtual environment.

This particular application has suggested to us the development of an optimization to reduce the journey of virtual beam. In particular, we have taken advantage of the information boundaries of the single 3D object displayed in the scene. The fact that beam goes through desolate zones of the 3D world is not useful. Therefore, the depth of the beam's starting point will be determined by the 3D object piece nearer the camera, and the depth of the beam's final point will be determined by the 3D object piece farther from the camera.

We use the 3D object boundary positions to determine the orthogonal plane of the camera intersecting the nearest object boundary (see Fig. 3). This plane will be the plane on which the beam's starting point has to lie. Then, we use the 3D object boundary positions to determine orthogonal plane of the camera intersecting the farthest object boundary. This plane will be the plane on which the beam's ending point will lie. Finally, the virtual beam will be generated.

4. CONCLUSIONS AND FUTURE WORK

This paper shows how a traditional mouse can be used to perform efficiently the pointing task in semi-immersive virtual environments. The wide acceptance of the mouse should maximize user performance in the pointing task.

Future work will be based on a formal evaluation of the usability of this proposed technique. We are also involved in the design of

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manipulation techniques, to be used additionally with the Wiimote, the controller of the Nintendo Wii console.

5. REFERENCES

[1] Bowman, D.A. and McMahan, R.P. 2007. Virtual Reality: How Much Immersion Is Enough? IEEE Computer. 40, 7 (July 2007). 36-43. DOI= http://doi.ieeecomputersociety.org/10.1109/MC.2007.257.

[2] Ichikawa, H., Homma, M. and Umemura, M. 1999. An experimental evaluation of input devices for pointing work. International Journal of Production Economics. Elsevier. 60, 1 (April 1999). 235-240. DOI = http://dx.doi.org/10.1016/S0925-5273(98)00162-5.

[3] Johnson, P.E., Dropkin, J.J., Hews, J., Rempel, D., 1993. Office ergonomics: motion analysis of computer mouse usage. In Proceedings of the American Industrial Hygiene Conference and Exposition (New Orleans, Louisiana, USA, May 15 - 21, 1993). AIHce '93. Fairfax, 12-13.

[4] Poupyrev, I., Billinghurst, M., Weghorst, S. and Ichikawa, T. 1996. The Go-Go Interaction Technique: Non-Linear Mapping for Direct Manipulation in VR. In Proceedings of the ACM Symposium on User Interface Software and Technology (Seattle, WA, USA, November 6 - 8, 1996). UIST '96. ACM Press, New York, NY, 79-80, DOI= http://doi.acm.org/10.1145/237091.237102.

[5] Hinckley, K., Pausch, R., Goble, J.C. and Kassell, N.F. 1994. A survey of design issues in spatial input. In Proceedings of the 7th annual ACM symposium User Interface Software and Technology (Marina del Rey, California, USA, November 2 - 4, 1994). UIST '94. ACM Press, New York, NY, 213-222. DOI= http://doi.acm.org/10.1145/192426.192501.

[6] Liang, J. and Green, M. 1994. JDCAD: A highly interactive 3D modeling system. Computer & Graphics 18, 4 (1994), 499–506. DOI= http://dx.doi.org/10.1016/0097-8493(94)90062-0

[7] Riege, K., Holtkamper, T.; Wesche, G., Frohlich, B. 2006. The Bent Pick Ray: An Extended Pointing Technique for Multi-User Interaction. In Proceedings of the IEEE Symposium on 3D User Interfaces (Alexandria, Virginia, USA, March 25 - 26, 2006). 3DUI '06. IEEE Press, Los Alamitos, CA, 62-65. DOI= http://dx.doi.org/10.1109/VR.2006.127

[8] Vogel, D., Balakrishnan, R. 2005. Distant freehand pointing and clicking on very large, high resolution displays. In Proceedings of the 18th Annual ACM Symposium on User Interface Software and Technology (Seattle, WA, USA, October 23-26, 2005). UIST '05. ACM Press, New York, NY, 33-42. DOI= http://doi.acm.org/10.1145/1095034.1095041.

[9] Bowman, D. A., Chen, J., Wrave, C. A, Lucas, J., Ray, A., Polys, N. F., Li, Q., Haciahmetoglu, Y., Kim, J. S., Kim, S., Boehringer, R. and Ni, T. 2006. New Directions in 3D User Interfaces. The International Journal of Virtual Reality 5, 2 (2006), 3-14. DOI= http://doi.ieeecomputersociety.org/10.1109/VR.2005.58.

[10] Dech, F. and Silverstein, J. C. 2002. Rigorous Exploration of Medical Data in Collaborative Virtual Reality Applications. In Proceedings of the International Conference on Information Visualization (London, UK, July 10 – 12, 2002). IV '02. DOI= http://doi.ieeecomputersociety.org/10.1109/IV.2002.1028753 .

[11] Bowman, D. A. and Hodges, L. F. 1997. An Evaluation of Techniques for Grabbing and Manipulating Remote Objects in Immersive Virtual Environments. In Proceedings of the Symposium on Interactive 3D Graphics (Providence, RI, USA, April 27 - 30, 1997). SI3D 1997. DOI= http://doi.acm.org/10.1145/253284.253301.

Digital Object Identifier: 10.4108/ICST.MOBIQUITOUS2008.3863
http://dx.doi.org/10.4108/ICST.MOBIQUITOUS2008.3863