3-Point++: a new Technique for 3D Manipulation of Virtual Objects

Thi Thuong Huyen Nguyen, Thierry Duval

3-Point++: a new Technique for 3D Manipulation of Virtual Objects

Thi Thuong Huyen Nguyen*
IRISA - INRIA Rennes Bretagne Atlantique

Thierry Duval†
IRISA - Université de Rennes 1

ABSTRACT

Manipulation in immersive Virtual Environments (VEs) is often difficult and inaccurate because humans have difficulty in performing precise positioning tasks or in keeping the hand motionless in a particular position without any help of external devices or haptic feedback. To address this problem, we propose a set of four manipulation points attached to objects (called a *3-Point++ tool*, including three handle points and their barycenter), by which users can control and adjust the position of objects precisely. By determining the relative position between the 3-Point++ tool and the objects, and by defining different states of each manipulation point (called *locked/unlocked* or *inactive/active*), these points can be freely configured to be adaptable and flexible to enable users to manipulate objects of varying sizes in many kinds of positioning scenarios.

Keywords: 3D Direct Manipulation, Virtual Environments

1 INTRODUCTION

Object position and orientation manipulation are among the most fundamental and important interactions between humans and environments in VR applications. Many approaches have been developed to maximize the performance and the usability of 3D manipulation. However, each manipulation metaphor has its own limitations and cannot be generally used in a broad variety of VEs. We are especially interested in precise manipulation of large objects in VEs. This task is usually difficult because of user's view obstruction caused by the size of objects during their positioning stages [2]. It is more difficult when the user has to place large objects with required precision. Some approaches [6, 7, 8] have been proposed to manipulate objects at a distance by creating their miniature models or by expanding the user's virtual arm. These propositions have an advantage for large objects manipulation: when the user has an overall view of objects or of environment, it is easier for him to know how to move these objects to the target position and orientation without worrying about obstruction problems. However, their main issue is that small movements of the miniature models or of the user's virtual hand from a distance are often magnified in the environment, making precise positioning difficult. A reasonable distance, at which the size of objects is not too disturbing and the user can still determine where to place them, is hardly found sometimes.

Some approaches have been proposed to manipulate objects more precisely and efficiently. PRISM [3] proposes a dynamical adjustment method which determines the relationship between physical hand movements and the controlled object motion, making it less sensitive to the user's hand movements. However, the user may feel a sense of incompatibility because of the difference between the visual feedback and motor control. Osawa [5] proposes a technique adding a viewpoint adjustment stage to enlarge the scene when the hand grasping the virtual object is moving slowly. Nevertheless, this adjustment may influence the user's immersion and may cause fatigue when the user manipulates large objects. In addition, there is no orientation manipulation in this technique, it means that it is incomplete for object manipulation in general. Precise manipulation is also often required in assembly modeling systems through constraint-based manipulation. These systems usually demand knowledge-based descriptions to be integrated in advance into a constrained behavior manager [4]. This manager realizes assembly relationship recognition, constraint solving and constrained motion. It can improve the precision of manipulation but it is quite complicated to apply them in the general case of manipulation.

*e-mail: thi-thuong-huyen.nguyen@inria.fr
†e-mail: thierry.duval@irisa.fr

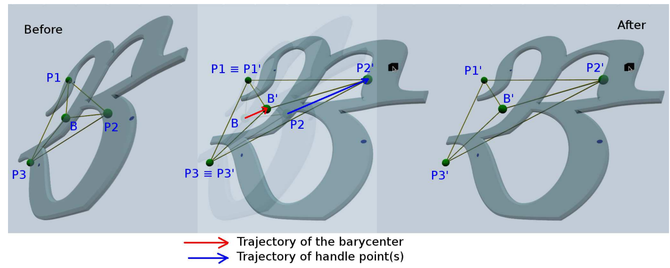

Figure 1: The handle point P2 is manipulated, the object is rotated around an axis created by the two handle points P1 and P3

The 3-hand manipulation technique [1] may facilitate the 3D manipulation by determining the position of objects through the position of three non-aligned manipulation points on a plane. However, this technique is mainly devoted to multi-user collaborative manipulation and it is quite difficult for one user to manipulate objects. In this paper, we want to enhance this technique for a general purpose of manipulating objects of varying sizes, especially large objects, in many kinds of positioning scenarios.

2 3-POINT++ TECHNIQUE FOR DIRECT MANIPULATION

We present an interaction technique which improves significantly the 3-Hand manipulation technique [1] for manipulating objects precisely and efficiently to a target position and orientation. This 3-Point++ tool consists in a set of four points (three handle points and their barycenter), that is attached to an object. This technique is based on the idea that for any kind of object, its precise position and orientation are always explicitly described by the position of the three handle points of this tool. On the other hand, by determining the position of this 3-Point++ tool, the position of the object can be calculated. By moving these points, the position and the orientation of the object are controlled. The barycenter can be used for approximate positioning to control the object directly without constraint, while the three handle points are used for precise positioning. This is the reason why the barycenter has 6 Degrees Of Freedom (6-DOF) in manipulation, while the three handle points has only 3-DOF. When the position of one of three handle points changes, the position and the orientation of the barycenter are recalculated and so are the position and the orientation of the attached object. If one handle point is manipulated, the object is rotated around an axis created by the two other handle points (Figure 1). If two handle points are manipulated at the same time, the object is rotated around the third handle point.

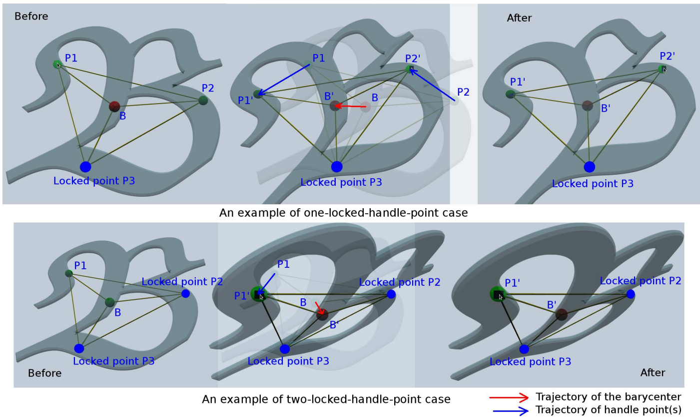

Figure 2: Two examples of locking and manipulating handle points

2.1 Configuring the offset of manipulation points relatively to the manipulated object

In order to adapt the 3-Point++ tool to objects of varying sizes, we propose an extension for configuring the shape formed by the three handle points as well as the offset distance between their barycenter and the object. This stage can be executed in the first place because depending on the shape of object, the relative position of the tool and the object need to be refined earlier for a better manipulation. The adjustment of these manipulation points can neither move nor rotate the attached object. It only allows a user to place the handle points relatively to the object to manipulate. During this adjustment, the offset distance between the barycenter of the manipulated object and the barycenter of the three handle points is re-computed. This offset will be used for the further real manipulation.

2.2 Locking and unlocking manipulation points

In the normal mode of manipulation, all the manipulation points are unlocked. When these points move, the object moves respectively. But the object movement depends on how many points are controlled and how they are controlled. If there is no locked manipulation point, there is a different effect on the movement of the attached object depending whether the movement is caused by the handle points or by their barycenter. The barycenter of the handle points changes its position with 6-DOF and the position of the object changes the same way. It means the position and the orientation of the manipulated object are determined by the position and the orientation of the barycenter itself. When one or two of the handle points are controlled, the other handle points stay at the same position. Because the position and the orientation of object are always calculated by the position and the orientation of the barycenter and the triangle shape formed by the three handle points can change, the translation of their barycenter (and also the translation of the object) is different from the translation of the controlled handle points. It causes the slide of the object on the surface of the tool and it makes the object move imprecisely. This is why we add another manipulation mode where the user can lock one or two handle points and control the other points to get the target position (Figure 2). By combining the configuration of relative position as mentioned above and this mode of locking/unlocking points, the user can decide which part of the object he does not want to move and which other part to be controlled to reach the wanted position. In addition, using such locked points allows the user to focus on the active points and makes the user more comfortable to adjust the orientation and the position of the manipulated object.

3 Preliminary Study

We conducted an experiment to evaluate the usefulness and efficiency of our proposition for manipulating virtual objects. The task of 18 subjects was to place three marks on each large 3D alphabet letter onto three corresponding targets on a support frame respectively at three different levels of difficulty. These levels were represented by the distance threshold d_{th} between one mark on each letter and its corresponding target. The more this threshold decreases, the more the manipulation needs to be precise. We tested the two manipulation techniques with three distance thresholds: 10, 6 and 3 centimeters which are considered easy, medium, and difficult level respectively. We measured the mean time to accomplish the task by the 3-Point++ technique and by a well-known technique using a 3D cursor to control an object directly with 6-DOF.

P values of average manipulation time of the two techniques at different levels of difficulty were calculated using repeated measures ANOVA and Tukey-Kramer post hoc analysis. The result revealed that there was no significant difference between the two techniques at the three levels of difficulty as well as in the general case. These statistical results could be explained by the fact that 3-Point++ technique usually took more time than using the 6-DOF technique because it was more complicated for users to change the mode of control, to reconfigure the offset distance between the manipulation points and object. This fact was also represented in the subjective estimation. So to improve our technique, its ease of use and intuitiveness need to be upgraded.

4 Conclusion and Future Work

We have presented the 3-Point++ manipulation technique, a new metaphor for the 6-DOF manipulation of virtual objects by controlling three manipulation points and their barycenter. In the future, the ease of use of our technique need to be improved to make it easier to use. We will have to enhance our approach for release adjustment to enable a more precise release in manipulation. This adjustment could improve the problem of quick release by estimating the position that seems to be the intended release position.

References

[1] L. Aguerreche, T. Duval, and A. Lécuyer. 3-Hand Manipulation of Virtual Objects. In *Proceedings of the 2009 Joint Virtual Reality Conference*, JVRC 2009, page 4, Lyon, France, Dec. 2009. Eurographics.

[2] D. A. Bowman and L. F. Hodges. An evaluation of techniques for grabbing and manipulating remote objects in immersive virtual environments. In *Proceedings of the 1997 Symposium on Interactive 3D graphics*, I3D '97, pages 35–38., New York, NY, USA, 1997. ACM.

[3] S. Frees and G. Kessler. Precise and rapid interaction through scaled manipulation in immersive virtual environments. In *Proceedings of Virtual Reality 2005*, VR '05, pages 99–106, March 2005.

[4] Z. Liu and J. Tan. Constrained behavior manipulation for interactive assembly in a virtual environment. *The International Journal of Advanced Manufacturing Technology*, 32:797–810, 2007.

[5] N. Osawa. Two-handed and one-handed techniques for precise and efficient manipulation in immersive virtual environments. In *Proceedings of the 4th International Symposium on Advances in Visual Computing*, ISVC '08, pages 987–997, Berlin, Heidelberg, 2008. Springer.

[6] J. S. Pierce, B. C. Stearns, and R. Pausch. Voodoo dolls: Seamless interaction at multiple scales in virtual environments. In *Proceedings of the 1999 Symposium on Interactive 3D graphics*, I3D '99, pages 141–145, New York, USA, 1999. ACM.

[7] I. Poupyrev, M. Billinghurst, S. Weghorst, and T. Ichikawa. The go-go interaction technique: non-linear mapping for direct manipulation in vr. In *Proceedings of the 9th ACM symposium on User interface software and technology*, UIST '96, pages 79–80, New York, USA, 1996. ACM.

[8] R. Stoakley, M. J. Conway, and R. Pausch. Virtual reality on a wim: Interactive worlds in miniature. In *Proceedings of the 1995 SIGCHI Conference on Human Factors in Computing Systems*, CHI '95, pages 265–272, New York, USA, 1995. ACM.