Design and Preliminary Evaluation of an Ego-Exocentric Technique for Cooperative Manipulation

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ABSTRACT

This work proposes and evaluates the EGO-EXO technique for cooperative manipulation in a Collaborative Virtual Environment (CVE). From the premise that simultaneous control over navigation and manipulation by the user can make interaction complex, this technique places two users in asymmetric viewpoint positions during the cooperative manipulation of an object, allowing one of them to follow the object. It applies the separation of degrees of freedom method between the two viewpoints to make the manipulation easier. The technique is evaluated through a user study to test its efficiency on handling cooperative manipulation. Results indicate that, for manipulation tasks that require high amplitude position control along precise orientation control, the technique performs with a lower collisions to time ratio.

Keywords: Cooperative Interaction, 3D Interaction, User Studies

Index Terms: H.5.3 [Information interfaces and presentation]: Group and Organization Interfaces—Computer supported cooperative work; I.3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques

1 INTRODUCTION AND RELATED WORK

A Collaborative Virtual Environment (CVE) is defined as an immersive virtual space where multiple users can interact with each other and the environment while trying to achieve a common goal. In some CVEs, users can interact with the same object at the same time using cooperative manipulation techniques [4].

Several cooperative manipulation techniques have been proposed in the literature in the past two decades [2–6]. Built upon techniques developed for single user Virtual Environments (VE), these cooperative manipulation techniques aim to take advantage of multiple users working together to allow the solution of complex tasks that would be difficult for a single user to perform [4]. In most VE implementations, the user must control navigation and object manipulation at the same time, often making it difficult to perform the manipulation efficiently.

This work presents the design and evaluation of a manipulation technique based on the placement of two users in asymmetric viewpoint positions, as proposed by Soares *et al.* [6] and Le Chénéchal *et al.* [3] for the IEEE 3DUI 2016 Contest. The EGO-EXO technique, however, restrains the interaction techniques to focus on the evaluation of the viewpoints. It applies separation of Degrees of Freedom (DOF) [4] between the users, with specific manipulation controls for each one. Based on these high level constraints, EGO-EXO aims to take advantage of multiple manipulation techniques and different viewpoint positions to provide an efficient method for cooperation.

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2 EGO-EXO TECHNIQUE

We proposed EGO-EXO, a cooperative object manipulation technique specifically designed for manipulation tasks which require high amplitude translation coupled with precise rotation of the object. It takes advantage of egocentric and exocentric viewpoints (figure 1). It aims to take advantage of two users in asymmetric viewpoint positions, along with a specific control over degrees of freedom for each viewpoint user.

The egocentric viewpoint (EGO) positions the user at the scale and in near proximity of the manipulated object. It allows the user to see the immediate surroundings of the controlled object, resulting in a better precision for rotation operations using a virtual hand technique. The EGO user position follows the manipulated object automatically, as it gets translated by the EXO user.

The exocentric viewpoint (EXO) has the user positioned at room scale and at a distance from the object to be manipulated. It allows the user to have a birds-eye view of the object and the environment surrounding it, resulting in better performance for high amplitude translations using a raycasting with reeling technique [1]. The EXO user places herself using some navigation technique at a suitable position before the start of manipulation, at which point navigation for this user is disabled, so she can focus entirely on the manipulation task.

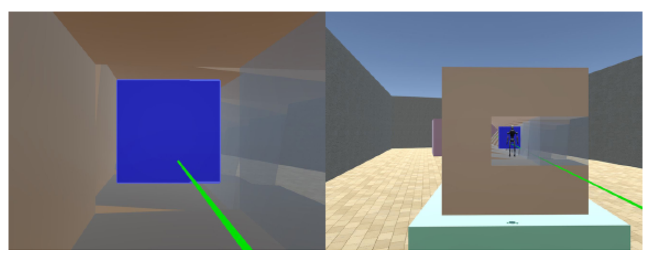

Figure 1: Egocentric viewpoint (left), Exocentric viewpoint (right).

By combining two users with specific controls over the manipulation of an object, some issues are addressed. It is difficult to rotate the object around its own axis using raycasting, but the EGO user can precisely rotate around all axes using a virtual hand technique. Conversely, it is difficult to translate the object long distances using a virtual hand, but since the translation is done by the EXO user through raycasting with reeling, high amplitude translations can be performed easily.

3 EVALUATION

We performed an evaluation to compare EGO-EXO to an exocentric-only (EXO-EXO) manipulation technique, where both users are able to change their viewpoint positions before selecting the object, while the division of the degrees of freedom was maintained. We believe the main contribution of EGO-EXO is the asymmetric viewpoints, thus we compared it against a technique where no user follows the object.

3.1 Apparatus and Participants

Oculus Rift DK2 head-mounted displays, with $960 \times 1080px$ resolution per eye, 75Hz refresh rate and 100° diagonal field of view, were used by both users. Tracking was provided by a Polhemus Fastrak magnetic device, which has guaranteed accuracy of 0.08cm RMS for position and 0.15° RMS for rotation within 76cm, 4ms latency and 60Hz refresh cycle. The receiver was attached to a mouse, allowing the user to use the same hand for tracking and pressing buttons.

The evaluation was conducted in pairs. 20 participants (3 females), with age ranging 18-47 years (median age 23 years). 14 participants were undergraduate students, 6 were graduate students 2 were professionals. 11 participants had experienced VR before, but only 4 had used an HMD prior to this test, while 15 participants had used some sort of tracking device.

3.2 Tasks

Four tasks were proposed. In each of them, the users needed to move objects through tunnels while avoiding collisions.

In the first task (Figure 2, left), the users had to move an object from the start position through a green obstacle, while applying a rotation of 45° in the roll (Z) axis. In the second task (Figure 2, right), the users had to move the object through a blue tunnel, while applying a rotation of -15° in the yaw (Y) axis and return to 0° in the roll (Z) axis.

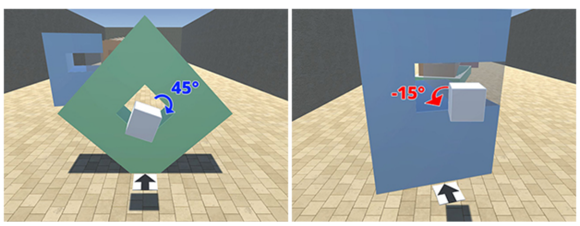

Figure 2: First task (left), Second task (right).

In the third task (Figure 3, left), the users had to move an object through a tunnel, while applying a rotation of 15° in the yaw axis, adding more 5° in the roll axis at each segment of the tunnel. In the fourth task (Figure 3, right), the users had to move an object through a red S-shaped tunnel, without the need to rotate the object.

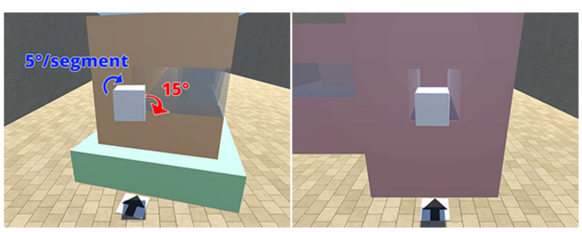

Figure 3: Third task (left), Fourth task (right).

3.3 Procedure

Each set of four tasks was performed under a specific block, in the following order: EXO-EXO; EGO-EXO; EGO-EXO with roles reversed; EXO-EXO with roles reversed. Users were advised to keep communicating with each other during the experiment to coordinate how the manipulation would work.

This within-subjects design and its ordering were defined to obtain more data from each pair, while minimizing a potential learning factor. The first block was used by the participants to learn how to use the devices and manipulation techniques. The second and third blocks evaluated the EGO-EXO technique while reducing learning, as users reversed roles. As this work aims to evaluate the efficiency of the EGO-EXO technique, the technique that was used for comparison (EXO-EXO) was the last one, after users had trained the most.

After the tests were completed, each participant completed a post-experiment questionnaire.

3.4 Results and Discussion

In three of the four tasks, the EGO-EXO technique performed worse than EXO-EXO, taking longer and spending similar or greater time in collision. However, in the third task, the only one that required translation and rotation operations to be applied at the same time, the EGO-EXO technique had a lower time in collision to total task time ratio (Figure 4).

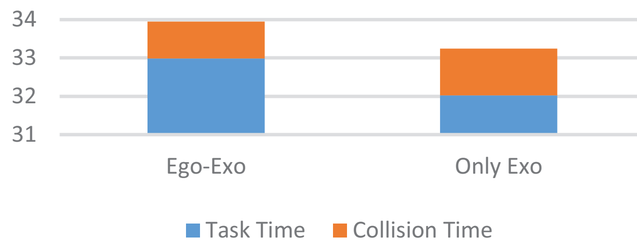

Figure 4: Third task results (seconds).

These results indicate that the EGO-EXO technique is only more efficient than the exocentric technique when both users need to apply the manipulations at the same time and with a high level of precision. The data suggests that this happens due to discomfort caused to the egocentric viewpoint user because her position is manipulated by the other user. When asked about whether they felt more discomfort using the egocentric viewpoint than the exocentric, 45% said they did. However, the questionnaire also showed that the participants generally preferred the EGO-EXO technique. Most participants (75%), considered the egocentric viewpoint better than the exocentric viewpoint when applying rotation operations. This indicates that, although the manipulation achieved worse results in most of the tests, users still preferred to stay close to the object, being able to clearly observe their actions.

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