A Study of Direct Versus Planned 3D Camera Manipulation on Touch-Based Mobile Phones

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ABSTRACT

Mobile interfaces are evolving towards touch-based approaches. This allows users to interact with their thumb directly on the screen. Such kind of direct approaches may be fussy for 3D interaction tasks, in particular because of thumb occlusions. In this paper, we introduce a new 3D user interface for the control of a planned trackball, where the users sketch horizontal or vertical movements to observe an object. A user study revealed no significant difference for error rate between this new approach and a standard trackball control. Despite a better completion time with the direct control, the study showed that the subjects preferred using the planned version of the trackball because it limits disorientation.

Categories and Subject Descriptors

I.3.6 [**Methodology and Techniques**]: Interaction techniques; H.5.2 [**Information interfaces and presentation**]: User interfacesInteraction styles

Keywords

3D Rotation, User Study, Mobile Devices, Interaction Technique

1. INTRODUCTION

Mobile user interfaces, which have been based on key strokes for a long time, are evolving towards touch-based approaches. This evolution is linked to the integration of sensitive technologies on the screens of today's mobile phones. With these touch-based devices, new user interfaces have appeared where the whole system is controlled by way of finger gestures on the surface of mobile devices. Following the same philosophy, we explore touch-based interfaces for the completion of 3D interaction tasks.

The advances in mobile graphics have favored the development of 3D applications on mobile devices[2]. In addition to short texts, sounds, images and videos, mobile users may now benefit from interactive 3D contents on their mobile phones. This opens new directions for tomorrow's mobile applications. On the other hand, interacting with 3D objects on touch-based mobile devices is a difficult task. Consequently, the level of interactivity offered to the user in 3D mobile applications is generally much reduced.

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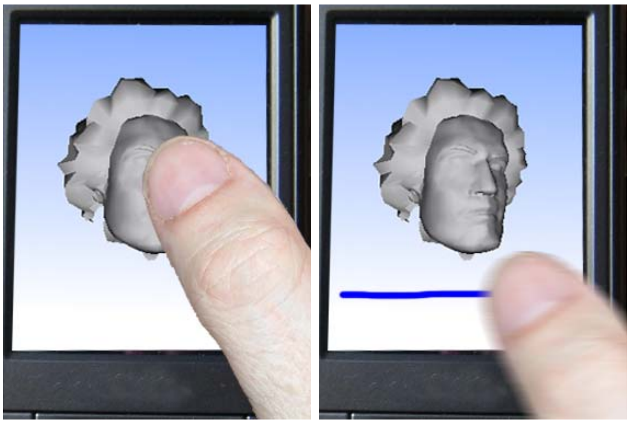

Figure 1: A standard trackball on a mobile device induces occlusions of the screen (left). A stroke-based adapted trackball favors the visualization of the 3D model (right).

The 3D user interfaces dedicated to the completion of 3D interactive tasks have generally been developed for desktop users. Whereas these 3DUI may be very efficient when used with a standard computer, they can become inefficient in a mobile context. Consequently, a special care must be taken when porting standard 3DUI to mobile devices.

One of the most famous 3DUI is the virtual trackball technique. This well-known technique has become a standard for the observation of 3D objects in a desktop context. On mobile devices there is no evidence that this technique remains efficient. Some inherent mobile constraints may affect the performance. In particular, the fact that the thumb of the user occludes a large part of the screen may be a problem when observing 3D objects, as illustrated on the left side of the Figure 1.

In this paper, we focus on the usability of the virtual trackball on touch-based mobile devices. We explore a new direction for the control of the technique, where the user manipulates the object by sketching horizontal and vertical strokes (see Figure 1, right). A user study allows us to better understand the influence of the control on the user performance for an observation task.

2. RELATED WORK

The mobile devices ergonomics have made evolved the standard UI towards dedicated mobile UI. In particular, the one-handed touch-based approach of the modern mobile phones has raised interesting questions.

Karlson et al.[12] focused on the following usability issues: “how users currently operate devices”, “how many hands are used for a variety of mobile tasks” and “how device size, target location and movement direction influence thumb mobility”. They provided some guidelines for thumb movements and suggest that Up↔Down or Left↔Right movements seem to be more comfortable than other ones.

The small size of mobile devices’ touchscreen induces specific usability issues. In particular, the thumb of the user occludes a large part of the screen. Moreover, the input provided is not precise. To overcome these issues, several works have been led in the scope of 2D applications. For example, Parhi et al.[13], have evaluated the optimal target size for one-handed thumb use of mobile devices equipped with a touchscreen. Other works propose alternative solutions to overcome the lack of precision, such as Shift[14] or Escape[15].

Today’s mobile devices are getting more and more powerful. They are now able to run 3D applications such as games or 3D model visualizations. Hwang [10] have demonstrated that users may benefit from mobile Virtual Reality applications, even with small visual field of view devices and limited processing power. Despite these new opportunities for mobile users, few 3DUI have been designed according the mobile devices’ constraints. Navidget[6], which is dedicated to 3D camera positioning, is fully based on 2D gestures. It is thus well suited for touch-based mobile devices such as PDA. However, this navigation technique does not address one-handed thumb interaction. Similarly, Hachet and Kulik [7] propose to add elastic feedback for two-handed stylus-based devices in order to increase user performance in navigation tasks. Other approaches explore the use of alternative inputs such as embedded cameras [3, 8], multi degrees-of-freedom joysticks [9], or tilt sensors[5].

In this paper, we focus on 3D camera manipulation around an object when controlled by the thumb of a mobile device user. This follows Karlson and Bederson’s recommendations [11], which state that ”a majority of phone and PDA users would prefer to use one hand for device interaction”. To control camera movements around a 3D object on a desktop computer, Chen et al.[4] have described the “Virtual Sphere” controller, and introduced the “Virtual TrackBall” metaphor. More recently, Bade et al.[1] have compared four standard 3D rotation techniques that use the trackball metaphor, and concluded that the “Two-Axis Valuator” seems to be the best 3D rotation technique.

3. ADAPTING THE TRACKBALL TO THE MOBILE CONSTRAINTS

Rotating the camera around a 3D model is a fundamental task in 3D interaction. It allows the user to understand the 3D structure of a model displayed on a 2D screen. The virtual trackball technique, which is available in any 3D viewer, allows the user to perform this task efficiently. On the other hand, this technique has been designed and evaluated for desktop configurations only, where the trackball is controlled by way of a mouse.

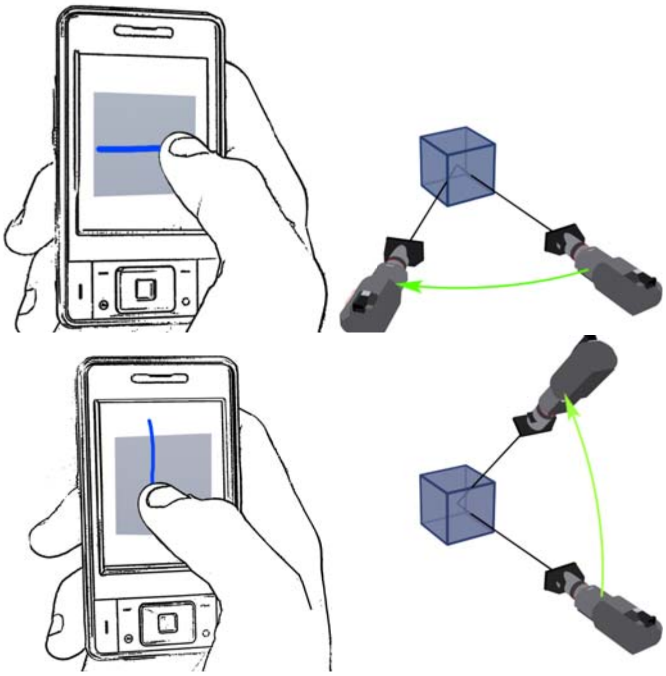

Figure 2: Horizontal movements produce rotation around the “up vector” of the camera (top). Vertical movements produce rotation around the “Right vector” of the camera (bottom).

On mobile devices, this technique is harder to control as soon as the user interacts by way of thumb gestures. In particular, the inherent occlusions caused by the thumb are contradictory with the main goal, which is to obtain a good visualization of the observed 3D models. Moreover, the anatomical constraints as well as the precision issues make the control of the virtual trackball harder with the thumb than with a mouse.

In order to overcome these issues, we have developed a “planned” version of the “Two-Axis Valuator” trackball technique. It is controlled by way of horizontal and vertical strokes drawn on the screen. Horizontal strokes result in rotations of the virtual camera around the axis defined by the center of the model and the up-vector of the camera, which produces a rotation along the horizontal plane, while vertical strokes result in rotations around the axis defined by the center of the model and the right-vector of the camera, which results in a rotation along a vertical plane (see Figure 2). After the user releases his or her thumb from the screen, the camera is smoothly rotated according to the inputed gesture. Hence, the user is able to move the camera around the 3D model by drawing successive strokes.

The rotation angle between two successive views is set according to the required precision. A small rotation angle results in numerous possible views. In this case, many input strokes could be required. On the other hand, a big rotation angle limits the number of strokes. However, this limits the number of obtained views, too. Our experience with the technique has shown that a 45 degrees rotation angle is a good compromise. It allows good visualization of the 3D

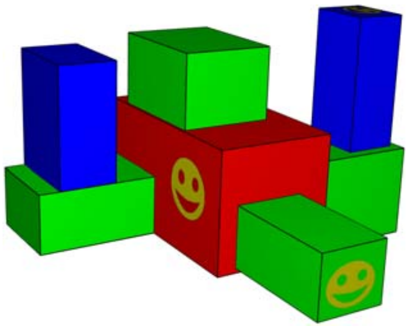

Figure 3: The 3D model used in the experimental task.

models while limiting the number of required strokes.

The animation duration depends on the time the user spent to draw the stroke: the faster the stroke is drawn, the faster the camera is rotated. We did not allow the user to draw diagonal lines, which would result in a combination of horizontal and vertical rotations. This follows Karlson et al.'s guidelines on thumb based mobile interaction[12].

Finally, by sketching horizontal/vertical strokes with their thumbs, the users are able to observe 3D models easily. This approach is inspired from the modern GUI approaches (eg. iPhone) where the users control some commands by way of simple gestures.

The planned trackball we propose induces a discretization of the possible views. Consequently, it is not well suited for precise 3D orientation tasks. Our approach follows the *sketching* philosophy, where coarse results are obtained by way of simple and fast commands. In the context of interactive 3D applications on mobile devices, we can assume that accurate positioning is rarely required. Coarse manipulation approaches can be better suited as soon as they allow the user to understand well the 3D structure of the objects.

4. USER STUDY

The planned trackball approach we have proposed offers some advantages, as we have discussed previously. On the other hand, such a discretized approach decreases the directness of the interaction, which can affect the user performance in 3D model observation tasks. In order to assess the influence of the directness of the control for trackball-like techniques on one-handed mobile devices, we set up an experiment.

Procedure.

The task for this experiment consists in counting the number of targets (yellow "Smileys") drawn on the faces of a 3D model, as shown on Figure 3. This requires the subjects to observe all around the 3D model to find the targets. We asked the subjects to perform the task twice, once with the *Direct Controlled Trackball* and once with the *Planned Controlled Trackball* we have proposed, with a 45 degrees rotation angle.

Before starting the experiment, participants experienced with both techniques. Then, we asked them to complete the task as fast as possible. The entire experiment takes about 10 minutes per participant. A trial started once the 3D model was fully loaded on the mobile device, and ended when the participant gave his or her answer. We recorded the correctness of the subjects' answers, as well as the completion times between the first tap on the screen and the answer given by the subject. The error rate is given by the number of times participants reported an incorrect number of smileys out of all tasks. After the experiment, we asked the participants to fulfill a questionnaire.

The participants completed six trials with each technique. The same 3D model was used for all the tasks, but six different distributions of the targets were used. We ordered these six distributions into two different series. The order of the techniques as well as the order of the series were counterbalanced. The only independent variable was *Technique* (Direct Control "DC" or Planned Control "PC").

Apparatus and Participants.

The experiment was conducted on an Asus P535, with a 44 x 60 mm - 240 x 320 pixel display. The effective resolution of the device is 5.33 pixel/mm. The mean frame rate during the experiment was 15 fps. Seventeen people (14 male and 3 female) aged from 24 to 50 (mean 28) participated in this experiment. All participants were mobile-phones users and right-handed. In order to motivate them, we awarded the participant who realized the lowest error rate and the fastest completion time.

5. RESULTS

5.1 Measured Performance

A paired t-test revealed no significant difference between the error rate means for the two techniques (DC: 53% / PC: 49%). In both conditions, the subjects tended to count some targets twice, which reminds that understanding the structure of 3D objects is difficult.

Concerning the completion times, a paired t-test revealed that subjects were faster with the Direct Control than with the Planned Control (completion time means DC: 106 164 ms / PC: 125 241 ms , $t_{(16)}$ = -2.180, $p < 0.05$). This can be explained by the time needed to run the animation after the users' strokes.

5.2 Subjective Comments

A 5-point Likert scale (1 = strongly disagree and 5 = strongly agree) was used for the questionnaire. The analysis of the answers allowed us to obtain user feedback about the two techniques, Direct Control and Planned Control. We used a Wilcoxon Z test to compare the subject's answers.

There was no significant difference for the general usability of the techniques (DC: 3.06, PC: 3.68). Similarly, the subjects did not feel significantly faster (DC: 3.37, PC: 3.68), nor freer (DC: 3.93, PC: 3.18), nor more precise (DC: 2.5, PC: 3.6) using the Direct Control compared to the Planned Control.

Participants indicated that they often felt lost when using the Direct Control. The analysis of the questionnaire revealed a significant difference for the statement "I did not feel lost" (DC: 1.2, PC: 3.4; Wilocxon Z test: Z = -3.319, $p < 0.001$). This difference can been explained by the fact that a planned control may help the users in the cognitive structuring of the movements. Indeed, the planned approach allows the user to better control their movements. For example, by inputting two successive strokes in the same direction, the user knows he or she will obtain a 90 degrees rotation. He or she can come back to the original orientation by stroking twice in the opposite direction. This may limit the disorientation.

Finally, the subjects reported that the occlusions induced by the thumb were disturbing for the Direct Control technique, whereas it was not the case for the Planned Control technique (DC: 1.6, PC: 3.6; Wilocxon Z test: Z = -3.093, $p < 0.005$). With the Direct Control technique, the subject need to frequently release their thumb to observe the model.

6. CONCLUSION AND FUTURE WORK

In this paper, we investigated the use of a stroke-based planned trackball for 3D observation tasks on one-handed mobile devices. The user study we conducted did not show that this technique was more efficient than a standard direct trackball technique. However, the feedback given by the subjects lets us think that such a planned approach may be a good alternative to standard techniques on mobile devices. In particular, we think that a planned approach may limit the disorientation that can appear with a direct approach. Further experiments should be conducted to confirm this results.

In many cases, direct control techniques are more powerful. On the other hand, in some situations, planned techniques could be competitive. This is the case for coarse orientation tasks we have described in this paper. Moreover, planned techniques are particularly interesting as soon as a realtime rendering cannot be insured. This is often the case when visualizing 3D data on mobile devices. The early tests we did have shown that a direct trackball approach becomes unusable on a mobile phone as soon as a lag appears between the user's actions and the resulting 3D model motions. On the other hand, a planned trackball technique sidesteps this issue. Objects can be adequately observed even if realtime rendering is not ensured.

In the future, we plan to evaluate the benefits of a planned control over a direct control for other camera movements. We also want to investigate how the frame rate can influence the user performance.

7. ACKNOWLEDGMENTS

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