Balloon Selection revisited – Multi-touch Selection Techniques for Stereoscopic Data

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ABSTRACT

With the increasing distribution of multi-touch capable devices multi-touch interaction becomes more and more ubiquitous. Especially the interaction with complex data (e.g. medical or geographical data), which until today mostly rely on mice and keyboard input or intense instrumentation, can benefit from this development. Multi-touch interaction offers new ways to deal with 3D data allowing a high degree of freedom (DOF) without instrumenting the user. This paper evaluates indirect multi-touch 3D selection techniques that can be used to interact with stereoscopic data. In this paper two gestural multi-touch selection techniques are presented and investigated with respect to positions on a stereoscopic multi-touch display and special consideration of objects displayed with different parallaxes. In an experiment it was shown that position and parallax have a significant impact on the interaction.

Categories and Subject Descriptors

H5.2 [**Information interfaces and presentation**]: User Interfaces. - Graphical user interfaces

Keywords

3D User Interfaces, Gestural Interaction, Selection techniques, Stereoscopic Display.

1. INTRODUCTION

Multi-touch technology has received considerable attention in the last years, especially for 2D user interfaces. Although multi-touch has great potential for exploring complex content in an easy and natural manner only few researcher have investigated so far how these concepts can be extended to 3D multi-touch interfaces. Current 3D user interfaces, as they are for example provided by virtual reality (VR) systems consist of stereoscopic projection and tracked input devices. But these are often expert systems with complex user interfaces and high instrumentation. On stereoscopic displays objects might be displayed with different parallax paradigms resulting in different stereoscopic effects. Objects may appear behind (positive parallax), on top (zero parallax), or in front (negative parallax) of the screen. Interaction with objects that are displayed with different parallaxes is still a challenging task even in VR-based environments [7]. Multi-touch technology might be a good tradeoff to overcome this limitation by allowing a rich set of interactions without high instrumentation. However, the benefits and limitations of using multi-touch in combination with stereoscopic display have not yet been examined in-depth and are not well understood [7].

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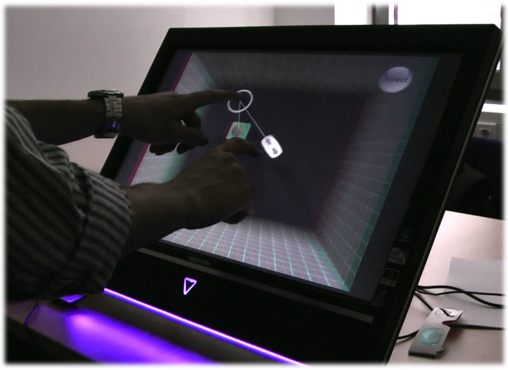

Figure 1: Interaction with stereoscopic data on a multi-touch surface with anaglyph display.

In this work we address the question how users can interact with stereoscopic data when the interaction is restricted to a two-dimensional multi-touch surface. Therefore two wigdet-based multi-touch selection techniques are presented and investigated. We present results of an experiment that gives insights on selection of stereoscopic objects displayed at different positions and with different parallax.

2. RELATED WORK

Today mice and keyboards are still used to navigate, explore and interact with complex systems (e.g. Geoinformation Systems and Desktop VR Systems) even though they are not optimal devices for this purposes. Nowadays several hardware solutions exist that allow multi-touch input on surfaces of different sizes (cf. Buxton's history of multi-touch surfaces and interaction[1]) but only few researchers have addressed the problem of 3D interaction on a 2D multi-touch

[1]http://www.billbuxton.com/multitouchOverview.html

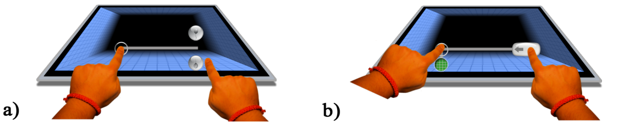

Figure 2: Balloon/Fishnet Selection: a) The basic tool selection menu. b) The fishnet tool allows the balloon selection for objects with positive parallax.

surface so far. Schöning et al. considered some of the challenges of multi-touch interaction with stereoscopically rendered projections [6]. One limitation all these approaches have in common is the constraint of the interaction and visualization to almost zero parallax because the plane of the interactive surface limits the interaction space more or less to the 2D surface.

Due to their natural and non-conflicting depth cues direct touching monoscopic 3D objects can be assigned to the image plane selection techniques [5]. In a stereoscopic multi-touch environment they are practically the same, but conceptually similar to ray casting methods, with a ray emitted into the negative and positive parallax space [3]. Accordingly, besides the difficulties already uncovered in [9], direct selection can be inadequate and ambiguous if several elements are intersected by the ray. Bimanual interaction techniques have a long tradition in human-computer interaction (e.g. [2]) and also have been applied to 3D interaction (e.g. [4]). The *Balloon Selection* approach by Benko and Feiner [1] is a multi-touch technique in an augmented reality setting that allows indirect selection in the 3D space above the tabletop. Most recently Strothoff et al. presented TriangleCursor, an interaction technique similar to Balloon Selection and compared it to an extended version of Benko and Feiner's approach in a manipulation task [8].

There is a need for further investigations on how to interact with complex three dimensional data in particular stereoscopic rendered data. This work investigates how the different parallax paradigms as well as the position of objects determine multi-touch selection techniques.

3. MULTI-TOUCH 3D SELECTION TECHNIQUES

Stereoscopic effects on screens are achieved by showing each eye of an observer a different image. The effect of objects floating in front of the screen is reached but the depth cues the brain obtains are ambiguous. The eye's convergence presumes that two different images are seen, but the eyes need to focus the screen instead of the objects in front. This leads to an accommodation contradictory to the convergence. To resolve the eye focus problem the selection tool is required to be blindly manipulated so that the focus can remain steadily on the scene objects.

In its original version the Balloon Selection used a head mounted display which avoids several ambiguities of depth cues. For stereoscopic multi-touch environments such as used in this paper indirect selection methods have not been considered yet. The aim of this work is to determine the effects of parallax and ambiguous depth cues during the use of the widget-based selection methods. In order to investigate this two techniques for stereoscopic touch displays are proposed: (1) the *Balloon/Fishnet Selection* and

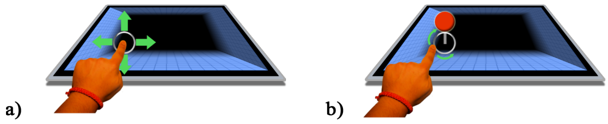

Figure 3: Corkscrew Selection: a) Dragging the circle widget allows x-, y-translation. b) A circular movement performs the z-translation.

(2) the *Corkscrew Selection*. The Balloon Selection has already shown to be adequate for this kind of task while the Corkscrew Selection is expected to allow a less rigid manipulation since it can be used bi- or single-handed. Taking two methods into account more general conclusions can be deduced from the study.

3.1 Ballon/Fishnet Selection

Besides the balloon metaphor that is still used to select objects with negative parallax a fishnet metaphor is used to support the selection of objects with positive parallax (see Figure 1 and 2). The manipulable balloon's string is of a fixed size, to allow reaching all objects visible in the scene. On its end a button widget indicates the possible interactions.

3.2 Corscrew Selection

The Corkscrew Selection technique is a selection technique that is somehow similar to the scalable selection pointer of the Balloon/Fishnet technique but it uses another metaphor to sink and lift the selection tool. Performing rotation gestures on a circular widget enables the user to steer the selection pointer (see Figure 3). Counter clockwise rotation on the widget makes the pointer rise up, clock-wise rotation makes the selection pointer sink. Touching and dragging the widget performs a translation along the x-, y-axes.

4. STUDY

According to the expected difficulties mentioned in the previous chapter, the hypotheses to be verified by the user study are: (1) The selection of elements with negative parallax is more difficult than the selection of elements with positive parallax since for the latter ones the more natural and unambiguous depth cues are provided. (2) The selection of the objects on the lower screen half is more complex than the selection in the upper screen half independent from the parallax. (3) Corkscrew Selection performs better than Balloon/Fishnet Selection.

The study apparatus was developed using the Ogre SDK[2] for the rendering of anaglyph stereoscopic 3D content, and the TUIO Reference Client[3] for the reception of the occurring touch signals. The implementation of the gestures was realized according to the approach used by Benko and Feiner [1]. As setup an All-In-One Medion Akoya P4010 (MD8850) touch computer running Windows 7 was used for the study. With a screen diagonal of 56 centimetre up to two simultaneous touches are supported. The computer renders red-cyan anaglyph pictures for stereoscopic 3D.The device stood on a bar table and was inclined by 45 degrees. The tables height was adaptable, and appointed the way users

[2]http://www.ogre3d.org/
[3]http://www.tuio.org/

can comfortably stay in front and work with arms inclined by 90 degrees.

As test scenario, the subjects were asked to perform a selection task with both selection techniques (within-subject design). The method with which a participant begins was constantly alternated. Clearly visible cubes, disposed on the corners of a fictive cube, that were placed at extreme parallax of each respective space, had to be selected. The center of the cube is on the zero parallax plane, on which another object to select is placed and a zero parallax element is provided for completeness. A successfully selected object vanishes and the next one appears. Objects appear in a fixed order, altering negative and positive parallax. The selection of one element corresponds to one trial. In total the selection of the nine elements had to be performed six times per selection method. The total amount of trials equals to: $9objects \times 6cycles \times 2methods = 108$. All interactions with were logged for later analysis.

In this study 10 subjects (5 male and 5 female) between 19 and 36 years took part. The test was structured as follows: After a short introduction the subjects were asked demographic questions. Then their ability to perceive stereo vision was tested. One of the two selection techniques was demonstrated (including a free trial phase of two minutes). Then the subject had to perform the actual tasks and select objects with the first selection technique. After a mandatory resting phase the second technique was tested. Finally after the completion of all trials a post study questionnaire had to be filled out before being debriefed. The overall duration took around 45 minutes for each participant.

5. RESULTS

In the following the performance of the different selection techniques are investigated with special focus on different parallax paradigms and the positioning within the parallax space. Parallax and position was treated as independent variable while task completion time and error rate were dependent variables. The data then was evaluated using one-way and two-way analysis of variance (ANOVA), t-test, under the assumption of a confidence interval of 95% for all tests. The error metric is defined as follows:

$$errortimerate = \frac{errortime}{taskcompletiontime}$$

An error is committed when between two consecutive image rendering frames the user increases the distance between the balloon pointer and the object to select, instead of diminishing it. The error time rate indicates the precision with which a single selection task is performed.

5.1 Balloon/Fishnet Selection

Testing trials with negative parallax against trials with positive parallax the t-test results in $t(23) = 2.91, p < 0.05$ for task completion time and $t(23) = 16, p < 0.001$ for error time rate. For both metrics a strong significance between negative and positive parallax exists. The average time on task as well as the average error time rate is considerably higher for objects with negative parallax.

To evaluate the importance of the object positioning within the different parallaxes, the values for time on task and error time from the four objects of positive and negative parallax were separately evaluated in a one-way ANOVA. For objects with positive parallax no significance is found between the different object positions. Neither for the time on task metric, nor for the error time metric (ANOVA results for Time on task: $F(3, 20) = 3.1, p = 0.34$ and Error time rate: $F(3, 20) = 3.1, p = 0.07$). Position is not significant regarding task completion time of elements with negative parallax. Indeed for the error time the position is significant. Trials with objects on the upper part of the display (lower occlusion) in negative parallax space have a lower error time rate (Time on task: $F(3, 20) = 3.1, p = 0.38$; Error time rate: $F(3, 20) = 3.1, p = 0.03$)

5.2 Corkscrew Selection

For corkscrew selection the t-test shows also a strong significance between the two parallaxes, for both metrics (Time on task: $t(23) = 3.33, p < 0.05$; Error time rate: $t(23) = 19.5, p < 0.001$). Similar to the Balloon/Fishnet technique, selecting objects with negative parallax took more time and was less precise than for objects with positive parallax.

Regarding object position for positive parallax objects no significance is found (Time on task: $F(3, 20) = 3.1, p = 0.81$; Error time rate: $F(3, 20) = 3.1, p = 0.58$). Similar to the Balloon/Fishnet Selection the time on task shows no significance, whereas for the error time there is a significance between the positions. Less errors were committed during the selection of the objects near the upper screen edge.

5.3 Balloon/Fishnet vs. Corkscrew Selection

The effects for the different parallaxes could be determined for both selection techniques. For the evaluation two consecutive two-way ANOVA tests are used, one for the time on task and one for related error time rate, to determine if one of the two methods has an impact on the selection in different parallax spaces. The variables in this test are the parallax spaces and the selection methods. The already mentioned significance for the selection of elements in different parallax spaces is visible ($p < 0.001$). A strong significance between the selection methods also exists ($p < 0.001$). Furthermore the selection method in conjunction with the parallax spaces has no significance ($p = 0.08$). The significance between the selection methods is due to fact that the Corkscrew outperforms Balloon/Fishnet. The average overall task completion time for the Balloon/Fishnet Selection corresponds to 320.8 seconds while for Corkscrew Selection it corresponds to 252.5 seconds.

For the error time rate analysis a strong significance exists between the selection methods ($p < 0.001$) as well as a significance in the conjunction between the selection method and parallax variable. The values show that the Corkscrew method is less precise than the Balloon Selection. For negative parallax the error time rate is 50% higher with Corkscrew Selection while for positive parallax it is more than three times higher.

5.4 Post-study Questionnaire

After the test the participants were asked to fill out a questionnaire containing answers in a seven point likert-scale as well as free text forms. The questionnaire contains questions about the stereoscopic 3D effects of the scene and about the selection methods in order to get an insight on selection of stereoscopic 3D elements, the usability, the learnability and the joy of use. The average results of the questions concerning the parallaxes in conjunction with the selection task are shown in Table 1. The results from the logs are consistent

Question	Parallax	B/F	CS
Easy to select	Negative	5.7	6
	Positive	6.3	6.2
	Zero	6.2	6.1
Recognisable during task	Negative	5.9	6
	Positive	6.4	6.7
	Zero	6.4	6.3

Table 1: Average results of the questions concerning selection in different parallax spaces, answered by a 7 point likert scale, 7 being the highest score.

with the participants' answers. Most subjects chose the Balloon/Fishnet Selection as favorite method by justifying that it was faster. The logs from the experiment however show that every user performed better with the Corkscrew.

6. DISCUSSION

The study revealed that object parallax and object positioning within a parallax space have a strong impact on the indirect multi-touch selection in stereoscopic environments. The selection of objects within the positive parallax space outperformed the selection within the negative parallax space. This leads to the conclusion that the selection of elements with negative parallax is more difficult than the selection of elements with positive parallax. It takes more time, while being less precise. This fortifies the previously introduced hypothesis that the selection of elements with negative parallax is more complicated than the selection of objects from the positive parallax space. For the object position the task performance time showed no significant difference for the selection of objects with different positions while the error rate shows strong significance for both selection techniques. Objects placed at spots implying lower occlusion by hands or the selection tools could be selected more accurately.

In direct comparison the same effects for the different parallaxes could be determined for both selection techniques. As supposed in hypothesis 1 selections in negative parallax space take longer and are more error-prone than in the positive parallax condition. But object positioning within the parallax space is also of importance (hypothesis 2). Due to the linear perspective of the 3D scene the selection performance can be improved. Overall Corkscrew performs better in task performance time (hypothesis 3). However the Corkscrew Selection is less precise with respect to error time rate. The better performance for the task completion time of the Corkscrew Selection can be the result of a more linear selection process with a more accentuated DOF separation, since as it is visible on the videos users preferred a single-handed manipulation. But even if the Corkscrew method performs better in terms of time on task, the precision is lower. By inspecting the video footage it can be observed that with the Corkscrew method the subjects often started rotating their finger around the widget, without previously worrying about the right direction.

The results of the post-study questionnaire underpin the results of the experiment, as they are also justifying the hypothesis that selection in negative parallax is more difficult. In contrast to the measured time on task duration the participants subjectively judge the Balloon/Fishnet Selection technique as faster than the Corkscrew technique. So the subjects' preference might therefore be related to a more dynamic handling offering a greater joy of use.

7. CONCLUSION & FUTURE WORK

In this work we investigated two indirect selection techniques that enable users to seamlessly select stereoscopic objects displayed with different parallax on a multi-touch display. We performed an experiment in order to gain insights on how the different parallax paradigms as well as the position of objects determine multi-touch selection techniques. The results of the user study indicate, that the selection of elements in the negative parallax space is more difficult to perform. This might be related to the ambiguous depth cues the touch interaction with such stereoscopic content involves. A second result of the study is that at regions at which the occlusion as well as the ambiguous depth cues are extenuated, the selection task was less difficult. We found out that even if the selection in negative parallax space is difficult it remains feasible. The effect the automated manipulation of the 3D scene and the usability of such environments should be addressed in future work. For example slightly changing the vanishing point of the 3D scene can diminish the object occlusion in which cases the manipulation in negative parallax space is eased.

8. ACKNOWLEDGMENTS

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