A Set of Interactions to Rotate Solids in 3D Geometry Context

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Abstract

Tablets with touch-screens, multi-touch interfaces and various sensors are becoming increasingly common. More and more schools are testing them with their pupils in the hope of bringing pedagogic benefits. Thanks to this new type of devices, new sets of interactions can be thought of. Yet, user reception has to be tested before any pedagogic benefits can be evaluated. In this paper, a set of interactions using multi-touch and sensors to manage rotation of solids is presented. It was largely accepted by a test group of learners aged 9 to 15.

Author Keywords

3D user interface; Interactions; tablets touchscreen; multi-touch; 3DOF; rotations; child-computer interaction.

ACM Classification Keywords

H.5.2. [Information Interfaces and Presentation]: User Interfaces – Interaction styles, G.4 [Mathematical Software]: User interfaces.

Introduction

More and more schools are testing tablets with their pupils in the hope of bringing pedagogic benefits. The popularity of multi-touch interfaces has grown rapidly, becoming an important component of many devices such as smartphones and tablets. In these tablets, multi-touch interfaces are now complemented with various sensors such as accelerometers and gyroscopes. These devices provide interaction techniques that are often intuitive and easy to use in 2D. However, manipulation of objects in 3D is still a challenge.

The objective of this project is to define a grammar of interactions for the 3D geometry-learning context with learners aged 9 to 15. Many researchers [3, 4, 6] have proposed different interaction techniques to manage rotation and translation in 3D but no grammar of interactions in our learning context is yet explored.

In this paper, we present a set of interactions to manage rotation of solids. Most of the interactions are already known but they have not been tested such as a set of interactions yet. Moreover we introduce a new interaction to rotate a solid around an axis defined by two vertices. In this paper, we present only the part of our grammar relative to rotations [12]. A preliminary study with a small number of participants had been conducted to test user acceptance before any pedagogic benefits could be evaluated. As our research is still in its early stages, this test user acceptance will help us identify issues which may arise while attempting to define a grammar of interactions in our context.

Related Work

Multi-touch interaction techniques in 2D have been widely explored. 3D manipulation of objects is still a challenge. The main difficulty is to transform a 2D gesture into a 3D motion. 3D widgets [1] have been largely used to make 3D manipulation easier. Moscovich [7] had shown how to design touchscreen widgets that respond to a finger's contact area. Schmidt et al. [10] have presented an interface for 3D object manipulation in which standard transformation tools are replaced with transient 3D widgets invoked by sketching context-dependent strokes.

Many researchers have explored multi-touch interaction techniques to manage several degrees-of-freedom (DOF) at the same time. Hancock et al. [3] have proposed to use from one to three fingers to handle objects in shallow depth. Martinet et al. [6] have extended the standard four viewports technique by adding a teleportation system. They [6] have introduced the bi-manual Z-technique too. Due to the complexity of multi-touch interaction techniques, Kammer et al. [5] have defined a grammar to formalize multi-touch gestures.

Tsang et al. [11] have introduced the *Boom Chameleon*, an input/output device consisting of a flat-panel display mounted on a tracked mechanical boom. The display acted as a physical window into 3D virtual environments. Hurst and Helder have [4] studied the use of accelerometer sensor to manage observer's rotation or rotation of scene and observer at the same time.

Prototype System

In our context we have restricted our study to mobile devices like iPad. This choice has implied two major constraints. The first one is linked to the size of the multi-touch surface. We have to be able to accurately manipulate a solid even if one or more fingers hide it. The second constraint is linked to the scene in our 3D geometry-learning context. The scene can contained

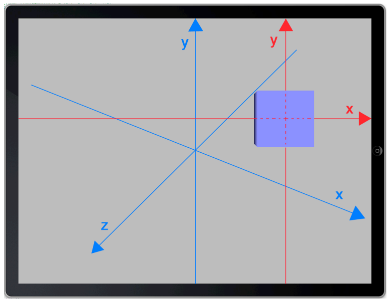

Figure 1. Observer's reference system (red) and Reference system of the scene (blue).

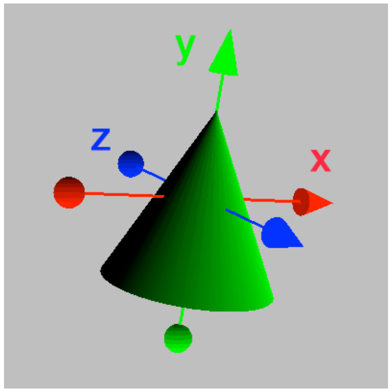

Figure 2. Reference system of the solid.

several mathematical objects. To permit the largest possibilities of manipulation, each solid had to be independently manipulated as well as the entire scene. To test our set of interactions we have implemented a prototype. According to Martinet et al. [6] when a finger touches a solid the interaction is direct. Otherwise the interaction is indirect. All rotation interactions from our set are indirect. We have mapped selection with a long press touch on the solid, translation with one-finger interactions and rotation with two fingers interactions. A solid has to be selected to be rotated. We have categorized rotation-interactions in three classifications depending on the reference system. The three reference systems we employed are the screen frame, the object frame centered on the object and the scene frame (Figure 1 and 2).

Rotations in the observer's reference system (FR; Free Rotation in the screen frame) use two fingers to rotate the object around the axes. We use the magnitude filtering technique [8] to minimize non-wanted rotations.

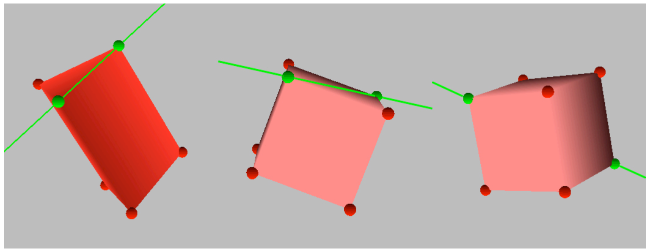

Figure 3. Axes of rotation defined by two vertices.

Rotations in the reference system of the object centered on the object (AR; Axis Rotation) are constrained by a defined axis. When a solid is selected its reference system appears (Figure 2). A touch on the sphere or the cone of each axis selects it. When a specific axis is selected the others become translucent. The solid can only rotate around the selected axis.

Rotations in the reference system of the scene (VR; Vertices Rotation) are all the other rotations where axis is defined by two vertices of the solid. The main problem is to define the axis of rotation. To solve the problem we have introduced two states of selection. Our selection system is cyclic. A one-second long press on a solid makes its reference system appear. One more second makes selectable vertices appear. A rotation axis is defined by selecting two vertices (Figure 3). A two fingers slide rotates the solid.

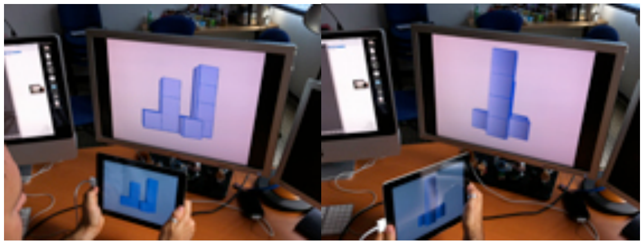

Figure 4. Gyroscopic sensor and video camera metaphor to turn around the scene.

We went in schools to observe 3D geometry lessons. Pupils turned around a real model of the exercise to verify their results. This interaction was so natural that we have decided to use it to turn around the scene (SR; Scene Rotation). A one–second long press with one finger on each side of the tablet begins or stops moving the observer. A new background color gives a visual feedback. The gyroscopic sensor is used to modify observer's position around the scene. We have

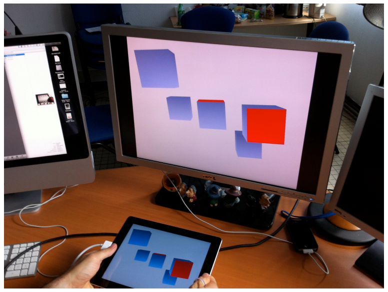

Figure 5. Implementation of our test-application.

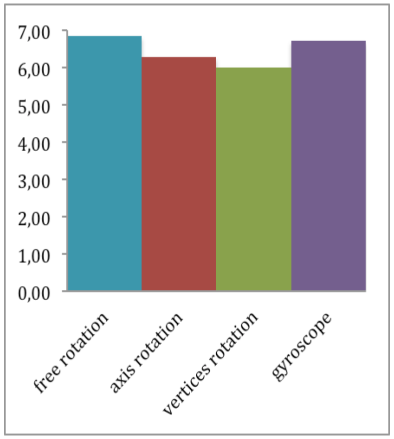

Figure 6. Ease of use.

used the video camera metaphor. The tablet acts as a window onto the scene and moving the tablet in space changes the viewpoint into the scene (Figure 4).

For now, our prototype maps one interaction with one type of rotation. Our goal is not yet to find the better set of interactions but to find at least an accepted set of interactions to evaluate pedagogic benefits and user reception of technology.

Initial user evaluation

To validate our set of interactions, we have designed simple test on our software prototype. In this experiment, users were asked to find cubes with a different color face. The goal of this experiment is to verify the acceptance of our set of interactions with pupils.

Participants and method

We recruited seven pupils, 3 males and 4 females aged between 10 and 15 (average 11.6, SD 1.59). None of the participants was colorblind. Two pupils haven’t used Apple iPad or similar before. Four pupils have already used a tablet and one participant had his own tablet. For the experiment, we implement a training-application with 2 cubes and a test-application with 5 cubes (Figure 5). The number of cubes had been chosen not to lead more an interaction than an other. After a 3-minute presentation, each participant had a 5-minute pre-training session to familiarize with using our application before starting the experiment. During the experiment, the participants were asked to find the number of cubes with a red face and for each red face its initial position on the cube. The experiment is composed of 7 trials on two sessions. Number and position of red faces changed at each trial. During the first session, the participants have 3 trials to complete. The second session was 6 days later. During the second session, the participants have to complete 4 trials. At each trial, we keep time for everyone and participants’ hands were videotaped. We noted strategy for each user. Priority was given to correct answers. A post-task questionnaire gathered opinions about ease and intuitiveness of interactions on a 8 point Likert scale where 7 means strongly agree and 0 strongly disagree. At the end, we interviewed participants.

Results and Discussion

Figure 7 shows the average completion time for each trial. For the first trial the average completion time is 189.7s (SD = 121.9) and decreases until 69.1s (SD = 28.4) for the seventh trial. The 6 days between the two sessions explain away the fourth trial increase completion time.

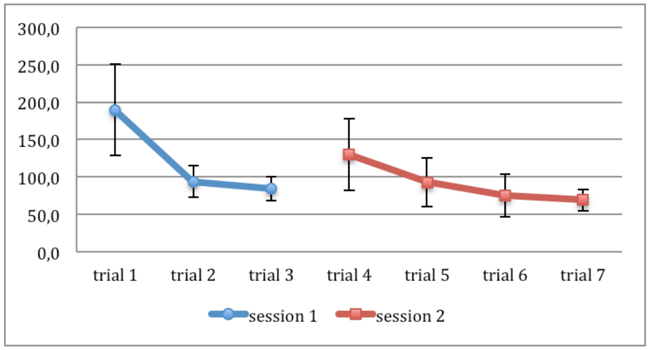

Figure 7. Completion time (sec.)

Figure 8 shows the rate of success to complete the task. 57.1% of success is obtained at trial 1, whereas 85.7% of success is achieved at trial 7. From the second trial, pupils were able to find 100% of red faces.

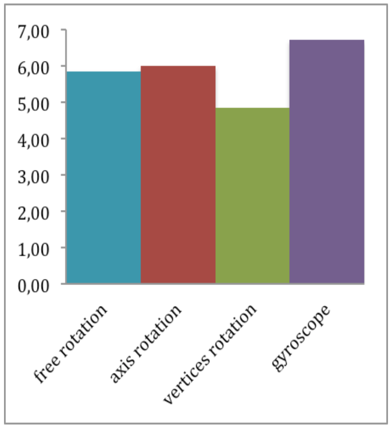

Figure 9. Interaction is felt natural.

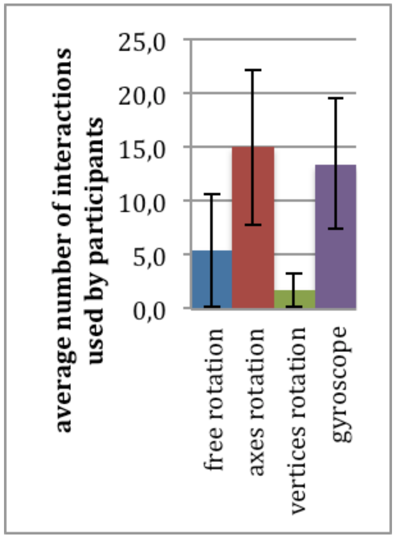

Figure 10. Logs of interactions. Average number of each interaction by participants.

The 6 days between the two sessions explain away the low rate of success at trial 4. The quickly decrease of needed time to complete task and the high rate of success show the acceptance of our set of interactions.

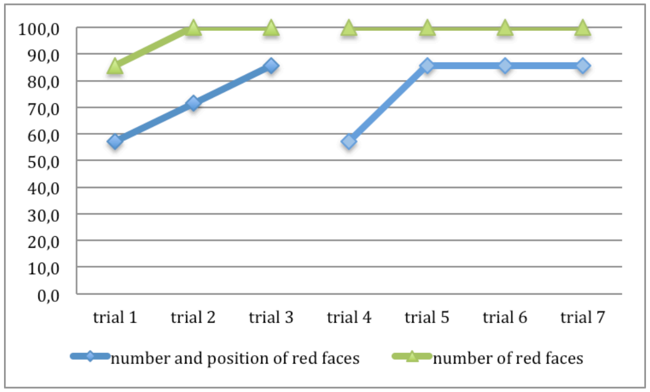

Figure 8. Rate of success (%) for task completion.

The user feedback suggests that participants are positive about our set of interactions. Implemented gestures were easy to use (Figure 6) and intuitive (Figure 9). However, two interactions were highly preferred by user. Discussions with the participants suggested that rotation around an axis of the solid reference system with multi-touch (AR) and rotation around the scene with gyroscope (SR) are felt such as the most efficient. According to users, the main reason for this was because AR has a reference system and the less parasite-movements while SR is the most intuitive. Our logs confirm that AR (average 15, SD 14.4) and SR (average 13.4, SD 12.2) are the most used (Figure 10). However, AR needs 5 interactions to observe all the cubes when SR needs only one interaction to give an overview of the scene. Moreover, two participants used AR after using AS to verify their results. Compare to rotation in the observer reference system (FR), AR adds a lock axis of rotation. Results make appear that participants viewed possibility to lock axis of rotation as important. AS a matter of fact FR and AR permit to complete the task in the same way but only one participant used FR to perform all the trials. Three participants tried to rotate cubes around an axis defined by two vertices (VR). Only one of them really used VR to complete the task. Define a specific axis is not necessary to complete the asked task that could explain the low use of VR. Although we have designed our test for rotation, one user attempted to use translation to see alternatively the left, right, top, bottom side of cubes. At least participants suggested that using gyroscope sensor to rotate around the scene is obviously the funniest interaction of the set.

Our prototype and the user evaluation suggest that multi-touch and sensors complemented each other. Most of the implemented interactions do not follow the real world interactions. The main reason is that multi-touch interactions are still limited by the 2D surface. For example, four users tend to use only one finger to rotate solids with AR. Discussions with the participants suggested that selecting an axis implies to perform a rotation. They were ready to use the same gesture for translation and rotation in function of the context.

Future works

Our implementation of the prototype permits only the translation and rotation of solids. However the initial user acceptance test is positive and lead us to evaluate pedagogic benefits in the resolution of 3D geometry problems. We have to implement the other parts of our grammar of interactions. Pupils need functionalities such as nets of polyhedra.

The observations and discussions with the participants lead us to explore other parts of our research. The first one is to explore and to combinate others innovative interactions such as tangible interfaces. The second one is to define simultaneously another grammar of interactions. Some participants prefered to use the same gesture for different functionalities. The second grammar of interactions could be define with same gesture in function of the context.

Conclusion

Multi-touch interaction is proving popular for 2D model interaction. We implemented and evaluated a 3D model, which utilized multi-touch and sensors such as gyroscope. Pupils found the combination of the two technologies made the 3D interaction to be intuitive and visually helpful. They believe that such technology can be very helpful in a 3D geometry-learning context.

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References

[1] E. A. Bier. Skitters and jacks: interactive 3d positioning tools. In I3D ’86: Proceedings of the 1986 workshop on Interactive 3D graphics, pages 183–196. ACM, 1987.

[2] A. Cohé, F. Décle and M. Hachet tBox: A 3D Transformation Widget designed for Touch-screens CHI 2011 Canada 3005-3008.

[3] M. Hancock, T. ten Cate, and S. Carpendale. Stickytools: Full 6DOF force-based interaction for multi-touch tables. In Proc. ITS, pages 145–152, 2009.

[4] W. Hürst and M. Helder. 2011. Mobile 3D Graphics and virtual reality interaction. In ACE’11 Proceedings of the 8th international conference on advances in computer entertainment technology. ACM, 2011.

[5] Kammer D., Wojdziak J., Keck M., Taranko S. Towards a formalization of multi-touch gesture ITS’10 novembre 7-10 2010 Saarbrücken.

[6] A. Martinet, G. Casiez, AND L. Grisoni 2010. The design and evaluation of 3d positioning techniques for multi-touch displays. In 3D User Interfaces, 2010 IEEE Symposium, 115 –118.

[7] T. Moscovich. Contact area interaction with sliding widgets. In UIST ’09: Proceedings of the 22nd annual ACM symposium on User interface software and technology, pages 13–22. ACM, 2009.

[8] Nacenta M.A., Baudisch P., Benko H., and Wilson A. 2009. Separability of special manipulations in multi-touch interfaces. In Proceedings of Graphics Interface 2009, 175-182.

[9] J. Reisman, P. Davidson, and J. Y. HAN 2009. A screen-space formulation for 2d and 3d direct manipulation. In Proceedings of the 22nd annual ACM symposium on User inter- face software and technology, 69–78.

[10] R. Schmidt, K. Singh, and R. Balakrishnan. Sketching and composing widgets for 3d manipulation. Computer Graphics Forum, 27(2):301–310, 2008. Proceedings of Eurographics 2008.

[11] M. Tsang, G.W. Fitzmaurice, G. Kurtenbach, A. Khan, B. Buxton. Boom Chameleon: Simultaneous capture of 3D viewpoint, voice and gesture annotations on a spatially-aware display. In UIST ’02: Proceedings of the 15nd annual ACM symposium on User interface software and technology, pages 698–698. ACM, 2002

[12] R. Vivian, J. Dinet & D. Bertolo, ''Spring: a solution for managing the third DOF with tactile interface", APCHI’12 Proceedings of the 10th asia pacific conference on Computer human interaction, pages 251-258. ACM, 2012.