ABSTRACT
In the last years 3D is getting more and more popular. Besides the production of an increasing number of movies for 3D stereoscopic cinemas and television, serious steps have also been undertaken in the field of 3D gaming. Complex games with stereoscopic 3D output might soon be available not only for gamers with high-end PCs but also on handheld devices equipped with 3D autostereoscopic displays.

Recent smartphone technology has powerful processors that allow complex tasks like image processing, e.g. used in augmented reality applications. Moreover these devices are nowadays equipped with various sensors that allow additional input modalities far beyond joystick, mouse, keyboard and other traditional input methods. In this paper we propose an approach for sensor-based interaction with stereoscopic displayed 3D data on mobile devices and present a mobile 3D game that makes use of these concepts.

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3D User Interfaces, Gestural Interaction, Mobile Interaction, Mobile Gaming, Stereoscopic Display

1. INTRODUCTION
In the last years there has been an increasing interest in 3D related technology e.g. 3D movies, augmented reality applications and gaming. Smartphones are nowadays powerful enough to process complex tasks like graphics or image processing. Most recently the release of handheld devices equipped with an autostereoscopic display fosters the development of stereoscopic 3D applications for mobile devices. Bringing stereoscopic 3D to mobile devices will allow a more realistic perception of augmented and virtual reality.

In this paper we propose sensor-based interactions for stereoscopic displayed data on mobile devices and present a prototype with anaglyph-based 3D visualization as a proof-of-concept. First, we briefly describe related work in this area. Secondly, a set of mobile 3D interaction styles is proposed. Emerging from these interactions, the concept of a game application will be then introduced. The paper concludes with a discussion as well as a conclusion and idea for future work.

2. RELATED WORK
This work covers a wide range of fields but mainly focuses on mobile interaction and 3D interaction. Only some researchers have addressed the problem of 3D interaction on mobile devices so far. 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 the other hand using stereoscopic displays allow users to perceive 3D data in an intuitive and natural way. But interaction with stereoscopic displayed objects is still a challenging task even in VR-based environments. Steinicke et al. discuss potentials and limitations for using multi-touch interfaces with mobile multi-touch enabled devices to interact with stereoscopic content.
Recent smartphones are equipped with various sensors (e.g. camera, accelerometer, gyrometer, gps etc.) and much research has been done in the field of sensor-based mobile interaction. Boring et al. introduced three interaction concepts to remote control a pointer on a display via scroll-, tilt- and move-gestures with a mobile phone \cite{3} while Benzina et al. \cite{2} explore travel-techniques for VRs using the sensors in the mobile phone. In an early work Rekimoto \cite{6} proposes a handheld device with one button and orientation sensors where 3D interaction is mentioned as one application for such a device. Capin et al. present a camera-based approach to navigate virtual environments on mobile devices \cite{4}. Decle and Hachet present a study of direct versus planned 3D camera manipulation on touch-based mobile phones \cite{5}. In contrast to related work multi-touch and sensor-based interaction with 3D stereoscopic data on a mobile device is investigated.

3. INTERACTION

In this section a set of mobile 3D interaction styles is proposed that allow the navigation in the scene as well as the manipulation of objects. These techniques rely on sensor-based input to track how the user is holding, moving and touching the device.

3.1 Navigation

The proposed navigation tasks are realized through rotation and flipping gestures of the mobile device. The movement of the mobile device in the real world also induces a change of view in the virtual world. This simply means that the camera in the 3D scene changes with respect to the movement of the mobile device. The mobile device can be seen metaphorical as a tangible camera. Thus the camera can be physically moved in every direction to change the field of view, its focus, etc.

The rotation of the mobile device allows a center rotation around an object or in 3D space. Rotating the mobile device corresponds to a rotation of the virtual camera in the scene. For a large 3D virtual space, rotation provides a viewpoint navigation method in the aspect of virtual camera rotation. For a single 3D object, it presents the 3D object as a fixed state which means a stereoscopic object is fixed in front of the mobile device while performing device rotation gesture (see Figure 2).

Zooming is realized though a flipping gesture that moves the virtual camera forwards or backwards in a step-wise manner. By flipping the mobile device quickly towards the user the virtual camera immerses along the z-axis (see Figure 3).

3.2 Manipulation

Object manipulation is realized by direct touch interaction. Furthermore the combination of tilting and rotation of the mobile with touch extends the interaction space and allows an easy and quick manipulation of 3D objects.

Object selection is realized by simple tapping it. The top-most object then will be selected. In combination with the navigation techniques this allows an intuitive and quick way to select objects that are even behind others (e.g. tilt and rotate the device to manipulate the scene and then touch to finally select the object).
Object rotation can be performed by touching an object and holding it followed by a rotation of the mobile device (see Figure 4).

Object translation can be done by touching and dragging which translates an object in 3D space with respect to the rotation and tilt of the mobile device. Figure 5 shows an example of moving an object with respect to the vertical plane defined by the position of the mobile device.

The latter interaction styles can be seen as a basic set of interactions for mobile 3D interaction. Dependent on a specific use case or application there might be the need to adapt the set to the requirements of the application. In the following an exemplary application is presented that illustrates this adaption.

4. FLIGHT CONTROL 3D

Based on the proposed interactions various application concepts can be developed. In this chapter a conceptual mobile 3D game “Flight Control 3D” is presented.

The game prototype was developed with the Android API [1] using OpenGl ES 2.0 (embedded system). It has two main components: the 3D virtual world renderer and the sensor controller. The objective of the 3D virtual world renderer is to create a virtual world with multiple objects such as the game map, airplanes, traces, airports etc. and to realize a stereoscopic renderer (i.e. anaglyph) by separating the camera with respect to different color masks (red-blue). The sensor controller on the other hand is aiming to control the sensors such as touch sensor, orientation sensor and accelerometers as input methods.

Flight Control 3D is a mobile game that combines the interaction styles proposed above with a 3D mobile game design. The game is inspired by Flight Control a popular game for mobile device platforms. In contrast to the original game the planes have to be controlled in a 3D world. This leads to several design issues and a game experience that totally differs from the original. First a simple 3D world has been developed that is based on a three layer concept: Ground layer, Sky1 layer and Sky2 layer (see Figure ??). The aircrafts are freely moving on Sky1 layer and Sky2 layer and only approach to the Ground layer when landing. The aircrafts can not collide when flying on different layers. So one strategy to avoid collision is the distribution of planes on the different layers.

By tilting the mobile device the view can be continuously...
changed from an above-view to a side-view. Depending on the view the user can define a trace to determine the movement of an aircraft. From above he or she can sketch the trace and from aside a layer change can be performed. As in the 2D version traces are defined by selecting and sliding. Layer changes are invoked by tilting the device in moving the plane to another level. Landing can be seen a special level change and is only possible from the level next to the ground level which is Sky1 layer in Figure ???. Successfully landing will be awarded just like in the original version.

5. DISCUSSION

Recent mobile technology is equipped with various sensors and powerful processors and thus is well suited even for 3D in- and output. Sensor-based interaction that enables the user to navigate in the virtual world by interacting with his whole body offers a rich set of metaphors and interaction for 3D. Movement in the real world such as viewpoint changes as well as travelling can be more or less directly mapped to the corresponding interactions in the virtual world.

From the game perspective interactions such as viewpoint navigation and object manipulation help to realize the game tasks. For selection, the airplane is simply selected by tapping on the screen on the relevant position. Moreover, tilting the device correspondingly rotates the viewpoint of the camera and adjusting an appropriate angle may help to select an airplane which is blocked by other airplanes. Drawing traces and landing lead in some cases to problems because sometimes it is hard to identify the current layer of an airplane from above. And as already discussed above, only in the layer next to the Ground layer the airplane can land so that the user needs to make sure to which layer the intended airplane belongs to. However, frequently tilting of the device assumes to be a solution for this problem: The layers of the airplanes are clearly achieved by getting the side view of the virtual world. Moreover, tilting the device over a threshold angle may trigger the layer change mode. Therefore, tilting the device as well as selecting and sliding the airplane may perform a layer change operation.

Some problems occur when adapting the interactions to the game. In the gaming scenario the flipping gesture (for viewpoint movement) has the disadvantage that flipping the devices is already associated with the rotating gesture. This can annoy the user when he or she does not want to rotate the device. For example, frequently watching the unexpected tilting of the stereoscopic scene will cause ergonomic problems because flipping is much more exhausting than normal tilting.

6. CONCLUSION & OUTLOOK

In this work we presented interaction styles for 3D interaction on mobile devices using touch and motion sensors. These interaction concepts were applied to a mobile (anaglyph-based) 3D game that was realized on the android platform.

Initial user feedback is also promising. Users that have tried out the first prototypes have given positive feedback on the interaction as well as on the game. To address this feedback we plan a thorough evaluation of the interaction concepts in an upcoming study. Especially the 3D perception and navigation has to be investigated more in depth. Beyond that the game needs to be tested on devices with different display technologies (e.g. auto-stereoscopic displays).

7. REFERENCES


