Controlling a planetarium software with a Kinect or in a multi-touch table: a comparison

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ABSTRACT
The wide availability of low-cost sensing devices is opening the possibility to easily create different interaction settings, which exploit various techniques for a more natural interaction, especially in public and shared settings. In this paper, we compared two different solutions for enhancing the interaction experience of a planetarium application, both replicable at a reasonable cost. The first version is based on a simple multi-touch paradigm, while the second one exploits a full-body interaction together with a projection on geodetic sphere. We detail the technical implementation of both versions and, in addition, we discuss the results of user-study that compared the two modalities, which highlights a tradeoff between the control and the users' involvement in the virtual environment.

Author Keywords
Full-body interaction, Multi-touch, Spherical display, Presence

ACM Classification Keywords
H.5.m. Information Interfaces and Presentation (e.g. HCI): Miscellaneous

General Terms
Human Factors; Design; Measurement.

INTRODUCTION
In this paper, we exploit different low-cost sensing devices in order to provide engaging interaction experiences, trying to put into practice the ubiquitous computing vision, where the user is expected to interact naturally with the technology without even realizing its mediation.

Nowadays, the availability and the decreasing cost of such sensing devices allows for the creation of interactive spaces, especially in public and shared settings, even with limited resources. We describe how we created a more immersive and engaging version of an existing virtual planetarium software for desktop systems, transforming it into both a multi-touch and a Kinect application. In particular, the Kinect version exploits also a geodetic projection on a hemisphere, enhancing the realism of sky visualization. Both settings are easily replicable for different applications and settings.

We report on a small-scale comparative evaluation of the two settings, which shows that, without an appreciable difference in the overall usability between the two settings, the multi-touch version gives the users more confidence in controlling the application, while the Kinect version is reported closer to a real experience.

RELATED WORK
Many investigators used the sky and space exploration to provide examples of immersive systems. A description of how virtual environments can be exploited for such kind of tasks can be found in [8] which describes, among the other settings, how such a kind of environment is exploited by the NASA. Another relevant example is the work in [10], where the authors exploited magnetic sensors in order to support the user while pointing or searching for real stars. In addition, they exploited also the Wiimote controller for guiding the recognition of the constellation shapes.

In [1], the authors exploited a spherical display for creating a 360-degrees space for visualizing content for multiple users minimizing the occlusion. The authors exploited such display for collaborative settings. We used a larger spherical display, and we implemented a free-hand interaction paradigm with such screen. In addition, we projected the image on the concave surface rather that the convex one.

Francese and colleagues [3] measured the presence and the immersion of different 3D gestures interaction techniques (namely remote-based and full-body). They concluded that the perceived immersion of such an interaction technique is high and that the users pass quickly from a novice to an expert style of interaction. We created a setting that exploits the same interaction technique, adding a more realistic projection of the sky map, in order to increase even more the user's immersion feeling.

PROTOTYPE DESIGN
In this section, we discuss the two different interaction settings we created for an interaction-enhanced version of a planetarium virtual environment. We used the Stellarium [5] software,

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which is able to show a 3D view of stars and planets according to the current time and the user-specified position in the world.

The application lets the user browse the sky using the mouse and the keyboard for moving the current point of view, and/or selecting planets and stars. The basic version of the application is controlled using a two button 2D (or 3D) mouse: moving the position of the pointer moves the current view, the left button can be pressed for rotating or panning the view, while the right one is used for scaling. However, this standard scheme of scene exploration can be easily enhanced for offering a more engaging environment. In order to support a more natural interactive scheme, we have designed an interactive model where users perform their tasks in a three dimensional space or touching directly the sky representation.

In both versions, we exploited the same technical solution for implementing the communication between the two different gesture recognition sensors and the existing Stellarium application, which is based on the TUIO [7] network protocol. The scheme is shown in Figure 1: on the one hand, we created an intermediate layer between the devices and the application that generates TUIO events according to the current state of the device tracking; on the other hand, we extended the Stellarium code in order to be able to translate such events into application commands, like rotating or panning the view or moving the current camera position.

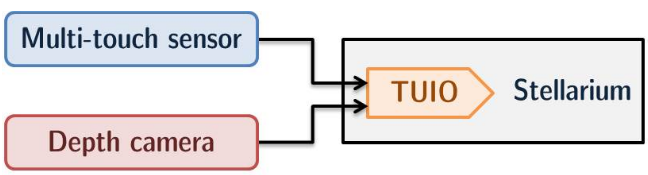

Figure 1. Connections among Stellarium and the gesture sensing devices.

Multi-touch version

We implemented the multi-touch version of the application exploiting the improved FTIR [4] table proposed in [6]. The resulting interaction setting is shown in Figure 2: the sky visualization is projected onto the multi-touch screen. The user controls a rotation hinged on the barycenter of the scene by touching the scene and moving the finger in different directions. In addition, it is possible to resize the scene touching the surface with two fingers: moving them apart from each other enlarges the scene, while moving the finger towards each other shrinks the scene proportionally.

With respect to the desktop version, the multi-touch interface has the obvious advantage of allowing the user to interact directly with the sky projection, without mapping the mouse movement into the scene. In this paper, we consider such setting as the baseline for a low-cost solution for creating an application deployment that can be exploited in a shared and/or public setting.

Full-body version

We enhanced the virtual planetarium experience with a different environment, which mimics the visualization of the sky ceiling through the projection of the sky map on a hemispherical surface.

Figure 2. The multi-touch planetarium application.

In order to keep low the cost of the implementation, we have built the entire surface using paper and glue. Following the scheme in Figure 3 we built a hemispheric mesh of kraft paper triangles. After that, using thin wood planks we built the shell holding the surface. The shell length and height are equals to the diameter of the hemisphere, which is about two meters. After securing the hemisphere to the shell, we painted the surface using a common white wall paint and finally we placed a black cover between the squared shell and the hemisphere borders which has a circular section. Once completed the construction of the hemisphere, we used a short throw ratio projector for displaying the sky map on the curve surface. In this case, the projection exploits an orthographic filter that is provided with Stellarium. The resulting setting is shown in Figure 4.

The interaction with such a kind of screen is based on a free-hand paradigm, using a Microsoft Kinect sensor. Such gestural interaction allows the user to navigate the sky map.

In order to mitigate the Midas touch problem, we exploited a grab gesture that has to be performed by the user in order to engage the interaction with the planetarium application. Therefore, in order to start the interaction with the application, the user has to close at least one hand, which resembles the act of grasping a real object.

We initialize the hands position detection with the skeleton tracking algorithm provided by the NITE framework [9], which also detects the hands in the depth image. Then, we incrementally track such positions in the subsequent images, recognizing hand open/closed shapes by estimating the local

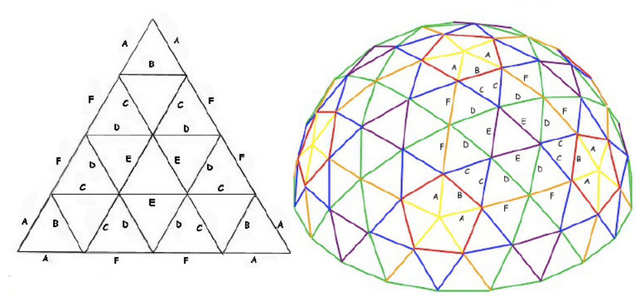

Figure 3. Geodetic sphere scheme.

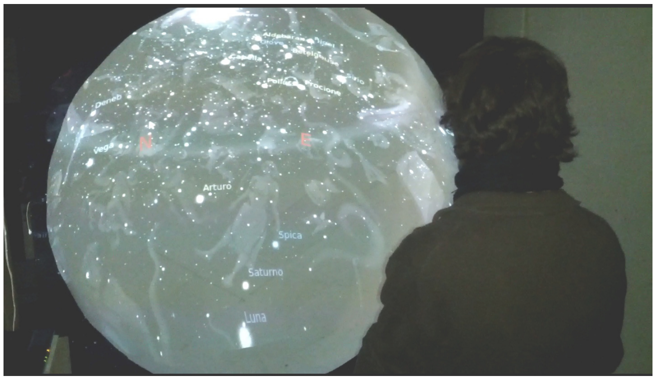

Figure 4. Full-body version of the planetarium application projected on a geodetic sphere

surface areas in the depth images (represented in red in Figure 5). The hand region is compared with its convex-hull area: if the hand is closed, the two silhouettes are nearly coincident, and such ratio is close to 1; otherwise, when the hand is opened, the two silhouettes will consistently differ. In this way we are able to tell when the user is moving for interacting with the application.

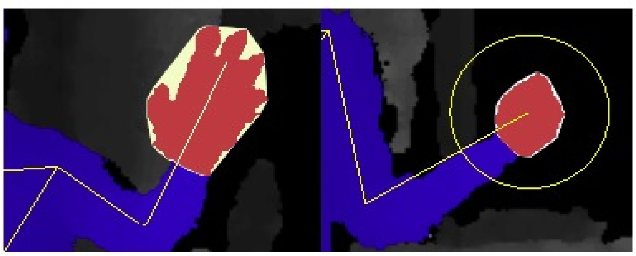

Figure 5. Hand open/closed recognition.

The user can interact with the sky visualization rotating the scene around its barycentre and enlarging or reducing it in order to get the desired level of detail.

We support the interaction through two gestures:

- rotation is supported simply performing an on-air grab with either the right or the left hand. Keeping the hand closed the user changes the hand position, and the view is rotated accordingly;

- the zoom is supported through a two hand gesture, closing both hands. The user can either enlarge or reduce the view size respectively moving the hands apart or moving them towards each other.

After building the projection screen and implementing the interaction gestures, we had our interaction scenario ready: the user was able to see the projection of the planetarium image on a spherical screen and to interact with the application simply standing in front of the hemisphere and performing free-hand gestures. Such setting is engaging not only for a single user, but also for a group of people: one of them controls the visualization while the others look at the projected sky map.

EVALUATION

We conducted a small-scale user test in order to compare the two interfaces for the interactive planetarium, which gave us some hints on the differences encountered by users in the different platforms (namely multi-touch and Kinect).

The aim of the proposed test is threefold. First, we wanted to evaluate the overall perceived difficulty while executing different tasks with the planetarium interface in both settings. Second, we wanted to determine whether the overall usability of the application was affected by the change of platform. Finally, investigated if there were differences in the factors that affect the user's presence perception, according to [11].

The test was organised as follows: after completing a small demographic questionnaire, the users had to complete the following tasks using both versions of the application:

1. Starting from a visualization where Saturn occupies the whole screen, the user had to go back to a point if view where it is possible to see the Earth.
2. The user had to complete a 360° horizontal rotation of the view (on the Z axis).
3. The user had to find Jupiter and visualize the name of its satellites.
4. The user had to change point of view in order to see at the center of the screen one constellation (selected by the user, but declared at the beginning of the task)
5. Starting from the a view of Saturn with a minimum zoom factor, the user had to enlarge it until it occupied the whole available space.

We alternated the starting version in order to minimize the carry-over effect. After the completion of each task, the users answered the Subject Mental Effort Question (SMEQ) [12] in order to evaluate the perceived difficulty. After completing the whole task set, the user had to fill two different questionnaires: the first one is the Software Usability Scale (SUS)[2] that evaluates the overall usability of the application, while the second one is the Presence Questionnaire [11], which measures different aspects of the user's presence perception. After completing both questionnaires, the user repeated the experiment with the other version (multi-touch if starting with the Kinect and vice-versa).

Thirteen users participated to the test, 9 males and 4 females, aged between 21 and 26 ($\bar{x} = 23.3, \sigma = 1.8$), 5 had a high school, 5 a bachelor and 3 a master degree. The users were more proficient with multi-touch applications ($\bar{x} = 5.54, \sigma = 1.6$ in a 1-7 Likert scale), if compared with the Kinect one ($\bar{x} = 4.3, \sigma = 2.1$).

For the post-task evaluation, we report in Table 1 the upper bound ($\rho = 0.05$) of the perceived user effort. According to [2], the perceived effort for all tasks is between 11 and 25, labelled respectively *"Not very hard to do"* and *"A bit hard to do"*. It is possible to notice that the multi-touch version required less effort for T1 and T2, while the Kinect version performed better for T4 and T5.

The SUS post-study questionnaire did not revealed any difference in the overall usability of the two versions. The score was

Task	Multi-touch	Kinect
T1	8.25	15.50
T2	8.67	13.80
T3	7.40	10.00
T4	18.76	11.96
T5	17.21	10.00

Table 1. Perceived task difficulty upper bounds ($\rho = 0.05$) .

$\bar{x} = 74.04, \sigma = 11.67$ for multi-touch and $\bar{x} = 70.97, \sigma = 11.57$ for the Kinect version. Therefore we can conclude that the perceived usability of the two versions is about the same.

For the presence post-study questionnaire, we disaggregated the scores of the different answers (1-7 Likert scale) according to the following factors [11]: Control Factors (CF), Sensitivity Factors (SF), Distraction Factors (DF) and Reality Factors (RF). Obviously, given the small number of participants, it is not possible to generalize the quantitative results. However, we want to point out here a qualitative tendency that explains the different perception of the effort for the different tasks.

In Table 2 we report the questionnaire results. The multi-touch version performed slightly better for the CF and the DF, while it was slightly worst for SF and RF. This means that the users had more difficulties with the Kinect version when a fine-grained control of the planetarium positioning was required (T1 and T2). However, the users were more involved from a sensory point of view, and they found more real the Kinect experience. Indeed, the more exploratory tasks had a higher rating with the Kinect version (T4 and T5).

Factor	Multi-touch	Kinect
CF	$\bar{x} = 4.96, \sigma = 0.82$	$\bar{x} = 4.77, \sigma = 0.22$
DF	$\bar{x} = 5.19, \sigma = 0.49$	$\bar{x} = 4.92, \sigma = 2.12$
SF	$\bar{x} = 5.15, \sigma = 1.2$	$\bar{x} = 5.5, \sigma = 0.22$
RF	$\bar{x} = 3.62, \sigma = 1.85$	$\bar{x} = 4.04, \sigma = 1.63$

Table 2. Disaggregated results of the post-study presence questionnaire.

From these results we can conclude that, given a comparable overall usability and cost of the two settings, it is better to select the multi-touch environment for a more fine-grained control, while if we want to increase the sensory and realism perception for the user (according to definitions in [11]), it is better to select the full-body version.

CONCLUSION AND FUTURE WORK

In this paper, we described the creation of a low-cost setting for an immersive virtual planetarium experience. Starting from an existing software for desktop platforms, we created both a multi-touch and Kinect version of the application. The Kinect versions employs a geodetic display that provides the user with a more accurate representation of the sky. We performed a small-scale user study in order to investigate the perceived difficulty in performing different tasks with the two settings, which was low for both versions. In addition, the post-test questionnaires did not highlight any significant different in the overall usability between the multi-touch and the full-body interaction. However, we found a difference in the perceived control of the application (which was higher in the multi-touch version) and in the perceived realism of the experience (which was higher in the Kinect version).

In future work, we plan to exploit more other devices for controlling the application (e.g. the Leap Motion for a more precise hand tracking) and to combine different sensors to increase the application interaction capabilities.

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