Batmen Beyond: natural 3D manipulation with the BatWand

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ABSTRACT

In this work we present an interactive 3D object manipulation system using off the shelf mobile devices coupled with Augmented Reality (AR) technology that allows editing 3D objects by way of natural interactions based on tangible interfaces paradigms. The set-up consists of a mobile device, an interactive wand marker and AR markers laid on a table. The system allows users to change viewpoint and execute operations on 3D objects - simultaneous translation and rotation, scaling, cloning or deleting - by unconstrained natural interactions, leveraging user's proficiency on daily object manipulation tasks and speeding up such typical 3D manipulation operations. Depth perception was significantly enhanced with dynamic shadows, allowing fast alignment and accurate positioning of objects. The prototype presented here allows successful completion of the three challenges proposed by the 2017 3DUI Contest, as validated by a preliminary informal user study with participants from the target audience and also from the general public.

Index Terms: Human-centered computing ~ Interaction techniques; Human-centered computing ~ Mixed / augmented reality; Computing methodologies ~ Graphics systems and interfaces

1 INTRODUCTION

Our approach to this year's contest challenge was to leverage the strong feedback obtained at the 2016 IEEE 3DUI Contest, bringing the functionality core of Batmen system [1] to a new level of maturity by fixing known issues and introducing new interaction features as well. Batmen is a cooperative Augmented Reality (AR) system of which interactive approach was inspired in the work of Ware and Jessome [2].

The contest theme alignment with fundamental aspects of the previous edition presented an opportunity for further development of Batmen's individual interactions, resulting in the Batmen Beyond upgrade. Expert feedback shown that cooperation in 3D manipulation tasks often introduce cognitive overload instead of obtaining speed gains.

Individual 3D manipulations designed for Batmen used simple finger based gestures on the mobile device screen. However, overhead resulted from unclear camera operations; confusion between camera and object operations; missing the AR markers; and a joystick-style method for translation operations that was not intuitively captured by users.

Camera operation issues might be solved by natural interactions, where users move in order to change viewpoint [3]. We hypothesize that interaction issues can be avoided by prioritizing natural movement while minimizing touch operations. Marzo *et al.* [3] indicates that AR applications for mobile devices benefit more from movement while touch operations are effective just for high magnitude operations, especially rotations.

Another limitation of Batmen and AR systems in general, was related to the lack of positioning feedback and visual acknowledgment of geometric constraints. Smith *et al*. [4] indicated that alignment references such as sliding or parallel planes are very effective to enhance depth perception in 2D screens in AR systems. Stuerzlinger *et al.* [5] claims that shadows, occlusion and perspective are natural environmental cues for depth perception and positioning. Following this principle, the authors also recommends avoiding exquisite situations such as floating objects and interpenetration. Another hypothesis is that natural interactions supported by other registered objects such as sticks can substantially assist object positioning and editing by providing depth and geometric feedback directly in the real world.

The Batmen Beyond system aims to enforce suggested improvements and to assess the aforementioned hypotheses, considering 3D artists as a specific target audience but still striving to achieve a simple and accessible system for the general public. A preliminary experiment was designed and results are presented and discussed in the next sections.

2 SYSTEM DESCRIPTION

The system relies on a tablet device and a movable marker called BatWand (Fig. 1), implemented in Unity using Vuforia AR library. The wand is hold by the dominant hand. Despite the possibility of some direct interactions in AR, movements such as grabbing are not possible without special interaction devices such as wired gloves. Cumbersome interaction mechanisms involving menus are the usual outcome of this limitation.

Complex menus usually create cognitive overhead in AR systems. For this reason, the tablet main function is to change user's viewpoint, serving as a window to the augmented scene. Touchscreen operations were minimized, as suggested in the literature [3], providing only minimal support to natural interactions executed with the wand (Fig. 1), by enabling indirect operations (such as grabbing) with a single tap in the touchscreen.

A simple pie menu (Fig. 1, left) allows selecting one of four possible operations on objects, or modes: grab (translation and rotation), scale, copy or delete. The target audience is familiar to the logic of modes, typical of 2D image processing and 3D modelling software. Initially, testers had difficulty finding a good grip and considered the tablet heavy to handle with only one hand. This issue was solved by a movable menu and both left and right-handed users were able to find a good grip and reach four buttons.

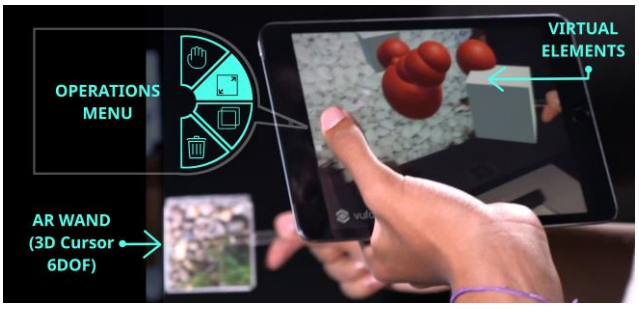

Figure 1: system configuration and detail of the pie menu (left).

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The BatWand is a specially designed AR marker, a true 6DOF interaction mechanism that allows extending the range of the arm and manipulating objects directly. The application shows in the screen an anchoring point, intending to clearly indicate the active tip of the wand (Fig. 2, upper left).

Operations are conducted in three steps: hover the desired object with the wand; hold the operation button as the wand moves; release the button when done. Each operation requires a specific wand movement (Fig. 2):

- GRAB: move and rotate to position;
- SCALE: rotate clockwise to increase size;
- COPY: position new item (system changes to GRAB);
- PARTICLE PARAMETER EDIT: execute GRAB operation on the 3D Sliders then move to change value.

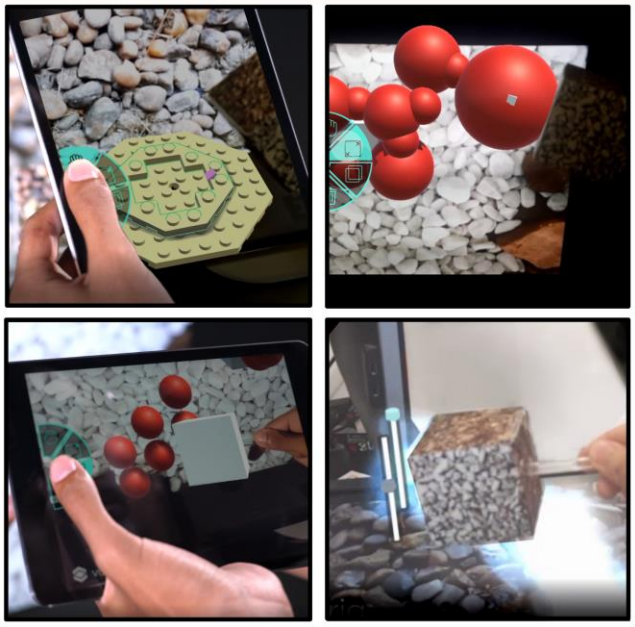

Figure 2: Grab, Scale, Duplicate and Parameter Editing operations.

Positioning aids were also implemented. Some testers had difficulty positioning and aligning the thin pieces on "Palm Tree" challenge (Fig. 2, upper left) due to the impaired depth perception, a typical issue in 2D visualization systems. The first solution, based on [4], was to couple semitransparent reference planes to the manipulated objects, but the result was visually confusing. The best solution found, as indicated by [5], was exploring shadows. Virtual dynamic shadows generated from two directional lights (one vertical and another following the camera) allowed faster approach and alignment of objects, with little visual interference (Fig. 2, upper left).

In order to maintain interaction consistency, particle objects can be positioned and edited using the same operations. Parameters are set by manipulating two constrained 3D sliders, representing gravity and force (Fig. 2, bottom right).

3 Preliminary User Study

The goal of the study was to assess the learning curve, usability and effectiveness of interaction techniques, by conducting a qualitative informal user study with 10 participants. The "expert" group had 5 participants familiarized with 3D modelling. The second group had other 5 well-educated participants with little experience on digital authoring tools and interactive systems.

After a briefing, users freely explored the system for 5 minutes. Then, instructions were given as needed and another 5 minute practice session was administered right away. In sequence, all users were presented the 3DUI Contest challenges: "Palm Tree" is an assembly challenge with 20 pieces; "Fried Sculpture" offers 8 balls that must be piled and scaled; "Particle System" starts with 3 particle generators (fire, smoke and water) and demands cloning and setting particle parameters to achieve a specific symmetric arrangement. After finishing the challenges, the users were asked whether they got tired or stressed with the experience and also about the ludic aspects, originality and value of the system.

4 Results and Conclusion

As expected, expert users learned and executed faster and a few needed additional instructions, but everyone completed the tasks successfully. All testers considered the basic interaction easy to master and agreed that the system is quite simple to use.

Non-experts found the experience ludic and fun, while the originality and value were acknowledged by most experts, arguing that the liberty of unconstrained movements (camera viewpoint and operations) allows dramatic reduction of the number of steps necessary to execute typical 3D modelling and compositing tasks.

Users complained about tired arms given the long time needed to complete the "Palm Tree" challenge. Ergonomic issues are typical of AR systems and must be addressed given that holding a mobile device or extending arms for long periods of time is unpractical in production contexts, as noted by some expert users.

The "Particle System" was considered the most difficult challenge, especially by non-experts, since they are not familiar with the configuration logic of particle emitters. However, 3D Sliders simplified setting parameters of particle objects and all users captured their logic after the training sessions. This solution is quite interesting and further improvements will be pursued.

While the dynamic virtual shadows were found useful, intuitive and unobtrusive as positioning and alignment aid, experts agreed that depth perception can be further enhanced by introducing stereoscopic vision using a Cardboard-like device or any available VR set, which might also reduce arm fatigue.

However, given the constraints defined by the 3DUI Contest, all users considered the system a good solution and their feedback will guide further improvements.

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