AffordIt!: A Tool for Authoring Object Component Behavior in VR

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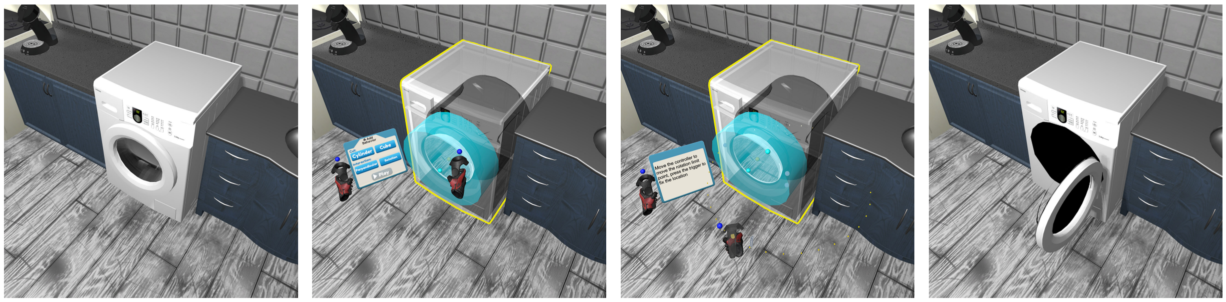

(a) (b) (c) (d)

Figure 1: These figures show a sequence of steps followed to add a rotation affordance to the door of a washer machine. (a) An object in the scenario. (b) Cylinder shape selection wrapping the door. (c) A user sets the amount of rotation the door will be constrained to. (d) An animation generated from the affordance can be visualized.

Abstract

This paper presents AffordIt!, a tool for adding affordances to the component parts of a virtual object. Following 3D scene reconstruction and segmentation procedures, domain experts find themselves with complete virtual objects, but no intrinsic behaviors have been assigned, forcing them to use unfamiliar Desktop-based 3D editing tools. Our solution allows a user to select a region of interest for a mesh cutter tool, assign an intrinsic behavior and view an animation preview of their work. To evaluate the usability and workload of AffordIt! we ran an exploratory study to gather feedback. Results show high usability and low workload ratings.

Index Terms: Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Human-centered computing—Interaction design—Interaction design process and methods—Scenario-based design

1 Introduction

As the prevalence of virtual reality increases for simulations and video games, there is an increasing desire for the development of virtual content that is based on real scenes and environments. A problem arises when a domain expert whose technical skills are based in realistic experiences necessary to a VR scene, but not asset creation (a situation described in Hughes et al. [3]) which are needed to build a virtual scene. To alleviate this problem, recent research has been focusing on frameworks to ease domain experts authoring as seen in [1]. 3D scene reconstruction [8] provides a suitable solution to the problem. Initially a 3D reconstructed environment will be composed of a continuous mesh which can be segmented via autonomous tools as shown in Shamir et al.'s survey [6] or human in the loop solutions as seen in [5].

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However, these tools fall short at identifying and applying affordances, the intrinsic properties, of the components of the object. For example, a storage cabinet may be segmented from a larger mesh, but the movements of the cabinet door remains absent. One solution is the use of a 3D modeler, such as Autodesk Maya or Blender, but if the domain expert is unfamiliar with the software then a technical expert in asset creation is required. This solution carries a cost, however, as the domain expert's own intuition and understanding of an object's affordances could be lost in translation, either in relaying requirements to a third party or to software they are not experts of. As our solution we introduce AffordIt! an online tool that allows a 3D scene author to isolate key components of virtual content and assign affordances to it using their own intuitive understanding of the object. Our interaction techniques derive from the research in object authoring by Hayatpur et al. [2] which presents three techniques for object alignment and manipulation in VR.

AffordIt! provides an intuitive method for a scene author to select a region of interest within a continuous mesh and apply affordances to it using procedures outlined in [4, 7]. Rather than relying on a sketch-based interface, we looked to the work of Hayatpur et al. [2], in which users could invoke a plane, a ray or a point to constrain the movements of a virtual object. As such, our procedure has a user first selecting a region of interest using shape geometry followed by defining a specific movement constraint. After processing the operation on the mesh an animation demonstrates the behavior attached to it as shown in Figure 1. An exploratory study evaluated the perceived usability and workload of the system.

2 Implementation

Our technique works by first cutting a mesh to define a region of interest using simple geometries (cube or cylinder) then applying intrinsic behavior (Figure 3) to the segmented portion (defined as a constrained movement). When a cut is performed the original mesh is divided into two, one inside the mesh cutter and the other one outside. Both steps require interactions with a user to define the region of interest and the behavior. The user's interactions can be performed independent of the mesh manipulation. In Figure 3a P_1, P_2 and P_3 define the plane, which constraints a perpendicular movement to that plane $P_g - P_e$ and in Figure 3b P_1 and P_2 define the rotational axis around the arc $P_g - P_e$.

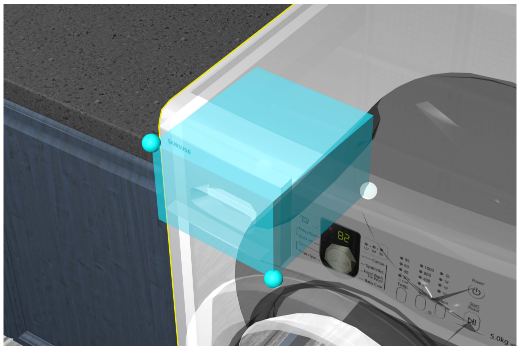
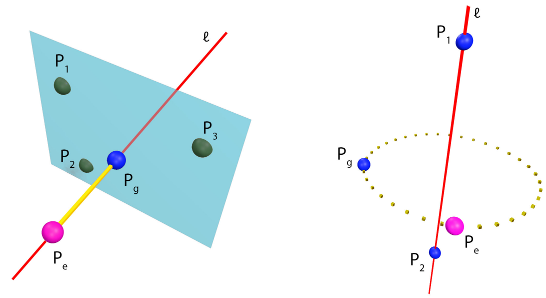


Figure 2: Cuboid mesh cutter placed on an object



(a) Perpendicular interaction (b) Rotation interaction

Figure 3: Proposed interactions used in the study.

3 User Study

An exploratory user study was performed to understand the usability of AffordIt!. Post-participation surveys gathered qualitative information on usability, workload and perceived ease of use of the different aspects of the techniques. Sixteen people (10 male, 6 female) ages 18 to 29 ($\mu = 21.31, \sigma = 3.20$) engaged in the study. All participants used an HTC Vive Pro Eye for the study and started at the center position of a room with approximate dimensions of 4x4 meters.

3.1 Scenario and User Interface

The virtual scenario chosen for the experiment is a kitchen with different household appliances placed within the scene. Participants were allowed to interact with four objects in the scene: an oven, a washing machine, a storage cabinet and a coffee machine. Every combination of mesh cutter and affordance definition was performed on the objects.

3.2 Tasks

For the exploratory study we focused on two mesh cutter shapes, cuboid (Figure 2) and cylinder(Figure 1b) and two behaviors for translation and rotation around a pivot as in Figure 1. To complete the tasks participants were required to add behaviors to the objects in the scenario by invoking a mesh cutter tool (cuboid or cylinder) and define the behavior of the segmented mesh with interactions. A perpendicular interaction is movement of an object in a straight line perpendicular to a plane (Figure 3a). A Rotation interaction is used for movements that are based on the rotation of an object around an axis (Figure 3b).

3.3 Study Procedure

The study was designed to be completed in approximately 45 minutes. Study participants were asked to fill out demographics and pre-questionnaire forms. Next, the problem was explained for 2 minutes followed by a 5 minute video tutorial session, which allowed participants to familiarize themselves with the concepts and user interface. This was followed by a training session which was performed for an additional 5 minutes. The training session required participants to use the tools of AffordIt! following proctor instructions. An example object in the form of a modular sink with three drawers and two doors was used for training. For the experiment, participants were randomly assigned 4 different objects from the kitchen scene to perform selection cuts in the objects' mesh and assign affordances to the component generated. After task completion post-participation surveys were provided.

4 Results

The user interface involved the use of menu buttons fixed to the left controller and placing points to define four different operations: Creating a Cube or Cylinder, Adding a Perpendicular or Rotation behavior. In a scale from 1 to 100, for overall usability, results from SUS scores ($\mu = 83.10, \sigma = 12.9$) show high usability for the user interface. Also, the overall subjective workload score per participant is ($\mu = 37.35, \sigma = 12.22$), which shows a low workload perception. Finally, in a (1 to 7) scale, aspects of the hardware, such as weight of the headset, causing issues had a low rating ($\mu = 2.44, \sigma = 1.46$), accuracy of the controllers had a high rating ($\mu = 6.00, \sigma = 0.94$) and buttons from the controller ($\mu = 6.25, \sigma = 1.03$) were well received by participants.

5 Conclusion

This paper introduces AffordIt!, a set of techniques that author object components behaviors in Virtual Reality. While limitations and observations were found, usability results show that the interface and interaction techniques were well received by participants, as seen in the high usability scores for SUS, low workload for the tasks, in the TLX and users comments that they enjoyed the experience.

Acknowledgments

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