Mixing realities for sketch retrieval in Virtual Reality

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ABSTRACT

Users within a Virtual Environment often need support designing the environment around them with the need to find relevant content while remaining immersed. We, therefore, focus on the familiar sketch-based interaction to support the process of content placing and specifically investigate how interactions from a tablet or desktop translate into the virtual environment. To understand sketching interaction within a virtual environment, we compare different methods of sketch interaction, i.e., 3D mid-air sketching, 2D sketching on a virtual tablet, 2D sketching on a fixed virtual whiteboard, and 2D sketching on a real tablet. The user remains immersed within the environment and queries a database containing detailed 3D models and replace them into the virtual environment. Our results show that 3D mid-air sketching is considered to be a more intuitive method to search a collection of models; while the addition of physical devices creates confusion due to the complications of their inclusion within a virtual environment. While we pose our work as a retrieval problem for 3D models of chairs, our results are extendable to other sketching tasks for virtual environments.

ACM Reference Format:
Daniele Giunchi, Stuart James, Donald Degraen, and Anthony Steed. 2019. Mixing realities for sketch retrieval in Virtual Reality. In *The 17th International Conference on Virtual-Reality Continuum and its Applications in Industry (VRCAI '19), November 14–16, 2019, Brisbane, QLD, Australia.* ACM, New York, NY, USA, 2 pages. https://doi.org/10.1145/3359997.3365751

1 INTRODUCTION

Sketching in Virtual Reality (VR) allows users to design and create objects in 3D virtual space. To aid users in the creation of complex 3D designs, existing methods are often supported by a retrieval algorithm capable of finding complex designs based on a simple sketch made by the user by searching a model database. Common approaches can be divided into methods focusing on gestural interaction [Deering 1995] or techniques allowing to freely draw

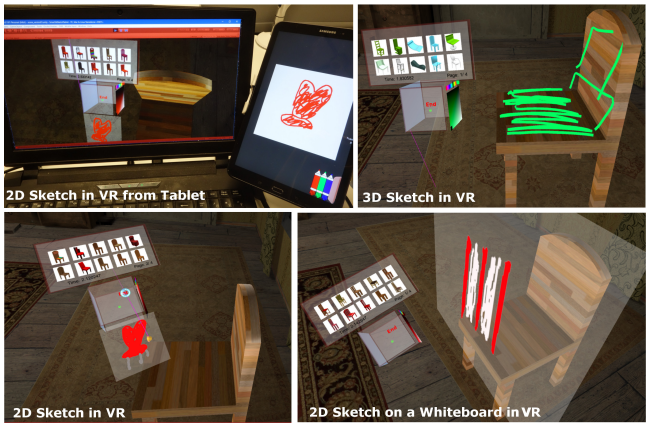

Figure 1: We consider 4 different interaction methods in virtual environments:(top-left) 2D sketching on a real tablet, (top-right) 3D mid-air sketching, (bottom-left) 2D sketching on a virtual tablet and (bottom-right) 2D sketching on a fixed virtual whiteboard.

sketches in either 2D [Fonseca et al. 2004] or 3D space [Giunchi et al. 2018]. Gestural interaction techniques are widely used to execute an action as a trigger mechanism or depict a simple trajectory in the design space. While gestures are generally easy to use, they are usually not suitable for characterizing detailed features of an object. However, both 2D and 3D sketches allow the user to convey complex structures including their details. These techniques extend the scope of potential designs to a large number of objects within a collection with significant variations in terms of both shape, color and texture.

Despite the growing interest in methods for Sketch-based Retrieval [Bui et al. 2016; Pang et al. 2019; Qi et al. 2016], only few examples apply to VR [Giunchi et al. 2018; Li et al. 2016].The reason for this is twofold: (1) the ability for sketch descriptions of an object to adequately express the model, and (2) ability for users to get confidence with the depiction of structural or fine-detailed elements. Prior work by Giunchi *et al.* [Giunchi et al. 2018] utilized a Multi-View CNN to solve for the first, and introduced on-model sketching in VR for the second. However, it is essential to understand how different interaction methodologies can impact on both user performance and user experience. We present a study to understand how users interact with physical and virtual devices framed

VRCAI '19, November 14–16, 2019, Brisbane, QLD, Australia

ACM ISBN 978-1-4503-7002-8/19/11…$15.00
https://doi.org/10.1145/3359997.3365751

in a retrieval context. Our work investigates different techniques for users to provide initial sketch designs as input for sketch-based retrieval algorithms in virtual environments.

2 INTERACTION METHODOLOGIES

We propose 4 distinct methods of interaction (see Figure 1), which vary using 2D or 3D interaction and physical devices while the user remains immersed in the virtual environment outline below.

- **3D Mid-Air Sketching:** Users perform free-hand strokes within the 3D environment by moving a pressed trigger on a controller. The mid-air strokes are then used to search the collection using the approach of [Giunchi et al. 2018].
- **2D Sketching on a VR Tablet:** We mimic a natural method of sketching, but placed within a virtual environment, a 2D virtual panel is attached to the user's non-dominant hand controller referencing the familiar artist sketching style.
- **2D Sketching on a VR Whiteboard:** The whiteboard method provides a panel onto which the user can sketch in 2D. A familiar design paradigm, the whiteboard technique extends the size of the tablet to that of a larger whiteboard in order to provide more space for sketching and is positioned in a fixed location.
- **2D Sketching on a Physical Tablet.** Using a real-world tablet (Galaxy Tab A 10.1") approach offers the user a tactile feedback to perform 2D sketching while immersed in the virtual environment. The user is able to sketch using her finger, thus this approach does not require the use of a controller.

2.1 3D collection and model retrieval

The ShapeNet[Wu et al. 2015] dataset provides a large collection of models for different categories of object. We focus on the chairs category of the dataset consisting of 3370 distinct chairs with colors or textures. To perform sketch retrieval, we adopt the retrieval architecture of [Giunchi et al. 2018]. The method works by generating a set of structured camera views that are then passed through the CNN and summated to obtain a final descriptor for the query. The query descriptor is then used to search the ShapeNet model collection (nearest-neighbor) and identify the 40 most relevant models. In the case of the single-view based methods, we take the CNN output directly without summation across views.

3 EVALUATION

We investigated the differences between the methods of interaction using sketches within a virtual environment. We evaluated our study over the 8 distinct chairs presented to each participant and 4 methods to test in terms of the accuracy of the returned model, time, and the number of queries to complete the task. To evaluate the accuracy we counted the number of successful searches among the total number of searches. The number of successful task completions for the 3D sketch was 37 out of 40 (92.5%), the 2D sketch with the whiteboard was 9 out of 40 (22.5%), the 2D sketch with virtual tablet was 6 out of 40 (15%) and the the 2D sketch with real tablet was 5 out of 40 (12.5%). For the efficiency of the methods we measured the time elapsed from the beginning to the end of the search and count for each session the number of submitted search queries. The average time among all the chairs for the the 3D sketch was 71 seconds, the 2D sketch with the whiteboard was 156 seconds, the 2D sketch with virtual tablet was 169 seconds and the the 2D sketch with real tablet was 166 seconds. Despite all the methods being intuitive, the 3D sketch is more accurate and satisfying to the user experience. In the case of 3D Sketch the user depicts the target chair using more naturally retaining the depth information, while in all the other methods user draws only a 2D projection of a three dimensional challenging to most users. While the real tablet method introduces physical feedback, the fixed location seem not to add significant benefit to the user. Although a free-hand approach may be more appealing it creates registration challenges and increased latency. It was also noticed that over the 32 searches performed by the user they optimized their strategy learning to exploit strengths and weaknesses within the descriptor improving there search efficiency over time. This lack of efficiency for the 2D sketches harms the user experience. The 2D drawing is conditioned by a continuous search of the feature that can trigger the right system's response. Thus, this attitude degenerates the sketching process in to simple or iconographic representation of a model.

4 CONCLUSION

We study 3D and 2D sketches in the context of database navigation while immerse in a Virtual Environment. This study fills a missing gap of whether traditional methods can be ported to within a Virtual Environment necessary to facilitate efficient searching or design tasks. Our study compared 3D, 2D sketch in virtual reality with a tablet or a whiteboard and a method that considers the use of a physical tablet. We identify that amongst the 2D methods, the provision a physical tablet did not improve the user experience. While, although intuitive, 3D sketching provides the best user experience and overcoming the familiarity of 2D based methods. We pose 3D mid-air sketching as a suitable direction within VR retrieval and related tasks.

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