

Mixing realities for sketch retrieval in Virtual Reality

Daniele Giunchi
University College London
United Kingdom

Stuart James
Center for Cultural Heritage Technology
Istituto Italiano di Tecnologia
Italy

Donald Degraen
German Research Center for Artificial Intelligence (DFKI)
Saarland Informatics Campus
Germany

Anthony Steed
University College London
United Kingdom

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 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.

CCS CONCEPTS

• **Human-centered computing** → **Virtual reality**; HCI design and evaluation methods; • **Computing methodologies** → **Object recognition**; **Ranking**.

KEYWORDS

Sketch, Virtual Reality, CNN, HCI

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>

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than ACM must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from permissions@acm.org.

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

© 2019 Association for Computing Machinery.

ACM ISBN 978-1-4503-7002-8/19/11...\$15.00

<https://doi.org/10.1145/3359997.3365751>

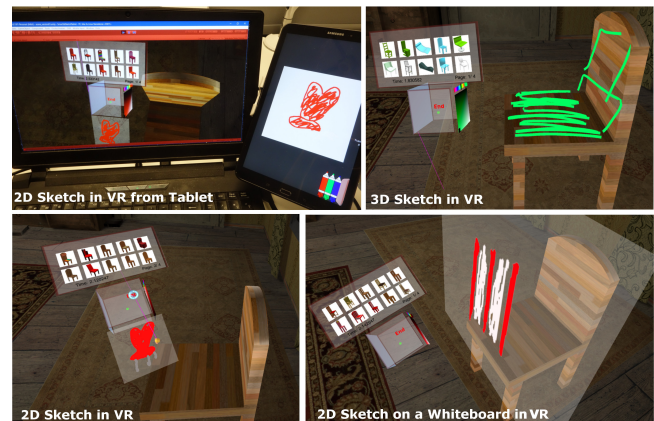


Figure 1: We consider 4 different interaction methods in virtual environments: (top-left) 2D sketching on a real tablet, (top-right) 3D mid-air sketching, (bottom-left) 2D sketching on a virtual tablet and (bottom-right) 2D sketching on a fixed virtual whiteboard.

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 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 reasons

are the ability for sketch descriptions of an object to adequately express the model, and the ability for users to get confidence with the depiction of structural or fine-detailed elements. Prior work by Giunchi [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 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 with user immersed in the 3D environment.

- **3D Mid-Air Sketching:** Users perform free-hand stroke by moving a pressed trigger on a controller. The mid-air strokes are then used to search the collection.
- **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. 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 without the use of the controller.

2.1 3D collection and model retrieval

ShapeNet[Wu et al. 2015] dataset provides a large collection of models for different categories of object. We focus on the chairs category consisting of 3370 distinct chairs with colors or textures. To perform sketch retrieval, we adopt the architecture of [Giunchi et al. 2018]. The method works by generating a set of 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 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 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, and in addition we measured the time elapsed from the beginning and the end of the search. 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 2D sketch with real tablet was 5 out of 40

(12.5%). The average time for 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 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 their 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.

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.

REFERENCES

- Tu Bui, Leonardo Ribeiro, Moacir Ponti, and John P. Collomosse. 2016. Generalisation and Sharing in Triplet Convnets for Sketch based Visual Search. *CoRR* abs/1611.05301 (2016).
- Michael F. Deering. 1995. HoloSketch: A Virtual Reality Sketching/Animation Tool. *ACM Trans. Comput.-Hum. Interact.* 2, 3 (Sept. 1995), 220–238. <https://doi.org/10.1145/210079.210087>
- Manuel J. Fonseca, Alfredo Ferreira, and Joaquim A. Jorge. 2004. Towards 3D Modeling Using Sketches and Retrieval. In *Proceedings of the First Eurographics Conference on Sketch-Based Interfaces and Modeling (SBM'04)*. Aire-la-Ville, Switzerland, Switzerland, 127–136. <https://doi.org/10.2312/SBM/SBM04/127-136>
- Daniele Giunchi, Stuart James, and Anthony Steed. 2018. 3D Sketching for Interactive Model Retrieval in Virtual Reality. In *Proceedings of the Joint Symposium on Computational Aesthetics and Sketch-Based Interfaces and Modeling and Non-Photorealistic Animation and Rendering (Expressive '18)*. ACM, New York, NY, USA, Article 1, 12 pages. <https://doi.org/10.1145/3229147.3229166>
- Bo Li, Yijuan Lu, Fuqing Duan, Shuilong Dong, Yachun Fan, Lu Qian, Hamid Laga, Haisheng Li, Yuxiang Li, Peng Liu, Maks Ovsjanikov, Hedi Tabia, Yuxiang Ye, Huanpu Yin, and Ziyu Xue. 2016. 3D Sketch-Based 3D Shape Retrieval. In *Eurographics Workshop on 3D Object Retrieval*. <https://doi.org/10.2312/3dor.20161087>
- Kaiyue Pang, Ke Li, Yongxin Yang, Honggang Zhang, Timothy M. Hospedales, Tao Xiang, and Yi-Zhe Song. 2019. Generalising Fine-Grained Sketch-Based Image Retrieval. In *The IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*.
- Yonggang Qi, Yi-Zhe Song, Honggang Zhang, and Jun Liu. 2016. Sketch-based image retrieval via Siamese convolutional neural network. In *2016 IEEE International Conference on Image Processing, ICIP 2016, Phoenix, AZ, USA, September 25–28, 2016*. 2460–2464. <https://doi.org/10.1109/ICIP.2016.7532801>
- Zhirong Wu, Shuran Song, Aditya Khosla, Fisher Yu, Linguang Zhang, Xiaoou Tang, and Jianxiong Xiao. 2015. 3D ShapeNets: A deep representation for volumetric shapes. In *IEEE Conference on Computer Vision and Pattern Recognition, CVPR 2015, Boston, MA, USA, June 7–12, 2015*. 1912–1920. <https://doi.org/10.1109/CVPR.2015.7298801>