# Mixing realities for sketch retrieval in Virtual Reality

Daniele Giunchi[1], Stuart James[2], Donald Degraen[3] and Anthony Steed[1]
[1]University College London, [2]Istituto Italiano di Tecnologia, [3]DFKI

## Introduction

In our work, we focus on supporting the user in designing the virtual environment around them by enhancing sketch-based interfaces with a supporting system for interactive model retrieval. Through sketching, an immersed user can query a database containing detailed 3D models and replace them into the virtual environment. To understand supportive sketching 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. 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.

## 3D collection and model retrieval

The database consists in a set of 3370 chairs that are part of ShapeNet [2]. ShapeNet is a large collection of 3D models where an extensive subset is made by chairs with or without colors or textures. To perform sketch retrieval, we implemented a back-end which hosts a pre-loaded CNN model. The method works by generating a set of structured camera views that are then passed through the CNN and a final descriptor is generated. The system is shown in Figure 1.

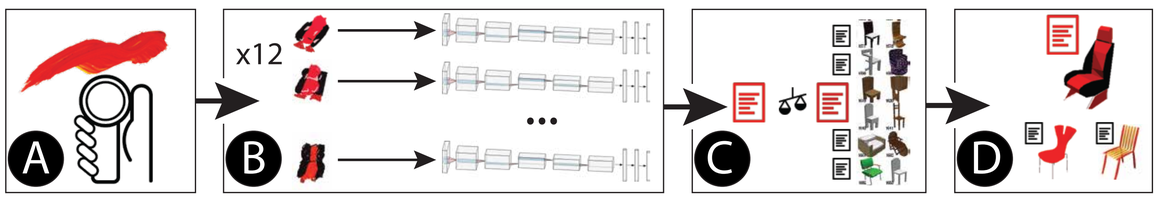


Figure 1: Overview of the system's model retrieval mechanic. Here, (A) the sketch created by the user results in a total set of 12 images (B) which are processed by 12 versions of the same CNN. After a max-pooling procedure, one descriptor is generated and (C) compared through Euclidean distance with the descriptors previously calculated for all the chairs of the collection. The result of the search is (D) a small subset of the most similar chairs from which the user can select.

## Interaction Modalities

Below the interactions we implemented as seen in Figure 2:
**3D Mid-Air Sketching.** This methodis similar to existing systems for sketching in VR and is directly based on the method for 3D mid-air sketching described in [1]. The user sketches in 3D space using a hand-held controller.
**2D Sketching on a VR Tablet.** With this method, we mimic a natural method of sketching, but placed within VR. A 2D panel is attached to the user's non-dominant hand controller , referencing the familiar painting palette.
**2D Sketching on a VR Whiteboard.** Similar to VR Tablet, the whiteboard method provides a panel onto which the user can sketch in 2D. The whiteboard technique extends the size of the tablet 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 physical tablet to perform 2D sketching while immersed in the virtual environment.

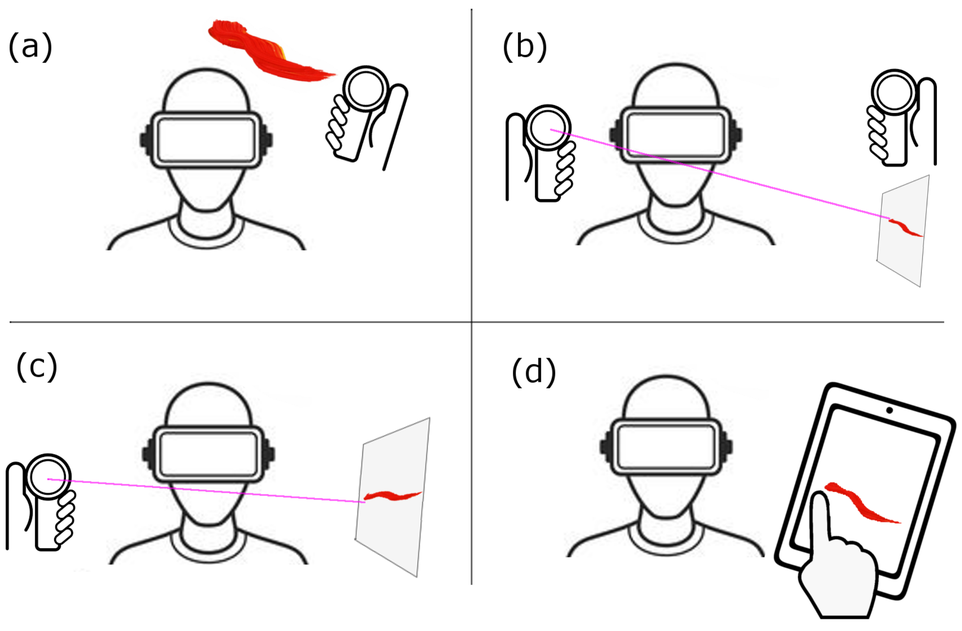


Figure 2: The 4 different interaction methods: (a) 3D mid-air sketching, (b) 2D sketching on a virtual tablet, (c) 2D sketching on a fixed virtual whiteboard, and (d) 2D sketching on a real tablet.

## Evaluation

We evaluated our study over 8 distinct chairs 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 and we measured the time to complete the search (see the Table 1).

| | 3D sketch | 2D Whiteboard | 2D Virtual Tablet | 2D Real Tablet |
|---|---|---|---|---|
| success rate | **92.5%** | 22.5% | 15% | 12.5% |
| time to complete | **71 s** | 156 s | 166 s | 169 s |

Table 1: 3D sketch achieve better results than other methods.

## Discussion

As 3D sketch interaction generates 12 input images from different points of view, the 2D sketch contributes only with one. With 2D sketch, each user quickly developed the idea of selecting the most significant view angle and tries to depict that projection. Despite this, as the success rate for 2D methods is lower than 3D Sketching. Some users drew the different points of view in the same texture, in some cases achieving successfully the target chair.

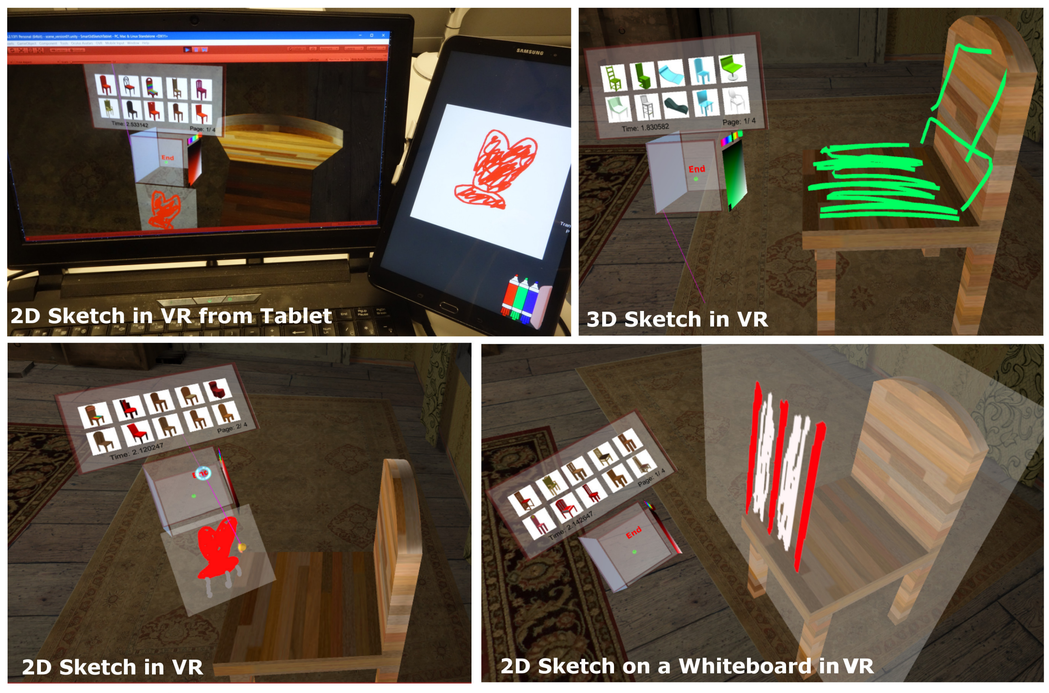


Figure 3: Our modalities can generate 3D or 2D sketches in a virtual environment.

## Conclusions

Our study fills this gap by comparing different sketch-based mechanisms including 3D and 2D modalities with users immersed in the virtual environment (see Figure 3 and Figure 4). We discovered that amongst the 2D methods, the provision a physical tablet did not improve the user experience. It is intuitive to conclude 3D sketching as a more suitable user experience within VR, overcoming the familiarity of 2D based retrieval.


Figure 4: Four Leftmost column: 3d sketches, then virtual tablet, whiteboard, real tablet 2D sketches. The rightmost column is the target chair.

## References

[1] Giunchi, D., James, S., and Steed, A. 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* (New York, NY, USA, 2018), Expressive '18, ACM, pp. 1:1–1:12.

[2] Wu, Z., Song, S., Khosla, A., Yu, F., Zhang, L., Tang, X., and Xiao, J. 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* (2015), pp. 1912–1920.

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