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Technical Report

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# A User Study Comparing 3D Modeling with Silhouettes and Google SketchUp

Alec Rivers, Fredo Durand, and Takeo Igarashi

massachusetts institute of technology, cambridge, ma 02139 usa — www.csail.mit.edu

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Alec Rivers
MIT CSAIL

Frédo Durand
MIT CSAIL

Takeo Igarashi
The University of Tokyo

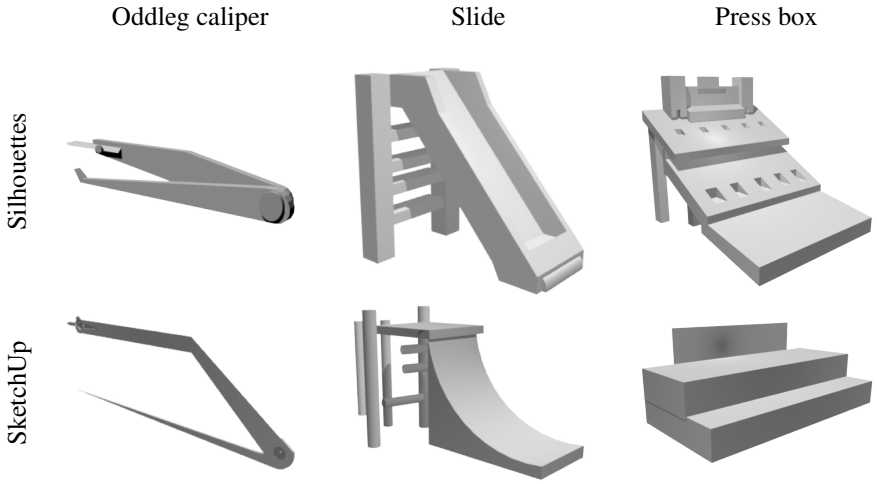


**Figure 1: Middle-ranked models:** *We performed a user study in which users were asked to model three objects using either 3D Modeling with Silhouettes or Google SketchUp. A separate group of users then ranked the models produced by the first group. Here we show for each object the middle-ranked model done using silhouettes and done using SketchUp.*

## 1 Introduction

We recently introduced 3D Modeling with Silhouettes [1], a new sketch-based modeling approach in which models are interactively designed by drawing their 2D silhouettes from different views. The core idea behind our approach is to limit the input to 2D silhouettes, removing the need to explicitly create or position 3D elements. Arbitrarily complex models can be constructed by assembling them out of parts defined by their silhouettes, which can be combined using CSG operations.

In this technical report, we describe a user study comparing 3D Modeling with Silhouettes and Google SkechUp [2]. We chose to compare to SketchUp as it is also intended for novice users, and also aimed at the creation of man-made objects.

| | Oddleg caliper | | | | | | | | | | Slide | | | | | | | | | | Press box | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Rank | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| 1 | 3 | 0 | 3 | 3 | 3 | 3 | 0 | 9 | 3 | | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | 9 | | 1 | 9 | 4 | 9 | 9 | 1 | 9 | 1 | 9 | 9 |
| 2 | 1 | 3 | 2 | 9 | 4 | 4 | 1 | 1 | 1 | 1 | 4 | 6 | 6 | 6 | 6 | 6 | 6 | 7 | 6 | 4 | 4 | 3 | 9 | 3 | 3 | 4 | 1 | 9 | 4 | 4 |
| 3 | 0 | 1 | 4 | 0 | 0 | 1 | 4 | 3 | 3 | 9 | 7 | 7 | 3 | 7 | 4 | 4 | 7 | 4 | 5 | 3 | 9 | 4 | 1 | 1 | 4 | 9 | 3 | 2 | 1 | 1 |
| 4 | 2 | 2 | 0 | 4 | 1 | 0 | 9 | 9 | 4 | 0 | 6 | 8 | 7 | 3 | 3 | 7 | 8 | 6 | 2 | 7 | 6 | 1 | 3 | 0 | 1 | 3 | 4 | 4 | 3 | 2 |
| 5 | 9 | 4 | 1 | 1 | 2 | 9 | 2 | 4 | 0 | 4 | 3 | 3 | 4 | 8 | 7 | 3 | 4 | 5 | 7 | 2 | 2 | 0 | 2 | 4 | 2 | 0 | 2 | 0 | 0 | 3 |
| 6 | 6 | 9 | 9 | 6 | 9 | 2 | 0 | 6 | 2 | 2 | 8 | 4 | 2 | 2 | 8 | 2 | 5 | 3 | 8 | 8 | 0 | 8 | 0 | 6 | 8 | 2 | 0 | 6 | 2 | 0 |
| 7 | 4 | 8 | 6 | 2 | 6 | 8 | 6 | 2 | 6 | 6 | 5 | 5 | 8 | 4 | 2 | 8 | 3 | 2 | 4 | 6 | 8 | 2 | 7 | 2 | 7 | 7 | 6 | 7 | 6 | 6 |
| 8 | 8 | 6 | 7 | 8 | 8 | 6 | 8 | 8 | 5 | 8 | 2 | 2 | 5 | 5 | 5 | 5 | 2 | 8 | 1 | 5 | 7 | 6 | 8 | 7 | 5 | 6 | 5 | 3 | 7 | 7 |
| 9 | 7 | 5 | 5 | 7 | 7 | 7 | 7 | 5 | 8 | 5 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 3 | 7 | 6 | 5 | 0 | 8 | 7 | 8 | 5 | 8 |
| 10 | 5 | 7 | 8 | 5 | 5 | 5 | 5 | 7 | 7 | 7 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 3 | 0 | 5 | 5 | 5 | 8 | 6 | 5 | 8 | 5 | 8 | 5 |
| Reviewer | a | b | c | d | e | f | g | h | i | j | a | b | c | d | e | f | g | h | i | j | a | b | c | d | e | f | g | h | i | j |

**Table 1: User study results:** *Each column is the ranking of a different reviewer (a – j) of the models done by the user study participants, with the best models at the top. Green boxes indicate models designed with our approach; red boxes are models designed with SketchUp. The numbers inside the boxes are the number of the user who created the model.*

## 2 Methodology

Our user study involved ten participants, recruited from the general population, all of whom were familiar with computers but none of whom had previous experience doing 3D modeling. Each participant spent twenty minutes following a tutorial of our modeler, and twenty minutes following a tutorial provided by Google for SketchUp[1], in randomized order. The participant was then shown a series of three photographs of objects: an oddleg caliper, a slide, and a press box, shown in Figure 2. These objects were taken from a random list of man-made objects generated as part of the evaluation in [1]. We tried to select objects from that list that had a range of scales, with each being complex enough to produce interesting results. The participant then modeled each of these objects in sequence, spending a maximum of 25 minutes on each. Each object was modeled only once, with each user alternating between using our modeler and SketchUp (each participant therefore created a total of three models). Half the participants started with SketchUp, and half with our modeler.

In the second phase of our user study, ten people who had not participated in the first phase were asked to sort rendered images of every model created into a total ordering by quality. The rendered images were produced in a third-party commercial renderer and could not be distinguished as to which modeler was used to create them. We call these users reviewers.

## 3 Results

The models created by the user study participants in the first phase are shown in Table 2, and the rankings done in the second phase are shown in Table 1. We show the middle-ranked model done with our approach and done with SketchUp for each object in Figure 1.

We believe that the rankings in Table 1 illustrate that models done with our modeler were consistently ranked higher than models done with SketchUp. By ANOVA analysis, the effect of the modeler on the model's ranking was statistically significant with higher than 99% confidence. To quantify the extent of this preference, we calculated that of all the pairs of a model done with our modeler and a model done with SketchUp, reviewers on average ranked the model done with our modeler higher 83% of the time.

However, a direct comparison of the ranks of the models made with our approach and those made with SketchUp can be misleading, as highly-skilled users' models tend to outrank less skilled users' models, regardless of the modeler

[1] "Start a Drawing" self-paced tutorial parts 1, 2 & 3, available at http://sketchup.google.com/3dwarehouse/

used. (See, e.g., user 9 in the rankings, who did well enough with SketchUp to outrank other users' models done with our approach, but did even better when using our approach.) It is more appropriate to analyze how each modeler fared when using our approach compared with when using SketchUp. We therefore calculated for each user the average rank of the user's models done with our modeler and the average rank of the user's models done with SketchUp. We found that every single user had a higher average rank for their models done with our approach, on average 3.19 places higher than the average for their models done with SketchUp. By ANOVA analysis, this result is statistically significant with over 99% confidence.

# 4 Discussion

In this section we will discuss some of the differences between these two modeling approaches that could account for the difference in quality of the models produced in our user study.

One difference has to do with the nature of the lowest-level building blocks of a model. In SketchUp, the most basic elements of a model are edges and surfaces, and 3D volumes exist only as boundary representations constructed out of edges and surfaces. By comparison, the lowest-level building block of a model in our approach is a 3D volume, specified by the intersection of 2D silhouettes. We found that working with volumes and silhouettes bypassed a variety of difficulties that novice users had when working with a boundary representation: for example, in SketchUp, users had to manually ensure the coplanarity of lines when generating a surface, be aware of and avoid T-junctions, ensure watertightness, and so on.

Another difference is with the interface that each modeling program presents: SketchUp uses a single 3D view, while our approach uses three 2D views. We found that users were more immediately comfortable with a single 3D view of the object. However, we also found that having a single view caused certain difficulties: because 2D sketching operations in a single view are ambiguous with regards to depth, users often made the mistake of performing a modeling operation that appeared reasonable in one view, only to rotate to another view and find that the actual shape was greatly distorted. In our interface, by comparison, all shapes are drawn in at least two views, preventing this type of ambiguity.

We also observed that users sometimes had difficulty envisioning what steps were necessary to achieve a desired shape in SketchUp. This was because in SketchUp there are usually multiple ways to achieve a shape, some being easy and others hard. In our study, users would often try one approach, only to have to delete the shape they had built and try again with a different approach. In our interface, by comparison, there is intended to be only one way to achieve any shape, and this pattern of deleting and trying again generally did not occur.

Our user study could have been improved by having an even number of models, so that each user could do an equal number of models with SketchUp and our approach. We limited the study to three models simply due to time concerns, as even with just three models the user study took roughly $2\frac{1}{2}$ hours per user. As a result, the overall statistics on rankings of models done with our approach versus those done with SketchUp could be affected by the skills of individual users if, for example, more skilled users were randomly selected to make two models with our approach. However, the comparison of each individual user's scores with each modeler is still valid, and shows that individuals always performed better with our approach.

# References


[1] Alec Rivers, Fredo Durand, and Takeo Igarashi. 3D Modeling with Silhouettes. *ACM Transactions on Graphics (Proc. SIGGRAPH)*, 29(3), 2010.

[2] SketchUp. Google. 2009.

(a) Oddleg caliper (b) Slide (c) Press box

**Figure 2:** *The photos shown to user study participants.*

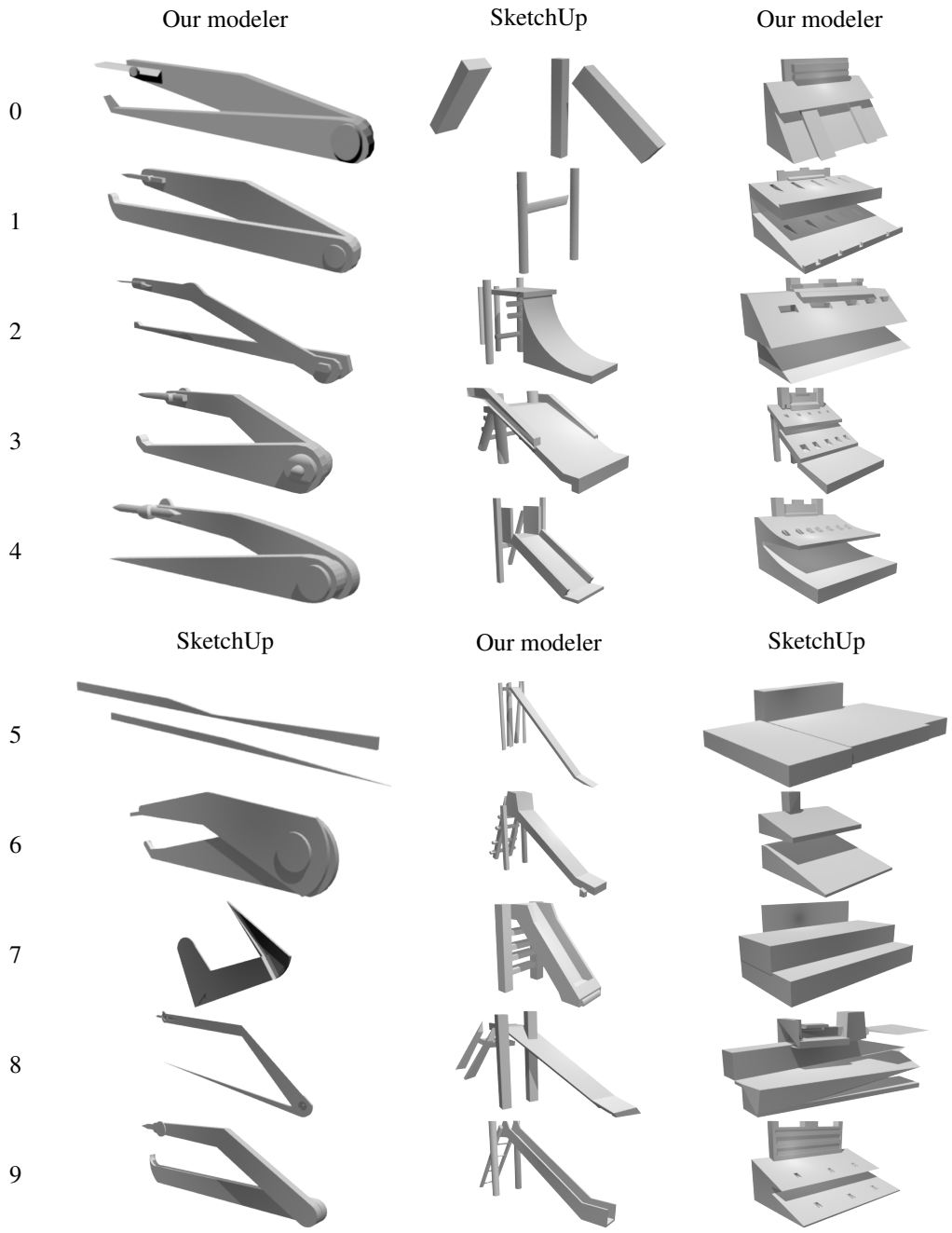


**Table 2: User study models:** *The set of all models generated by our ten users. Note that five users started with our modeler, while the other five started with SketchUp.*