Results of an observational study on sketching

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Abstract
We present the results of an observational study on sketching. Artists were asked to sketch a small number of objects and comment on how and why they made the marks they did. We summarize these findings, from low-level details on individual marks through the drawing construction order. Based on these observations we provide suggestions for future research directions in 3D sketching.

Categories and Subject Descriptors (according to ACM CCS):   I.3.3 [Computer Graphics]: Picture/Image Generation—Line and curve generation

1. Introduction

This paper presents the results of an observational study on how artists draw, conducted in the summer of 2010. The goal of the study was to gain insight not just into how marks are made on the paper, but the entire process of creating a drawing — how and why artists chose the lines they do. Although each participant had their own style, there was commonality in both how they made marks on the paper and the order in which they built up the drawing. Common across all participants was that the 2D aesthetics of the drawing — weight of light and dark, placement of lines on the paper — was just as important as capturing the lines of the shape.

We summarize the observations from the study and suggest possible directions for existing painting and sketching systems. A complete version of the paper, with images and movies, can be found at www.cse.wustl.edu/˜cmg/drawing.htm.

1.1. Study

We selected a small number of relatively simple shapes that had the following properties: 1) They ranged from man-made (the train) to more organic shapes (the horse). 2) Several objects had elements that could not be captured with planar curves (eg, the horse's leg and Mr. Potato Head ®'s arms). 3) The objects were simple enough that they could conceivably be created with a 3D sketching program.

The participants were asked to chose one or more of the models, and to draw them from whatever view and in whatever media they wished. For view angle, they were asked to chose a view they thought was informative or interest-

Figure 1: *Variation in marks made by a single tool.*

ing. The drawing surface was video taped as best as possible without interfering with the drawing process. About half the participants talked while they drew. All were were asked leading questions such as "Why did you put that line there?" in order to elicit further information if necessary.

1.2. Previous work

Perhaps the closest study to ours is the one on silhouettes by Cole et al [CSD*09]. We were less concerned about capturing the specific lines drawn and more about the drawing *process*, in particular how artists mapped 3D shapes to marks in the drawing plane. Working from 3D shapes is also very different than working from a photograph, which is essentially

a 2D to 2D mapping. We therefore have more qualitative data and less quantitative.

1.3. Study observations

Even with pencil and pen there was a surprising amount of variation in the marks made by a single tool (see Figure 1). This expressivity was enhanced by using a shaped tool (a rectangle cut at an angle to the drawing surface). Artists varied the pressure, the angle (by tilting or rotating), the speed, and the amount of water. These variables changed the width of the line, its intensity value, and the sharpness of the boundary.

Artists also used other objects (smudge sticks, erasers) to lighten and broaden lines, softening the boundary between media and paper. For ink or single-color brush painting, the stone or palette is used to control how much ink is on the nib or brush, and how watery the ink is. Sponges and paper towels control water content on the paper.

We define a "stroke" as being a line with semantic meaning, such as the silhouette of a body, the outline of an eye, or an interior contour or shading line. A "mark" is defined by the tool touching the paper, moving, then lifting up again. In many sketching systems the two are considered to be the same thing [NISA07, CA09], although some systems support merging several overlapping marks into a single stroke [BBS08]. From our observations, it usually is not that simple — we show examples in the accompanying videos.

The relationship between marks and strokes can be complex. Multiple marks can make up a single stroke, and conversely, a mark can cross between strokes, usually at a corner. Strokes were used to place or align objects on the paper, as shadows, contours, details, shading, and for over-marking existing lines.

We analyzed the videos to determine if there were any commonalities in how the artists approached constructing their drawings. Broadly speaking, the artists tended towards the following stages. These stages held both at the entire drawing level (getting started) and at individual components where relevant (body or sub parts). Stages: Rough blocking, outlining, sweeping across the model, return to detailing, and adding interior shading followed by ground plane or background shadow.

There appears to be two competing trends. The first is to do structural lines first (exterior and interior silhouettes) followed by interior detail (contour lines and detail). The second is to add lines close to existing ones, usually sweeping in one direction, but sometimes spiraling around. This implies that spatial coherence and proximity is just as important (or more so) than the more abstract concept of stroke type. Jumping around happened only at the end, when the artist was making small adjustments to the contours and adding shading.

We provide specifics for four cases where we had several artists sketch the same shape (Mr. Potato Head®, the teapot, train, and the horse) in the videos.

1.4. Future directions

While many painting and stroking applications take advantages of angle and pressure information for controlling media as it is applied to the surface, we are not aware of any that use these pen attributes to control how media is applied to the brush (eg, how watery, how mixed, how dark, how thick). Artists use a variety of objects (ink stones, water jars, palettes, paper towels) to control this. Physically moving the brush "off-screen", as it were, between when needed to reload the brush with ink or change the water content (and hence the diffusion properties) is very natural.

One largely untouched area in sketching interfaces is how marks are accumulated into strokes. Most sketching and diagraming applications enforce a "one mark, one stroke" rule, or possibly a sequence of overlapping (in both time and space) marks makes a stroke [SKSK09]. Overstroking is also available in some systems, although usually as a specific select the curve and apply an overstroke "brush" operation. From our analysis of actual drawing styles, a more natural system would support accumulating marks into strokes on the fly (see Strokes video):

One obvious advantage of computer-aided drawing is that it is possible to pick up and move around strokes. Nearly every drawing system has the ability to rotate, scale, translate, or keystone strokes or groups of strokes. Many systems also support rectification of some kind — right angles, straight and parallel lines, circles, etc. Few systems, however, allow the artist to semantically group marks as 2D strokes representing the boundaries of 3D objects. The ability to quickly build approximate 3D geometry and embed the 2D strokes on that geometry would support 3D beautification, small-scale viewpoint adjustment, semantic editing, and non-linear perspective effects.

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