

An Alternative Way of Drawing

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ABSTRACT

Current object-oriented drawing programs have an established way of drawing in which the shape of an object is controlled by manipulating control points. While the control points are intuitive in their basic use, it is not clear whether they make more complex drawing tasks manageable for the average user. In this paper we describe an alternative way of drawing and editing a drawing using new direct manipulation tools. Our approach resembles sculpting in two dimensions: the user begins with a large block and uses different tools to give it the desired shape. We also present a user evaluation in which the users could try our new tools and compare them to their previous experience of control points. The users claimed to understand the operations better with our tools than if they had needed to use curves and control points. However, our tools were better suited for sketching the artwork than for making very detailed drawings.

Keywords

Drawing programs, direct manipulation, two-handed interaction, interaction techniques, sculpting

INTRODUCTION

Direct manipulation has widely been accepted as one of the preferred styles of interaction. Drawing programs were among the first applications that made use of direct manipulation, and are strongly based on its principles. Still, many operations that the user carries out using direct manipulation are based on the interaction techniques that were first suggested when the programs were developed [1, 12]. It is not clear whether they are the best in all situations.

We have suggested an alignment tool that is based on direct manipulation and two-handed interaction [15]. The use of this *alignment stick* has been observed to make some alignment tasks more efficient than carrying them out with

the command-based alignment menus and palettes [16]. The users also learned the purpose of the tool quickly and did not have any conceptual problems with it. Here we explore the stick metaphor further by introducing four new tools with which the user can edit drawings and diagrams. We show how the use of these tools allows an alternative way of drawing.

The final implementation of the alignment stick has been used as the base of our new tools, each of which has its own design considerations and problems. All the tools follow the same interaction style; thus learning one helps learning the others. The choice of the new tools was inspired by the tools that craftsmen and sculptors use, namely planes, drills, chisels, scissors, different carving sticks and cutting wire. Using these tools is like working on wood, shale or other raw material and combining several tools to make the final artwork. There are some volume sculpting systems that are based on a similar kind of metaphors [7, 21], but these systems are used for 3D modeling. Our system was independently developed for 2D drawing in which the sculpting metaphor has not been studied before.

This paper is organized as follows. First, we will present the previous work in the area. After that we briefly describe the alignment stick and explain the current state of its design and functionality. Next we describe the new tools that we have developed together with some implementation details, and show an example of their use. This is followed by a brief user evaluation and discussion of the suggested interaction style. We conclude with suggestions for developing this interaction style further.

BACKGROUND

The way the user draws a picture is almost identical in all current drawing programs. First he or she selects a drawing tool, then uses the tool to draw a number of objects and starts manipulating them. This process can be repeated many times and may require the use of many different drawing tools. The objects can be modified by manipulating so-called "control points" that act as handles and are normally placed at the corners of an object. With the standard shapes, for example rectangles and ellipses, this

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procedure is clearly based on direct manipulation. It is also easy to understand when drawing rectangles and polygons. Drawing an ellipse may be a little more difficult to grasp, but real problems arise when the shape should be extensively reshaped. Then we usually have to deal with some sort of splines [6, 9, 14, 19, 20] and their control points.

Splines and related curves are mathematically manageable and well suited for free-form drawings. There are many kinds of splines that allow different kind of drawings to be constructed. Although most of the spline types are equivalent in theory, their individual properties suggest that different input strategies depend on the underlying mathematics, and thus the possible results and the user interfaces differ from each other [2]. In the basic case the control points are not within the curve being manipulated, but somewhere near it. For most ordinary users the result that they get by adjusting these points is not clear at all, as indicated in [3, 6, 9, 14, 20]. In order to understand the behavior they should know how the underlying mathematical model behaves. This is clearly something that we can't expect from an average user. The design is more focused on technology than users' needs.

Naturally this problem has been observed repeatedly and the computer graphics community has developed various solutions to the problem. Hsu *et al.* [10] present a direct manipulation technique that lets the user manipulate the object directly. Any part of the object can be adjusted using a cursor, and the system calculates the necessary alterations to the control points. This is a simple example of abstracting the control points so that the user need not manipulate them directly. Many researchers have accomplished the same goal by adding physical effects to the interface [14, 19, 20] or letting the user change geometric properties rather than just control points [6]. Another line of research is based on developing geometric representations of modeling operators, as in [8, 18].

The common object-oriented way of drawing resembles drawing on paper, but the metaphor breaks when the user is allowed to select the objects and alter their shape, color, size and depth level. The fact that most novice users find a bitmap-based painting program much easier to learn than an object-oriented drawing program shows that the currently chosen interaction style may have some shortcomings. It does not mean that the current style is wrong, but suggests that we should not be content with it and stop exploring other alternatives that might be better in some circumstances.

THE STICK METAPHOR

The *alignment stick*, seen in Figure 1, is based on the stick metaphor. It can be thought of as a ruler or simply as a straight stick that can align objects. It is one example of using the stick metaphor in drawing programs, but there are potentially many more uses for it. In this section we first

describe the alignment stick and then generalize the stick metaphor to be used in our new tools.

The Alignment Stick

The alignment stick works as follows. When the stick is pushed, it aligns every unlocked object that it touches. The orientation of the stick can be changed between horizontal, vertical, and free angle stick. Also, the length of the stick can be varied so that the stick does not touch unwanted objects. The stick is implemented as a large mouse cursor, which changes to the normal pointer when moved outside of the drawing area. Further discussion of the functionality included in the stick can be found in [15].

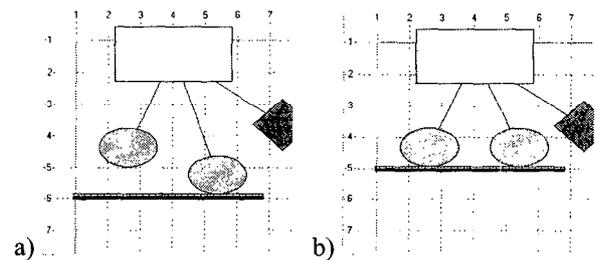


Figure 1: The alignment stick in use: a) The stick is activated and moved upwards. b) The stick is in its intended position aligning the ellipses by their bottom sides.

Normally the stick aligns the objects by their borders. However, it is possible to set so-called *alignment points* for each object, and when they have been set, the alignment is made using these points, not the borders. The most commonly used of these points is the center point that allows carrying out the center alignment in the same way as the border alignment. The points also enable new kinds of alignment operations. For example, the user could align the center point of one object with the right border of another. If several objects are grouped, they behave as one object and have only one set of alignment points for the whole group.

Two methods prevent accidental errors with the stick. First, every stick operation is reversible, following Shneiderman's [17] definition for direct manipulation. An operation is defined so that it begins when the user activates the stick and ends when the user deactivates the stick. Second, objects can be locked, and in the locked state they are not affected by the stick tools. Locking is a property of each object and can be selected from its pop-up menu or by pressing the appropriate button in the toolbar.

Generalizing the stick metaphor

Clearly the only purpose for a real stick is not to align objects. Thus we envision other uses for the stick metaphor. To have the necessary consistence for the user, the different sticks have to be similarly controlled. They also need to have similar undo mechanisms. When we generalize the

stick metaphor, we will vary two properties: the visual appearance of the stick, and the effect that the stick has on the objects that it touches. Differences in visual appearance help users recognize the current tool, which is important when there are many sticks in a drawing program. The tools are recognized from their pattern, size and color. In effect, some of the new tools need not be sticks at all. They can be available in different forms to have a broader range of tools.

We have made small changes in the stick controls that were presented in [15]. The assignment of the devices to different tasks was explained in detail there. Figure 2 shows the controls that all of the current stick tools respond to. The stick is moved with the mouse. Rotating the trackball changes the length of the stick. The left button activates the stick and the middle button enables changing the orientation of the stick. If it is clicked, it switches between horizontal and vertical sticks. If it is kept down, the user can rotate the stick to any angle using the trackball. The most important change from the previous implementation is keeping grip of the manipulated objects as long as the left mouse button is pressed, for example, when the stick is used to push objects upwards and then moved downwards.

There are some general issues that need to be addressed when implementing new stick tools. Maybe the most important of them is, what is the extent of the effect of the stick. If an object is only partly touched with the stick, should it be included in the operation completely, partly or not at all? Another general design issue is what happens when the stick is being rotated? It is not clear whether in every case the stick should do something or even what that something is. With the alignment stick the objects are included completely in the operation and they are aligned to the rotated stick but they are not changed in their appearance. We will address these issues when we describe the new tools.

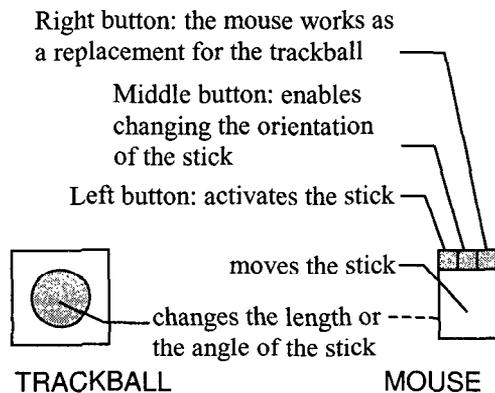


Figure 2: The controls of the stick tools.

THE NEW TOOLS

The new tools that are presented in this section are all based on the same interaction technique that was used in the

alignment stick. The way of controlling the tool is the same; the differences are in what the tool does and in the visual appearance of the tool. Next we briefly describe each tool and the specific design problems that are related to it.

The carving stick

The use of the carving stick (Figures 3, 7 and 8) is like sculpting in two dimensions. When the stick is active and touches an object, the portion being touched is removed. This way drawing an object can be started by drawing a large enough rectangle. After that, the carving stick can be used to shape it in any way the user likes. The stick behaves as an efficient plane that can be used to shape the outer boundaries of an object, or as a drill or chisel when it is used to shape the inside of the object.

The carving stick has one obvious design problem: what happens if the user pushes the stick all over the object? Should that object completely disappear or remain on screen in minimal size? The answer is not clear, but we chose to delete the object in this case. Leaving something small on screen would not be consistent with the real world metaphor. For example, in the real world one can use a plane and end up having no object at all, but a pile of chips.

The "chips" are another issue in this tool. If the metaphor were very accurate, we would end up with having a pile of garbage on screen. Fortunately, we can choose not to produce garbage when implementing the sculpting metaphor.

The nature of the carving stick requires that the stick have an effect on only that part of the object that it touches. This is different from the operation of the alignment stick, in which the whole object is affected. Also, the carving stick can be active during rotation. This allows carving round shapes.

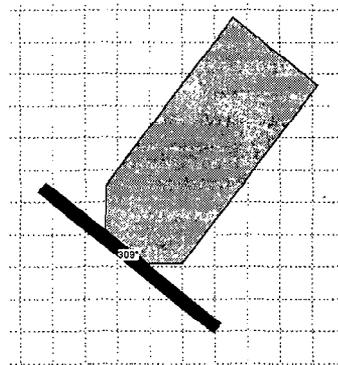


Figure 3: The carving stick in use. The stick is being pushed to northeast direction, and it changes the shape of an initially rectangular object.

The shrinking stick

The shrinking stick (Figure 4) is used to resize the objects that it touches. When the objects are pushed with the stick, they get smaller, but their shape remains the same. This tool

replaces the resizing handles that are commonly offered in drawing programs.

The operation of the shrinking stick is not very different from the resizing handles, but allows simultaneous resizing of many objects in many ways. The user can decide which side of the objects will be affected by moving the tool. In a way this is an alternative alignment operation, in which the objects are aligned by adjusting their size, not position.

The shrinking stick shares a problem with the carving stick: what happens if the object is pushed so that it becomes too small and it disappears? The solution here is consistent with the carving stick, so this kind of operation leads to deletion of the object, but this can be cancelled with the undo operation.

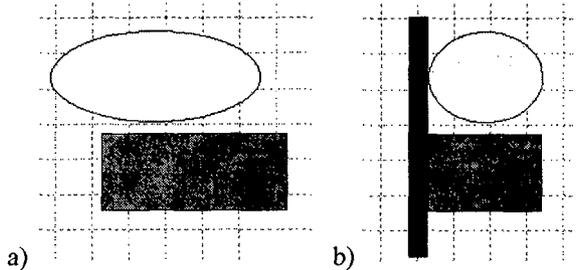


Figure 4: The shrinking stick in use. The stick is used to make the two objects equally wide. Their basic shape and height are preserved.

The cutting stick

The cutting stick (Figures 5 and 9) takes its metaphor from scissors or a knife. When the stick is placed over one or more objects, each object is cut in two pieces along the stick. This operation is clearly something that current drawing programs do not allow, but can prove useful in some cases. For example, if the user wanted to split a complex object in two pieces using current drawing programs, he or she should make a copy of it and try to remove the unwanted parts of both objects in some way. With the cutting stick all that needs to be done is to choose the cutting position and use the left mouse button.

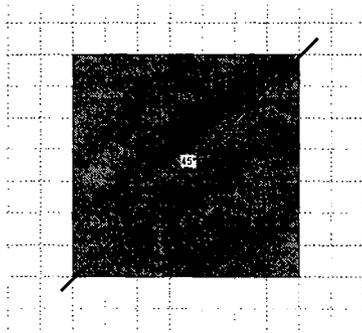


Figure 5: The cutting stick in use. The resulting objects are two triangles.

We decided to choose the take-off strategy (similar to the one used with touchscreens, e.g. [13]) as the signal that the object(s) should be cut. This was because the mouse can move slightly when a button is pressed down, and this way the user can still change his or her mind when the tool has been activated. The final cutting position and direction is selected when the user lifts the left mouse button up. If the operation needs to be cancelled, the user just moves the stick outside of the object before releasing the button. This take-off strategy is motivated by the fact that the cutting stick shares some problems of exact positioning with touchscreen input. If the cutting were made when the button is pushed down, it could result in cutting in the wrong place.

The rotating stick

When the original alignment stick is rotated, the orientation of the objects does not change, but they align to the stick in their original orientations. This decision was motivated by the choice that the alignment stick should not make any changes in the shape or orientation of the objects.

Since the user may still need to rotate some objects to a certain angle, the rotating stick (Figure 6) was developed for this purpose. When the stick touches objects, they align to the stick just like real objects would do if they were pushed with a ruler or another straight object. The rotating stick is another natural application of our stick metaphor, since all of the sticks allow rotation to any angle. This functionality could have been added to the alignment stick, but it would have made it more complicated and thus more difficult to use.

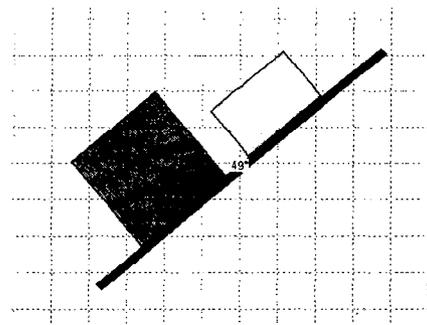


Figure 6: The rotating stick in use. Two rectangles have been rotated 49° from the horizontal level, and they are aligned to the stick.

IMPLEMENTATION

The prototype implementation has been done in the Microsoft Windows environment using C++. The carving and cutting operations are based on the use of regions, free-form objects that are internally composed of a set of rectangles. Regions were good prototyping tools for us since Windows offers operations that, for example, join regions or subtract a region from another. Most common GUI's have similar region structures. Unfortunately, the regions are

also the reason for the fact that the implementation slows down when there are many complex objects on screen. They are clearly not the optimal implementation for our tools, but still their use helps us in prototyping and testing new ideas. The implementation can be made more efficient by implementing a custom data structure for complex objects and calculating the points at which the stick crosses a boundary of an object instead of the expensive subtract operation between regions.

In detail, the carving operation is done with the regions by taking the initial area of the object and subtracting the stick region from it. Cutting is done by dividing the bounding rectangle of the object in two parts along the stick. Then the new objects are created by subtracting first one and then the other half from the initial object. The Windows API also offers operations for scaling and rotating these complex region objects. These operations enable the use of the shrinking and rotating sticks with region objects. The alignment stick has always been based on regions, so it need not be changed because of the complex region objects.

A DRAWING EXAMPLE

In this section we show an example of how the tools can be used in drawing. This example is aimed at giving a practical demonstration of combining the tools. It is illustrative to try to picture how this example would be done with current drawing tools. Most likely it would take much more time and require many more steps to be certain that the result is exactly what it was meant to be.

In Figure 7, a rectangle has been drawn on screen, and the carving stick has been selected and activated. We want to shape the rectangle so that there is a new edge in the object that is at a 45° angle to the edges that it connects to.

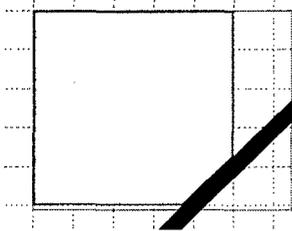


Figure 7: The starting phase in shaping new objects. The carving stick has been activated.

Next we make the object symmetrical so that it has two parallel edges at a 45° angle, while the rest of the edges remain as they were in the initial rectangle. The parallelism is guaranteed by not rotating the stick between the two carving operations. The result is presented in Figure 8, and has been accomplished with just two gestures. The first gesture started in Figure 7 and was extended as far as can be seen in Figure 8. The second gesture is in its final position in Figure 8. Note that the grid is used to accomplish the symmetry.

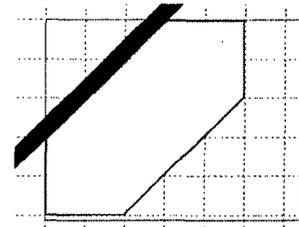


Figure 8: The object is being shaped with the carving stick. In this case, the symmetry is preserved by utilizing the grid.

After the object has been shaped as we wanted, we decide to divide the object in two symmetrical parts. We switch to the cutting stick and use the grid to make the objects of equal size. Figure 9 shows the cutting stick in position just before it is activated.

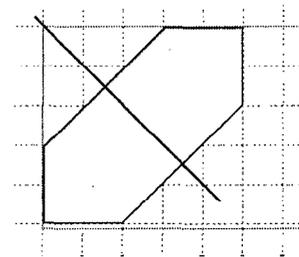


Figure 9: The cutting stick is being used to divide the object in two parts.

Finally, after cutting we have two new objects. In Figure 10 they have been rearranged to make a new type of form in the drawing. The resulting objects can be grouped together to act as one object again. They can also be aligned using the alignment stick or further reshaped with the new tools.

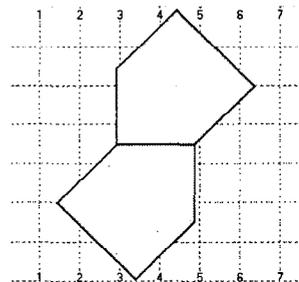


Figure 10: The resulting objects have been rearranged.

The versatility of the new stick tools can be observed in this example. The presented set of operations is not the only one that results in the shape that is presented in Figure 10. One alternative is to shape just one of the objects with the carving tool, make a copy of it, and rotate the copy 180 degrees with the rotating stick. Still another alternative is to

use just the carving tool and shape the rectangle to be the form that is composed of the two resulting objects in Figure 10. The shape can then be cut in two objects with the cutting stick. This last alternative is somewhat more complex than the method that was presented in this section. These alternatives illustrate the fact that the user has many parallel alternatives when creating a drawing with the new stick tools.

EVALUATION

We have evaluated the new tools with six users. All of them are experienced in computing, but their knowledge of drawing programs differed from basics to comprehensive, including two pretty confident spline users. One of the users is a sculptor and three of the others consider themselves as artists or talented in drawing. Five of the users use spline or Bezier curves at least occasionally, but only one of them claimed to understand their behavior in all cases. The users had no previous experience in using the stick tools.

The evaluation was qualitative and focused on testing the potential use of our new tools. All trials were videotaped in our usability laboratory and the tapes were analyzed to find out usage patterns and potential problems with the new tools. The evaluation began with a five-minute introduction to the alignment stick, to make the users familiar with the stick controls. This stage was followed by a demonstration of the other new tools. After a short rehearsal the users started to prepare their drawings. The task was to draw whatever they wanted and use only the new stick tools after creating the initial objects. Examples of the drawings can be seen in Figures 11-13. Each evaluation session lasted 45-60 minutes in total. The users could make comments during the drawing and each session concluded with an interview.

The users could use the tools any way they liked. All of them started the process by drawing one or more large blocks on screen. Then they selected the carving stick and worked on the drawing until it was satisfying. The unlimited undo operation proved very useful since the users tended to make movements that were too extensive at the beginning of the trial.

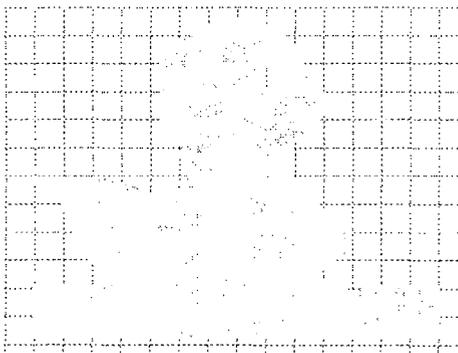


Figure 11: A bird that was made from a few blocks using the carving stick.

The bird seen in Figure 11 was created by our sculptor. In her opinion the carving stick and the cutting stick act very closely like their real counterparts and make the sculpting process understandable. She wished for different kinds of heads to the carving tool to match more closely the different stick tools that sculptors use. She also wanted to be able to use her hands directly to shape the object, as she normally does when working on shale. This may be possible with a drawing tablet that has a built-in display, and will be taken into account in our later studies.

The alignment stick was used to align wheels when working on the cars in Figure 12. In these kinds of drawings the cutting stick, rotating stick and shrinking stick were not needed, but they can be used when working on more complex drawings that include many structures.

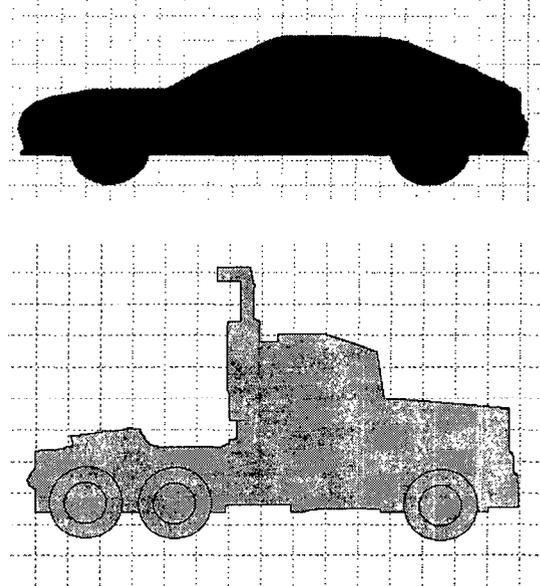


Figure 12: Two examples of the drawings that were made during the user evaluation.

Most of our users chose to create a single structure that was shaped with the tools. One user, however, wanted to create something more. Even though the evaluation period was pretty short, she managed to build a simple scene using just object creation and the stick tools. Especially in this kind of drawing, the possibility to lock objects outside the effect of the stick proved very useful. When, for example, the skyline in Figure 13 was finished, it was locked, and all subsequent changes left it untouched.

The users found the stick tools natural, but the naturalness was partly hampered by the slowdown that the complex drawings caused in our prototype. The purpose here was to test the metaphor and functionality of the new tools, not what they would be in a final consumer product.

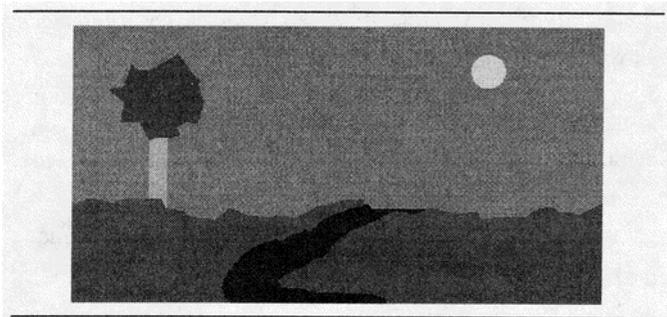


Figure 13: A different kind of drawing that was made using our tools.

Interestingly, one of our users commented that he normally does not draw much with computers since the drawing style of current drawing programs does not match the one that he uses with the paper. He said that our tools are much closer to his sketching process.

With all of the users it was noticed that sometimes they would prefer an increased level of accuracy, but usually the carving stick was appropriate for sketching the form. Accuracy can easily be increased with a zooming feature that enables careful shaping of details. Also, it became evident that a triangular variation of the carving stick will be useful when working in detail. In some cases the users also wanted to change the width of the stick in addition to its length. This is allowed in our latest prototype by using the x- and y-values of the trackball to change each dimension.

All of the users used their two hands naturally to control the stick tools and commented that the large-sized trackball was well suited for the second hand. They also said that given more time to practice they would perform much better than in their first trial.

DISCUSSION

The tools that were presented in this paper allow an alternative and new way of drawing. Instead of trying to draw exact forms at the time of their creation, the user can begin with a general form (like a pile of raw material) and start working on it with the tools. The main difference from current tools is the way of working: building a drawing from individual components vs. sketching the structure by reshaping larger objects. Our new tools can be used to sketch something that the user is not sure of when he or she starts working on a drawing. In our evaluation this happened especially with the user that produced the drawing seen in Figure 13. For example, she started to draw clouds, but later decided to make them pools of water. The new tools may thus be better suited for artistic drawing than the previous tools in drawing programs.

Gross and Do discussed the same issue in their paper on electronic cocktail napkins [9]. Their argument was that the precisely defined graphical elements eliminate the suggestive power of sketches that helps being creative.

Another powerful feature that is present in all of the new stick tools is the range of their effect. Usually drawing programs require changing each of the objects separately, unless they have been grouped or simultaneously selected. With the stick tools the user can implicitly select which objects to manipulate by changing the length of the stick and moving it. For example, resizing all the objects so that their right borders are at the same level is just one gesture when the shrinking stick is used. Normally each of the objects would have to be selected and resized from its resizing handles, since this kind of action is not possible for grouped objects.

The power of not needing to explicitly select the objects has the potential for making operations more efficient. It can also be a disadvantage in some circumstances, such as when the user accidentally touches objects that were not meant to be changed. Sometimes a drawing may also be arranged so that it is not possible to manipulate just those objects that are desired. Because these shortcomings may have serious consequences, we provided two solutions to this problem, undo operations and object locking. They seemed to be enough for the users that evaluated the new tools.

The new tools are highly based on direct manipulation. The alignment stick pushes the objects directly on the same line and does not require selecting each of them. The carving stick changes the shape of the objects directly, and requires no other tools or menu commands in the process. The cutting stick follows the same idea by dividing the objects with the tool, and the rotating stick directly rotates one or more of the objects to a certain orientation. The second pointing device was used to make the mouse less modal and allow changing different properties of the tools at the same time. This design decision was supported by our test users; this gives support to the use of two-handed interfaces in drawing programs that was introduced by Bill Buxton and Brad Myers in 1986 [4].

As Hutchins et al. [11] have suggested, direct manipulation has an inherent problem of accuracy. This problem did not seem to hinder our test users, since they were 'not working with accurate drawings. The stick tools seem to work well in this kind of sketching tasks. However, it seems plausible that supplemented with a zooming function the tools can be used to polish these sketches. Another option to finalize the drawing is to automatically convert the shapes to splines after sketching the drawing, as is done in many sketching systems, for example in [3].

The alternative way of drawing that was presented in this paper gets additional support from Helaman Ferguson [5]. As a sculptor his process involves direct carving and cutting away material. He prefers this method over the construction or addition process since the method is more interesting and challenging to him. This difference in sculpting is analogous to the difference between the common object-oriented drawing style and the way presented in this paper.

CONCLUSIONS AND FUTURE WORK

This paper described an alternative way of drawing. Instead of building drawings consisting of many objects that are manipulated with control points, we start with larger blocks and use different tools to sculpt them the way we wish. This closely resembles sculpting in two dimensions.

The brief user evaluation suggests that our two-dimensional sculpting metaphor suits well for sketching creative drawings, even though the tools are somewhat different from the basic drawing tools. Further studies are needed to make more accurate comparisons between the current and proposed interaction styles and to find out the tasks that our metaphor suits best for.

Until now our tools have been different kinds of sticks. The sticks have performed well in their tasks, but the stick shape is not a requirement for these tools. We are currently designing alternative shapes to make the interface even more expressive. The new tools will be available for public testing in a new Java version of our prototype system.

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