HabilisDraw DT: A Bimanual Tool-Based Direct Manipulation Drawing Environment

Colin G. Butler and Robert St. Amant
Department of Computer Science
North Carolina State University
Raleigh, NC 27695
stamant@csc.ncsu.edu cgbutler@eos.ncsu.edu

Abstract
In this paper, we present a two-handed tool-based drawing environment based on the principles originally incorporated into the HabilisDraw interactive drawing system. These principles include persistent tools that embody intuitive aspects of their physical counterparts and an approach to interface learnability that capitalizes on the user's inherent ability to use tools both separately and in conjunction with other tools. In addition to these principles, the DiamondTouch variation of HabilisDraw (HabilisDraw DT) extends the physical-virtual tool correlation with bimanual input via the MERL DiamondTouch input device and a close adherence to the direct manipulation interaction model. This paper presents the HabilisDraw interface, explores the benefits of a desktop metaphor that closely mimics the behavior of tools and objects in a two-dimensional drawing environment, and argues for the applicability of the system's fundamental principles for improving interface usability in the future.

Categories and Subject Descriptors: H.5.m [**Information interfaces and presentation**] – Miscellaneous.

General Terms: Human Factors.

Keywords: Two-handed input; direct manipulation; drawing applications.

INTRODUCTION

The desktop metaphor for computer interfaces has existed since the Xerox Star project, released to the public in 1981, pioneered bitmapped interfaces to replace command-line text mode interfaces. Since then, the metaphor has spread across all major operating systems on all major consumer PC architectures, including Windows, Macintosh, and several flavors of Unix and Linux. This metaphor has proven popular due to its similarity to the familiar real world workplace scenario and the resulting gains in learnability and ease of use.

Accompanying every commercial implementation of the desktop metaphor are many of the underlying principles outlined by the direct manipulation interaction model proposed by Schneiderman [9]. The basis of our project is to apply a strict form of the direct manipulation model to a desktop metaphor that extends beyond the common WIMP (Windows, Icons, Menus, and Pointer) interface and attempts to emulate a user's real world interface to physical objects. The framework of the project is a two-dimensional tool-based drawing environment called HabilisDraw, originated by Horton and St. Amant [10,11]. The DiamondTouch variation of HabilisDraw applies the tool use metaphor that was fundamental to the design of the original version and marries it to a bimanual direct manipulation interface using the MERL DiamondTouch hardware. The result is a system that we hope will demonstrate the application of tool use principles in direct manipulation environments and provide insight into potential areas of consideration for the future improvement of user interfaces.

CHI 2004, April 24–29, 2004, Vienna, Austria.
ACM 1-58113-703-6/04/0004.

RELATED WORK

Ever since Buxton and Myers [4] demonstrated that human users inherently parallelize interface tasks between both hands and that task performance speed is correlated to this parallelism, much research has been devoted to investigating the applications of bimanual interaction. Several past projects have influenced our research in their combination of bimanual interaction, tool use, and direct manipulation.

The most familiar work on bimanual interaction is probably due to Xerox PARC, in the Toolglass and Magic Lenses system [3]. The design of this system involves a trackball for the non-dominant hand, controlling a transparent tool palette; and a mouse for the dominant hand, controlling the primary cursor. By positioning the palette over the object of interest with one hand and clicking "through" the palette with the other hand, many of the inefficiencies of a modal interface are streamlined into an intuitive bimanual interface. Additionally, palettes can act as "lenses," representing some alternative mode of display for all objects beneath it.

In other related work, Cutler et al. developed a system called the Responsive Workbench [5], for which they developed a two-handed three-dimensional user interface for medical training and automotive design applications. Both hands are used to manipulate both the user's perspective and the virtual objects on a 3D tabletop display. The conclusions drawn from the project support Guiard's bimanual frame of reference concepts in a 3D virtual-reality context.

A recent trend in bimanual interaction research has been to interpret psychophysical behavior in terms of theory in human motor control, in particular to Guiard's Kinematic Chain theory [6]. This work proposed a model differentiating between dominant and non-dominant hands in a bimanual task and forgoing the classification of tasks as unimanual, bimanual symmetric, or bimanual asymmetric. This model serves as the foundation for many systems in which the user manipulates an interface, physical or virtual, using both hands.

In the area of tool-based interaction, the most closely related system is Bederson et al.'s KidPad [2], in which tools are first class objects that can be picked up and manipulated like other objects in the interface, in contrast to more common menu- or palette-based tool designs.

Similarly, Patten et al. have developed a hardware system called Sensetable [7], which electromagnetically tracks tangible interface objects on a tabletop and projects relevant information directly onto the tools themselves. Their system supports direct bimanual manipulation of interface tools with no mediation or indirection whatsoever.

This is only a small sampling from a sizeable body of research pertaining to bimanual user interfaces, and a much smaller area related to tool-based interaction. There is only one project that we know of which combines tool-based interaction and a bimanual interface, and that is the Raisamo alignment stick project [8]. The difference between Raisamo's interface and ours is that our interface uses a direct contact interface instead of Raisamo's mouse and trackball configuration.

HABILISDRAW DT

HabilisDraw DT uses a very literal desktop metaphor in its interface, providing a blank wooden desktop arrayed with various instances of drawing tools. The tools and objects that are immediately available are labeled in Figure 1 as follows:

1. Two pens, blue and black
2. Ruler
3. Cutting arm (fixed)
4. Eight inkwells of different colors
5. Two empty inkwells
6. Trash can (fixed)
7. Stack of paper
8. Tape dispenser

The hardware side of HabilisDraw is based around the MERL DiamondTouch input device, which is a collaborative multi-user USB tablet designed to provide multiple users with simultaneous input in two dimensions. Images can be projected onto the surface from overhead, supporting direct manipulation of an interface. The device uses capacitive coupling to register a unique input from each user, but this limits a user's input to either a single point or a bounding box around all contact with the surface. Our setup consists of the DiamondTouch input device and a ceiling-mounted projector projecting onto the Diamond-Touch surface, but adds a pair of gloves designed to overcome the limitations of a single input point per user and provide two unambiguous input points per hand, placed at the tips of the thumb and forefinger of each hand. To the DiamondTouch, a single HabilisDraw DT user appears to be four users, each corresponding to a fingertip contact. This allows the user to manipulate objects using natural motions as if they were placed flat on a table surface.

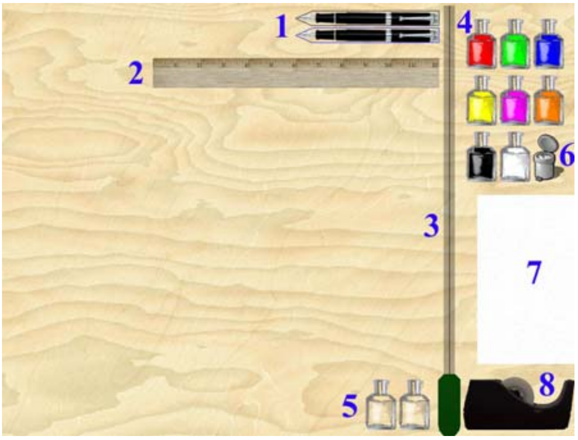

Figure 1. The HabilisDraw DT Desktop

One of the principal guidelines in the design of HabilisDraw is that minimal distinction should be made between tools and objects. The motivation for this is that human users often determine what will act as a tool and what will be the target object of a tool on an ad hoc basis. What is used as a tool in one instance may later be operated upon as an object by another tool, and vice versa. For example, a user might use a ruler to take a measurement, then use a pen on the ruler to preserve the value. Similarly, one could even use a sheet of paper as a stencil mask against another sheet of paper. This demonstrates the lack of natural classification in objects as far as human consideration is concerned. Our system attempts to accommodate this lack of classification by representing tools as a subclass of objects, only differing in some cases by the addition of tool-specific code. Tool-specific abilities are treated more like special attributes than a complete reclassification. Thus a ruler is specified as a standard object, except with the ability to constrain an ink line against its edge. It can be treated as an object or as a tool, according to the user's incidental classification whims.

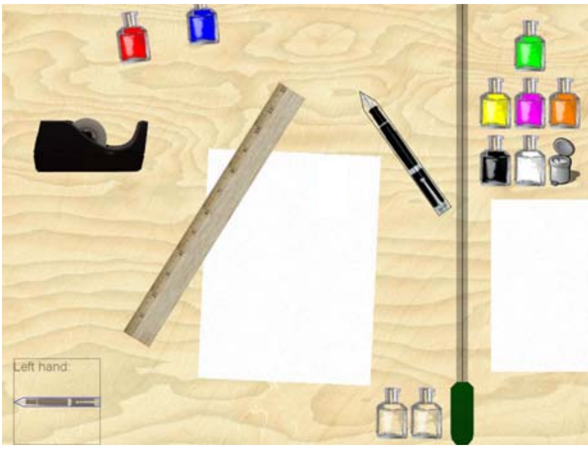

Figure 2. Holding an object shows a transparent representation of what is in each hand.

Another important design consideration for HabilisDraw is ease of learning. While the interface is clearly not as easy to use as a direct physical interface such as a desktop arrayed with pens and paper, it uses relatively natural interactions to take the place of those that cannot be represented in the same way that they might with a physical implement. The supported actions are as follows:

- *Moving an object* – The user can move an object by simply placing any thumb or forefinger down on an object and sliding it along the desktop. The orientation of the object is not affected by this movement; only its position changes.
- *Rotating an object* – The user can rotate an object by placing both the thumb and forefinger of one hand on the object and rotating the contact points. Coupling a rotation action with a movement action is trivial, as the object positions itself to best match the relative positioning of the two points, given any movement.
- *Picking up an object* – By placing both contact points of one hand down and bringing them closer to each other, the topmost object between the two points is then picked up by that hand. Early trials showed that users often forgot whether or not they held an object, so an unobtrusive semi-transparent display of what each hand holds appears when an object is picked up (Figure 2).
- *Dropping an object* – By placing the thumb onto the surface followed by the forefinger, a held object can be placed back onto the desktop without invoking its action (in the case of pens, tape, etc.). Lifting the fingers immediately will only pick the object back up, but if the user spreads his or her fingers in the reverse of the picking up motion, the object will be dropped back onto the desktop.
- *Using an object* – Due to the variety of objects represented and the different ways one might use each object, there are three classes of object use supported by HabilisDraw:
- *Pick up and use* – This involves picking up an object, such as a pen, and using it by placing the forefinger of the hand which holds the object down onto the surface. For a pen, this draws a line. For the tape, it marks a green line between the start of the motion and the end of the motion, under which all intersecting objects are joined. For an inkwell, this "adds ink" to the target object, which affects different objects accordingly: paper is colored completely, pens change their ink color, empty inkwells are filled with ink, and filled inkwells change colors gradually to simulate mixing inks.
- *Touch* – Touching some tools causes an action to be performed. The cutting arm cuts all paper intersecting its blade when touched. In the case of an inkwell, touching it with a pen in hand will change the pen's ink color, simulating dipping the pen. For the stack of paper, touching it will instantiate a new sheet of paper, simulating dragging a sheet off the top of a limitless stack. Finally, holding a piece of paper and touching it to the trash can will dispose of the paper.
- *Drag onto* – Dragging is only supported by the trash can. Dragging a piece of paper onto the trash can will throw the paper away.

When possible, actions were designed to be performed exactly as they would in real life. When an action cannot be performed *exactly* the way it would be in the physical realm, the similarity between the simulated HabilisDraw action and its physical counterpart should in most cases improve learnability for new users.

Figure 3. Inks can be mixed for intermediate colors.

SUMMARY

In HabilisDraw, we have designed a system by which we can explore the benefits of applying a bimanual tool-based interaction model to a graphical interface. A large part of the original design is a strict adherence to direct manipulation principles and a close approximation of real world motions to accomplish commonsense goals. By allowing a user to use both hands with the interface, we support both an unbiased left/right hand interface and a dominant/non-dominant kinematic chain model as proposed by Guiard. No reconfiguration should be necessary between any two users, and new users should be able to adapt to the interface with minimal instruction or learning curve, due to the proximity of both the hardware and software interface designs to a real world desktop scenario.

Over the course of several informal trials with college-age subjects, users have shown that the interface is easy to learn, often picking up the basic interaction concepts through either minimal instruction or watching another user operate the system for only a couple of minutes. User evaluations were favorable with respect to the experience of using the interface, and some users who were asked to create a pair of similar drawings using HabilisDraw's tool-based system and Microsoft Paint were more satisfied with the outcome of the HabilisDraw picture. These results are informal and as such inconclusive, but they show that there is a certain amount of promise in the future of HabilisDraw DT. In the future, we intend to perform a larger study with a wider age range, including children and users unfamiliar with Microsoft Paint's interface, if possible.

While HabilisDraw simulates several aspects of physical interaction rather well, there are some major limitations we have yet to address. First, we intend to consider physical interactions between objects more thoroughly. The ruler interacts with the pen when drawing, but for the most part, local physical interactions are rare. The original HabilisDraw allowed the user to align objects by pushing them with the ruler. We hope to eventually resolve issues between positioning, layering, and colliding objects, allowing us then to use objects for more constraining tasks than simply using a ruler as a straightedge for the pen. Additionally, we are considering bridging the physical and virtual worlds with a hybrid tangible interface, in which some tools may be represented by physical objects, either connected to the interface like the gloves, or tied to a location on the DiamondTouch surface. This could negate the difficulties in approximating real world actions with a two-dimensional contact surface.

ACKNOWLEDGMENTS

This effort was supported by the National Science Foundation under award IIS-0083281. The information in this paper does not necessarily reflect the position or policies of the U.S. government, and no official endorsement should be inferred.

REFERENCES

1. Beaudouin-Lafon, M. (2000). Instrumental Interaction: An interaction model for designing post-WIMP user interfaces. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '00)*, pp. 446-453, 2000.
2. B. B. Bederson, J. D. Hollan, A. Druin, J. Stewart, D. Rogers, and D. Proft. Local tools: an alternative to tool palettes. In *Proceedings of the 9th annual ACM symposium on User Interface Software and Technology*, pp. 169-170. New York: ACM Press, 1996.
3. Bier, E., Stone, M., Pier, K., Buxton, W., and DeRose, T. (1993). Toolglass and Magic Lenses: The See-Through Interface. *Proceedings of Computer Graphics*, (August 1993), pp. 73-80.
4. Buxton, W. and Myers, B. (1986). A study in two-handed input. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '86)*, pp. 321-326.
5. Cutler, L., Fröhlich, B. and Hanrahan, P. (1997). Two-Handed Direct Manipulation on the Responsive Workbench. *Proceedings of the Symposium on Interactive 3D Graphics*, (April, 1997, Providence, RI).
6. Guiard, Y. (1987). Asymmetric division of labor in human skilled bimanual action: The kinematic chain as a model. *Journal of Motor Behavior*, 19(4):486-517.
7. Patten, J., Ishii, H., Hines, J., and Pangaro, G. (2001). Sensetable: A wireless object tracking platform for tangible user interfaces. *Proceedings of Conference on Human Factors in Computing Systems (CHI '01)*, pp. 253-260.
8. Raisamo, R. (1999). An alternative way of drawing. *Proceedings of Conference on Human Factors in Computing Systems (CHI '99)*, pp. 175-182.
9. Schneiderman, B. (1983). Direct manipulation: A step beyond programming languages. *IEEE Computer*, vol. 16(8), pp. 57-69, August.
10. St. Amant, R., and Horton, T. E. (2002). A tool-based interactive drawing environment. *Proceedings of the ACM Conference on Human Factors in Computing Systems (CHI '02) Extended Abstracts*, pp. 762-763, 2002.
11. St. Amant, R., & Horton, T. E. (2002). Characterizing tool use in an interactive drawing environment. In *Second International Symposium on Smart Graphics*, pp. 86-93.