Informal Animation Sketching: Requirements and Design

Richard C. Davis

Group for User Interface Research
Computer Science Division
University of California, Berkeley
Berkeley, CA 98125-1776
rcdavis@cs.berkeley.edu

James A. Landay

DUB Group
Computer Science and Engineering
University of Washington
Seattle, WA 98195-2350
landay@cs.washington.edu

Abstract

We present an interface design for creating informal animations from sketches. Current tools for creating animation are extremely complex. This makes it difficult for designers to prototype animations and nearly impossible for novices to create them at all. Simple animation systems exist but severely restrict the types of motion that can be represented. To guide our design of an animation sketching interface, we conducted field studies into the needs of professional and novice animators. These studies show the wide variety of motions that users desire in informal animations and indicate how to prioritize these types of motion. The interface described here allows the most important types of motion to be defined with pen gestures, and gives visual feedback for coordination of events.

Introduction

Animation is a popular medium for entertainment, education, and communication, but it is out of reach for many. This is unfortunate, because animation is a rich mode of communication. It is a convenient way to express moving visual images, it can represent dynamic concepts, and it can make information more attractive and engaging (Park & Hopkins 1993). Thus, it can be argued that the ability to create animation can make anyone a better communicator.

The simplest way to create animation is to draw a series of images in a flip-book. This is tedious, but more and more users have access to computer hardware that can remove this tedium. One problem remains: animation tools and skills are still in the hands of a small number of designers. Current animation tools have extremely complex interfaces with many, specialized methods for generating motion from static specifications. This may be easier than designing every frame by hand, but only if users can master a complex interface.

Our research seeks to improve access to animation through an intuitive interface for animating sketches. By focusing on informal sketches and gestural input, we hope to make animating a rough drawing about as easy as drawing it. The following section briefly reviews the wealth of related work in animation, animation tools, and informal tools. Then we describe field studies we conducted to determine the types of motion an informal animation tool should support. Finally, we present an interface design for sketching informal animations and conclusions.

Related Work

Cognitive Science, Psychology, and Education researchers have long tried to understand how animation aids learning and understanding, though most conclusions are rather tentative and unsurprising (Park & Hopkins 1993). The best results from these fields indicate when and how to use animation effectively. Rieber described conditions under which animation aids learning of concepts involving motion or trajectory (Rieber 1994). Bertamini & Proffitt demonstrated that translation is an easier motion to recognize than rotation or divergence (Bertamini & Proffitt 2003). Tversky and colleagues explain why many animations fail to communicate effectively, and note that interactive playback control is important (Tversky *et al.* 2002). These results foreshadow the types of animation that will become popular in the future, and we use them to guide our designs.

Currently, however, animators have a confusing array of tools to choose from. Most professional 2D animators who show their work on film or video begin the process with pencil and paper drawings. These drawings are either scanned into a computer to be animated with video software such as Adobe AfterEffects or photographed with a movie or video camera. Professionals who create web animations often create drawings directly in animation software such as Macromedia Flash, which can generate in-between frames automatically. Non-professionals prefer to use software that fits their domain. Presenters can create very simple animations with Microsoft PowerPoint, though some use more specialized tools such as the Slithy animation programming language (Zongker 2003) for complicated animations. Sketchy is a simple tool for use in the classroom (Tatar *et al.* 2003). Whether for professionals or non-professionals, most of these tools require a considerable investment of time and money to produce any animation, and simple tools severely limit the types of motion that can be represented. We seek to remove the complexity barrier and allow average users to create a wide variety of animations quickly.

Research in informal sketching tools hints at ways to remove this complexity barrier. Guided by research showing how sketching helps creative design (Goel 1995), other researchers have built sketching systems that facilitate the design of user interfaces (Landay & Myers 2001), web pages (Newman *et al.* 2003), multimedia applications (Bailey & Konstan 2003), and architectural designs (Gross & Do 1996). These methods may enable us to create a sketching tool that supports animation.

The first informal animation sketching tool was Baecker's Genesys system (Baecker 1969). Genesys demonstrated that a computer could make an animator's work easier by capturing in-between frames from sketched input. Today, sketching is applied more often to 3D animation, such as when defining geometry (Igarashi *et al.* 1999), motion paths (Pickering *et al,* 1999), or the motion of articulated figures (Davis *et al*. 2003)(Thorne *et al.* 2004). We believe 2D animation to be simpler and more accessible to the average user.

There have been noteworthy systems that generate domain-specific 2D animations from sketches of mechanical systems (Davis 2002) and math equations (LaViola & Zeleznik 2004), but we focus instead on general-purpose animation. Some have created complex morphing techniques to facilitate general 2D animation (Di Fiore and Van Reeth 2002)(Lankton 1998). This work has great promise, but we believe simple morphing to be sufficient. The animation work of Moscovich and Hughes (Moscovich & Hughes 2004) is very similar to ours in spirit. However, they do not support any type of motion beyond translation and motion hierarchies, and we do not support precise timing or motion hierarchies. Once again, these decisions are motivated by our field studies that show users to be less interested in these capabilities than they are in simpler motion types. Details of these studies are given in the following section.

Field Studies

It can be argued that general animation tools are complex because the range of motions that need to be supported is so broad. Indeed, simpler tools such as PowerPoint and Sketchy gain their simplicity by supporting a narrower range of motion. Our tool will be simpler than most animation tools because we are using sketching and gestural input both for creating objects and for animating them, but this alone is not sufficient. We must still decide how we will automate the animation process, and there is a convenience vs. complexity tradeoff with every type of motion we choose to support.

To guide our design we conducted field studies that investigated potential users' needs in an "informal animation sketching" tool. We held two sets of interviews, one with people who currently produce 2D animation on a regular basis and one with people who wish to produce animation but cannot cross the complexity barrier. We took examples from these interviews and produced them with existing tools to verify our assumptions about users' needs and the complexity of these tools. Our analysis identified twelve animation "features" or types of motion that our animation tool could support. This section closes with a description of those features and how we determined their priority ordering.

Informal Interviews of Animators

Table 1 summarizes the results from our interviews with seven animators. As shown there, four participants work in the entertainment industry and primarily use pencil and paper (or other physical media) to create animation. One

#	Occupation	Main Tools	Purpose of Animation	Need for Informal Animation	Features Needed (see Table 4)
1	Prof. Animator	Pencil / Paper	Entertainment	Prototyping: moving frames of animatics	Trans, Sound (few objects)
2	Prof. Animator	Pencil / Paper	Entertainment	Prototyping: sketch pad for character work	Trans, Morph, Cell (few objects)
3	Prof. Animator / Anim. Teacher	Pencil / Paper	Entertainment	Prototyping: moving frames of animatics Learning tool: automated flip-book for students	Prototyping: Trans, Rep, Sound, Cell (few objects) Learning: Trans, Rot, Scale, T+R, Morph, Rep, Copy, Sound (few objects)
4	Prof. Animator	Pencil / Paper	Entertainment	New medium for finished works	Morph, Rep, Copy, Sound, Cell (few objects)
5	Prof. Animator / Anim. Teacher	Flash	Web Sites	None (prototypes in Flash)	
6	Comp. Science Grad Student	Slithy	Presentations	None (does not prototype)	
7	Comp. Science Grad Student	Slithy	Presentations	Prototyping: evaluate anim. before building	Trans, A/D, Rep, Copy (many objects)

Table 1: Results of informal interviews with animators.

participant produced web sites and worked primarily in Flash. Two participants were computer science graduate students who produced animated conference presentations using Slithy.

All participants were asked to imagine a sketch pad that allowed them to easily animate their drawings and were asked for specific examples of how they would use it. Five of the seven gave enthusiastic responses summarized in the table. Most were interested in prototyping longer or more complex finished works. For two of the animators, these prototypes were in the form of animatics, which are storyboards set to a sound track. Animatics are an important step in many animators' work process, and an informal animation sketching tool could simplify their production.

The two participants who saw no value in an informal tool are noteworthy. The Flash animator noted that she prototyped her animations directly in Flash. This is possible because of her extensive experience with Flash, and would not be possible for a novice user. The computer science graduate student who does not prototype his animated presentations made similar statements. His work was simple enough that he could produce it directly in Slithy. The other Slithy user, however, was interested in sketching out certain animations so that he would not waste his time producing animated visuals that added little to his presentations.

Informal Interviews of Non-Animators

The eight non-animators we interviewed had a wide range of ideas. All had expressed an interest in animation, but all felt that animation was out of their reach because the tools were too complicated. Participants were asked the same questions that the animators were asked, and all gave specific uses for an informal animation sketching tool. Table 2 summarizes the results of these interviews.

Six of the participants were primarily interested in animation as an education tool, while two were interested in visualizing ideas in a different setting (one to better understand his own dance designs, and one to better explain concepts to colleagues). Seven wanted animations that represented dynamic concepts, and one simply wished to create eye-catching visuals when she tutored children learning to read. Rieber refers to this use as visual "rewards" and there is reason to believe it is beneficial (Rieber 1994).

Informal Animation Experiments

To verify our analysis of the example uses we collected from our interviews, we chose to examine a subset more closely. Seven animations with widely different subjects were taken from the responses of five participants. In addition, we invented four example animations that were similar to participants' examples or other example uses we conceived. One of these examples shows the sequence of

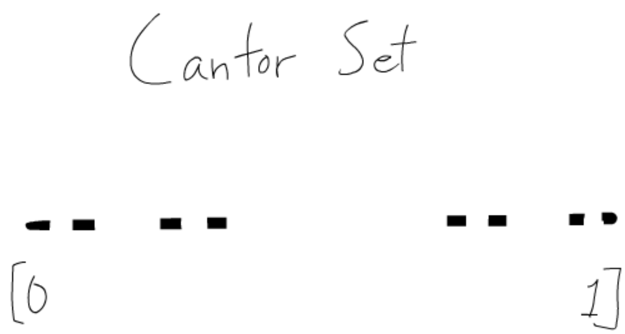

Figure 1: Cantor set construction example (low drawing complexity, low motion complexity, 1 track). New pieces of the dashed number line disappear every second.

#	Occupation	Purpose of Animation	Need for Informal Animation	Features Needed (see Table 4)
1	High School Teacher / Education Grad student	Education	Student exercise: meiosis	Morph (few objects)
2	Education Grad Student	Education	Student exercise: detection of distant planets	Trans, Scale, A/D, Rep, Copy (many objects)
3	Mechanical Engineering Professor	Education	Illustration: dislocations in molecular structure	Trans, A/D, Copy (many objects)
4	Comp. Science Grad Student / Contra Dance Caller	Visualization	Illustration: contra dance	Trans, T+R, Rep, Copy (few objects)
5	Chemistry Professor	Education	Illustration: particle collisions, rusting reaction, battery reaction	Trans, Scale, A/D, Morph, Rep, Copy (few objects)
6	Control Systems Researcher	Visualization	Illustration: construction equipment tread motion	T+R, A/D, Phys (few objects)
7	Math Instructor (college level)	Education	Illustration: cantor set construction	A/D (few objects)
8	Reading Tutor (children)	Education	Fun visual "rewards" for correct answers	Trans, Scale, A/D, Morph, Sound, Cell (few objects)

Table 2: Results of informal interviews with non-animators.

Subject of Animation	Features Needed (see Table 4)	From Interview?	Animation Length	Drawing Complexity	Motion Complexity	# Tracks (not motion guides)	Production Time
Gear reduction	Rot, Rep, Copy	no	16 sec.	med	med	4	29 min.
Contra dance	Trans, Rep, Copy	yes	27 sec.	low	high	5	151 min.
Automobile accident vis.	Trans, T+R, A/D, Phys	no	27 sec.	high	med	6	76 min.
Detection of distant planets	Trans, Scale, A/D, Rep, Copy	yes	2 sec.	high	high	34	153 min.
Chemistry: Particle Collisions	Trans, A/D, Phys	yes	7 sec.	low	low	6	46 min.
Chemistry: Rusting reaction	Trans, Morph	yes	6 sec.	med	med	5	83 min.
Chemistry: Battery reaction	Trans, A/D, Rep, Copy	yes	6 sec.	high	med	9	52 min.
Construction equip. tread	T+R, A/D, Phys	yes	13 sec.	low	med	3	42 min.
Cantor set construction	A/D	yes	6 sec.	low	low	1	4 min.
Stick figure "movie"	Trans, T+R, A/D, Copy	no	180 sec.	med	low	5 (+3)*	347 min.
Sailing (tack vs. jibe)	T+R, Morph, Copy, Hier	no	6 sec.	med	med	9	61 min.

* This example used only five tracks for the first 173 seconds and added three tracks in the last 7 seconds.

Table 3: Results of informal animation experiments using Flash.

events in an automobile accident. Another represents a class of short, stick-figure "movies" that are becoming more popular among amateur animators. This example is notable because it is significantly longer than the others, but it may still be appropriate for an informal tool.

Table 3 shows the data we collected by producing these example animations. Each example was produced in Flash by the first author and the production time was recorded. Care was taken to separate production time from planning time and time spent learning about Flash. The experience that the author gained with each new example should be taken into account, however, and examples are therefore listed in the order that they were produced.

The table also attempts to give a sense of the complexity of each example. Drawing complexity is a measure of how difficult it was to draw the objects in the animation. Motion complexity indicates how difficult it was to specify the motion of objects in the animation. The number of tracks (not including motion guide tracks) indicates the number of independently moving parts in the animation. Figures 1, 2, and 3 show examples of these various levels of complexity.

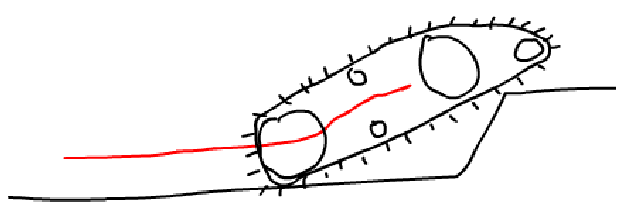

Figure 2: Construction equipment tread motion example (medium drawing complexity, medium motion complexity, 3 tracks). The treat traces out a motion path as it rolls over a bump.

Discussion

These results verify our initial assumptions. Animation tools are complex enough that many animators avoid them when prototyping ideas and non-animators balk at learning to use them. The time needed to build each example animation (median 61 minutes) demonstrates that non-animators' fears are well-founded. The wide variety of examples collected from both sets of interviews also supports our assumption that a general animation tool should not place severe restrictions on the types of motion that can be represented. But how should we use this data to determine the types of motion to support?

Table 4 shows the motion categories that we extracted from the data. Translation, Rotation, and Scaling are self-explanatory, but the others may need some explanation.

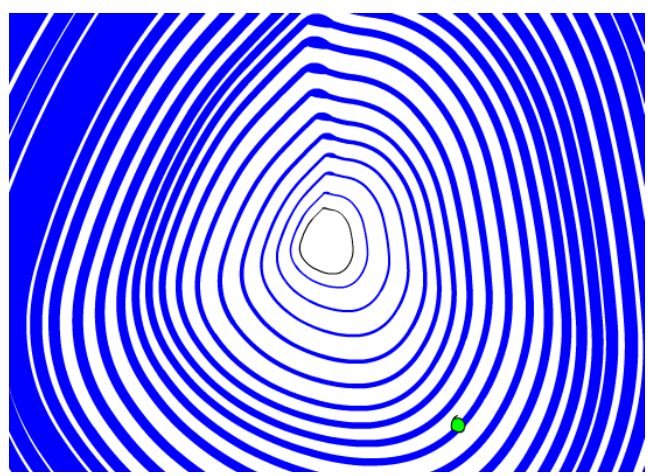

Figure 3: Detection of distant planets example (high motion complexity, high drawing complexity, 34 tracks). Electro-magnetic waves emerging from the star show ripples as a planet revolves around it.

Code	Feature	Animators Needing	Non-Animators Needing	Examples Needing
Trans	Translation of objects	4	5	7
Rot	Rotation of objects	1	0	1
Scale	Scaling of objects	1	3	1
T+R	Simult. translate and rotate	1	2	4
A/D	Appearance/disappearance	1	6	7
Copy	Copying of objects/motion	3	4	6
Rep	Repeating motion	3	3	4
Morph	Morphing of objects	3	3	2
Phys	Collisions / phys. modeling	0	1	3
Hier	Motion Hierarchy	0	0	1
Sound	Synch. with sound	3	1	n/a
Cell	Support for object cells	3	1	n/a

Table 4: Motion categories with codes. The columns at right show how many animators, non-animators, and examples made use of each category. Our design supports those categories above the line, but we aim to support repetition and morphing as well.

T+R: Some objects were simultaneously rotated and translated, such as vehicles that point in the direction they are heading.

A/D: Some animations required objects to appear or disappear in the course of the animation.

Copy: Some animations had repeated objects and/or motions. Copying the objects/motions sped up production.

Rep: Some motions needed to repeat indefinitely.

Morph: Some motions changed a drawing from one appearance to another. We refer to this as a "morphing" motion (see Figure 4).

Phys: Some examples would have been easier to produce with physical modeling for collisions or gravity.

Hier: As the boat in the sailing example moved through space, its sail was also moving. Such animations determine a hierarchy of motions; one motion is best described before it is attached to another moving object. The motions of skeletal figures fall into this category.

Sound: Some examples required motion to be synchronized with sound. (We did not produce any examples with sound.)

Cell: Some examples would be easier to produce if there were some facility for associating a set of drawings (or "cells") with a moving object. This would enable a character to cycle through a series of appearances as it moved or enable the animator to switch appearances at appropriate times. (We did not produce any examples requiring cells.)

As the table shows, the majority of the eleven examples we collected require objects to appear, disappear, and translate through space. Many examples would benefit from the ability to copy motions or objects, as well. We consider these to be the most important capabilities of an informal animation sketching tool. We group scaling, rotation, and simultaneous translation and rotation with translation because a translation interface can support them without a significant increase in complexity. These categories appear above the line in Table 4, because these are the categories of motion that our design supports.

The two categories immediately below the line, repeating motion and morphing motion, were requested by fewer users. These are less important but still important enough to be included in a general tool. We are looking for ways to extend our design to support these motion categories without radically increasing complexity.

The following two categories, physical modeling and motion hierarchies, were required by so few animators and in so few examples that we feel justified in ignoring them. The final two categories, synchronization with sound and support for cell-based animation, may be worth considering in the future. These capabilities are interesting primarily to professional animators. It may be worth extending our current design to support them, but there is a danger of greatly complicating the interface.

There are two other observations we can make about this data. First, we note that of the numerous examples we collected, most required the coordination of six or fewer moving objects, and only three required more than ten. This suggests that it is less important for an informal interface to support large numbers of independently moving objects. As Bertamini and Proffitt suggest, such "divergent" motions are hard to recognize, anyway.

Finally, we note that precision timing of events was not important for most examples. Only two animations appeared to require timing that could not be accomplished with natural hand gestures. The animation in Figure 3, for example, required the timing of each wave to be so precise

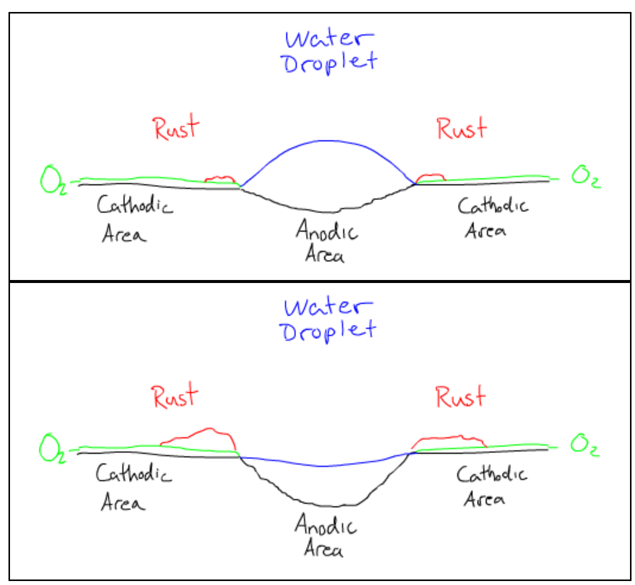

Figure 4: Chemistry - rusting reaction example. Changes to the water droplet, hole, and rust could all be specified more easily with a morphing motion.

that ripples could be detected in the wave pattern. We believe rough timing will be acceptable for most animations. The interface presented in the following section will show how we apply this observation and others we made through our field studies.

Animation User Interface

We have designed a simple animation user interface that will allow users to create motions of the types our studies showed to be most important, translation and appearing/disappearing objects. The interface is most appropriate for a small number of objects, and timing is imprecise, relying on users own hand gestures for timing. Rotation, scaling, and simultaneous translation and rotation are also supported without overly complicating the interface. Copying motion paths is also easy.

Users draw on a blank canvas that contains only a slider bar for controlling position in time and a "GO" button that runs the animation (see Figure 6a). This allows seamless transitions between drawing and animating. To define motion, the user presses "GO," and all drawings, modifications, or pauses are recorded as if a video camera were pointed at the canvas. When a drawn object is selected, the selection widget in Figure 5 appears. This widget has multiple control zones so that users may specify a variety of motions (such as translating or scaling) or other operations (such as moving the center of rotation). By integrating many tools into one, this widget is similar to Tracking Menus (Fitzmaurice *et al.* 2003), though it does not follow a hovering pen as Tracking Menus do.

After the user presses "STOP," visual feedback (a motion path) becomes visible (see Figure 6b). This motion path can be deleted to erase the motion, modified to change the path, or copied to apply it to a different object. As shown in Figure 6d, more moving objects can be added by rewinding, drawing a new object, and pressing "GO" to start the recording again. Objects will move as they have been defined to move, and the user can coordinate the motion of new objects with her hands. This interface relies on the user's intuitive sense of timing to make coordination easy. Timing will be imprecise, but as we have seen, precision is not always needed.

Our design is best suited to supporting a small number of objects. However, there are some examples that require as many as 10, 20, or even 30 objects to be coordinated. We may scale gracefully to larger numbers of objects by

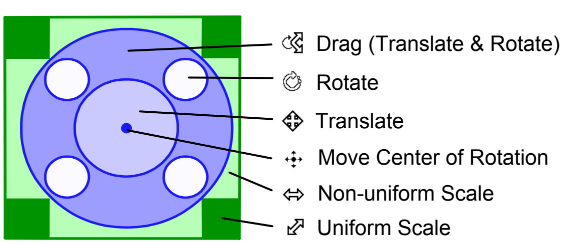

Figure 5: Selection Widget with Control Zones.

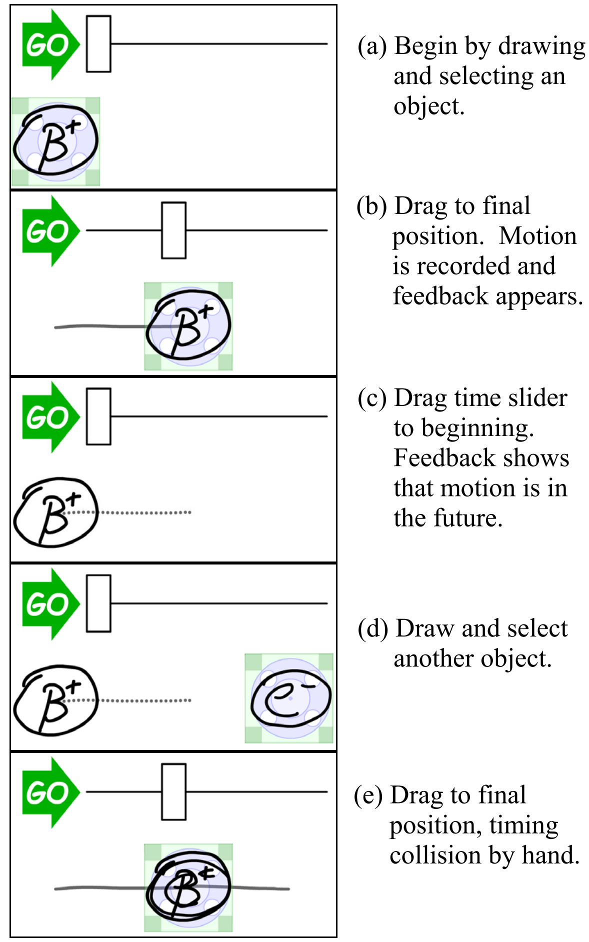

Figure 6: Creating a particle collision animation with our interface.

fading some motion paths to the background when they are not being manipulated.

This interface design supports all the motion categories that our field studies identified as most important. Note that this simple design supports three important capabilities identified by education research. First, the interface makes it very easy to create diagrams of ideas involving motion and trajectory, the case Rieber identified as important. Second, it focuses on translation more than rotation or divergence, in response to Bertamini and Proffitt's study. Finally, it provides interactive playback controls, which Tversky shows to be important for any learner viewing the animation.

Conclusions and Future Work

We have presented the design of an informal interface for animating sketches. Interviews with animators and non-animators as well as production of "informal" animations have guided our design by showing the types of motion that an informal animation tool needs to support. This interface has the potential to make the production of moving drawings about as easy as producing static drawings, giving computer users access to a powerful expressive medium.

We are currently investigating ways to extend this interface to support morphing and repeating motions without complicating the basic operations. Then, our interface needs to be implemented and tested with users like those in our interviews.

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