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# Exploring Frame Gestures for Fluid Freehand Sketching

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**Abstract**

*In this paper, we explore a minimalistic, gesture-based interface for fluid freehand concept sketching with vector graphics. Our approach leverages the advantages of both the GUI and gestural interface paradigms. We describe how to use frame gestures to control rotation, translation, and scale of the drawing canvas and of stroke selections. Based on an implementation of this concept we evaluate our tool with both novices and experts, and report on both its benefits and drawbacks.*

Categories and Subject Descriptors (according to ACM CCS): Computer Graphics [I.3.6]: Methodology and Techniques—Interaction Techniques

## 1. Introduction

The control of drawing and sketching systems with sketch-based interaction techniques seems natural to users and has recently received considerable attention (e. g., [BBS08, BBS09]). With the increasing complexity of drawing systems, however, the set of required command gestures for purely gestural interfaces increases as well. This requires users to learn and remember an increasing number of commands, which might compromise the usability of such sketching systems, in particular for novice users. The fluent and direct interactions that are possible with gestures, however, also bear great potential for rapid editing of drawings.

In this paper we explore a minimalistic, gesture-based interface for fluid freehand sketching with vector graphics. In such an interface, the fluid switching between three types of basic interactions are needed: (1) normal drawing, (2) interaction with the drawn strokes, and (3) interaction with the canvas itself. We explore new interactions that enable a fluid switching between these types, based on mapping canonical transformations (translation, rotation, scaling) of the whole canvas or of stroke selections to contextual gestures that are started from the canvas border or the selection frame. Combined with elements from existing drawing systems, this frame-based interface lets us investigate contextual gestural control for the placement and orientation of the canvas. The analogous interaction with stroke selections facilitates fluent and direct rigid transformations of strokes without having to switch between dedicated operating modes.

We evaluated the proposed concepts in an informal user study and learned that the concepts were generally well-received and that our interface requires only minimal instruction for a user to become familiar with it. Artists proficient in digital drawing particularly liked the notion of a directly-manipulatable canvas, and novices were especially attracted by the ease of learning and use. We also report on some shortcomings of the proposed interface in form of restrictions by the *actual* interface border and the use of a hold gesture to make selections or to erase groups of strokes. In summary, this paper contributes a new way of mapping canonical transformations of both canvas and stroke selections to their frame, and an evaluation of the proposed techniques with novices and experts.

## 2. Related Work

The interaction design of our sketching system relates to work in pen-based interaction, sketch-based interfaces, digital drawing, and interactive stroke-based NPR. Specifically, our work relates to sketch-based interfaces for concept sketching, which has been studied in detail for 3D content creation. For example, Zeleznik et al.'s SKETCH [ZHH96] used a purely gestural interface for sketching 3D scenes. In the subsequent UniCam system [ZF99], the camera can be rotated in 3D via 2D gestures starting from the border re-

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gion of the viewing window. We draw upon this idea and use location-sensitive gestures on the interface border for manipulating both drawing canvas and strokes. Unlike UniCam's use of gestural 3D camera transformations in the interface's center region, we integrate all 2D canvas manipulations into the border region, leaving the center region for inking interaction. This decision relates to the mode switching problem between ink and gesture modes in pen interfaces which was analyzed experimentally by Li et al. [LHGL05]. They report that pressing a button with the non-preferred hand offers the fastest performance. We satisfy this finding by providing hotkeys in our interface, but also offer pure pen interactions for all system functionality. For the BezelSwipe [RT09] interaction, Roth et al. as well make use of gestures on the interface border to prevent mode errors in the interaction with mobile touch screen devices. In ILoveSketch [BBS08], in contrast, a non-preferred hand button is employed for switching between inking and gesturing modes. Bae et al. integrate recent advancements in sketch-based interaction and modeling in this 3D sketching program, here a purely gestural interface provides access to all sketching interactions as well as camera and drawing surface manipulations. With EverybodyLovesSketch [BBS09], they adapt the system to the needs of a broad audience. While our sketching system conceptually overlaps with Bae et al.'s work, our concept is targeted at 2D sketching, investigates the use of contextual gestures for switching modes explicitly when interacting with the 2D canvas in order to avoid having to learn a fairly large gesture vocabulary. In this respect, our design is more similar to the sketch-based implicit surface modeling tools Teddy [IMT99] and ShapeShop [SWSJ05] which also rely on both gestures and a GUI and use a toolbox for explicit mode changes.

Apart from sketching and modeling 3D content, pen-based interfaces were investigated for editing text and graphics documents. The gestural interface of Hinckley et al.'s InkSeine [HZS*07] supports active note taking tasks and in-situ search queries on tablet PCs. Although InkSeine provides visual feedback in the form of labeled gesture previews, our approach differs from the purely gestural interface of InkSeine. At the same time it also differs from menu-based gesture-enabled GUIs for pen input as found in, e. g., ScanScribe [SFLM04], a sketch-based graphics and text editing program, or Zeleznik et al.'s Fluid Inking [ZM06], an approach that augments free-form inking with gestures. In this respect, our approach lies more along the lines of the sketch-based animation tool K-Sketch [DCL08]. In this system, Davis et al. present a gesture-enabled widget for manipulating objects. The stroke manipulation in our program follows a similar concept. In contrast to a purely gestural interface, the gesture-augmented GUI approach allows us to reduce the gesture vocabulary. We make use of a small, consistent set of command gestures, so we can avoid advanced techniques for handling complex gestures such as gesture delimiters [HBRG05]. Hinckley et al. also present ideas on multiple-stroke selection [HGA*06]. Similar to these approaches we also use crossing interactions for selecting strokes, but chose an explicit mode for multi-stroke selection. Our interface design also contrasts the use of gesture-invoked implicit mode changes found in most of the described purely gestural interfaces. Instead, we make use of two basic editing modes in the form of an inking and a stroke shaping tool, which are selected via a button menu. Similar to [HGA*06], our button menu is optionally local or non-local. The crossing interactions that we provide for multi-stroke selection and erasure borrow from the drawing application CrossY [AG04].

Our work also relates to research in interactive stroke-based NPR. For instance, we employ a stroke model that builds upon Hsu and Lee's skeletal strokes [HL94] who also investigate a pen tablet as input device for their pen and ink drawing system. This idea was further investigated by Kalnins et al. [KMM*02] who presented a system for drawing strokes onto 3D models. In digital painting, Baxter et al. [BWL04] as well as Vandoren et al. [VLC*08] presented interfaces that physically emulate the painting process. Related to this work, we derive interaction metaphors from physical actions in the process of concept sketching with pen and paper and provide them within a minimalistic user interface. We employ an adjustable canvas that has just recently found its way into drawing packages, although the benefit of supporting artwork orientation in digital drawing has been investigated before [FBKB99]. In this context our system relates to the many digital drawing and painting systems that followed the seminal Paint [Smi78]. Specifically, our work directly relates to dedicated sketching and painting systems such as Painter, SketchBook Pro, or ArtRage. Similar to these programs, we make use of a minimalistic user interface and interactions that emulate physical drawing actions. In contrast to their use of menu-based GUI and hotkeys to support canvas transformations, however, we examine a means of direct canvas manipulation via gesture-sensitive interface borders.

## 3. Interaction Concepts

A striking difference between a traditional sketching setup and a digital one is the way the artist can interact with the actual canvas. In traditional sketching, the sketchbook can be held or placed freely by the artist and rotated to his or her liking. In digital drawing, the canvas was traditionally aligned with the computer screen. More recently, developers started to equip drawing software with the possibility to adjust the drawing canvas to a preferred orientation, location, and size. These canvas interactions commonly are provided to the user as menu entries which can alternatively be performed with hotkeys. We examine purely pen-based interaction metaphors for canvas and stroke manipulations: the use of the screen border as an active interface element that allows manipulations of the canvas and the interaction with strokes or groups of strokes in an equivalent way.

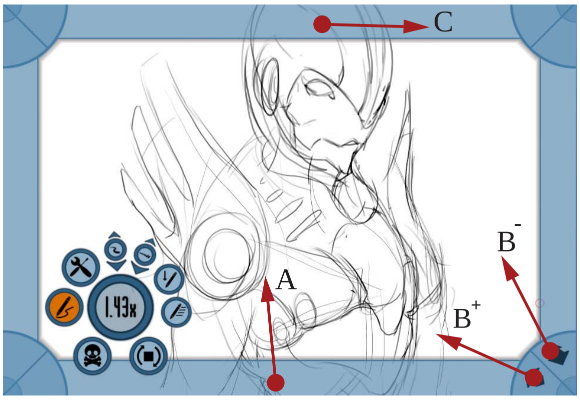


**Figure 1:** *Canvas manipulation. The arrows depict the click and drag motions for the different frame gestures, where A is translation, B is scaling and C is rotation.*

To enable pen-based interaction with the canvas we use the interface's border as an active element enabled with contextual gestures (Fig. 1). Actions performed on this border are mapped to manipulations of the canvas. Using the interface border for canvas transformations provides direct access to these interactions from the entire central interface area as well as allows us to reserve the central area for inking and stroke interactions. Of the three 2D canvas transformations (canvas translation, canvas rotation, and canvas scaling), the first two are inspired by the affordances of non-digital sketchbooks, whilst scaling of the canvas offers the benefit of a digital sketchbook for working at arbitrary magnification levels. In analogy to touching the border of a piece of paper with a single finger and moving the finger either along or perpendicular to the border, we use the following mappings. A *frame gesture* invoked by touching the border and dragging roughly parallel to the border (C in Fig. 1) is mapped to a *rotation* of the canvas, enabling artists to easily rotate the canvas to their liking. This gesture emulates the feeling of dragging parallel on the border of a sheet of paper to rotate it. Alternatively, a frame gesture that starts on the border but drags the pen perpendicular to it (A in Fig. 1) results in a *translation* of the canvas. Both behaviors resemble the rotate-and-translate (RNT) interaction for working with mobile objects in direct-touch settings [KCST05]. Another option to distinguish rotation and translation commands would be to split the interface border in two separate regions for rotation and translation, but this would require a higher pointing precision. We designed our interface with touch displays in mind and thus opted for large interface elements, allowing for imprecise and rapid grab and drag interactions. Additionally, with our discrimination of rotation and translation by gesture direction we simulate the haptics of rotating and moving a physical canvas ontop of a drawing surface. Apart from this, we did choose not to use the frame corners for canvas rotations, as these would most naturally map to a gesture direction tangential to the corner. The lack of display space to perform such a gesture in the interface corners was a reason for us to use the center of the borders for canvas rotations. Finally, we employ the corners to enable canvas scaling, an interaction that is not possible with the real-world counterpart. Because we cannot move further outward from the corner of the interface when it is enlarged to fill the screen, we offer two regions for each corner ($B^+$ and $B^-$ in Fig. 1), one for zooming in and one for zooming out. All frame gestures, once they are started and recognized, are no longer restricted to the frame and users can freely move across the interface.

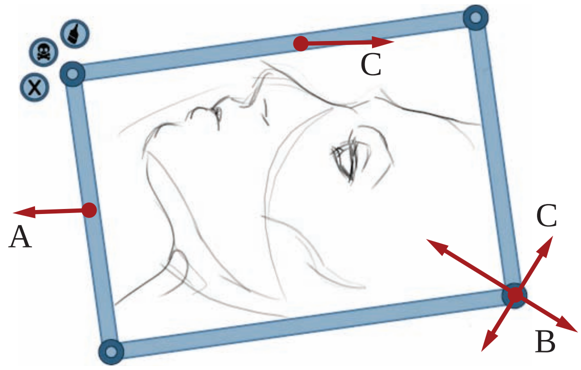


**Figure 2:** *Stroke selection frame and transformation gestures (arrows): A—translation, B—scaling, C—rotation.*

*Rigid transformations* of strokes or stroke selections (selections are created using a hold-and-scratch gesture which is described below) are provided to users of our system analogously to the canvas transformations, using a gesture-enabled selection frame (Fig. 2): *translations* are performed by dragging perpendicular from the frame (A), while *rotations* are possible by dragging parallel along the frame (C). *Rotations* can also be performed by dragging tangentially from the circular corners. Because there is usually enough display space around stroke selections to drag tangentially from the corners of the selection frame, we make use of this gesture as an additional means of rotating groups of strokes.

*Scaling* is done by dragging a corner towards or away from the center of the selection (B; in contrast to the canvas case, here we do not need to differentiate between scaling directions because users can freely move away from selection corners). This fluid grab and drag concept allows us to make all these transformations of strokes directly accessible without explicit mode changes.

*Erasing* is performed with the eraser tip of the pen. 'Drawing' with the eraser tip partially erases strokes, while groups of strokes can be erased with a 'scratch out' gesture. To invoke this latter mechanism without an explicit mode change, we make use of a dedicated *hold gesture* (touching and holding for 0.5 s to prevent interference with quick partial erasing): clicking on the blank canvas and holding for half a second creates a red circular marker, drawing a line out from it

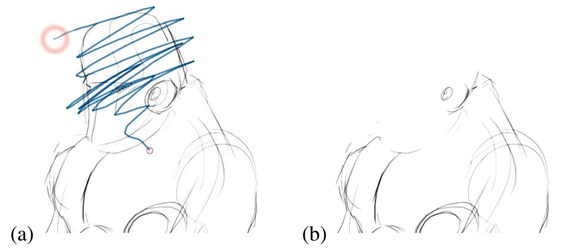


**Figure 3:** *Erase-line interaction: (a) the (fading) circular marker that started an erase-line drawn from it; (b) shows the result.*

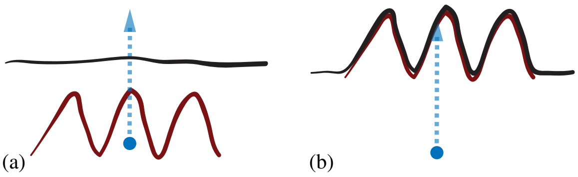


**Figure 4:** *Local reshaping using a red custom stroke (a) as a brush to shape an existing black regular stroke (b).*

**Figure 5:** *An artist working with the system.*

invokes the multi-erase line (Fig. 3). We employ the same holding and scratching mechanism to create stroke *selections* (Fig. 2), using the pen's drawing tip. Singular strokes can also be selected by clicking and holding on them. A selection of strokes can be de-selected, erased, or defined as a brush tip for stroke deformations via clicking dedicated buttons (the three small buttons to the top left of the selection frame in Fig. 2). The crossing-based multi-stroke erasure and selection interactions not only permit fast and loose erasing or selecting with zig-zag gestures but also precise control by drawing selectively over particular strokes.

*Local reshaping* of strokes can be accomplished with local displacement tools, using either a circle or a custom stroke as a brush. These tools directly alter the stroke geometry. When applied to a stroke, this stroke is locally displaced and extended along the brush geometry and dragging direction. We build upon equivalent tools in existing vector drawing applications, such as the *warp* tool in Illustrator. We extend the existing methods, e. g., with a softness parameter for the radial brush and the generalization to custom strokes (Fig. 4).

## 4. Evaluation

The merit of these concepts, of course, can only be judged by actual users. We received feedback on our techniques in an informal study which showed that the frame interaction was generally well-received. We discuss the benefit of our techniques based on insights we gained with this study.

Our informal user study was conducted with two distinct groups of participants: a group that consisted of five (all male) artists who are proficient in digital drawing ('experts') and a group of five (one female, four male) people with little to no experience in digital drawing ('novices'). This distinction refers to the expertise in digital drawing, not in using our system. All participants were unfamiliar with the interaction concepts in our application. The actual study was conducted as follows: each participant was instructed to interact with the implementation using a pen tablet (Fig. 5). The participant was told to experiment with the program, while voicing his or her thoughts. During this phase, the participant received no explanation regarding the interface. After this phase, the interactions and tools were explained. The participant was then encouraged to use the tools to create a sketch.

For novices we observed that they could immediately start drawing with our tool, without any further explanation. After the new interaction concepts were explained, novices started using them, mostly in an exploratory and playful manner but also purposefully. Comments from novices included, e. g., that they enjoyed the ease of use and simplicity of our system. Expert participants, in contrast, learned and applied the new interactions even faster. Experts also directly compared our application with existing software, revealing both shortcomings and benefits of our system. The lack of an undo operation, specifically, was commonly identified as a limitation. Support for layers, usage of hotkeys, and a way to texture strokes were proposed as useful extensions. Nonetheless, the feedback was positive in general. People found the interface to be comfortable to work with. The canvas manipulations were particularly liked, especially the canvas rotation.

The analysis of the interaction and response from novice participants indicated that our interaction concepts can easily be learned and adopted and that they can facilitate the access to digital drawing for this user group. We see this suggested by the fact that people who had never worked with a drawing software before could immediately draw and execute other basic operations after a short explanation. It appeared that the reduced complexity of the interface encouraged people to use our application. Reducing the need for explicit mode changes was arguably beneficial for this purpose, judging from the fact that novices could execute various editing interactions without having knowledge about the internal operating modes of the system. In a traditional graphics program, novices would have had to learn how to select and apply different editing tools to achieve the same results. Thus, we assume the proposed concepts to be well suitable for an educational context. The techniques are similarly suited for use by experts, e. g., for rapid concept sketching, evident in the quality of images that can be created as shown in Fig. 6.

The study also helped us to identify some limitations of our system. A drawback of our design of the canvas translation interaction is that the canvas can only be translated in a direction pointing generally inward from the respective interface border. For example, a translation to the right can not be performed from the right border, as there is no screen space of moving the pen pointer to the right. This also leads to the arguably unnatural requirement to move in a inward direction to zoom the canvas both in and out from the interface corners, but this was not commented negatively by study participants. Another limitation of the system is the use of hold gestures. We initially used tap gestures for the line-select and line-erase interactions, but this lead to unintentional selections resp. erasures of strokes. We remedied this by using hold gestures, but these do not permit as fluid interactions as taps and demand people to learn how to perform them. Furthermore, our interaction concepts are not entirely self-explanatory as was evident from the explanations that participants required to start using the new methods. The reduced interface comes with the cost of limited visual indication for certain functions. Most of the interactions possible with the system require an explanation to become evident to the user, which could probably be improved upon by employing tool-tips or gesture previews.

In a separate session, we asked a digital drawing artist to specifically compare our software with Autodesk's SketchBook Pro. The artist stated that he prefers our frame-based interaction techniques with the canvas and groups of strokes to the marking menu strategies used in the professional software. He also noted similar shortcomings with respect to general drawing functionality as noted above, but implementing a complete drawing application is beyond our scope.

## 5. Conclusion

With the goal of providing a minimalistic and intuitive interface for digital freehand sketching, we designed and explored new ways in which artists can sketch and interact with both strokes and the canvas (see example results in Fig. 6). In general, we use the interaction with the frame of the canvas and of stroke selections to apply canonical transformations to these elements without the need for explicit mode changes. We identify some limitations of using the interface border for interaction, emerging from the restriction to 'inward' directions for gestures, and we propose ways of dealing with this problem. We also found that using a tap gesture interferes with drawing short strokes, and that replacing it with a hold gesture does not permit as fluid interaction as taps. In the informal evaluation our interaction elements have shown to be well-received in general. People could successfully learn the interactions in a short period of time. Specifically the use of location-sensitive, contextual gestures rather than explicit mode changes allows us to provide a fluid transition between interaction techniques that are essential for rapid concept sketching and digital drawing. We hope that these interaction elements will inform the development of future sketching tools. Our techniques can be provided as a useful interface alternative in combination with the much more elaborate features such programs provide.

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**Figure 6:** *Artwork created with our frame-based sketching tool by expert study participants (top) and the first author (bottom).*


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