# Enhancing Naturalness of Pen-and-Tablet Drawing through Context Sensing

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**ABSTRACT**

Among artists and designers, the pen-and-tablet combination is widely used for creating digital drawings, as digital pens outperform other input devices in replicating the experience of physical drawing tools. In this paper, we explore how contextual information such as the relationship between the hand, the pen, and the tablet can be leveraged in the digital drawing experience to further enhance its naturalness. By embedding sensors in the pen and the tablet to sense and interpret these contexts, we demonstrate how several physical drawing practices can be reflected and assisted in digital interaction scenarios.

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**General terms:** Design, Human Factors

**Keywords:** Drawing, pen interface, context sensing.

## INTRODUCTION

The digital pen-and-tablet has become widely adopted by artists and designers, is used as a natural device for digital drawing. The pen-and-tablet takes on the metaphor of a physical pen and paper, while the digital application extends its functionality. For example, one digital pen can mimic the visual effects of many drawing implements such as a paintbrush or a sketching pencil. The tablet can be switched between various canvases and layers. While such diverse virtual functionalities are appreciated by users, most of them need to be explicitly manipulated using abstract operations such as a mode switch, menu selection, parameter adjustment, and so on. This arguably makes the pen-and-tablet experience depart from the physical practice of drawing and more into the purely digital realm. The cognitive loads for users to understand, memorize, and recall these abstract mappings may distract their attention from the task itself. This can be particularly problematic for creative tasks such as drawing.

Our approach to address this problem is by closely examining the physical practices of drawing and translating them to the digital pen-and-tablet drawing experience to enhance naturalness. When we include human practices and intentions into the ecosystem, there are several factors providing unique contexts and affordances that suit the particular drawing at hand, such as the way the drawing implement is grasped, the setup of the drawing surface, and the spatial relationships between the drawing implement, the surface, and the subject being drawn. There has not been work that specifically leverages such rich contextual information beyond the pen itself to facilitate the task of digital drawing. We aim to explore this design space in this paper.

## RELATED WORK

As additional controls on a digital pen are limited, dimensions such as rolling [2], tilting [12], pressure [9], and finger gestures on the barrel [10] have been proposed as alternative input methods. Most of them are used for triggering abstract commands. In this paper, however, we take a different approach and interpret physical contexts to facilitate interactions in ways that directly analogize existing drawing practices.

There have been many digital creation tools that mimic practices using physical implements and props. To name a few, the digital tape drawing [1] system retains the fundamental properties of the physical tape drawing commonly used in an automobile industry and enables this in the digital world. HandSCAPE [8] is an orientation-aware digital tape measure that uses embedded sensors to capture the linear measurements of physical workplaces. In the pen space, Project Gustav [3] attempts to mimic the paintbrush experience by constructing virtual brush strokes in 3D using pen orientation information and physics simulation. This paper differs from these works in that we aim to understand the higher-level contexts of drawing determined by the user, instead of reproducing lower-level physicality.

Context sensing and its applications have been a popular topic for several years. Hinckley et al. [6] demonstrate on a mobile device that a proximity sensor, a capacitive touch strip, and an orientation sensor can be combined to


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implicitly change the state of mobile applications. Codex [5] demonstrates how the configuration of a dual-display tablet can be used to seamlessly switch between individual work, usage as an ambient display, or collaboration with another user. Comparatively, we are the first to explore context sensing in a drawing application.

In particular, researchers have attempted to understand the context of a device usage by capturing ways that people hold the device [7, 10, 11, 13]. Graspables [11] demonstrates how an array of capacitive sensors can be wrapped around various form factors, such as a bar of soap or a sphere, to allow different grips to be recognized and utilized for input. Kim et al. [7] and Wimmer et al. [13] both propose interaction techniques to automatically initiate an application by observing the hand grip and the orientation of a mobile phone. Most relevantly, Song et al. [10] presented the multi-touch pen, which supported switching between three different digital pen effects using different pen grips, in addition to other more abstract finger gestures.

## MOTIVATION

To further ground our research, we interviewed a professional oil painter with over 20 years of experience, as well as observed her drawing a portrait. She owns over 50 types of oil brushes in her studio, and usually uses around 10 different brushes in a single painting. In addition, she uses spatulas to apply or scrape paints, and charcoal sticks to sketch outlines. She holds the oil brush, the spatula, and the charcoal stick with very different grips as well as at different angles. Within a single painting, she needs to change between tools at a high frequency to achieve different effects. When she does oil painting, she places her painting canvas on a desktop easel, which offers four different tilt angles of 25°, 45°, 65°, and 85°. She changes different canvas tilt angles based on different drawing tasks.

When the artist sketches still life, getting the correct proportion is one of her main concerns. In order to do so, she often closes one eye and holds up the charcoal/pencil in front of the eye to measure the physical subject being drawn, and using a finger to mark the length. This is a very common technique among artists.

These interviews and observations verified the importance and richness of contextual information in the drawing practice, such as the grip on the implements and the configuration of the drawing surface. We created a prototype to explore how we may sense and interpret such contexts to facilitate interactions in digital drawing.

## PROTOTYPE PLATFORM

The multi-touch pen hardware [10], which is a Wacom Cintiq grip pen enclosed in a cylindrical layer of capacitive multi-touch sensor array to detect the finger/hand contact image (20x10 px, gray scale) on its barrel. In addition, we attached an orientation sensor (Inertial Measurement Unit or IMU, model CHR-6dm AHRS) to the pen to sense its full 3D orientation angles (yaw, pitch, and roll) (Figure 1). Both the capacitive sensor and the IMU are connected to the computer via USB. Similarly, we attached an IMU to a 12-inch Wacom Cintiq 12WX tablet to measure its tilt angle as well as orientation (rotation within the display plane). This lightweight tablet can be easily tilted and reoriented while on a stand or held in hand.

## INTERPRETING CONTEXTS FOR INTERACTIONS

We now detail our interaction designs, categorized by the dimension of the contextual information as well as their interpretations. The key rationale here is to look at the relationship between the user, the pen, and the tablet as a holistic ecosystem, instead of focusing on a single device.

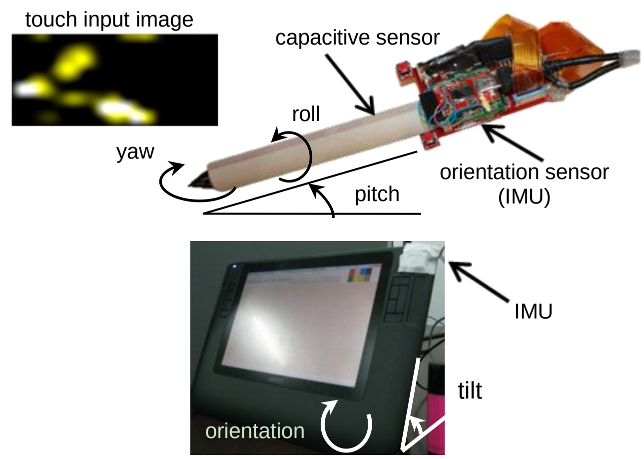


Figure 1. Pen and tablet augmented with sensors.

Artists hold different drawing implements with different grips, often enforced through their professional training. With our prototype, users can simply change the grip on the pen to activate different virtual implements that will be mentioned below. The grip is recognized by the system combining input from both the touch sensor and the orientation sensor (IMU).

Although [10] has briefly demonstrated using pen grips to switch between three pen effects as one of the possible capabilities of the multi-touch pen device, this work fundamentally differs from it in that we are taking a scenario-driven approach, directly aiming at facilitating the activity of digital drawing as a whole, and does not necessarily dictate a specific technology. And while the focus of the vast majority of the interaction techniques in [10] is in improving the *digital* pen experience, we chose to solely focus on implicit interpretations of contexts that already exist in *physical* drawing practice. Moreover, the addition of the orientation sensor both enables many new virtual implements and interactions to be detailed later and significantly improves the grip recognition capability compared to [10]. The pitch (i.e. tilt) angle of the pen helps further differentiate grips that are otherwise similar. The roll angle of the pen is used to normalize the touch input image (circular shift along the barrel circumference), so that the recognition is invariant to pen rotation along its longitudinal axis. On the recognition algorithm side, we used a k-Nearest Neighbor (KNN) algorithm that matches both the touch input image and the pen tilt angle to prerecorded templates from the same user. Both the input and the template image are Gaussian-blurred before the matching, in order to account for slight misalignment in the user's finger positions. Compared to attempting to segment the fingers from the touch image as rotationally invariant features as in [10], here template matching directly on the raw touch image (normalized by the IMU) allows us to capture subtle differences in grips, and is not susceptible to segmentation errors. An empirically determined threshold is set on the maximal acceptable distance between the input and the nearest training sample to filter out non-gestures. Six subjects participated in the recognition experiment to evaluate the classifier by using 4-fold cross-validation. We were able to achieve 86.3% recognition rate for a set of 10 different pen grips with user-specific training data.

In our demo application, the name of the currently recognized drawing implement is displayed at the upper right corner of the screen (Figure 2). In addition to switching implements with static grips, where applicable the user can also use finer finger movements to operate the currently selected implement, such as controlling an airbrush (detailed later), again directly analogizing the way the respective physical implement is operated. To avoid finger movement accidentally causing confusions to the grip recognition, once the expected movement starts, the current implement selection is locked, until a significant change of the pen tilt that reactivates the grip recognition.

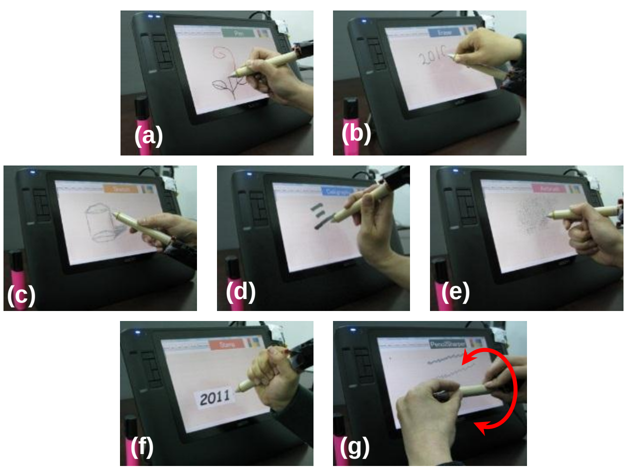


Figure 2. Virtual implements. (a) Pen (b) Eraser (c) Sketching pencil (d) Chinese calligraphy brush (e) Airbrush (f) Stamp (g) Pencil sharpener for width adjustment.

## INTERACTION TECHNIQUES

Our prototype currently supports the following virtual implements that reflect physical grips and the orientation of the tool.

In addition, the configuration of the tablet and its relationship with the pen is also accounted for in our later interaction techniques.

### Virtual instruments

*Pen*, *Eraser*, *Sketching pencil*, *Chinese calligraphy brush*, *Airbrush*, and *Stamp* (Figure 2a-f) are examples of one-handed implements. These implements can be easily switched and operated with a single hand. Of special note is the airbrush (Figure 2e), where fine movement of the index finger emulates the air trigger found on physical airbrushes. The "air pressure" is mapped to the distance that the finger traveled backwards from the starting position. The further the user moves their finger back, the higher the air pressure is, and hence the denser the resulting paint.

Implements triggered and operated with two hands further allow richer dynamic operations. The *pencil sharpener* is triggered by holding the two ends of the pen using both hands, similar to holding a physical pencil inserted into a sharpener (Figure 2g). A twisting action from either or both hands operates it, resulting in adjusting the stroke width of the sketching pencil implement, and then the user can continue sketching with the selected width.

### Proximity between Pen and Tablet : Alternative Usage of the same Implement

In the real world, the same physical implement has been given different implicit operation modes. For instance, a pencil can be used to sketch or to measure, depending on whether it is used on the paper or in the air. This concept is applied to our sketching pencil grip (Figure 2c). When the pen is away from the tablet (out of tracking range), the system infers that the user is trying to use the pencil to measure, and displays a one-dimensional grid on the tablet to facilitate the measuring. The angle of the grid rotates to match the current tilt angle of the pen, so that the user can measure the digital drawing at the same time and along the same direction as she measures the physical object, thus helping the user translate the proportion of the object to her drawing.

### Tablet Tilt : Different Drawing Layers

People often configure their drawing surfaces at different tilt angles for different types of drawings. For example, when painting an outdoor scene, a near vertical canvas is optimal to align the perspective of the drawing to the physical surrounding; a horizontal desk suits cartoon illustrations, especially when the artist needs to trace drawings to create animations; for engineers, a slightly slanted drawing board makes drawing with tools most comfortable. The tilt angle of the drawing surface is a good indication of the type of drawing being done.

In our prototype, we adopt the general notion of interpreting different tablet tilts as different drawing types. Within the range of 0-90°, the user can tilt the tablet freely to activate one of several drawing layers (3 in the current implementation: 0-30°, 30-45°, 45-90°). In addition to the regular drawing layers, when the tablet is tilted towards the user (120-180°), a private layer is activated where the user can write private notes that are only visible in this configuration. The note is conveniently hidden from other people nearby, occluded by the tablet itself. Again this is consistent with how people would hide information in the physical world.

### Tablet Orientation : Different Subjects of Drawing

For both physical and digital drawing, artists usually choose canvases of various aspect ratios to suit different types of drawing [4]. For example, today we used words like portrait and landscape as generic terms to describe aspect ratios, which precisely originated from the fact that vertically elongated canvases are suited for portraying people, and horizontally elongated canvases are suited for depicting natural landscape.

Like physical canvases, the drawing tablet can be rotated to be either the portrait or the landscape orientation. This orientation contains contextual information to infer which type of subjects that the user may like to draw, and we can provide digital assistance accordingly. As a simple demonstration, our prototype offers templates of common subjects to help the user guide their drawing. The user can open the template library, preview them, and choose one to be displayed in the background so that she can develop her drawing on top of it. The available templates are filtered according to the current tablet orientation.

## PRELIMINARY USER FEEDBACK

To obtain preliminary user feedback, we invited three university art students, aged between 20-26, to try our prototype. They had between 2-7 years of physical drawing experience, and between 0.5-2 years of experience drawing with digital pen and tablets. After being introduced to and familiarized with the prototype features, each participant was asked to make three drawings: one still life, one portrait, and one free creation. We observed their behavior using the prototype, and interviewed about their experience afterwards. All participants quickly mastered the prototype, and were able to quickly trigger the functions they needed. They all highly rated the naturalness, convenience, and comfort of the system. The sketching pencil together with the pencil sharpener was rated the highest. Interestingly, opinions were divided around the drawing grid activated by moving the pen away from the tablet. Some agreed that the grid helped them in sketching the rough skeleton, which would be especially helpful for beginners. On the other hand, they complained that the grid was sometimes triggered unintentionally since it appeared as soon as the pen was out of the tracking range. To address this, we could augment our system with a finer distance sensor (e.g. a range finder to allow higher flexibility and accuracy). We individually asked about the naturalness of each mapping between the contexts and interactions, and they agreed that each of these mappings was natural to them.

## CONCLUSION

This work explored how context sensing can be used to enhance the naturalness of digital pen-and-tablet drawing. We achieved this by interpreting contextual information that is crucial in physical drawing practices in order to facilitate interactions with digital drawing. The result is a digital drawing experience that more intuitively aligns with the physical drawing practices, while at the same time leverages the benefit of the digital drawing to further aid the drawing activity. Although we do acknowledge that a practical system may need to combine or compromise between physical and abstract interactions, in this paper we deliberately push on the boundaries of interaction design that we learned from the physical drawing practice to provide a more complete vocabulary in this direction that interaction designers can leverage.

In the future, we plan to further investigate how to incorporate other contextual information in drawing such as environmental lighting, as well as looking more closely into the interactions of multiple context dimensions, such as the relative position and distance between the pen and the tablet beyond simple proximity. We are also interested in applying context sensing in other creative domains such as music.

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