Tracking, Animating, and 3D Printing Elements of the Fine Arts Freehand Drawing Process

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Abstract
Dynamic elements of traditional drawing processes such as the order of compilation, and speed, length, and pressure of strokes can be as important as the final art piece because they can reveal the technique, process, and emotions of the artist. In this paper, we present an interactive system that unobtrusively tracks the freehand drawing process (movement and pressure of artist's pencil) on a regular easel. The system outputs captured information using 2D video renderings and 3D-printed sculptures. We also present a summery of findings from a user study with 6 experienced artists who created multiple pencil drawings using our system. The resulting digital and physical outputs from our system revealed vast differences in drawing speeds, styles, and techniques. At TEI art track, the attendees will likely engage in lively discussion around the analog, digital, and tangible aspects of our exhibit. We believe that such a discussion will be critical not only in shaping the future of our work, but also in understanding novel research directions at the intersection of art and computation.

Author Keywords
Interactive drawing; Digital visualizaion; Movement tracking

ACM Classification Keywords
H.5.m [Information interfaces and presentation (e.g., HCI)]: Miscellaneous

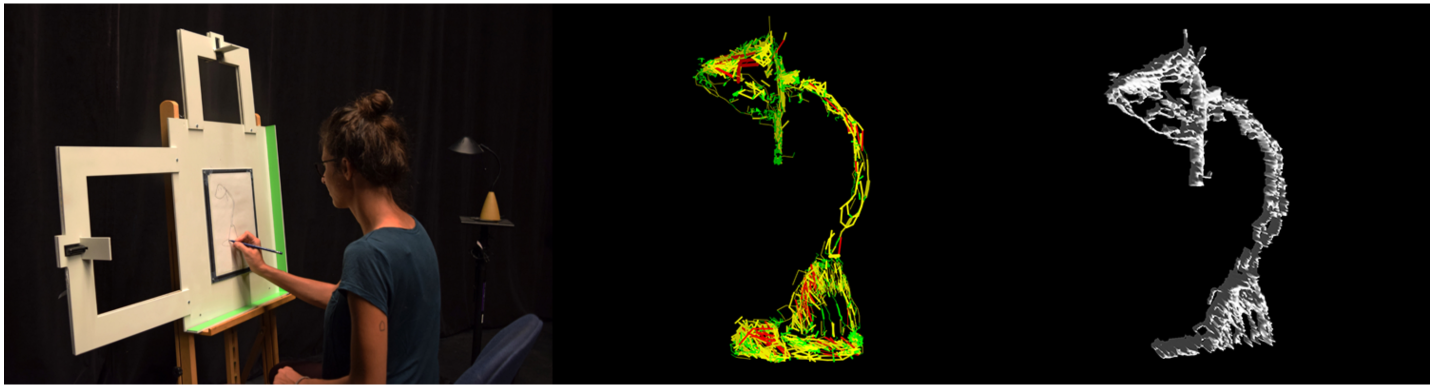

Figure 1: Our interactive drawing setup(left), 2D visualization(middle) and 3D bas-relief model(right) generated by our system

Introduction

Drawing is one of the oldest forms of human creative expression and is highly regarded as the foundation of human artistic practices. Over the years, the TEI community has shown a great interest in exploring novel ways of blending human creativity with digital technologies [2;, 5;, 8, etc.,]. The creation process of a drawing can be as fascinating and valuable as the final static end-product because it represents the moment of time in which it was created [11]. Dynamic elements of the drawing process such as the order of compilation, lengths of strokes, speed of the movement, and the pressure applied to the drawing surface reveal unique aspects of the drawing process, including the artists' skill, technique, artistic apprehension, and mood [1]. Although the final art piece can reflect these elements, more dynamic visualizations such as video recordings, animations, or tangible mediums such as 3D printed sculptures can vividly represent the nuances of the drawing process to create richer experiences of art making and art appreciation.

Within prior HCI research, the intersection of art and computation has been broadly examined through interactive drawing interfaces [6, 4], digital-physical hybrid fabrication tools [13] and interactive art installations [7, 9]. However, the work presented here follows a different trajectory by tracking dynamic elements of drawing processes such as speed of hand movements and pressure exerted on the drawing surface. The key goal of our work is to explore a novel way of creating a digitally mediated art making and viewing experience by visualizing dynamic elements of drawing processes. To this end, we developed a system that unobtrusively tracks the freehand drawing process on a regular easel and then visualizes the output. Using cameras and acoustic sensing, the easel tracks pencil movements and the pressure exerted on the drawing surface without disrupting traditional freehand drawing practice. The captured information is shown using 2D video renderings and 3D printed sculptures, which represent sequential order of stroke compilation, pencil speed, and pressure at each point of the drawing process(Figure 1). Unlike existing digital drawing applications for tablets [6] our system supports traditional pencil and paper based drawing process and allows us to study traditional fine arts practice.

We conducted a user study with six experienced artists whereby they created multiple pencil drawings using our setup. Afterwards, they reflected on the digitally synthesized outputs of their drawings during a group discussion of all six artists. Our study provided the opportunity for constructive discussions between artists and researchers. Hence, in this paper we describe—1) our interactive drawing system, and 2) a summary of insights gained by working with experienced artists. By presenting our system at the TEI art track, we hope to engage a wide audience—from processional artists to anyone who can make a simple sketch with a pencil—to use our system and reflect on the broader implications for TEI in the realm of fine art and computation.

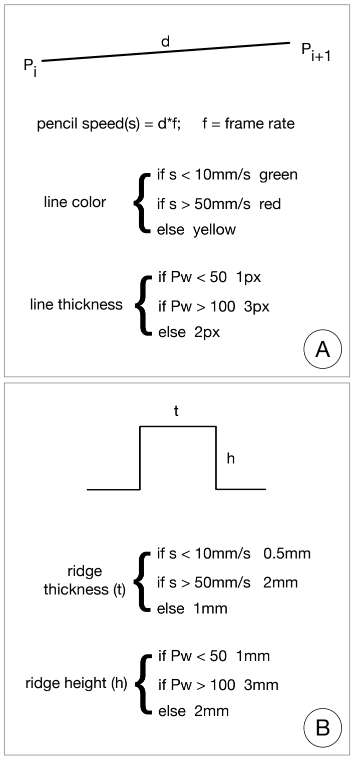

Figure 2: Representation of pencil movement and pressure in (A)2D video renderings and (B) 3D bas-relief models

System

Our interactive system is comprised of a regular drawing easel, which is augmented with two independently functioning subsystems — the pencil tracking system and the pencil pressure sensing system.

Pencil Tracking

In order to track the drawing pencil, our system uses two cameras, which are mounted on the top and left sides of the easel. Images captured at 20 fps from these cameras are processed by a custom implemented image processing program in order to determine the vertical and horizontal positions of the drawing pencil. To increase the accuracy of the tracking mechanism, we use drawing pencils, which are fully covered with a layer of blue ink, except for the graphite tip. In addition, we mounted two green colored background strips along the bottom and right edges each facing the camera mounted on the opposite side(Please refer to Figure 1(left)) The horizontal and vertical locations of the drawing pencil is determined by locating the blue color blob created by the pencil against the green background. In order to map the pencil's pixel locations to the physical coordinates of the drawing surface, the system was calibrated by placing a grid marked in millimeters on drawing surface. Please refer supplementary materials for more details. Since the cameras were permanently fixed to the easel, this calibration process was only required once.

Pressure Sensing

Our pencil pressure sensing system is based on an acoustic sensing mechanism [3]. We experimentally observed that the intensity of the sound wave created by friction between the drawing surface and the tip of the pencil can be used as a close approximation for pencil pressure . Even though this relationship is not reliable enough to measure the subtle variations of pressure accurately, we found it is sufficient for detecting the major changes. In implementing this system, we designed an acoustic sensing module which contains a Teensy 3.2 microcontroller and an Adafruit electret microphone module with built-in amplifier. We placed 12 of these modules in a 3 X 4 grid on the back side of the easel. Each of these modules were programmed to read the digital output of the microphones 20 times per second in sync with the two cameras of the pencil tracking system. Weighted averages*(Pw)* of the three sensors closest to the pencil (based on the pencil position determined by the tracking system and microphone) are used as the approximation of pencil pressure exerted on the drawing surface at each frame.

Data Visualization

In order to visually represent the pencil location and pressure data captured from our system, we implemented a pro-

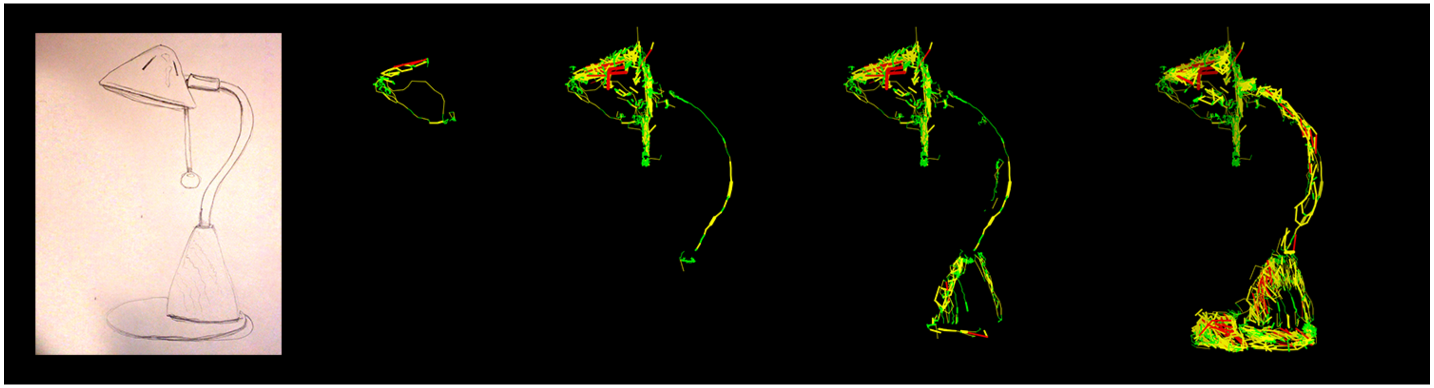

Figure 3: Pencil drawing of the table lamp by a study participant (on left) and 4 stages of the drawing progression as seen in the digital visualization (on right).

cessing 3.0 based application. This application renders the pencil speed and the pressure exerted on the drawing surface as an animation. Figure 3 shows multiple frames of the animations of a single art piece, while Figure 4 shows the final renderings of drawings by multiple artists. Please refer the supplementary video to see full 2D renderings. Here the pencil speed is determined by calculating the cartesian distance *(d)* between two adjacent data points. The pencil strokes which were drawn in slow(< 10mm/s), medium(>= 10mm/s and <50mm/s), or high(>= 50mm/s) speeds are represented distinctly in the visualization using green, yellow and red colors respectively. By analysing the pencil pressure data collected from our study, we observed the practical range of *Pw* as 0 -170 (audio signal ranged from 0 to 2.5Vrms with 50x gain). Therefore the different pressure levels are depicted using different line thicknesses (Low 1px, Medium 2px and High 3px) based on the Pw value as shown in Figure 2(A).

Additionally, we implemented another processing 3.0 programme to generate 3D bas-relief models displaying the drawing data of each artist. The model takes the form of a slate with raised ridges where lines were drawn. Figure 1(right) shows an example of one of the printed 3D models. Here the thickness *(t)* of the ridges is based on the speed of the drawing , while the height *(h)* of the ridges is based on the pressure of the drawing stroke. Please refer Figure 2(B). The height of the ridge can be compounded if several lines are drawn over the same area.

User Study with Artists

To explore the potential applications and limitations our system and gain insights from experienced art practitioners, we conducted a study with six local artists—two female MFA students, two male cartoonists, one female primary school art teacher, and a female independent fine artist. Each artist was invited to a drawing session during which they created three sketches. For the first two sketches,

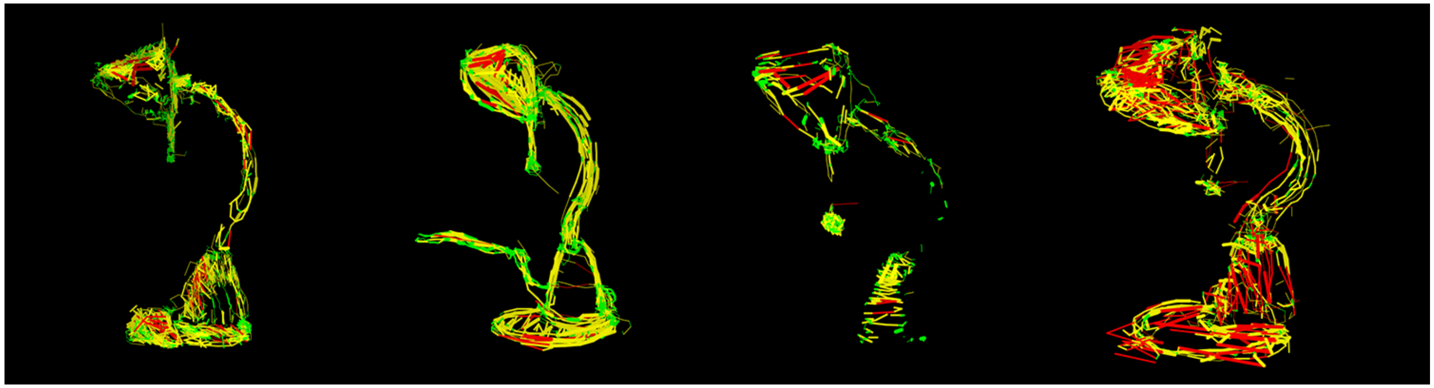

Figure 4: Corresponding 2D renderings of pencil drawings by 4 different artists

we requested that all participants draw specific objects located in the room (a table lamp and a flower pot). For the third sketch, participants were invited to draw whatever they wanted, including non-representational or imaginary scenes. In between creating the sketches, the artists were shown the 2D video rendering and the 3D bas-relief rendering of the sketch they had just completed. In addition, between the drawings and at the end of each artist's session, we used semi-structured interviews to gather feedback about the artists' opinion of the process. Furthermore they discussed potential application areas of our system especially in the domain of art education. Participants were compensated $15 per hour for their time spent participating in the drawing session and workshop.

Summary of findings

All artists who took part in our study were able to complete the drawing tasks and considered our tracking system to be unobtrusive. From the onset, all artists were very interested in being able to see an animation of their pencil movements. Most of them mentioned that the digital output of their drawings enabled them to re-live the experience of performing the drawing and compared the 2D video rendering to *"seeing the muscle memory on the screen"*. Moreover the 2D video renderings revealed unique characteristics among the drawing styles of participants. For example, they clearly showed that some participants, particularly the cartoonists, tend to use thicker lines in their drawings when compared to the others. In addition, the participants discussed the different drawing approaches that each artist used, such as starting with lighter, quicker lines to sketch in broad shapes before adding finer details. Some of our participants remarked on the potential of our system to be used as a learning tool. As studying the techniques of experienced artists and trying to mimic their styles (known as *"learning through art reproduction"*) is widely used in classical and contemporary art pedagogies, artists discussed the potential of using 2D video rendering of trained artists to help beginners grasp new approaches. In addition, some of them mentioned that our system may be used as a tool to study the evolution of a particular artist's style or track the improvements of art students' drawing techniques.

The participants also reflected on the potential of enhancing engagement with art audiences through the digital outputs of our system. They pointed out that the sequential order of strokes and the pressure variations at each point, when shown in combination with the original drawing, enable audiences to understand unique traits of the artist's technical process. This in turn allows the audience to be more aware of the subtle differences each pencil stroke has made in the final piece. The artists also noted that the 3D prints offered an interesting physical representation of their work. In the realm of TEI, this suggests future systems that materialize aspects of 2D drawings in order to provide multi-sensory art viewing expireinces.

Presentation

Our system creatively visualizes aspects of the freehand drawing process, and we propose to demonstrate it at TEI for two reasons. First, TEI is increasingly interested in supporting and intersecting with practices with the fine arts [10, 12]. Second, our system is engaging for a wide audience, including anyone who likes to sketch design ideas, or simply "doodle" for fun, which will make our technology a valuable contribution to TEI arts track.

The art exhibit will consist of the interactive drawing easel and the digital and physical artifacts (original pencil drawings, 2D video renderings, and 3D printed bas-relief models) from our study with artists. The 2D video renderings will be displayed in digital photo frames. Viewers will have the opportunity to create quick pencil drawings using our interactive drawing setup and see the resulting digital renderings. Our visualization will reveal unique aspects of each person's drawing process, and attendees will likely engage in lively discussion around drawing techniques and the broader implications of applying TEI research in the domain of fine arts. Our goal is that the analog, digital, and tangible aspects of our exhibit will be a catalyst for broader discussion on digitally mediated art making and art viewing within the TEI community. We believe that the outcome of such a discussion will be critical not only in shaping the future of our work, but also in understanding novel research directions at the intersection of art and computation.

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