The Simulation of Ink Rubbing to Preserve Eroded Inscriptions

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ABSTRACT

For over fifteen hundred years Chinese Ink Rubbings have played a vital role in the preservation and distribution of Chinese texts, poems, and even illustrations. The Field Museum of Chicago's China Hall displays a book of ink rubbings taken from inscriptions on Mount Yi about the Qin Emperor's reign, but it is behind glass and thus limited in its interaction with visitors. We propose a tangible extension to the exhibit that allows visitors to simulate the act of ink rubbing to encourage visitors to better appreciate this valuable technique. With the use of an artificial tablet of ancient Chinese inscriptions and mock tools, visitors can perform the ink rubbing technique in steps, gradually revealing the translation of ancient Chinese characters, and then continue to engage in the process as a reproduction method by sharing their work with others.

Author Keywords

Museum; museum learning; tangible interaction; ink rubbing.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION

Before the invention of paper, scholars recorded information by carving into stone and metal. However, the stone inscriptions wore down with time and weather, and such heavy objects were not as convenient to transport in order to disseminate their contents. With the invention of paper in China, scholars could record and reproduce inscriptions much more easily through the process of ink rubbing, and those ink rubbings are often the only surviving artifacts of the carvings [2]. The Field Museum's China Hall holds a book full of such inscription reproductions, copies of the original carving in 219 BC of a monument on Mount Yi to the Qin Dynasty's First Emperor (see Figure 1), but it is displayed behind a glass case, with only a plaque explaining what the inked characters represent [6]. Instead of such a restricted learning experience, we propose that visitors should be able to contrast the weight of such a stone block with the weight of a paper reproduction as they work through the process of preserving it through ink rubbing. As visitors perform the complex two-step process, they will gain an understanding of the sensitive effort of the work that went into each page to make it durable and legible. They will also be able to contrast the aging of each medium, to appreciate ink rubbing for all the artifacts that it preserved, and that we would not have otherwise. By emailing themselves their work, they get a souvenir for their efforts - a reminder of what they have learned at the exhibit and, as they share it with others, a reenactment of the use of these ink rubbings for the diffusion of information.

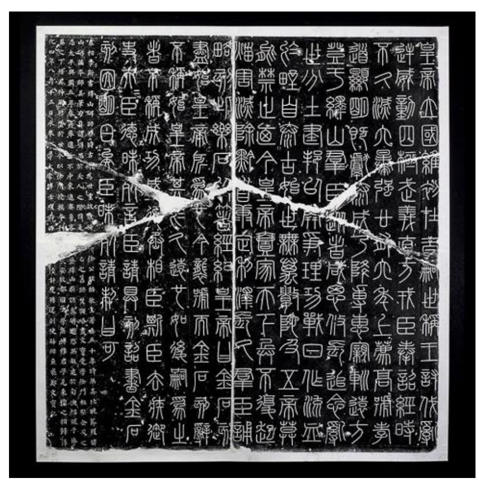

Figure 1. The original ink rubbing. Our product uses the first six characters for the simulated rubbing. Image: "Inscription from Mount Yi." ***Cyrus Tang Hall of China*****. Field Museum, n.d. Web.**

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MOTIVATION

We propose the following learning objectives for our display:

1. Through the reenactment of the ink rubbing process, visitors gain a stronger appreciation for its difficulty and beauty. As users rub over the block, the screen displays their progress as though they were actually using ink for comparison against the original character displayed in the case. If they botch their attempt, either by not pressing the paper into the groove hard enough, or not using enough "ink," the screen stalls; this way they are more likely to appreciate the process as the art that it was than they are just by viewing the final product.
2. Visitors understand the purpose behind ink rubbing as a preservation technique by transcribing ancient passages that otherwise would no longer exist. As visitors reveal the characters, they also reveal proof of how much of Chinese culture ink rubbing saved, and details about the passage they are preserving. By physically working through the process on an actual ancient message, users gain a deeper connection to the history.
3. Visitors understand the purpose behind ink rubbing as a reproduction technique by making a copy of the information inscribed into the block. When visitors email themselves a copy of their work and show it to friends, they carry on the information sharing process that began with the first ink rubbing of that same inscription.

RELATED WORK

One instance of simulated ink rubbings comes from Ichirou, Toshio, and Kosuke's attempt to create realistic looking ink rubbings from 3D objects using a 3D digital scanner and virtual ink rubbing system [5]. The motivation for such a system was to allow people to conduct ink rubbings without damaging ancient relics and stone with actual ink, as pressing ink onto fragile artifacts and relics can wear them down. This autonomous system would first scan an object and create a digital model within 0.2mm accuracy [5]. A computational model of paper is applied on top of the digital model and deformed under the physical shape and texture of the object, and then smoothed over using a method called bicubic spine interpolation. The end result was a near identical virtual ink rubbing.

Yet, while the simulated ink rubbing looked very similar to actual ink rubbings, the computational paper method took too much time for any practical use at this point [5]. Additionally, since no person had to physically use a brush to perform the ink rubbing, given the same 3D scan of a relic, each subsequent rubbing result was identical to the last. Though that is an advantage for this method's goal of creating accurate ink rubbings, it conflicts with our goal of allowing visitors to create a personalized ink rubbing dependent on their performance.

Wu, Zhong, and Wen had their own simulated rubbing technique that instead created digital simulated rubbings using photographs of relics and stone etchings, rather than 3D scans of objects [13]. Their method used computational rice paper, a computer generated set of fiber bundles, and simulated ink diffusion by water to emulate rubbings that looked natural. The model rice paper was given a simulated moisture value that when combined with the ink, would allow some of the black ink to seep into white "text character" area and create an irregular distribution of faded ink bordering the characters. This resulted in a halation effect around the borders as the black ink fades into the white characters, emulating how ink rubbings appear in reality. When the moisture value of the rice paper was altered, the halation effect of the characters would also change, becoming more apparent and irregular the more moisture there was [13].

Both these previous attempts at simulating ink rubbings however were not tailored to be used in any sort of interactive manner, and were kept completely autonomous. We work to simulate not just the look of ink rubbings, but also the experience of creating them. Our ink rubbings should have distinct looks dependent on the participant's actions and result in a unique personal ink rubbing.

Chen previously modeled the actual physical brushing technique of Chinese hairy brushes using 3D software that was capable of not only creating the brush object itself, but also allowed it to write simulated calligraphy on modeled rice paper [1]. The big advantage of their brush model was its ability to emulate the bending of brush hair tips as pressure was applied on them when pressed onto the rice paper. This resulted in a more realistic simulation between a brush object, ink, and rice paper [1].

While Chinese hairy brushes are different from ink rubbings, the concept of creating a believable interaction between a brush object and a simulated sheet is related to our goals. However, we look to instead skip modeling a brush on a screen and opt for having our own physical and tangible brush like object that museum visitors use in simulated ink rubbings. Also our brush techniques rely more on the constant dabbing motion of a brush, rather than actual strokes, which would give different looking results.

In support of their research on haptic feedback and "Feelable User Interfaces" instead of simply "Tangible User Interfaces," Wolf and Bennett designed a box which enables users to explore textures without visual cues [11]. The box has an opaque, flat top, the underside of which contains a variety of textures and patterns. Inside the box is a metal ball, and users are instructed to use a magnet on the top of the box to control the ball. Wolf and Bennett used analogue textures in their box, similar to Chinese characters carved into stone. Without the ability to see the patterns, users had to move their magnet around until they located and could follow the grooves. This often meant that the users could distinguish between patterns, but not identify any of them, indicating that the addition of visual cues could have added to the learning experience [11]. Similarly, our placement of paper over the stone replica of the carvings means visitors cannot see everything about the characters, and must combine their haptic and visual experiences to get a full impression of the characters.

In [9], Salisbury discusses a method of combining haptic interfaces and graphics in order to add tangible sensations to 3D virtual objects. His team's haptic interface, the PHANTOM, applies forces back to a user's hand in a way that mimics the sensation of touching real objects. A user is presented a visual model of objects with which they can interact. The computer is given a model of each object's geometry and material properties (i.e. texture), and the haptic interface tracks the user's motion, allowing a rendering algorithm to generate forces in response to a user's movement and exploration. Although, in reality, a user is grasping at air, they experience the sensation of touching a physical object, regardless of whether or not they are provided visual cues. This haptic interaction with a virtual environment expands the digital reality more than simply looking at the 3D graphics alone.

THEORETICAL BACKGROUND

Tangible interaction works to seamlessly bridge the gap between the physical world and the virtual world, allowing users to touch and manipulate real and digital objects in an intuitive way that does not require a high level of technological experience. Tangible interaction thinks of the body is an "input device;" it is a more intuitive and less restrictive tool than a mouse, keyboard, or touch screen [4]. Haptic interfaces allow for users to more directly interact with digital models, providing a more educational and connected experience than simply looking at a screen or touching flat glass.

In [4], Hornecker and Buur explain that tangible interaction builds upon users' experiences of interacting with the real world, rather than relying on their level of technological experience. This lowers participation thresholds for the activity, inviting people of all ages and backgrounds, regardless of technological prowess, to approach the interface. Tangible interaction also supports social interaction and collaboration across all domains because the interface is not limited to a single screen with which users must interact one at a time. Groups of users can share experiences, observe activities and their results, and discuss strategies.

Our idea falls under Hornecker's and Buur's "expressive-movement-centered view" of tangible interaction because it emphasizes the physical interaction with objects in order to exploit the "sensory richness and action potential of physical objects" in order to generate a meaningful experience. Furthermore, our design is an example of "Tangible Manipulation," or more specifically, "Haptic Direct Manipulation" [4]. This means that the user physically manipulates the interaction objects and feels haptic feedback like texture and material. This works well for one-to-one mappings between physical action and digital result; however, we strive further. Computational resources allow us to attach more information to physical interactions. We augment the physical activity with a sense of purpose – the preservation of a specific, authentic passage – ensuring that users walk away having learned something valuable.

We strive for lightweight interaction [4]. A user will be much more immersed in the activity if they can proceed in small, experimental steps, and then receive rapid feedback in response. They can try different strategies to see what works best, and they can decide their own actions while being nudged in the right direction by the interface. Isomorph effects are also key to the smoothness of haptic interface interaction [4]. Users must be able to perceive a clear relation between actions and their effects. The combination of lightweight interaction and isomorph effects create more intuitive and fluid interaction experiences.

Tangible manipulation provides a means for museum interactives that attract diverse groups of visitors by combining traditional exhibits with digital and hybrid interactives [4]. The amalgamation of new and old-fashioned technologies makes activities accessible and engaging to people from all walks of life. A haptic interface must be visible; visitors can observe others interact with the interfaces. If an interface looks "cool" and fun to try, it will attract more users than a plain touch screen. It is important that a visitor feel invited to grab and interact with the product. They should feel comfortable lifting and placing, covering and blotting.

It is also important to make the interaction engaging and educational for children. In [3], Guha et. al. focus on partnering with children to create designs catered towards children. This leads to some ideas about how children might use a product. It is important to keep an interface interesting and intuitive for children as well as adults. When they see the ink rubbing interface, what will they want to do? Play? Create? Discover? Children want to exercise control over an outcome. They tend to be less interested if they feel their ideas are not important, not just in design, but also in usage [3]. The personalization of the interaction is key, so we have made the interaction framed by a story, a plea that only their actions can salvage the emperor's message.

Haptic interaction allows humans to feel and manipulate objects, receiving information about them in return. This adds another dimension to the human sensing and learning experience. Though the use of a stylus to interact with objects in the environment provides a great deal of sensory information, the ability to physically touch with hands and fingertips provides a greater depth of understanding. Haptic interfaces, especially when paired with 3D graphics, tremendously help people simulate certain manipulation tasks, such as surgery or painting, allowing users to mimic and learn about a certain process or to practice a skill [11]. Being able to feel the structure, texture, and details of an object tells one much more about it than simply moving a hand across a smooth, flat, glass touch screen.

Wolf and Bennett argue that there should be a subclass of Tangible User Interfaces, called Feelable User Interfaces (FUIs), which eliminates the visual component from the design [12]. They base their support of FUIs around the belief that when visual cues are available, that sense dominates all others and dims the opportunity for haptic learning. They distinguish between active and passive haptic feedback, where passive includes object manipulation (the use of a utensil to apply the ink), and active is an actual changing sensation that occurs while using the interface (the feeling of the utensil sinking and rising over the grooves in the stone carving as the ink is applied) [12]. When visual perception is allowed to dominate, the haptic feedback is mostly passive - the feel of a finger on a touchscreen, or a variety of similarly made tools with labels.

While we do not remove visual perception from our display, since we are working with artwork and the end result of the ink rubbing process incorporates strongly into our learning goals, we add active haptic feedback to the design. Instead of focusing on the visual at the expense of the physical, we pushed to find a realistic physical design that downplays the importance of the visual veracity. Visitors use an actual brush, not a stylus, to imitate applying ink on a realistic replica of a stone carving, and only use the screen as a way to visualize their progress as if they were using real ink. According to Wolf and Bennet, the design of the brush is just as important as the feedback from the texture of the carving, as it should provide “natural physical feedback” in its weight, friction, and shape, so we use a real, functional brush instead of a stand-in [12].

Klatzky, Lederman, Hamilton, Grindley, and Swendson also investigated the use of a probe with haptic cues, but this time with the purpose of comparing the experience to using a bare finger [7]. Their research suggests that while the rate of texture and roughness perception of a bare finger varies linearly with the space between grooves, if the tip of the probe is small enough to fit in the grooves being tested the variation of perception increases to quadratic. However, in both cases the speed at which the finger or probe is passed over the surface is directly related to how much texture is perceived, with smaller spacing being perceived at slower speeds [7]. This implies that using a probe, like a brush, for authenticity increases the opportunity for texture detection, but at the cost of the sensitivity that the pad of a finger affords. We do not have control over the speed that each visitor performs the ink rubbing process, but we followed the recommendation of this research to widen the grooves of the carvings in the replica to ensure the characters can provide adequate haptic feedback.

Additionally, we were lucky enough to be visited by Matt Matcuk, Exhibitions Development Director of the Chicago Field Museum. He explained to us what a successful interactive exhibit must accomplish, as well as what kinds of common mistakes we should avoid. He stressed the importance of appealing to all types of museum visitors, regardless of background or technological experience.

First the exhibit must engage the audience. People should not walk away, but rather be motivated to stop and look. Ideally an interactive exhibit should gain a visitor’s attention by appealing to their curiosity or nostalgia. Furthermore, exhibits might be able to engage social groups by allowing for group interaction or discussion [8]. Next, the exhibit has to reward the visitor; the visitor should be able to take something meaningful away with them after interacting with the exhibit. It should leave the visitor with some sort of new knowledge that he can take with him and possibly apply to his own life. Thus, we provide the visitor with both concrete (an emailed copy) and abstract (background about the message they are translating) takeaways. Lastly, it must encourage the visitor to investigate further about the exhibit’s subject or similar subjects, and to visit related exhibits. Ideally, the visitor will learn something that makes him or her look for more info about subjects related to the exhibit [8].

Matt also explained that we must be careful to avoid common pitfalls for interactive exhibits. The interactive aspect should not be the main takeaway; rather it should bolster the exhibit’s ability to teach the visitor about its subject. An example of a poor interactive exhibit would be the “marble mudslide” exhibit where visitors could simulate a mudslide via a marble that could potentially knock into a wheel. The goal of the exhibit was to encourage visitors to try to keep the marble from hitting the wheel, but visitors got distracted by the ability to launch marbles at a quick speed, turning it into a game, which kept the exhibit from fulfilling its goal [8].

Additionally, the underlying meaning of the exhibit’s interactive aspects should be relatively simple and intuitive. Visitors should easily be able to understand the exhibit’s learning goals. Mr. Matcuk provided a counterexample of a Kinect-enabled “Orb Catching Game” that allowed visitors to use their bodies to catch virtual falling orbs. The exhibit attempted to show visitors that by cooperating together,

Figure 2. The setup of the Leap Motion Controller and the recreated carved tablet. The tablet is placed at an angle to improve the reliability of the Leap Motion Controller.

they could catch more orbs, but most visitors would instead try to set personal milestones and compete with one another. Rather than leaving with a greater understanding about environmental issues, visitors essentially played a game without learning anything [8].

We must appeal to all types of museum visitors. The "social butterflies" are ideal for interactive exhibits. Often they will travel in groups and engage each other in discussion about exhibits. They are also more willing to try out different interactive exhibits, and encourage others to do the same. The "curious types" often visit exhibits with the intention of learning something new. They can be in groups or alone, and are a little more hesitant to participate in interactive exhibits if there is no clear learning objective.

Since Mr. Matcuk informed us that no physical materials or items can be given away at exhibits due to limited funds, we allow users to email their revealed passage to themselves from the display screen.

DESIGN

Our proposed idea for an exhibit consisted of an artificial tablet, mock tools, and a laptop interface. Visitors were to lay a sheet of paper over the tablet, perform the ink rubbing process using the tools and ink or some ink like substitute, and then have a reactive image and translation of the tablet's characters show up on the laptop screen. To keep track of which character the user was rubbing or brushing, we thought of two possible methods: pressure sensors under each character of the tablet, and computer vision to detect hand motion over the tablet. Additionally, after a rubbing was completed, visitors could take their ink rubbings home as an educational souvenir.

We quickly ran into a few issues with our proposed design. Our two proposed methods of tracking a visitor's progress in the ink rubbing process required technology that we either did not have access to, or did not have enough experience with. We were also informed that the Field Museum would most likely not fund the distribution of free souvenir rubbings as the cost would be too much. As a result, we scrapped the idea to distribute ink rubbings and turned to using a Leap Motion Controller for hand and tool tracking. With these factors in consideration, we moved on to create our rough prototype.

In our rough prototype, we built a foam core replica of the stone column by carving six ancient Chinese characters into its surface. We taped a napkin to its face to replicate the thin rice paper used for the ink rubbing. We used a pencil and a crumpled piece of paper to imitate the brush and dab tools. We used a Leap Motion Controller to detect the hand and tool motion over the imitation carving. As the user interacted with the characters on the model, the image of the ink rubbing from the Field Museum display filled in on the laptop screen.

The Leap Motion Controller was unreliable and imprecise, often losing sight of the user's hand or changing the coordinate plane in the middle of the position tracking. This most likely occurred because we put it right below the model column on the same flat horizontal plane, so the user's arm got in the way of the tracking, affecting the calculated hand position. Furthermore, the hand was often out of range of its view in this setup.

CURRENT IMPLEMENTATION

Our final design is composed of three parts: a physical base, physical tools, and a virtual interface.

Physical Base

Our physical base is similar to our rough prototype, but we compensate for the Leap Motion Controller issues with a few modifications. The foam core model column is twice as big, assigning to each character a larger trigger space in the hand positioning plane. The block is tilted at an

Figure 3. The tools used to simulate the ink rubbing process. From left to right: the imitation rice paper on which to apply the ink, the brush to gently wet and smooth the paper onto the tablet, the ink dabber.

angle to the Leap, allowing us to use X, Y, and Z positioning to minimize arm interference and out-of-range issues (see Figure 2). As the workspace for the physical ink rubbing, the block and Leap Motion Controller are fixed to a table, ensuring that they remain a fixed position apart from each other.

We want museum visitors to have an authentic feel when touching the column, so we leave the gray-painted model face open so they can look at the characters and feel the grooves. We then allow them to flip the tissue sheet over the face as a step to prepare for the ink rubbing process.

Physical Tools

We have provided a collection of tools for museum visitors to utilize in order to reenact ink rubbings: a thin sheet of tissue paper, a brush, and an ink dabber (see Figure 3). Each tool is used for a successive step in the process. The tissue mimics the damp rice paper placed atop the block in the first step. The imitation brush is used in the second step to smooth the paper over the block and fit it into the grooves of the characters. The ink dabber is used in the third step in order to perform the ink markings

We used a long-handled scrub brush to imitate the rabbit hair flattening brush. We created the ink dabber by wrapping a small cylindrical brush in a cloth, and then painted the bottom black to emulate the presence of ink. The weight and texture of these more realistic tools in the user's hand make the simulation feel more authentic and satisfying to carry out.

Virtual Interface

The virtual interface is an HTML page that walks users through the journey of discovering and preserving a historical passage using ink rubbing (see Figure 4). The Leap, which is connected to the computer, tracks the position of the user's hand in order to interpret which character touches on the block, and then passes this information to the screen.

Figure 4. The user interface. Popups display instructions in between steps.

Figure 5. The user interface. As visitors perform the steps the result on screen transforms. The final result on screen is an image of the actual ink rubbing of the first six characters from Figure 1.

The virtual interface splits the ink rubbing process into three steps: (1) placing the paper, (2) brushing the paper flat, and (3) dabbing the ink. We use the Leap Motion Controller to interface with all three of these actions, triggering a modal with instructions each time a step is finished. We also display GIF files of an ink rubbing expert at each step [10], showing the user a visual example of how to interact with the block and the tools (see Figure 5).

First, the user places the tissue upon the block. Then the visitor uses a brush to flatten the paper onto the block, gradually displaying a digital representation of the paper-covered stone column in order to emulate the wet paper sticking into the character grooves. Once this image is fully rendered on screen, users can blot the block with the ink dabber to progressively reveal parts of the resultant ink rubbing image on screen, as well as the translation of the passage.

This incremental and targeted reveal helps users understand the purpose behind ink rubbing as a preservation technique by transcribing ancient passages that otherwise would no longer exist. As visitors reveal the characters, they also reveal proof of how much of Chinese culture ink rubbing saved. They also reveal the translation, making the passage relevant to the user, as well as showing the significant meaning of the passage.

Once users finish their ink rubbings, they have the option to email the final image and translation to themselves in order to save and share what they accomplished. Ink rubbings began as an information reproduction technique, so when visitors email themselves a copy of their work and show it to friends, they carry on the information sharing process that began with the first ink rubbing of that same inscription.

The tangible effort required in working to reveal a virtual ink rubbing of the characters allows users to gain a stronger appreciation for the difficulty of the process, as well as the art of the preservation procedure. Whereas today they could create a copy of the characters by clicking a button on camera, during the ancient dynasties in which the Chinese used this delicate process it was the only option, and it required much more commitment.

A video of our final implementation can be found at: https://www.youtube.com/watch?v=LY6hjj1KsMU.

CONCLUSION AND FUTURE WORK

We have developed a tangibly interactive display to complement the glass case display "The Paper That Beat Stone" at The Field Museum. Using replicas of the materials used to create the ink rubbings in the display case, visitors may engage and empathize with the historical process, while the opportunity for an activity causes them to pause longer and absorb more information. Instead of reading about the ink rubbing process and its purpose, the activity affords visitors the ability to experience it.

To further develop our product, we would first search for an alternative to the Leap Motion Controller as a means of detecting hand motion. The Leap Motion Controller is too unreliable and imprecise, especially for a display whose intended users include children. Instead, we would investigate using a Raspberry Pi paired with a web camera for computer vision, or pressure sensors under each character.

We would also work to build out the functionality, beginning with fully implementing the email tool. Then we would focus on further personalizing the experience for the user, such as allowing each visitor to select a passage from the book in the display to work with, rather than exclusively using the first sentence. Finally, we would add more details about the process to build on what is provided on the plaque by the case. For example, we could reveal a new archaeological site that an actual ink rubbing copy of this passage was found as the user translates more of the tablet.

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