Gogh Bike: Bicycles as a tangible interface for creative expression

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Abstract
Gogh Bike is a tangible interface harnessing the various affordances of a bicycle for creative expression. Unlike other tangible interfaces for painting, Gogh Bike does not use a brush to simulate painting, and unlike other tangible interfaces for bicycles, Gogh Bike focuses on creation instead of journeying through a virtual landscape or exercising. With Gogh Bike, people can paint on a virtual canvas by pedaling, steering, and braking. A paint bucket on the back of the bicycle also allows for collaboration: because bikers cannot reach the paint bucket, they must rely on other people to mix colors and refill their paint. People who tested a prototype implementation enjoyed being able to paint. However, the gap between the canvas and the bicycle remains a problem. Future implementations may place the canvas on the floor, so that bikers are literally leaving a trail of where they have been.

Keywords
Tangible user interfaces, bicycle, painting

ACM Classification Keywords
H.5.2. Input devices and strategies—bicycle; H.5.2. Interaction styles—tangible user interface. J.5. Fine arts—painting

General Terms
Tangible user interface, bicycle, painting, color mixing

Introduction
Bicycles are familiar, everyday objects that provide access to a wide variety of inputs. These include pedaling, steering, gear selection, and braking, all of which impact the speed and direction of the bike. Many people who have learned to ride a bicycle can manipulate these inputs fluidly, making it a device with a rich set of affordances.

Nearly all existing bicycle interfaces use real or virtual bicycles as a direct representation of a bicycle in a virtual space. With our project, Gogh Bike, we seek to explore less conventional applications of the bicycle as an interface. Gogh Bike simulates biking across a large canvas with paint flowing to the rear tire that can be used to make brush strokes. Adding this canvas transforms biking from an act of transportation to a form of creative expression.

To further the metaphor, Gogh Bike has a paint bucket mounted on the rear of the bicycle which represents the color and volume of paint currently used to draw. Because the paint bucket is mounted on the back, effective use of this interface requires a second person to fill the bucket and mix colors for the user, prompting a collaborative experience.

Background
Currently, the majority of tangible user interfaces associated with painting digitally recreate the act of painting, usually via electronically-modified brushes. These systems traditionally take the form of dipping the electronically-modified brush in an ink displayed on the screen, then using the brush to paint on the screen. Most of the systems we surveyed also allowed for color mixing on digital palettes. CoolPaint [1], DIP-IT (also written up as IntuPaint) [2, 3], DAB [4], and I/O Brush [5, 6] are all tangible user interfaces based on painting via brush. CoolPaint, DIP-IT, and DAB in particular focus on how to digitize the Newtonian mechanics involved with an actual physical brush, such as how pressure affects the brushstrokes or how the shape and material of the brush creates different effects. I/O Brush departs the most from the non-digital act of painting by creating a brush that can sample surrounding motions, textures, and patterns as the ink. As these systems behave very similarly to traditional painting practices—the user takes a brush, dips it in ink, then paints on a canvas—they have very little to

Figure 1. A user rides the Gogh Bike prototype while another fills the rear paint can with yellow paint. Photo courtesy of Nathan Yan.

offer users who are not skilled with painting via brush. Furthermore, the canvas size is limited by the user's reach, as the user is painting with a handheld brush.

Tangible user interfaces that allow users to paint on a larger scale with more unconventional methods include MobiSpray [7], Urban Sketcher [8], and CavePainting [9]. Both MobiSpray and Urban Sketcher allow users to "paint" their environment. Although CavePainting also enables painting on a large scale, it is most similar to the brush-painting systems described above. While these three systems can generate much larger paintings, their reliance on handheld tools—a spray can, brushes, and pens—again leaves out users who are already unskilled at painting.

On the other hand, most tangible user interfaces incorporating bicycles either simulate riding through a virtual space or attempt to make exercising more fun. Sinclair, Hingston, and Masek's "Considerations for the design of exergames" [10] explores the space of games to promote exercise; many of the systems they cover include bicycles, from research projects like Virku to commercial systems such as Wii Bike and Cateye GameBike. These systems incorporate exploring virtual worlds, educational games, or using a bicycle's power to activate electronics in order to motivate users to exercise. Yim and Graham's study of games [11] for exercise supports this reading of a bicycle as a means for exercise. The few non-exercise interfaces for bicycles, such as FIVIS [12], still focus on the bicycle as transportation and attempt to simulate that experience. Given that we believe biking to be a fun activity regardless of any physical benefits, and given the multitude of products in the exercise bicycle space, we decided to take a completely different path and focus instead on creative expression.

Gogh Bike deviates from current painting interfaces by using a bicycle as a painting tool, and it differs from current bicycle interfaces by focusing on creative expression, an activity not usually associated with bicycles. Although the combination of "bicycle" and "creative expression" may seem unnatural, cyclists like Danny MacAskill have been turning the act of biking into performance art, filming their own feats on a bicycle. Skywriting similarly uses airplanes as a writing tool, and with skywriting, pilots can demonstrate their fine control over their vehicle by producing an extremely large and public display. Like skywriting, Gogh Bike is a tool that enables bikers to display their biking skills in the process of creating something aesthetic.

Furthermore, because of a bicycle's different physical affordances, the paintings created with Gogh Bike would be difficult to recreate via brush. First, the scale of movement on a bicycle lets users create art pieces that are much larger than they could with handheld tools. Second, the way bicycle steering works means that users can draw curves and spirals more easily than straight lines, in contrast to the difficulty of doing so by hand. Finally, the separation of creative expression from more traditional art tools may free users who believe themselves to be artistically unskilled to free themselves from these negative associations and attempt creative expression in an entirely new way. Just as Articulated Paint uses painting to allow non-musicians a means of musical expression [13], Gogh Bike uses biking to allow non-artists a means of painting.

Figure 2. The prototype bike is connected to a stationary trainer. It is equipped with a photosensor to detect brake use (A), a potentiometer to detect steering (B), and a reed switch combined with magnets to detect wheel rotation (C). The paint can is mounted on a cargo rack over the rear wheel.

Gogh Bike's color-mixing system is similar to other color-mixing interfaces; like PALette [14], it uses the idea of mixing paint together, and like RGBy Desk [15], Gogh Bike uses lights to express colors. The main difference lies in separating the act of mixing colors with the act of painting. With Gogh Bike, users must work with others to ensure that colors are mixed to their specifications. Even though the biker is in control of what is painted, others can control the colors the biker is using.

Installation

Gogh Bike is designed to be used in a defined outdoor space where the location of the bicycle can be tracked. Sensors attached to the bicycle report its position, speed, direction, gearing, and brake use. A can of paint is mounted on a cargo rack above the rear wheel. This can is filled with colored light which is used to represent color of the paint. A window in the can exposes the color and volume of "paint" in the can. Information about the bike and the can are transmitted wirelessly to a computer controlling a series of projectors. The movement is translated into brush strokes which are projected onto the ground as the bicycle moves.

Changes in the gearing affect the width of the brush stroke, with higher gears corresponding to thicker strokes. Just as the rear brake stops the rear wheel, the front brake stops the flow of paint to the ground so the user can "pick up" the brush and move to another part of the canvas.

The can of paint on the back of the bike indicates that the amount of paint the bike can use is limited. When the paint runs out, the brush stroke on the canvas fades away correspondingly. The biker can then stop on the canvas and call for bystanders to pick up buckets of red, blue, yellow, or white "paint" and have them mix colors and refill the paint can.

Because the movements of the bicycle are expressed in sensor data, this movement can be easily recorded. For particularly interesting creations, recordings can be replayed so that people can see how a given piece was created. Typically people only have the opportunity to see a finished piece of artwork, but Gogh Bike allows them to see the process as well. This playback also

Figure 3. Users mix colors into the bicycle's paint can using buckets that project colored light (left). The paint can contains a color light sensor and LEDs to indicate what color paint the bike is using, as well as how much remains.

allows other users to try and emulate pieces that they particularly like, as the users can watch the recording of the artwork while also biking along with it on the canvas.

Interactive Prototype

To examine our proposed interaction, we constructed a prototype using a mountain bike. For practical purposes we connected the bike to a stationary trainer that allowed people to pedal against resistance without the bicycle moving. The bicycle was outfitted with sensors to detect the rotational speed of the rear wheel, the angle of the handlebars, and if the front brake was depressed. To detect the rotational speed, we used three magnets and a reed sensor; for steering we used a potentiometer attached to the handlebars; and to detect use of the front brake, we used a photosensor mounted in the brake handle. The right brake remained attached to the rear wheel and allowed the user to slow down or stop the bike.

On a cargo rack on the rear of the bicycle we mounted an empty steel paint can with 12 multicolored LEDs and an array of photosensors with colored films to detect the colors of light. We installed light bulbs in white plastic buckets and colored them with the same red, yellow, and blue films used with the photosensors. These buckets hung on a rack behind the bicycle. Using this equipment, people could use light to mix colors of

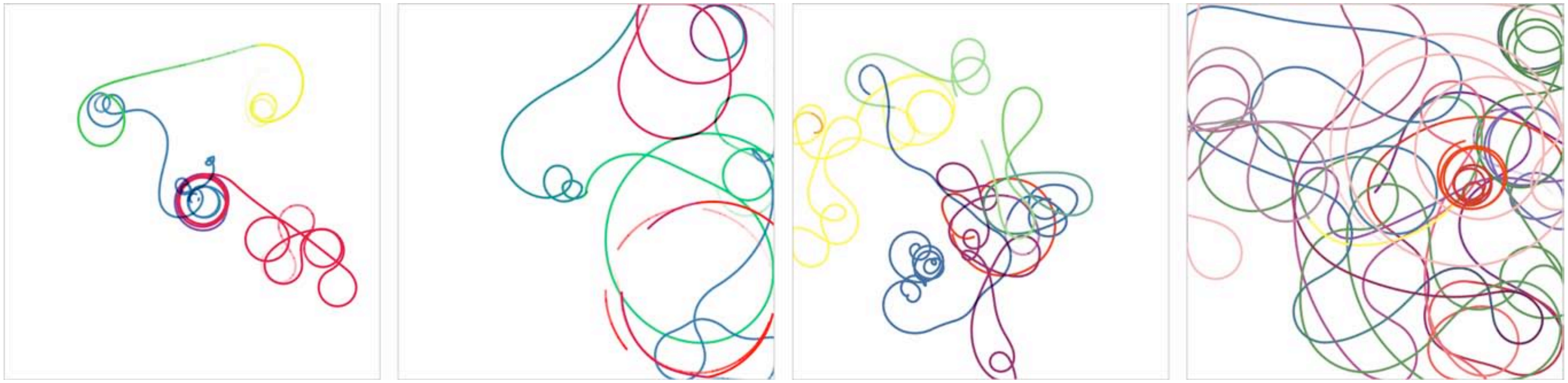

Figure 4. Creations made by users testing Gogh Bike.

paint by "pouring" the light from the white plastic buckets into the paint can on the back of the bicycle.

These inputs and outputs were connected via Arduino boards to a Processing program that translated movement of the bicycle into brush strokes on a projected canvas. The program also recorded the bicycle's movement so that creations could be replayed.

Evaluation

We evaluated our prototype during two 90-minute exhibitions of student works. The first element that attracted people was not the bicycle itself, but the colored buckets used to mix paint. In fact, some people preferred not to ride the bike and instead mixed paint for another person who was riding. This fit nicely with our expectations that the system could be used collaboratively by people with differing interests and abilities.

When examining the buckets of light used by our prototype as a metaphor for paint mixing, several people asked if they could mix the colors of paint. They were satisfied when they learned they were able to mix colors intuitively. The buckets are wrapped in colored gels and contain light bulbs which represent paint, which sets up a possible mismatch between the additive color model of light, where all colors combine to make white, and the subtractive color model, where all colors combine to make black. We initially assigned buckets to match the RGB color space, but users found the mixing to be unintuitive. Untrained users do not usually think of mixing red and green to get yellow [16]. We changed to use a subtractive color model which matched people's assumptions more accurately: they could mix yellow and blue to make green, or red and yellow to make orange. Because the color light sensor we used in our prototype needed the paint buckets to be held at a particular distance and angle in order to correctly detect the color, we added sensory feedback so users would know if they had poured the paint correctly. If the photocells detected the light and color, the LED array within the bucket would gradually light up, indicating approximately how much paint had been poured, and a speaker on the ground would also play the sound of liquid being poured.

People who tested the bicycle expressed satisfaction that they could see their actions translated to the projected canvas. Some people said that changes in direction were detected slowly. A few people commented that the brake, which stopped the flow of paint when depressed, was their favorite part of the system because they could see their influence immediately. Issues that users had with the steering was due to the limited sensing resolution of our prototype, as well as mechanical issues that necessitated recalibrating the data from the potentiometer on the steering.

We made a number of modifications to the software receiving input from the bicycle after feedback from the first exhibition. During the first exhibition, the projected canvas was "wraparound," so that when people riding reached the end of the canvas, their brush strokes continued on the opposite side of the canvas. When we designed this feature, the idea was that users could create patterns striping across the canvas by steering in a single direction and pedaling. In practice, this caused confusion as people lost track of where their brush was, and it didn't map appropriately to our proposed physical implementation of this project. Once we changed the software so that people "collided" with the edge of the canvas, users appeared to have less trouble tracking brush movement.

The first version of the paint canvas was also projected onto a wall with a static orientation. People riding often became confused because the canvas did not reflect their orientation towards it. When biking up the canvas, steering left would move the brush stroke left. When biking down the canvas, however, steering left could move the stroke right. In our second implementation, we mirrored the real world perspective for the rider by continually rotating the canvas. We suspect that shifting the projection to the ground, rather than on an upright screen, would help reinforce the idea of painting using the bicycle's wheels. In the complete implementation of this project the wraparound and rotation problems are solved by the constraints of the real world.

Most of the users who tested the bicycle were excited by seeing their movement in the world translated to a creation onscreen. Two users asked if they could email a video or image of their painting, suggesting that they found some value in their creation. Some users who were familiar with bicycles changed gears to facilitate higher- or lower-speed drawing. At the same time, no user progressed beyond creating trial drawings as they learned to use the bicycle. Hardly any users tried to draw concrete objects, though the limited resolution and response time of the prototype steering mechanism may have been a factor. Furthermore, expecting users to develop the skill to draw complicated objects may be an unrealistic expectation when the users have only been exposed to the interface for a short time.

Discussion

As our current prototype is still stationary, the bulk of future work to be done is to free the bike from the constraints of wires. Once that is done, we will be able to implement a large canvas on the ground, rather than one projected onto a wall. With a canvas that the bikers can physically ride on, we may be able to detect even more from the bicycle, such as how much pressure the bicycle exerts on the ground to enable jumping or hopping the bike. This will also overcome some of the problems users had with disorientation and lack of control in our prototype.

Our prototype also displays paint strokes in a visually rudimentary fashion that resembles markers more than paint. Adding more realistic-looking brush strokes would reinforce the metaphor of painting. The paint strokes could also look like bicycle tire treads to further the metaphor of having paint on the bicycle wheels. Other improvements could incorporate more of the expected physics of the bike and the environment: when the paint can is full brush strokes could be extra thick, or paint could splatter on the canvas when the bike is moving fast.

We could also modify the way refilling the paint bucket works to provide actions for non-bikers. One idea is to allow people to splash paint across the canvas in puddles and have the biker bike through the puddles to spread the color around the canvas. Another is to wire paint buckets so that others can refill the bike's paint can remotely.

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