

CS 550 – Fall Quarter 2018

Paper Analysis Project

Augmented Airbrush for Computer Aided Painting (CAP)

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Abstract

In the paper, *Augmented Airbrush for Computer Aided Painting (CAP)*, the authors first gave a brief introduction of the topic and the motivation. Then, they mentioned about how to use their invention and the technical parts including hardware, physical model, software, and the algorithm. Finally, they presented some experimental examples and some surveys on testers who are unskilled in painting.

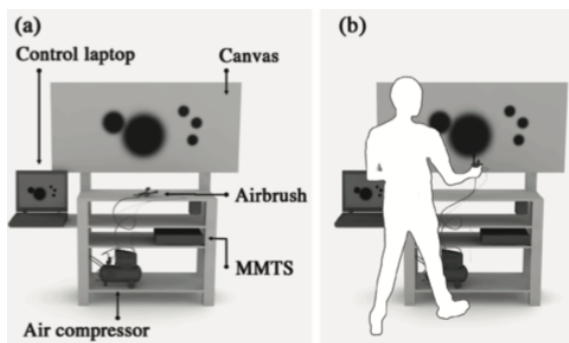


Fig. 1. (a) (b) Interactive augmented airbrush.

What is the general theme of the paper you read? What does the title mean? What are they trying to do? Why are they trying to do it? (I.e., what problem are they trying to solve?)

The *Augmented Airbrush for Computer Aided Painting (CAP)* is a physical spraying device with an intelligent assistive tool. By using 6DOF tracking, augmentation of the airbrush trigger, and a specialized

algorithm, the airbrush can control the maximum amount of paint a user can apply to certain area of the canvas according to the reference image (Fig. 1). Different from a normal paint brush, the airbrush has at least one control over its trigger for augmentation. Besides, the airbrush can render blurrier strokes and make an explosive-like pattern. With the technique of computational reduction and inverse-rendering approach, the airbrush transposes visual data to a manual painting process on the physical canvas.

Due to the fact that a new research field of smart handheld tools is rising and there are many researches on physical creative experience and virtual simulation, an augmented airbrush tries to combine both digital technology and manual creativity. The innovation allows unskilled users to do physical painting instead of prevalent virtual painting and learn the performative qualities of painting. The finished artifact will be unique because the result depends on users' skill and acquaintance on the device. The main motivation of the design is to enable novice users do a complex painting as well as keeping their personal qualities of the manual painting. Besides, the design tries to let user learn how to paint on the physical canvas while the computer only intervenes when it is necessary.

Who are the authors? Where are they from? What positions do they hold? Can you find out something about their backgrounds?

There are four authors for this paper, Roy Shilkrot, Pattie Maes, Joseph A. Paradiso, and Amit Zoran. They all were members in MIT media lab while two are still members of it. Shilkrot is now an assistant professor in department of computer science at Stony Brook University and completed his ph.D under the supervision of professor [1] Maes. Maes is a professor in Media Arts and Science and run the Media Lab's Fluid Interfaces research group which is for radically reinventing the human-machine experience [2]. She has several awards including *one of 50 most influential designers named by Fast Company (2010)*, *100 Americans to watch for in the year of 2000 picked by Newsweek* [2], and many more not mentioned here. The TED talk she gave, "the 6th sense device" is among the list of most-watched TED talks [2]. Aside from her academic contribution, she co-founded several venture-back companies, including Firefly Networks, Open Ratings, and Tulip Co [2]. Professor Paradiso directs the Responsive Environments group which explores how sensor networks augment and mediate human experience, interaction, and

perception [3]. Zoran is now a senior lecturer at the school Engineering and Computer Science at the Hebrew University [4]. In his lab, he focuses on digital design, craft and fabrication, and human-computer interaction research [4].

Interesting enough, they come from different departments and have their expertise. This explains how important it is to merge knowledge from different fields to invent new products. In addition, the communication skill is important when it comes to delivering professional concepts to others who are not familiar with them. Furthermore, the communication between the group to designate tasks is crucial for success in the project.

What did the authors do?

Learned from the examples in areas of fabrication and sculpturing, sketching, and painting, the authors wanted to develop a new hand-held hybrid device in the area of computer assisted graphics. In order to keep track of the motion of the airbrush, the authors designed rapid-response hardware and software along with a physical model of a paint jet and a GPU-based algorithm. To control the maximum amount of paint, a Motion Magnetic Tracking System, virtual history of the painting process, and physical

augmentation of the airbrush are used. The augmented painting device is used as a real medium to capture the physical markings of the paper and paint that painting on the physical canvas becomes feasible.

Starting from making a custom augmented hardware, the authors designed the augmentation module with a potentiometer to measure the trigger, a servomotor to limit the range of trigger, gear systems for potentiometer and servomotor, two printed circuit boards, and 3D printed nylon 12 and titanium for the augmentation. Other important parts are trigger for controlling the amount of paint, color container for the ink, and Polhemus 6DOF magnetic motion sensor for tracking the movement. To be noticed, the firmware polls the sensors at 120Hz and uses a filter to get rid of noise which may decrease the performance of the airbrush.

The authors also built a physical model to adapt the airbrush into fast reaction and accurate prediction. They designed an approximate paint jet distribution model according to a lookup table, the parameters of the tool's position, and trigger state. There are four parameters in the model, tool's distance from the canvas, the radial distance from the center of spray projectile, the value of the trigger, and the duration of the spray. Based on the model, 3D Spray Differential

Intensity Function (SDIF) and Inverse Temporal Spray Function (ITSF) were established and sampled as 512x512x16 3D textures in the GPU for lookup table in the shaders.

As for the software part, the authors utilize threads executing in parallel to support the real-time tactile feedback of the airbrush that the trigger is constrained to a range when the virtual tracking violates the reference image. The software also allows users to choose the reference image, set the risk calculation parameter, and calibrate the canvas. The process of the software is, tracking, filtering, predicting, signaling, and rendering. The key idea in the paper is using software to get accumulative paint on virtual canvas from the physical painting and compare it with a reference image texel by texel. It is useful to determine if the certain area on the physical canvas needs more paint or not. All the operations mentioned above are implemented on the GPU in vertex and fragment shader.

To show off the result, the authors first used the airbrush to paint some monochromatic painting. They changed the model aggression parameters constantly to achieve a good result. Afterward, they decomposed a colorful reference image into layers of pigment for multi-pigment painting. There is a special painting (Fig. 2) of

chameleon using the technique of white opaque color elimination to get complex color for layers and textures. What the authors did in the end to evaluate the design was testing the device on five people who did not have any former experience in painting. The testers started the testing from simple lines and shapes to gray scale images. Finally, the authors analyzed the result by the aid of Amazon's Mechanical Turk voters.

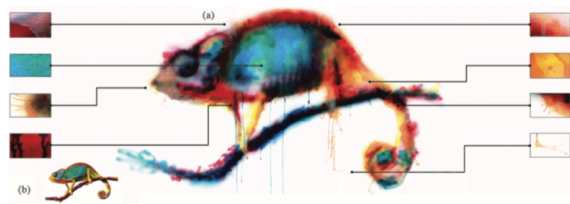


Fig. 2. Watercolor painting of a chameleon with unique physical details.

What conclusions did the paper draw?

Based on the user study, the paper concludes that the device successfully helps novices improve their ability in painting with the support of spatial information without any visual cues. However, while testers did a good job on painting with only binary data, they found it hard to make improvement in few days in drawing grayscale images with complex reference. Most of the testers mentioned that the learning process was weird in the beginning and became interesting after they knew how to

manipulate the device. In accordance with the anticipation of designers, the testers relied differently on the device and made the artifacts with their own styles.

Although it is a successful design combining both manual engagement and virtual assistance, there are some limitations needed to be improved. First, the device cannot prevent a small amount of the pigment from seeping while a user squeezes the trigger when the paint fluid valve is still closed. Second, the servo reaction time and torque cannot restrain the paint jet immediately while the airbrush is going over edges quickly. Third, painting near sharp edges may cause extra blurriness because of the risk factor. In consequence, the result depends largely on users' ability and experience, and further studies in the same direction of hybrid painting are needed to be made.

What insights did you get from the paper that you didn't already know?

If not reading this interesting paper, I would not learn or come up with the idea that painting can be combined with the computer graphics and shaders. In the CS 550 class, we got a brief introduction about the vertex shader and fragment shader. However, there are many details waiting for us to explore if

we want to take advantage of it. In this paper, the authors just mentioned the shaders without further explanation. The reason might be that the concept is too basic to explain. As a result, it is our own duty to learn fundamental stuffs when studying more difficult papers.

From the introduction of the paper, I read about other methods to assist users in painting and I searched some resources about the methods. It is enjoyable to know that while many methods approach the solution by paint-by-numbers and virtual simulation, this paper approaches in totally different way. The benefits of the method from this paper are physical painting plus personal learning and creative process.

In order to better understand the paper, I looked up some technical words. For example, 6DOF, which stands for six degrees of freedom. It gave me a brand-new insight on how objects move in computer graphics. Another example is the difference between 3-value median filter and linear low-pass filter. It was my first time seeing the word, median filter, that I learned it is a good way to reduce noise in an image.

Did you see any flaws or short-sightedness in the paper's methods or conclusions? (It's OK if you didn't.)

In the user study, there are two strategies used by most testers, which are dotting-then-filling and filling-then-stopping. In the dotting-then-filling strategy, the users dot the outline of the shape first and fill the area inside the outline by strokes. In the filling-then-stopping strategy, the users start from a location inside the shape and move in any direction until being stopped by the device. These two strategies might be good in making a nice result, however, it helps little on improving the users' technique about painting because professional painters normally do not use these methods for painting. In conclusion, I think the authors need to consider about a better way if they want to increase the painting ability of their users.

Aside from the function problem of the design in the paper, the interaction method was not clear enough for me. It made a little bit confused when reading the paper because the authors did not mention about the proportion and boundary between reference image and calculated virtual image. If I was a user, I doubted whether I knew how to start and draw the image complying with my anticipation.

If you were these researchers, what would you do next in this line of research?

If I were the researchers, I will try to combine the design with augmented reality. Users can decide whether to project the reference image on the physical canvas to compare with their own works. In addition, I will modify the physical model and algorithm that users can get different notification based on different situations. For example, if the airbrush approaches the boundary, the notification will be different from meeting the boundary point. Moreover, users can get a cue when they press the trigger too hard. I think users can improve their ability more if they know what they did wrong. The final goal of my research is turning users into good painters in few weeks even without the aid of the device.

Reference

- [1] Roy Shilkrot, Stony Brook University, <https://www.cs.stonybrook.edu/people/faculty/RoyShilkrot>
- [2] Pattie Maes, MIT media lab people, <https://www.media.mit.edu/people/pattie/overview/>
- [3] Joseph A. Paradiso, MIT media lab people, <https://www.media.mit.edu/people/joep/overview/>
- [4] Amit Zoran, Amit Zoran Homepage. <http://amitz.co>