Guide to Augmented Airbrush for Computer Aided Painting

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Original Paper: Augmented Airbrush for Computer Aided Painting (CAP)

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Introduction:

The Plastic arts of painting or sketching a portrait or sculpture or image using computer graphics and Human Computer Interaction has been researched more in todays time. Researchers are looking for a creative process to do so more easily than acquiring the manual skills of that of a true artist. This paper introduces a device and a software for any beginner to be able to sketch or draw using airbrush with the support of visual rendering device. The previous attempts include creating manual rendering method based on paint-by-numbers approach with computational assistance. Paint-by-numbers is nothing but a color model on paper with each number referring to the paint to used to fill that part of the paper. Beyond this some researchers have also studied the manual styles of skilled graphic artists and stored their action as a physical signature to be used in a virtual environment. The authors emphasize that most of the work in CG simulate these actions in a virtual environment. Instead the authors propose enhancing the physical action of these moves used to paint and simultaneously render it visually. Recent years have shown increase in enhancing smart hand-held devices. Intelligent manual devices have been developed to fill the gap between physical creative experience and its virtual simulation. The authors present their new version of smart hand-held device for the same purpose i.e. an Augmented Airbrush for Computer Aided Painting (CAP) that allows unskilled users to render physical paintings and explore the performative and expressive qualities of paintings previously absent from virtual painting.

Airbrush: It is not like a simple paint brush. It has at least one mechanical degree of control in its trigger, making it a good platform for augmentation. Airbrushes render more blurrier strokes than paintbrushes and morph colors and give smooth gradients.

Focus: This research uses computational reduction only to assist the user and not to simulate qualities of airbrush. The authors state that they intend to preserve the unique patterns and ink staining created by artists to express their personal style and intentions and these specific qualities are not expressed in digital reduction of airbrush simulations. The usual graphics design process uses manual input and a virtual canvas to simulate visual date (Microsoft Paint). The authors focus on inverse rendering approach that transposes visual data as control or input to manual rendering process on a physical canvas which adds new levels of non-simulated complexity to the process.

Motivation: The motivation here is to enable novice users to render a complex art piece while preserving their unique expressive qualities. They do not want this process to be like making a human copying or printing device, instead allow for personalized results through unique physical signature of each user and preserve the whole painting experience.

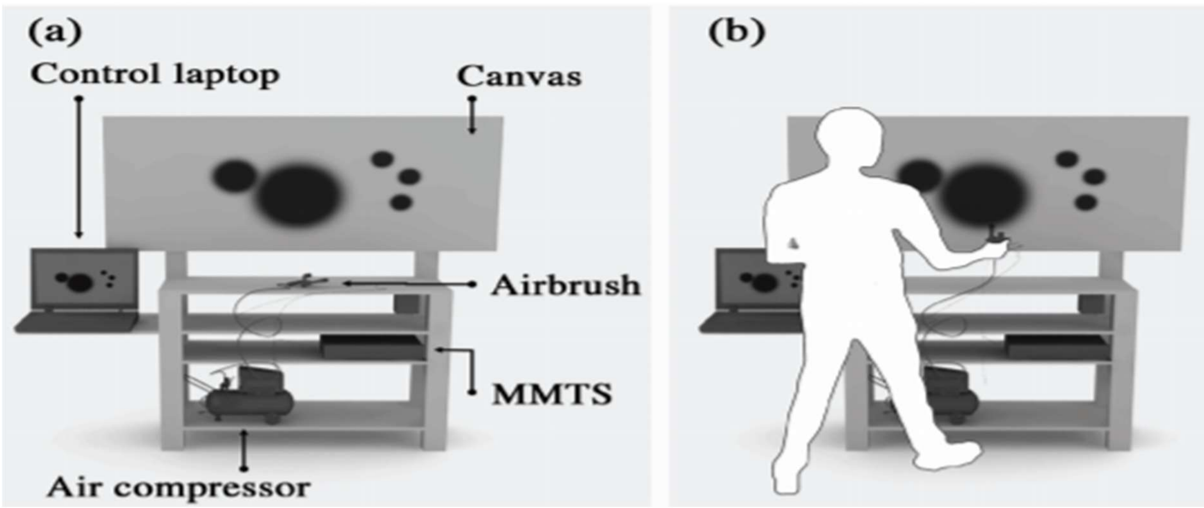

Figure 1.a)&b.) Interaction Modality with the digital brush

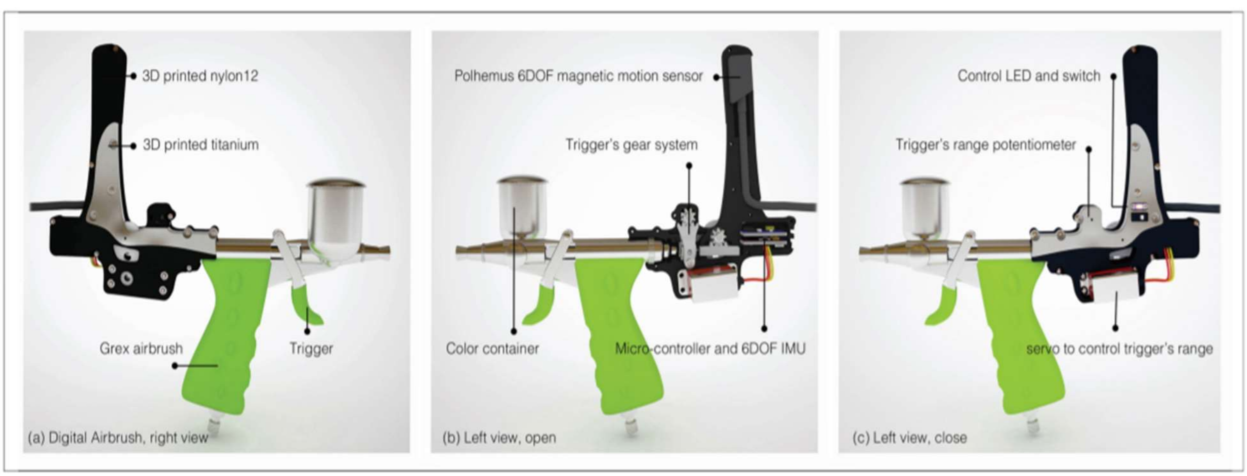

Fig. 2. Augmented airbrush tool. (a) The Grex airbrush with augmentation in black nylon and titanium; (b) an open view of the augmentation reveals the twin gear systems, servo, circuitry, and tracking device; (c) closed view shows the LED and switch button.

Digital Airbrushes: There have been number of attempts to create a computer assisted airbrush device in the past decade. The authors focus on nonvisual instrumented painting through subtle computerized control and also allow for creation of paintings as well as virtual simulations. The previous attempts have focused on creating airbrush paintings using a magnetic tracker and a mock-airbrush device which is like the play stick used in gaming consoles except it does not use motion sensors. The authors develop a paintbrush which adapts to the input given to the airbrush to draw a certain painting using at least one mechanical degree of control as trigger.

Simulating Paint: Authors seek to reintroduce physical painting artifacts to the graphics creative practice as a unique signature of individual users. Researchers have studied virtual simulation based on real measurements. Large body of work already exists that utilizes scanning or models of real brush strokes from which user can interactively generate digital paintings. The authors proposed device uses a real medium and therefore captures the physical markings of the paper and paint, rather than creating a simulation program.

INTERACTION AND TECHNOLOGY:

Figure 3: Depicts a typical painting session with the augmented airbrush.

The typical painting session has the user stand in front of the canvas and work on any part of the painting using any style while consulting the computer screen for reference. The Reference screen and canvas are aligned with a calibrated center point that acts as the virtual origin. The computer will intervene only when the virtual tracking corresponds to a violation of paint projection with virtual reference on control monitor. The computer will prevent the user from doing so by blocking the trigger that is pressed on the airbrush to apply paint. The device used here is based on a Grex Genesis.XT, a pistol-style airbrush without its rear paint-volume adjustment knob. The authors develop a custom designed augmentation mechanism to allow digital control of paint mixture. The device uses Grex air compressor supplies pressurized air at 20 PSI, and a Polhemus Fastrack magnetic motion tracking system positions the device in 6DOF (6 degrees of freedom: bidirectional movement along each 3D axis).

Custom Augmentation Hardware:

The hardware and its specification is shown in Figure 2. The main parts of the hardware to focus here are the magnetic tracking sensor to track users motion while painting and a potentiometer to measure the trigger, a servomotor(servo) to limit the range of trigger, two gear systems (for potentiometer and servo) and PCB's. Two o 3D printed titanium supports were produced in a Direct Metal Laser Sintering (DMLS) process to prevent the user's finger or torque applied by the servo from warping the structure or affecting the position of the magnetic tracking sensor. The servo-gear system implements a paint-volume restriction that limits the linear motion of the airbrush. The linear controller is driven by a servo and a gear that translates approx. 100 degrees of angular motion to 2 mm linear motion. The painter may only pull the needle back with the trigger until blocked by the servo-driven constraint. The system thus provides a digital control that limits the amount of paint fluid mixed with the air jet. However, the user may apply excess force on the trigger and back drive the servo overriding the digital control. A highly accurate sensor detects the user's trigger pull with a specialized gear mechanism that rotates an angular potentiometer. The original tool's paint-needle lock is fitted with a custom brace, which pushes a gear that translates the needle's 2mm linear motion to 100◦ rotation (Figure 2(c)). The angular position is recorded by the potentiometer and sent to the control software at 120Hz. The spring-loaded trigger pulls the needle and authors augmentations back to their original resting position. An external spring is added to increase the force of the pull.

<u>Physical Model.</u>

The authors have designed an approximate paint jet distribution model based on a lookup table and the parameters of the tool's position and trigger state. This enables fast reaction and accurate prediction. Many of the open parameters are constrained: air pressure (20 PSI), tool's angle to canvas (set as perpendicular to canvas), paint mixture (10% weight diluted Carbon Black), paper (a drawing paper with minimal absorption rate), and environment (no air draft, fixed humidity and temperature). The parameters available for modeling are the tool's distance from the canvas (d), the radial distance from of the center of spray projectile (r), the value of the trigger (Trig), and the duration of the spray (t). The authors also performed several motionless testes where the tools position is unchanged, and the trigger is opened as in figure 4a).

In total 6 tests were performed with the variant of distance from the canvas in each test, for varying spraying duration and trigger pressure values. The appearance of paint on the canvas was recorded using a HD video camera (60 fps). Data was later registered (Figure 4(a) and (b)). To measure differential data such that at a moment how much paint is added to the canvas, the data was differentiated with respect to time. The pigment drying rate, which affects its perceived intensity, was modeled with a linear function based on additional measurements taken from paint that left out to dry.

The authors developed a 3D D Spray Differential Intensity Function (analog SDIF) represents the paint intensity increment given d, r, and t (see Figure 4(c)). The trigger value (Trig) and the elapsed time (dTime) are external factors, thus, the additive spray for time k + 1 is :

$$\mathrm{Spray}[i]_{k+1} = d\mathrm{Time}_k * g(\mathrm{Trig}) * \mathrm{SDIF}(r, d, t_k), \quad (1)$$

$$\mathrm{Int}[i]_{k+1} = \mathrm{Int}[i]_k + \mathrm{Spray}[i]_{k+1}, \quad (2)$$

$$g(\mathrm{Trig}) = 1 - \mathrm{Trig}^2. \quad (3)$$

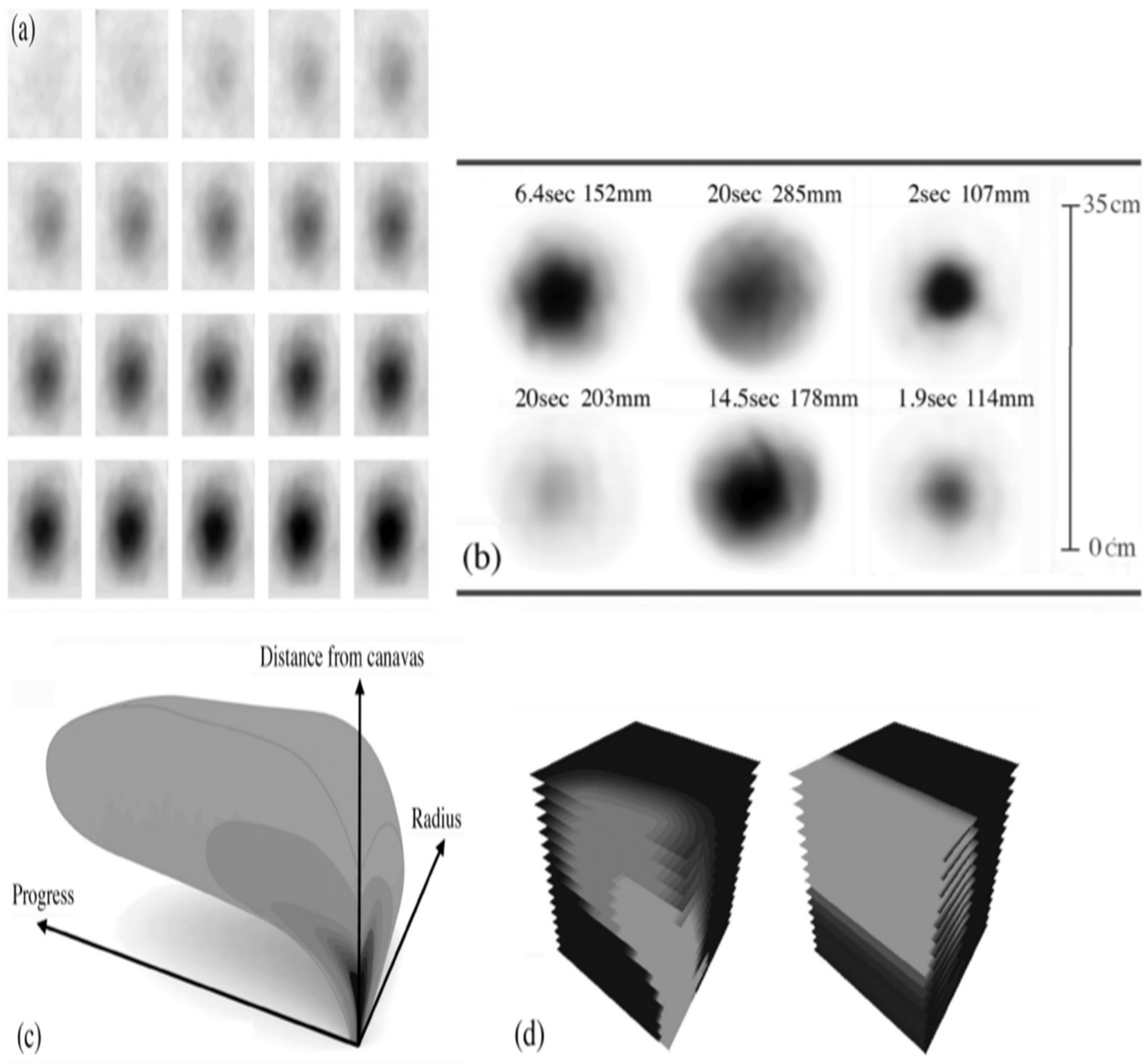

Fig. 4. Spray physical model. (a) Equidistant samples of spray distribution (100msec between samples); (b) aligned spray measurements; (c) illustration of the analog SDIF; (d) the sampled SDIF and ITSF as represented in the GPU as 3D textures.

In this model time t spent spraying is proportional to its intensity Int[i]] in the SDIF. Hence t can be obtained from the current intensity via an inverse function that essentially codes how long it takes the texel i to reach the intensity Int[i] given as the Inverse Temporal Spray Function (ITSF) Fig(4d). g(Trig) is rough approximation of the trigger’s impact on the pigment saturation i.e. a parabolic function of its linear translation (Eq. (3)). The SDIF and ITSF are sampled and saved as 512x512x16 3D textures in the GPU; they serve as a lookup table for the shaders.

<u>Software:</u>

The Software is used to enable real-time tactile feedback to the painter. It has been divided into a number of threads executing in parallel, to maximize the usage of the CPU cores and the GPU. The impact of the spray on canvas is measured by the time driven system at the rate of measurements coming from the tracking system which is approx.. 120Hz. These measurements also derive the risk to the work, and determine what the tool's reaction should be. It does all this while maintaining an up-to-date simulation of the canvas. After the calibration process users can initiate the governor that controls the tools.

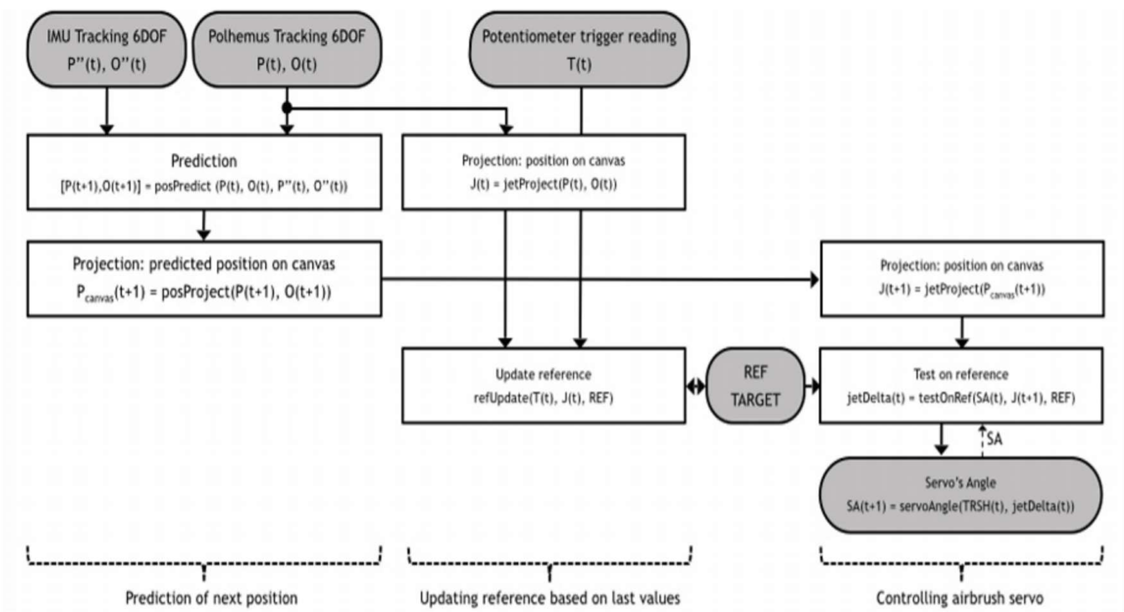

Fig. 5. The control algorithm, flow diagram. Dark rounded boxes are inputs/outputs in the system, and bright straight boxes represent computation points.

The three main subdivisions of the software algorithm is as follows:

1) Tracking, Filtering, Predicting and Signaling:
   A 6DOF position measurement is collected for the brush tip at 120Hz from the magnetic tracker by a software thread. Future estimate of the brush position is created from a 4th-order Bezier spline extrapolation to compensate for the servo's lag. The position measurement stream ´ is then filtered to a 20Hz signal that matches the speed of the servo's response time
2) Calibration: There is a considerable distance between the position of the tracking sensor and the tip of the paint jet. Thus we need to calculate an offset vector for this reason. This is done by collecting a large number of samples taken from the position and orientation of the sensor around a fixed point. The samples lay on a sphere which is

centered on the fixed position of the nozzle. Therefore, a spherical model is fit to the data (four parameters) with a gradient descent algorithm based on the distance of each sample from the surface of the sphere. The offset can be calculated by obtaining the central point and offset can be fixed in relation to the frame of the sensor as the distance between the nozzle and the tracking sensor never changes due to the hardware design. To calibrate the working canvas, the system collects a large number of position samples on the canvas by instructing the user to slide the nozzle across the surface to its corners. The potentiometer and servo were manually calibrated to span the linear motion required to constrain or detect the volume of pigment, mapping the values to the [0, 100] range for simplicity.

3) Canvas Rendering: The system now can estimate the amount of paint that will hit the canvas using the trigger pressure and distance from the surface. The accumulated paint on virtual canvas is compared with the input reference texture to determine if per texel more paint is required in that location or if it has reached the saturation. The per-texel risk measure is summed up over the entire canvas to get a global risk factor that, in turn, translates to servo commands:

$$\text{servo} = 1 - \text{Aggression} * \frac{\sum_i \text{RefSub}[i]}{\sum_i \text{Spray}[i]}, \tag{5}$$

$$\text{RefSub}[i] = \text{Ref}[i] - (\text{Int}[i] + \text{Spray}[i]_{\text{prediction}}). \tag{6}$$

The user determines the aggression parameter which can affect how the computation regards the risk.

INITIAL EXPLORATION AND COLOR

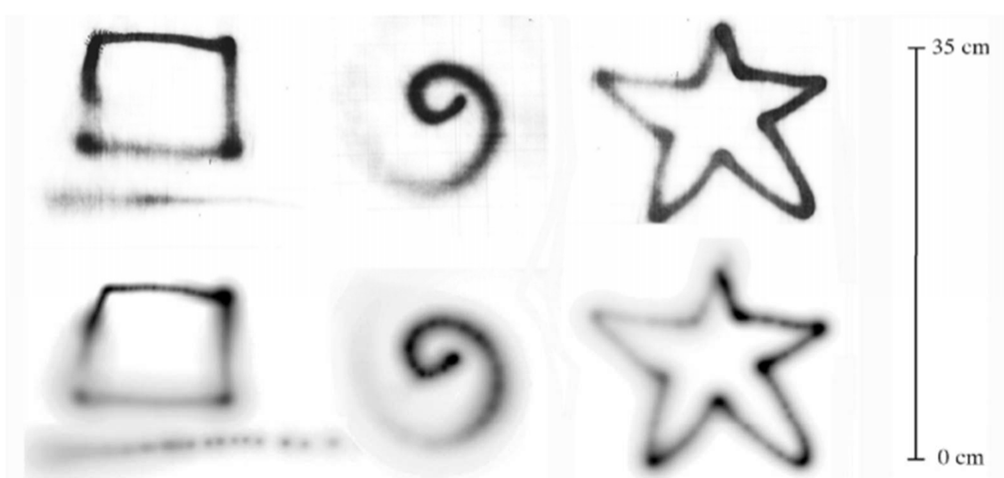

Fig. 6. Spray model sanity tests. Top: Scannings of the canvas. Bottom: Computer simulations using our model.

This section presents several experiments conducted using the airbrush. The authors divide these experiments as : 1) Monochromatic painting, 2) Bichromatic painting and 3) full-colored paintings. Simple primitive free-hand gestures were performed to visualize the accuracy of our physical model using a Carbon Black pigment, comparing the virtual simulation and manual interaction(Fig. 6).

Technical Limitations:

- It does not simulate paint advection or runoffs as this model does not consider the effect of air and pigment-water fluid in real-life. Instead it can detect runoff risk if it reaches saturation
- The airbrush used is dual action in which trigger option opens both pressured air valve and the paint fluid valve. Due to this even the lightest pressure on the trigger sprays a small amount of paint that seeps from the closed paint valve. The pigment density is low in such case and the results depends on the user’s dexterity.
- The servo reaction time and torque does not guarantee immediate blocking of the paint jet especially near the edges and if the user applies excessive force.
- The edges appear blurry which can be seen as airbrush quality instead of a drawback.

Conclusion:

This digital airbrush allows a novice user to experience the manual painting process with the unique physical artifacts of the results.