

# ArtworkVR: Novel Interaction Techniques for Virtual Painters

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## ABSTRACT

Virtual Painting is a form of art which is yet to be explored. Although existent research has been conducted over the years, there is yet room for new innovations and interaction techniques in helping artists bring their art to the world. This paper presents two innovations: one novel new interaction technique designed specifically for aiding the artist create new art, and one novel visualization technique designed specifically for museums and personal use alike.

## Author Keywords

Painting, interaction techniques, primitives, Virtual Painting technologies, visualization techniques, Unity technology, Virtual Reality, Augmented Reality

## INTRODUCTION

Art is present in our daily lives. Even if we are talking about music, movies, games or painting, we all feel it in a way or another. For this paper we are going to focus on painting. To paint, the artist needs a canvas and some kind of paint. The paint might be water-based paint or oil based. Traditional way of painting is done like this: using different kinds of brushes, the artist will create different forms which will be printed on the canvas. The printing process is a hard one and requires a lot of intense training and concentration as every mistake is irreversible.

The painting is defined by the set of all the lines which were drawn by the artist. Figure 1 shows an example of oil-based painting.

The fact that the paint diffuses into the canvas makes it impossible for the artist to reverse or reiterate over. This problem can be easily solved by changing the interaction mode between the artist and its art. Using digital technology, different interaction techniques can be applied in such a manner that they completely eliminate the above problems. By creating a new way in maintaining the art, different interaction techniques can be implemented in such a way which makes it possible for the artist to express himself in a much direct and creative way.

In the past few years, virtual and augmented reality started to catch more and more interest, both in industry and in academic worlds. Different fields like engineering, design, business, entertainment and art start to be shaped by these technologies. Taking art into account, there are very few programs and interaction techniques which aid the artists

into their work, considering the fact that virtual reality is the perfect way for aiding the painter in his work.



**Figure 1. Fluid based painting**

Virtual reality lets the painter to draw and paint in a three-dimensional space, while augmented reality lets the end user admire the art in a direct and interactive way. Also, the number of persons holding an augmented reality device increases from year to year.

The objective of this paper is to introduce new and novel interaction techniques for the painters using virtual and augmented reality. Virtual reality will aid the painter in his process of creation by adding a few new tools to his arsenal, while augmented reality will help the end user see the art as it was created.

The paper is structured as follows: this section is the Introduction and describes the general problem and challenges and sets the theme and objective of the paper. The next section presents the related works reported in scientific literature. The third section presents the main concepts for this field. The fourth section presents the main innovation: the new interaction and visualization techniques. Then experiments and validation is carried out for the proposed techniques. The last section concludes on the achievements and sketches further work.

## RELATED WORKS

By looking in the history, one of the first sketch systems was implemented by **Galyan and Hughes** [1] designed and implemented a sketching tool based on voxels. This system imitates clay sculpting. They present different tools for adding or cutting the material. The functional block of the system is the voxel, which is going to be manipulated by the user, similar to the paintbrush program. Paintbrush changes the pixel value from 0 to 1 or vice versa. The same thing is happening here, but with voxels. The system has a variety of tools, ranging from an addition tool, to a sandpaper tool, to a heating tool etc. The system does not restrict the topology of the model. The models range from simple forms to complex shapes and topology. This fact is compensated by the lack of detail from the art's point of view.

**Sachs** [2] presents a CAD system for designing 3D models by using 6DOF input system. This input system is designed for hands. The models consist of lines. The user is following four important steps in drawing:

1. Drawing
2. Editing
3. Surface matching on points
4. Surface manipulation

**Holosketch** [3] is the first sketching system designed for virtual reality. It was designed by Deering. Its main purpose was to create and manipulate 3D geometry. Deering drew inspiration from sculpting. The user is using the controller in the same way the sculptor is using the sculpting tool to create new shapes.

By being the one of the first virtual reality drawing applications, and one of the first virtual reality systems in general, no general principles existed for designing user interfaces, so Deering had to come with some of them. Feeling was the main inspiration for the user interface. If a menu felt better in 3D than in 2D, it was designed to work in 3D. Same applies for 2D.

**CavePainting** [4] is the first sketch system for "CAVE" virtual reality systems. The system follows a real painting brush. The virtual brush's size may be configured at runtime. There are different types of brushes. Some of them are configured to follow the user's real brush, others have a specific velocity from which the paint gets out of the brush. Some of them apply gravity to the paint so it falls down on the ground.

**FreeDrawer** [5] allows the user to create and manipulate free surfaces based on splines. The main drawback of the application was the lack of tactile input from the system. To solve this problem, Drawing on Air was invented.

**Drawing on Air** [6] uses tactile sensors and actuators in order to draw 3D curves in a "fishtank" like virtual reality

system. The main feature of the application is that it allows the user to adjust the curve's parameters at runtime.

**Rausch** [7] presents a user interface system to do interactive changes to architectural models in real time. The users can create drawing lines and add annotations to existing objects. This system is extended by the authors with another **one** [8] which recognizes sketches made on paper and transforms them into 3D objects. It supplies the user with a set of 28 commands.

**LiftOff** [9] is an immersive virtual reality 3D modeling system. It allows the user to create complex 3D models in a virtual environment. The artists are starting their sketches on paper and then they import it into the application. By using extrusion, the system allows construction of 3D shapes and creation of new surfaces by using the input system.

**Goia and Gorgan** [10] propose a new approach to modeling 3D structures by introducing augmented reality interaction in the context of an Augmented Space Editor. The user (3D artist) is able to define shapes in the real world by using a custom defined pencil in his one hand and view the created shapes in real-time in the context of an augmented reality scene on a mobile device, held in his other hand. The research experiments a robust camera pose estimation algorithm based on the detection of the marker, allowing for pose retrieval even in situations where marker is partially occluded.

**TiltBrush** [11] is probably the most impressive and known drawing system for virtual reality. This is a commercial title owned by Google which offers the user 24 type of brushes and effects like fire, smoke, lighting and snow.

TiltBrush is the first drawing system for the new virtual reality kits. It was designed with 6DOF in mind. There is a mouse and keyboard version, but it is available only for debugging purposes. TiltBrush allows the user to select from a variety of brushes and colors. The controller movement in 3D spaces creates the paint which follows the controller.

The users are able to export their art in .fbx, .usd and .json formats. TiltBrush also allows the user to take a snapshot, an animated GIF or render 360 videos.

**FluidSketching** [12] is probably the most recent addition to the drawing systems for virtual reality. It was designed and implemented at the Aachen University. It simulates fluid physics in order to model the real process. This allows for better drawing control for the painter. The painter is able to modify physical properties of the fluid and stop the diffusion process when they are satisfied with the result. The interaction with the art is done either by the controller or by "blowing" techniques.

## CONCEPTS

**Art** represents a large variety of human activities in which the author creates an artifact in the form of visual, auditory or performance. The strict purpose of art is to be appreciated by other people for its beautifulness and for its emotional power [13].

**Virtual reality** is an experience taking place within a simulated and immersive environment that can be similar or completely different from the real one. Applications of virtual reality can include entertainment (i.e. gaming) and educational purposes (i.e. medical or military training).

**Augmented reality** is an interactive experience of a real-world environment where the objects that reside in the real-world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory and olfactory [14].

**Interaction techniques** are the main way of the communication between the user and the system. They represent the core of this paper.

**Tracking** [15] represents the technology from which a device estimates its relative position to the environment. It uses a hardware-software combination to get the final position of the device. This technology is essential for both virtual and augmented realities. In the case of virtual reality, tracking technology allows for advanced user tracking for gestures like jumping, crawling, ducking or leaning. Also, based on tracking, virtual hands and real objects can be represented, making possible for actions like real hand to virtual object interaction.

Another big advantage of the tracking systems is the fact that it allows for better 3D perceptions based on the parallax effect. By using tracking, virtual reality systems are able to reduce nausea which is one of the main negative factors of it.

**Catmull-Rom** curves is the main concept behind the drawing system. The user defines some 3D points on which the system is going to add some “tubes”. During runtime, the system adds another point to the existing tube, deciding the next part of the line. This is similar to the way the artist is using the brush on canvas.

**Primitive** is the main concept introduced by this paper. The primitive is a set of points – a curve if you want that can be instantiated by the user. The user has complete control over the primitive in the sense that the primitive can be instantiated as much as the user wants in the space, can be translated, scaled and rotated. The user has complete control over what he/she can do with the primitive. The concept of primitive can be extrapolated to other fields, like music or literature. Multiple primitives will form the final art. In this sense, the primitive is the atomic element.

The user is able to define his own primitive. Also, he is able to share primitives with other artists, free or against a fee.

Primitives are going to be instantiated in the world space by the user using the controller. A highlight mode is first used to showcase the way the primitive is going to look like in the final version. This is the step where the user has complete control over the primitive. Once the primitive has been instantiated in the world space, it will be added to the final art and its position will be set.

Reusability is the main advantage of the primitives. The user can define a primitive to range from a simple line to a fully drawn painting. For example, the user can specify that a 3D house drawn by him is the primitive. He will be able to instantiate the house where he wants, how many times he wants. Then he will be able to draw a village in a matter of seconds! The village will take a long time to draw if every house has to be done manual. The system also allows for this.

**Translation, scaling and rotation** represents the main manipulation operations that the user is able to apply to a primitive. Translation represents the movement of the primitive in space. It is represented by a translation matrix. Scaling represents the modification of the size of the primitive. The painter uses the trackpad on the controller in order to change the size. Scaling is represented by a scaling matrix. Rotation represents the rotation of the primitive in space. It is represented by a quaternion. The rotation is also manipulated by the trackpad of the controller.

**Visualization techniques** represents the way the end user is able to view the art. It is done using augmented reality technology.

**Stereoscopy** is a technique to create or augment depth illusion [16]. This illusion is used in virtual reality systems where the users must be present in a three-dimensional space. Any stereoscopic image is called stereogram.

Stereoscopy works as follows: for the final scene there are two different images rendered: one for the left eye and one for the right eye. When these two images are overlapped and presented to the brain, it interprets the image as a three dimensional one. The brain is the main component that gives the depth feeling. By being rendered from different angles in the way that our eyes work, a three-dimensional image is created. The left eye sees the world from a specific angle, while the right eyes sees the world from another angle (the difference is pretty small, but high enough to see everything in 3D)

**Marker** represents a pattern based on which augmented reality applications are based in order to do the tracking. The main role of markers in our work is to do tracking for art which is going to be displayed in museums.

Marker based tracking [17] uses the image which comes from the camera and computes a relative position of it relative to the camera. When the marker has been recognized, a template matching algorithm is being applied

and when the ID was detected, then the real calculations are being done.

**Markerless tracking** represents a tracking method without any patterns. Their main advantage is that the room in which the augmented reality application takes place doesn't have to be setup. This is the main disadvantage of the fiducial marker. It makes for a perfect application for the end user to see the art in his home. Also, markerless tracking allows the user to free roam around his room. The application will still get information about position and orientation, from different sensors from the phone, like gyroscope and accelerometer.

### PAINTING AND VISUALIZATION

In this part we focus our attention to the implementation of the concepts. The main innovations are the primitives and the visualization.

For the implementation, we used Unity Engine because it offers us the tools necessary to build such a system. Unity has already a good 3D renderer implemented, and it uses C# as a scripting language, which we can use in order to deal with input and different logic aspects. For the virtual reality part, we used an HTC Vive Virtual Reality kit. The communication between Unity and Vive is done by using SteamVR library. For the augmented reality part, we used a Huawei P20 lite with ARCore support. ARLibrary is the communication framework between Unity and ARCore.

We start by putting a drawing system in place. The drawing has to be 3D. Tubes are used for the paint. For the brush, Vive's right hand controller is used. Catmull-Rom curves are used for rendering the art. In Catmull-Rom, the only visible part is the part between the middle points. By taking a sample number of points between these two points and drawing lines between these points, we render the curve. The lines represent the axis of the cylinder. These cylinders have a material mapped on them, so it allows Unity to draw it with a specific color. When the user is holding the right trigger, new points are added to the main curve, extending it. This is the way the artist is able to draw lines in 3D.

**Primitives** are implemented as follows: between a trigger push and a trigger release, all the points added by the movement of the controller are saved into a list. The system maintains a list of such lists. When the user wants to instantiate a primitive, it pushes the grip button of the right trigger. The system holds a reference to the current primitive. When the grip button is pushed, the system draws the lines between the points saved in the list, but at the controller's position, with a specific transparency. This is the highlight mode. In this mode, by touching up and down the trackpad, the user is able to scale up and down the primitive. Left and right touch lets the user rotate the primitive around. When the user is happy with the current result, he hits the right trigger of the controller. Then, the primitive's position, orientation and scale are saved and placed in the real world, while its points are saved to the

art's list of points. In this way, reusability is achieved by a clean, fast and elegant design. Figure 2 shows the drawing system with some primitives instantiated by the user.

Whenever the artist is happy with its art, he/she can save it. In the same way, he/she can choose it to upload it to a server, where it can be downloaded by users and be seen at their home or at a museum. NetMQ is the library used for network communication. The server maintains a database ordered by categories, like abstract, acrylic, nature etc. and the end user can choose what type of art he/she wants to see.



Figure 2. Acrylic example made of primitives

The end user has an Android application. He/she is able to select the category from the main ones, and then they can choose what art they want to see. This is a virtual catalogue. When they are happy with the selected result, the application enters in the placement mode. When they tap on the screen, the art is placed at that position in the space. ARCore is responsible for keeping track to the position of the art in the space.

When talking about the end user application to be used at home, we are talking about markerless tracking. ARCore achieves this by using the gyroscope and accelerometer. The user is able to look freely at the art, in the same way the artist was when he/she envision it.

By maintaining a list of 3D points and using the drawing system based on Catmull-Rom curves, the drawing can be easily ported from virtual reality to augmented reality systems. This system is easy to maintain, extend, draw and has a low impact over performance as the tubes are simple meshes that are easy to render. The optimized Unity Engine makes the drawing even easier and its cross-platform build system allows us to develop for both virtual and augmented reality.

In the case for a virtual museum, there is a special category in the database. With each art, a specific marker is uploaded. When the user selects a specific art, the application downloads both the art and the marker. When the user wants to instantiate it into the real space, the application looks for the marker. The marker is only

available in specific designated museums. In this way, art galleries can be built by using only fiducial markers.

The main innovations given by this way of visualization is the fact that more and more end users are able to enjoy art as more and more augmented reality devices are available on the market. This also helps the artists make their art available to a larger audience. Compared to existing painting systems for virtual reality, each of them requires a specific kit (which ranges from personal use kits like Vive, which costs some money to specifically build virtual reality rooms like the CAVE system). Our system lets the user enjoy art on their personal devices.

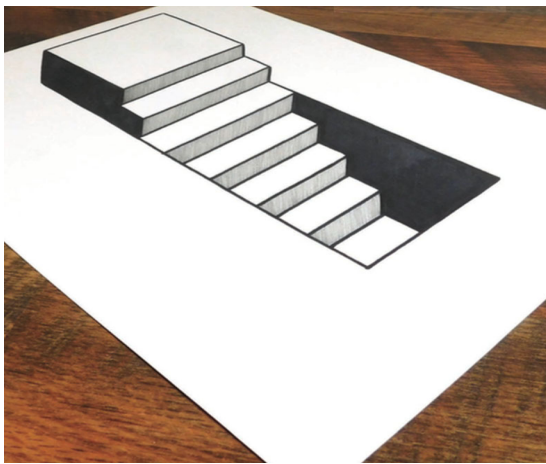


Figure 3. Reference picture for the students

#### EXPERIMENTAL RESULTS AND VALIDATION

By being a visual and interactive application, the best way to test it is to compare it to other applications. For this, a group of students from our University was chosen in order to do the comparison.

There were employed two test methods: traditional and technical. Traditional methods consist of direct observations and verbal reports, while technical approaches consist of design experiments and surveys [18]. The test was conducted as follows: the students were given a piece of paper in order to draw their own idea. Then they were asked to paint the same idea twice. The first painting was done in our application, while the second painting was done in TiltBrush.

The direct observation provided us with most of the information we wanted. While drawing, the students who had repetitive patterns in their drawings (like a village) praised the primitive system. The others used it as an enhancing feature, by adding a new layer to their drawings by using the same shapes in different positions. A new level of artistic enhancement was given only by the implementation of this system.

A time test was performed by the students: they were given a reference picture represented by figure 3.

The students were asked to draw the same picture (stairway) both in TiltBrush and in our application, with and without the primitive system. The students finished the work almost twice as fast by using the primitive systems than without it. An interesting use was that a student, instead of using a straight line as a primitive, he defined a whole step as a primitive and did the picture in literally few seconds!

While the primitive system was a success, the students still reported that they wanted an additional number of brushes types in order to correctly express their artistic vision. Also, they wanted a better material for the looks of the paint. These are features that are being considered, but the main focus of the research was the primitive system. The fact that it speed up a few parts of the drawing made this research a success.

The verbal reports were positive and the users were satisfied with the new implemented system.

Afterwards, a survey was conducted on the students. The questions for the survey were:

1. How often did you find yourself using the primitive system? (1 – not so often to 5 – always)
2. Rank the following features: primitive, brush type, brush size settings, brush color settings (1 – least liked to 5 – most liked)
3. How often did you changed the way of approaching the art while using the primitive system against not using it? (1 - not at all to 5 – changed my way of thinking)
4. Rank the frustration level of using the application (1 – extremely frustrated to 5 – perfectly balanced)
5. Rank the reusability of the primitives (1 least reusable to 4 most reusable)

The users found themselves using the primitive system pretty often especially after discovering its potential. The average of the grades was 3.5 out of 5, which is a good one, considering the fact that manual drawing also had to be done on parts that weren't reusable. Also, some of the artists add their own little touch while reusing the art, which gave it even more potential, a feature that the authors haven't taken into account.

The primitives were also the favorite feature of the users, followed by brush type then after brush size color settings and by brush size settings.

The approach wasn't totally changed by the user, as they always had the feel that they can draw everything manually, without using the primitive system. From a morale point of view, this is good as the user will not feel intimidated by the application.

The above paragraph presented us with the response to the next survey question: the frustration level. The frustration was 2 out of 5, as the material on the paint has to be changed. It seems that the normal material of Unity is not so good for an artistic point of view.

The score 4 out of 4 was given by the users to the primitive from a reusability point of view, as it will help the user to draw everything faster. The main principle that was taken into account was the Fitts' Law for faster iterations (this was applied in the primitive system as a faster instantiation rather than manually draw everything else).

For the visualization, comparison with other existing applications is sufficient. While other applications allow you to view the art either in virtual reality or on desktop (e.g. TiltBrush), our application allows for a greater audience. The fact that the user is able to see the art in augmented reality builds interesting scenarios like virtual galleries and museums. Also, the fact that the user is able to see the art at his home replaces the need for art magazines.

By making a comparison with the CAVE or with the older systems, the users need special equipment in order to view the art. Our system requires only a phone with augmented reality support (i.e. ARCore), a device that almost everybody has. By having the user admire the art on his personal phone, the system allows for a greater number of people to experiment the art, in the way that the painter envision it. In this way, both the artist and the people will benefit from it. Also, our system opens the door for the museum of the future: everything is a marker and the user admire the art by using their personal devices.

The number of users which are able to see our art is bigger than the number of users which are able to see the art from other systems. This number shows that the purpose of this research was achieved, and it represents a validation for the visualization part.

### CONCLUSIONS

This scientific research and the practical experiments have proven that new interaction techniques can be constructed from the existing ones. The main innovation presented in this paper is the primitive system. More research is going to be conducted for a better experience between the artist and his art, starting with different ways of representing the art which is going to be both performant and pleasantly more aesthetical for both the painter and the end user.

The research and the presentation through this paper have proved that virtual reality and augmented reality represent the next platforms for the artists and for the end user. This paper concerned with a novel interaction technique and a visualization one: primitives and the ability to represent the art in augmented reality.

New ways of representing the art in the core data structures to make it more pleasantly aesthetical will be conducted in further research. Also, new interaction techniques are going

to be studied for both the artist and the painter. This research is going to focus on different ways of visualization manipulation, like different effects on the tubes and the way the painter is going to be able to manipulate the primitives in novel ways.

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