# Interactive Virtual Graffiti System

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Entertainment & Art & Internet: Interactive Art

***Abstract*— The Interactive Virtual Graffiti (IVG) system is an artistic medium that uses dummy spray can nozzle strokes to create graffiti in a fully immersive CAVE environment. Two sensor gloves, a six degree of freedom hand-held controller (Space Orb $360°$) and a tracking system are used to recognise physical gestures. Realistic paint splat is simulated directly on 3D objects in the virtual world. This paper describes the interaction devices, spray paint simulation algorithm, 3D colour and nozzle picker and the user interface. Several users have tested the system and their feedback along with the results of two evaluations are presented. Some sample graffiti are also attached.**

***Index Terms*— virtual graffiti, immersive system, scene-graph, real-time simulation, ray-tracing**

## I. Introduction

THe first thing that appears in most people minds at the mention of 'interactive art' is an internet application for designing and creating images. In contrast, this paper presents an Interactive Virtual Graffiti (IVG) system, a Virtual Reality (VR) system, which allows virtual spray to be used on virtual buildings in an immersive environment. Integrating modern VR hardware and software technology, the IVG system offers users the flexibility to work on a virtual wall in the usual way, as if they were spraying on a wall in a public place. The interaction is made as easy and as natural as possible.

The term 'graffiti originates from the Greek word 'graphein', which means to scratch a message into another medium [11]. It predates the Greeks - witness Stone Age carvings of messages on stones and walls. Graffiti art has since become a form of communication and a way to gain acknowledgement from others. It does not distinguish between artists on age, racial, social, economic or educational background. It speaks cross-culturally and can be a communication medium for anybody who has the nerve to perform the act.

This 'culture' has been preserved and is still practised in the modern era but with a change in the tools used. Today, graffiti is carried out using aerosol spray, applied to the walls of public places. It gives the environment an additional layer of information. Young people, especially in urban areas, use it as a method of expressing their attitudes and thoughts. Ultimately, it has begun to find its way to walls of galleries and museums [1]. These acts are variously considered rude, humorous, political or constituting vandalism, and are generally illegal. Because of the illicit nature of graffiti, they usually emerge and disappear lightning-like and often only traces remain in our memories.

The IVG system offers a solution to the problem of illegality by bringing the graffiti art into the virtual world. It gives graffiti a new form of life while at the same time preserving and documenting the constantly disappearing works of art. Moreover, it eliminates the possiblity of walls becoming too dense with marks.

Following the development and implementation of IVG system, youngsters or graffiti artists no longer need to buy aerosol sprays and are able to express their opinions and creativity lawfully. It also displays the ability of modern VR technology in coping with society's problem. It can alleviate the problems caused by carrying out bans on the sale of aerosol paints and recovering ruined properties.

It will attract public attention to what virtual reality can do in helping to uncover hidden talent in society as the artists no longer need to worry about the lifespan of their graffiti. Users' masterpieces can be stored in other devices such as disks for archiving and later use. An interesting proposal that is worth consideration would be to display these artworks in art gallery or museum. This would be a credit to the graffiti artists at the same time preserving the legally emerging art. Publication of the artworks on the World Wide Web is also possible.

Meanwhile, the user can have fun during the experience. Emergence of this kind of system reflects the potential that future art and the future of VR will be intertwined. It addresses both the mechanical and sociological barriers that currently prevent many graffiti artists from gaining a recognition on their masterpieces. What VR itself will become, and what new art forms will emerge, are questions that must continually be addressed in the present.

This paper is organised as follows: in Section II, a brief overview of the historical approaches to digital graffiti is presented. Section III describes IVG system in detail. Section IV presents the evaluation results.

Some performance issues are found in Section V. Section VI summarises the system while section VII outlines directions for future development.

## II. Previous Work

The closest analogous work to the IVG system is the Virtual Graffiti system [11] developed by Fraunhofer IGD in Germany. This system enables a projected surface approximately 3m by 2m to be sprayed using VR technology and allows removal of graffiti without trace. It uses an imitation of an aerosol spray can equipped with a sensor placed inside the can tracked by an electromagnetic tracking emitter. When the user pushes the button of the can, the system simulates the spray at the corresponding position, taking into account the pressure applied and the distance to the wall. Sharp edges and frayed edges can be sprayed as well as thick and thin lines. Colour and cap size can be changed from a menu activated by the dummy can. When spraying, the user sees a projection filled totally by a 2D wall. Only when the user steps back from the wall and triggers the displaying of the menu does the system create 'normal' 3D rendering. The end of session is detected when the user places the can back on its docking station. The graffiti is then stored permanently as an image file and presented on a web page.

This system is more like a painting application as the user is spraying in a 2D environment. It only allows the user to spray on a chosen wall from a New York back yard location whereas IVG system allows any surface in the scene from flat to curvy surfaces to be sprayed in a true 3D environment. The 3D CAVE setting raises the user's feeling of presence and improves immersion as opposed to the single back projection screen. It also provides facilities to reset the scene and to navigate in the virtual world. Thus, the user has the freedom to move around the environment and select any place of interest to perform graffiti rather than being limited to a predefined location.

An earlier (1996) system called 'Vandalism' [3] provided users with a set of VR spray cans, a virtual camera, a virtual eraser and a virtual magnet. The user alters existing artworks such as Mona Lisa, Van Gogh's self-potrait and Monet's Cathedral at Rouen in an art gallery. They can spray on 3D paintings as well as on 3D sculpture. Spraying is applied by painting onto texture maps of objects in the scene. The system also supports networking and users are represented using simple avatars. The most interesting feature is the ability of users to paint on other people's avatars just as if they were other objects in the scene. The user who prefers a blank canvas is offered the freedom to create his or her own. Users can also pick and drop objects, take a snapshot of current scene using the virtual camera, restore artworks, deform objects and warp the positions of the sculptures in the gallery. They are offered the freedom to navigate around the scene under the control of the wand and its buttons.

In comparison, IVG system allows the whole scene to be saved rather than just a snapshot and its clearing facility clears the whole patch of paint instead of a particular portion. Although IVG does not provide object pick-up, object drop or object deformation, it has a graphical user interface, a useful guide for the user during the graffiti session that 'Vandalism' lacks.

Another version of a virtual graffiti system combines communication, the Internet and computer graphics technology [12]. It offers an Internet face for the creation of graffiti (Virtual Graffiti Painter) and a mechanism for the graffiti manifestation (Light Bombing). Virtual Graffiti Painter operates over the Internet and allows users to choose a physical location on which they want to paint the scene. It allows the user to paint over the image of a specific site and offers a progressive save. These scenes can then be presented using light bombing, which refers to the beaming of graffiti onto the physical wall of a building using a digital projector and a portable computer. It could take place anywhere, at any time and on any surface as long as the light conditions allow. Feedback loops can be set up by 'web-camming' the art as it is projected onto a wall then returning images of the space to the Internet audience.

However, this system does not offer an immersive experience. Graffiti is created through the Internet without any bodily interaction. All the user needs is a desktop - state-of-the-art VR technology such as CAVE, pinch gloves or a Space Orb are not required. Users can select a tool and specific colour from the side palette then create the graffiti by moving a 2D mouse.

The idea of 3D painting has also been explored in CavePainting [4]. It uses analogues of 2D brush strokes to create 3D works of art in a fully immersive CAVE environment. It provides a natural and intuitive interface for creating a virtual 3D scene using simple physical props and gestures. Artists interact with the system in a way similar to a traditional painter working on a large canvas. Strokes are created by moving a tracked paint brush through the air or dripping or throwing paint out of a bucket onto the wall and floor of the CAVE. The system facilitates stroke size selection, stroke type selection, colour selection, scene translation and scene scaling. Two-handed interaction is another feature of CavePainting where the user utilizes both the pinch glove and the brush simultaneously. The pinch glove is employed to provide quick access to a colour picker and other options during painting. 3D text is presented next to the appropriate finger on a 3D icon of the hand whenever the user turns his or her hand so that the palm faces up to help the user remember the function of each pair of finger combinations. A timeline widget is also available to keep track of the artwork in progress and provides an interactive viewing mode following the completion of the painting.

In contrast, the IVG system has taken advantage of its two-handed interaction by utilizing a pair of pinch gloves as the interaction interface. It also exploits the idea of presenting small 3D text beside the non-dominant hand. The dominant hand performs spraying and navigation while the non-dominant hand provides quick access to menus and colours as well as nozzle sizes.

Schkolne constructed Surface Drawing [13], a freeform 3D surface construction tool for drawing organic surfaces in 3D space with hand and tangible tools which uses a Responsive Workbench [9] as interface. In addition, a head-tracked stereoscopic display and sensors are used to track the body and handheld tools [14]. The user wears a CyberGlove with a motion tracker on the wrist that directly turns the hand motions into shapes in real-time.

Other related projects like Body Language User Interface (BLUI) [2], 3DM [7], HoloSketch [10], and 3-Draw [5] use a tracked wand to create freeform lines or geometry.

The difference between the IVG system and these freeform modeling applications is that it runs in a fully immersive CAVE environment while freeform modeling applications usually run in semi-immersive workbench environments. The IVG system allows the user to work in a natural environment rather than focus on the mechanics and artefacts of technology. It also provides the user with fine control over colours and can nozzles with which to work.

## III. The System

The IVG system provides the user with a feeling of naturalness while executing graffiti in a virtual environment. It is intuitive for users of various age groups. The CAVE, a fully immersive virtual environment driven by an SGI Onyx2 Infinite Reality 2 triple-rack system has been chosen as the interaction interface. The CAVE provides users with enough space to move around and step back to observe their graffiti, analogous to real graffiti creation. Freedom of movement increases the sense of immersion in users because they have more control and autonomy over the environment.

IRIS Performer [6], an extensible software toolkit for creating real-time 3D graphics, offering high-level support for visual simulation, virtual reality and graphics intensive tasks was chosen as the rendering system. It has the scenegraph concept as its base. In order to use Performer in the CAVE, CAVE Library (CAVELib) was exploited.

Basically, IVG system is made up of 3 main subsystems, the interaction subsystem, the Spray subsystem and the Graphical User Interface (GUI) subsystem which are further divided into subcomponents. Fig. 1 shows IVG system's main features while Fig. 2 shows its functional architecture.

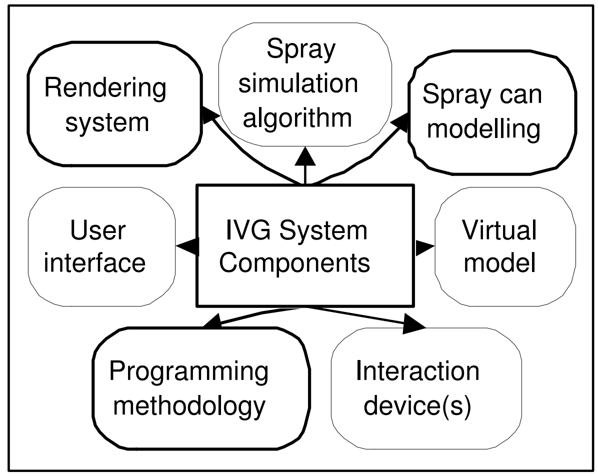


Fig. 1. IVG System Components

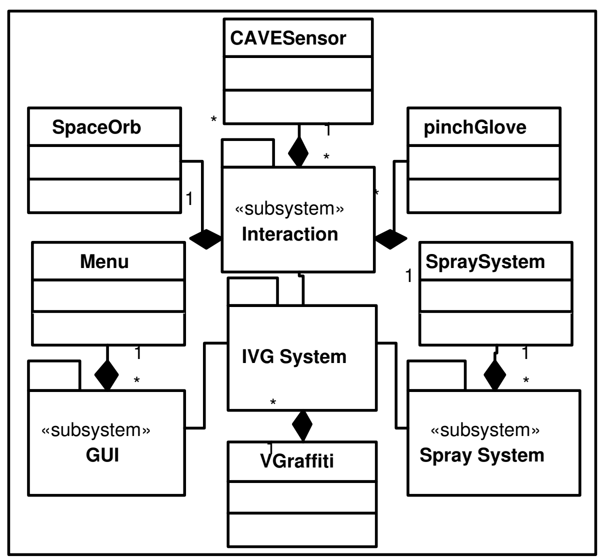


Fig. 2. IVG System Architecture

The interaction subsystem consists of all the interaction devices - a pair of stereoscopic glasses, a pair of pinch gloves, a Space Orb, a dummy spray can and a Flock of Birds, 6 degree-of-freedom magnetic tracking system. In order to have a perspective view of the 3D space, the user is required to wear a pair of stereoscopic glasses. Stereoscopic glasses offer virtual as well as real-world vision, reducing the user's awareness of the existence of both the different worlds. It stimulates a feeling of presence and allows the user to perform accurate spraying in the 3D environment.

A pair of pinch gloves is used in conjunction with a dummy spray can which plays a role similar to that of its real counterpart. Users are more likely to believe that they are performing real graffiti with a dummy can in their hands rather than by moving a bare hand in the act of spraying. Combining these tools, users can then pinch and hold down their fingers to start spraying or navigate around the 3D environment. The CAVE is fully equipped with magnetic tracker that detects the position, orientation and the direction of the sensor attached to the dummy spray can, as well as senses the current touching fingers on the pinch gloves.

The pinch glove is also used to clear graffiti, trigger menus and provide quick access to colours and nozzle sizes picker. Different fingers combination are customised to activate different functions. The St. Andrew's school model created by Miguel Carballal was chosen as the graffiti canvas. The wide school compound with large walls makes it a practical place to carry out graffiti. Besides that, adventurous graffiti artists can demonstrate their talent on the furniture. The model was projected onto the walls of the CAVE using a projection system which comprises of 3 rear projectors for each side of the CAVE and a front projector for the floor. In addition, the Space Orb which comprises of a PowerSensor ball and 6 programmable buttons can also be used as navigation and command activation tool similar to the pinch gloves.

Fig. 3, 4, 5 and 6 show the interaction devices of the system.

Fig. 3. Stereo Glasses

Next, the spray subsystem performs real-time simulation of spray paint on the 3D objects in the virtual world. Timeliness, dynamic internal structure and reactiveness of the system were the major concerns. The information obtainable from pinch gloves and the sensor on the dummy can are the current active fingers, the sensor position, orientation and direction. These information is exploited for the calculation of accurate and realistic reproduction of spray paint. The nearer the user's hand is to the wall, the denser the splat it creates.

Fig. 4. Pinch Gloves

Fig. 5. Space Orb

This simulation process involves ray-tracing algorithm which assumes that a ray is cast from the nozzle of the dummy can into the scene. The algorithm was amalgamated with scenegraph geometry manipulation where point primitives represent paint particles. First, the position and the direction of the sensor on the dummy can are obtained. Then, multiple rays are generated randomly which are cast into the scene. Valid intersection points are then generated and the distance between the points and the sensor is calculated in order to determine the paint density. Finally, the paint particles are grouped into

Fig. 6. Dummy Spray Can

a splat and added to the scene at the position where the user is pointing. The scenegraph provides the flexibility to add nodes, supporting dynamic generation of graffiti as the users move their hands, producing an image. Each splat of paint is added to the existing base graph that eventually results in a complete scenegraph when the user ends the spraying session.

Transparency blending was explored to ensure that the appearance of the paint on the surface is as natural as possible so that it reflects the underlying surface material, particularly if the surface is bumpy, dented or otherwise not smooth. However, since the CAVE is quite gloomy and the 3D objects are textured instead of having real material properties, the resulting effect was not obvious. Therefore, transparency was omitted since the cost it imposed on processing power far outweighed the value of the outcome it produced.

The GUI subsystem offers a user-friendly interface. A menu was implemented to assist the user during the graffiti session. It contains buttons that will be pushed in slightly as the user chooses an option. In addition, a 3D text icon was presented beside the non-dominant hand as indication of the paint colour and can nozzle size. It changes according to user selection. This convinces the user that the system is reacting to their action in the expected manner, thus increasing naturalness in interaction. In addition, a user manual was generated to provide users with an initial picture of the system.

The programming methodology adopted in the IVG system is object-oriented (OO) paradigm. The programming language, C++ allowed development of efficient programs for real-time high performance graphics application. The IVG system provides facilities that are outside the realm of real graffiti such as saving, clearing and resetting the scene and quitting the program. Both pinch gloves and Space Orb are utilized in this case.

## IV. EVALUATION

Formative evaluation [8] was exploited to gather data about the usability of the system design from time to time. Overall, two user evaluations have been successfully carried out. The characteristics validated in each evaluation were: the ease of use of interaction devices, user friendliness of the user interface, degree of realistic spray paint simulation, naturalness of interaction, real-time response and degree of resemblance of IVG to real graffiti. One point to note here is that subjects for the evaluations were proxy graffiti artist.

The first evaluation, carried out during mid development reflected flaws which were improved in the final IVG system. Only half a dozen subjects were involved in this evaluation while the number was increased to twenty in the final course of action. Instead of spraying with bare hands, in the final version, a dummy spray can was put into action. To avoid distraction, the menu previously displayed in the middle of the CAVE front screen was shifted automatically to the top left hand corner of the screen once the user chose Spraying mode. To prevent information overload, only a single finger name was displayed on the menu and different colours were used for the menu title and menu buttons.

A user manual was also provided. As a substitute for menu activation, a 3D picker that appears beside the user's left hand was implemented. An increment in the size of point particles was imposed, so that bigger paint particles with wider coverage were generated to produce more realistic simulation. Satisfactory results were observed and it proved a significant improvement in comparison to the first evaluation.

Presented in Fig. 7 is a comparison of the results of both evaluations.

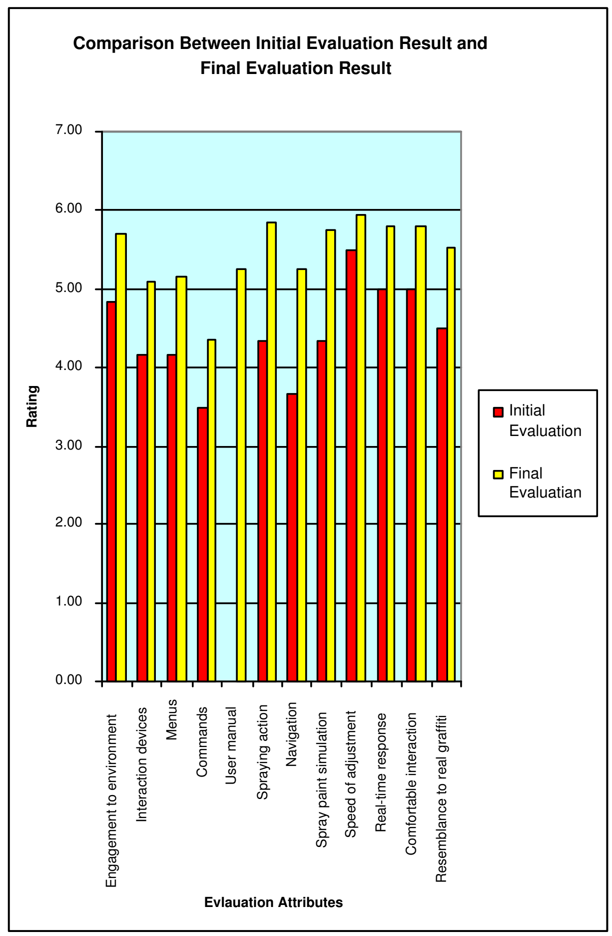


Fig. 7. Comparison of the results of both evaluations

With the maximum rating of 7, naturalness of interaction achieved a rating ranging from 5.25 to 5.95 in the final version of the implementation. Users felt more natural and comfortable holding a dummy spray can and spraying at the position pointed at by the can nozzle analogous to real graffiti. A 35% improvement was recorded for naturalness of spraying action while ease of use of interaction devices recorded 22% improvement. The sense of navigating around the virtual environment achieved the highest improvement, that is, 43%. Devices were found to be more usable and easier to operate alongside, and to have increased flexibility. Even so, there is still a restriction in the freedom of movement. Tangled wires can result in inaccurate position reading which is why some participants found the spray position unpredictable. Besides that, the size of the pinch glove restrained its user groups and affected its effectiveness as well as responsiveness. A glove too large for its user may result in loose positioning of sensors at the user's fingertips leading to a failure of contact between sensors when the user pinches his fingers.

The degree of realistic spray paint simulation had been substantially improved. The rating leaped from 4.33 in the previous evaluation to 5.75, which accounted for a 33% increase. In conjunction with this improvement, real-time response received a near excellent rating. This is due to the fact that bigger spray particles made graffiti creation faster and more visible.

Implementation of a 3D picker allows users quick access to colour and nozzle size options without taxing their memory. However, user interface evaluation signified the need for further enrichment. Participants still find remembering commands tough because of the vast number of options available. This problem might be eliminated with a reduction of the number of available events to be activated but this would mean a less functional system. Generally, the degree of resemblance of the whole process to real graffiti arrived at a satisfactory level with a rate of 5.53.

Fig. 8 shows subjects at work whereas Fig. 9 presents graffiti created by subjects.

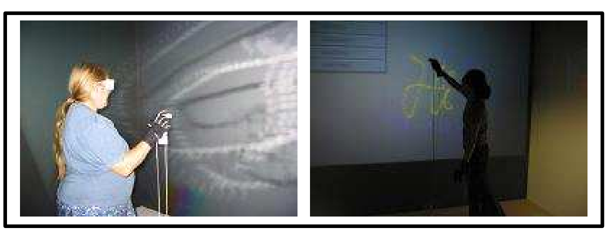

Fig. 8. Subjects at work

Critical and constructive opinion on the final system has also been elicited from a real graffiti artist, Temper [15]. From a graffiti artist's perspective, the main flaw and distinguishing characteristic of the IVG system from real graffiti creation is speed and accuracy. He recommended reconstruction of the dummy spray can to include additional flexibility so that it conforms more to its real counterpart. Furthermore, he thinks that an indicator of the spraying position will be helpful as the accuracy of the current tracking system is sometimes doubtful. A more powerful processor is necessary to speed up the rendering rate and wireless interaction is desirable for increased naturalism.


Fig. 9. Some graffiti

## V. Discussions

In this system, the most fundamental consideration is that of immersiveness in interaction. The interface was designed to allow the users to walk around the CAVE and have them feel comfortable doing so. It can be rather intimidating experience for a first time user to walk into the gloomy CAVE filled with wires and VR devices. To allow a user to really walk around and use the whole space of the CAVE indicates that we first need to reduce user's fear of bumping into wall and objects in the virtual scene as well as falling through the wired devices. Therefore, a short introductory period is useful for user adaptation to the surrounding.

The stereoscopic glasses, which allow viewing of both virtual and real world may also help. However, the use of stereoscopic glasses impose an issue on the viewing of graffiti during interaction. As all sensors on the VR devices are tracked by the Flock of Birds magnetic tracking system, user head movement might sometimes block the sensor on the stereoscopic glasses from the tracker. When this happen, the glasses will turn dark and user will see a dull color scene and graffiti. The normal color of the display can be viewed through the glasses only when the sensors are in track.

Responsiveness is another feature that can not be neglected. The system updates at a rate of 30 fps. When the system starts, the ray-tracing calculation and graffiti creation is performed instantaneously. The graffiti is displayed almost immediately as it is created. However, the system slows down after a short period of usage, when the scene becomes loaded with graffiti. This is because as more and more new paint particles are added to the base scenegraph, the size of the virtual model grows proportionally, thereby increasing the rendering time of each frame.

As the devices are all wired, the accuracy of position and orientation reading varies, hence, an indication of ray direction is helpful. In addition, the sensor for ray-tracing is only temporary attached to the nozzle of the dummy spray can. Rubber bands are used to tie the sensor in place. Accidental pulling of its wire can affect the orientation and loosen the attachment. And again, user movements can prevent the sensors from being tracked, which is why sometimes, the system does not seems to response to the user action because no new position and orientation information is transmitted to the processor. This also happen if the user is activating the actions faster than that the system is able to handle.

As there is no collision detection facility, the system is not able to alert the user when they are colliding with virtual objects in the scene. When this happen, ray-tracing algorithm can not be performed as the tracing is done only on object surfaces. This flaw decreases the effectiveness of the system because a user might not realise the collision and think that the system is not responding as expected.

It can be seen that the existing technology for input devices is limiting to creative processes, as mentioned by Temper. There is a great need for better design of tools to bridge the gap between the artists and VR system if we are aiming for a system that operates to the real artists' standard.

A great artistic question is how to display one's artwork since using VR as a medium make a big difference to the graffiti created using traditional method of spraying on physical wall. In this application, the user can choose to display their art as 3D model in the CAVE or 3D VRML model on desktop computer. They can also take snapshots of the 3D scene from different angles and display them as 2D images.

## VI. Conclusions

The IVG system aims to make the most out of the flexibility and advantages of the previous works to form a new improved version of Virtual Graffiti system. The key improvement is the 3D spraying setting. This novel approach provides the user with the exciting experience of performing graffiti in the immersive CAVE environment. The system provides all the basic functions a graffiti artist will need, from moving around the 3D surroundings and changing spray colour and nozzle size to functions extraordinary to real graffiti art such as clearing, saving and resetting the scene. Two handed interaction, helpful menus and 3D text are other attributes of this system. A dummy spray can acts as counterpart to the real can. Spray paint simulation is made as natural as possible with a variety of effects to convince users that they are performing real graffiti.

## VII. Future Work

In further development, it would be better if the devices are wireless and pressure sensitive, as accuracy can be improved and pressure information is useful for paint simulation. Adding a contact on top of the spray can may provide a more intuitive interaction and eradicate the need to wear a pinch glove on the dominant hand. Besides that, a more attractive and user-friendly menu should be developed. This entails a more extensive user involvement. In addition, a progressive save facility can be a bonus feature of the IVG system. It will allow playback of the graffiti creation process as an animation at a later time, which indisputably makes the system more modern. Light bombing projection of the artwork is another attractive feature. To construct a more realistic environment, collision detection and sound feedback ought to be considered. These features will undoubtedly increase the user's sense of presence and immersiveness and thus intensify satisfaction in the interaction.

## VIII. Acknowledgement

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