VR Spray Painting for Training and Design

Jonathan Konieczny*
Gary Meyer
Clement Shimizu
University of Minnesota

John Heckman
Mark Manyen
Marty Rabens
Pine Technical College

Abstract

A system is introduced for the simulation of spray painting. Head mounted display goggles are combined with a tracking system to allow users to paint a virtual surface with a spray gun. Ray tracing is used to simulate droplets landing on the surface of the object, allowing arbitrary shapes and spray gun patterns to be used. This system is combined with previous research on spray gun characteristics to provide a realistic simulation of the spray paint including the effects of viscosity, air pressure, and paint pressure. The simulation provides two different output modes: a non-photorealistic display that gives a visual representation of how much paint has landed on the surface, and a photorealistic simulation of how the paint would actually look on the object once it dried. Useful feedback values such as overspray are given. Experiments were performed to validate the system.

CR Categories: H.5.1 [Information Interface and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities

Keywords: Paint, VR applications, Visualization, User Training

1 Introduction

Training spray painters to apply modern paints can be an expensive process. Paints can vary significantly in how they must be applied to a surface, forcing painters to vary spray gun settings, speed of spray gun movement, and distance of the gun from the surface of the object. Therefore, training new painters can be costly in both time spent training the painter and in amount of paint used. The goal of the virtual reality system described in this paper is to provide a realistic spray simulation along with useful output to hasten the training process without the expenditure of costly paint. It also allows paint designers to create new paints and gauge how easy they will be to use prior to manufacture.

2 Relevant Work

The two most relevant pieces of research describe basic spray paint simulation for the ship building industry [Yang et al. 2007] [Kim et al. 2007]. Yang et al. employs a tracked spray gun and head tracker to place the user in a virtual environment. The user then sprays the virtual object with the spray gun, and gets feedback on the resulting paint thickness. Kim et al. uses a spray paint simulation that employs ray casting and a flood fill algorithm to fill the nearby texture pixels next to the striking coordinate spot. The approach described in this paper supports arbitrary object shapes. In addition, this research adds a realistic paint display model, realistic lighting and environment, adjustable paint and gun parameters, and user testing/validation.

*e-mail: jkonie@cs.umn.edu

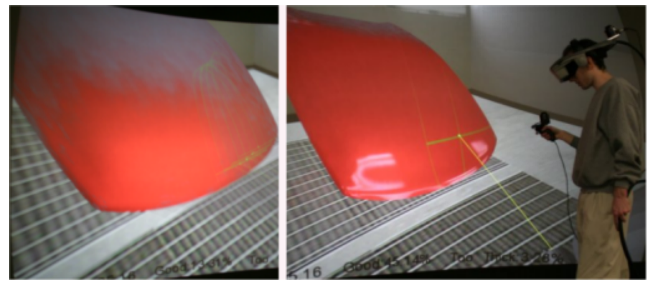

Figure 1: *Left: Photorealistic rendering (as seen in headset) of directionally diffuse paint on a car hood. Right: The final result of the painted car hood after a gloss coat has been applied. Both the lighting setup and environment surrounding the user was captured on site at a paint facility using the method described in [Debevec et al. 1997], allowing the user to paint in a familiar environment.*

3 Setup and Spray Paint Simulation

Figure 1 shows the critical components of the virtual spray paint system. A tracked head mounted display allows the user to navigate around a virtual environment. The user holds a tracked “spray gun” that is used to spray paint objects placed in the environment.

A natural method to simulate spray painting is ray casting, as casting a ray toward a virtual surface is very similar to a paint particle striking a real surface. However, since any drop below a real time frame rate could result in improper training, calculating a ray cast for every paint particle is computationally infeasible. Fortunately, a good compromise between realism and rendering speed can be accomplished by firing fewer rays, and having each ray that strikes the surface spread paint over a reasonable area. Thus, each particle fired from the spray gun is intersected with the virtual object using a ray cast calculation, and “splats” onto the surface, much as a real particle of paint would do. Varying the size of the splat allows more or fewer rays to be used, allowing a balance between realism and rendering speed. As these rays splat onto the object, a density map is built up on the virtual object representing the thickness of the paint at each point on that object. This can then be used to give output back to the user on how well the painting has been performed.

The first method of user feedback is a non-photorealistic (NPR) display(Figure 2). This method takes the thickness data from the texture map and attempts to visualize it in a manner that allows the user to immediately judge exactly how thick and uniformly the paint has been applied. This is an excellent way to provide training information to new painters, or discover defects in an existing paint procedure.

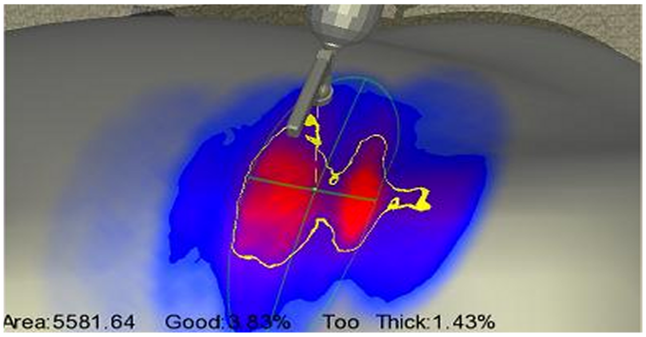

Figure 2: *A NPR rendering with a shape that has been painted using a range of thicknesses. A cold-hot color visualization scheme has been used to show the user the thickness of the paint, with grey indicating unpainted, blue thin paint, and red thick paint.*

In addition to an NPR algorithm, a photorealistic rendering algorithm was implemented. This algorithm is a modification of a metallic car paint simulator described in [Shimizu et al. 2003]. The metallic paint simulator allows a user to design a paint color, and then displays it on a model using environment map based lighting. Figure 1 shows this rendering with both a partially complete diffuse coating as well as a fully painted object.

4 Spray Paint Parameters

Simply allowing a user to spray a surface with a virtual spray gun and seeing the resulting paint thickness leaves out a critical fact: not all paints spray onto a surface in the same way. Changing the spray gun can also have a dramatic effect on the application of the paint. Factors such as air pressure, paint pressure, and viscosity of the paint must be taken into account when determining the final appearance of the painted object.

The simulation presented in this paper makes use of research performed by [Kwok 1991]. Kwok did trials of spray painting using differing paint spray gun characteristics. The resulting distribution of paint on a target surface was carefully measured for a variety of variables. By using the results of this study, variables have been added to the simulation: viscosity, A/P ratio (the ratio of air pressure to paint pressure), target distance, paint flow rate, and spray gun cone size can all be controlled by the user with realistic results. Overspray is also accurately calculated and displayed to the user.

5 User Studies

The system has been tested with both controlled experimentation as well as field testing in actual spray paint companies. The controlled experiments consisted of two tests. In both experiments, each participant was allowed as much time as they wanted to familiarize themselves with the virtual environment, and were allowed to paint a few test objects before starting the actual experiment. Tests were limited to only a few professional painter participants, as getting enough professional painters for a full statistical study is infeasible. These tests do, however, provide basic verification that the system performs in a similar manner to real spray painting. The tests and their results are summarized in tables 2 and 3. In both tests, the virtual system showed a high correlation to real spray painting, with expert painters outperforming less skilled ones.

Variable	Expert1 (Real Paint)	Expert2 (Virtual Paint)	Novice (Virtual Paint)
Gun Dist (1st Coat)	5in.	6in.	6-10in.
Gun Dist (2nd Coat)	6in.	7in.	N/A
# Passes (1st Coat)	11	10	5
# Passes (2nd Coat)	8	6	0
Time (1st Coat)	33secs	38secs	50secs
Time (2nd Coat)	16secs	13secs	N/A
Correct Coverage (%)	100.0%	97.4%	79.9%

Table 1: *The first experiment: An expert was tracked spray painting a panel. Then, the same setup was recreated virtually and painted by another (different) expert as well as a novice using the system.*

Variable	Expert	Novice
Car Hood % Correct	99.75%	60.0%
Car Hood Time	1min21secs	1min21secs
Car Hood Overspray	52%	40%
Car Hood Gun Dist.	10-11 inches	6-10 inches
Motorcycle % Correct	98.0%	71%
Motorcycle Time	2min8secs	1min58secs
Motorcycle Overspray	44%	57%
Motorcycle Gun Dist.	10-11 inches	12-14 inches (bottom) 4-9 inches (top)

Table 2: *The second experiment. Two shapes were painted by both an expert painter and a novice, and their performance recorded.*

6 Conclusions

This paper has presented a spray paint simulation system. The primary purpose of this system is to train spray painters to use different paints and spray guns without wasting valuable paint. At the same time, the system gives very specific and helpful feedback about their performance. In addition to training spray painters, the system can also be used to evaluate the properties of new paint formulas without the need to actually manufacture the paint. Finally, user testing has been used to verify the system's usefulness as a training tool.

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