# 3D PAINTING: PARADIGMS FOR PAINTING IN A NEW DIMENSION

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**ABSTRACT**
This paper describes the design process of an innovative digital 3D paint program. The system enables industrial designers to paint surface details directly on rough 3D models for the first time. Contextual inquiry into designers' work inspired a real-world metaphor of painting a physical model. This provided the foundation for making 3D tools as natural to use as 2D. Familiar 2D digital painting paradigms, such as brushes, layers, and masks, were extended to 3 dimensions without adding complexity to the interface. Our informal evaluation sessions have shown that with a cursory introduction, designers who have never seen the interface were able to paint 3D models as easily as they could sketch.

**KEYWORDS**
3D Painting, contextual inquiry, direct manipulation, texture mapping

**INTRODUCTION**
With the growing use of computer-based 3D modeling tools by industrial designers, there is an increased demand to integrate painting surface detail with the conceptual design phase of product development. The process of texture mapping is currently available to add visual detail to a 3D shape without modeling. However, it is typically restricted to after-the-fact cosmetics rather than an integral part of the design process due to a complicated and indirect two-step interface. First, an image is created in a 2D paint package. The image is then projected onto a model using geometric mapping techniques in a modeling package. Since few complex surfaces match basic geometric shapes, the projection often fails, producing undesirable distortions such as stretching and seamlines[1]. The designer is then faced with the trial-and-error process of painting and aligning the image on the model to undo the distortions.

Research by Hanrahan and Haeberli explored an alternative method to paint directly on 3D shapes[2]. Their technique disregards the advantages of texture mapping by adding polygons to support the painted detail. The weight of the model can grow rapidly with each paint stroke. Although this method enables direct painting, it is impractical for rapid iterative design. Interactive performance is greatly decreased and more importantly each design alternative requires a unique model.

This paper describes the design of a 3D paint system that has been embraced by designers. It lets them work in their natural environment rather than focus on the mechanics and artifacts of technology. Designers can use familiar 2D and 3D techniques, such as airbrushing, patterning, and decaling to paint directly on 3D models. The paint interacts with the model surface and lighting environment to create a realistic representation.

**CONCEPTUAL MODEL**
We began to explore the system design using contextual inquiry to observe the work of two sets of users[3].

- The first group were industrial designers using traditional techniques to hand paint physical prototypes. They used painting, masking and decaling tools to increase the realism of prototypes for design evaluation.
- The second group were 2D and 3D computer artists working in entertainment and multimedia markets. The 2D artists use digital painting software to create images that are texture mapped onto the shapes modeled by the 3D artists.

Observing the work practice of these two domains provided both a traditional user model and an electronic system work model. The computer artists' work model is clearly embodied in the system itself[4]. Their work is more complicated than needed because they must account for the 3D distortions while painting in 2 D.

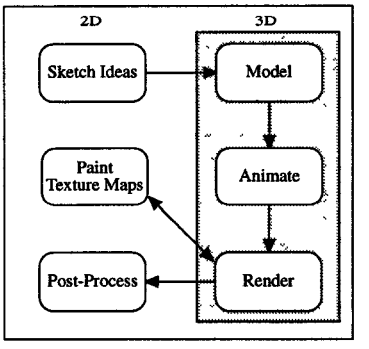

Figure 1: 2D/3D Workflow

Industrial designers' work practice inspired a real-world metaphor of painting a 3D model. We then abstracted this concrete metaphor to electronic media to eliminate the mechanics and artifacts of texture mapping. Most importantly, this new paradigm enables rapid design by integrating all aspects of the 3D creative process.

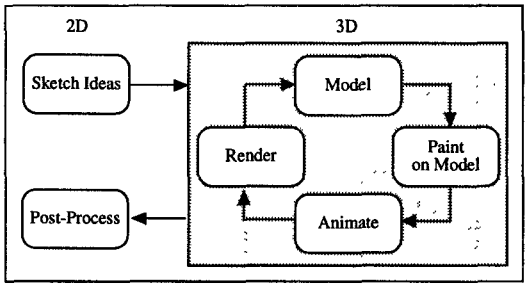


Figure 2: Integrated Workflow

We tested this conceptual model with both target user domains. The model was familiar and attractive to the industrial designer. However, the 2D computer graphic artists initially resisted the change. Not only did they fear that much of their expertise would be unnecessary, but they felt working in 3D would be too complicated. Only when were able to show them a much more detailed prototype did they embrace 3D painting.

## DETAILED DESIGN

Guided by what we learned from contextual inquiries into real-world 3D painting, 2D digital painting and 3D computer graphics, we set out to design the details of the system. Our primary goal was to make 3D painting as easy to learn and use as 2D and to make the integration of the two seamless. A secondary goal was to impose as few constraints as possible since we cannot predict the ways users will apply this new technology.

Our approach was to abstract the existing paradigms of 2D digital systems into 3 dimensions using the traditional painting techniques of 3D designers as a guide. We wanted to develop a suite of direct manipulation tools that would not simply mimic the standard toolset but would instead offer flexible new behaviors to enhance the creative process.

We started with layers, digital equivalents to transparent sheets of vellum that allow a designer to experiment freely by isolating changes. Using a shrinkwrap metaphor we extended flat layers to conform to a model's surface. Conventional 2D masks were abstracted to live on the surface of the model and thus duplicate the use of masking tape to paint a straight edge. We extended digital 2D pasteup to allow decals to slide over a model's surface conforming to its shape while rotating and scaling the artwork.

The next key question was how the user would switch between painting 2D or 3D. The most obvious solution is for the user to specify whether they are painting a model or an image, but this does not allow the flexibility to mix and match 2D and 3D effects. We explored creating separate 2D and 3D layers but this imposed too many constraints and was overly complicated. The simplest and most flexible solution was to add a 2D/3D button. All tools including brushes, washes, masks and pasteup either paint on a flat canvas or conform to the underlying 3D shape depending on the setting. By adding one button, we introduced a new functional area and let the user switch back and forth with ease.

We evaluated these designs with scenarios derived from the contextual inquiry and with informal usability testing at our site and the users' workplace. Using an early prototype, designers who had never seen the interface painted models with only a cursory introduction and even competed for the best 3D painting at a national design conference. The integration of 3D turned out to be so natural to many traditional designers that they did not realize they were using a 3D product.

## DISCUSSION

We have shown how contextual inquiry can contribute to designing easy-to-use 3D products. By grounding our design in the user's work practice, our early findings have shown that we were able to successfully match to the user's model. Users can focus on their jobs instead of the mechanics and artifacts of technology. We will be conducting more rigorous usability studies in design studios to test these findings.

In the future, we would like to incorporate more physical qualities of paint, painting techniques and surfaces such as viscosity or thickness, 3 dimensional positioning of airbrushes, and surface polish or roughness to make the user metaphor richer and more realistic.

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