



Contents lists available at ScienceDirect

## Computers &amp; Graphics

journal homepage: [www.elsevier.com/locate/cag](http://www.elsevier.com/locate/cag)

## Technical Section

## Creativity enhancement of painterly rendering using a suggestive interface

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## ARTICLE INFO

## Article history:

Received 18 July 2017

Revised 5 November 2017

Accepted 6 November 2017

Available online xxx

## Keywords:

Non photorealistic rendering

Painterly rendering

Stroke-based rendering

Suggestive interface

Perceptual distance between images

## ABSTRACT

Non-photorealistic rendering (NPR) can use various parameters and techniques to automatically generate a wide range of images with different painterly appearances. However, a real painting is the result of a creative process, and traditionally, many artists have developed their own media, styles, and techniques. Fortunately, the computer can also be used in different ways, for instance, as a tool to support and enhance creativity. We propose a system to interactively generate a painterly image through a suggestive interface. After the artist intuitively selects a region, our system immediately offers different suggestions of NPR modifications. The multidimensional NPR parameter space is transformed in a more perceptual space by optimization, which is validated by a user study. The suggested images generated from sampled parametric variations are displayed according to our perceptual distance. Through the same interface, our system allows for refinement or exploration without any need to understand the various parameters involved in generating NPR effects. The interest of our suggestive interface is supported by another user study, where participants felt that it stimulated their creativity as they interactively and iteratively created painterly images by choosing suggested images for the selected regions. Another experiment showed that different viewers found the resulting images more creative than their initial automatically generated images.

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## 1. Introduction

Non-photorealistic rendering (NPR) [1] develops techniques to generate an image inspired by an artistic medium, style, and technique. Two types of approaches have been developed to support NPR. In one approach, tools are developed to simulate how devices affect media. They include brushes and stroke types, paint colors and types, canvases and papers, filters, erasers, transparencies, layers, etc.; all tools that mimic and enhance what an artist uses to create. In the other approach, various image transformations and processings are applied to a photo in order to produce an effect. They include gradients, edge detectors, resampling and filtering. Naturally, hybrid methods also exist to use the former on the latter, where the tools are interactively applied to the photo. Either way, the computer acts as a tool to support the user's actions.

Traditionally, many artists have developed their own medium, style, and technique. Producing a painting is a creative process. We can argue that although NPR tools can much simplify painting tasks, they are not truly aimed at enhancing user creativity. In this paper, we develop a prototype system that lets the computer provide more creative assistance to the user, without as much relying on his artistic skills or his understanding of the NPR parametric space.

Creativity can take several forms. Here, we consider that it emerges from the user iteratively defining a region and replacing it by his choice of an image among suggested generated images, sampled through a potentially large parametric space of NPR methods and parameters.

Our strategy has therefore been to let the computer inspire the user through suggestions. This is similar in essence to the original work of Sims [2], followed by the *Design Gallery* approach [3] (we call it a suggestive interface). Both methods let the user navigate through a complex parameter space by interactively picking a favorite image in a set of suggested images, and refining the process by suggesting new images parametrically closer to the previous choice.

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However, such a system does not efficiently enhance creativity if it only suggests images at random or very similar to each other. To enhance creativity, suggestions should include notions of unpredictability and controllability [4]. Through a mapping of image perceptual distance in painterly parameter space, our suggestions are ordered by distance, where perceptually nearby images allow for controllability and refinement, while further images allow for unpredictability and exploration. As we have observed in our development, the fine-grain order is not as critical as much as the global order, or ordered sets, with nearby images vs. semi-distant images vs. distant images.

We propose a complete workflow in the form of a prototype system for generating a painterly image with a suggestive interface. Starting from a photo, the user selects a draft amongst many suggested painterly images. Next, he selects a region by painting over it, and refines its associated details of the painterly image by choosing one generated image from the ones suggested by the system. Iterating over this process, the user converges to his composed painterly image, while never needing to understand the parameter space nor to develop specialized painting skills.

Because we wanted to focus more on the process itself rather than on NPR tools, we decided to develop a simpler system as a prototype for painterly image generation that realizes the above concepts. To evaluate our strategy, we conducted a user study. The participants were very satisfied by our system, feeling that our system stimulated their creativity as they interactively created paintings. This was also supported by comparing automatically generated painterly images with user-modified painterly images with our system.

In summary, this paper offers the following contributions for generating a painterly image:

*Enhancing creativity:* We propose a method that makes efficient suggestions with unpredictability and controllability in a suggestive interface, ordering NPR images perceptually.

*Integrating in a painting workflow:* To satisfy the user's preference, we propose a painting workflow exploiting a suggestive interface. The user selects a base image and then interactively and iteratively improves on it by selecting regions and replacing them with suggested images. We also propose algorithms to realize the workflow.

## 2. Related work

### 2.1. Stroke-based rendering

A painterly image can be generated with a stroke-based approach. There are many methods to define stroke locations, their shapes and individual appearances, their layouts and overlays, etc. Hertzmann [5] and Vanderhaeghe and Collomosse [6] detail these methods in surveys.

The pioneering work of Haeberli [7] proposes to generate a painterly image by a distribution of brush strokes. Each brush stroke has several parameters, such as a location, an orientation, a size, a color, and a texture type, all derived according to Haeberli's work. Even as today, state-of-the-art painting systems, such as the one from Benedetti et al. [8], are based on this method.

Our painterly image generation is based on Haeberli's method. However, to control a painterly image, our system is also inspired by other contributions, such as for stroke locations and sizes [9], interpolating stroke orientations [10], and color transfer [11]. Details of our painterly image generation are described in Section 4.1.

### 2.2. User-specified painterly rendering

The best way to generate a painterly rendering satisfying the user is of course that he paints it himself. For example, some

systems [12,13] provide functionalities for creating rich painterly images. Unfortunately, they require to be familiar with a painterly system, as well as to be a talented artist.

Some painterly systems are devoted to novice users. Lu et al. [14] propose a system that translates query strokes into expressive strokes using stroke data created by artists. In the system of Benedetti et al. [8], the user paints locations of changes with a brush tool, and the painting is generated interactively. A similar solution is to manually paint/edit intuitive maps [15,16]. Finally, another solution is to analyze the context of the input image in order to determine where to generate painting effects [11].

In our system, the user needs only to identify regions that he would like to improve and to select his favorite suggested image, similar to the map edition approach. Therefore even a novice user can easily create painterly images without any knowledge nor manipulation of complicated NPR parameters. Contrary to map edition, our system proposes new results for the selected regions with a suggestive interface.

### 2.3. Suggestive interface

The suggestive interface proposed by Marks et al. [3] inspired us on how to present various results to the user.

There are many applications of suggestive interfaces. Igarashi and Hughes [17] use a suggestive interface for 3D drawing. When the user gives a hint of geometric components to the system, the system infers possible operations from the hint and suggests results of the operations as thumbnails. Murugappan et al. [18] propose a method to drive beautification of freehand sketches using geometric constraints. The system interprets ambiguous freehand sketches and suggests beautified sketches to the user. In assembly-based 3D modeling, Chaudhuri et al. [19] define a probabilistic graphical model that encodes semantic and geometric relationships among shape components. The system suggests suitable components of the assembled 3D model using the probabilistic graphical model.

Our goal is a system to enhance user creativity. Most of the above research contributions have different goals from ours. To enhance creativity, suggestions should include notions of unpredictability and controllability [4]. Their suggestion methods do not have unpredictability and controllability. On the other hand, our method does not suggest only results with high confidence of user's preference, but also results with some unpredictability and controllability.

In 3D modeling, Xu et al. [20] propose a method to enhance creativity by using user's preference (controllability) and randomness (unpredictability) for suggestions. Their application domain and the layout of suggestions are different than in our work. Our layout of suggested images is a key component of the effectiveness of our approach, with similar (nearby) images to the left of the scrolling display, and more and more different images further to the right.

## 3. System overview

Several NPR methods aim at producing an image that looks like a painting from a photo. However, creating a painting is much more often a creative task. Therefore, instead of offering sets of not-always-intuitive parameters to tweak in order to achieve automatic results, we propose a suggestive interface [3] to support and enhance user creativity. This section describes our system workflow and its suggestive interface.

The workflow, summarized in Fig. 1, follows these steps:

*Step 1:* First, the user selects an input photo from which our system, using NPR methods described in Section 4.1, generates many painterly images by varying values for different parameter

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