Computational Aesthetics in Graphics, Visualization, and Imaging (2009)
O. Deussen and P. Hall (Editors)

Automated landscape painting in the style of Bob Ross

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Abstract

We present a system that can generate convincing synthetic landscape paintings with no user intervention whatsoever, nor any information about 3D geometry or lighting. The system is based on a direct implementation of the "wet-on-wet" oil painting technique taught by Bob Ross for many years on his show The Joy of Painting. We implement a canvas model and a set of brushes that correspond to the canvas and brushes that Bob Ross used on his show. We then compose brush strokes into landscape features that replicate his approach stroke by stroke. Finally, we develop an engine for automatic layout of these features in a painting. We demonstrate this automated system in the context of the Bob Ross painting Forest Hills.

Categories and Subject Descriptors (according to ACM CCS): I.3.4 [Computing Methodologies]: Computer GraphicsGraphics Utilities J.5 [Arts and Humanities]: Fine arts

1. Introduction

The field of non-photorealistic rendering was motivated in part by the desire to capture and reproduce the appearance of specific artistic styles and media. In some ways, this goal has been achieved many times over; we can routinely render interpretations of images and three-dimensional scenes in a wide variety of traditional artistic media, as well as more generic painterly styles.

More difficult is the problem of reproducing the style of any particular artist. We have seen some success when the style is based on restrictions in colour or technique, as in Seurat's Pointillism [Her98] or Pollock's abstract expressionism [LOG06]. But in general, an artist's style encompasses choices of media, colour palette, tools, dynamics, composition, and subject matter. Moreover, we usually have only the finished canvases (or worse yet, photographs of them) to work from, and almost never the "performance" of those canvases. Rarely do we have an artist's account of how they paint, and when we do those accounts often obfuscate or even outright contradict their actual approach.

One way to understand an artist's technique is to observe them firsthand as they work. If time or circumstances put artists out of reach, a related strategy is to use instructional material carefully designed by a specific artist. The latter possibility is perfectly exemplified by Bob Ross. Between 1983 and 1995, Ross hosted over 400 episodes of an instructional television program called "The Joy of Painting". In every half-hour episode he created a complete oil painting, explaining every step along the way. He also released a number of books and videos, which continue to be sold today (see `www.bobross.com`). Ross's mission was to instill a love of painting in novices and foster their talents.

Bob Ross is an ideal subject for research in computer-generated art. We have images of his finished works, combined with his written and spoken explanations of how to produce them. Even better, we have a complete video record that captures every stroke and every mixture of paint. Though the artistic merit of his finished works might be subject to debate, one observation is inescapable: Bob Ross is probably the most well documented artist in all of history. He can serve as the exemplar for computer simulation of an artist's style, a stepping stone to other artists whose work is not accompanied by so extensive a record.

Bob Ross used the traditional "wet-on-wet" oil painting technique in which new paint is blended onto a canvas without letting the current layer of paint dry. His approach was streamlined, reliable, forgiving, and highly accessible. He used a small set of brushes and pigments and a limited vocabulary of strokes. At a higher level, his paintings had a consistent layout and iconography. A typical canvas may have a background sky behind distant mountains, with a lake

DOI: 10.2312/COMPAESTH/COMPAESTH09/115-122

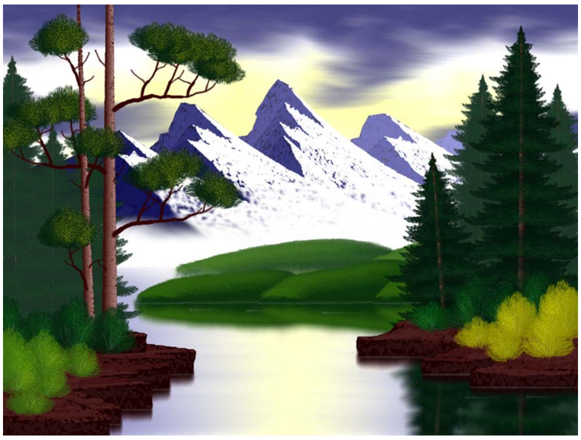


Figure 1: *A rendering of Bob Ross's painting Forest Hills, created automatically by our system.*

or river in the foreground framed on the sides by trees. This degree of consistency suggests that Bob Ross's technique might admit a computer implementation.

On the other hand, Ross's landscapes are highly *inconsistent* (i.e., abstract) with respect to physical reality. He frequently summarized complex details like foliage with a few simple stabs of the brush. His compositions do not have any consistent 3D geometry or lighting information. His work is what Robert Bridson has called "psychorealistic": it is not based on any physical landscape, but evokes the same psychological response. In this respect, we can learn a lot about the stylized depiction of reality by studying his paintings.

In this paper, we present a proof-of-concept system that paints Bob Ross landscapes without any user intervention whatsoever. Our landscapes are variations of Ross's painting *Forest Hills*, chosen as a canonical example of his style. A sample painting appears in Figure 1. We simulate Bob Ross's style stroke by stroke, exploiting his ability to express plausible naturalistic detail with a few coarse brush strokes. We find that with sufficient information about this artist's use of paints and brushes, and his technique for creating and composing pictorial elements, we can indeed automate the painting process from start to finish.

This paper is primarily concerned with the high-level ideas behind our approach and our core contributions. Our goal here is not to communicate the technical details or features of our implementation, only the ways in which our design was influenced by direct observation of an artist at work. In practice, the system relies on a wide range of technical details: RGB colour values, brush geometries, stroke shapes, paint load amounts, brush pressures, stroke descriptions, and so on. These details can be found in the Master's thesis by Kalaidjian [Kal07].

Our system has a layered architecture. At the lowest level, we model the interaction of brushes, paint, and canvas (Section 3). We then compose brush strokes into complete landscape features, such as mountains and trees (Section 4). Finally, we create a complete landscape by placing individual features on the canvas (Section 5). Each of these layers is also accessible interactively, offering a painting program with varying levels of automation.

2. Related work

Little research attempts to encode the artistic process from start to finish. One well known example is Harold Cohen's AARON [McC90]. AARON creates compositions of human figures and plants, drawn in a contemporary illustration style that does not attempt to emulate any human artist. Gómez et al. produced art in the style of Mondrian [dSGL05]. Dodgson studied the amount of randomness in paintings by Bridget Riley [Dod08].

This paper is inspired more directly by previous work that emulates artistic media and styles. In Strassmann's early work on Hairy Brushes [Str86], a brush is simulated as an arrangement of bristles that hold ink and transfer it to paper and other bristles. Later work by Xu et al. [XTLP02] greatly augments the original model with realistic 3D bristle geometry and physical behaviour. Hertzmann's stroke model [Her98], later extended by Hays and Essa [HE04], made it easy to express different artistic styles by manipulating a set of intuitive parameters. These image-based techniques compute stroke locations and colours by analyzing low-level image features. Yu et al. used an image-based approach to place textured strokes in the simulation of Chinese landscape paintings [YLP03]. Curtis et al. presented a physical simulation of watercolour painting [CAS*97], though the convincing shortcuts taken by Bousseau et al. [BKTS06] are of greater relevance to our work. There have also been convincing simulations of pencil drawing [SB00], and Pollock-style jets of paint [LOG06].

Our paper is based on Bob Ross's wet-on-wet oil painting technique. Baxter et al. studied the physical simulation of viscous paint flow on canvas [BLL04, BWL04]. Given suitable programmatic control, Baxter's system could serve as the basis for our implementation. We chose to develop our own low-level library (explained in the following section), in which we deliberately sought the simplest possible implementation that would support Bob Ross's style.

3. Canvas and brushes

Rather than attempting to reproduce the physical behaviour of oil paint, it suffices to construct the simplest simulation possible, however physically unrealistic, that captures the visual quality of the brush strokes used by Bob Ross. This point of view allows us to omit many complex details. The texture of the canvas is irrelevant, because Ross covered his canvas with a layer of liquid white paint before starting. For the sake of simplicity, he also deliberately suppressed most of the nontrivial dynamic properties and three-dimensionality of oil paint. We are left primarily with colour blending as the feature of real paint that we must support. We have developed a simple, ad hoc model of a canvas and brushes that accommodates Bob Ross's technique.

3.1. Painting Entities

The basis of our brush model is the "Painting Entity" (PE), an abstraction that functions like a bristle in a Strassmann-style hairy brush. Unlike more recent research, a PE has no geometry, only a current location at which it may interact with the canvas. Every PE also has a current paint colour and load (the amount of paint on the brush).

A PE deposits a drop of paint by blending its paint colour with the colours of canvas pixels in a 3x3 region around the PE's location. The blend amounts are chosen uniformly at random from intervals, with more weight given to the central pixel. At the same time, the PE colour is blended with a small fraction of the canvas colour to simulate the transfer of paint from the canvas back onto the brush.

To drag a PE along a path, we create a piecewise linear approximation of the path, rasterize it, and deposit a paint drop at every rasterized pixel in turn. Bob Ross also made frequent use of "stab" strokes, in which bristles would leave marks by flattening into short paths on the canvas. We simulate stabs by moving PEs along short line segments in a controllable stab direction.

A PE loses a small random amount of load after every drop (the randomness leads to paint striations at the ends of strokes). When the paint load goes to zero, a dry brush is still able to blend paint already on the canvas (an important part of Bob Ross's technique).

3.2. Brushes

Most of the time, Bob Ross painted landscapes with a limited arsenal of implements: one- and two-inch brushes, a round brush, a filbert, small and large fan brushes, a liner brush, and small and large palette knives. We simulate all of these via suitable arrangements of PEs relative to a local brush coordinate system. The footprints of the filbert and fan brushes can change depending on pressure. The brushes and knives, together with the pressure-dependent effects, are all demonstrated in Figure 2.

The PEs that make up the palette knife are treated differently than those belonging to regular brushes. First, they do not acquire paint from the canvas. Real paint tends to "roll" off the palette knife, suppressing blending effect. Also, when its paint load drops below a threshold, a PE may with a certain probability be be disabled temporarily. The gap left behind on the canvas gives the appearance of breaking paint. Bob Ross used this behaviour to model patchy snow on mountains.

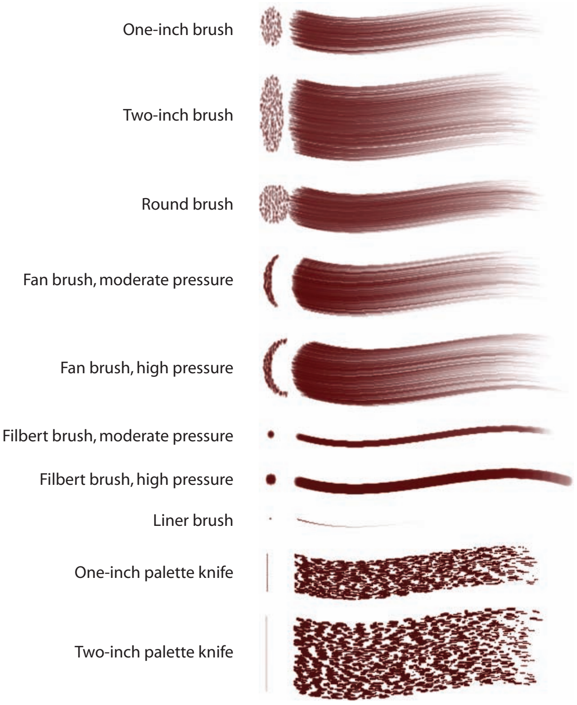


Figure 2: *Samples of strokes produced by the brushes in our system. Each row shows a single stab followed by a longer Bézier stroke. Some brushes are shown twice, to show the effect of varying stroke pressure.*

4. Landscape features

At this point, the canvas and brush model in the previous section is perfectly functional as an interactive painting program reminiscent of commercial tools such as Corel Painter. More importantly for this project, it serves as an infrastructure upon which we can automate the features Bob Ross used in his landscape paintings. Every feature is a procedural description of a set of strokes that yields an object from Bob Ross's repertoire. There is no underlying geometry or lighting information, just paint colours and stroke trajectories.

After studying many episodes of The Joy of Painting, we have divided Bob Ross's vocabulary of stroke trajectories into a small number of categories: stabs, straight line segments, parabolas, and circles. Occasionally he also uses more complex curve trajectories, which we model with Bézier curves. Every long stroke can also be jittered by randomly displacing the vertices in its piecewise linear approximation.

We focus our investigation on a prototypical example of Bob Ross's work, *Forest Hills* (Season 9, Episode 7). This painting requires eight landscape features: WISPY SKY, SNOWY MOUNTAINS, LAKE, ROLLING HILLS, EVERGREEN TREE, DECIDUOUS TREE, ROCKY SHORE, and

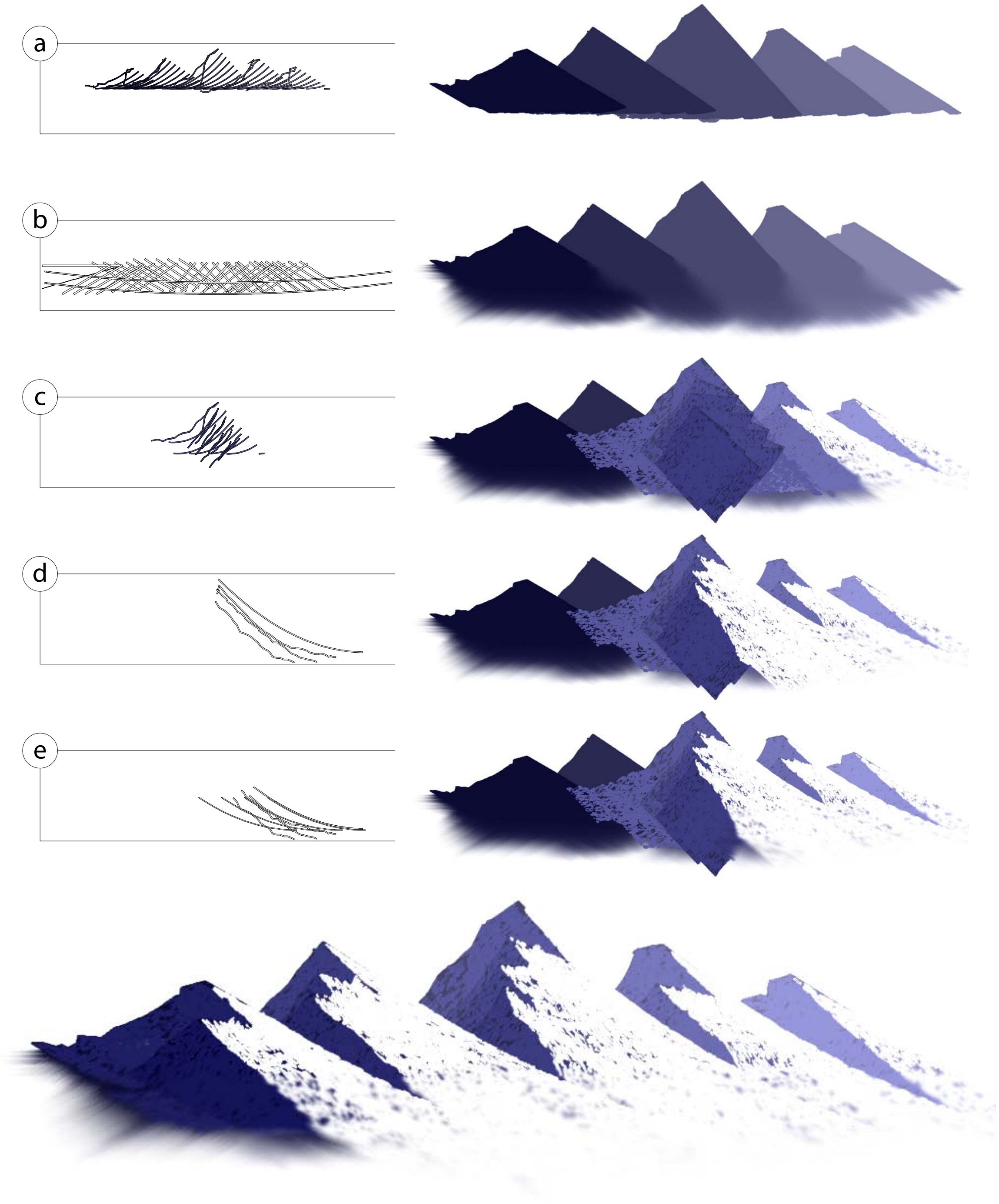


Figure 3: *Painting a* SNOWY MOUNTAINS *feature. The major steps in the painting process are shown, with the strokes illustrated schematically on the left and the resulting intermediate images on the right. The undercoat is shown freshly painted in (a) and blended with a dry brush in (b). In (c), the two most distant peaks are complete, and the shadow colour has been applied to the central peak. The illuminated snow is applied in (d), and the central peak's snow is blended in (e). Most paint strokes are parabolic and applied with the palette knife; the blending strokes use the two inch brush. The finished painting is shown at the bottom.*

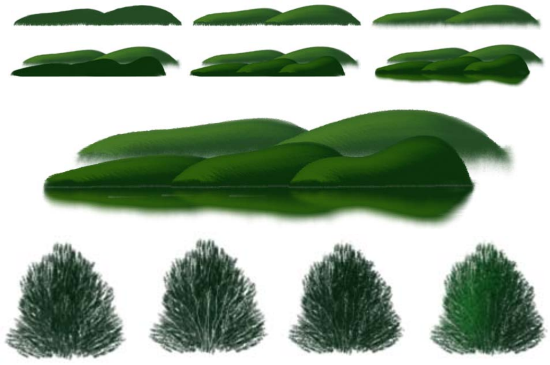


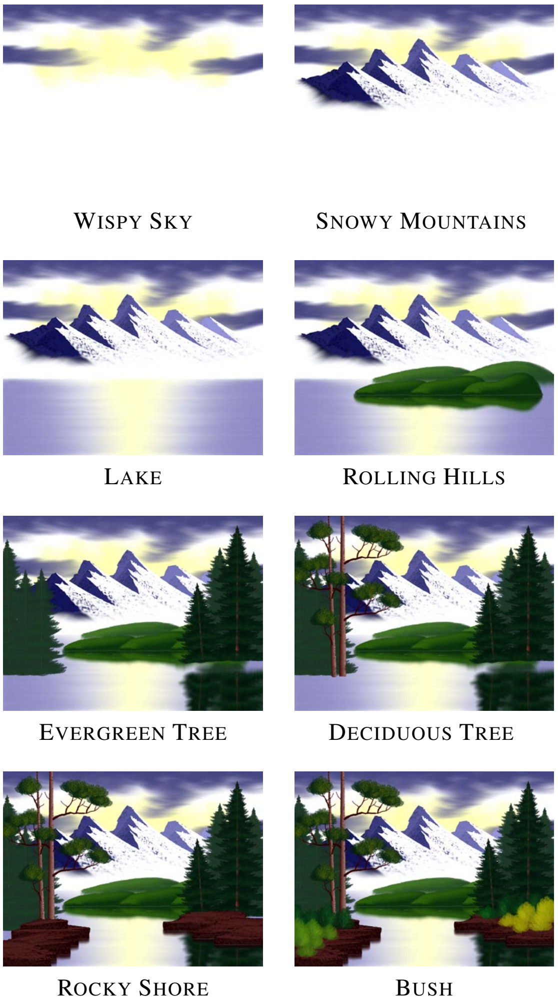
Figure 4: *Steps in the constructions of the* Rolling Hills *and* Bush *features.*

Bush. We describe Snowy Mountains as a typical example. This feature consists of a range of distant snow-covered peaks. Bob Ross painted this feature in several stages. First, he used the palette knife to paint an "undercoat", a shadow colour that fades peak by peak to give a sense of atmospheric attenuation. The undercoat is blended extensively at the base of the mountains with the two-inch brush to conceal the lack of detail there; the mountain bases will appear to be shrouded in mist, and will largely be occluded by later primitives.

Ross then used the palette knife to paint snow on each peak in turn, from back to front. He would apply the knife with light pressure to draw breaking snow along one face in a shadow colour, and along the other face in an illuminated colour (this breaking effect can be seen in the sample knife strokes of Figure 2). Finally, he would use a dry brush to blend the snow at the peak's base downward into mist.

As shown in Figure 3, Bob Ross's approach can be translated directly into a computer implementation based on the canvas and brush model of Section 3. We paint the same stages, made up of the same strokes, using the same brushes. The paths of our strokes are derived by watching his brush motions on The Joy of Painting.

We have developed similar procedural descriptions for the other seven landscape features used in *Forest Hills*. The Wispy Sky and Lake are built up from several passes of paint and blending with a two-inch brush. The shapes of the Rolling Hills come from Bézier strokes. The leaves of the Evergreen Trees and Bushes come from stabs of the fan and one-inch brushes. (The leaves of the Deciduous Trees are just Bushes.) The sharp shoreline and Bush branches are produced with scratches of the palette knife. Some foreground features must be drawn in the Lake upside-down with low detail, which when blended will give the appearance of a reflection. Reflection is the only case of interaction between different landscape features.



Wispy Sky

Snowy Mountains

Lake

Rolling Hills

Evergreen Tree

Deciduous Tree

Rocky Shore

Bush

Figure 5: *A sequence of steps in the automatic construction of Forest Hills. The caption of each image indicates the landscape feature that was added one or more times to the previous image.*

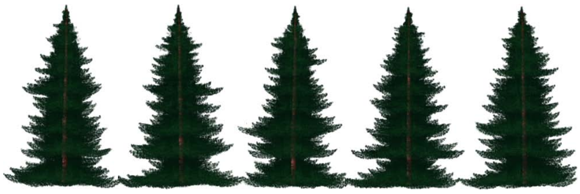


Figure 6: *A demonstration of the random variation in multiple paintings of the same* Evergreen Tree *feature.*

Figure 4 shows the steps in the construction of Rolling Hills and Bush. Full details regarding the construction of all landscape features can be found in Kalaidjian's thesis [Kal07].

5. Landscape layout

The system described so far is available directly via the user interface. Not only can the user paint with brushes interactively, they can also place entire landscape features with a single click of the mouse. In this section, we take the final step in generating landscapes: we automate the placement of the landscape features of Section 4 in a final composition. We have implemented a layout algorithm that creates paintings reminiscent of *Forest Hills*, though a similar analysis could be applied to many other Bob Ross landscapes. Figure 5 shows an evolving canvas to which the eight landscape features are successively added automatically by our landscape layout algorithm.

Understandably, Bob Ross used the "painter's algorithm": he would paint landscape features from farthest to closest. After each feature was complete, he would blend parts of it down into the canvas. He would control the brush to paint subsequent features on top without picking up lower layers of canvas paint.

In *Forest Hills*, Bob Ross first painted the WISPY SKY, SNOWY MOUNTAINS, and a LAKE. He covered a large part of the mountain base with several layers of ROLLING HILLS, growing inward from the edge of the canvas. Next, he painted EVERGREEN TREEs along the sides of the canvas, further covering the undefined parts of the mountains. Background trees are painted in a lighter colour and lower contrast, to add to the illusion of depth. He also painted the reflections of these trees in the LAKE. As he often did, he included one shorter tree, bent inward over the water. Opposite the foreground evergreens, he painted some overlapping DECIDUOUS TREEs. Finally, he painted a few layers of ROCKY SHORE and some BUSHes to sit on them.

Note how Ross carefully plans ahead, using foreground features to mask gaps in lower layers. The ROLLING HILLS cover up the lack of detail at the base of the SNOWY MOUNTAINS; the foreground BUSHes cover any exposed LAKE between the ROCKY SHORE and the EVERGREEN TREEs, and conceal the unattractive base of the DECIDUOUS TREE. This careful organization allowed him to complete a landscape painting in half an hour.

Our landscape layout algorithm consists of a sequence of invocations of the individual algorithms for the landscape features. The locations of the features are constrained as decribed above to ensure that artifacts or incomplete areas are occluded by other features in the finished painting. Our layout algorithm, combined with the techniques of the previous sections, can paint a finished landscape such as the example in Figure 1 with no user intervention whatsoever.

6. Theme and variations

Once the basic layout of *Forest Hills* has been achieved, the challenge becomes one of pushing the limits of variation while still adhering to the original theme. We do not wish to restrict ourselves to the same set of features in the same locations as the original *Forest Hills*. Throughout this work, we have made an effort to introduce sources of random variation. This variation arises at multiple levels:

1. Paint colours and load amounts for PEs in a brush;
2. Jaggedness of individual strokes;
3. Gross stroke shape, as in the shapes of the peaks of SNOWY MOUNTAINS or the curves of ROLLING HILLS;
4. Jittering of landscape feature locations; and
5. Overall compositional decisions, such as which ROCKY SHORE will receive the DECIDUOUS TREEs.

The first three sources of variation affect the painting of individual landscape elements, ensuring that every instance is unique. The trees in Figure 6 were all painted with identical high-level parameters, but are obviously different. The first four sources of variation guarantee that even with the same overall composition, every instance of *Forest Hills* will be unique. The paintings in Figures 1 and 7 exhibit many differences in layout, shape and texture.

The top-level compositional parameters must be chosen more carefully based on the source painting. In our implementation, the locations of many features are keyed to the placement of the DECIDUOUS TREEs. Figure 8 shows a version of *Forest Hills* in which the DECIDUOUS TREEs appear on the right. The opposite side of the canvas receives the break in the clouds, as well as the foreground EVERGREEN TREEs and their reflections. These variations were chosen carefully to maintain a balanced overall composition.

7. Implementation and results

Our painting system is implemented in C++ with an Fltk-based user interface. Though we did not implement any special hardware acceleration or software optimization, the painting program runs interactively on average hardware. When run with full automation, the program can paint an instance of *Forest Hills* in about twenty minutes (comparable to the duration of an episode of The Joy of Painting, minus discussion, paint mixing, and "beating the devil out of the brush"). We find it enjoyable and instructive to watch the paintings being created (as with The Joy of Painting itself).

Automatically painted instances of *Forest Hills* are shown in Figures 1, 7 and Figure 8. Two additional paintings are shown in Figure 9, demonstrating use of the system with greater manual intervention. The top painting demonstrates the use of a FLUFFY SKY feature, adapted from a different Bob Ross painting. This sky can easily be requested as the background for *Forest Hills* before automated painting. The bottom painting was created manually except for the trees, which are a variation of the EVERGREEN TREE feature with downward-facing limbs and snowy highlights.

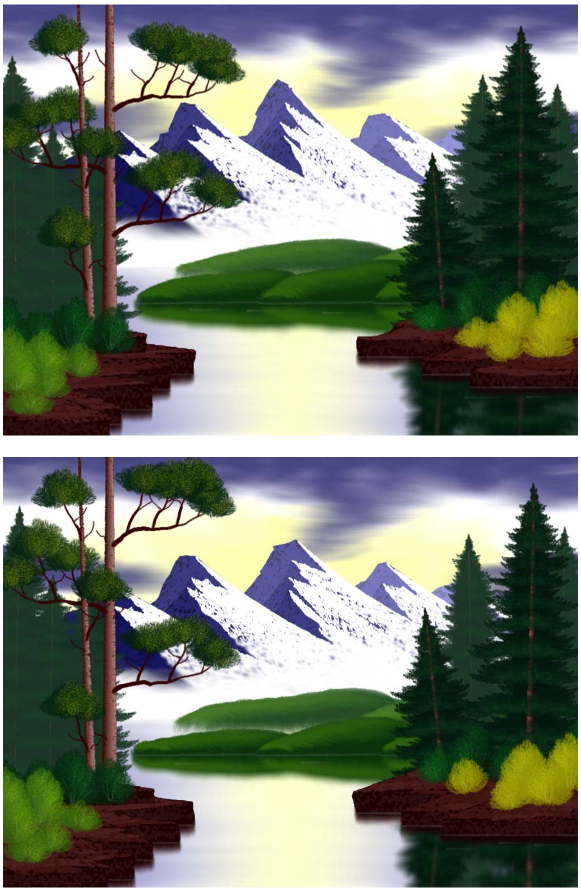


Figure 7: *Two instances of Forest Hills, painted with different randomly-chosen compositional parameters. Note the many small differences in the shapes and layouts of individual features.*

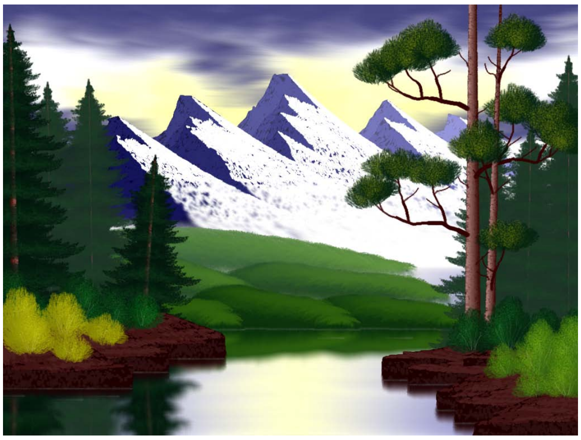


Figure 8: *An instance of Forest Hills in which foreground elements on the left and right sides of the canvas are swapped.*

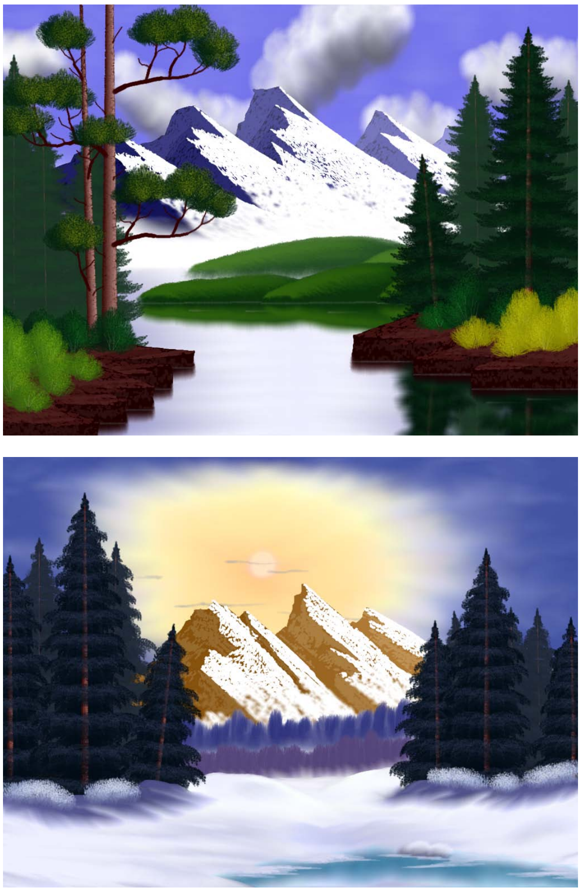


Figure 9: *Examples of paintings created using our system with varying levels of automation, as explained in Section 7.*

8. Discussion and future work

This paper shows that convincing computer-generated paintings can be generated without the usual necessities of geometry or lighting. The resulting paintings are certainly inconsistent, but the inconsistencies are like misdirection in magic or continuity errors in film—they are rarely noticed until one's attention is directed to them. In this regard, Bob Ross used many of the same tricks and conventions as any other landscape painter. By focusing on an appropriate set of visual cues, he was able to construct effective illusions with relatively little effort. It is the stroke-by-stroke record of his process that motivated us to single him out for study.

Our work is a proof-of-concept that establishes the feasibility of automated landscape painting. We know of no previous work that can create paintings of this kind entirely automatically. We could achieve this level of automation because the artist in question documented his technique so thoroughly. Armed with a detailed understanding of his approach, we might recognize many of the same visual tricks in the work of other artists, and use the same approximations when creating similar paintings digitally. Other artists might also be studied in a similar way by capturing their "performances" of paintings, or perhaps by deriving stroke information from detailed 3D scans of paintings.

We introduce a wide range of mechanisms for varying our paintings, but more possibilities exist. We would like to add to our repertoire of landscape features. With the addition of a few Bob Ross staples, such as ROCKY CREEK, DIRT PATH and SNOWY GROUND, we would be able to cover a very large set of his paintings. We would like to make it easier to add new landscape features to our system, perhaps by developing a concise script-based representation for them. Another approach would be to synthesize new instances of a feature automatically from a few user-supplied examples.

With a large vocabulary of features, the challenge would then be to automate landscape composition in a way that can dynamically mix features from different source paintings. To be general, such an algorithm would have to be based on high level geometric and semantic relationships between features, beyond the specific constraints of a layout such as *Forest Hills*. Features would need a way to indicate incomplete areas that should be covered later in the painting process (as in the base of the SNOWY MOUNTAINS feature). It may also be possible to derive a layout from a simple sketched description, or even a photograph.

This work could be applied in contexts where a non-specific landscape background is needed in computer-generated imagery. While we would not want to corrupt the technique by generating 3D geometry, it may be possible to associate $2\frac{1}{2}$D depth information with our landscape features. The paintings could then be incorporated more easily into games or animation.

Acknowledgments

The authors would like to thank Shalini Aggarwal, Bill Baxter, Andy Bearsly, Elodie Fourquet, Cindy Grimm, Doug Kirton, Ed Lank, Jie Xu, and Linda Zhou for contributions in the form of encouragement, feedback, ideas, prototypes, test runs and other interactions.

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