Learnable Stroke Models for Example-based Portrait Painting

Tinghuai Wang[1]
Tinghuai.Wang@surrey.ac.uk
John Collomosse[1]
J.Collomosse@surrey.ac.uk
Andrew Hunter[2]
Andrew.Hunter@hp.com
Darryl Greig[2]
Darryl.Greig@hp.com

[1] Centre for Vision Speech and Signal Processing
University of Surrey
Guildford, UK

[2] Hewlett Packard Laboratories.
Stoke Gifford,
Bristol, UK

The stylization of photographs into high quality digital paintings remains a challenging problem in computer graphics. In recent years, sophisticated *painterly rendering* algorithms have been proposed that rely increasingly upon Vision to interpret structure and drive the rendering process. Although such algorithms generate a pleasing aesthetic for many image classes e.g. scenic shots, they typically perform poorly on portraits. The human visual system has a strong cognitive prior for portraits, and is particularly sensitive to distortion or loss of detail around facial features (Fig.1, right). Yet such artifacts are frequently observed when applying general purpose painterly algorithms to photographs of faces. High quality rendering of faces is important, as many scenarios for artistic stylization focus upon movie post-production, or consumer media collections, which predominantly contain people.

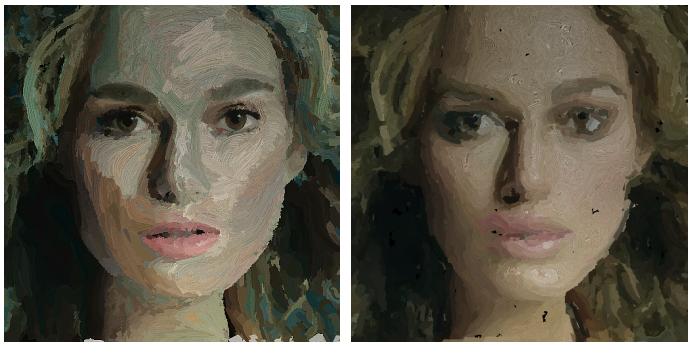

Figure 1: Portrait rendering using our algorithm (left), and a popular multi-resolution curved brush algorithm [2] (right). Facial details are preserved. Highlighting and stroke patterns were learned by example.

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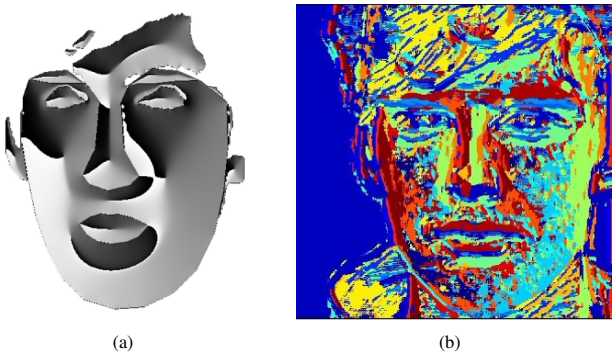
Our paper contributes a new stroke-based rendering (SBR) algorithm for stylizing photographs of faces into portrait paintings. SBR algorithms create paintings by compositing a sequence of curved spline strokes on a 2D canvas. In contrast to SBR algorithms that encode various rendering heuristics to target a particular artistic style, our algorithm learns the style of a human artist *by example*.

Given a photograph, and an ordered list of strokes (and related attributes) captured from a training session in which an artist paints that photograph, we are able to learn the artist's style and render previously unseen photographs of faces into portraits with a similar aesthetic. To enable our two core contributions; robust learning of styles, and the synthesis of high quality portraits, we harness Computer Vision to parse visual structure from the source image and drive our rendering process (Fig.2).



(a) (b)

Figure 2: Stroke parameters are learned local to each facial region according to visual structure.: (a) Orientation field and facial regions derived from ASM; (b) Codeword map inferred from dense SIFT and MRF.

Our algorithm is aligned with Image Analogies [1] and derivative techniques that learn non-parametric models of image filters from a pair of unfiltered and filtered greyscale images. Such systems are able to learn filters, including edge preserving filters reminiscent of a painterly effect, by sampling pairs of corresponding patches from the two images. The learned filter is applied by looking up patches from the new image. Our approach differs as we train at the level of the stroke, learning how the placement and appearance of each brush stroke is modulated according to underlying visual features in the training image. As such, our approach is specialized to the task of painting, enabling a wide variety of artistic styles. We specialize further to portraits by learning stroke models independently within semantic regions of the face, identified using an Active Shape Model (ASM) and Graph Cut. Image features are composed using a Markov Random Field (MRF) model to ensure spatial coherence of stroke style during learning and rendering. To the best of our knowledge our system is the first to explore portrait stylization by example at the level of the stroke.

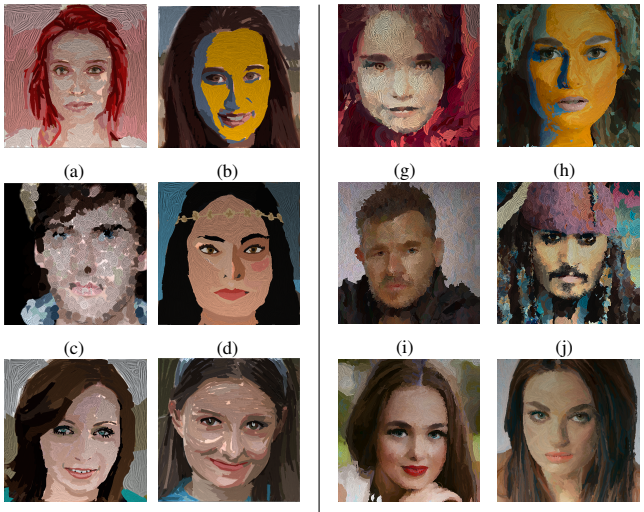


Figure 3: (a-f) Style training paintings: (a) Warm color; (b) Shading using complementary color; (c) Blobby strokes; (d) Thick, haphazard strokes; (e) Natural color, medium thick strokes; (f) Long strokes for hair. (g-l) Renderings using models learned from (a-f).

We are able to depict faces without the loss of salient detail exhibited by more general painterly methods [2] and without relying on a pre-painted arrangement of strokes to warp over the face as in the most closely aligned prior work by Zhao *et al.* [3]. In contrast to warping pre-captured stroke maps, we algorithmically place strokes as a function of image content presenting the first portrait painting algorithm to learn stroke style parameters by example (Fig.3).

[1] A. Hertzmann, C. Jacobs, N. Oliver, B. Curless, and D. Salesin. Image analogies. In *Proc. ACM SIGGRAPH*, pages 327–340, 2001.

[2] Aaron Hertzmann. Painterly rendering with curved brush strokes of multiple sizes. In *Proc. SIGGRAPH*, pages 453–460, 1998.

[3] Mingtian Zhao and Song-Chun Zhu. Portrait painting using active templates. In *Proc. ACM NPAR*, pages 117–124, 2011.