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Image stylization by interactive oil paint filtering

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ABSTRACT

This paper presents an interactive system for transforming images into an oil paint look. The system comprises two major stages. First, it derives dominant colors from an input image for feature-aware recolorization and quantization to conform with a global color palette. Afterwards, it employs non-linear filtering based on the smoothed structure adapted to the main feature contours of the quantized image to synthesize a paint texture in real-time. Our filtering approach leads to homogeneous outputs in the color domain and enables creative control over the visual output, such as color adjustments and per-pixel parametrizations by means of interactive painting. To this end, our system introduces a generalized brush-based painting interface that operates within parameter spaces to locally adjust the level of abstraction of the filtering effects. Several results demonstrate the various applications of our filtering approach to different genres of photography.

1. Introduction

Image-based artistic rendering received significant attention in the past decades for visual communication, covering a broad range of techniques to mimic the appeal of artistic media [1]. Oil paint is considered to be among the most popular of the elementary media because of its qualities for subtle color blending and texturing [2]. Starting with the beginning of semi-automatic painting systems in 1990 [3], stroke-based techniques that align and blend primitives on a virtual canvas have been the pre-dominant category to simulate oil paint [4]. While their example-based texturing approach is able to provide high-quality outputs of expressive nature and great opportunities for layering, however, stroke-based techniques are usually hard to parameterize to simulate paint with soft color blendings or no visible borders—e.g., as practiced in the Renaissance era (such as *sfumato* [5]) and prevalent in many figurative art works (Fig. 1). To this end, image filtering is a promising alternative approach to produce painterly looks with more subtle color blendings—in particular with the recent advancements in shape-adaptive smoothing [1], such as anisotropic diffusion [6] and shock filtering [7]. Simulating the visual characteristics of oil paint via image filtering, however, is a difficult task with respect to three main issues:

I1 The color distribution should be optimized to conform to a global color palette while preserving contrasts of important or prioritized features.
I2 The paint texture should be oriented to the main feature curves to mimic the way an artist might paint with a brush.
I3 The stylization process should be locally adjustable to enable creative control over the visual output.

In this work we present a technique for image stylization that employs (re-)colorization and non-linear image filtering to devise artistic renditions of 2D images with oil paint characteristics.

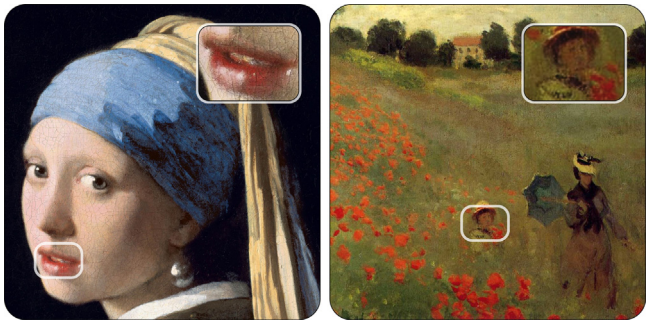

Fig. 1. Oil paintings by J. Vermeer (1665) and C. Monet (1873). The artists use constrained color palettes with soft color blendings, two characteristics we simulate by our filtering technique.

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0097-8493/

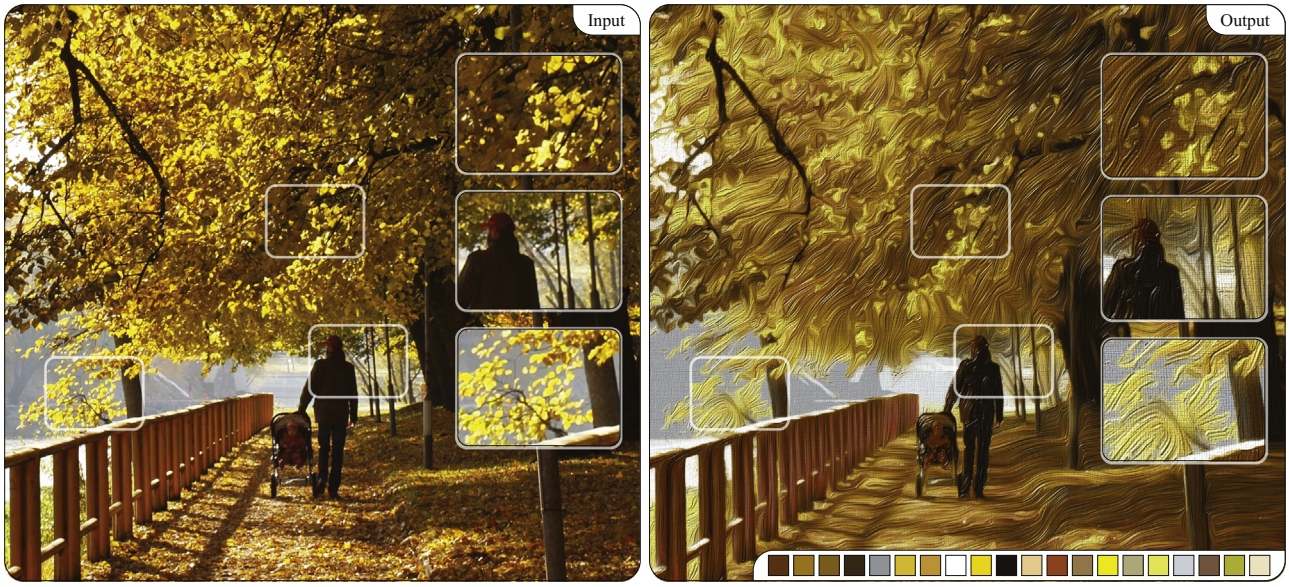

Fig. 2. Exemplary application of our technique to automatically transform a color image (left) to a filtered variant with oil paint characteristics (right). (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this paper.)

Rather than attempting to simulate oil paint via aligned strokes [3,8–10] or through physically based techniques [11,12], this work formulates I1 to I3 as sub-problems of image filtering (Fig. 2). The first problem is solved by performing a recolorization, using the optimization-based approach of Levin et al. [13], with the dominant colors of the input image for quantization. This approach produces more homogeneous color distributions than local image filtering techniques and gives users more control in refining global color tones. The second problem is solved using the smoothed structure tensor [14], which is adapted to the feature contours of the quantized output, together with principles of line integral convolution [15] and Phong shading [16] to obtain a flow-based paint texture in real-time. Finally, the third problem is addressed by an interactive painting interface that implements GPU-based per-pixel parametrizations via virtual brush models to give users local control for adjusting paint directions, shading effects, and the level of abstraction. Our approach provides versatile parametrization capabilities to resemble paint modes that range from high detail to abstract styles.

This paper represents an extended journal version of the CAe 2015 paper by [17]. Compared to the original paper, the major contributions are twofold: (1) we provide new methods to parametrize our local filtering effects according to image masks (e.g., derived from saliency-based metrics) and create outputs of varying level of abstraction, and (2) we expand our original algorithms towards an interactive painting system with brush tools for creative image editing. Accordingly, the remainder of this work has been restructured as follows. Section 2 reviews related work on image stylization and filtering, color quantization, and paint texture synthesis, now including topics such as brush-based painting and level of abstraction for stylized renderings. Section 3 presents the methods used for oil paint filtering, including extended methods to adjust the level of abstraction according to importance masks, e.g., using depth or saliency-based information. Section 4 proposes our interactive painting interface with brush tools to locally adjust paint configurations and the level of abstraction. Section 5 presents further results and implementation details, including comparisons to previous stroke-based techniques and an updated prospect on future work. Finally, Section 6 concludes this paper.

2. Related work

Related work is found in the fields of image stylization and filtering, color quantization, paint texture synthesis, and brushed-based painting interfaces.

2.1. Image stylization and filtering

For artistic image stylization, three approaches can be distinguished: (1) stroke-based and example-based methods, (2) region-based techniques, and (3) image filtering [1]. A classical method for stroke-based stylization is to iteratively align brush strokes of varying color, size, and orientation according to the input image [3,8,18,9,10,19,20]. For an overview on this topic we refer to the survey by Hegde et al. [21]. Example-based rendering typically involves texture transfers by image analogies [22], a method previously used to create portraits with a painterly look [23,24] and in neural networks to mimic painting styles [25], but which typically requires training data as an input. An essential building block for region-based stylization is segmentation. Several methods based on a mean shift have been proposed for image abstraction [26,27] and the simulation of artforms and fabrics, such as stained glass [28] and felt [29]. However, the rough boundaries of the segmented regions created by these methods would require elaborate post-processing to achieve color blending characteristics of oil paint.

To substantially modify areas or image regions, local image filtering that operates in the spatial domain may be used, which is often based on anisotropic diffusion [6]. A popular choice is the bilateral filter, which works by weight averaging pixel colors in a local neighborhood according to their distances in space and range [30], e.g., for image-based abstraction [31]. Flow fields have been used to adapt bilateral filtering [32,33] and particle-based techniques [34] to local image structures. In this work, quantized color outputs are smoothed by flow-based Gaussian filtering to provide smooth interpolations at curved boundaries, however, we restrain from weighting in the color domain to achieve firmer color blendings.

Additional filter categories include morphological operations using dilation and erosion (e.g., for watercolor rendering [35]), and global optimization schemes for image decomposition, such as

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