Optik 125 (2014) 4624–4628

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

An extended flow-based difference-of-Gaussians method of line drawing for polyhedral image

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ARTICLE INFO

Article history:
Received 21 September 2013
Accepted 24 April 2014

Keywords:
Non-photorealistic rendering
Line drawing
Edge detection
Flow-based filtering

ABSTRACT

This paper presents a non-photorealistic rendering technique for stylizing a photograph in the line drawing style. The flow-based difference-of-Gaussians (FDoG) filter constructs lines of style and quality, which usually used to extract the line drawing for some images. In this paper, we inspired by the polyhedral image feature (the line of which are mostly straight line), proposed the method based on the standard FDoG to extract the line drawing of polyhedral image. First, we detect line by fast line segment detector with a false detection control (LSD); then construct a smooth and coherent edge tangent flow (ETF) of the polyhedral images. On the basis of the ETF, the anisotropic FDOG is used to render the lines. This scheme gives clear line features for polyhedral images without much noise, which is also simple and easy to implement, and is robust. The experimental results prove that our algorithm is more efficient than the traditional FDOG approaches in render line drawing for polyhedral image.

1. Introduction

Non-photorealistic rendering (NPR) is the effective integration of computer science and artistic, which can be divided into three classes according to the type of the input image: 2D, 3D and cartoon. Many researchers have been dedicated to non-photorealistic rendering (NPR) techniques in order to create a wide variety of expressive styles such as painting, drawing, technical illustration, and animated cartoons. Line drawing is one of the most popular styles using in NPR applications, which is able to use the minimum lines observing the shape of objects effectively as the simplest and the oldest visual expression method. In aspect of visual information transfer and subject identification, line drawing's effect is even better than the real photograph, because it focuses on capturing and conveying meaningful features while minimizing possible distractions from relatively insignificant details. Nowadays, most of the line drawings are addressed by existing edge detection or image segmentation techniques, such as literature [1], where a system is developed for interactive pen-and-ink illustration. In the system, an edge detector [2] is used to construct the outline strokes and clip the interior strokes. The same method is used to similarly clip the paintbrush strokes and preserve feature line [3–6]. Furthermore, DeCarlo and Santella [3] employed the edge detector to produce line drawing and the mean-shift filter [7] to perform region smoothing and segmentation. However, most of the methods used the canny edge detector; the canny edge detector often fail to qualify as good illustrations, and is too computationally expensive, so cannot be used in real-time applications. Orzan et al. [6] developed a multi-scale image abstraction system based on the canny edge detector and the gradient reconstruction method. Kang et al. [5] showed that it is also possible to obtain image abstraction via stroke-based rendering, constrained by the lines generated from a modified canny edge detector. While canny edge detector [2] has been often used for line drawing, there are other line extraction methods as well. Gooch et al. [8] developed a facial illustration system according to the Marr–Hildreth edge detector [9] based on a difference-of-Gaussians (DoG) filter, both of them used the filter in conjunction with binary thresholding to produce a black-and-white illustration. Recently, Winnemöller et al. [10] extended the DOG filter through a slightly smoothed thresholding function to increase the temporal coherence in general color images and video, employing the DoG filter for line drawing and the bilateral filter for region smoothing. The DoG edge model is more effective for artistic illustrations than canny method because it can capture interesting structures better (as shown in literature [8]), and produce a set of stylistic edges automatically (in non-uniform thickness). Although the DOG filter

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http://dx.doi.org/10.1016/j.ijleo.2014.05.031
0030-4026/

is better, the aggregate of edge pixels may clearly reveal the sense of 'directedness' (and thus may look less like lines) because of the nature of isotropic filter kernel. In addition, the threshold edge map may exhibit some set of isolated and scattered edge components that make the output clutter, especially in an area with noise or weak contrast.

We expect improving the edge coherence by adjusting the threshold, but the results are even poorer due to added noise. Kang et al. [11] presented a flow-based difference-of-Gaussians (FDoG) filter that automatically generates a high-quality stylistic line drawing from photograph. Firstly, they used a kernel-based nonlinear vector to smooth and preserve the feature of local edge tangent flow (ETF), and then they used the FDoG filtering technique to directly produce the line illustration. Fast separated implementations of the FDoG filter with comparable high-quality results have been developed in [12,13]. In addition, such flow-based filtering frameworks are widely adopted in various image and video abstraction applications [12–16]. Winnemöller extended the DoG method in further and proposed the XDoG algorithm, achieved much effect of styles rendering [17].

The line drawings, though they consist of only line segments on a plane, convey much information about three-dimensional object structures; when we see them, we can easily understand what is represented there. The line drawings are widely used in various fields of human communication, especially for the engineering drawings of mechanical parts, the architectural design; these objects that can be considered are polyhedrons. In real life, we are often attracted by chiseled line of the objects, when we observe the polyhedral objects, we find its line and contour are clear, its art style show by its outer profile. In addition, designers often use line drawings to show the design art during design process, enhance art expressive force of the objects in space, and make the overall performance of polyhedral object more rich and perfect. We see all kinds of variety of lines in polyhedron objects, cross section and its contour lines, vertical lines of decorative wall, the window lines, axis of mechanical parts, and so on. Most of these lines consist of straight lines, broken lines and slash lines. Lines enhance ensemble expression of polyhedron; make the ensemble expression and the function of the polyhedron object richer and more perfect. At present, most of the line drawings about polyhedron objects are manual. Though there are some drawing methods [18–20], abstract rendering of line drawing about polyhedron image is less, so we proposed a automatic method of line drawing rendering of polyhedron image. Firstly, the straight of the polyhedron image is detected by LSD algorithm (the LSD method has better performance comparing to Canny or Hough method in line extraction), then reconcile with the original gray image. Finally, we use the ETF and FDoG reaching to the line drawing. In order to get better effect, we use the median filtering method to remove the noise.

2. The extraction algorithm of line drawing for polyhedron

Line drawing of polyhedral composes of straight segments (straight and diagonal are all include straight segments), so we study mainly straight lines of the image. Straight segments of line drawing about polyhedral are smooth, continuous and concise generally, the images are clean and tidy, the noises are less, which can express the whole style of polyhedral. Lines with different thickness, direction, light are alternate, connect, overlap, density permutation and form model with various complexity, various style. In this paper we extracted line drawing from the polyhedron images; the line drawing of polyhedron image is essentially composed of straight segment (straight line, broken lines and slash lines all contain straight segment), so we focus on the straight line of the image. On the basis of flow-based abstract image algorithm [11,12],

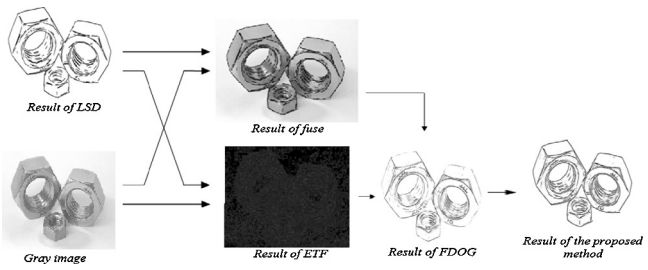

Fig. 1. Process overview.

we add the LSD method during constructing the EFT, which improve the application in polyhedral line rendering mostly. Using result of LSD to adjust ETF and FDoG, The features of line are strengthened and outward appearance of polyhedral is emphasized. Because there are many straight segments in polyhedral image to detect the straight from the image before constructing the new feature flow which strengthen the effect of line, then through raising gradient weight of straight to enhance line on the basis of constructing EFT of original image. The whole process is shown in Fig. 1.

2.1. Detect the straight segment

Straight line detect is one of the important contents and the classics problem in compute vision, which is the process that liberalizes the disperse edge dot and estimates the parameter of straight line. At present, among the straight line detect algorithm, as a classic algorithm Hough transform [21] is used widely and improved by many researchers. In fact, the standard method extracts contour using canny operator from gray image, and then extracts straight line by Hough transform. One of the biggest advantages of Hough transform is that has strong robustness and fault tolerance for noise, and the detection speed is slow. On the other hand, the most serious disadvantage is there are many wrong results in detecting texture regions of the high edge density, the reason is the direction of the edge points are ignore, so the detected line segment are messy and no direction. Among the improved algorithm, Burns [22] proposed a linear time segment detection method, which does only use gradient direction and ignore gradient amplitude, and not begin from edge points. The method made a major breakthrough in the line segment extraction. Kahn [23] detects line segment in small scope, but there is still exist a method about threshold, which false detect the texture of objects as line segment. In literature [24], the progressive probabilistic Hough transform (PPHT) shortened the computation time through choosing any edge points, and improved the algorithm performance using the image gradient information and error detection control. Compare with the original Hough transform the effect is improved obviously, but a lot of short line segments are missed. On the other hand, detecting parameters of the method is detection error probability after analyzing each boundary point, so the adaptability is poor.

Grompone [25] proposed a fast line segment detector with a false detection control (LSD); the LSD need no parameter tuning and gives accurate results, so we use the LSD method to extract the linear features of polyhedral objects.

In the paper, line segment detection algorithm of literature [25] is applied to the extraction of polyhedral, which is the tool of polyhedral line segment extraction. Extracts line segments in several steps:

(1) Using median filter with protecting edge to eliminate the noise of the image.
(2) Convert the original image to gray image.