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Sketch-based 3D modeling by aligning outlines of an image

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Abstract

In this paper we present an efficient technique for sketch-based 3D modeling using automatically extracted image features. Creating a 3D model often requires a drawing of irregular shapes composed of curved lines as a starting point but it is difficult to hand-draw such lines without introducing awkward bumps and edges along the lines. We propose an automatic alignment of a user's hand-drawn sketch lines to the contour lines of an image, facilitating a considerable level of ease with which the user can carelessly continue sketching while the system intelligently snaps the sketch lines to a background image contour, no longer requiring the strenuous effort and stress of trying to make a perfect line during the modeling task. This interactive technique seamlessly combines the efficiency and perception of the human user with the accuracy of computational power, applied to the domain of 3D modeling where the utmost precision of on-screen drawing has been one of the hurdles of the task hitherto considered a job requiring a highly skilled and careful manipulation by the user. We provide several examples to demonstrate the accuracy and efficiency of the method with which complex shapes were achieved easily and quickly in the interactive outline drawing task.

Keywords: Sketch-based modeling; CAD; Image edge extraction

1. Introduction

Sketching in 2D is much easier than that in 3D since most designers are capable of sketching but unfamiliar with 3D modeling tools. It is common to build a 3D model based on an object which already exists. But it requires professional skills and experience to develop an irregular shape. Even if we have those skills and experience, it still takes a long time and great efforts to draw and adjust the special shape to meet our requirements. Therefore, it will be much more convenient if we can use an existing 2D shape directly from an image especially when the object is in an irregular shape. The image of the object can be a cartoon picture or a sketched image.

Extracting a 2D shape from an image is still a difficult task because of the countless possibilities of the input sketch lines owing to different design techniques. Sometimes we need to segment the special shapes into several smaller parts which facilitate model-building, but sometimes we need the shape as a whole for the same purpose. So it is better to snap the sketch lines to the image contour, rather than merely show the shape extracted from the image according to the sketch lines. The precision of the results lies in the correspondence between the hand-drawn sketch lines and extracted contour lines. To obtain the correspondence as precise as possible, not only need we interpret the purpose of sketching, but we also need to understand the meaning of the contour lines extracted from the image. Both of tasks are difficult for a machine to achieve.

In this paper, we consider the image features as a useful clue to comprehend the meaning of the sketch lines so that the two of the tasks turn to an alignment of hand-drawn sketch lines to the contours of an image. We believe that there must be a set of rules for alignment. This allows the user to carelessly continue sketching while the system intelligently snaps the sketch lines to the image contours, no longer requiring the strenuous effort and stress of trying to make a perfect line during the modeling task.

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We come up with an algorithm to align the input sketch lines to the contour lines extracted from a background image. The user first inputs an image with the target object, such as a cartoon picture or a sketched image. Then, the user draws a closed sketch line around the shape which he/she is interested in. The system will automatically choose the contour lines which the user is interested in and adjust the sketch line to fit the target shape in the image, and finally a 3D model is generated based on the sketch line. We demonstrate the accuracy and efficiency of the algorithm by running experiments with several example cases in Section 7.

The contributions of our method are as follows:

(1) We propose an automatic alignment method for sketch-based 3D modeling to reflect the user's original intention. Therefore, the efficiency of 3D modeling is improved.
(2) A geometric approach is employed to align a sketch line to the outlines of an image by using their features. A sketch line can be aligned to several discontinuous contour lines of an image so that complex 3D objects can be modeled.
(3) We use an editable curve to represent the aligned sketch line so that its shape can be further adjusted interactively to create a 3D model with high accuracy.

2. Related work

Our method is related to two kinds of modeling methods. One is based on images and the other is based on sketches. There are several image-based modeling methods and sketch-based modeling methods, each applied for different purposes. We aim to realize a sketch-based modeling method with the information extracted from the image [1] to harness the intelligence of a back-end CAD application. Inspired by top-down alignment methods such as the active contour models [2], we use alignment to replace the artificial selection to take more advantage of the input images.

2.1. Image-based modeling

Gingold et al. [3] presented a system for 3D modeling of free-form surfaces from 2D sketches. A 3D model is created by placing primitives and annotations on the image. The system allows users to maintain a single view of the model. It needs manual choices between given primitives to fit the particular shapes in the image, but it cannot be used to build a model with an irregular shape due to the fact that all the primitives are regular shapes. Chen et al. [4] presented another image-based modeling technique called 3-sweep, which deforms the input strokes according to the image contour. It is notable that the extraction of the 3D model is based on the observation that man-made objects are made of several regular primitives, such as the cylinder, cuboid, etc. It has the same limitation that it cannot be used to design objects of irregular shapes. Lau et al. [5] presented a framework that allows a user to participate in the entire process of designing their own objects, from the initial concept stage to the production of a new real-world object that fits well with the existing complementary objects. In the method a single photo is used as a rough guide for the user to sketch a new customized object that does not exist in the photo, and accurate extraction of information is not necessary.

There are several image guided drawing methods to refine the sketches. Orbay and Kara [6] proposed with a method to identify and group numbers of arbitrary strokes and beautify each group into a parametric curve. A neural network is trained to group the sketches by studying existing sketches. Su et al. [7] presented an algorithm to refine the sketch strokes with the gradient features of the image. However, the methods focus on refining segments of sketch lines, and features of the object being drawing are usually not taken into account.

2.2. Sketch-based modeling

There are some common problems in sketch-based modeling methods. In a 3D modeling system, the view selection is essential to the modeling process. It is difficult and frustrating for users to have to design in more than one view. There is one solution in [3] that they let the user to sketch in one view and deform the model in other views. The automatic model generation can be controlled by modulating the thickness of the 3D model by the users. Similarly, there are several systems used to design 3D models [8–11], and they convert 2D sketches to 3D models by inflating the closed regions. The region of 2D sketching inflates in both directions in proportion to the width of the region. Generally, the sketch-based modeling method is based on sketch recognition techniques which convert a given 2D line into a 3D model such as the systems in [12] and [13].

2.3. Active contour models

The method to align the sketch line is inspired by the active contour models [2]. It uses an energy-minimizing spline guided by external constraint forces and influenced by image forces that pull it toward features such as lines and edges. For the traditional snake method, the initial contour should be close to the boundary of the interested object in an image, or else it would converge to the wrong result. In addition, active contours have difficulties progressing into boundary concavities. Moreover, the traditional snake method and its improved methods are prone to get into local minimum because snake models are non-convex.

In our method, we use a geometric method to align a sketch line to the outlines of an image. The features of the sketch line and the contour lines of the image are analyzed so that the user's intention can be reflected correctly. The sketch line can be any irregular shape, and complex 3D objects with high accuracy can be modeled based on the background image.

3. Overview

To build a 3D model based on an image, our method needs to take an image with the target object as input. Usually a complex object is consisted of several simple parts. To design