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A hybrid approach for character modeling using geometric primitives and shape-from-shading algorithm

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Abstract

Organic modeling of 3D characters is a challenging task when it comes to correctly modeling the anatomy of the human body. Most sketch based modeling tools available today for modeling organic models (humans, animals, creatures etc) are focused towards modeling base mesh models only and provide little or no support to add details to the base mesh. We propose a hybrid approach which combines geometrical primitives such as generalized cylinders and cube with Shape-from-Shading (SFS) algorithms to create plausible human character models from sketches. The results show that an artist can quickly create detailed character models from sketches by using this hybrid approach.

Keywords: Sketch based modeling; Character; Modeling; Shape-from-shading; Sketch

1. Introduction

Organic modeling of 3D characters is a challenging task when it comes to correctly modeling the anatomy of the human body. An artist views the human body in the form of several parts which can be modeled using simple primitive objects. For example, limbs (arms and legs) can be approximated with cylinders, head can be approximated with spheres or ellipsoids. However some artists make character sketches in which the characters are wearing armor, and clothes. We propose a 'cube' as a new primitive which can be used to model armor and clothes.

Most sketch based modeling approaches generate base mesh models only without details. Realistic models require details on their surface. To create more realistic looking models, artists tend to use sculpting packages such as ZBrush [1], or Mudbox [2]. These packages provide tools which are often difficult to learn and master by novice artists, and are not designed to be used in a more natural way. Thus the artist is required to give a keen attention to detail, often making the entire process very laborious and time consuming. These packages also require computers with high specifications for GPU with considerable amount of memory, as most of the features are designed to be executed on the GPU, thus making them less favorable for 3D artists focusing on low resolution 3D graphics for indie games.

Shape-from-Shading provides a promising and efficient method to create details from images. The idea for reconstructing 3D surface details from images and combining it to a low-polygon base mesh comes from the philosophical work by Koenderink [3]. In this paper the author discusses in detail the philosophy behind generating 3D surfaces from shaded/lighted images. Several SFS techniques have taken inspiration from Koenderink work such as [4], [5], and [6].

Our proposed hybrid approach solves the problem of producing better quality character models than the previous sketch based modeling (SBM) approaches [7], through easy inputs by integrating SBM approaches given in [7] with the shape-from-shading algorithm in [9]. The work presented in [7] and [9] has inspired us to combine them together to produce a hybrid technique leading to better results.

Our main contributions are as follows:

1. We have proposed a novel and hybrid approach which harnesses some of the techniques of [7] and [9] to generate

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good quality character models through sketching. The previous techniques in Sketch Based Modeling [7] generate simple base mesh models, thus limiting the artist to create highly detailed models.
2. Our approach provides artists two additional tools in addition to the generalized cylinder including cube and ellipsoid as geometric primitives to create base mesh models quickly and easily.
3. Instead of requiring the artist to provide a template source mesh as input as in [10], our approach instantly generates relief mesh using shape-from-shading algorithms, which can be easily transferred to the target base mesh.
4. Utilizing the technique in [9], we generate surface details from a single picture or sketch, and provide tools to interactively add the details to the base mesh.

2. Related work

Sketch based modeling systems can be roughly categorized in solid modeling, and organic modeling systems. Notable examples of sketch based solid modeling systems are Google SketchUp [11,12], and more recently [13]. On the other hand organic sketch based modeling systems provide tools to create character models mainly using feature curves, and suggestive contours [14] etc. Organic modeling systems provide tools to the artists to create 3D models from simple primitives such as ellipsoids and using inflation techniques to inflate a closed 2D region/sketch (e.g. a circle, oval etc.) such as Teddy [15], and FiberMesh [8]. In [7], Gingold et al. used generalized cylinder and ellipsoids for modeling of organic models directly from a single view model, and provided annotations to artists so they can manipulate the models easily and quickly. However their system provides a limited set of tools to the artist for modeling and only provide two primitives (cylinder and ellipsoid). Most artists make use of more primitives to model a human character. One important primitive used by artists is the box primitive as demonstrated in tutorial video by the leading comic artist Stan Lee [16]. In this tutorial, he tells us how easily we can decompose a human body into simple primitive geometric shapes.

In FiberMesh [8], the authors have proposed a system to add details to simple 3D models. However using this system, adding finer details is not easy and requires great attention to detail for the novice artist. Moreover very subtle details are not very easy to add. In [17], the authors have presented an intuitive technique for mesh editing via sketching instead of vertex manipulation.

Shape-from-Shading (SFS) has undergone considerable amount of research in the past decades. Several excellent surveys exist on SFS such as [18,19]. SFS algorithms have immense applications not only in the animation/gaming industry but also in the archeological research where scientists are reconstructing ancient artifacts and base reliefs to preserve them in digital form such as Project Mosul (http://projectmosul.org/). Hahn et al. has proposed a two-step method for surface reconstruction using 2D strokes and a vector field on the strokes. They have used TV and H1 regularization with a curl-free constraint for obtaining a dense vector field and using this dense vector field to obtain the final height map. However this method is very computation intensive and requires complex GPU implementation to speed up the computation. This method also involves solving energy minimization functionals. Lee and Kuo [32] used the brightness constraint and the smoothness constraint. Surfaces were approximated by the union of triangular surface patches. The vertices of the triangles were called nodal points and only nodal depths were recovered. They have used interpolation to recover depth at the pixels. For each triangular patch, the intensity of the triangle was taken as the average intensity of all pixels in the triangle and the surface gradient of the triangle was approximated by the cross product of any two adjacent edges of the triangle. This established a relationship between the triangle intensity and the depth at its three nodal points. Tsai and Shah [20] presented a very fast and simple algorithm for computing the height map from a single greyscale image. Their approach uses a linear approximation of reflectance in the z axis, and the results are very convincing. In [21] the authors have presented a new algorithm for base relief reconstruction using Adaptive Histogram Equalization, which optionally uses a template model to compute the height fields via orthogonal or perspective projection. The shape features of the base relief are enhanced by using gradient scaling factors. The results of this approach are in general better looking than other techniques; however, as pointed out by the authors, the basic drawback of this technique is without optimization it is time consuming taking around an hour to process a high resolution photograph.

Several researchers have addressed the problem of stitching/transferring details from one mesh to another mesh. To stitch the details onto the base mesh, our hybrid approach utilizes the Discrete Exponential Map (DEM) algorithm first proposed by Schmidt et al. [22] and then generalized by Takayama et al. [10]. In [23] the authors have proposed a novel approach for mesh cloning approach based on pyramid spherical coordinates driven by boundary loop, which extends an existing algorithm for computing offset membrane on mesh. The source and target meshes are mapped onto a 2D parametric domain using geodesic polar maps. During cloning, the boundary loop of the region of interest (ROI) on the target mesh is fitted in real time by B-spline curve to register the boundary loop of the source ROI. Via the reconstructed boundary loop, the ROI is deformed to register the target mesh by pyramid spherical coordinates to ensure that the clone result is seamless and natural.

For modeling a base mesh model, our system mainly draws inspiration from Gingold et al [7] and in addition to this, our system aims at enhancing the system by providing a new shape primitive for modeling i.e cube. It uses the same definition for creating the generalized cylinder as well as the ellipsoid. Moreover we use the technique in [9] to generate a 3D surface from purely 2D images by computing the height values at each pixel. The authors in [9] have proposed a novel SFS method based on hybrid reflection model which contains both diffuse reflectance and specular reflectance. According to the authors, when discrete characteristic of digital images is considered, finite difference approximates differential operator. The