Graphical Models 76 (2014) 152–161

Contents lists available at ScienceDirect

Graphical Models

journal homepage: www.elsevier.com/locate/gmod

Content-aware texture mapping

Yao Jin, Zeyun Shi, Jun Sun, Jin Huang *, Ruofeng Tong *

College of Computer Science and Technology, Zhejiang University, China

ARTICLE INFO

Article history:
Available online 7 December 2013

Keywords:
Content-aware
Texture mapping
Parameterization
LSCM+
Non-uniform
Importance map

ABSTRACT

Interactively mapping texture into a curved surface has wide applications. Apart from mapping texture to desired positions with low distortions, which has been considered by existing works, few work considered the intuitive need to distribute distortions according to the texture contents. In this work, we present a texture mapping method guided by importance map to preserve the shape of the prominent content. We formulate it as an importance-value-weighted parameterization. The mapping distortions are measured by LSCM+ energy, which is capable of decreasing the appearance of shrunken and fold-over triangles as well as shape preservation; and the weights are efficiently calculated by transforming the area integral into a line integral. To solve the parameterization, we employ the 'L–M' (Levenberg–Marquardt) method and alternately update the weights and the coordinates since they are dependent on each other. Finally, we show some examples to demonstrate the content-aware effect by comparison to traditional parameterization.

1. Introduction

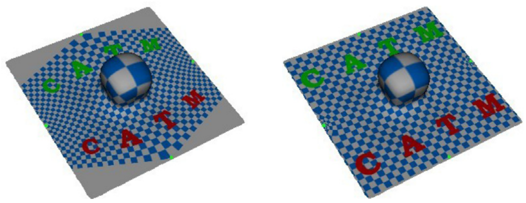
Texture mapping is widely used in graphics community to enhance the visual effect of realistic rendering. It puts 'texture skins' to a polygon mesh via assigning texture coordinate to each vertex. And the so called texture coordinates are commonly obtained by planar parameterization, namely embedding a disk-shaped polygon mesh into a 2D texture space [1]. However, it's theoretically and practically impossible to remove all the distortions of such an embedding in general and may cause undesired mapping effects. Thus tremendous methods are proposed to reduce the distortions as much as possible. Despite of the fact that some of these works did achieve great success, to the best of our knowledge, none of them considered the need that users might want to control the distribution of the mapping distortions to enhance the result of the important content in the texture while sacrificing the effect in other areas. We call this kind of texture mapping as 'content-aware texture mapping'. By 'content-aware' we mean that the important content of the texture is expected to have lower distortions and thus its shape is preserved well and looks more realistic. This technique is potentially useful in texture design and its related areas. An example using traditional and content-aware texture mapping is shown in Fig. 1, where the texture in Fig. 2(a) is mapped to a pot-cover-like model with four positional constraints. It can be seen that two lines of alphabets 'CATM' mapped onto the left model are severely curved and inhomogeneously scaled compared with the right model whose corresponding texture shape is nicely maintained.

To achieve this kind of texture mapping effect, we present an importance map guided parameterization method. With the importance map defined on texture, we formulate it as a non-uniform-weighted parameterization and iteratively update the importance weights and the texture coordinates by the well known 'L–M' non-linear least square optimizer. The major contributions of our proposed work can be summarized as follows:

- An importance map guided parameterization method that can furthest preserve the important contents of the texture.

* Corresponding authors.
E-mail addresses: fool1025@zju.edu.cn (Y. Jin), shizeyun@zjucadcg.cn (Z. Shi), jsun@zju.edu.cn (J. Sun), hj@cad.zju.edu.cn (J. Huang), trf@zju.edu.cn (R. Tong).

1524-0703/$ - see front matter © 2013 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.gmod.2013.11.001



(a) Traditional mapping (b) Content-aware mapping

Fig. 1. Traditional and content-aware texture mapping. The left one is generated by the traditional LSCM parameterization and the right one is the result of our content-aware parameterization. Positional constraints are marked in green points here and elsewhere in the paper. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

- An improved 'LSCM' distortion metric that can preserve shapes well, and avoid shrunken and fold-over triangles greatly.
- A line integral algorithm for calculating triangles' weight that is faster than the way of brute force summation.

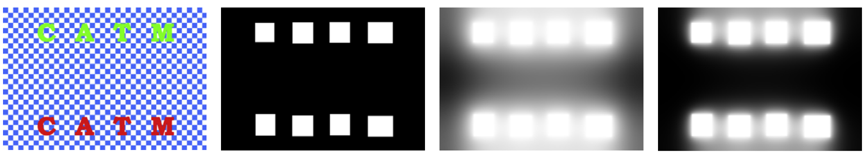
The rest of the paper is organized as follows: Section 2 reviews the relevant work. Section 3 describes our content-aware parameterization method. Section 4 gives the numerical solution in detail. Section 5 makes discussions on the behavior of the algorithm and displays some experiment results. And the final section concludes the paper.

2. Related work

Texture mapping has been an active research field for many years. It is commonly formulated as a problem of the well studied mesh parameterization. Current works on texture mapping mainly concerned about low-distortion parameterizations and various approaches have been proposed to reduce the mapping distortions. A thorough survey on parameterization can be found in [1] and references therein. Here we only introduce some typical works. Some works aimed at variational parameterizations with positional and directional constraints [2]. They tried to minimize distortion energies with different geometric metrics, such as Dirichlet energy [3], conformal energy [4,5], stretch energy [6], Green–Lagrange energy [7], and ARAP (as-rigid-as-possible) energy [8]. Several other works attempted to generate texture atlas to reduce distortions. The main idea is to introduce artificial boundaries to absorb the undesired curvature [6,5,7]. The mesh is cut into atlas and parameterized separately, then the cut boundaries are continuously stitched to make the whole mapped texture seamless. Furthermore another type of works focused on constructing smooth embeddings. This is achieved by computing smoothing functions (i.e. RBF) which interpolate the constrained vertices [9,10] or by adopting a two-step procedure that first embedded the mesh into the 2D texture space, and then iteratively aligned the feature points and optimized the texture coordinates [11,12,10]. Besides, apart from these global methods, some local methods parameterizing the local region of the mesh are appealing as well. The representation works were done by Schmidt who used discrete exponential map and its extensions [13,14] to approximate the isometric mapping. All the works introduced above generated texture coordinates solely on the geometry of the mesh and had no control of the distribution of mapping distortions.

Except from these geometry based texture mapping methods, there are a few early works taking the information of the texture into account [15–17]. These works aimed at predistorting the texture map to increase the texture resolution in areas of details. Sloan et al. [15] introduced the notion of 'importance map' and used it to drive the texture coordinates optimization. Balmelli et al. [16] studied a similar problem. They used wavelet-based technique combined with parametric distortion metric to compute a frequency map, then warped the image to evenly distribute frequency content across the image according to the frequency map. Sander et al. [17] proposed a signal-specialized parametrization. They used the notion of signal and produced it automatically by computing the total distortions of the mapping from the parameter domain to the space of signal values and did parameterization by the signal-specialized metric. Though these works have similarity with ours in considering texture content, they did not address on how to mostly preserve the shape of the important regions.

Parameterization based image retargeting is a topic related to our work as well. These works aimed at warping an image to another arbitrary shaped 2D domain by parameterizations while preserving the shape of the importance contents. Gal et al. [18] introduced an inhomogeneous 2D texture mapping guided by a feature mask. They took specified feature masks as foreground which was constrained to undergo a similarity transformation and the background regions were allowed to deform more. Guo et al. [19] formulated the image retargeting problem as a constrained parameterization. They constructed a triangle mesh representation of an image and incorporated boundary, salience and structure constraints into a stretch-based mesh parameterization. Zhang et al. [20]



(a) Texture (b) Feature masks (c) Diffused map (d) Enhanced map

Fig. 2. A texture and its corresponding importance maps.