Graphical Models 75 (2013) 104–117

Contents lists available at SciVerse ScienceDirect

Graphical Models

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

Efficient synthesis of gradient solid textures

Guo-Xin Zhang [a,*], Yu-Kun Lai [b], Shi-Min Hu [a]

[a] TNList, Department of Computer Science and Technology, Tsinghua University, China
[b] School of Computer Science and Informatics, Cardiff University, UK

ARTICLE INFO

Article history:
Received 30 August 2012
Received in revised form 17 October 2012
Accepted 26 October 2012
Available online 17 November 2012

Keywords:
Solid textures
Synthesis
Vector representation
Gradient
Vectorization
Distance fields
Tricubic interpolation
Editing propagation
Real-time rendering
2D exemplars

ABSTRACT

Solid textures require large storage and are computationally expensive to synthesize. In this paper, we propose a novel solid representation called *gradient solids* to compactly represent solid textures, including a tricubic interpolation scheme of colors and gradients for smooth variation and a region-based approach for representing sharp boundaries. We further propose a novel approach to *directly* synthesize gradient solid textures from exemplars. Compared to existing methods, our approach avoids the expensive step of synthesizing the complete solid textures at voxel level and produces optimized solid textures using our representation. This avoids significant amount of unnecessary computation and storage involved in the voxel-level synthesis while producing solid textures with comparable quality to the state of the art. The algorithm is much faster than existing approaches for solid texture synthesis and makes it feasible to synthesize high-resolution solid textures in full. We also propose a novel application—instant editing propagation on full solids.
© 2012 Elsevier Inc. All rights reserved.

1. Introduction

Textures are essentially important for current rendering techniques as they bring in richness without involving overly complicated geometry. Most previous work on texture synthesis focuses on synthesizing 2D textures, which require texture mapping with almost unavoidable distortions when they are applied to 3D objects. Solid textures represent color (or other attributes) over 3D space, providing an alternative approach to 2D textures that avoids complicated texture mapping and allows real solid objects to be represented with consistent textures both on the surface and in the interiors alike.

Due to the extra dimension, solid textures represented as attributes sampled at regular 3D voxel grids are extremely expensive to synthesize and store. To provide sufficient resolution in practice, a typical solution is to synthesize only a small cube (e.g. 128^3), and tile the cube to cover the 3D space. However, tiling may cause visual repetition (see Fig. 8). While repetitions could be alleviated with some rotations, they cannot be eliminated completely when the volumes are sliced with certain planes. Further it is possible only when the solid textures have no interaction with the underlying objects, and thus cannot respect any model features or user design intentions. To address this, previous approaches [4,42] synthesize solid textures on demand; however, handling high-resolution solid textures is still expensive in both computation and storage.

Inspired by image vectorization, for pixels (or voxels) with dominantly smooth color variations (within each homogeneous region), vectorized graphics provide significant advantages such as being compact, resolution independent and easy-to-edit. The possibility and effectiveness of vectorizing solid textures have been recently studied in [33]. This work is essentially a 3D generalization of image vectorization, which requires voxel-level (raster) solid textures as input and inherits similar advantages over traditional raster solid textures. It remains computationally

* Corresponding author.
E-mail addresses: zgx.net@gmail.com (G.-X. Zhang), Yukun.Lai@cs.cardiff.ac.uk (Y.-K. Lai), shimin@tsinghua.edu.cn (S.-M. Hu).

1524-0703/$ - see front matter © 2012 Elsevier Inc. All rights reserved.
http://dx.doi.org/10.1016/j.gmod.2012.10.006

costly and involves large intermediate storage for raster solid textures to synthesize high resolution solid textures with a nonhomogeneous spatial distribution (e.g. [42]).

This paper is an extended version of the conference paper [43] with substantially extended technical details, experimental results, evaluation and applications including solid vectorization and instant editing. In this paper, instead of first synthesizing the full voxel solid textures before vectorizing them [33], we propose a novel approach to directly synthesize vectorized solid textures from exemplars. Inspired by gradient meshes in image vectorization [29], we propose a novel *gradient solid* representation that uses a tricubic interpolation scheme for smooth color variations within a region, and a region-based approach to represent sharp boundaries with separated colors. This representation is compact, more regular than Radial Basis Functions (RBFs) [33] and thus particularly suitable for real-time rendering and efficient solid texture synthesis. Our approach can be used to vectorize input solids, which is over 100 times faster than [33] and leads to reduced approximation errors in most practical cases, as shown later by extensive comparative experiments. As discussed later in the paper, while the proposed representation is not suitable for all textures, it is sufficient to represent a variety of practical solid textures in high quality, in particular those having dominantly smooth color variations within each homogeneous region.

We further treat solid texture synthesis as an *optimization* process of *control points* of gradient solids to produce synthesized solids with similar sectional images as given exemplars. Compared with traditional solid texture synthesis, we have *far less* control points than voxels, leading to a much more efficient algorithm. While we solve both bitmap solid synthesis and solid vectorization together and produce solid textures with comparable quality as the state of the art, it is over 10 times faster than existing synthesis methods.

The main contributions of this paper are:

- A new *gradient solid* representation with regular structure that is compact, resolution-independent and capable of representing smooth solids and solids with separable regions.
- A novel optimization-based algorithm for *direct* synthesis of high quality solid textures vectorizing high resolution solids which is efficient both in computation and storage.
- We also propose a novel application—*instant solid editing*, as demonstrated in the paper.

To the best of our knowledge, this is the first algorithm that synthesizes vector solid textures directly from exemplars, allowing high resolution, potentially spatially nonhomogeneous solid textures to be synthesized *in full*. Thanks to the new compact representation, solid textures can be directly synthesized in this representation, significantly reducing the computational and memory costs. Our representation also allows instant editing without resorting to time-consuming conversion between vector and raster solids. Both of these would be difficult to achieve, if possible, by previous methods. This addresses major drawbacks of using solid textures in practical applications, namely large storage requirements and synthesis time. Various techniques have also been developed to effectively improve the quality or reduce the computational cost.

A typical example of high-resolution gradient solid texture synthesis and editing is given in Fig. 1. In Section 2, we review prior work in texture synthesis and vectorization. Our vector solid representation is described in Section 3 and the algorithm details given in Section 4. Experimental results, applications and discussions are presented in Section 5 and finally concluding remarks are given in Section 6.

2. Related work

Our work is closely related to example based texture synthesis and vector images/textures.

Solid texture synthesis: Texture synthesis has been an active research direction in computer graphics for many years. Please refer to [35] for a comprehensive survey of example-based 2D texture synthesis and [28] for a recent survey of solid texture synthesis from 2D exemplars.

Early work on solid texture synthesis focuses on procedural approaches [26,27]. Since rules are used to generate solid textures, very little storage is needed. Procedural solid textures can be generated in real-time [2]. However, only restricted classes of textures can be effectively synthesized and it is inconvenient to tune the parameters. Exemplar-based approaches do not suffer from these problems, and thus received more attention. 2D exemplar images are popular due to their wide availability. Wei [34] extends non-parametric 2D texture synthesis algorithms to synthesize solid textures. An improved algorithm is proposed in [13] to generate solid textures based on texture optimization [14] and histogram matching [8]. Further extended work [3] considers *k*-coherent search and combined position and index histograms to improve the results. To synthesize high resolution solid textures, Dong et al. [4] propose an efficient synthesis-on-demand algorithm based on deterministic synthesis of certain windows from the whole space [16] necessary for rendering, based on the fact that only 2D slices are needed at a time for normal displays. This work is extended in [42] that introduces user-provided tensor fields as guidance for solid texture synthesis. This approach allows synthesizing solid textures with nonhomogeneous spatial distributions, thus cannot be achieved by tiling small fixed cubes.

Alternative approaches for solid texture synthesis exist. Jagnow et al. [10,11] propose an algorithm based on stereological analysis which provides more precise modeling of solid textures. Du et al. [5] synthesize solid textures by analyzing the shapes and colors of particles from 2D exemplars and appropriately placing particles to form consistent sectional images as the exemplars. This is conceptually similar to salient structural element analysis in 2D texture synthesis [24]. The method is particularly suitable for semi-regular solid texture synthesis. However, these approaches only work for restricted types of solid textures with well separable pieces. Lapped textures have been

Download English Version:

https://daneshyari.com/en/article/442439

Download Persian Version:

https://daneshyari.com/article/442439

Daneshyari.com