Computers & Graphics 51 (2015) 67–73

Contents lists available at ScienceDirect

Computers & Graphics

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

Real-time continuous self-replicating details for shape deformation

Damien Rohmer [a,b,*], Stefanie Hahmann [a], Marie-Paule Cani [a]

[a] Université Grenoble-Alpes – CNRS (Laboratoire Jean Kuntzmann) – INRIA, France
[b] CPE Lyon, Université de Lyon, France

ARTICLE INFO

Article history:
Received 12 March 2015
Received in revised form
13 May 2015
Accepted 16 May 2015
Available online 30 May 2015

Keywords:
Shape deformation
Surfaces
Modeling
Detail preservation
Temporal coherence

ABSTRACT

We address continuous free-form sculpting of 3D models that carry self-similar geometric details. In addition to being maintained when the model is bent or twisted, repetitive details should be duplicated rather than deformed in stretched regions, so that their distribution and appearance are preserved. Doing so in a temporally coherent way is essential in applications where the user sculpts through continuous deformation gestures. We propose a simple, yet effective solution for achieving such temporal coherence while enabling duplication of details. Our method maintains the set of existing details during stretch but seamlessly grows new ones in between. Similarly, some of the details progressively fade out when a region shrinks. Our solution is example-based: it uses the triangles of the initial support surface as exemplars to be selected and re-used in deformed regions. As our results show, our method achieves continuous free-form deformation of complex models while best preserving, at each time step, the properties and appearance of their initial distribution of details.
© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Being able to deform 3D models in an intuitive and efficient way is essential for both interactive modeling applications and those related to animation. Many 3D models, especially those representing natural objects are characterized by self-similar details on the surface, as shown in Fig. 1. They add an extra level of difficulty when one tries to deform these models, since the details should not be subject to the same shape deformation to keep the result intuitive. Standard methods for shape deformation manage to preserve the consistence of details as long as the deformation does not include any change in local scale such as stretching or compression, in which cases, the details would also deform and can therefore destroy the natural appearance of the model. For example stretching a tree trunk with bark, a dinosaur wearing protruding scales, or land with trees, will also stretch out those details. In contrast, what the user usually desires is the deformation to be applied only to the base surface, while repetitive details are duplicated in order to maintain the overall appearance of the object. While some approaches for duplicating details have already been proposed, they result into pop-up effects when new details are synthesized.

We present the first method that ensures temporal coherence during mesh deformation while maintaining distributions of geometric details. This means that during stretching, pre-existing details are maintained and new details are continuously created in between without any *pop-up* effect. Similarly, during compression the surplus details continuously disappear. This allows the user to apply smooth sculpting gestures without being annoyed by visual jumps in the geometry thus improving immersion and the feeling of direct interaction with a shape. We believe that it is one important step towards "making tools as transparent to the artists as special effects were made transparent to the public", which is a main remaining a challenge in Computer Graphics following Cook [1].

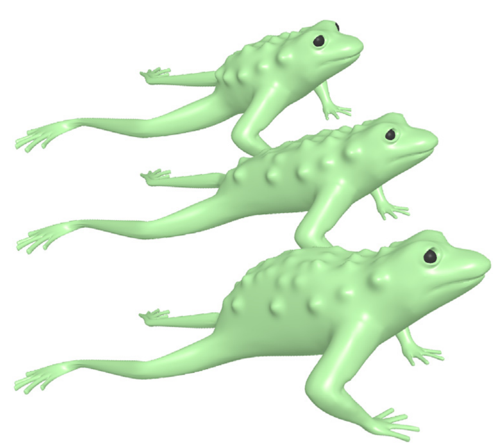

Fig. 1. Example of deformation of a surface with continuous duplication of details from the top (original surface) to the bottom.

* Corresponding author.
E-mail address: Damien.Rohmer@inria.fr (D. Rohmer).

http://dx.doi.org/10.1016/j.cag.2015.05.011
0097-8493/© 2015 Elsevier Ltd. All rights reserved.

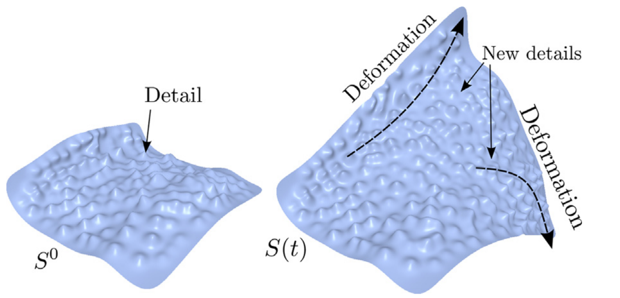

Fig. 2. Left: Initial surface S^0 and its details. Right: Surface $S(t)$ after deformation with newly introduced details.

Our method tracks the distortion of the surface over time to see when and where new details should be generated or whether existing details should be deleted. In both cases, the actual duplication or deletion process is guided by the extraction of similar exemplars from the original model, enabling us to maintain the expected detail distribution though a transfer process. We handle *natural* objects as opposed to *artificial* (manmade) objects. Our models can be subject to arbitrary 3D continuous deformation except those causing topological changes.

1.1. Related work

Detail preserving 3D deformation. Many mesh deformation methods use an alternative coordinate system to encode the mesh [2–4]. These approaches have in common linking the orientation of the details to the orientation of the underlying surface so that the details follow the deformation naturally. In case of stretching, the details however undergo the same deformation as the surface, which may lead to unnatural shape distortions. This is particularly true when the amount of stretching is significant.

Kraevoy et al. [5] introduce a non-uniform scaling method able to maintain the important features of a 3D model such as circular parts. Dekkers and Kobbelt [6] avoid undesired detail distortion by extending a successful image resizing technique, called seam-carving [7], to surface meshes. Their "geometry seam-carving" approach preserves the shape and size of salient features and redistributes the distortion over the remaining surface regions between the details. In both methods, the user needs to manually identify the details of interest. Moreover, although great steps towards making deformations intuitive, these methods do not address the problem of preserving distributions of details, which require the introduction of detail duplication/suppression mechanisms, presented next.

Preserving distributions of details. Owada et al. [8] propose a "copy-and-paste" approach to edit a 3D model that carries a distribution of self-similar details. The user defines the zone to be copied and uses guiding curves to set its final shape. This method is however limited to models only having repetitive details along one direction and therefore only allows stretching in that direction. Bokeloh et al. [9] propose a deformation preserving the regular structure of a model. During deformation, the elements of the profile are then continuously inserted or removed. Both works [8,9] are only applicable to artificially manufactured objects, built of planes, spheres or cylinders of marked symmetry. In our case, we are particularly interested in natural objects whose surfaces are not limited to those sets of basic geometric shapes.

Other methods for preserving distributions of details for 3D shapes build on 2D image editors [10] or texture synthesis methods that handle the preservation of repetitive texture patterns [11]. Bhat et al. [12] generalize texture synthesis to geometric textures, but the method is very costly in computation time. Emilien et al. [13] handles distributions of 3D shapes on a support surface, but with no geometric continuity. Chen and Meng [14] and Alhasim et al. [15] introduce a method that non-uniformly resizes a 3D shape by duplicating all the details thanks to a texture synthesis approach. Still, the first one cannot handle non-homogeneous geometrical textures, while the second is limited to one-dimensional deformations described by a skeleton curve embedded into a shape of zero topological genus.

Although they share the same goal of preserving distributions of details during deformation, none of the previous methods tackled the problem of providing temporal coherence during deformation. Our approach is thus a new step towards seamless sculpting of complex shapes.

2. Framework for self-replicating details

We introduce a new shape deformation technique able to continuously replicate self-similar non-structured details in order to preserve their initial distribution and size along the deformation process (Fig. 2). Our method decouples the user-defined deformation of a given base shape from its 3D detail texture and uses an anisotropic detail replication algorithm based on re-synthesizing details from the original surface.

Let us denote S^0 the initially given manifold surface mesh, called the *source surface*, but without restriction S^0 can also be a parametric spline surface or a bivariate height field. Let $f(x,t) \in \boldsymbol{R}^3$ the deformation process applied to the surface points $x \in \boldsymbol{R}^3$ at time step $t \geq 0$. We assume the original surface and all deformed surface instances to be represented as a composition of a base surface B and a set of details of interest D, see Fig. 3 (top). The initial set of details $D^0 = \{d_i^0\}_{i \in [0,N]}$ is a set of N similar geometric details. Each detail d_i^0 is parameterized by the pair (s_i^0, p_i^0), where s_i^0 is the characteristic size of the detail, and p_i^0 its position in space.

Saying that all details of interest of S^0 are *similar* means that they share the same basic geometry. In our implementation, this basic geometry is a function that procedurally generates the detail either as a 3D mesh added on top of B^0, a procedural function acting as a height field deformer on B^0, or as a hole in the surface B^0, see Fig. 3 (bottom). A given set of details parameters D^0 with the associated geometry therefore defines a *distribution* of details over the surface B^0.

The input for our method are the base surface B^0 and the distribution of a set of details of interest D^0. Note that the automatic extraction of the self-similar geometrical details from original model S^0 is beyond the scope of this work. We refer the reader to existing approaches such as symmetries and similarity analysis [16,17] and surface decomposition [18].

The deformation is assumed to preserve the surface topology and to be smooth both in space and time to ensure a visually continuous deformation. It could be produced using for instance space deformations, skinning deformations, Laplacian editing or any other procedural or user-driven surface editing technique.

Algorithm overview. Our goal is to determine a sequence of continuously deforming surfaces $S(t)$, so that at any time $t \geq 0$ the distribution of details on the new surface stays approximatively the same as the original distribution D^0 for S^0. This means that when the surface stretches, the existing details do not stretch, but new details smoothly appear instead. We call this process *continuous self-replication of details*.

The general framework to achieve this goal consists of deforming the underlying base surface $B(t)$ following the deformation f at time t, whereas the details distribution and size are updated on top of this. Herein, all positions p_i of details existing at the previous time step $(t-dt)$ are transformed into $p_i(t) = f(p_i(t-dt), t)$, while their size $s_i(t)$ is continuously adapted as well. Moreover, new details can smoothly appear such that the overall

Download English Version:

https://daneshyari.com/en/article/442529

Download Persian Version:

https://daneshyari.com/article/442529

Daneshyari.com