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Quadrangulation of non-rigid objects using deformation metrics

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A B S T R A C T

We present a novel method to generate quad meshes for non-rigid objects. Our method takes into account the geometry of a collection of key poses in one-to-one correspondence or even an entire animation sequence. From this input, on a common computational domain, an extremal metric is computed that captures the local worst case behavior in terms of distortion as the object undergoes deformation. An anisotropic, non-uniformly sized quad mesh is then generated based on this metric. This mesh avoids undersampling when deformed into any of the poses specified in the input and thus reduces artifacts. Hence, in contrast to previous approaches which target static geometry, our method aims to optimize the mesh's adaptation to the shape for every pose expected during animation or deformation rather than for one specific reference state.

1. Introduction

In recent years a variety of versatile methods for the automatic quadrangular remeshing of surfaces has been developed. These methods typically optimize the properties of the quad mesh, such as element *size*, *anisotropy*, *orientation*, and mesh *connectivity*, with respect to the specific given surface geometry. Note that this is appropriate only when dealing with rigid objects with static geometric properties. At the same time, it is common for quad meshes to be used in animation or simulation. In this case, while the quad mesh might be well adapted to a particular specific state or pose (based on which it was generated and optimized), it may be a poor match for other poses or states of deformation (cf. Figs. 1, 8, and 9).

We present a method that aims to produce quadrangulations *adequate for every pose* during deformation or animation, rather than *optimal for a single pose* (cf. Figs. 1 and 2). If known a priori, the deformation can be given as input in form of a complete surface animation sequence. Otherwise, the expected space of deformation can be outlined by a set of extremal key poses.

Based on one-to-one correspondences between the key poses or animation frames we analyze the deformation structure and construct an extremal metric corresponding to the worst-case local metric behavior at every point of the surface. Furthermore, information about preferable mesh element orientation is determined jointly over the expected deformation. Together, this allows us to generate an adapted quad mesh with anisotropic element sizing that avoids undersampling artifacts due to being too coarse in any region for any pose when being deformed.

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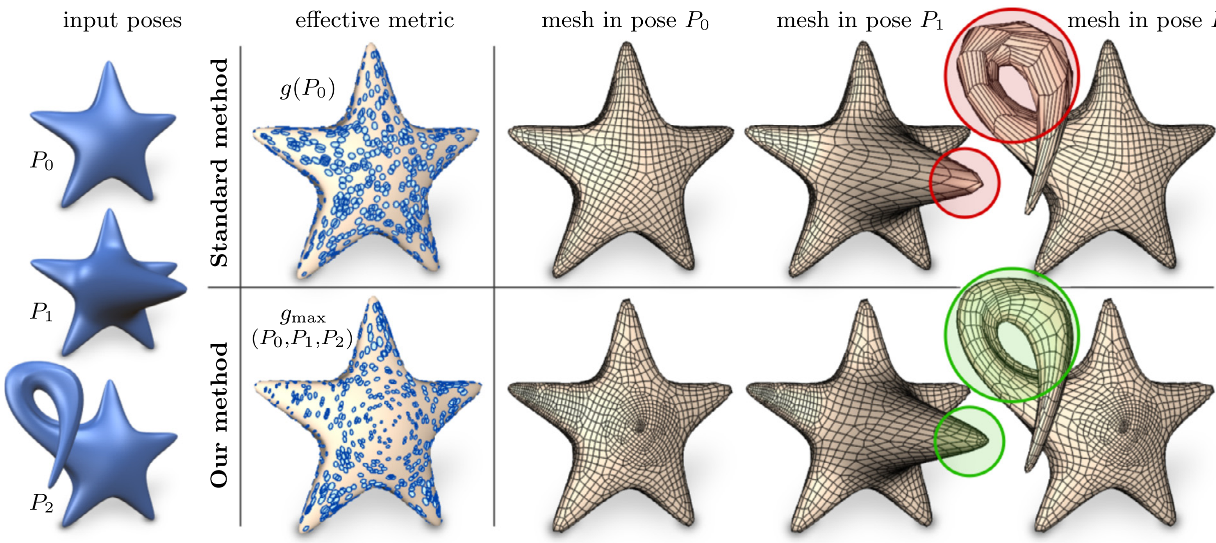

Fig. 1. Illustration of our deformation-aware mesh generation method in contrast to a standard, static method (Jakob et al., 2015). Three poses (left) are taken as input. The standard method optimizes the mesh with respect to the metric of one specific pose, P_0; ours uses an extremal metric it computes over all poses. In the top row, the resulting quad mesh deformed into the poses other than P_0 exhibits artifacts, especially in areas of significant stretching and bending (red). Our quad mesh (bottom row) shows better behavior (despite even having a slightly lower total number of elements) in these poses. Notice that this comes with an increased number of irregular vertices; these are induced by the stronger local variation in element size and shape due to deformation-awareness. (For interpretation of the colors in the figure(s), the reader is referred to the web version of this article.)

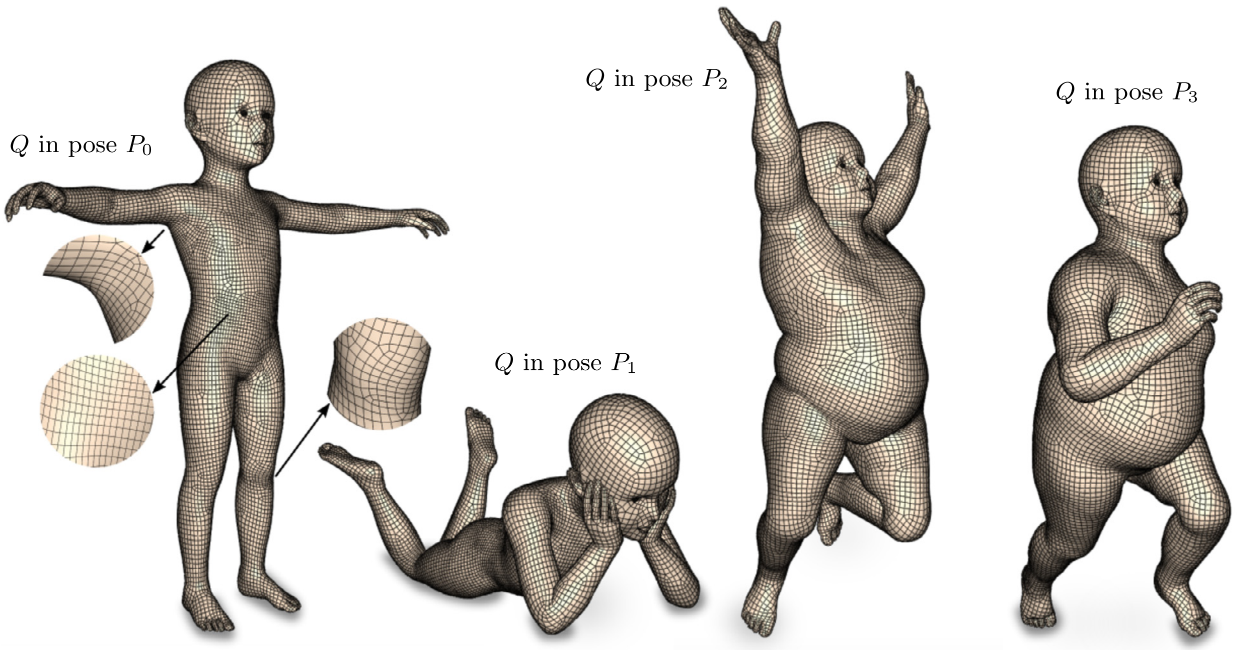

Fig. 2. The same quad mesh Q in four different poses for which it was jointly optimized using our technique with extremal metric. Notice, for instance, the higher density of the mesh in the left pose on the knees (because they get bent strongly in poses P_1 and P_2), under the arm (because it gets stretched in pose P_2), and on the belly (because poses P_2 and P_3 are more corpulent).

2. Related work

Quad meshing An account of modern quadrangular surface remeshing techniques is given in a recent survey (Bommes et al., 2013b). Parametrization based techniques have received the most attention in recent years for their flexibility and result quality (Kälberer et al., 2007; Bommes et al., 2009, 2013a; Pietroni et al., 2011; Liu et al., 2011; Myles and Zorin, 2013; Panozzo et al., 2014; Ebke et al., 2014; Campen et al., 2015; Campen and Zorin, 2017). These methods all optimize the mesh properties for one specific surface pose.

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