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Automatic posing of a meshed human model using point clouds

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ABSTRACT

We introduce a markerless approach to deform a quality human body template mesh from its original pose to a different pose specified by a point cloud. The point cloud may be noisy, incomplete, or even captured from a different person. In this approach, we first build coarse correspondences between the template mesh and the point cloud through a squeezed spectral embedding technique that exploits human body extremities. Based on these correspondences, we define the goal of non-rigid registration using an elastic energy functional and apply a discrete gradient flow to reduce the difference between a coarse control mesh and the point cloud. The deformed template mesh can then be obtained from the deformation of the control mesh using mean value coordinates afterwards. Our experiments show (see the supplementary video) that the approach is capable of equipping a mesh with the pose of a scanned point cloud data even if it is incomplete and noisy.

1. Introduction and previous work

The flexibility of the human body allows human to perform many large deformations in the real world. This makes non-rigid registration of the human body a difficult problem in computer graphics. When the body deforms continuously over time, the deformation between two consecutive frames is relatively small, and spatio-temporal coherence can be fully explored to improve the registration quality. Commonly known as *performance capture*, continuous non-rigid registration has been widely studied by researchers and it has been successfully handled by many techniques for human bodies [1–4] and human faces [5–9].

Compared with performance capture, a more generic yet challenging problem is how to perform non-rigid registration between two arbitrary human body shapes. If this problem can be solved, the resulting technique will be useful in human model reconstruction and completion, performance capture initialization, human pose and shape detection, and many other applications. Existing techniques on this problem can be roughly classified into two groups: those that require parametric body models and those that do not.

Model-based registration: The parametric human body models [10–12] and their variations [13,14] developed by researchers previously can be used as templates for non-rigid registration of two body shapes under large deformation. Using these models, aligning a human body model with a novel body shape in a different pose can be formulated into a parameter optimization problem. In general, template-based registration is robust and fast. But since it must represent human bodies in the parametric space, it is difficult to handle the detailed body of each individual person, without using a large number of parameters (and data samples). Constructing a large and detailed human body database and extracting models from it is also complex and time consuming.

Registration without a model: Any technique that does not rely on a parametric human model can be classified into this group, including those using human body templates. Many of these techniques [15–17] require manual intervention to specify point correspondences. Without using user-specified correspondences, Li et al. [18] handled non-rigid registration between two incomplete surfaces by nonlinear optimization, if the deformation is not too large. Other techniques [19–21] are typically formulated based on isometric constraints, assuming that the geodesic distances should not change when the body deforms from one pose to another. Especially, spectral methods based on Laplace operator has been proved to be powerful tools for this purpose, see the survey by Zhang et al. [22] for detailed coverage of them.

In this work, we propose an approach to deform a detailed human body template from its reference pose to a largely deformed pose, represented by a point cloud. Our approach first establishes a few correspondences between points of the template mesh and the point cloud. For these correspondences, we draw upon spectral based methods that have been shown to be effective in dealing with non-rigid transformations [23–25]. Based on Global Point Signature (GPS), our method first calculates only five correspondences as Fig. 2a shows. They are further extended to more automatically selected points. Our method then uses the correspondences and the discrete gradient flow to evolve a coarse

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0097-8493/

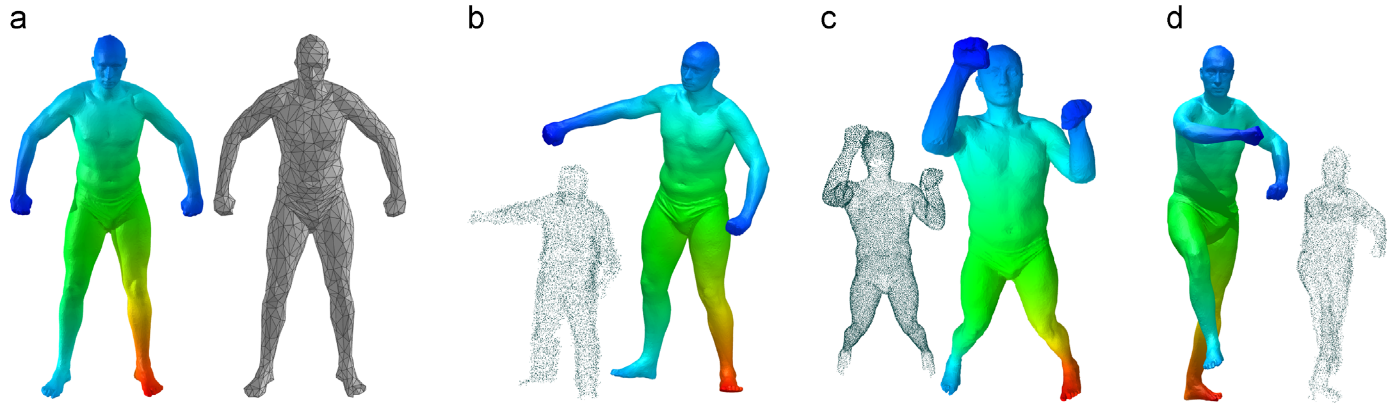

Fig. 1. Our method can robustly and automatically deform a template mesh in (a) into different poses as shown in (b), (c), and (d), even when the point clouds are noisy and incomplete. We color the meshes to indicate the correspondences among them. (a) The template mesh and its control mesh. (b) Mesh posed by 20 K points. (c) Mesh posed by 20 K points. (d) Mesh posed by 19 K points. (For interpretation of the references to color in this figure caption, the reader is referred to the web version of this article.)

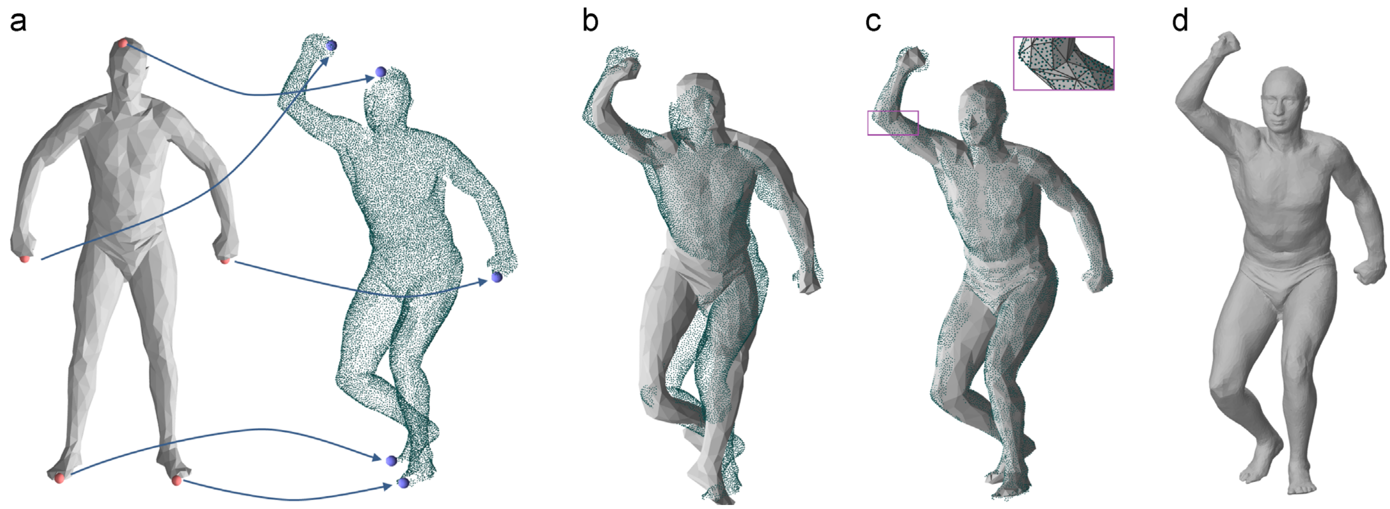

Fig. 2. Intermediate results of our method. (a) Initial correspondences. (b) Initial alignment. (c) Final alignment. (d) Deformed mesh.

control mesh from the reference pose into the new pose as shown in Fig. 2b. Finally, it refines the alignment by minimizing the difference between the control mesh and the point cloud, and transfers deformation to the fine template mesh, as Fig. 2c shows.

The main advantage of this automatic approach lies in its robustness against noise and occlusions as demonstrated by our experiments. This is due to two unique contributions that we propose in this paper:

- *A spectral based method specifically geared toward establishing correspondences between different human body poses*: The main observation is that the five extremities of human body, the four arm and leg ends and the head-top can be matched robustly and reliably by a *squeezed* spectral embedding even in the presence of typical occlusions and noise. Furthermore, we bootstrap the initial five correspondences to a larger matching by registering and uniformly sampling the squeezed embedding.
- *A variational approach for human body deformation and alignment*: By formulating an energy functional as the sum of the elastic energy and the alignment energy, we use a discrete gradient flow to find the deformed body shape in an iterative way. Using this approach, we can conveniently adjust the result quality between better shape size preservation and better alignment (i.e., non-rigid registration). Experiments with real data scanned by Kinect depth cameras demonstrate that our approach is efficient and robust against data noise and incompleteness.

2. Computing correspondences

We are given a complete template surface mesh **M** of a human body and a scanned point cloud **P** of another body possibly in a different pose and with occlusions and noise. Our goal is to establish a few reliable correspondences between the points of **M** and those of **P** first which are bootstrapped further. In particular, we look for identifying the extremities such as the end points of hands, legs, and the top of the head. One could choose to do so in the model spaces of **M** and **P** directly using heat kernel signature (HKS) [23,24,26]. However, separating these specific extremities from others in the model space is hard. We take the advantage of a squeezed spectral embedding to detect them. Also, the presence of occlusions and noise make the HKS approach challenging. More serious is the problem posed by the symmetry present in the human body. Although spectral matchings are good in factoring out the isometric deformations [27,25], they sometimes provide wrong correspondences in presence of human body symmetries. For example, the left foot extremity in one model may match to that of the right foot in another model leading to