Deforming With Sparsity

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Interactive deformation of digital shapes is a well-studied subject in computer graphics. It finds applications in many domains such as engineering, medicine, and entertainment. In a typical deformation session, the user sets a few constraints, such as the desired locations of a few points on the shape (called *handles*), and an algorithm deforms the shape subject to those constraints.

Developing deformation algorithms that produce "plausible" results remains a challenging task. Here, the definition of "plausibility" may vary by the shape to be deformed, the application context, and the user. Traditionally, geometry-based deformation algorithms express the result either as a mathematical function of the user constraints or by optimizing some predefined geometric energy. However, it is difficult for such algorithms to mimic complex physical behaviors (for example, muscle bulging) or capture the intent of individual users (for example, artistic styles). Unlike geometry-based methods, data-driven methods replace hand-crafted formulations by a set of example deformations provided by the user. The results are typically expressed as a weighted combination of the basis modes extracted from the examples. With sufficient examples, these methods can produce highly plausible deformations.

In "Sparse Data Driven Mesh Deformation,"[1] authors Gao et al. made the insightful observation that, by considering weighted combinations of all basis modes, existing data-driven methods are exploring the entire linear space spanned by these modes. On the other hand, the set of plausible deformations typically form a submanifold within this space. To better approximate the submanifold, their method considers only a few basis modes in the vicinity of the desired deformation. This is achieved by adding an L1 sparsity term in the objective energy for optimizing the weights of the basis modes. The authors showed that their new, sparse formulation can effectively select just a handful of basis modes, out of a few dozens,

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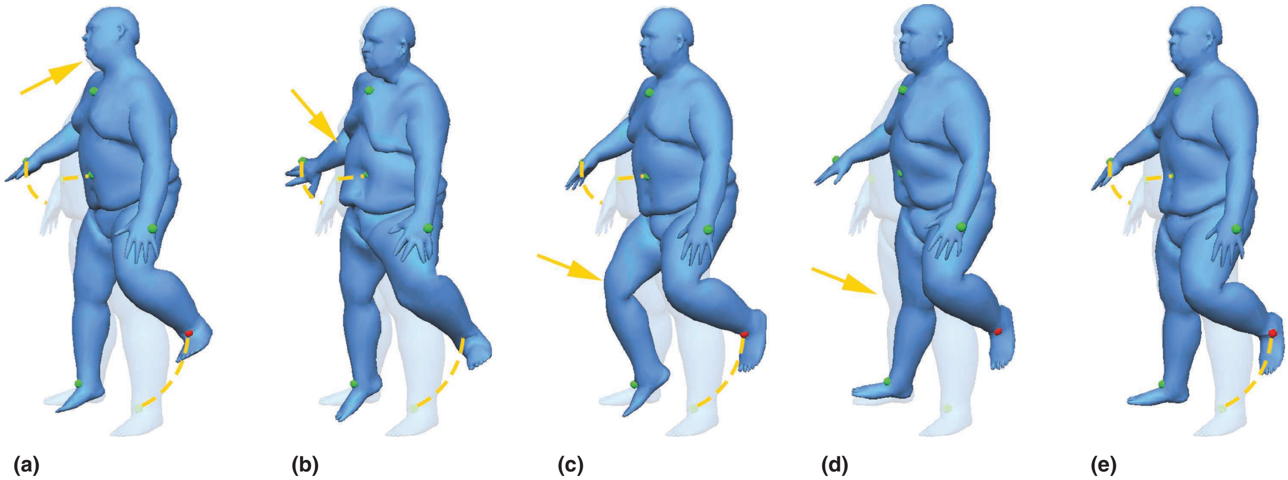

FIGURE 1. (a)–(d) Deforming a digital character using data-driven methods without sparsity and (e) with sparsity. The user placed a few deformation handles on the body (green and red balls) and moved three of them (along the yellow dotted paths) while fixing the rest. Yellow arrows point to places of unnatural or unintended shape changes.

whose weighted combination offers more pleasing deformation effects than without the sparsity term. An example is shown in Figure 1.

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Besides introducing sparsity, the authors made two other technical advances in their robust and efficient deformation system. First, they introduced a novel way of encoding deformations at the vertices of the triangular mesh that can robustly handle large rotations, such as movements of hands and arms. Second, they developed a highly efficient solver for their energy using precomputations, which allows the user to see deformation results in real time. ■

REFERENCE

1. L. Gao, Y.-K. Lai, J. Yang, L.-X. Zhang, S. Xia, and L. Kobbelt, "Sparse data driven mesh deformation," *IEEE Trans. Vis. Comput. Graph.*, vol. 27, no. 3, pp. 2085–2100, 2021. doi: 10.1109/TVCG.2019.2941200.

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