Subspaces for Simulation of Deformations and Contact

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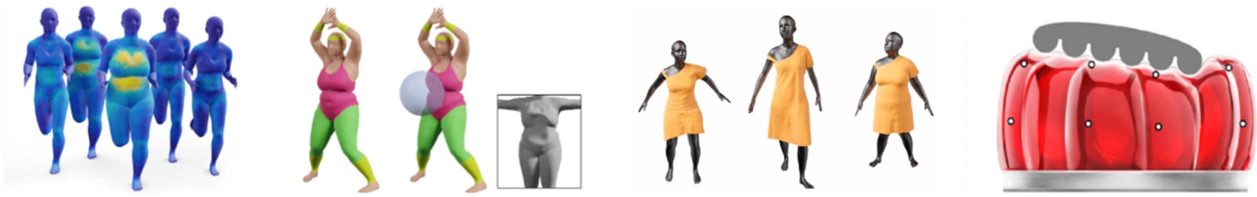
As we approach a new world of interaction between the real and the virtual, one of the grand challenges is to create accurate, robust, and efficient digital models of humans and their interaction with their surroundings. Such digital models can serve to understand and digitalize the real world, to represent digital twins in the context of digital design, testing, and training, or also to create virtual worlds.

We propose to address the complexity of digitizing human biomechanics and the interaction of humans and surrounding objects by combining two fundamental methodologies of computational modeling: physics-based simulation and machine learning. The cornerstone of the approach lies in building subspace models of human biomechanics, object deformation, and human-object interaction that tightly connect physics-inspired and machine-learning representations. Such tight connection can lead to (1) effective simulation models with a superior cost-accuracy trade-off, and (2) robust model estimation algorithms with superior conditioning of the search space. Subspace models employ a parameterization of the deformation and interaction space that is decoupled from the discretization of object deformation, and hence allow more efficient simulations with comparable accuracy. However, finding suitable subspace representations is not easy.



Skeletal soft-tissue: Santesteban et al. 2020 | Physics-based soft-tissue: Tapia et al. 2021 | Skeletal cloth with contact: Santesteban et al. 2021 | Physics-based contact: Romero et al. 2021

In our research group, we have already gathered evidence of successful combinations of physics-based and machine-learning representations to build subspace simulation models, as summarized in the figure above. Santesteban et al. [2] augmented parametric human models with skeleton-driven dynamic deformations. Tapia et al. [4], on the other hand, endowed these augmented deformation dynamics with a physics-based model to support contact interactions. Santesteban et al. [3] designed a subspace of learning-based cloth animation that is inherently collision-free. And Romero et al. [1] developed a machine-learning model of contact-driven dynamic deformations. These recent works span subspace representations for skeleton-driven or physics-based deformations, with and without contact.

Joint work with: Igor Santesteban, Cristian Romero, Javier Tapia, Jesús Pérez, Dan Casas.

References

[1] Cristian Romero, Dan Casas, Jesús Pérez, and Miguel Otaduy. Learning contact corrections for handle-based subspace dynamics. *ACM Trans. Graph.*, 40(4), 2021.

[2] Igor Santesteban, Elena Garces, Miguel A. Otaduy, and Dan Casas. Softsmpl: Data-driven modeling of nonlinear soft-tissue dynamics for parametric humans. *Computer Graphics Forum*, 39(2):65–75, 2020.

[3] Igor Santesteban, Nils Thuerey, Miguel A Otaduy, and Dan Casas. Self-Supervised Collision Handling via Generative 3D Garment Models for Virtual Try-On. *IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR)*, 2021.

[4] Javier Tapia, Cristian Romero, Jesús Pérez, and Miguel A. Otaduy. Parametric skeletons with reduced soft-tissue deformations. *Computer Graphics Forum*, 2021.