Sketch-based design of stuffed furniture and accessories

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Mélina Skouras, IMAGINE team, Inria Grenoble (France)
http://imagine.inrialpes.fr/people/mskouras/
melina.skouras@inria.fr

Figure 1: This project aims at developing a method to automatically generate a 3D model from a 2D sketch representing a stuffed piece of furniture or a stuffed accessory such as a cushion.

Context

Designing realistic 3D scenes typically starts by an exploration phase during which the designer sketches 2D representations of the various objects that forms the scene. 3D objects corresponding to the drawings are then created using complex modeling softwares such as Blender or Maya. In the last few years, several tools have been proposed to facilitate this 2D to 3D conversion, such as True2Form [3]. These methods typically leverage design and perceptual principles to infer the depth of the drawn curves when lifted from 2D to 3D. The curves are then smoothly interpolated in 3D. While this approach works well for man-made rigid objects, these methods cannot be directly applied to reconstruct deformable objects whose current shapes must be also consistent with the physics of the system, e.g a cushion must maximize its volume to area ratio so as to minimize pressure energy, local internal forces must balance contact forces in contact areas, etc.

Generating physically valid 3D shapes is even more important when the object is meant to be subsequently animated or fabricated for real. To tackle this problem, recent works have proposed to invert the physics and to directly optimize the rest shape of the object, i.e. the one before deformation, for example to create inflatables [2] or elastic shells [1]. However, most of these approaches aim at matching idealized 3D target models given as input and do not support imprecise or partial data such as the one that arise from a sketch.

Research goals

The goal of this project is to develop an algorithm to automatically generate a 3D model from a 2D sketch representing a stuffed piece of furniture or a stuffed accessory such as a cushion. To obtain a realistic 3D shape, we will leverage the knowledge we have of the system: the object is made of flat panels sewn to each other and is "inflated" thanks to pressure forces. Therefore, instead of optimizing the 3D shape directly, we will optimize the shape of the 2D panels, the material properties of the fabric and the orientation of the object, such that the deformed shape matches the input sketch as well as possible. To do so, we will need to devise an effective constrained optimization algorithm minimizing a suitable metric. In particular, one of the challenges will be to find a problem formulation that will allow to both satisfy the constraints imposed by the physics, i.e. the deformed shape should correspond to a stable equilibrium state, and the constraints coming from the sketch, i.e. the projection of the deformed shape should match the sketch.

This internship will thus provide the opportunity to explore the benefits of combining physics-based simulation and sketch-based design methods in the context of 3D deformable object design and to investigate how physics can be used to regularize depth ambiguities inherent to 2D sketches when reconstructing 3D objects from 2D views.

Requirements

The candidate should have strong programming and mathematical skills as well as knowledge in computer graphics, geometry processing and physics-based simulation.

References

[1] Mickaël Ly, Romain Casati, Florence Bertails-Descoubes, Mélina Skouras, and Laurence Boissieux. Inverse elastic shell design with contact and friction. *ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH ASIA)*, 37(6), 2018.

[2] Mélina Skouras, Bernhard Thomaszewski, Peter Kaufmann, Akash Garg, Bernd Bickel, Eitan Grinspun, and Markus Gross. Designing inflatable structures. *ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH)*, 33(4), 2014.

[3] Baoxuan Xu, William Chang, Alla Sheffer, Adrien Bousseau, James McCrae, and Karan Singh. True2form: 3d curve networks from 2d sketches via selective regularization. *ACM Transactions on Graphics (Proceedings of ACM SIGGRAPH)*, 33(4), 2014.