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Computational Design Tools for Expressive Robot Characters

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Abstract

Most robots today are still being designed manually, by engineers. This talk will discuss some of our recent project in the domain of developing design tools that leverage physics-based simulation and optimization in order to solve design problems computationally. I will showcase different projects that highlight various aspects of such tools, illustrating how computational tools can significantly speed up design iterations and enable robot designs that would otherwise not be feasible.

Our pipelines take as input a creative intent, in the form of an animated digital character, thus leveraging standard workflows and tools from digital animation that are familiar to digital artists. We then computationally solve a design

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problem, enabling the fabrication of a physical robot that matches the original creative intent.

A first example [1] is a design tool for cable-actuated linkages, where we automatically route a network of cables through the linkage in order to match a prescribed set of target deformations when actuated. Here, we solve both the discrete problem of the *number* of cables as well as the continuous problem of how each cable should be routed.

Next, I will show a tool [2] that design compliant cable-actuated wire structures with controllable deformation behaviour. By placing and sizing different spring-like entities at locations along the wire, with nonlinear and anisotropic stiffnesses, we are able to tune the deformation under cable actuation to match a set of prescribed targets. This enables expressive characters that are mechanically very simple, using only a bent piece of wire.

While digital characters are not governed by physics, soft and compliant structures can suffer from unwanted structural vibrations. To deal with this, I will present a framework [3] for the vibration-suppressing motion transfer. This leverages a differential dynamic simulator coupled with an optimization framework that suppresses structural vibrations in an open-loop manner.

I will also present our work on the design of sensing as well as actuation fibre networks for soft-bodied continuum robots. For the sensing networks [4], we are able to reconstruct the full deformed state of a soft robot using measurements from a set of embedded strain sensors, and we optimize the set of sensors in order to best reconstruct a set of target deformations. Actuation can be considered the dual of sensing, and in [5] we continuously optimize the routing of artificial muscle actuators through a soft body in order to match a prescribed set of deformation targets.

These projects illustrate how simulation and optimization tools greatly facilitate the transfer of a creative intent for a robot character into a physical realization of that character. By relying on standard digital animation workflows for prescribing the input to the system, we make it easy for artists and engineers to specify their creative intent. By using simulation and optimization to solve the difficult design problem, we significantly reduce manual design work required, and ultimately enable more expressive robot characters.

References

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