Stiffness control of an anthropomorphic finger

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Abstract

Human hands have attracted a wide attention in the field of robotic grasping. Indeed, they represent a very interesting tool to interact with the environment and can handle a large variety of tasks through their inner compliance. While the large majority of robotic designs try to reproduce their behavior through a rigid chain of elements linked through stiff joints, a recent trend is being investigated with a more accurate reproduction of the deformable structures present in the human hand. These anthropomorphic designs presented in [1] and [2] try to reproduce the tendons and ligaments in order to offer a passive compliance comparable to what the nature provided to our hands. While these conforming properties are of great importance in the field of robotic grasping, they also present a challenge for the control through the additional complexity that they induce in the model of the robotic system. However, simulation-based control in the field of soft robotics offers interesting results that can be applied to such designs. Using the algorithm developed in [3], we are able to control the displacement of each finger to perform a global grasping of an object by a robotic hand composed of soft elements. This algorithm makes use of a Finite Element model of the soft robot to obtain the relation between actuation values and displacement of the controlled points. This relation is then used in an inverse optimization to obtain the required actuation for a desired displacement. While the positioning of the fingers is important in a grasping task, it is also necessary to control the force applied by the hand on the objects or the environment while performing the closing of the hand. In that purpose, a method of stiffness control has to be used to manage various situations such as manipulating an egg without crushing it or using a door handle without wasting energy in an excessively firm grasp. Our recent results [4] in the field of stiffness rendering make use of the previously described position-control algorithm to apply a force dependant on the difference measured between expected and effective position. This dependence can be parametrized to render different apparent stiffness freely. Through the use of the developed solution, we can therefore control the grasping process to perform a variably compliant movement. While these two results rely on an inverse use of the Finite Element Analysis, we also developed simulations of directly actuated soft fingers taking into account the contacts with the environment (Fig 1). This feature allows to perform virtual grasping tasks and a current work-in-progress seeks to consider the contacts directly in the inverse control algorithm.

In this current work, we are trying to design a prototype with more deformable structures present in our hands by adding finger pulp and skin to the designs already involving tendons and ligaments. Through the use of different varieties of silicone and 3D printed elements (molds of the deformable structures and bones), we aim to obtain a mechanism closer to the real one that would therefore inherit its compliant behavior properties. With the use of the Finite Element model of the elements, directly created with the 3D models used for their making, we can obtain a numerical model that will be used with the presented algorithm to control accurately the displacement of the finger when bending while controlling its compliance.

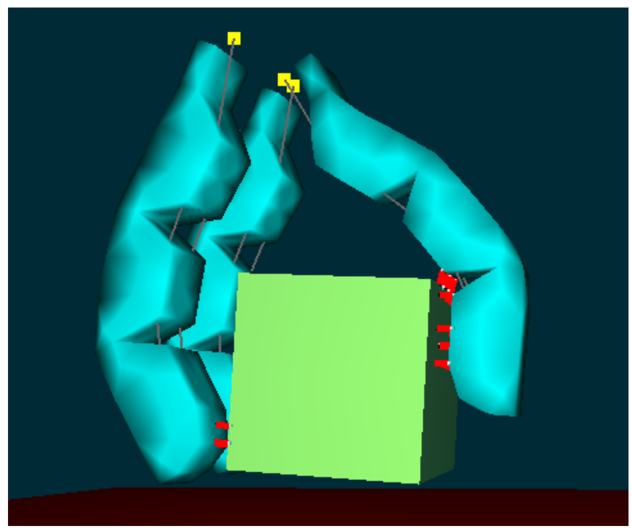

Fig. 1. Simulation of grasping with 3 soft fingers actuated with tendons under the SOFA framework. The grasping contacts can be visualized with the red segments.

References

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