Modelling of tensegrity structures

The building brick of the bird neck is a "Snelson X-shape mechanism" [3]. The kinematic and dynamic modelling has been done for one module first, then extended to several modules.

The direct kinetic model (DKM) is easy to compute but the inverse kinematic model (IKM) turns out to be more challenging. A practical method is provided in [4] and permits to come up with a quartic polynomial of minimal degree. The singularities are computed and show that the mechanism is cuspidal according to a geometric necessary and sufficient condition, and can have up to 4 inverse solutions to its IKM.

The geometric condition of cuspidality and all the cuspidal behavior of the robot is presented in [7].

The dynamic modelling of a neck composed of N serial modules has been derived thanks to the Lagrangian equation, and put in the following equation of motion:

$$M(\alpha)\dddot{\alpha} + C(\alpha)\dot{\alpha}^2 + G(\alpha) = Z_1f_1 + Z_2f_2 + Z_0f_0$$

The computation of this dynamic modelling allows us to control a stack of modules. By simplifying this model for one module and only with the static terms, the wrench feasible workspace (WFW), i.e all the reachable wrench, is computed [5].

Optimization

For one given module, we are able to compute the WFW for a given set of parameters (spring stiffness, length of bars, external forces,...). We can see that the size of the WFW depends on all the parameter, and that an optimal value of geometric parameter can be found to maximise the size of the WFW [6].

So for a given set of parameters, we obtain with our optimization algorithm different optimal length and size of the WFW.

This method has been extended to the full bird neck. As each module on the neck (as bird vertebrae) does not have the same external load, the same geometry and workspace, the idea is to try to find an optimal shape of the bird neck, maximizing the WFW of each module. Different optimization objectives could be define (energy, mass,...) in order to be closer to nature and better understand evolution process.

Prototyping

The realization of a prototype in under progress. The idea is first to design and build a single module to verify the dynamic on one module. Then, the base of the prototype will be conserved and several modules will be stacked, which will create some challenge on the actuation and cable routing.

References


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This PhD is part of the AVINECK project which involves biologists and roboticists guided by the following assumption: "The bird neck, an arm for the robot". The project aims at:

- having a better understanding of musculo-skeletal systems in bird necks.
- Designing an efficient and innovative robotic arm inspired from nature.

Tensegrity structures, a stable assembly of tensile and compressive elements [1][2], seem suitable to answer those problematics.