Academic year 2017-2018

Thesis Proposition for research master's degree in computer science SIF

Internship Title: **Simulation and control of a tensegrity mechanism inspired from a bird neck**

Hosted by: Laboratoire des Sciences du Numérique de Nantes, UMR 6004,
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Team : Robotique et Vivant

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Context of the internship:

Existing robots have limited performances as compared to living organisms. One of the main reasons comes from their inherent mechanical structures. Biological systems can be modeled using the concept of tensegrity. Tensegrity structures are made of isolated elements subject to tension and compression. The compressed members (bars or struts) do not touch each other but they lie inside a net of continuous tension made of prestressed tension elements (cables or tendons). Originally, tensegrity structures were introduced by architects and artists to build elevated constructions [1], see fig. 1.

Fig. 1 The Needle Tower by Kenneth Snelson

More recently, tensegrity structures have been used to model various biological systems such as cells and human spines [2, 3], see fig. 2. We then speak of biotensegrity.

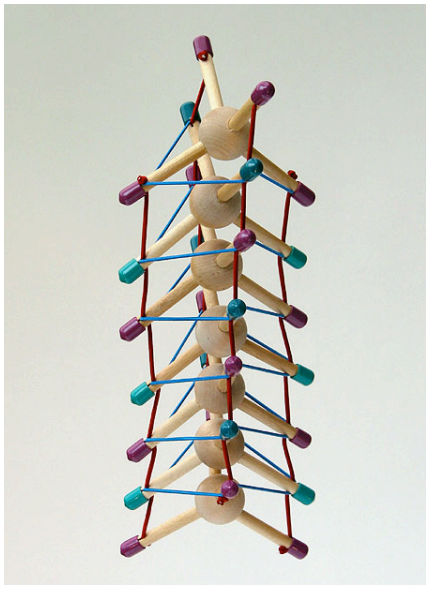

Fig. 2 Tensegrity structure as a model of human spine

Some roboticists have also tried to use tensegrity structures as alternative robot designs [4, 5]. Tensegrity structures possess a number of interesting features such as their lightness and their ability to store energy. Literature review reveals few links between the two research communities (biology and mechanics).

The topic of this internship is linked to a collaborative research project called Avineck between the LS2N laboratory (Nantes) and the MNHM (Museum National d'Histoire Naturelle, Paris) that aims at better understanding the functional behavior of bird necks and their potential interests in designing bio-inspired innovative robotic arms. A planar tensegrity model of a bird neck (plotus) has been designed recently in the frame of a former master thesis [6] (fig. 2).

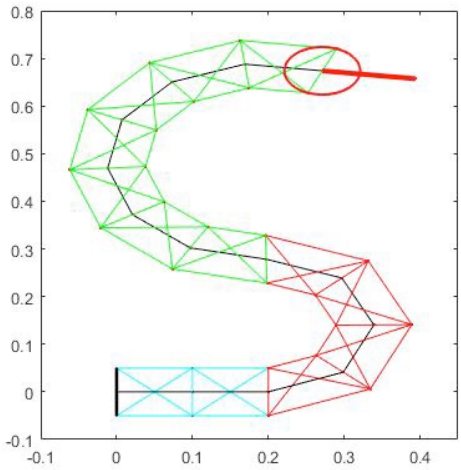

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Fig. 2: Plotus neck in its rest configuration modelled with several stacked tensegrity modules

This tensegrity model is built with several one-degree-of-freedom tensegrity mechanism modules arranged in series. The goal of this internship is to study the simulation and control of such a system in order to reproduce motion observed of the bird's beak.

Detailed description

The study will be decomposed into 4 parts

- Development of a simulator for the tensegrity mechanism. The number and type of modules will be defined after discussion with MNHM colleagues in order to be consistent with the observations of the bird. This part of the work will be based on the previous work of other master students to develop a simulator with matlab/simulink.

- Definition of observed motion of the neck of the bird based on video record in collaboration with the team of the MNHM in order to define observed motion, velocity and acceleration of the head of the bird and of the vertebrae.
- Proposition of a control law that is able to reproduce in simulation the motion observed on the bird. An actuation system will be proposed based on a biological assumption and the redundancy of actuation will be used to reduce the force used to produce the motion.
- If possible a comparison with more classical serial robots will be done to show the efficiency of the tensegrity mechanism.

The analysis will be conducted with the help of a CAD system and Matlab/Simulink.

Keywords
Robotics, Bio-inspiration, Simulation, Control

Bibliographical references:
[1] Fuller RB. Tensile-integrity structures. US patent 3,063,521. November 13, 1962.
[2] Randel L. Swanson II, Biotensegrity: A Unifying Theory of Biological Architecture With Applications to Osteopathic Practice, Education, and Research—A Review and Analysis. The Journal of the American Osteopathic Association January 2013 | Vol 113 | No. 1.
[3] Levin SM. The tensegrity-truss as a model for spine mechanics: biotensegrity. JMMB. 2002;2(3):375-388.
[4] Arsenault, M., and Gosselin, C., 2006, "Kinematic, Static and Dynamic Analysis of a Planar 2-DoF Tensegrity Mechanism," Mech. Mach. Theory, 41(9), pp. 1072–1089.
[6] M. Lettl, "Kinetostatic analysis of tensegrity mechanisms, application to the modelling of bird necks", Master thesis, Ecole Centrale de Nantes, 2017.
[7] M. Arsenault, "Développement et analyse de mécanismes de tenségrité," Ph.D. dissertation, Faculté des sciences et de génie Université Laval Québec, 2006.

Required or appreciated skills:
- Interest for multi-disciplinary project and curiosity
- Experience in robotics