Muscular hydrostats biomechanical model to investigate *morphological computation* in grasping with soft structures

Vito Cacucciolo, PhD student
v.cacucciolo@sssup.it

The BioRobotics Institute, Scuola Superiore S.Anna, Pisa, Italy

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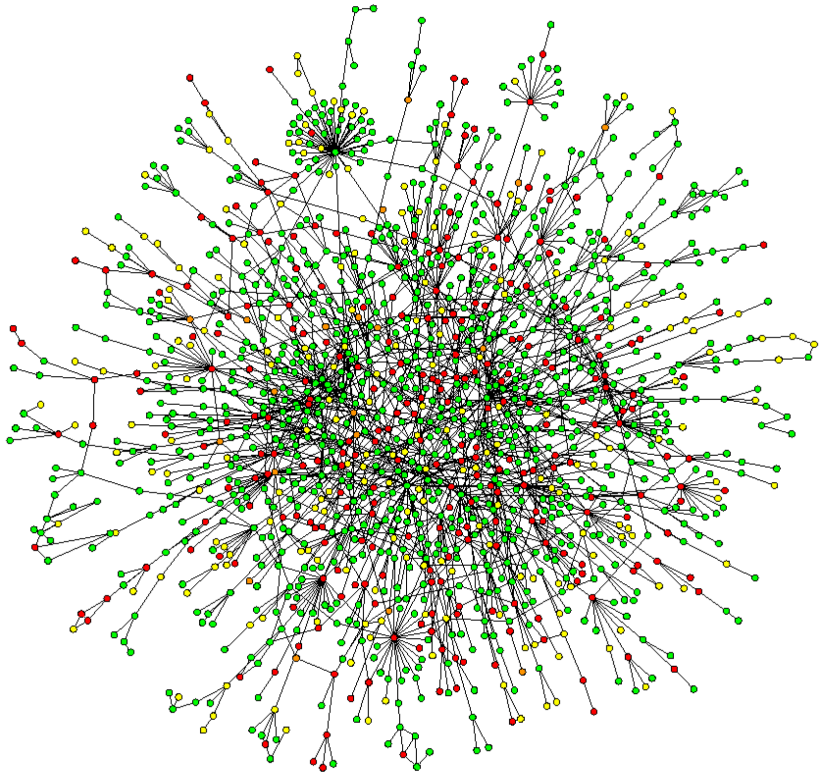
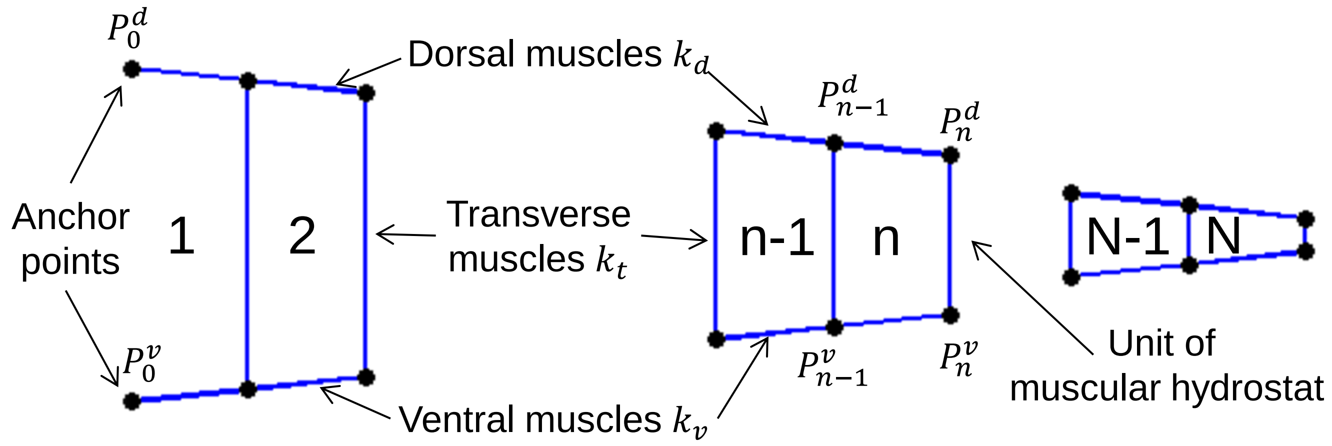
Goals and theoretical basis

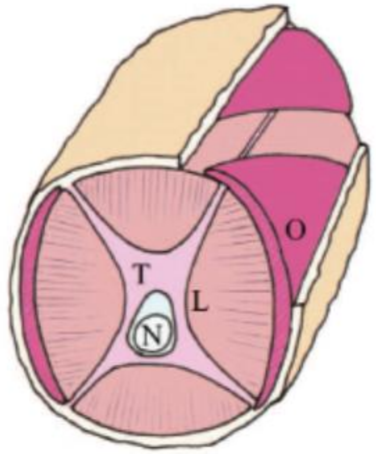
- ***Morphological computation***
  - Rich and complex behavior let the body compute;
  - Nonlinear dynamics;
  - Interaction with the environment.

- **Body as a *complex system***
  - Interaction of *agents* (e.g. muscles, sensors, structure) lead to the emergence of the system behavior (*self-organization*);
  - Apply complex systems theory and Computational Mechanics tools;
  - Complex network of springs and masses.



Why a mathematical model?





- **Understand the basic principles**
  - Extract the basic principles of *muscular hydrostat* structures (synthetic methodology);
  - Transfer them into an artificial manufact bypassing technological limits (artificial muscles).

- **Generality:**
  - soft animal structures (e.g., squid and octopus tentacle, elephant trunk);
  - soft robotic arms with lumped actuation (e.g., pneumatic, hydraulic, sma).

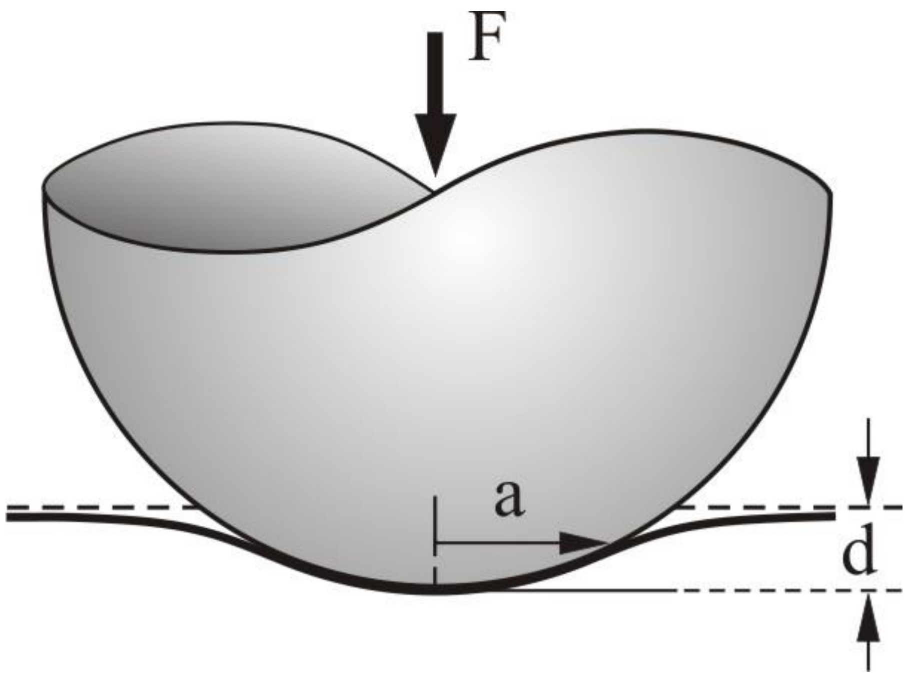
Methods

- **Lagrangian dynamics:**
  - Energy based, good control on large number of DOFs;
  - Implicit solver – stiff equations due to constraints;
  - Constant volume constraint through penalty method.

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{\boldsymbol{q}}}\right) - \frac{\partial L}{\partial \boldsymbol{q}} = 0$$

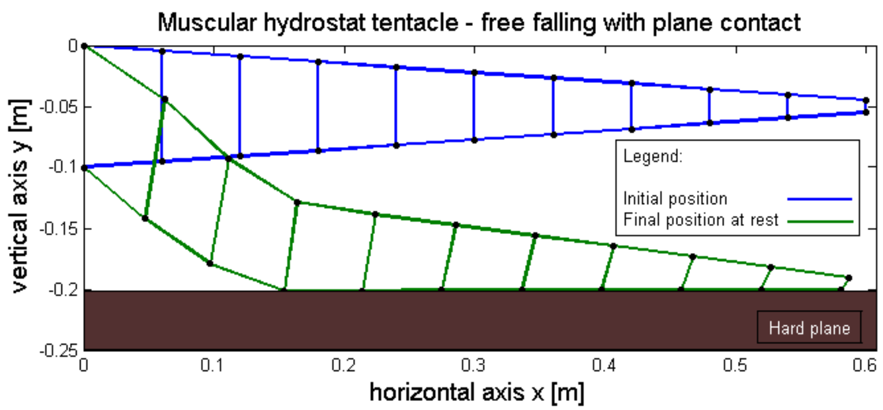
$$\boldsymbol{M}\ddot{\boldsymbol{q}} + \boldsymbol{F}^{E}(\boldsymbol{q}) = \boldsymbol{f}$$

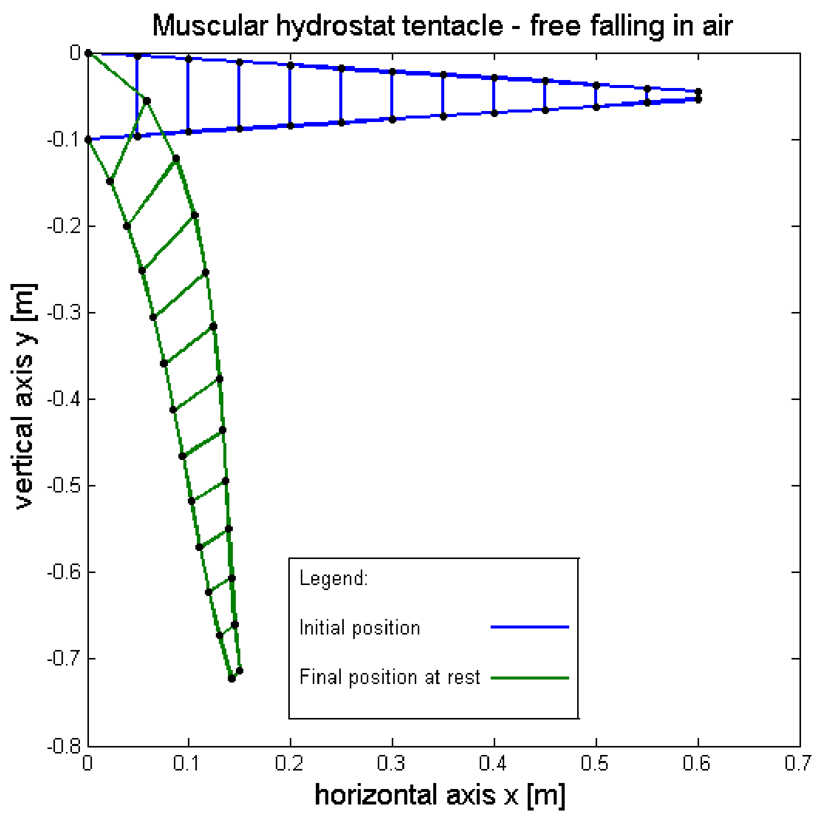
- **Contacts:**
  - Interaction with the environment;
  - Grasping;
  - Combination of penalty method and a step activation.

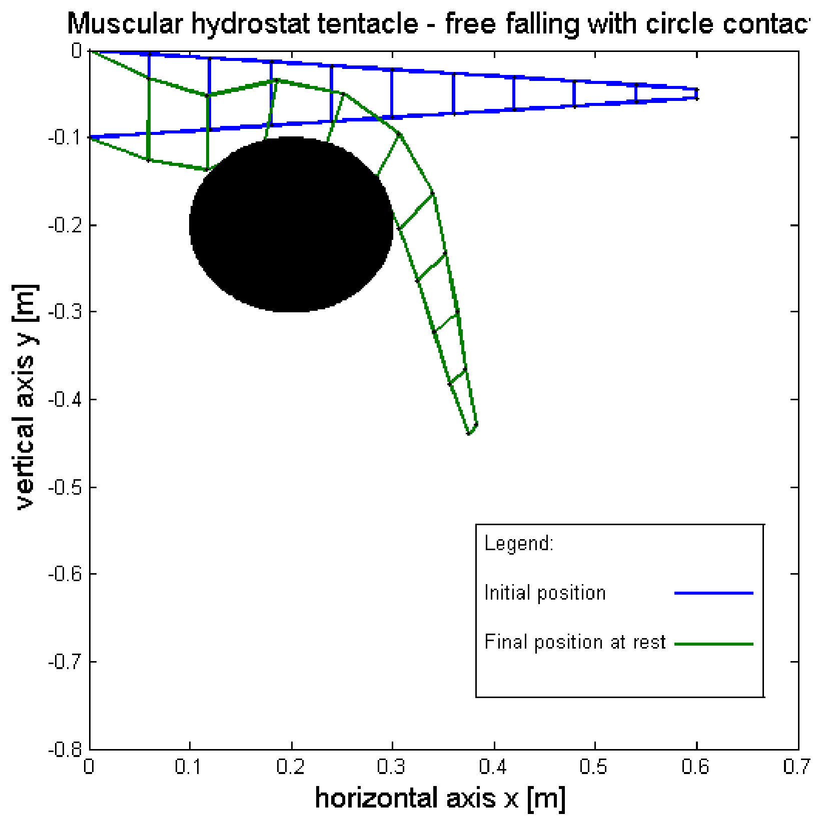


Results (preliminar)

- **Math is ready:**
  - N-segments nonlinear dynamics;
  - Constant volume constraint;
  - Contact constraint.





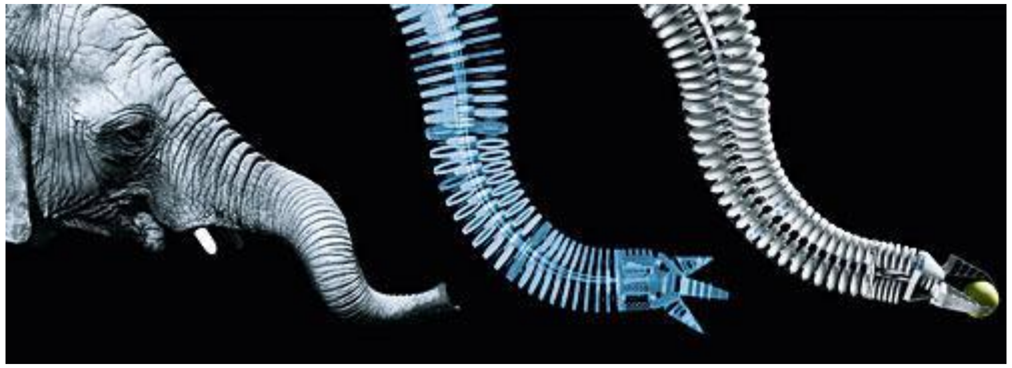


Outomes – next steps

- ***Morphological computation* in grasping**
  - Relation between structure and control strategies in grasping tasks above animals with soft structures;

- **Evolutionary studies**
  - Co-evolution of morphology and control;
  - How optimal control strategies are modified by changes in the structure.

- **Soft robotic arm design**
  - Apply results of biomechanical investigations;
  - Cheap bio-inspired control.



Thank you for your attention.