Bioinspired Design and Shared Autonomy for Underwater Robots with Soft Limbs

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Project Goal: Establish a framework for underwater soft manipulation by studying the structure, control and planning of cephalopod-inspired robot arms.

MODELING SOFT ARMS FOR DESIGN

Model-based design can produce more capable soft robots than iterative prototyping, but existing models are arm specific. We developed a generalizable bending model by characterizing constituent actuators (Fig 1).

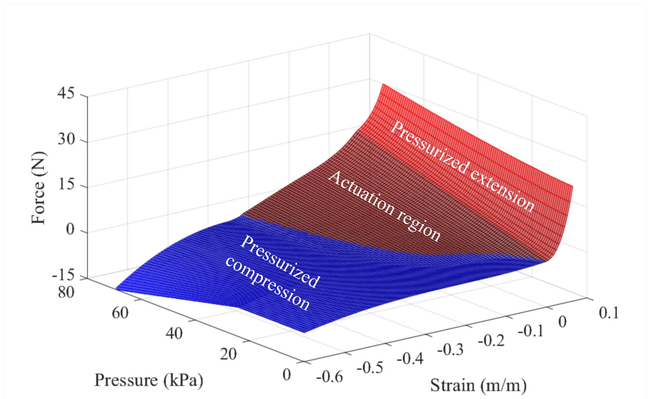

Fig 1. McKibben actuator characterization.

The actuator characterization replaced linear material descriptions in an Euler-Bernoulli beam model.

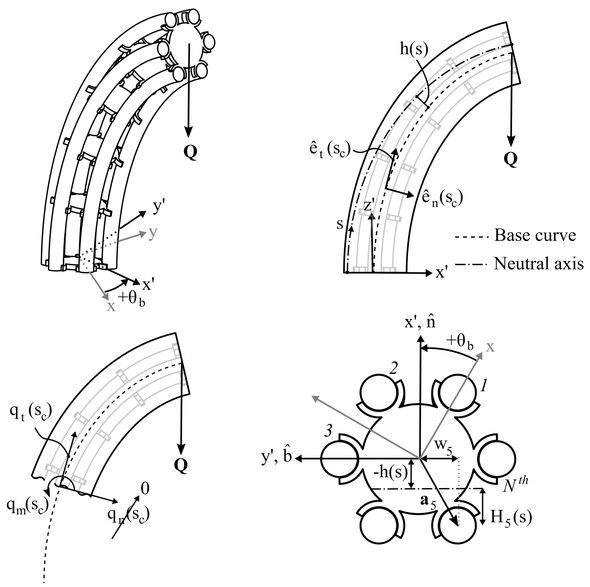

Fig 2. McKibben actuator characterization.

VALIDATION

We validated the model using planar and spatial (Fig 3) soft arms. The model matches the shape and direction.

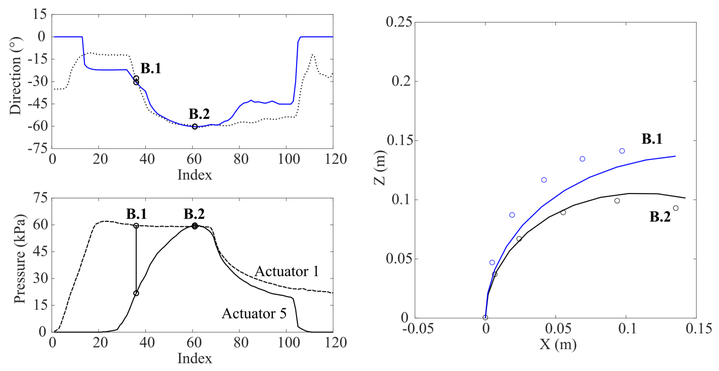

Fig 3. Spatial arm under self weight and a 0.29 N tip load.

LOADED WORKSPACE ANALYSIS

We analyzed workspace using the model. An arm's maximum force diminishes rapidly at the workspace edges (Fig 4), and arm tapers improve workspace size and maximum force (Fig 5).

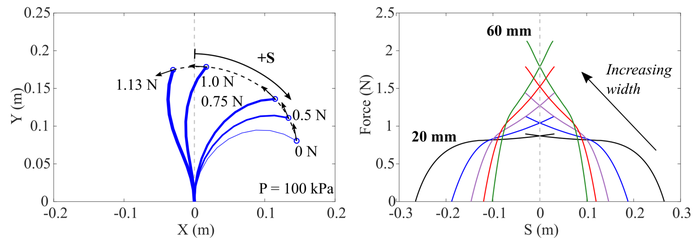

Fig 4. Single segment loaded workspace.

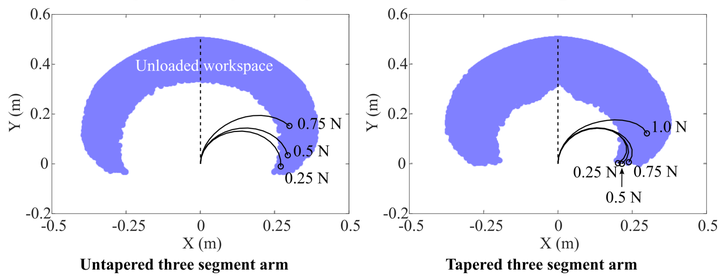

Fig 5. Multisegment arm workspace comparison .

MOTION PLANNER

Our Rapidly-Exploring Random Trees (RRT) planner uses a piecewise constant curvature kinematic model. RRT planners can be more efficient at planning in high dimensional applications, such as multisegment soft arms.

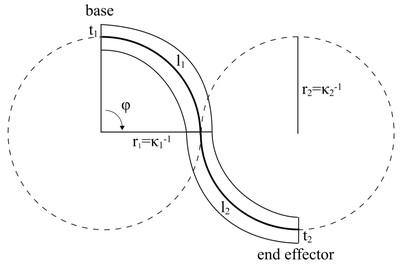

Fig 6. Planner kinematic model.

We demonstrated the planner in simulation and hardware.

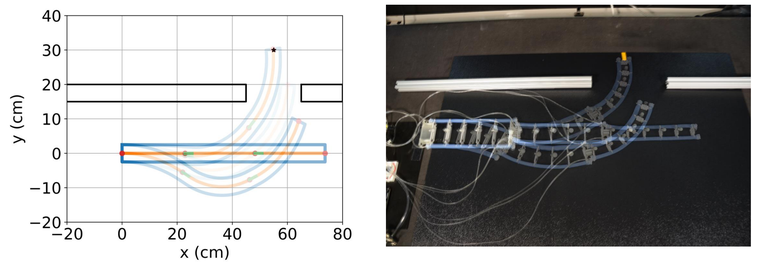

Fig 7. Comparison of simulated and executed plan.

Our RRT planner achieved a >90% success rate within 20 min. for three segment arms in randomly generated maps with three obstacles.

FUTURE DIRECTIONS

- Explore overactuated designs using alternative configurations (e.g., elliptical) and tapered arms.
- Expand motion planner to include loads and collisions.
- Develop shared autonomy strategies that translate general user-selected motions into specific pressurization schemes.

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