A quasi-static approach to modeling soft-tissue structures

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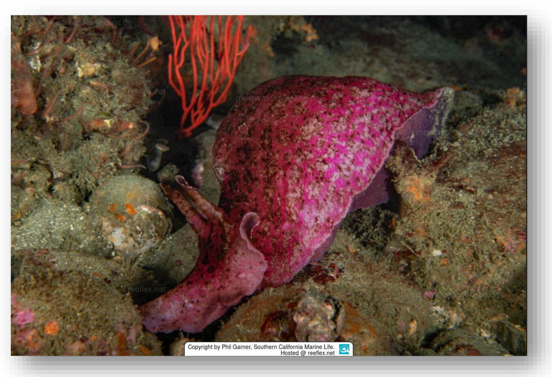
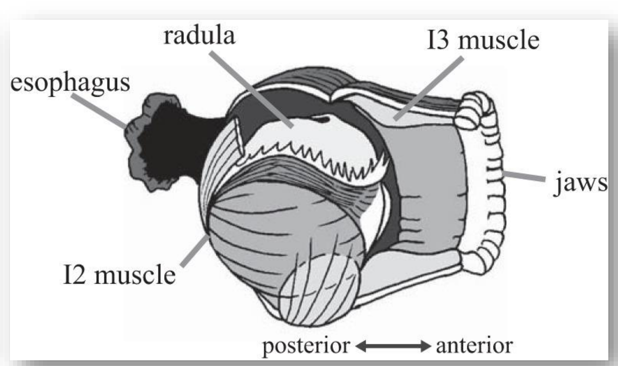
Abstract 9763 Poster 579.20

Abstract

- We have studied the feeding behavior of *Aplysia Californica*
- Comparatively, a computationally fast mathematical model has been provided
- Quasi-static formulation has been followed in this modeling
- Balancing only muscle forces for soft-tissue type structure(buccal mass), dynamical equilibrium positions have been found.



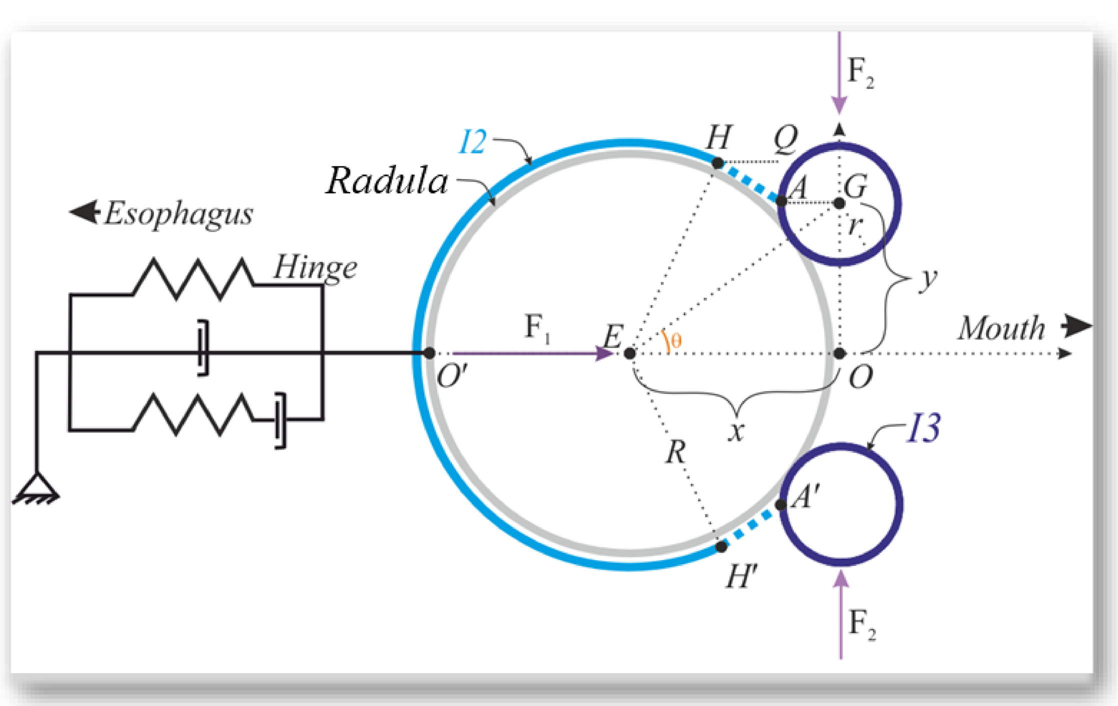
Aplysia Californica



Side-View of feeding apparatus

Introduction

Original Complete Newtonian (2nd Order) Model



From Newton's law of motion: ***Mass x Acceleration= Total Force***

$$(m\ddot{y} + F_2)cos(\theta) = (M\ddot{x} - F_1)sin(\theta)$$

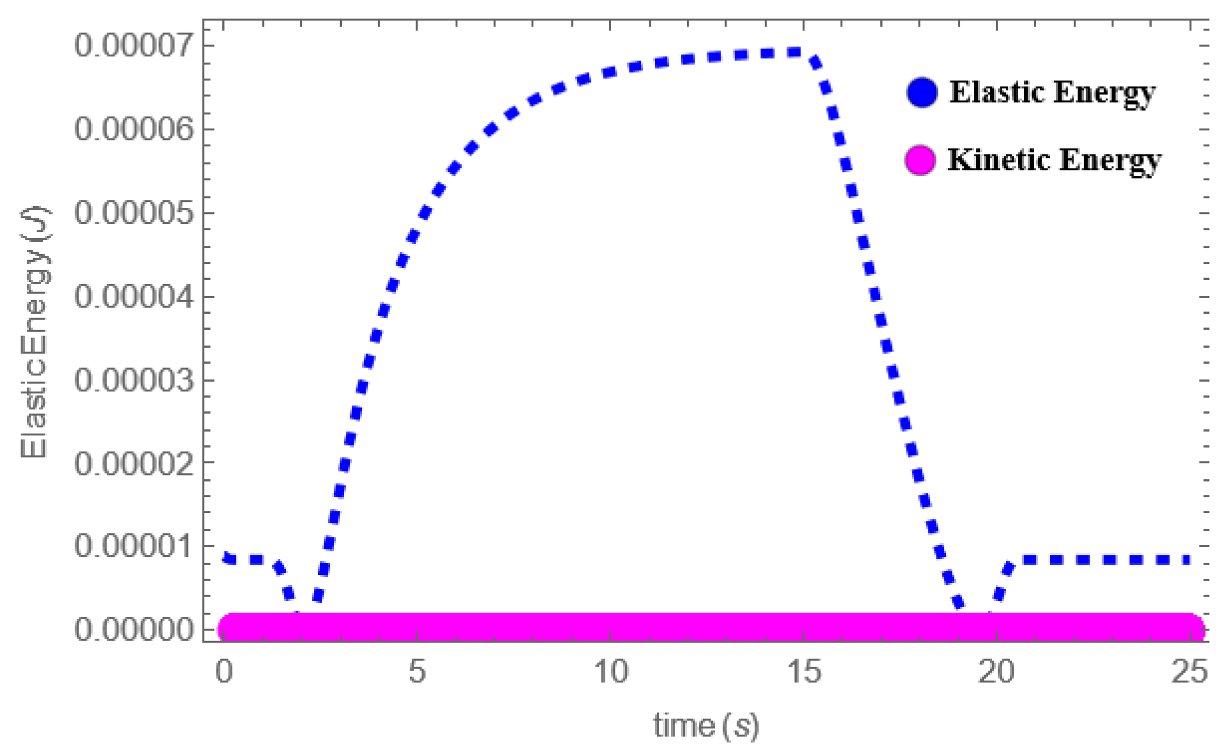
m: mass of I3 muscle, *M:* mass of the radula

However, the existing model is computationally expensive.

This model needs **14 seconds to simulate 1 second** of feeding behavior.

Observations

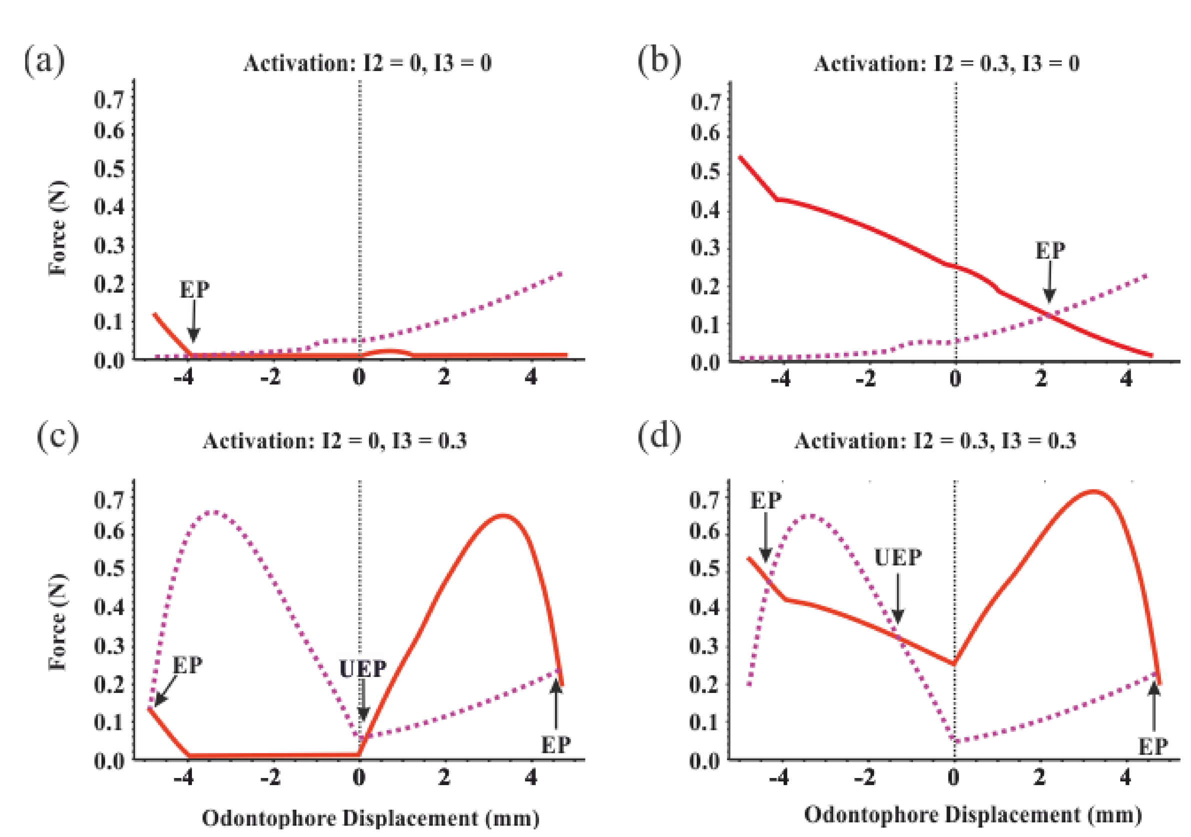
- Change in velocity or acceleration is negligible
- Elastic energy is <u>*over four orders of magnitude*</u> higher than the Kinetic energy



Quasi-static reformulation

$$(m\ddot{y} + F_2)cos(\theta) = (M\ddot{x} - F_1)sin(\theta)$$

$$F_2\ Cot(\theta) + F_1 = 0.$$



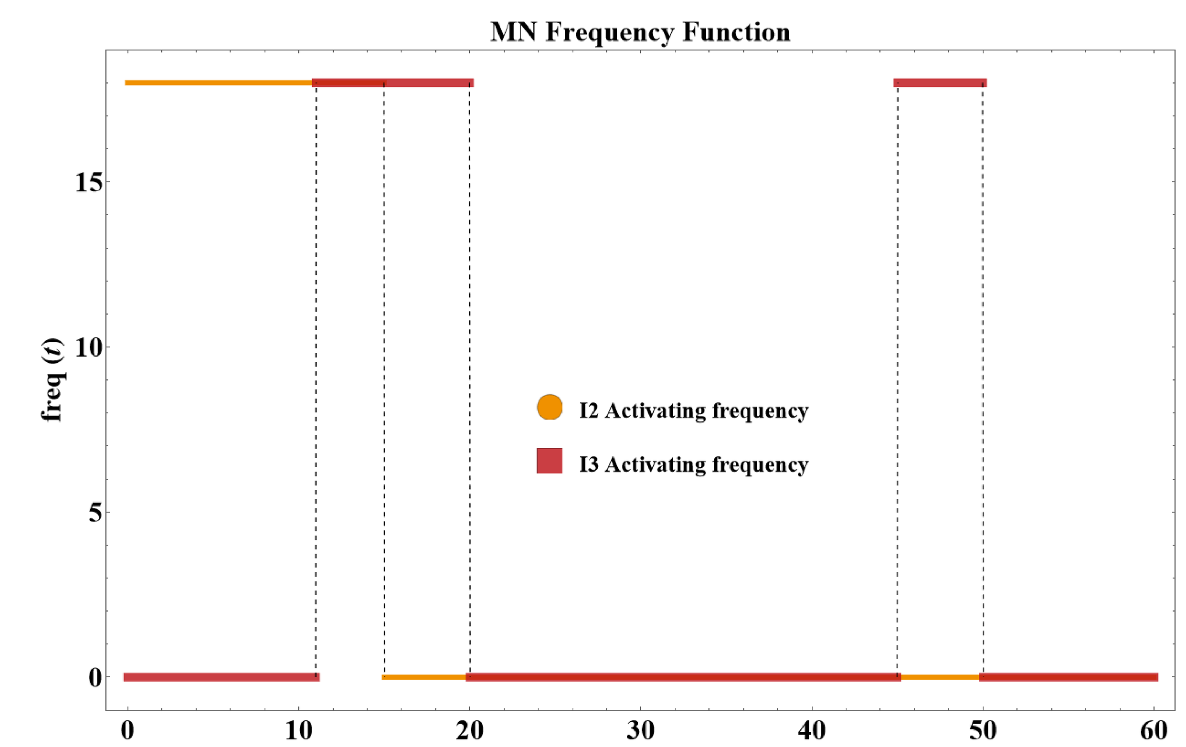
EP: Equilibrium point UEP: Unstable Equilibrium point

Equilibrium point is the position of the radula at that instant

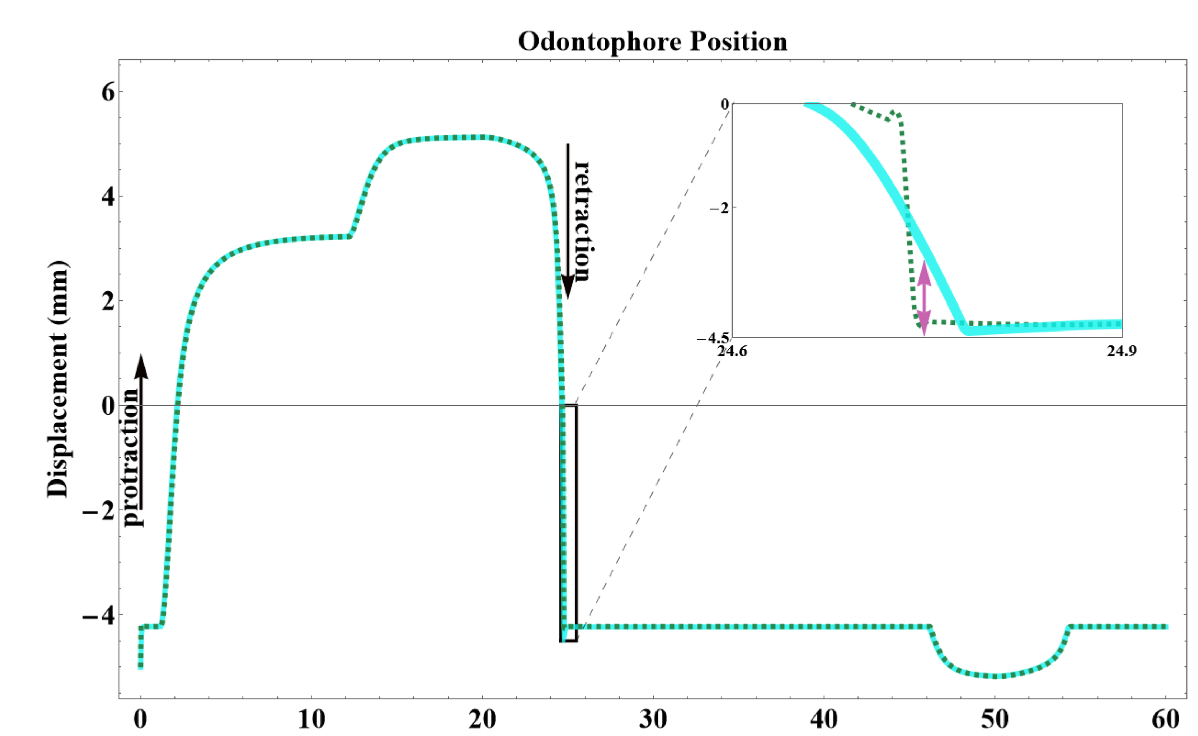
Methods

- These equilibrium points were found numerically using Newton's method
- Python *scipy* function *fsolve* has been used to find the root

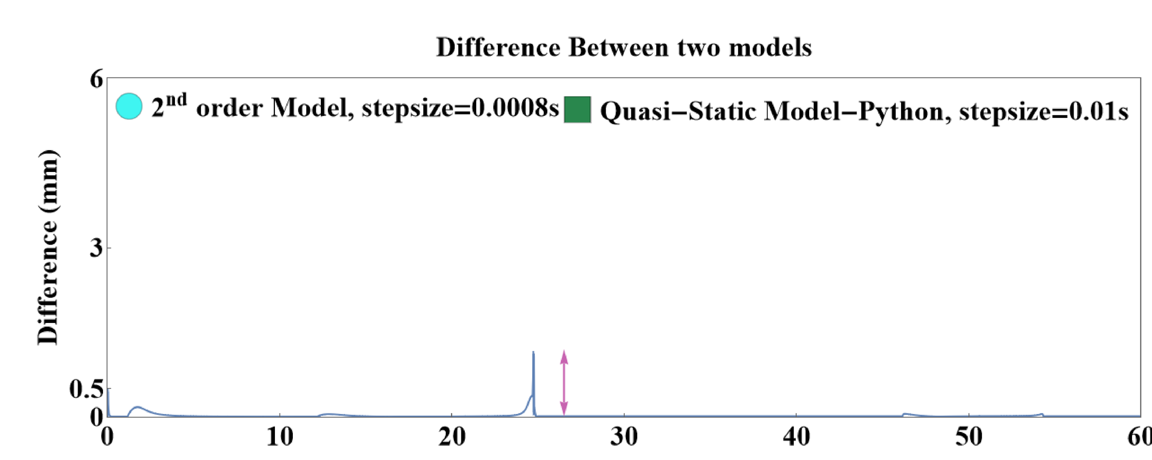
Results



Firing frequency function of motor neurons



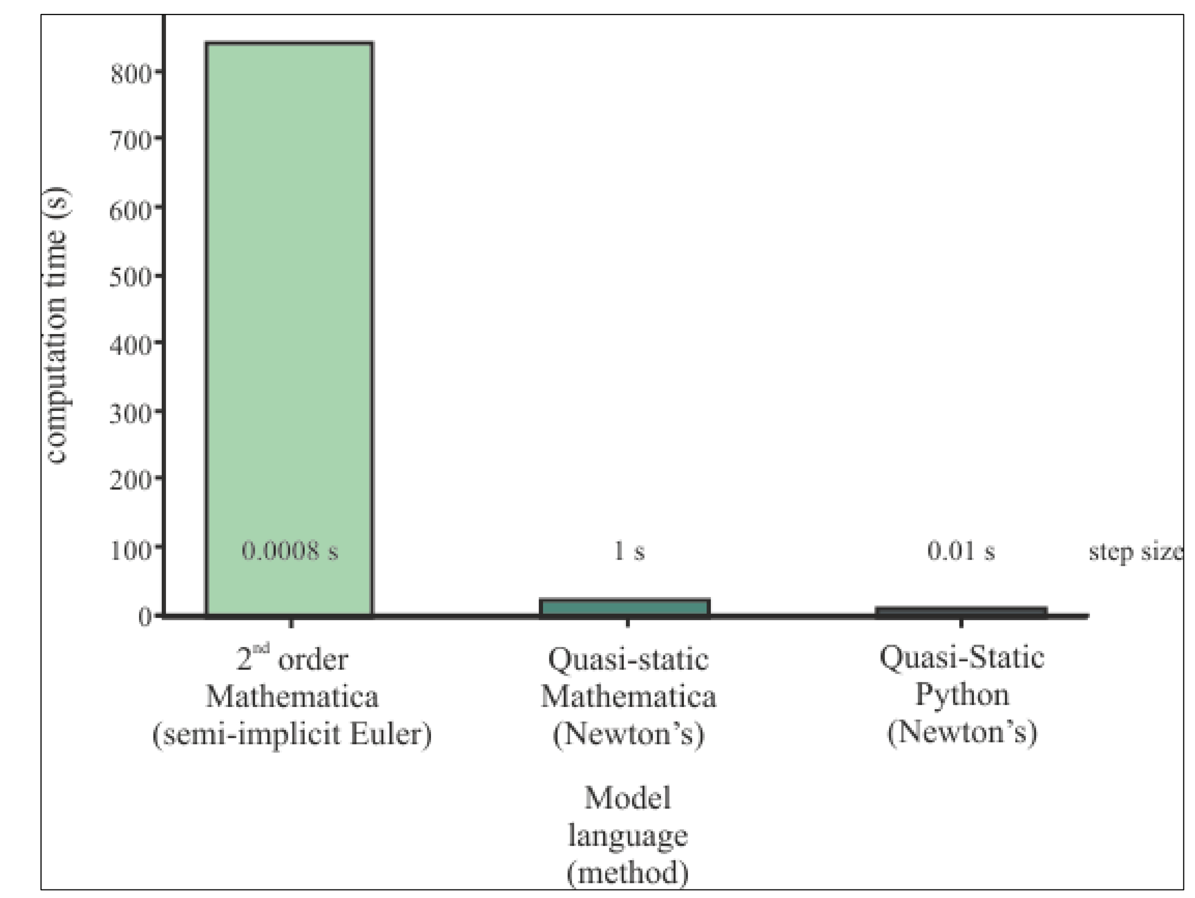
Displacement of the radula modelled using 2nd order (turquoise) and quasi-static (dashed, green) formulations



The difference is almost negligible

Conclusions

This detailed biomechanical model is now computationally cheap



Great reduction of computational time

Future Work

We will use this quasi-static biomechanical model to study the neuronal control including feedback mechanism

Acknowledgements

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References

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[4] McManus et al., *J Neurophysiol* 112: 778–791, 2014.