Team 5 - Gripper

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EGR 557

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Biomechanics Background and Initial Specifications

Biomechanics:

1. G. M. Erickson, A. K. Lappin, T. Parker, and K. A. Vliet, “Comparison of bite-force performance between long-term captive and Wild American alligators (alligator mississippiensis),” *Journal of Zoology*, vol. 262, no. 1, pp. 21–28, Feb. 2006. *

   This journal article discusses the bite forces of alligator jaws depending on the various biological modifications, for example, jaw length, head shape, and body form, that occur with different environments and conditions. It also discusses the different parameters that can reveal conflicting results, such as the performance differences between wild and captive alligators. From this journal, we are able to determine the ideal geometry for a gripper to ensure the highest possible “bite force”.

2. A. Saber and A. Hassanin, “Some morphological studies on the jaw joint of the Australian saltwater crocodile (Crocodylus porosus),” *Journal of Veterinary Anatomy*, vol. 7, no. 2, pp. 55–74, 2014. *

   This journal studies the biting forces exerted by the jaw of a saltwater crocodile. It provides information about how the construction and anatomical structure of the jaw joint lead to the forces it can exert. It looks at a variety of different skulls to properly analyze the different parts, such as ligaments and muscles, that play a role in the force exerted by the jaw.

3. A. Herrel, J. C. O’Reilly, and A. M. Richmond, “Evolution of bite performance in turtles,” *Journal of Evolutionary Biology*, vol. 15, no. 6, pp. 1083–1094, Nov. 2002, doi: 10.1046/J.1420-9101.2002.00459.X.*

   This paper empirically tests how the differences in body dimensions of several turtle species are related to their bite performance. It determines how the bite force tends to change in proportion to the jaw size as well. It relates the scaling laws and concludes that changes in body size are associated with the design of the jaw apparatus. It also explores the relationship between force and speed of closing of the jaw and the tradeoffs associated with scaling the size of the jaw apparatus.

4. S. Burgess, “A review of linkage mechanisms in animal joints and related bioinspired designs,” *Bioinspiration & Biomimetics*, vol. 16, no. 4, p. 041001, Jun. 2021, doi: 10.1088/1748-3190/ABF744.

5. M. Sakamoto, “Jaw biomechanics and the evolution of biting performance in theropod dinosaurs,” *Proceedings of the Royal Society B: Biological Sciences*, vol. 277, no. 1698, pp. 3327–3333, Jun. 2010.

Bio-inspired:

1. Liu, C., Maiolino, P., Yang, Y., and You, Z. (2020). “Hybrid Soft-Rigid Deployable Structure Inspired by Thick-Panel Origami”. *Proceedings of the ASME 2020 International Design Engineering Technical Conferences and Computers and Information in Engineering Conference*: 44th Mechanisms and Robotics Conference (MR). Virtual, Online, August 17–19, 2020, 10. doi:10.1115/detc2020-22246 *

This paper proposes a novel structure, inspired by thick-panel origami, with hybrid rigid bodies and flexible hinges. Able to be expanded, flipped, and rotated, the waterbomb origami pattern has been chosen to produce a large number of configurations. The mechanism and motion analysis of a single unit and its basic assembly are conducted theoretically and also simulated. An additive fabrication method based on 3D printing makes it a one-step process to achieve a balance between rigidity and flexibility in the structure. Different configurations are demonstrated in three assemblies that exhibit good transformability, reconfigurability, and scalability. With the expansion/packaging ratio ranging from 0.11 to 7.2 in a modular unit, a mechanical metamaterial of negative Poisson’s ratio can be obtained at any spatial size.

2. Joshua C. Triyonoputro, Weiwei Wan, Kantapon Akanesuvan, Kensuke Harada, "A Double-jaw Hand that Mimics A Mouth of the Moray Eel", Robotics and Biomimetics (ROBIO) 2018 IEEE International Conference on, pp. 1527-1532, 2018. *

In this paper, a moray eel’s jaw was used as a bio-inspiration and a gripper was designed with two separate linked jaws like a moray eel which were pharyngeal jaw and oral jaw, the pharyngeal jaw can move front or back and is able to grip different machines and assemble and disassemble it parts, this improves the mobility and the grip strength can be varied as needed.

3. K. C. Galloway et al., "Soft Robotic Grippers for Biological Sampling on Deep Reefs", Soft Robot, vol. 3, no. 1, pp. 23-33, Mar 2016. *

In this paper, development of a 3-D printed soft robotic tri-gripper embedded with tactile sensor array is presented. A facile fabrication strategy by 3D-printing thermoplastic polyurethane (TPU) was employed to fabricate the soft tri-gripper consisting of 9 capacitive tactile sensor-laden phalanges. The 3D-printed TPU itself was used as a sensory dielectric for the fabricated tri-gripper. The sensor and interconnect electrodes have been designed to have minimum cross-sensor capacitive coupling with stretchable interconnects to ensure robust integration. The designed sensors were patterned as copper electrodes on top of flexible polyimide film and embedded within the gripper during the 3D-printing process. The sensors were characterized and it exhibited a maximum sensitivity of 2.87 %/kPa. The gripper was tested for up to 100 cycles of compression and expansion. The developed sensory gripper finds application in industrial and agricultural robotics

4. J. Gafford et al., "Shape deposition manufacturing of a soft atraumatic deployable surgical grasper", Journal of Medical Devices, vol. 8, no. 3, 2014.

5. Zhang, W., He, Z., Sun, Y. *et al.* A Mathematical Modeling Method Elucidating the Integrated Gripping Performance of Ant Mandibles and Bio-inspired Grippers. *J Bionic Eng* **17,** 732–746 (2020). https://doi.org/10.1007/s42235-020-0065-9 *

	Saltwater Crocodile	Panthera tigris	Alligator Mississippiensis	Parrot fish
Weight	400 lbs	200 - 600 lbs	500 lbs	45 lbs
Bite Force	3,700 PSI	1000 PSI	2900 PSI	530 PSI
Snout Length	62 inches	13 inches	78 inches	4 inches

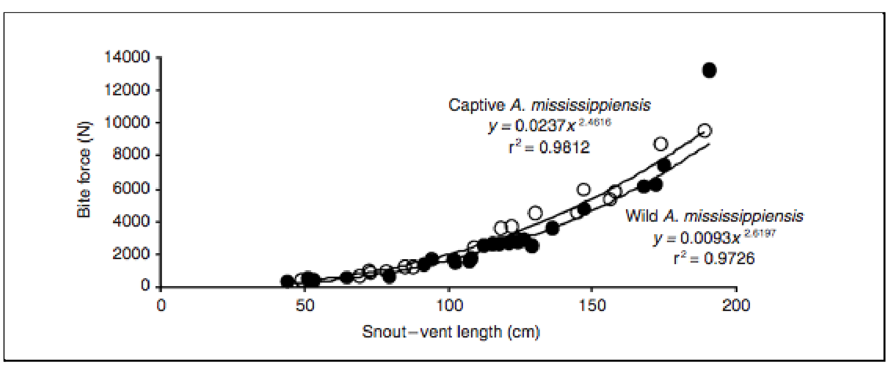

Figure 1: Alligator Mississippiensis Bite Force vs Snout Length

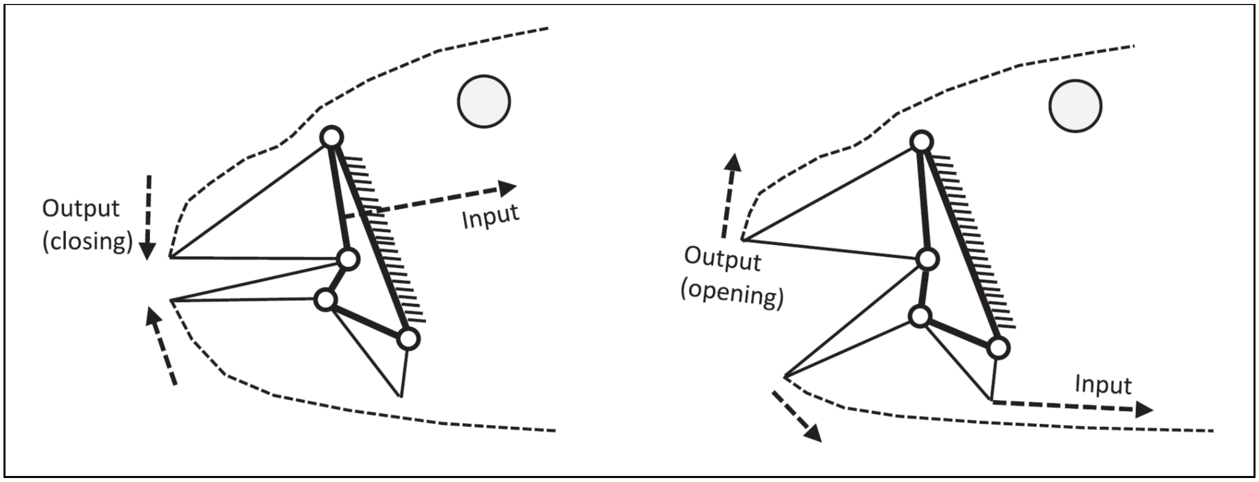

Figure 2: Parrot fish jaw demonstrated in 4 bar linkage

Engineering Drawing

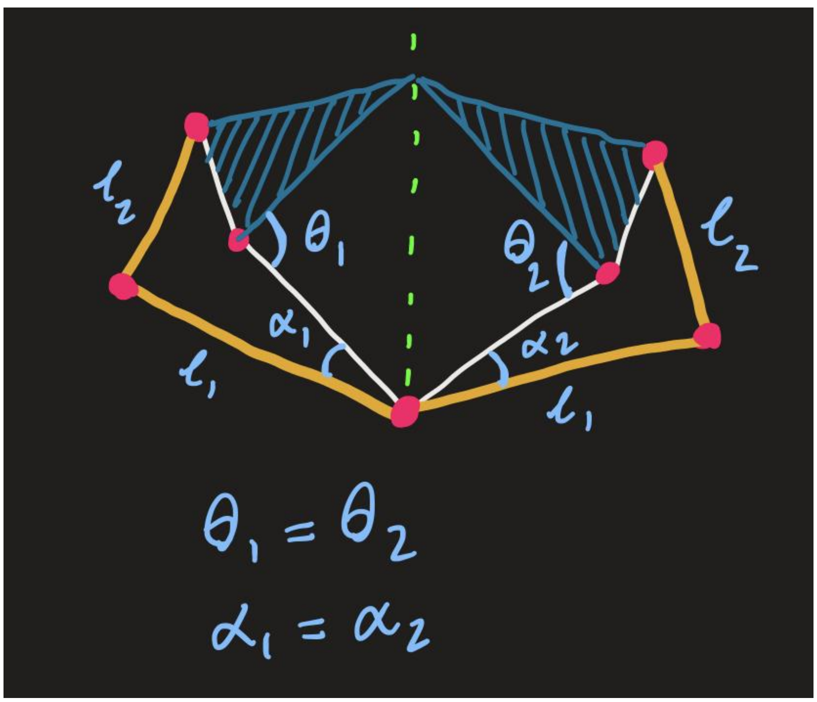

Figure 3: Rigid body diagram showing linkages inspired by the parrot fish. The yellow links are rigid and the blue shaded area demonstrates the end effector.

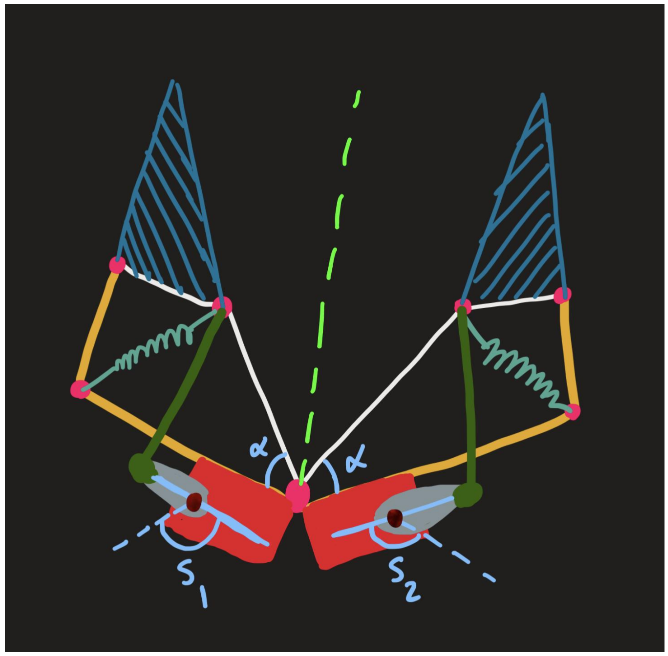

Figure 5: Location of springs, actuators, and connection to the rigid links

Discussion

Discuss your rationale for the size animal you selected in terms of your ability to replicate key features remotely with limited material selection.

> We decided to choose a parrot fish due to it's high bite force and small size. In the scope of this project, it is more realistic to replicate a smaller animal than a large animal, such as an alligator, due to the limited material selection and time. With affordable yet reliable actuators, replicating a parrot fish is possible for this project

Find a motor and battery that can supply the mechanical power needs obtained above. Consider that motor efficiencies may be as high as 95%, but if you can't find it listed, assume you find a more affordable motor at 50-70% efficiency. Compare the mechanical watts/kg for the necessary motor and battery vs the animal's mechanical power/mass above? Which one is more energy dense?

> <u>Motor:</u> BETU 2Pack 25KG High Torque RC Servo
> <u>Battery:</u> ABENIC DC 12V 2A (24W) 4000mAh Super Rechargeable Portable Li-ion Lithium Battery DC12400 Blue
>
> Mechanical watts/kg: 12/0.2 = 60 Watts/kg
> Parrot fish power/mass: 610626.050146222/20= 30531.3025073 kg/cm^2*kg
> The parrot fish is more energy dense.