3D Movement in Genus Panthera

Cassidy Barrett

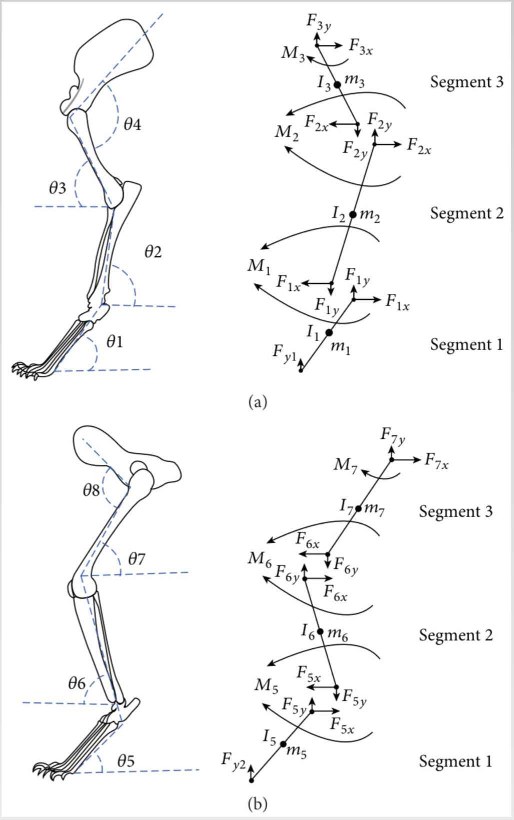
Mechanical Engineering Department

INTRODUCTION

Mimicking biology in mechanical systems, while no longer a new solution to design problems, does indeed allow for innovation compared with traditional design. Biological systems are often highly efficient and can offer engineers a blueprint to create from. For example, members of the genus Panthera, (lions, tigers, leopards, jaguars, and snow leopards), defined here as "big cats", are naturally optimized for speed and power in killing prey. They are apex predators yet still maintain balance and stealth as they hunt. The goal of this project is to analyze the muscular structure of the legs in big cats from a mechanical force analysis. The five big cats will be compared graphically based on average size, weight, food consumption, relative speed, and strength. Computational algorithms describing the mathematical model of motion of each component of the muscle system will be developed. Variables of interest will be identified and tested, hypothesizing to see what combination of graphed characteristics creates the strongest/fastest/lightest/most fuel-efficient system. This information can then be applied to the design of a machine as a mechanical system prototype inspired by the given characteristics and the basic structure of a big cat's leg.

WHAT CAN WE TAKE FROM BIG CATS TO USE IN MACHINERY?

PREVIOUS RESEARCH



When I was originally starting this project, I spent time looking for the ways others had analyzed the legs of Genus Panthera. While I did not find much specifically dedicated to big cats, there was a plethora of information on the leg structure and movement of four-legged animals, particularly dogs and cats. A 2015 study (1) dove deep into the mechanics and the different phases of motion after building a walking quadruped robot a decade beforehand. Another study, (2) examined why cats can land gently from great height while humans can be seriously injured. I did not find what I was looking for in my search for forces directly related to animal size, nor their acceleration. However, these did offer a basis for what I am working towards and I found many papers that would be good resources for my future work.

METHODS

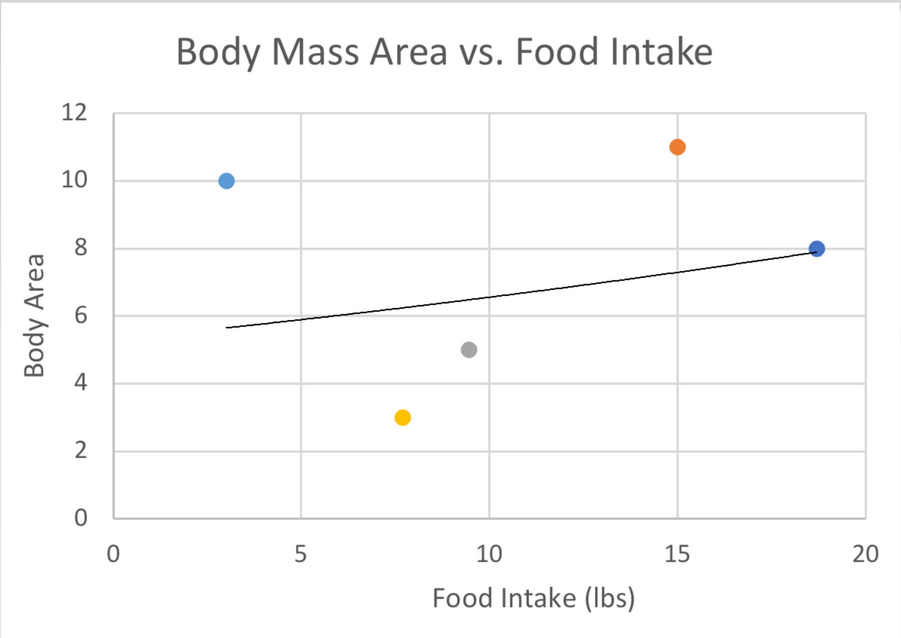
1. Compile average characteristics of members of Genus Panthera
    1. Height
    2. Length
    3. Weight
    4. Food intake
    5. Speed
    6. Body weight divided by height times length (BODY AREA)
2. Graph all numbers and observe trends
3. Create mathematical model for trends
4. Isolate variables and test to confirm trends
5. Find strongest, fastest, and most food efficient animals
6. Create 3D model of each animal's front and hind leg

RESULTS

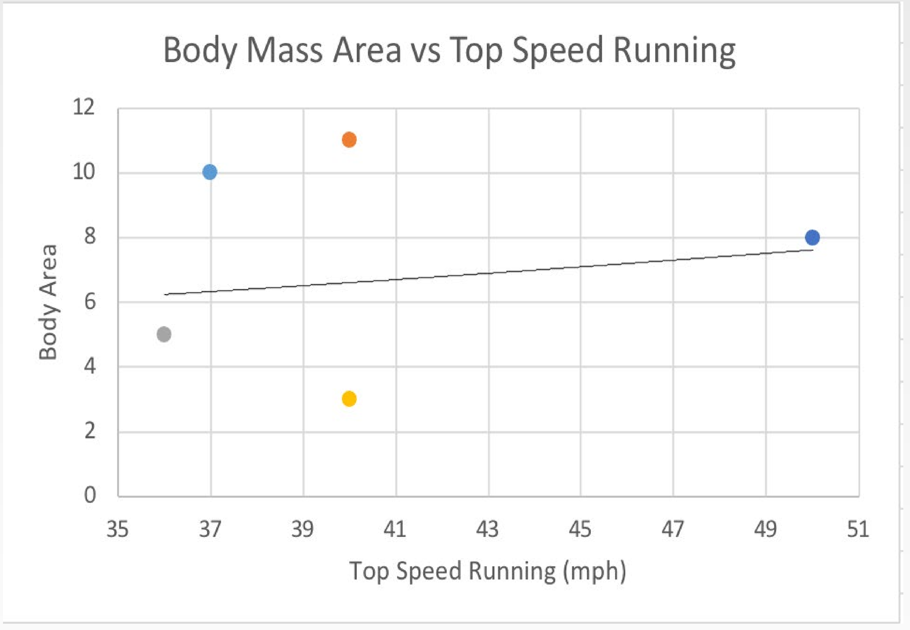
	Lion	Tiger	Leopard	Snow Leopard	Jaguar
Weight (lbs)	450	440	122.5	70	175
Shoulder Height (in)	46.8	37	25.6	24	27
Body Length (in)	117	104	87.5	84	60
Daily Food Intake (lbs)	18.7	15	9.5	7.7	3
Top Speed Running (mph)	50	40	36	40	37
BMA (lbs/in^2)	8	11	5	3	10

	Lion
	Tiger
	Leopard
	Snow Leopard
	Jaguar

LEGEND



y = 0.1079x + 6.2374



y = 0.0633x + 4.8295

DISCUSSION

The category of force was not able to be found due to inadequate resources at the moment, so I was unable to add it to the other graphs. Less former research was available on this subject than I originally thought.

I used the category of Body Mass Area (BMA) to gauge the animal's characteristic off their relative size.

The formula is here:

[100*(Body Weight)]/(Height*Length)

The formula is multiplied by 100 to create a whole number, not a decimal.

Height is the height at the animal's shoulder.

Length is the length of the animal's body including their tail.

All measurements those of adult males.

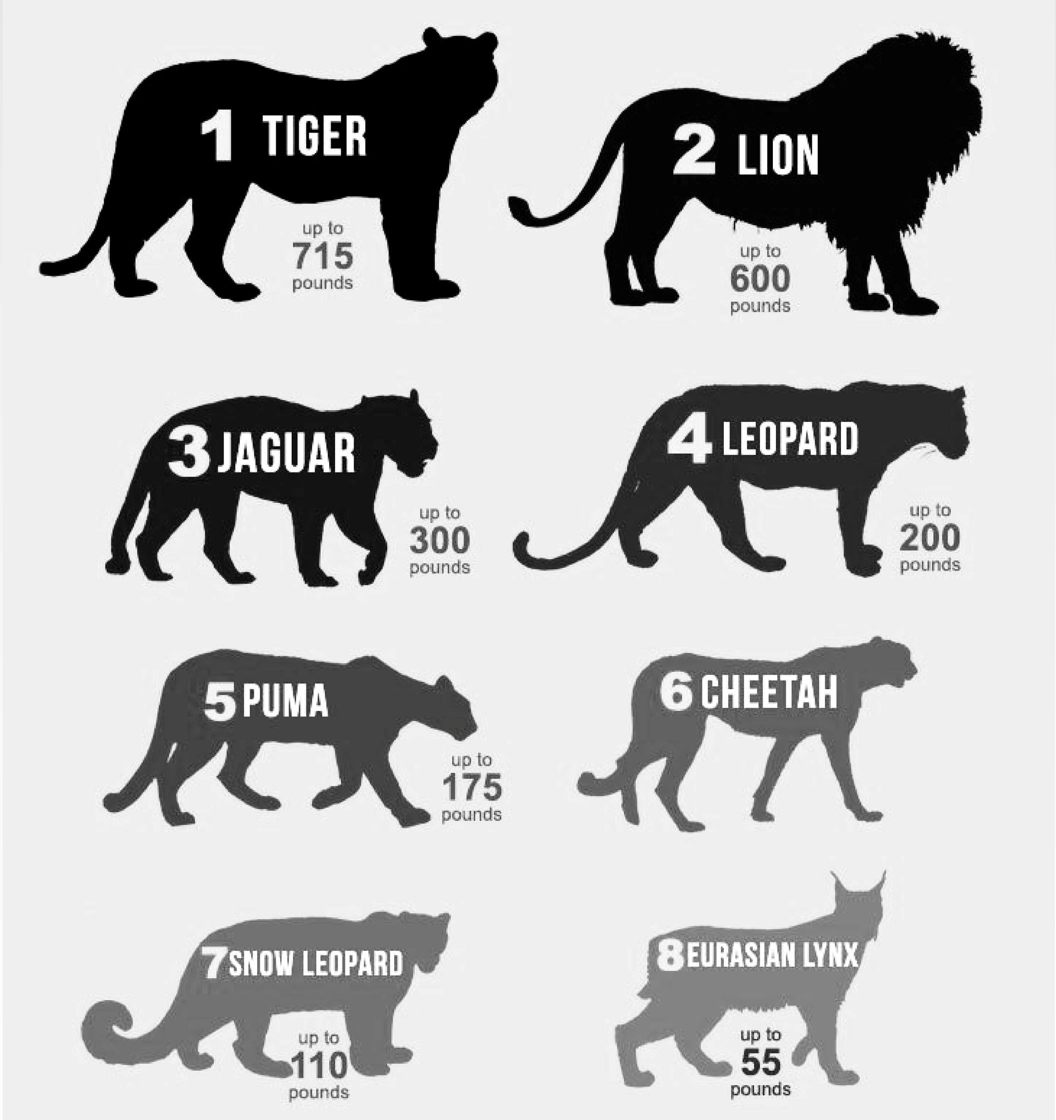
While on the graph, most animals strayed either up or down from the trendline, in both cases the lion was the closest to the marker. The lion exceeds all others in both food intake and speed, though It does not top the chart for BMA. It stands out as the fastest with the other cats at least 10 mph slower at top running speed.

The jaguar stands out in how little food it consumes versus its body size. Its BMA rivals a tiger, yet it consumes less than the smallest member of the group, the snow leopard.

The jaguar is clear winner in the category of least food intake for body size. The lion is the fastest animal in running.

The other three cats fall in the middle with their respective sizes. The snow leopard being smaller, though is fairly fast.The tiger consumes a good amount of food and is large but has an average speed.The leopard is midway on food intake, but the slowest of the group by just 1 mph.

The chart underneath shows the basic size comparison of the cats for reference.



Please note, the puma, cheetah, and Eurasian lynx are not part of Genus Panthera

Image credit: (3)

FURTHER RESEARCH

What has been done here is merely the start of this project. This project will continue along the steps laid out in METHODS and extend further into the upcoming semesters.

The steps immediately following this include:

- Continuing to look for data on acceleration in Genus Panthera
- Creating mathematical models for each of the three superlatives: fastest, most forceful, and lowest food intake.
- Creating a working 3D model from each superlative
- Continuing reading research papers dedicated to this and similar subjects.

Later steps may include:

- Researching ways to optimize the muscle structure
- Applying the muscle structure to modern machinery for stronger systems
- Applying the muscle structure to puppets for more life-accurate animatronics for education.
- Seeking to answer the question of "What can big cats teach us about machinery?"

ACKNOWLEDGEMENTS

Thank you to Dr. Sally Pardue of the Mechanical Engineering department for her mentorship and encouragement in starting down this path of research. Thank you as well to Dr. Nikki Panter of the Biology for her encouragement and assistance with resources.

REFERENCES

Bradford, Alina. "Facts About Leopards." *Livescience.Com*, 27 Nov. 2014, www.livescience.com/27403-leopards.html.

(3) Brindley, Hal. "The Biggest Cats in the World." *Travel For Wildlife*, 5 Nov. 2020, www.travel4wildlife.com/biggest-cats-in-the-world.

Dickinson, Peter. "What Do Tigers Eat in Zoos?" *Owlcation*, 29 Mar. 2021, owlcation.com/stem/What-Do-Tigers-Eat.

Editorial Team. "How Fast Can a Leopard Run? It's Slower than Most of Its Prey." *Africa Freak*, 28 July 2020, africafreak.com/how-fast-can-a-leopard-run.

"Frequently Asked Questions | College of Biological Sciences." *Cbs.Umn.Edu*, 20 Feb. 2015, cbs.umn.edu/research/labs/packer/faq.

(1) Fukuoka, Yasuhiro, et al. "A Simple Rule for Quadrupedal Gait Generation Determined by Leg Loading Feedback: A Modeling Study." *Scientific Reports*, vol. 5, no. 1, 2015. *Crossref*, doi:10.1038/srep08169.

"Jaguar Energy Requirements." *Animals of the Amazon Jungle*, 4 Mar. 2015, animalsofthejungle.wordpress.com/jaguar-energy-requirements.

"LibGuides: Jaguar (Panthera Onca) Fact Sheet: Diet & Feeding." *Libguides*, ielc.libguides.com/sdzg/factsheets/jaguar/diet. Accessed 12 Apr. 2021.

"Lion Fact Sheet | Blog | Nature | PBS." *Nature*, uploaded by PBS, 3 Sept. 2020, www.pbs.org/wnet/nature/blog/lion-fact-sheet.

"Tiger: The Animal Files." *Theanimalfiles.Com*, www.theanimalfiles.com/mammals/carnivores/tiger.html. Accessed 12 Apr. 2021.

(2)Wu, Xueqing, et al. "Contributions of Limb Joints to Energy Absorption during Landing in Cats." *Applied Bionics and Biomechanics*, vol. 2019, 2019, pp. 1–13. *Crossref*, doi:10.1155/2019/3815612.

Zooologist. "How Much Does a Tiger Weigh - Tiger Weight." *Zooologist*, 21 Apr. 2019, zooologist.com/how-much-does-a-tiger-weigh.