

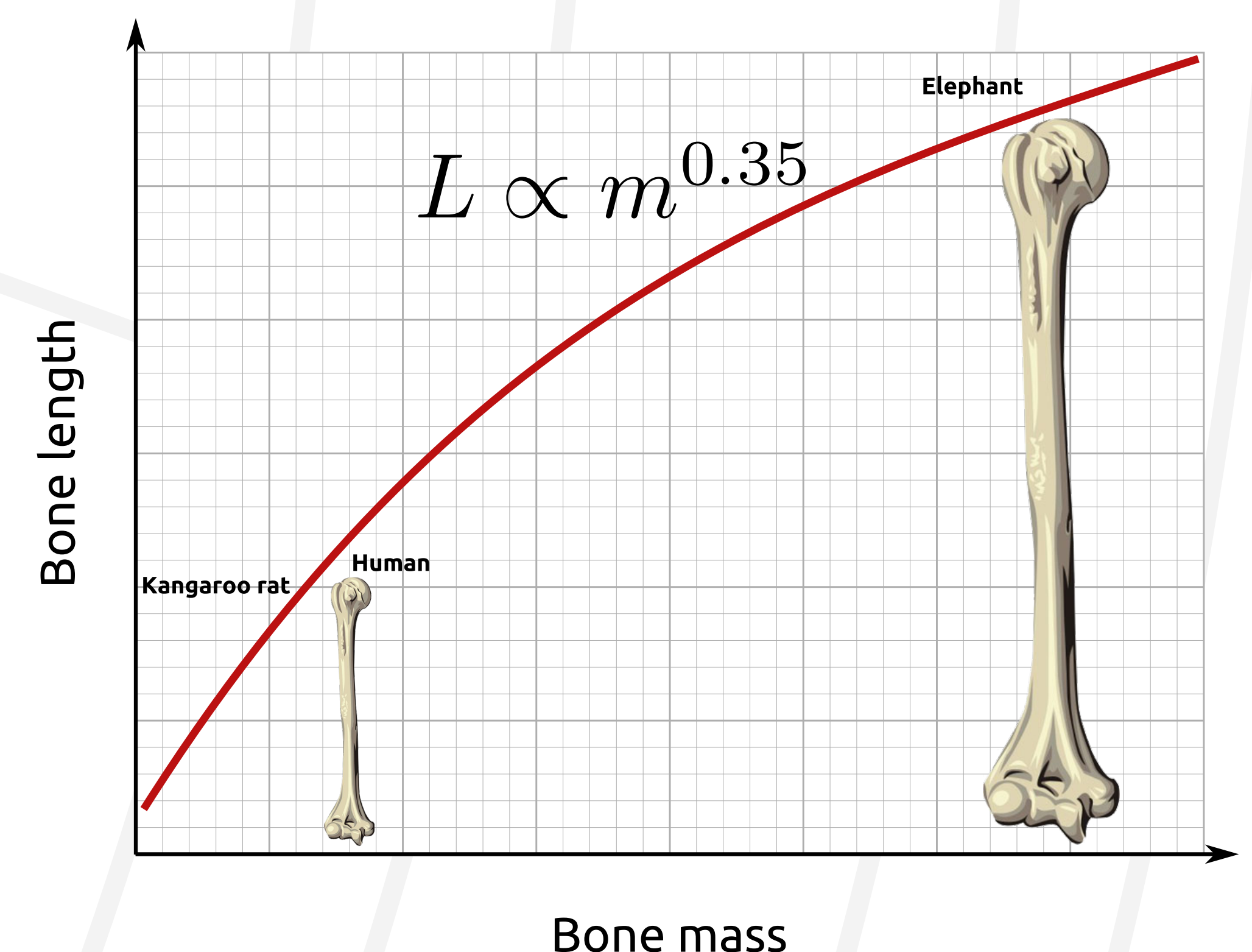
Scaling laws in robotics

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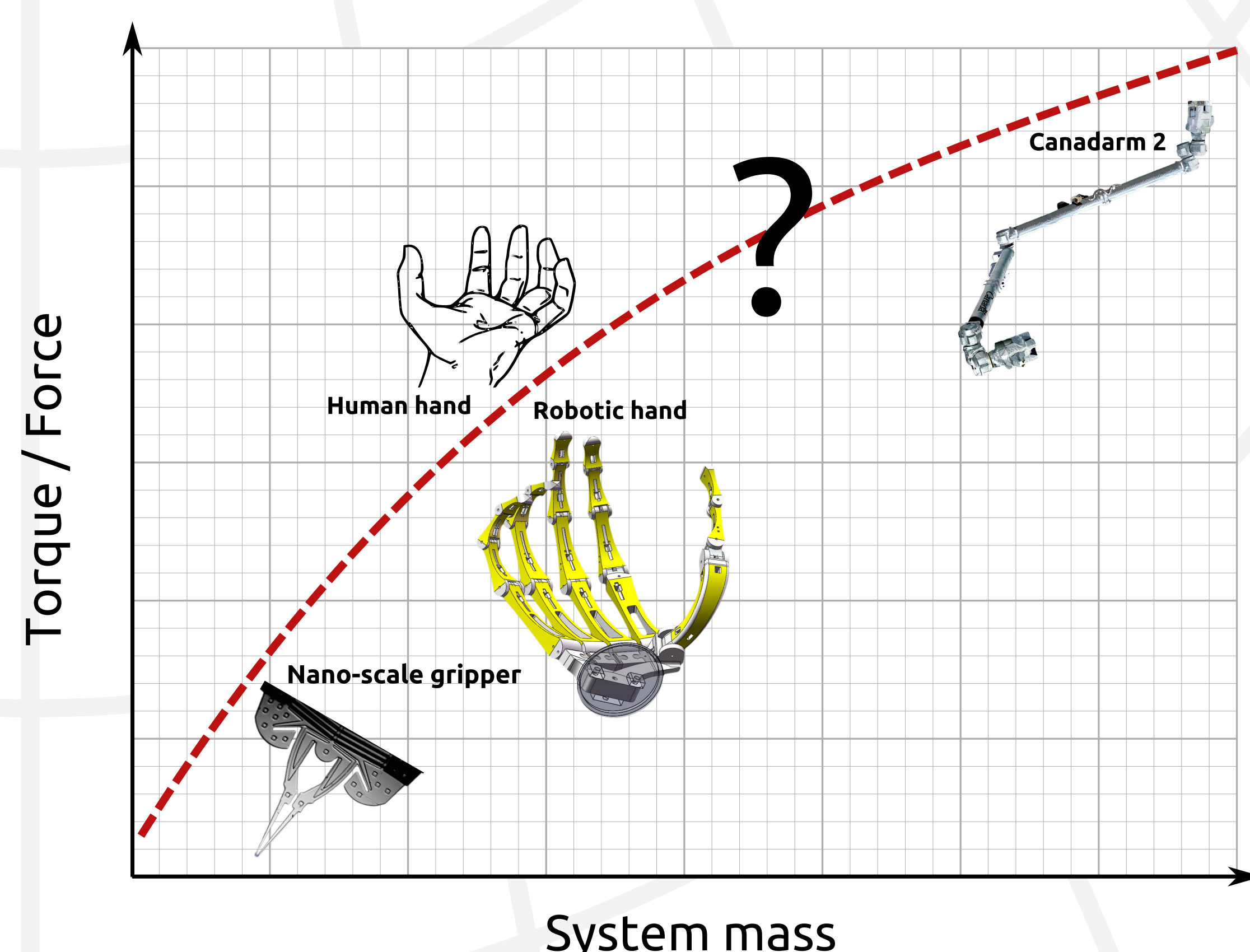
Introduction

Life processes cover more than 27 orders of magnitude in the mass scale, with systems ranging from molecules to whales. The essential features of these systems are dictated by universal, quantifiable **scaling laws** [1]. Known laws relate mass to many such features, from DNA substitution rate, genome and aorta length, to species' lifespan, metabolism and bone length.

Recent findings outline a scaling law of the maximum **specific force** of both biological and engineered actuators. This law is of particular interest for the robotics research field, as it can affect the design phase of robots.



Robotic design



Designing a robotic system requires the identification of **relevant criteria** such as:

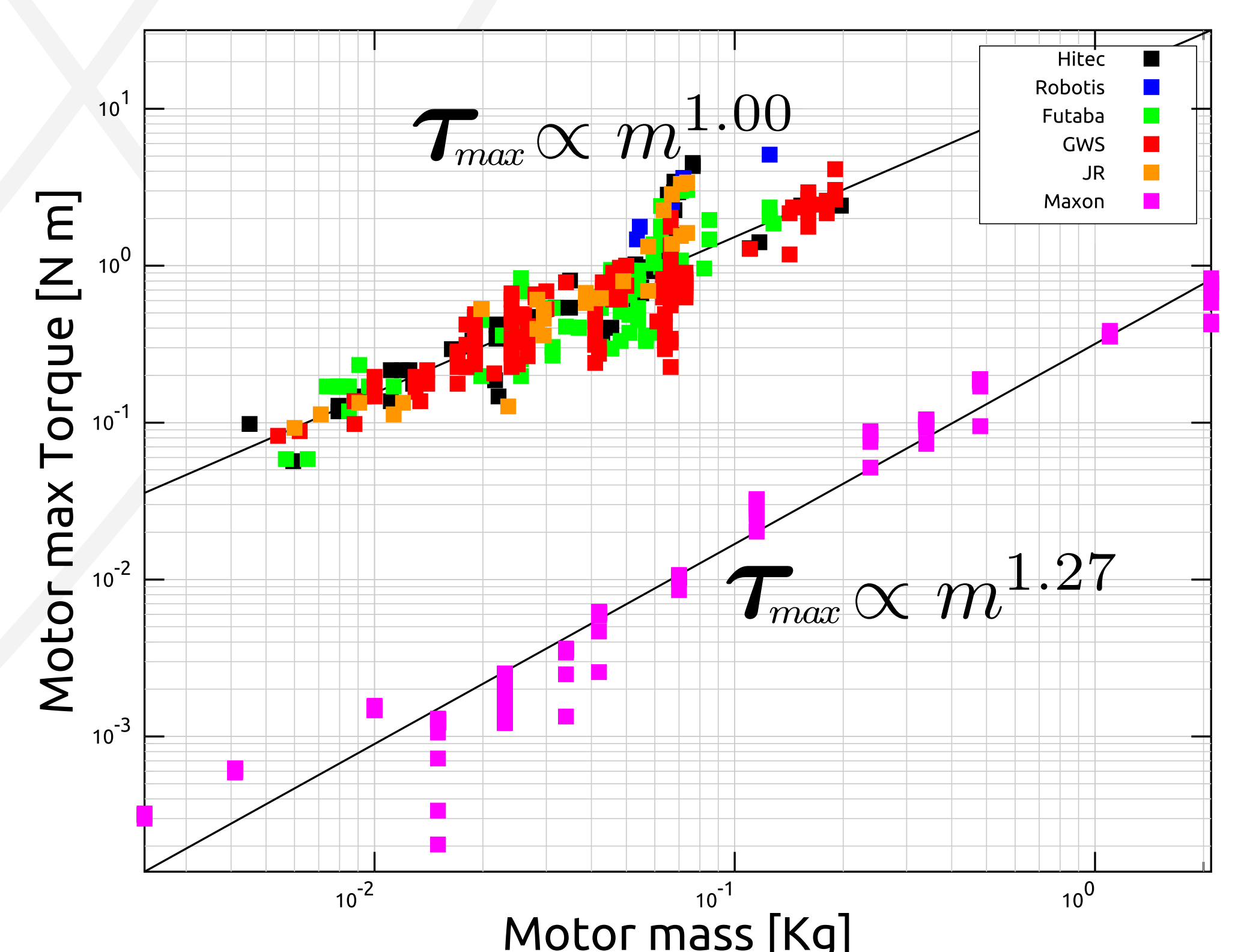
- Weight scale.
- Material choice.
- Actuator torque/force.

In this study, we aim to identify whether the maximum specific force scaling law mentioned holds for motors that are pervasively used in robotics, and if so, how it can influence the design process of robotic systems. By identifying scaling laws present in robotic systems, design complexity can be reduced. Further, robots can be **optimized** and **benchmarked**.

Results and discussion

In this study we focus on rotary electric motors, consisting of hobby RC-servos and high-end Maxon motors. Data consists of 497 motors, with 322 RC-servos and 175 motors spanning twelve Watt scales.

We show that scaling laws previously found are present in the maximum **specific torque** of motors used in robotics. Further studies will aim to explain the reason behind the two different groups of motors apparent. If it is indeed the case, as speculated by Marden et. al. [2], that the two groups are related to fatigue and load-life, this would imply an upper limit on maximum specific torque for any given scale.



References

- [1] G. B. West and J. H. Brown. Life's Universal Scaling Laws. *Physics Today*, 57(9):36, 2004.
[2] J. H. Marden. Scaling of maximum net force output by motors used for locomotion. *The Journal of Experimental Biology*, 208(Pt 9):1653–64, May 2005.

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