Hopper: A Biomimetic, Tendon-Driven, Series Elastic Jumping Robot

Ferenchick, William (School: Wilson High School)

What makes robots seem robotic? Traditional robots are stiff, making them precise and stable, but not agile; they have difficulty negotiating the variability of natural environments. In contrast, animals have elastic muscle-tendon systems, giving them flexibility. They utilize a process called Power Modulation to elastically store energy and then explosively release it, allowing movements like jumping. Drawing inspiration from nature, we can make robots more agile by introducing elasticity into their joints. I designed and built a jumping robot to demonstrate the efficacy of biomimetic knee-like structures. Powered by a high torque, low speed motor, it can store energy in its elastic tendons, release it quickly, and execute a vertical jump. It has a removable patella (kneecap) which acts as a lever arm to provide variable mechanical advantage. The 32cm robot was able to clear a height of 42 cm and land back on its feet. A mathematical model was developed to evaluate the theoretical performance of the robot and design 6 patella profiles with different force curves. The model accurately predicted the force curves, jump heights, and the relationship between jumping efficiency and mass distribution—validating a tendon-driven design to reduce leg weight. Changing the profile of the patella, and therefore the force curve, modestly affected the efficiency of the jump. It also improved jump characteristics: reducing jerk, mechanical wear, and made jump triggering easier. Biomimetic series elastic robots like Hopper have great potential to improve the efficiency of robots over rough terrain, improve the safety of human-machine interactions, and aid in creating more natural prosthetic devices. The biomimetic knee-inspired design can be used to make robots more agile.

Awards Won:
Office of Naval Research on behalf of the United States Navy and Marine Corps: The Chief of Naval Research Scholarship Award of $20,000