Beetlebot: A Stable, Energy-efficient Hexapod Inspired by the Discovery of a Unique Bump and Gait in the Japanese Rhinoceros Beetle

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Robots are entering an increasingly mobile era, yet hexapods, though promising high versatility, have been kept from widespread practical use due to low energy efficiency and unnecessary leg movement. In addressing this, I demonstrate the efficacy of mimicking the Japanese rhinoceros beetle, Allomyrina dichotoma septentrionalis, by identifying anatomical adaptations to stable, efficient locomotion while carrying heavy loads, and test a novel leg design, supporting structure, and gait on a robotic model. Through close observation of live beetles, I discovered a unique bump on their underside, and force measurements with a loaded beetle confirmed that the bump supports over half the total weight during both rest and movement. Furthermore, motion tracking revealed that they walk with a variant of the tripod gait. I also specified the joint structure and rotation of the beetle's legs. I then designed and constructed a 3D printed robot faithfully mimicking beetle anatomy at a 1 to 6.5 ratio, and implemented the above characteristics. Adding an original, compliant supporting structure based on the beetle's bump reduced average and maximum power consumption by 24.7% and 32.8% respectively, and simplified turning as an axis to enhance rotary motion. Adopting the beetle's distinct leg structure cut down on excess joint motion. Applying the beetle-like gait led to stability. With these improvements, the beetle-bot was able to carry 3.1kg, 1.2 times its weight, with only a 13% decrease in speed. This innovative approach to six-legged locomotion achieves performance unattainable with conventional hexapods while maintaining high versatility, and has potential for practical applications requiring mobility under load such as cave, disaster zone, and planetary surface exploration.