Researcher looks to whirligig beetle for bio-inspired robots

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Whirligig beetles are named for their whirling movement on top of water, moving rapidly in and taking off into flight.

While many may have found the movements curious, scientists have puzzled over the apparatus behind their energy efficiency—until now, thanks to a study performed by a team led by Mingjun Zhang, associate professor of mechanical, aerospace and biomedical engineering, at the University of Tennessee, Knoxville.

"The propulsive efficiency of the species has been claimed in literature to be one of the highest measured for a thrust-generating apparatus within the animal kingdom," Zhang said. "But nobody knew exactly why, so we conducted a quantitative study with experiment support that uncovered this mystery."

Zhang saw the curious beetle as inspiration for developing energy-efficient propulsion mechanisms for swimming vehicles and robots. His team discovered separate leg functions, alternative patterns of leg propulsion, a unique take-off technique and maximizing surface area as key to the beetle's inner workings.

The findings have been published in this month's PLOS Computational Biology.

His team performed a combination of microscopic high-speed imaging, dynamics modeling and simulations to unlock the beetle's secret.

They discovered each of the beetle's three pairs of legs conducts a different function. Their curved swimming trajectories gained energy efficient over linear trajectories by alternating the ways leg propelled. Using high-speed cameras, the researchers observed that the beetles beat their legs in different directions in order to transition from swimming to diving. This provides the force required to alter the angle of the body's tilt and break the surface tension of water. Finally, the swimming legs rely on the extension of "swimming laminae" to increase the surface area and generate larger thrust.

"Nature folds the laminae, or a thin tissue, after the beetle is done moving its legs," Zhang said. "It extends it when it is propelling to generate thrust. The legs may also be oriented at different angles, so that the maximum area is not perpendicular to the direction in which the beetle is moving. I am always amazed how nature does this with the small organism."

Zhang's team looks to nature for inspiration in engineering. By studying the movements of the whirligig beetle, the team is applying nature's principles to bio-inspired swimming and diving robots. He is designing the robots for the Office of Naval Research through their Young Investigator Program award which he received in 2011. The award gives him $170,000 in annual research grants for three years.

Provided by University of Tennessee at Knoxville