Researcher discovers how to predict movement for animals of all shapes, sizes and speeds

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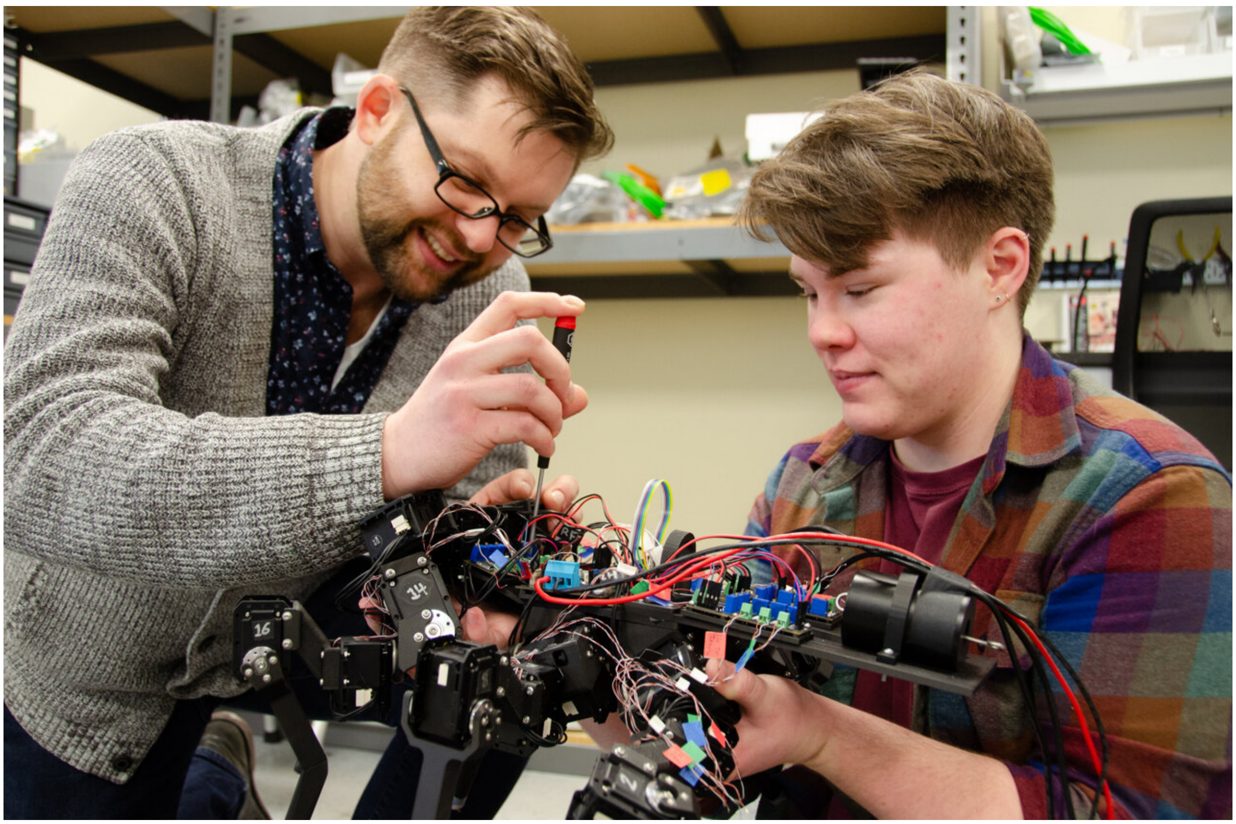


Nicholas Szczecinski, an assistant professor at the WVU Benjamin M. Statler College of Engineering and Mineral Resources, and doctoral student Clarus Goldsmith work on a robot. Szczecinski developed a way to predict the neuron and muscle patterns controlling locomotion for animals of any size, moving at any speed. Credit: WVU / Savanna Leech

A West Virginia University mechanical engineer has developed a way to predict the neuron and muscle patterns controlling locomotion for animals of any size, moving at any speed.

The discovery by Nicholas Szczecinski, assistant professor at the WVU Benjamin M. Statler College of Engineering and Mineral Resources, will help roboticists build working models of animals that precisely reproduce each species' limb movements. Not only could robots then replace live animals in some experiments, but tiny animals like fleas or enormous ones like elephants could be replicated in robotic form at a more manageable scale for study.

"I'm an engineer, but this is a work of biology that takes account of all the diversity of life," Szczecinski said. "Every animal does something special. It's been very cool to learn about that as we try to compare one creature that's on the order of a millimeter with another on the order of a meter."

PNAS Nexus published his findings.

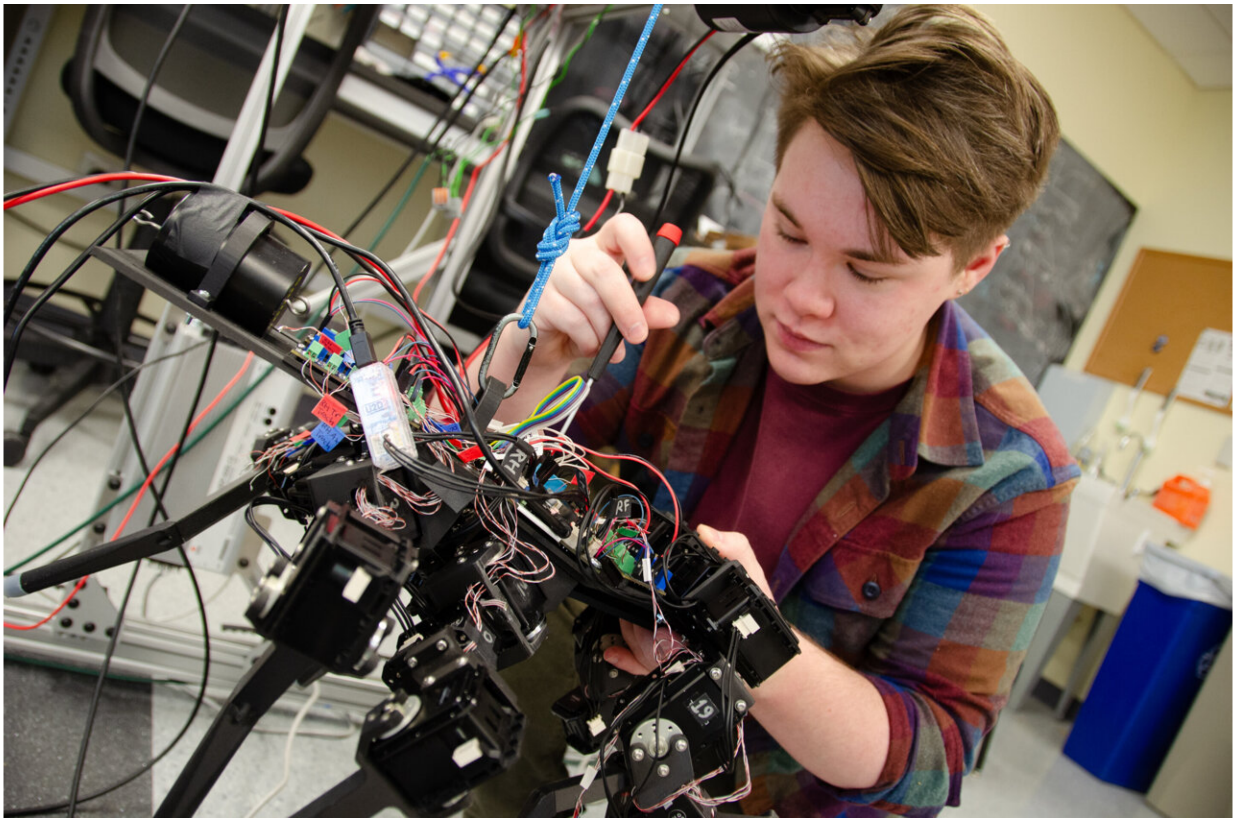
The model created by Szczecinski and his collaborators works by measuring how far an animal's limb moves from its resting position against the energy required to move it—parameters that involve the limb's size, weight and speed. That measure predicts how the limb will respond to the four intertwined forces of gravity, inertia, elasticity and viscosity.

"Some animals are so small their mass doesn't matter as much, while others are so slow their acceleration is too low to have much impact," Szczecinski explained. "When you're doing yoga, for example, you're generally not accelerating a lot, so inertial force doesn't affect you much. Instead, the way your body is moving is mostly an interplay between gravity trying to pull your limbs down and the elasticity of your muscles trying to keep everything tight and in place."

This research has benefited students in their own endeavors.

"In my lab, it's the undergraduate and graduate students and postdoctoral researchers who are designing the robots, operating them and collecting data," Szczecinski said. "They're the ones coming up with novel solutions for debugging the hardware and software."

Clarus Goldsmith, a doctoral candidate in mechanical engineering from Columbus, Ohio, came to WVU to work in Szczecinski's Neuro-Mechanical Intelligence Laboratory. Goldsmith applied Szczecinski's "biologically inspired robotics" to the design of Drosophibot, a robot that's roughly the size of a cat but moves like a fruit fly. When Drosophibot walks, it experiences forces in the same way a fruit fly does.



Clarus Goldsmith, a doctoral student at West Virginia University, works on a robot in the lab. Credit: WVU / Savanna Leech

"The fruit fly is an important animal model for neuroscientists," Goldsmith said, "but there are still some experiments that are difficult-to-impossible to perform on fruit flies due to their small size. Drosophibot allows us to perform biologically informed experiments on the robot and get data that can be used to inform hypotheses about the animal."

For Szczecinski's study, if an animal's movement fits with two main assumptions made, he can predict the neuronal and muscular activity involved and compare it with other animals.

"The first assumption is that the movement in question involves a backand-forth motion," he said. "The other assumption is that the motion involves 'loaded' and 'unloaded' phases, such as when your foot is on the ground and then when it's swinging freely. Lots of things besides walking are that way, so we can apply this to a bird or insect flapping its wings, even a snail contracting and releasing its feeding muscles."

While existing models have only facilitated comparisons between animals of similar sizes and speeds, Szczecinski believes his model could be extended to compare animals with varying modes of locomotion—how they move from one place to another—or different numbers of legs.

The decision to "treat everything as having two legs" was a key simplification that enabled the model's universality, he said.

"We could make that simplification because when four-legged animals like dogs or horses trot, they put down two legs at a time in pretty close synchrony. Insects, with six legs, have a 'tripod gait,' putting three legs down at once. It's not the same as walking on two legs but they're working with two sets of legs at a time. That gave us a bird's eye view of whether, say, a cockroach running fast is ever similar to a horse running fast, because there are some really fundamental differences between these animals that previously made it hard to compare them."

Because mammals' limbs are relatively big and heavy, they work in complex ways against the forces of elasticity, gravity and inertia. For example, when a human reaches to pick up an object, muscles both move the arm toward the object and stop it from moving past the object. But insect movement is completely different.

"An insect walking is like the little kid in 'A Christmas Story' when his mom puts all the coats on him and he can't put his arms down," Szczecinski said. "That's how a bug skeleton works. If you find a dead insect on the ground, its legs are sticking up, not flopping to the side with gravity. That consequence of how elasticity changes with size versus how much mass changes with size is at the heart of this research."

Szczecinski said he and his collaborators are eager to apply his model to help build robotic versions of animals of interest to researchers.

"Because the mechanics match, we can use what we see in a robot to tell us about the animal it's based on without a need for experiments on live animals. We don't have to take the animal apart to understand it. We can build a copy that will tell us if we really understand how the movement happens or whether there are things we're missing."

More information: G P Sutton et al, Phase shift between joint rotation and actuation reflects dominant forces and predicts muscle activation patterns, *PNAS Nexus* (2023). DOI: 10.1093/pnasnexus/pgad298

Provided by West Virginia University

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