# Study of 20,000 jumps shows how a hopping robot could conserve its energy

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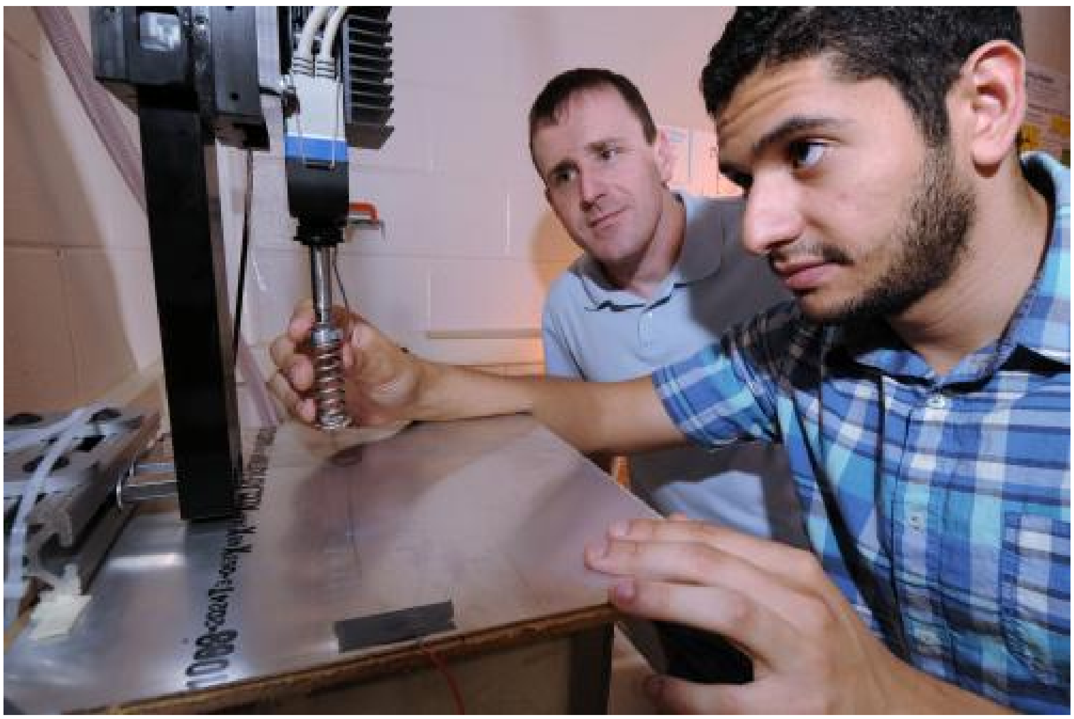

Georgia Tech Assistant Professor Daniel Goldman (left) and Graduate Student Jeffrey Aguilar examine a simple robot built to the dynamics of jumping. The research could lead to reduced power consumption by hopping robots. Credit: Gary Meek

A new study shows that jumping can be much more complicated than it might seem. In research that could extend the range of future rescue and exploration robots, scientists have found that hopping robots could dramatically reduce the amount of energy they use by adopting a unique two-part "stutter jump."

Taking a short hop before a big jump could allow spring-based "pogo-stick" robots to reduce their power consumption as much as ten-fold. The formula for the two-part jump was discovered by analyzing nearly 20,000 jumps made by a simple laboratory robot under a wide range of conditions.

"If we time things right, the robot can jump with a tenth of the power required to jump to the same height under other conditions," said Daniel Goldman, an assistant professor in the School of Physics at the Georgia Institute of Technology. "In the stutter jumps, we can move the mass at a lower frequency to get off the ground. We achieve the same takeoff velocity as a conventional jump, but it is developed over a longer period of time with much less power."

The research was reported October 26 in the journal Physical Review Letters. The work was supported by the Army Research Laboratory's MAST program, the Army Research Office, the National Science Foundation, the Burroughs Wellcome Fund and the GEM Fellowship.

Jumping is an important means of locomotion for animals, and could be important to future generations of robots. Jumping has been extensively studied in biological organisms, which use stretched tendons to store energy.

The Georgia Tech research into robot jumping began with a goal of learning how hopping robots would interact with complicated surfaces – such as sand, granular materials or debris from a disaster. Goldman quickly realized he'd need to know more about the physics of jumping to separate the surface issues from the factors controlled by the dynamics of jumping.

Inspired by student-directed experiments on the dynamics of hopping in his nonlinear dynamics and chaos class, Goldman asked Jeffrey Aguilar, a graduate student in the George W. Woodruff School of Mechanical Engineering, to construct the simplest jumping robot. Aguilar built a one-kilogram robot that is composed of a spring beneath a mass capable of moving up and down on a thrust rod. Aguilar used computer controls to vary the starting position of the mass on the rod, the amplitude of the motion, the pattern of movement and the frequency of movement applied by an actuator built into the robot's mass. A high-speed camera and a contact sensor measured and recorded the height of each jump.

Aguilar and Goldman then collaborated with theorists Professor Kurt Wiesenfeld and Alex Lesov, from the Georgia Tech School of Physics, to explain the results of the experiments.

The researchers expected to find that the optimal jumping frequency would be related to the resonant frequency of the spring and mass system, but that turned out not to be true. Detailed evaluation of the jumps showed that frequencies above and below the resonance provided optimal jumping – and additional analysis revealed what the researchers called the "stutter jump."

"The preparatory hop allows the robot to time things such that it can use a lower energy to get to the same jump height," Goldman explained. "You really don't have to move the mass rapidly to get a good jump."

The amount of energy that can be stored in batteries can limit the range and duration of robotic missions, so the stutter jump could be helpful for small robots that have limited power. Optimizing the efficiency of jumping could therefore allow the robots to complete longer and more complex missions.

But because it requires longer to perform than a simple jump, the twostep jump may not be suitable for all conditions.

"If you're a small robot and you want to jump over an obstacle, you could save energy by using the stutter jump even though that would take longer," said Goldman. "But if a hazard is threatening, you may need to expend the additional energy to make a quick jump to get out of the way."

For the future, Goldman and his research team plan to study how complicated surfaces affect jumping. They are currently studying the effects of sand, and will turn to other substrates to develop a better understanding of how exploration or rescue robots can hop through them.

Goldman's past work has focused on the lessons learned from the locomotion of biological systems, so the team is also interested in what the robot can teach them about how animals jump. "What we have learned here can function as a hypothesis for biological systems, but it may not explain everything," he said.

The simple jumping robot turned out to be a useful system to study, not only because of the interesting behaviors that turned up, but also because the results were counter to what the researchers had expected.

"In physics, we often study the steady-state solution," Goldman noted. "If we wait enough time for the transient phenomena to die off, then we can study what's left. It turns out that in this system, we really care about the transients."

**More information:** Control a demonstration of the jumping studied in this project

Aguilar, Jeffrey et al., "Lift-off dynamics in a simple jumping robot,"

*Physical Review Letters* (2012): prl.aps.org/abstract/PRL/v109/i17/e174301

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