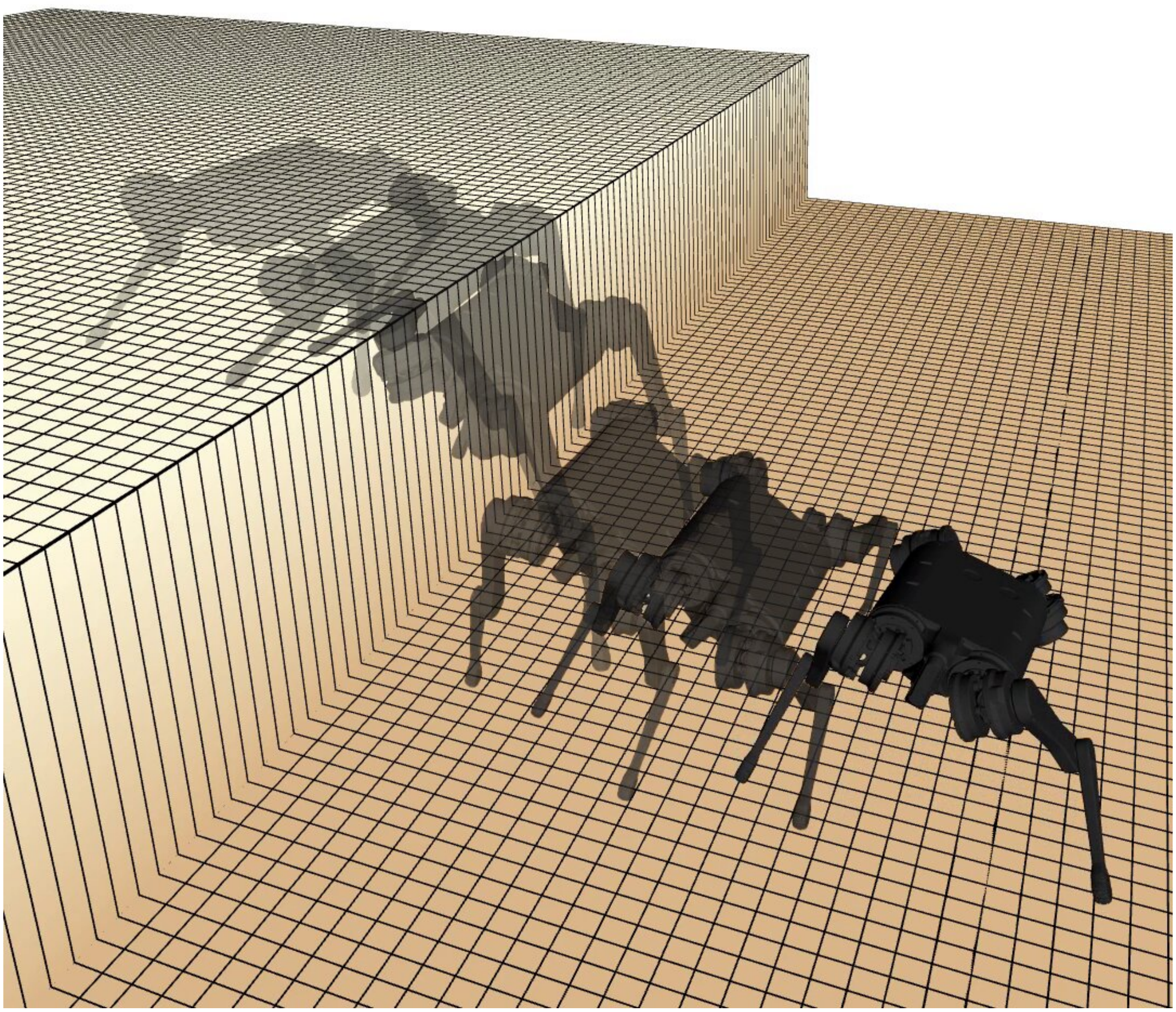
A new design that equips robots with proprioception and a tail

April 7 2023, by Ingrid Fadelli



The proposed control and planning system helps robots safely navigate unexpected cliffs. When the robot's proprioception senses that it has lost contact with the ground, the system quickly adjusts its steps to ensure a safe landing and lifts its leg to avoid getting stuck. Credit: Yang et al, Robomechanics Lab at CMU

Researchers at Carnegie Mellon University (CMU)'s Robomechanics Lab recently introduced two new approaches that could help to improve the ability of legged robots to move on rocky or extreme terrains. These two approaches, outlined in a paper pre-published on *arXiv*, are inspired by the innate proprioception abilities and tail mechanics of animals.

"Our paper aims to bring legged robots from the ideal lab environments into real-world environments, where they may encounter challenging terrains such as rocky hills and curbs," Yanhao Yang, one of the researchers who carried out the study, told Tech Xplore. "To achieve this, we drew inspiration from both animals and engineering principles."

Many animals, including cats and other felines, are known to walk along their own footprints, as this allows them to ground themselves and maintain their stability on different terrains. Yang and his colleagues tried to replicate this behavior in robots, merging proprioception and motion planning techniques.

The techniques they used allow robots to "sense" the environment and move more reliably by gathering information about their own body's position, actions and location. This capability, known as "proprioception," overcomes the limitations of computer vision systems, which are known to be adversely impacted by sensor noise, obstacles in the environment, light reflections on nearby objects, and poor lighting conditions.

Animals and humans are innately born with proprioception, yet most existing robots make sense of their surrounding environment using the data provided by vision systems. Instead of using vision systems, which rely on cameras, lidar technology and other external sensors, Yang and his colleagues propose the use of data collected by sensors integrated inside the robot, such as motors, encoders and inertial measurement devices.

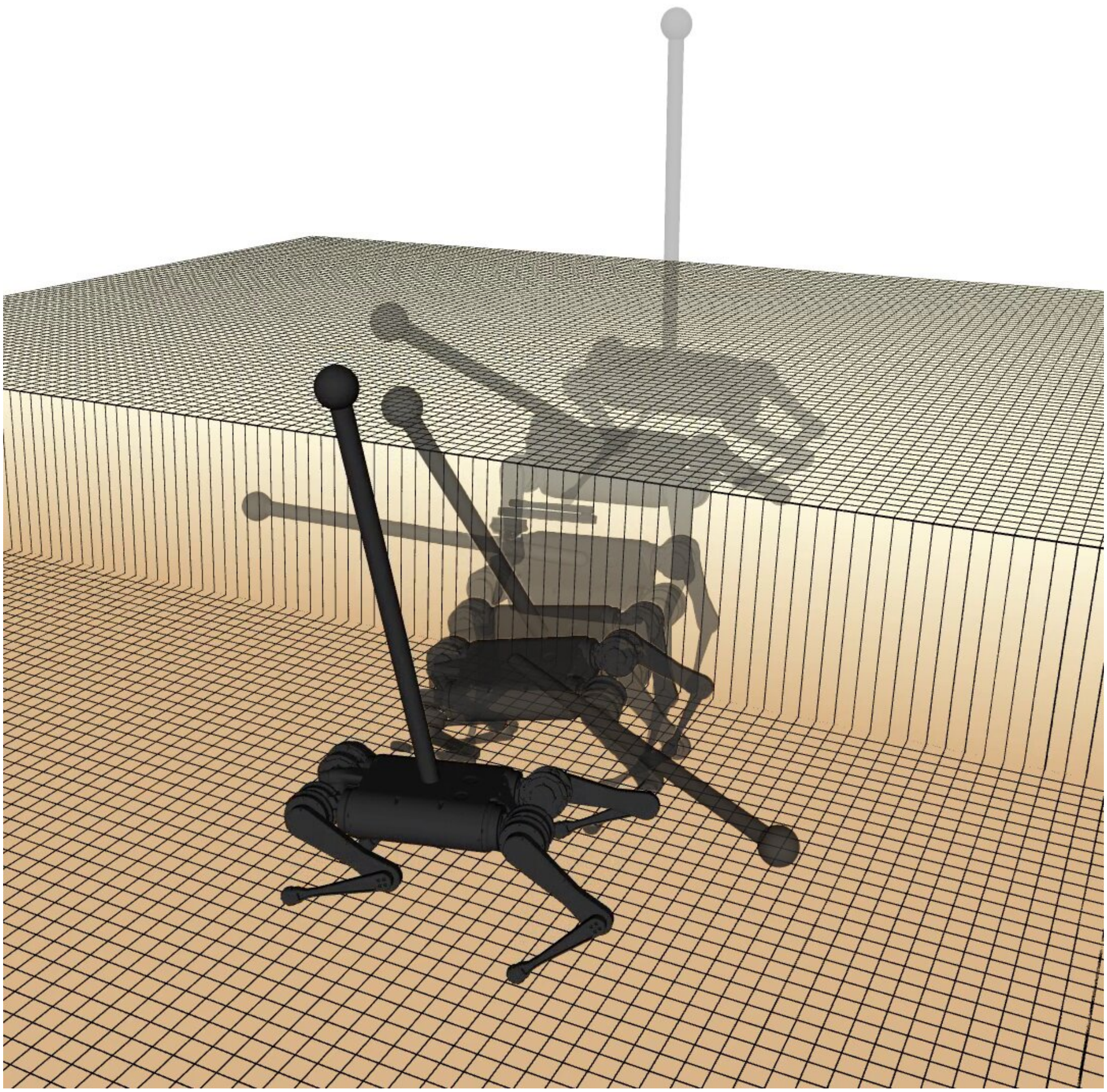
"This helps the robot detect when it slips or falls, and adjust its movements to avoid tipping over," Yang said. "The main advantage of this system is that it's more robust to environmental noise like obstacles, reflections, or lighting conditions. The challenge is to make correct control and planning decisions under uncertainty when the proprioception senses an accident."

In addition to their proposed proprioception system, the researchers created a computational model that allows robots to control an artificial tail, similarly to how animals move their tail when navigating environments. Many animals, including squirrels and cats, use their tail to keep their balance when jumping or hopping onto surfaces.

"We noticed that animals use their tails to assist their agile locomotion, but most robots do not have tails," Yang said "For example, cheetahs use their tails to achieve rapid acceleration, deceleration, and quick turns, while squirrels use their furry tails to balance when jumping between branches. We adapted this idea by adding a tail to our quadruped robots, which helps balance when the robot misses a foothold or falls off."

Yang and his colleagues also created a control system that allows a legged robot's artificial tail to work in coordination with its legs, helping it to retain its balance even when one or more of its legs are lifted off the ground. This can significantly improve the robot's navigation in rough or uneven terrains, while also maximizing its efficiency in narrow or small spaces.

Yang and his colleagues evaluated their motion planning approaches in a series of simulations. Their findings are highly promising, as their bio-inspired proprioception and tail control methods allowed simulated legged robots to reduce unexpected slips and falls, while also improving their ability to reliably move in extreme and changing terrains.



The proposed approach further improves the robot's ability to navigate extreme terrain by adding a tail that helps balance the body when the legs are off the ground. The controller produces a conic motion for the tail to make it as effective as possible within the limited rotation angles. Credit: Yang et al, Robomechanics Lab at CMU

These new motion planning methods could be applied and tested on real legged robots, potentially allowing them to navigate challenging environments more reliably, reducing collisions and falls. This could make these robots better equipped to successfully complete search & rescue missions, environmental monitoring operations and other real-world tasks that entail moving on uneven or challenging terrains.

"One of our main goals for future research is to test our proposed method on actual hardware," Yang said. "This will be a challenge because we need to accurately estimate the state and contact information, which are crucial for the proprioception and control of the robot."

In their next works, Yang and his colleagues also plan to improve how their framework models and controls the tails of robots. This could further reduce collisions, including those between the tail and other parts of the robot's body or the environment.

"Another area of improvement is to extend the method to more complex terrains, such as narrow ravines or stepping stones," Yang added. "Currently, our approach assumes relatively simple terrain variations, but on more challenging terrains, the robot's legs may trip or hang. In these cases, our controller will still try to lower the robot's body to maintain stability, but we can further improve this by adding more events to the gait planning process."

More information: Yanhao Yang et al, Proprioception and Tail Control Enable Extreme Terrain Traversal by Quadruped Robots, *arXiv* (2023). DOI: 10.48550/arxiv.2303.04781