Bot inspired by baby turtles can swim under the sand

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The robot is equipped with flipper-like appendages which allow it to swim under sand. The two black fins on its nose ensure that it remains submerged under the sand. Credit: David Baillot/University of California San Diego

This robot can swim under the sand and dig itself out too, thanks to two

front limbs that mimic the oversized flippers of turtle hatchlings.

It's the only robot that is able to travel in sand at a depth of 5 inches. It can also travel at a speed of 1.2 millimeters per second–roughly 4 meters, or 13 feet, per hour. This may seem slow but is comparable to other subterranean animals like worms and clams. The robot is equipped with force sensors at the end of its limbs that allow it to detect obstacles while in motion. It can operate untethered and be controlled via WiFi.

Robots that can move through sand face significant challenges like dealing with higher forces than robots that move in air or water. They also get damaged more easily. However, the potential benefits of solving locomotion in sand include inspection of grain silos, measurements for soil contaminants, seafloor digging, extraterrestrial exploration, and search and rescue.

The robot is the result of several experiments conducted by a team of roboticists at the University of California San Diego to better understand sand and how robots could travel through it. Sand is particularly challenging because of the friction between sand grains that leads to large forces; difficulty sensing obstacles; and the fact that it switches between behaving like a liquid and a solid depending on the context.

Credit: David Baillot/University of California San Diego

The team believed that observing animals would be key to developing a bot that can swim in sand and dig itself out of sand as well. After considering worms, they landed on sea turtle hatchlings, which have enlarged front fins that allow them to surface after hatching. Turtle-like flippers can generate large propulsive forces; allow the robot to steer; and have the potential to detect obstacles.

Scientists still do not fully understand how robots with flipper-like appendages move within sand. The research team at UC San Diego conducted extensive simulations and testing, and finally landed on a tapered body design and a shovel-shaped nose.

"We needed to build a robot that is both strong and streamlined," said Shivam Chopra, lead author of the paper describing the robot in the journal Advanced Intelligent Systems and a Ph.D. student in the research group of professor Nick Gravish at the Jacobs School of Engineering at UC San Diego.

The bot detects obstacles by monitoring changes in the torque generated by the movement of its flippers. It can detect obstacles above its body, but not below or directly in front of it.

To keep the robot at level depth in the sand, researchers designed two foil-like surfaces, which they call terrafoils, on the sides of the bot's nose. This allowed them to control lift, as the robot had a tendency to keep its nose pointed toward the surface.

Researchers tested the robot in a 5ft long tank in the lab, as well as at La Jolla Shores, a beach near the UC San Diego campus. They found that the robot slowed down in wet sand, which offers more resistance.

Next steps include increasing the robot's speed; and allowing it to actually burrow into sand, in addition to digging itself out of sand.

The work was presented in *Advanced Intelligent Systems*.

More information: Shivam Chopra et al, Toward Robotic Sensing and Swimming in Granular Environments using Underactuated Appendages, *Advanced Intelligent Systems* (2023). DOI: 10.1002/aisy.202200404

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