

Swarming robots avoid collisions, traffic jams

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One hundred small robots line up in the laboratory.
Credit: Northwestern University

For self-driving vehicles to become an everyday reality, they need to safely and flawlessly navigate one another without crashing or causing unnecessary traffic jams.

To help make this possible, Northwestern University researchers have developed the first decentralized [algorithm](#) with a collision-free, deadlock-free guarantee.

The researchers tested the algorithm in a simulation of 1,024 robots and on a swarm of 100 real robots in the laboratory. The robots reliably, safely and efficiently converged to form a pre-determined shape in less than a minute.

"If you have many autonomous vehicles on the road, you don't want them to collide with one another or get stuck in a deadlock," said Northwestern's Michael Rubenstein, who led the study. "By understanding how to control our swarm robots to form shapes, we can understand how to

control fleets of autonomous vehicles as they interact with each other."

The paper will be published later this month in the journal *IEEE Transactions on Robotics*. Rubenstein is the Lisa Wissner-Slivka and Benjamin Slivka Professor in Computer Science in Northwestern's McCormick School of Engineering.

The advantage of a swarm of small robots—versus one large robot or a swarm with one lead robot—is the lack of a centralized control, which can quickly become a central point of failure. Rubenstein's decentralized algorithm acts as a fail-safe.

"If the system is centralized and a robot stops working, then the entire system fails," Rubenstein said. "In a decentralized system, there is no leader telling all the other robots what to do. Each robot makes its own decisions. If one robot fails in a swarm, the swarm can still accomplish the task."

Still, the robots need to coordinate in order to avoid collisions and deadlock. To do this, the algorithm views the ground beneath the robots as a grid. By using technology similar to GPS, each robot is aware of where it sits on the grid.

Before making a decision about where to move, each robot uses sensors to communicate with its neighbors, determining whether or not nearby spaces within the grid are vacant or occupied.

"The robots refuse to move to a spot until that spot is free and until they know that no other robots are moving to that same spot," Rubenstein said. "They are careful and reserve a space ahead of time."

Even with all this careful coordination, the robots are still able to communicate and move swiftly to form a shape. Rubenstein accomplishes this by keeping the robots near-sighted.

"Each [robot](#) can only sense three or four of its

closest neighbors," Rubenstein explained. "They can't see across the whole swarm, which makes it easier to scale the system. The robots interact locally to make decisions without global information."

In Rubenstein's swarm, for example, 100 robots can coordinate to form a shape within a minute. In some previous approaches, it could take a full hour. Rubenstein imagines that his algorithm could be used in fleets of driverless cars and in automated warehouses.

"Large companies have warehouses with hundreds of robots doing tasks similar to what our robots do in the lab," he said. "They need to make sure their robots don't collide but do move as quickly as possible to reach the spot where they eventually give an object to a human."

More information: Hanlin Wang et al, Shape Formation in Homogeneous Swarms Using Local Task Swapping, *IEEE Transactions on Robotics* (2020). [DOI: 10.1109/TRO.2020.2967656](https://doi.org/10.1109/TRO.2020.2967656)

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