Robotic motion planning in real-time

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George Konidaris, assistant professor of computer science and electrical and computer engineering at Duke University. Credit: Duke University

Once they've mastered the skills of toddlerhood, humans are pretty good at what roboticists call "motion planning"—reaching around obstacles to precisely pick up a soda in a crowded fridge, or slipping their hands around a screen to connect an unseen cable.

But for robots with multi-jointed arms, motion planning is a hard problem that requires time-consuming computation. Simply picking an object up in an environment that has not been pre-engineered for the robot may require several seconds of computation.

Duke University researchers have introduced a specially-designed computer processor for motion planning that can plan up to 10,000 times faster than existing approaches while consuming a small fraction of the power. The new processor is fast enough to plan and operate in real time, and power-efficient enough to be used in large-scale manufacturing environments with thousands of robots.

"When you think about a car assembly line, the entire environment is carefully controlled so that the robots can blindly repeat the same movements over and over again," said George Konidaris, assistant professor of computer science and electrical and computer engineering at Duke. "The car parts are in exactly the same place every time, and the robots are contained within cages so that humans don't wander past. But if your robot is using motion planning in real time and a part is in a different place, or there's some unexpected clutter, or a human walks by, it'll do the right thing."

Speedy motion planning saves the time and expense of engineering the environment around the robot, said Konidaris, who will be presenting the new work June 20 at a conference called Robotics: Science and Systems in Ann Arbor, Mich.

Motion planning has been studied for 30 years, and recent advances have brought the time required to find a plan for a sophisticated robot down to a few seconds. With few exceptions, these existing approaches rely on general-purpose CPUs or computationally faster but more power-hungry graphics processors (GPUs).

The Duke team designed a new processor specifically for motion planning.

"While a general-purpose CPU is good at many tasks, it cannot compete with a processor specially designed for just a single task," said Daniel Sorin, professor of electrical and computer engineering and computer science at Duke.

Konidaris and Sorin's team designed their new processor to perform collision detection—the most time-consuming aspect of motion planning—such that the processor performs thousands of collision checks in parallel.

"We streamlined our design and focused our hardware and power budgets on just the specific tasks that matter for motion planning," Sorin said.

The technology works by breaking down the arm's operating space into thousands of 3D volumes called voxels. The algorithm then determines whether or not an object is present in one of the voxels contained within pre-programmed motion paths. Thanks to the specially designed hardware, the technology can check thousands of motion paths simultaneously, and then stitch together the shortest motion path possible using the "safe" options remaining.

"The state of the art prior to our work used high-performance, commodity graphics processors that consume 200 to 300 watts," said Konidaris. "And even then, it was taking hundreds of milliseconds, or even as much as a second, to find a plan. We're at less than a millisecond, and less than 10 watts. Even if we weren't faster, the power savings alone will add up in factories with thousands, or even millions, of robots."

Konidaris also notes that the technology opens up new ways to use motion planning.

"Previously, planning was done once per movement, because it was so slow," said Konidaris, "but now it is fast enough that it could be used as a component of a more complex planning algorithm, perhaps one that sequences several simpler motions or plans ahead to reason about the movement of several objects."

The new processor's speed and power efficiency could create many opportunities for automation. Konidaris, Sorin and their students are counting on it, and have incorporated a spinoff company, Realtime Robotics, to commercialize the technology.

"Real-time motion planning could really be a game-changer for robotics," said Konidaris.

Provided by Duke University