New algorithm, metrics improve autonomous underwater vehicles' energy efficiency

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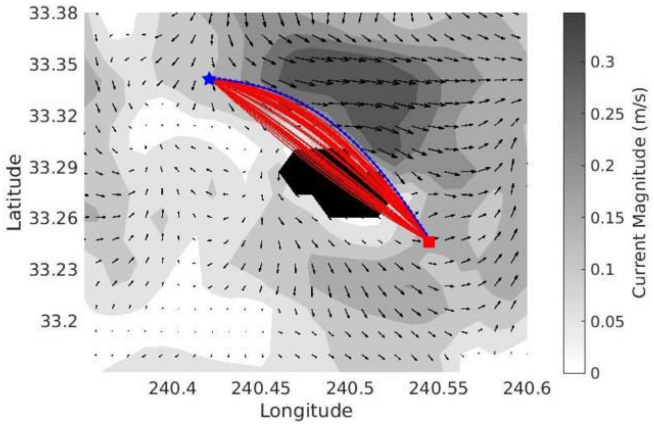

Autonomous underwater vehicle paths planned by EESTO using historical ocean current data from Jan. 21, 2013. Red paths are the solutions found at the end of each iteration. The final path is represented in blue. The path starts at the blue star and ends at the red square. Credit: Oregon State University

Robotics researchers have found a way for autonomous underwater vehicles to navigate strong currents with greater energy efficiency, which means the AUVs can gather data longer and better.

AUVs such as underwater gliders are valuable research tools limited primarily by their energy budget - every bit of battery power wasted via inefficient trajectories cuts into the time they can spend working.

"Historically, a lot of oceanography data sets and sampling came from using ships, which are expensive and can only really be out for a few days at a time," said Dylan Jones, a third-year Ph.D. student in Oregon State University's robotics program and lead author on the study. "With autonomous underwater vehicles, you can get months-long monitoring. And a way to extend those vehicles' missions is through smarter planning for how they get from one point of interest to another."

Jones and Ph.D. advisor Geoff Hollinger, assistant professor of mechanical engineering in OSU's College of Engineering, have built a framework for the vehicles to plan energy-efficient trajectories through disturbances that are strong and uncertain, like ocean currents and wind fields.

The framework involves an algorithm that samples alternate paths, as well as comparison metrics that let a vehicle decide when it makes sense to switch paths based on new information collected about environmental disturbances.

The researchers tested the framework in a simulated environment—a data set of currents from the Regional Ocean Modeling System—and also on a windy lake with an autonomous boat.

The results, recently published in *IEEE Robotics and Automation Letters*, show that the algorithm can plan vehicle paths that are more energy efficient than ones planned by existing methods, and that it's robust enough to deal with environments for which not much data is available.

Findings also indicate that three of the framework's five path comparison metrics can be used to plan more efficient routes compared to planning based solely on the ocean current forecast.

"We generalized past trajectory optimization techniques and also removed the assumption that trajectory waypoints are equally spaced in time," Jones said. "Removing that assumption improves on the state of the art in energy-efficient path planning.

"These are under-actuated vehicles—they don't go fast in relation to the strong ocean currents, so one way to get them to travel more efficiently is to go with the flow, to coast and not use energy," he added. "We're building more intelligence into these vehicles so they can more reliably accomplish their missions."

Jones notes that overcoming strong disturbances is a critical component of putting any kind of robot in a real-life environment. Past planning algorithms haven't always considered the dynamics of the vehicle they were planning for, he said.

"Sometimes we make assumptions in the lab or do simulations that don't translate in the real world," Jones said. "Sometimes a disturbance is too strong to be overcome, or sometimes it can be overcome but the path deviates so significantly that it would put the robot in a danger area. We have to consider all the possible locations of a robot. There are smarter ways of considering these various disturbances, and this gives us a better way of planning paths that are least affected by disturbances."

Any disconnect between the controller and the planner can be dangerous, Jones said.

"The way we see this work going is to bridge that gap - how do we look at paths that are easier for controllers to follow, and how do we make controllers follow paths better?" he said. "We can be more energy efficient when we consider the whole environment, planning paths so that the controller of the vehicle doesn't have to work as hard."

Future research will also deal with "informative path planning"—planning paths that initially gather information about the environment and disturbances that the algorithm can use later to plan more energy-efficient routes.

"How do we combine these two ideas—planning a path for energy efficiency while also trying to gather information that will inform efficient path planning?" Jones said. "There will be tradeoffs and it might come down to, do I pay five hours now to save six hours later on? Another possible research direction is to look at a multivehicle situation where one vehicle can scout ahead and relay information to one or more others—they could possibly have a low shared energy cost by intelligently assigning goals and sharing information."

More information: Dylan Jones et al, Planning Energy-Efficient Trajectories in Strong Disturbances, *IEEE Robotics and Automation Letters* (2017). DOI: 10.1109/LRA.2017.2719760

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