Robo Lobster to Sniff Out Mines

By Louise Knapp

Stanford University• *Enlarge image*
A robo-lobster sniffing the waters.

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Teams of sniffer robots may someday scour land and sea, using their artificial snouts to root out mines in places and situations humans would rather avoid.

At least this is the goal of a team studying the lobster -- a creature considered a paragon of odor analysis -- in order to create a robotic version of the lobster's snout.

"The idea is that evolution has developed the lobster antennule (nose) to do the job very efficiently, and if we can understand how it works, we can replicate it," said John Crimaldi, assistant professor of engineering at the University of Colorado.

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Many objects emit odors that are transported by chemical plumes downstream or downwind. Mass-produced mines are no exception.

"A side impact of the mass production of mines is that they leak TNT, which has an odor -- humans can't smell it, but an appropriate type of sensor could," Crimaldi said.

The study -- a joint effort of Stanford University, the University of California at Berkeley and Bowling Green State University -- is focused on discovering how the lobster can trace these chemical odor plumes back to their source.

A lobster isn't that bright, according to Crimaldi, but it is a veritable whiz when it comes to plume tracking. Even when the waters are choppy and the odor plume patchy, the lobster will always find its target.

The study used the Caribbean spiny lobster as its guinea pig. The lobster has two olfactory antennules -- 2-inch-long antennae covered with arrays of odor-sensitive hairs --

that can sniff out food, friend or foe.

Getting the critters to perform as required in the experiments -- to stay put and sniff on demand -- proved to be tricky.

"Live lobsters don't behave -- it's pretty hard to train a lobster," Crimaldi said.

To avoid this problem, the researchers discarded the live lobster in favor of a recently shed lobster exoskeleton, which they filled with epoxy to weigh it down in a tank of water. One of the lobster's antennules was replaced with a computer-controlled steel wire, and then a real antennule was slipped onto the wire before each experimental trial.

"The antennule is slipped over the wire like a sock, and then the computer is programmed to flick the antennule in the same way as the real ones do," said Mimi Koehl, professor of integrative biology at the University of California at Berkeley. Each flick of the antennule is equivalent to one lobster sniff.

The lobster was then submerged in a tank of water.

"The tank is about 20 meters long and one meter wide. The lobster was placed a meter downstream from the thing it smelled. The tank had to be this big in order to create the right turbulence," Koehl said.

The team then released a fluorescent dye into the tank to act as the odor plume.

"In the real world the odor plume is made up of something like an amino acid -- we used a fluorescent dye of the same kind of acidity as the real thing, so it has the same kind of physical transport that a real odor plume would have," Crimaldi said. "The only difference is we can see ours if we shine a green laser light into the tank."

As the plume flowed downstream toward the lobster, the robotic antennule was flicked through the water at the same speed that a real lobster would move it -- about 100 milliseconds for the fast downstroke and 300 milliseconds for the slower upstroke, with a 400 millisecond pause between each flick.

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By analyzing high-speed videotapes taken of the tank action, the researchers were able to establish how the size, motion and hair structure within the antennule enabled it to analyze the odor plume.

A lobster sniff begins with a rapid downstroke that turns the antennule into a sieve, allowing water to flow between its hairs, while capturing molecules from the plume.

Then on the upward stroke, the antennule acts more like a paddle -- the water flows around it, leaving intact the pattern of dye or odor molecules picked up during the downstroke.

Retaining the odor molecules gives the lobster time to work out what is producing the scent and where it is.

As the lobster repeats the flick, the samples of dye previously trapped are washed out, resetting the lobster's snout between each sniff so it can move on to a new spot and do further odor analysis.

The experiments also afforded a lot of information about the structure of odor plumes.

"We learned that there is an incredible fine spatial detail in an odor plume," Koehl said.

"When you look at smoke coming out of a chimney stack, it just looks like a big old cloud, but if you make a slice through it in the way an antennule would, it shows a really fine detail. And antennules can capture this detail without disturbing it," Koehl said.

While the team has a lot of information on the size, motion and activity of the antennule, they have yet to understand how the lobster turns the information gleaned from the odor plume into an understanding of where the source lies -- this will be the next stage of their research.

The team believes, however, that the information they have to date will be extremely useful in the creation of a sniffer robot.

"We now know the mechanism they use to do this, the speed they have to go at -- we have all these rules.

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We've learned the physical design that you would need to put chemo-sensors onto a robotic version," Koehl said.

The study was funded by the Chemical Plume Tracing Program of the Defense Advanced Research Projects Agency and the Office of Naval Research.

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