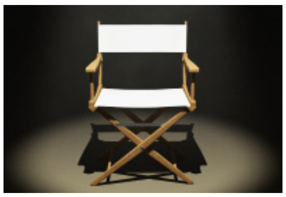
Blogs



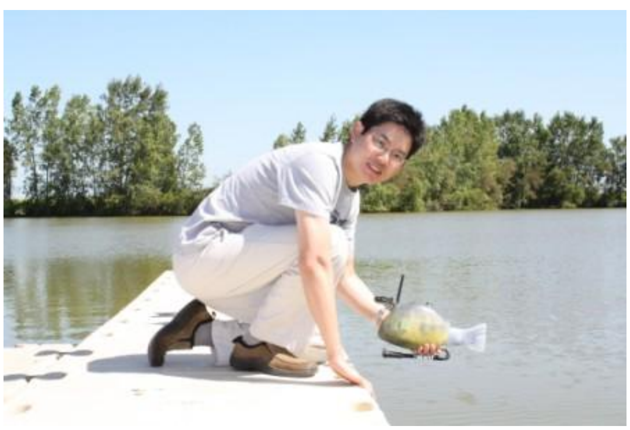
Guest Blog

Commentary invited by editors of Scientific American

Synchronized swimming: patrolling for pollution with robotic fish

By Robin Anne Smith | September 19, 2011 |

In landlocked East Lansing, Michigan, you're unlikely to swim with dolphins. But you can swim with robotic fish, thanks to a team of scientists who are developing underwater robots that swim in schools to monitor water quality.



Xiaobo Tan takes a robotic fish for a test swim in a Michigan lake. Equipped with onboard sensors and wireless capabilities, the robofish will be used to patrol for algal blooms and oil spills in lakes, rivers and oceans. Photo by Freddie Alequin-Ramos.

A surprisingly lifelike robotic fish swims in an aquarium on the Michigan State University campus, its tail fin flexing back and forth.

The demo is part of a three-day meeting at BEACON, a National Science Foundation-funded think tank dedicated to research at the intersection of biology, engineering and computer science.

Scanning the list of the day's sessions, one title in particular gets my attention: "Evolving robotic fish." Coffee cup in hand, I dash down the hall to a darkened seminar room and settle in among the seats.

There, researchers discuss their efforts to develop robotic fish that can navigate underwater and patrol for pollution in oceans, lakes and rivers.

"Fish behave in ways that underwater vehicles can't yet equal," explained Michigan State University electrical engineer Xiaobo Tan.

Fish can swim in synchronized perfection. They can also take sharp turns and change directions instantaneously, darting in a fraction of the time a submarine can.

Imitating nature

Tan belongs to a growing group of robotics researchers who believe that by taking insights from nature, they'll be able to build robots with capabilities that current robots don't have.

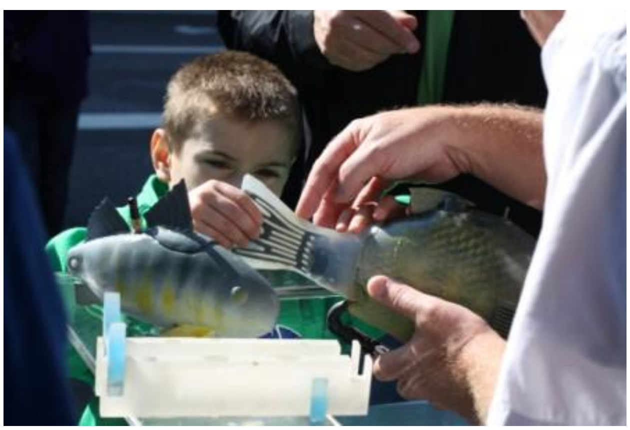
Animal-inspired robots aren't new. Computerized cockroaches, mechanical snakes, and even a robo-cheetah have crawled, slithered, and sprinted their way through engineering labs in recent years.

Now, Tan and other researchers are hoping to bring water quality monitoring to a new level by building robots with the speed, agility and coordination of real fish.

Later that day I visited Tan's lab, a room full of drills, bits, clamps, pliers, and empty aquarium tanks on the Michigan State University campus.

Tables strewn with electronics and plastic fish parts in different stages of assembly lined the walls. Next to me sat a 6-inch prototype, a robot with grey and yellow stripes modeled after a fish called a yellow perch.

Artificial muscles



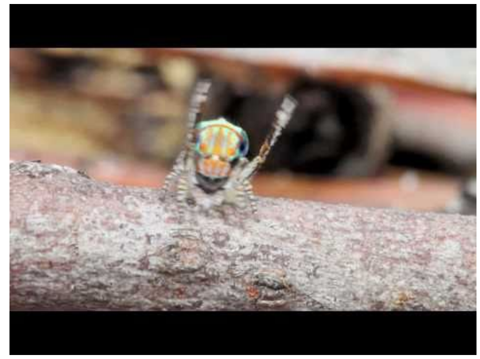
Many of Tan's robotic fish swim through the water via flexible tails. Photo taken by Xiaobo Tan at the 2011 US Science and Engineering Expo in Washington, DC.

Some of Tan's robotic fish swim through the water thanks to tail fins made of electroactive polymers that move in response to electricity. No motors, no gears.

"These materials are often referred to as artificial muscles because they change their shape in response to electrical stimulation, much like muscles do," Tan said.

Artificial muscle works the other way too: apply an electric current, and it moves and bends; bend it, and it generates an electric current. This allows the robofish to 'sense' motion in the water, just like real fish do.

PhD student Alex Esbrook takes a two-inch strip of artificial muscle from a dish on the lab bench. A thin ion exchange membrane sandwiched between two layers of platinum, it looks like a piece of silver ticker tape.



Esbrook inserts one end of the strip into a clamp attached to a battery, and the free end of the strip starts bending and straightening like a levitation magic trick.

“Of course the movement of actual fish fins is much more complicated,” Tan explained. But by binding several strips of artificial muscle together in sheets, they can make flexible artificial fins that twist, curl and bend in complex ways, just like the real thing.

Printing fish parts

To make and test different robofish designs, the researchers create patterns for various fish parts in the computer, and then make multiple copies quickly and cheaply using a three-dimensional printer.

A large rectangular machine the size of a foosball table, the 3D printer works by depositing thin layers of plastic on top of each other. When the researchers feed different plastics into the printer in different ratios, they can produce three dimensional objects that are stiff in some spots and soft and flexible in others.

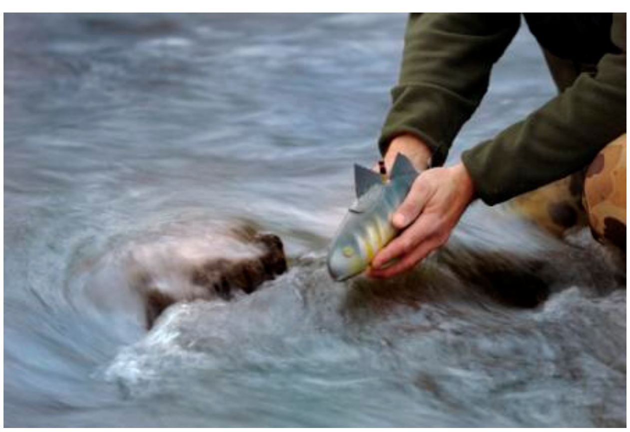
PhD student Sanaz Behbahani reveals the result — into my palm she puts a tiny replica of a fish fin, the size of a fingernail.

“They’re very much like a real fin; we can print out a lot of different versions,” collaborator and computer scientist Phil McKinley told the seminar crowd earlier that day. “Our goal is to print fish that can swim and dart just like real fish.”

By powering their fish with fins, the team hopes to make bots that are smaller, cheaper and quieter than they could with propeller-driven vehicles.

“Underwater vehicles propelled by conventional motors can only get so small,” Tan said.

Swim lessons



One of the next steps is to design fish that can swim against strong currents. Photo by Kurt Stepnitz, courtesy of Michigan State University.

Tan leads me down the hall to the large indoor tank where the robofish take their first test swims.

Tan tested his first fish in the university swimming pool, late at night after the students had gone back to their dorms. Now they have their own lap pool, an enormous tank in the basement of the Michigan State University engineering building.

At fifteen feet long, ten feet wide, and four feet high, it could be a mermaid tank in a restaurant bar. “That’s 18 tons of water,” McKinley said.

In a corner of the room I spot one of the early fish prototypes — a block of green plastic with a rigid tail, it's capable of swimming straight and making simple turns. Now with funding from the National Science Foundation, Tan's team is working to make autonomous robofish that can swim in schools and navigate around obstacles with minimal, if any, human intervention.

"Swimming is a basic behavior, but if we want them to move in formation and work together we need to enable them to behave in more complex ways," McKinley said.

To mimic the coordinated movements of schooling fish, Tan's PhD student Jianxun Wang has been developing mathematical models that can be used to control how the robofish behave in groups.

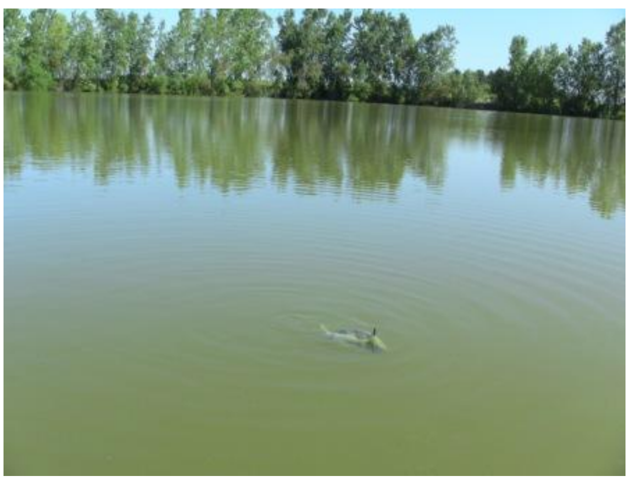
The robofish are programmed to sense what direction their neighbors are moving in and estimate the distance to neighboring fish — behaviors that enable them to stay near each other but not bump into each other.

The fish communicate with each other and with a base station via wireless transmitters.

"With remotely operated vehicles you have to send continuous commands: turn right, turn left, speed up, slow down," Wang said. "But our approach is to tell the fish their next destination and let them guide themselves on their own."

Patrolling for pollution

In the wake of the 2010 Gulf oil spill disaster, Tan applied for emergency funding from the National Science Foundation to develop a fleet of robotic fish capable of detecting crude oil in seawater. The fish are equipped with onboard sensors that use lasers to detect the oil.


A robotic fish takes a test swim. Photo by Xiaobo Tan.

In collaboration with aquatic ecologist Elena Litchman, the team is also developing robotic fish that can detect harmful algal blooms in lakes — the buildup of microscopic algae that can kill fish and birds and make people sick.

A whole fleet of robofish can spread out over a pond or lake, collecting and sending a continuous stream of fine-scale data about water temperature, dissolved oxygen level, and other environmental variables. That's a level of spatial and temporal resolution that traditional water quality testing can't match.

The next step is to design fish that can swim deep underwater and against strong currents. “We’ve already tested surface-swimming fish in lakes, now we’re working on developing fish that can dive and ascend,” Tan said.

The researchers hope to deploy their robofish in the Gulf of Mexico next summer.

“What if they get eaten?” I wondered. “We’ll have to consider that possibility,” Tan said. ”We don’t want to lose the robots or pose a risk to predators.”

With help from collaborator Jenny Boughman, who studies cooperation and social behavior in stickleback fish, first they’ll set up mixed aquarium tanks of live and robotic fish to see how they interact. “We’re planning to use the robotic fish to play the role of a predator” and better understand the escape behaviors of real fish, Tan explained.

Back at the BEACON headquarters, a group of graduate students puts a second fish into the aquarium tank to show off what it can do.

It has a GPS unit mounted on its head, a 3D compass embedded in its belly, and a long rod coming out of its underside that one of the students tells me is an oxygen sensor.

“If there’s anything that kids love more than water, it’s water with robotic fish swimming in it,” McKinley said.

Kid or no, I know I’m hooked.

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About the Author: Robin Smith taught writing at Duke University for four years before joining the news room at the National Evolutionary Synthesis Center in Durham, North Carolina, where she writes about life in the deep sea, atop the world's highest mountains, and everywhere in between. Robin earned a PhD in evolutionary biology in 2005, and has published academic articles in *Evolution, American Naturalist*, and the *American Journal of Botany*. She has also written for the *Raleigh News and Observer*, the *Charlotte Observer*, and the blog column of *Scientific American*. Robin is a member of the National Association of Science Writers, and serves on the board of the local science writing group, Science Communicators of North Carolina. When she's not at her desk, Robin spends her time dancing, hiking, and learning the secrets of homemade sorbet. She tweets at @NESCent and (more rarely) @robinannsmith. Follow on Twitter @robinannsmith.

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