Searching underwater for cyanobacteria, terrorists, and mines is all in a day’s work for a robot ray developed by a team of aerospace engineering students.

Maaike Muller

“This is our creature,” says aerospace engineering student Alwin Wilken, pointing into a large box he has just opened. Inside is shiny black contraption wearing a blue skirt. Meet robot ray.

“It’s a nature-inspired underwater sensor platform,” Wilken explains. He is one of the students who developed Galatea, as the robot ray is also known. In the belly of this robotic beast are various sensors that can be used for a variety of different purposes, such as searching underwater for mines. For robot ray’s propulsion, the designers decided to forego the standard propeller-driven solution; instead, robot ray moves through the water by slowly undulating the sides of its body, which is how a real ray swims. Or, as Wilken’s teammate Remco Jutte puts it: “It uses an undulating movement to push water backwards, which propels it forward.”

The prototype built by the eight-member student team has just completed its first swimming lessons. “At first it veered off course a bit,” Jutte says, “but by adding lead to the body in the right places, it can now swim pretty straight.” Long before robot ray took its first swim in the test tank at the maritime technology faculty, the students had already completed 18 months of intensive study and testing.

Gold

“Underwater robots are hot,” says Dick Simons, a professor of earth observation at the Faculty of Aerospace Engineering, explaining why, back in 2007, he and lecturer Hans van der Marel decided to assign two groups of students the task of designing a port patrol system. The system was to consist of a swarm of autonomous, unmanned submersibles, each of which would guard a small section of a harbour and transmit information to a buoy. On shore, the information from the buoys would then be used to compile a picture of the entire port system. Simons: “Individually, each robot wouldn’t be capable of much, but in large numbers they can protect a harbour against terrorist attack.”

One group of students designed a yellow, torpedo-like mini-sub. “But machines like that already exist,” says Simons, who consequently was much more interested in the original design produced by the other team. He points to a drawing of a rather bulky predecessor of Galatea: “That ray can lie on the bottom to conserve energy, and whereas a propeller would soon become entangled in debris or vegetation, this robot simply flaps its fins twice and is ready to swim again.”

It was a nice concept, Simons agreed: “But it was still nothing but a study on paper, so I decided to see if I could put together a team to build such a robot.” He put aside the idea of providing port security, as this would require a whole swarm of robots. “Just one of them is enough to get started,” Simons explains. “I thought I’d struck gold. And now I really think we’re getting close.”

With its speed of only one to two metres per second, the robot ray cannot keep up with other underwater robots. Nonetheless, it does have a few major advantages, according to Jutte and Wilken, who promptly show a short film in which the Galatea glides quietly and smoothly through the water. “This is exactly what makes it so useful for underwater inspection work,” Wilken says. “It’s also extremely manoeuvrable; it can rotate around its own axis with ease.”

Empty box

These properties are among the reasons why the Dutch navy, the Ministry of Transport, Public Works and Water Management, and Fugro, a geotechnical surveying company, have all expressed interest in Galatea. “The number of applications is vast,” says Simons, who then has no trouble spending an hour listing them. The robot ray must be an ‘empty box’ capable of containing a variety of sensors. “A simple camera, a sonar system, or a chemical sensor, for example,” Simons says, ticking them off. “Inspections that are now being done using ships loaded full of equipment and crew may soon be done much more inexpensively and efficiently with our robots.”

Using sonar sound waves, the robot ray could help the navy locate the many mines left on the bottom of the North Sea after the Second World War. Or the robot ray could use its sonar to map a riverbed, which would assist the department of water management in deciding where to start dredging in order to keep rivers navigable. “And the fishing industry is also interested,” Simons adds. “Features of the sea bed can be used to deduce where certain species of fish have their habitat.”

A robot ray equipped with a chemical sensor could help the authorities monitor the growth of cyanobacteria in the lakes and ponds where people swim during the summer months. Moreover, equipped with a camera, robot ray could inspect pipelines located 300 metres beneath the sea.
for companies like Fugro. “I also recently got a call from customs, asking whether the robot ray could help them search for the drugs that traffickers sometimes attach to the outside of a ship’s hull,” Simons adds. Simons is now looking for the investors needed to develop one of Galatea’s applications within the next year. “If we can prove that robot ray works, we can take it from there. Put it on the market.” The students of the Galatea team are already thinking of setting up a company to sell the robot ray when the time comes. First, however, more research and tests must be conducted before their first prototype becomes a marketable product.

The shape of the ray’s hull, which is based on an aircraft’s wing, will require little changing: wind tunnel tests have shown the hull to be hydrodynamically correct. “We will probably be able to control the ray using just its fins,” Wilken says, “but to be on the safe side, we divided the rear trailing edge into two moveable flaps, which we can also use to control the ray during our tests.”

**Watertight**

The designers admit however that the next prototype will have to be more user-friendly. Jutte: “Each time we conduct tests, we must spend half an hour with tape and screws to make the ray watertight enough to swim. But even then, water sometimes gets in.” The vessel’s controls also need some rethinking. “GPS and standard radio communication don’t work underwater,” Simons explains. “Other technologies exist, but we must apply the right one.” Three of the team’s students have made the robot ray’s propulsion method their graduation project assignment; they are trying to improve the undulating motion of the ray, in collaboration with Wageningen University’s department of experimental zoology and TU Delft’s Faculty of Aerospace Engineering’s aerodynamics group. The robot ray’s current design features 17 ribs on each side, with each rib capable of being individually controlled.

‘Customs asked us if robot ray could help them search for drugs underwater’

Simons believes there must be a simpler way: “The current system is ideally suited for conducting research, however.” Initially, the students were not even sure if their idea for an artificial ray would work. To test their idea, they fashioned a fin out of 17 metal ribs and a piece of cotton fabric. This contraption was then suspended in a pool in the workshop, and the ribs made to move in succession, rather like a Mexican wave in a sports stadium. The students almost started their own wave of joy when they saw the fin slide along the metal suspension rack. The principle had been validated: the fin was able to propel itself through the water. Wilken: “That was certainly a moment for cheering.”

(see also infographic on the following pages)