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News & Highlights

Robotic Boats Test the Water

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An open-topped, metallic gray boat about the size of a compact car churns across a small harbor in central Amsterdam, the Netherlands. The craft detours around a pier jutting into the harbor and then slows as it approaches a customized dock. Turning sideways, it eases closer and closer until two hooks swing out from its side and latch onto the dock.

Steering and docking are standard boating maneuvers, but the vessel performed them without a human pilot. It is one of two autonomous prototypes (Fig. 1) that have been undergoing testing in Amsterdam since mid-2021 as part of Roboat, a joint project of the Massachusetts Institute of Technology (MIT) in Cambridge, MA, USA, and the Amsterdam Institute for Advanced Metropolitan Solutions [1]. Once trial runs are complete, the project's participants hope to deploy Roboats on Amsterdam's network of canals, where they could ferry passengers and cargo, collect trash, and interlock to form pop-up bridges for pedestrians and cyclists [2]. "The goal is to have something that can operate by itself 24/7," said David Fernández-Gutiérrez, a postdoctoral researcher at MIT and the boat's co-designer.

Boats and ships have long relied on autopilot for navigation, but artificial intelligence (AI) and other technologies are allowing them to move nearer to full autonomy. Companies such as Sea Machines, based in Boston, MA, USA, now offer AI systems that integrate information from video cameras, radar, and other sources to help vessels steer a more efficient course and detect and avoid objects [3,4]. However, these systems aid rather than replace the crew. Roboat and other similar projects take autonomy further, and some crewless watercraft are already plying the waves. Robotic vessels have sailed into a hurricane and circumnavigated Antarctica to collect scientific data [5,6]. In 2021, a self-piloting passenger ferry launched in another part of the Netherlands [7]. And a flotilla of other automated watercraft—including barges, cargo ships, and tugs—is undergoing testing and could start commercial operation in the next few years [8,9]. But these vessels are not quite ready to solo. They will still require at least some human supervision, and possibly even small crews.

Fig. 1. A Roboat steers around an obstacle during a test run in Amsterdam in 2021. The 1200 kg craft, propelled by four electric motors, can carry up to five passengers or 1500 kg of cargo. Credit: Pietro Leoni/MIT (public domain).

Compared with human-operated vessels, autonomous craft offer several advantages. Because they do not require quarters or facilities for a crew, they can be smaller, potentially reducing fuel costs [8]. Robotic boats may also be safer, avoiding many of the maritime accidents that result from human blunders [10]. Autonomy could help solve worsening crew shortages in some countries [11]. Another advantage emerged during the COVID-19 pandemic, when numerous crewed ships were unable to sail because of virus outbreaks—a problem that would not affect robotic ships [8].

Some experts predict that boats will be fully autonomous before cars because, at least in some ways, they pose simpler problems for designers [12]. For one thing, boats travel much slower. Roboat's top speed, for example, is 12 $km \cdot h^{-1}$, and on Amsterdam's canals it will not be permitted to travel over 6 $km \cdot h^{-1}$ [13]. As a result, robotic boats do not have to process as much data or respond as quickly as self-driving cars. Autonomous boats will also operate in environments that are typically less complex and congested than the teeming city streets that self-driving cars must negotiate [12]. Another reason that autonomous boats may be easier to develop is that traffic regulations for boats vary less from place to place than those for cars, said Thiru Vikram, chief executive officer of Buffalo Automation in Buffalo, NY, USA, which makes the autonomous water taxis now operating in the Netherlands. "Nobody is driving on the left side versus the right side," said Vikram.

Still, robotic watercraft will have to master many of the same tasks as self-driving cars [14]. Like their automotive counterparts, autonomous boats need to recognize objects in their vicinity and decide on an appropriate action, which requires the capability to make subtle distinctions in complicated situations. If a robotic boat and a sailboat are heading toward each other, for instance, the robotic boat is supposed to turn to avoid a collision—unless the sailboat is using its engine, when different rules apply. Thus, the robotic boat must be able to discriminate a sailboat from other types of craft and determine its status. To ensure that autonomous

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craft make the right decisions, their image recognition and navigation behavior algorithms will have to be modeled, trained, and tested using huge amounts of data collected from real vessels as well as synthetic data from simulators, Vikram said.

Robotic boats also must contend with unique challenges, such as docking. "It is one of the most complicated maneuvers. It is much harder than parking," said Fernández-Gutiérrez. A self-driving car is not bobbing on the waves as it tries to maneuver into a parking space.

Engineers have crafted a variety of designs to enable robotic boats to meet these challenges. The Roboats being tested in Amsterdam are 4 m by 2 m modular craft outfitted with four propellers—one at the front, one at the back, and one on each side. This configuration allows the vessels to travel backward, forward, and sideways, and to rotate. Power for the motors comes from a 12 kW·h^{-1} lithium battery mounted in the keel that can provide electricity for about 10 h before it needs to be recharged [15].

The boats use GPS to set their course autonomously [2]. During the trials, a technician on land provides a destination via a laptop computer, Fernández-Gutiérrez explained, but when the boats are operational, passengers might direct them through a cell phone app. Fernández-Gutiérrez said that the team is still deciding which combination of sensors will work best. The boat is equipped with light detection and ranging (LiDAR) and cameras, but the team may also add sonar for localization and to map underwater objects, he said.

Roboats can transport up to five people or 1500 kg of cargo, and they could serve as water taxis or delivery vehicles. But hauling trash is likely to be their first use, said Fernández-Gutiérrez. When the boats will graduate from the testing stage and start performing that job is still uncertain, he added.

A similar project to Roboat is the self-driving ferry built by Buffalo Automation, which has begun carrying bicycles and passengers (Fig. 2). The solar powered Greycraft is a floating platform about 3.7 m by 2.6 m that navigates with GPS, LiDAR, radar, and video cameras [16]. The company unveiled the vessel in Knoxville, TN, USA, in early 2021, and in July of that year a trial passenger service using one Greycraft launched about 40 km south of Amsterdam [7]. The ferry transported users across a small canal, providing access to a recreation area. Vikram said that in May of 2022 the service will expand to five vessels in several locations. Passengers will summon a ferry and pay for the ride through a cell phone app.

Other autonomous craft have plunged into some of the most grueling environments on Earth so that scientists do not have to. Saildrones, built by Saildrone, Inc., in Alameda, CA, USA, look a bit like windsurfers whose riders have fallen off (Fig. 3). And like a windsurfer, the craft, which consist of a vertical wing mounted on a surfboard-style body, are propelled mainly by the wind [17]. The three Saildrone models range from 7 to 22 m in length and can carry a range of instruments, including multibeam sonar for mapping the ocean floor and an inertial measurement unit for gauging wave height [17]. The vessels have completed some scientific feats. A Saildrone circumnavigated Antarctica in 2019 to gather data on the carbon cycle, and in 2021 one of the vessels sailed into Hurricane Sam to record video and take measurements [6,18,19].

Larger autonomous vessels are also making test runs and may soon be delivering cargo, transporting vehicles, and guiding other ships into port. In 2021, Sea Machines' robot tugboat completed a 1650 km journey around Denmark [20]. And in early 2022, researchers in Japan ran successful trials of an autonomous car ferry and two autonomous container ships that could be commercially operating as soon as 2025 [9,21]. One of the container ships was the first autonomous vessel to dock itself, using a drone to deliver the mooring line to the pier [9,21].

Despite their demonstrations of independence, today's autonomous vessels still require human intervention—and some may initially carry a minimal crew [22]. For example, the Sea Machines tug controlled itself for almost its entire journey, but its pilots had to take the helm—remotely from Boston—about 3% of the time [20]. A remote captain will also monitor the Greycraft ferries in the Netherlands from a central command center and will be able to take control in an emergency through a browser-based web application, said Vikram.

Experts predict that robotic boats' capabilities will continue to improve, and that autonomy will spread to more kinds of craft. However, on some vessels, including oil tankers, larger cargo ships, and commercial fishing boats, human crews still perform indispensable roles in addition to navigation, such as engine maintenance. These vessels probably will not become fully autonomous or dispense with crews anytime soon, said Vikram. "They will have a human presence."

Fig. 2. A Greycraft ferry transports passengers across a canal in the Netherlands during its trial period in the summer of 2021. The ferry can reach a top speed of 5 km·h^{-1}. Credit: Buffalo Automation (public domain).

Fig. 3. Autonomous Saildrones, like this craft used by researchers to track great white sharks, can spend up to 12 months at sea gathering scientific data. The vessels rely on the wind for propulsion—although some models also have electric or diesel backup motors—and the electricity for their scientific instruments and computers comes from solar panels. Saildrones use GPS to steer to a set of waypoints selected by researchers. Credit: Saildrone, Inc. (public domain).

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