FEATURED RESEARCH

Underwater Robotics

The use of robotics is rapidly expanding into many aspects of human activities, including manufacturing, aerial drones, search-and-rescue crawlers, planetary space exploration, micro-surgery, student competitions, and household products. In most of these applications the vehicles are employed in a familiar environment, using sensors humans are accustomed to, and the status and position can be observed by the operator via visual or radio frequency (RF) links. Untethered, free-swimming, underwater robots are different.

In most underwater environments, light and RF can only be used for distances up to a few feet. Sound is the best option for communications and sensing, but its bandwidth and propagation speed are relatively low. Thus a vehicle operator can neither control the vehicle remotely nor see the sensor data in time to react to any problems. Since the wavelengths of underwater sound are much longer than light (20,000 times longer), the resolution and quality of acoustic images are much lower than typical camera images. Additionally, very few humans have any experience being underwater and using a sonar to sense and understand the environment, making designing autonomous computer algorithms to perform these functions very challenging.

Advanced Technology Laboratory develops sonar systems for autonomous,free-swimming UUVs requiring innovative, miniaturized designs.

Underwater robotic vehicle with forward and side looking sonars.

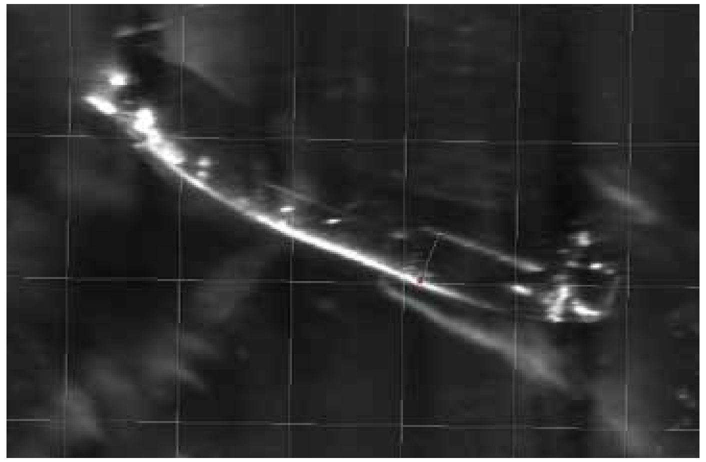
ARL:UT has decades of experience designing, developing, and operating high-frequency sonar systems to “see” in front of a vehicle, find objects, or maneuver through complex hazardous areas. The Advanced Technology Laboratory (ATL), specifically, has built proof-of-concept and prototype sonars for fast-attack and one-of-a-kind submarines such as the USS Dolphin (AGSS 555), submarine NR-1, and Deep Submergence Rescue Vehicles. ATL has also developed handheld sonars for U. S. Navy SEALs and explosive ordnance divers to detect and inspect objects in the water or on the seafloor.

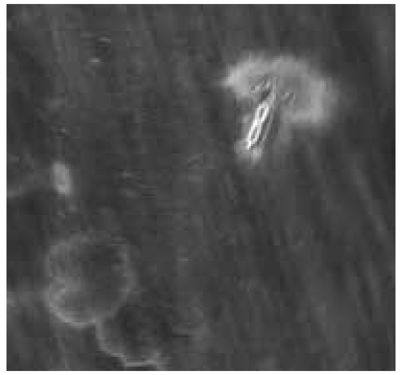
More recently, ATL has been developing sonar systems for autonomous, free-swimming Unmanned Underwater Vehicles (UUVs). These sonars are significantly smaller than submarine sonar, yet still need the same number of acoustic transducers and electronic components to deliver comparable functional performance. In addition, UUVs are powered from batteries instead of nuclear reactors. These constraints required engineers to develop innovative miniaturized designs. These systems have similar functions as submarine sonars but are smaller and use less than a tenth the power.

The underwater environment is complex, and understanding sonar data is challenging. Physics and vehicle size dictate that the resolution of sonar images is much lower than that of cameras used on land and in air-based robots. Sound rays bend vertically as they travel through water, so objects usually appear above or below their actual locations. Also, the sea surface and seafloor have mirror-like properties, which means operating a sonar in some shallow water areas is similar to trying to unravel the multiple reflections of every object in a large, low-ceilinged room completely covered in mirrors. In the underwater environment, everything that generates sound is like adding a glowing or strobe light source in that room.

Even so, engineers must understand this sonar data to operate manned or unmanned vehicles in underwater environments. ATL continues to develop algorithms and software applications to unravel many of these complexities and present understandable information to human operators. Some applications autonomously detect, locate, and identify specific types of objects. Others build large area maps from thousands of pings of individual sonar data. Still others estimate the topography of the seafloor within the view of the sonar.

The next challenge is to provide unmanned, robotic vehicles with the intelligence to use processed sonar data for driving around obstacles, avoiding seafloor ridges and cliffs, localizing and tracking the edges of rivers or ship channels, listening for large ships to move out of the way, and maneuvering near interesting objects for closer inspection. These underwater robots could build maps of an unmapped area or gather information to improve a nautical chart. They could be looking for specific objects, such as downed aircraft or historical shipwrecks. There are vast underwater areas that have never been explored and others that are familiar but not known in detail. The availability of reliable, free-swimming vehicles opens the possibility to explore all these areas.





Left: A UUV starts a mission and begins its dive.

Right: Shipwrecks

This is clearly a new frontier of robotics where scientists must become familiar with the characteristics of imperfect sensors in an environment with many unknown features. The feedback from these robots to their operators is limited so that even small experiments in autonomy must be sufficiently robust to maintain the safety of the vehicle. For example, UUVs have been caught in anchor lines for buoys, horizontal lines between lobster pots, and floating clumps of kelp. They have been washed onto the shore by turbulent waves near the surface and run over by large tankers, grabbed by sharks, pushed by dolphins, and buffeted by schools of sea-snakes. Most of these UUVs cannot pause to determine the best next step like many land-based rovers do. Instead, they must continually look and plan ahead even with imprecise information. ATL is investigating and developing autonomous intelligent algorithms to decide and control the actions and paths of a number of UUVs.

At ARL:UT, engineers are working in all these areas of sonar data processing, seafloor map building, and autonomous vehicle and sensor control using UUVs. ATL has surveyed many different areas for a wide variety of reasons, and in doing so discovered shipwrecks, located a WWII plane wreck, found whale skeletons, mapped potential glacial activity in the Great Lakes, and imaged an unknown volcano crater. ATL leads the nation in designing and implementing high frequency sonar systems and sonar for UUVs, consistently delivering advanced capability to the U.S. Navy and other sponsors.

While leading the nation in the design and implementation of high frequency sonar systems, ARL:UT has discovered shipwrecks, located a WWII plane wreck, mapped potential glacial activity, and imaged an unknown volcano crater.