THE NEXT FRONTIER: MARITIME DEXTEROUS MANIPULATION SYSTEM

Don’t just move through your world...INTERACT with it.

A Publication of RE2 Robotics
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Introduction

In the world of mobile robotics, you can do three things:

1) Move through the world
2) Perceive the world
3) Interact with the world

A mobile chassis can maneuver through its environment. Cameras and sensors can enable a robot to perceive the world. But in order to interact with its surroundings, the robot must be equipped with manipulators (arms) and end effectors (grippers).

In this paper, we discuss how our dual-arm Maritime Dexterous Manipulation System (MDMS) provides the same high degree of accuracy and dexterity as our terrestrial systems.

We also discuss the capabilities and technical requirements of an underwater system, as well as the benefits of the system’s electromechanical design, when compared to conventional hydraulic robotics.

This eBook is part three in a four-part series on Mobile Manipulation.
Recognizing a Need

With 90 percent of global trade conducted by sea, Waterborne Improvised Explosive Devices (WBIEDs) and mines pose a significant threat to our vessels, bridge and ports. When placed in congested areas such as bridge pilings, WBIEDS are particularly difficult to access and defeat. Recognizing the inherent dangers present in the detection and inspection of WBIEDs, there is a critical need for robotic systems that can perform Explosive Ordnance Disposal tasks with the accuracy and speed of a naval diver.

Recognizing this need, RE2’s researchers set out to design an agile, human-like system for the inspection and detection of WBIEDs, using the same technology and capabilities present in our dual-arm Highly Dexterous Manipulation System (HDMS), which is used in military and industrial settings. The goal? To allow for the teleoperation (and eventual autonomous operation) of Unmanned Underwater Vehicles (UUVs) to counter WBIEDs and mines. The result? RE2’s Maritime Dexterous Manipulation System, or MDMS.

Transitioning a land-based robotics system to a maritime one is not without challenges. The system must be able to withstand operation at a target depth of at least 150 meters and counteract the corrosive effects of extended salt water exposure. Moreover, the system must be firmly sealed against water exposure, and controllable in dynamic subsea environments. Early research has shown that our proven electromechanical technology can be adapted for underwater use. By designing modified seals and engineered materials, we have quickly demonstrated success in shallow waters.

RE2’s MDMS will allow for the teleoperation of UUVs to counter WBIEDs and mines.
Benefits of MDMS

The electromechanical MDMS features dual robotic manipulator arms that can be easily mounted onto a variety of third-party underwater remotely operated vehicles (ROVs). Like our HDMS dual-arm robot, MDMS features an open architecture, supporting the Joint Architecture for Unmanned Systems (JAUS) and Robot Operating System (ROS) communication protocols. This allows the system to be integrated with any JAUS or ROS-based robotic platform.

Benefits include:

• Electronically driven, energy-saving system frees up subsea UUV power for cameras and sensors to interrogate the environment
• Lightweight, compact design allows for smaller “footprint,” or volume, in constricted or precarious environments
• Neutral buoyancy ensures system stays controllable at designated depth
• Closed, sealed design protects electrical system from water ingress and grit, reducing system maintenance and downtime
• Multi-level corrosion management system, including the use of sacrificial anodes and anodized joints, allows for extended subsea interactions
• Reference joint design means system can be easily configured for different degrees of freedom, should the system be reconfigured
• Designed to integrate with existing ROVs, including those made by Teledyne Seabotix, General Dynamics Mission Systems and Oceaneering.
• Intuitive control using RE2’s Imitative Controller technology, which provides instinctive and easy-to-use command of the system
Technical Overview

MDMS is an electromechanical system designed with two symmetrical arms to ensure modularity, simplify development, gain economy of scale, and aid in ease of repair. Each manipulator arm consists of six Degrees of Freedom (DoF), for a total of 12 DoF. The arms are assembled using low-density, low-volume syntactic foam, which provides neutral buoyancy in and around each arm segment.

Key Features:

- **12 DoF**: This includes two six-degree of freedom arms, including:
  - Wrist roll
  - Wrist pitch
  - Elbow pitch
  - Elbow roll
  - Shoulder pitch
  - Shoulder yaw
  - An additional DoF provided by each end effector (gripper) located at the end of the arms
- **Modular joint design**: This allows for the easy addition and removal of joints, making the system highly configurable

Pressure Balance

Using a pressure compensator, each arm is a pressure-balanced, oil-filled system that provides positive pressure relative to the surrounding environment. This allows the system to currently support subsea depths of 150 meters.

Payload

In its current configuration, the system can lift at least 3.6 kg (approximately 8 pounds) under water.

ROV Integration

MDMS has been designed to integrate with underwater vehicles already in use by the U.S. Navy, eliminating the need to purchase all new ROVs for underwater operations.
Electromechanical vs. Hydraulic

Many existing robotic systems are driven with complex and often expensive hydraulic systems. Due to the need for a pump, motor, and numerous valves and manifolds, hydraulic systems are typically bulky, heavy and, therefore, power-draining. Moreover, the constant cycling of oil on a hydraulic system—coupled with pressure depth—puts stress on hoses and seals, which can lead to oil contamination and seal failure, as well as costly downtime of the system.

MDMS, on the other hand, is driven by an electromechanical design. Without the added bulk of a motor with a pump, the system is much more lightweight and power efficient than a hydraulic one. Electromechanical systems only use small amounts of oil to compensate for the pressure of depth and do not have as many surfaces to seal. Therefore, they offer greater reliability and require less maintenance while reducing the risk of seal failure, contamination and downtime. Because the system draws less power, a simple electrical battery can serve as the power source. In addition, electromechanical systems only use power when they are in use, allowing the system to remain dormant on the ocean floor for long periods of time and then quickly be “awakened” and ready for use.

Overall, electromechanical drive systems eliminate or significantly reduce many of the mechanical problems that occur with hydraulic systems, enhancing productivity and reducing costs.

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*MDMS is a lightweight, electromechanical system that is much more power-efficient than typical hydraulic systems.*
Intuitive Control, On Land or Underwater

MDMS is controlled with RE2’s Imitative Controller technology, which provides highly intuitive command of our terrestrial dual-arm manipulation systems. Intuitive and easy to use, the Imitative Controller is essentially a “puppet master,” allowing the user to move a scaled model of the robot’s manipulators from the safety of a remote location, such as from a ship or shore.

Imitative Controller technology is extremely intuitive and power efficient. The easy-to-master technology allows operators to intuitively control a UUV from ship or shore with the same dexterity and accuracy of a naval diver, even inside tight, cluttered environments, such as under bridge pilings, around reefs, or through the remains of a shipwreck or plane crash.

Through numerous demonstrations and training exercises of our HDMS system, we have determined that training time for new users is typically less than one minute, and time to proficiency is estimated at one hour. Similar results can be expected with testing of our MDMS system.
Looking Ahead

With two-thirds of the earth’s surface covered in water, there is great potential for robotic systems to assist in the exploration of our oceans and waterways. Oceanographic research, industries such as oil and gas, and construction applications can all benefit from the development and application of underwater robots. Overall, the potential applications for the MDMS are limitless.

RE2 Robotics remains committed to creating state-of-the-art robotic technologies and is focused on developing products that can save human lives. Whether used for military operations, industrial tasks or commercial applications, our Maritime Dexterous Manipulation System presents an unmatched level of human-like control in the field of underwater robotics.

RE2 Robotics develops technologies that save lives and improve quality of life.
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