

16-665

Marine Mobility

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Q1.

The four main challenges discussed in the lecture (Slide 9) are as follows:

1. **Testing:** The testing of marine robots requires special facilities and expensive field tests, so the deployment of such robots require a lot of capital and funding.
2. **Salt water:** Salt water corrodes metals and disrupts electronics, so expensive specialized components need to be used on the marine robot to counteract this disturbance.
3. **Communication:** Radio waves do not propagate underwater, so there is no GPS for localization and only acoustic communication works underwater, which have higher latency and limited bandwidth, causing significant restrictions on data transmission.
4. **Hydrodynamics:** Marine robots need to withstand high water pressures, which requires costly materials for structural integrity and expensive sensors that work under extreme pressure (e.g. CMU students ☺); additionally, the robot's dynamics is subject to solving the Navier-Stokes equation, which is very hard to model and solve.

Q2.

Gravity is not constant around an ellipse around the earth due to varying mass distributions underneath each position causes the gravitational force to be stronger or weaker at each location. Variations in gravity affect marine navigation by introducing errors in gravity-dependent sensors such as the gyroscope and accelerometers used for dead reckoning underwater, causing trajectory deviations and inaccurate navigation.

Q3.

The vehicle does not stay level because its center of buoyancy and center of gravity are not aligned vertically, causing instability as there will be a net torque on the vehicle and cause it to pitch and/or roll. To fix this, we could adjust the internal weight distribution (e.g. adjust water in the ballast tanks) to ensure that the center of gravity is vertically aligned with the center of buoyancy.

Q4.

A remotely operated vehicle (ROV) would be the best choice for studying volcanic deposits and picking up small pieces of debris. Being remotely operated allows the robot to be much more dexterous in using manipulators for precise operations and be able to take teleoperation commands from the end user to determine which debris to pick up. Referring to the Ocean One rover below, some desirable qualities for emulation are that it is relatively small (thus highly maneuverable in volcanic environments), very dexterous manipulators (so it can pick up debris), can be tethered (for extended operations and bringing the robot back to the surface), can take teleoperation commands (for precise operations), and being rated for over 800 meters (so it can operate for the desired depth of 50 to 100 meters).

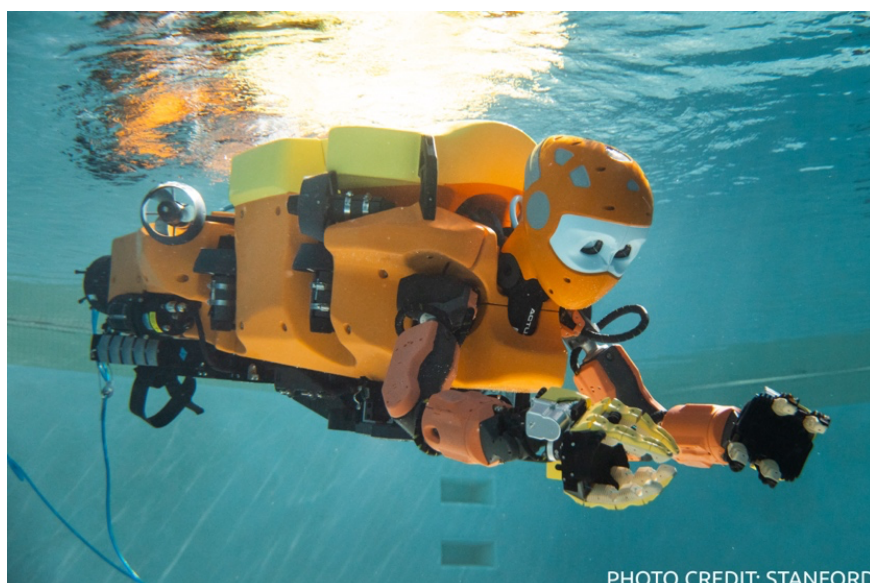


Image: Ocean One Rover from Stanford University

Image Source: Khatib, O. (n.d.). *Ocean One K: The robotic diver for ocean exploration*. Stanford Robotics Lab. Retrieved November 24, 2024, from <https://khatib.stanford.edu/ocean-one-k.html>

Q5.

One method of localization at a depth of 5000 meters is to use Ultra Short Base Line (USBL) positioning, which uses the time-of-travel and angle of acoustic pings sent by a surface ship to the underwater vehicle in addition to the position information of the surface vessel to determine the underwater vehicle's position. Referring to Slide 145 of the lectures, one positive attribute is that it is easily deployed (i.e. no fixed transponders are required to be deployed beforehand) as the transponder and transceiver are all hull mounted. However, a negative attribute is that since the localization is dependent on the surface ship location, both the sensors used for surface ship localization (to account for ship motion) and the underwater vehicle mounted sensors (which need to account for changes in salinity, water properties, and environmental noise as they alter the time-of-travel of acoustic pings) need to be precise.