Design of a Cable-Mounted Robot for Near Shore Monitoring

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Abstract

The coasts are an essential resource. About 600 million people reside along the coasts at an elevation of less than 30 feet above sea level, and this number is projected to double by 2060. In addition to being critical to human society, biodiverse coastal habitats such as estuaries, wetlands, coral reefs and upwelling areas support and provide breeding grounds for organisms such as fish, marine mammals, sea turtles, and migratory birds.

Given the role the coasts play in billions of lives, monitoring this highly dynamic environment is an urgent concern for both safety and conservation efforts. Due to climate change, vulnerable coastal ecosystems are experiencing strains from sea level rise, increased temperatures, changes in storm patterns, and ocean acidification. These changes necessitate reliable observations that will help us reach a deeper understanding of the coasts.

However, surveying the coastal waters is not an easy task as conditions change rapidly in these areas. In the shallow waters along the coasts, tidal currents build up speed, especially in zones with narrow openings such as bays and estuaries. The tidal range along the coasts can vary between zero and 16 meters. Moreover, surface currents and waves in coastal regions are influenced by local winds and change in accordance to weather and seasonal patterns. In the most extreme scenarios, eg. hurricane landfall, important transient events that occur are impossible to measure and sample using current technology. These variables create a complicated environment for any coastal surveillance system to navigate. Within this environment, current coastal monitoring approaches are inefficient and expensive. Researchers need an affordable and reliable method of data collection to further understand this critical area.

We propose a robotic system that can contribute to widespread, low cost, and consistent coastal monitoring. An overview of the system is shown in Figure 1. The robot will traverse a fixed, partially underwater cable and autonomously collect water samples and data. The anchored nature of this system allows it to more easily overcome the many challenges of navigating a coastal environment. The cable restricts the robot to only one axis of motion, making it much easier to return to a precise location over time for measurements in long-term studies. In addition, it minimizes the need for human supervision and maintenance, dramatically reducing costs while increasing sampling rates. The system will collect information regardless of weather and with much greater temporal resolution than manual methods. It is also highly modular and can be equipped with different sensor suites depending on the application and deployment location. By focusing on simplicity, reliability, and versatility, the proposed system can better meet the requirements associated with coastal monitoring.

In the process of designing the system we investigated potential obstacles that might prevent the robot from functioning. Specifically, we identified waterproofing, power consumption, efficient propulsion, biofouling resistance, and user experience. In this paper we will focus mostly on waterproofing, propulsion,

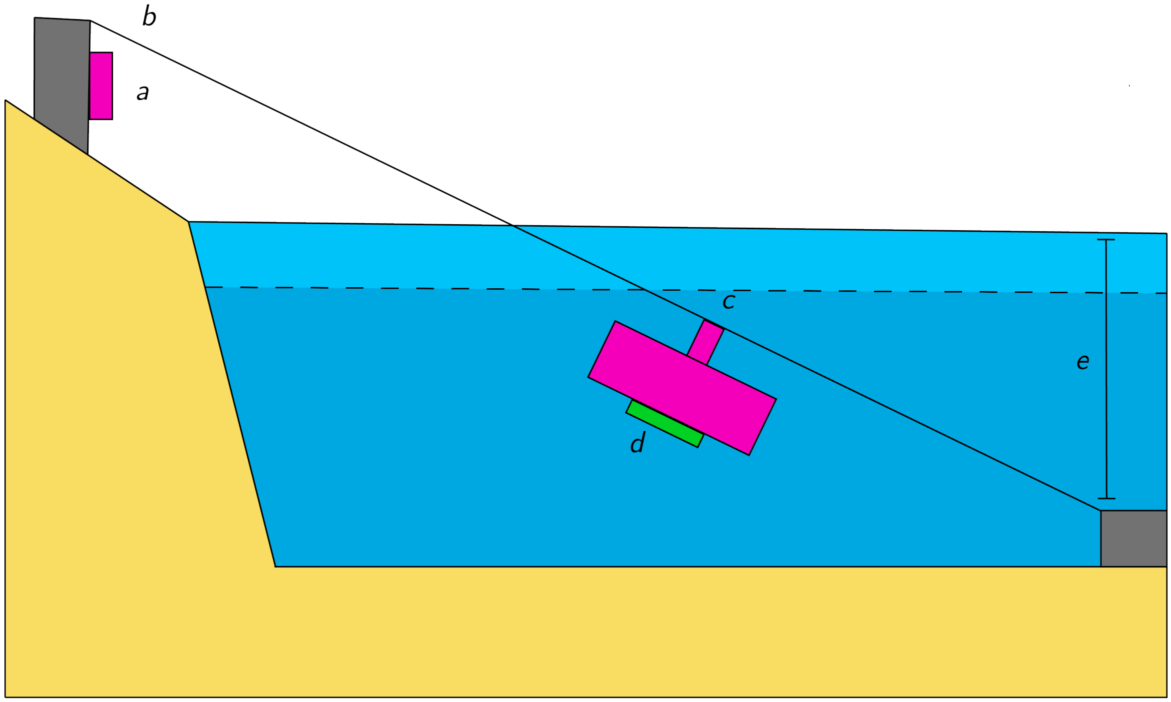

Figure 1: Diagram of robotic coastal monitoring system with tidal change. a) Dock on land provides power and servicing. b) Fixed supports at either end of the cable ensure little movement between readings, even in adverse conditions. c) Vehicle is sealed for underwater operation. d) Vehicle is compatible with a wide range of sensing and sample collection packages. e) Three meter depth rating allows surface and sea floor sampling.

and user experience, though all factors were considered during the design process.

We conducted multiple experiments to test different configurations of our design to compare their performance in each of the three focus areas. To test waterproofing we subjected the system to depths far beyond where it is designed to operate, exposed raw materials to salt water for extended periods to assess corrosion, and tested the entire system off the Massachusetts coast in up to three meters of water to ensure it would not leak or degrade even on long deployments. In developing the propulsion system we prototyped over 20 wheels in six materials and evaluated each based on grip strength and durability. We then designed and prototyped six different drive systems to accommodate different wheel designs as well as improve the ease of waterproofing. Finally, we created a user interface that allows the robot to be controlled wirelessly from any computer without proprietary hardware and is easy to use and understand with little prior experience. We evaluated its design with prospective users and assessed its ease of use. In this paper, we present the results of our tests and recommendations for future research.