ABSTRACT

Jun Han Bae, Purdue University, December 2021. Development of Unmanned Sediment Sampling System. Major Professors: Byung-Cheol Min and Richard Voyles.

Sediment has a significant impact on social, economic, and environmental systems. With the need for an effective sediment management and monitoring system growing more important, a method for precisely and reproducibly obtaining sediment samples that represent the actual environment is essential for water resource management and researchers across aquatic domains (such as lakes, rivers, reservoirs, mine drainage ponds, and wastewater lagoons). Sediment sampling is usually carried out less frequently than water sampling because of the cost and labor involved. However, more frequent sediment sampling and an increase in the range of the sampling area are necessary to more effectively monitor the ecosystem and water quality.

To fill this gap, robotic approaches for sediment sampling have been introduced. However, they are not tailored to a sediment sampling method and do not focus on the quality of the sediment sample. Moreover, there are many challenges involved in developing such a sediment sampling system for the surface water of rivers, streams, lakes, ponds reservoirs, and lagoons. Thus, this study aims to design and develop an unmanned sediment sampling system for surface-water environments, including rivers, streams, lakes, and ponds, based on marine robot platforms that are capable of collecting intact sediment samples from a range of sediment types. As part of this study, an unmanned surface vehicle (USV) was used to deploy the underwater sediment sampler (USS) at the sampling locations. The USS adopted a core sampling method to collect the sediment samples. The specific requirements were integrated, taking into consideration the challenges posed by surface water and underwater environments, to design and develop an unmanned sediment sampling system.

The USV has two missions - *deploying* and *positioning*. Users can deploy the USV with the USS to the desired sampling area. Once the USV arrives, it has to maintain its position while launching the USS and during the sampling process. The USS also has two missions — *launching* and *sampling*. The USS must be a negative-buoyancy platform so it can reach the bottom and maintain its stability during sampling. To sample the sediment, the USS has to generate a sampling pattern. We defined and formulated challenges based on the missions of each platform. Extensive field experiments were conducted to evaluate the proposed system, utilizing the data from the sensors installed on each platform.

The USV is consists of three sub-systems; propulsion, launching, and monitoring system to accomplish missions. The propulsion system and launching system are necessary to accomplish deploying and positioning missions. The propulsion system consists of two thrusters to navigate the USV. The launching system is to launch anchors for positioning and the USS for sampling. The monitoring system is to monitor and control other systems on-board via online video. The USS is the tethered system and connected with two types of cables from the USV. One is the serial cable for data transmission, and another is the physical cable to launch the USS from the USV. The USS is a negative buoyancy platform to submerge itself to the bottom of the water. The USS can generate sampling patterns based on three motions; linear, rotational, and hammering motion. We integrated servos, sensors, and mechanical components to generate three

motions. The main system of the USS is completely waterproof, even for linear and rotational motion with enclosures, o-rings, and rubber bellows. Since the USS operates underwater, the water pressure causes the pressure difference between inside and outside the enclosure. We designed a pressure-equalizing system to compensate for the volume change because of sampling motions and pressure differences. We installed sensors to measure the depth of the water, the orientation of the USS, and the reaction force acting on the USS. We can monitor real-time data from all sensors, and we installed the underwater camera to monitor the core sampler while sampling.

Extensive field experiments were conducted to evaluate the proposed system. Users can monitor and control the system from the base station based on all data and images from each platform. The evaluation of the system is based on the data from sensors installed on each platform. Deploying and positioning missions of the USV can be shown based on the trajectory data. Launching and sampling missions of the USS can be validated based on depth, orientation, and reaction force data. We had success and failure trials throughout the field experiments. In the case of successful trials, the whole procedure went smoothly, and we could collect a certain amount of sediment. In the case of failure trials, something went wrong during the procedure to complete the missions, and we could not collect sediment. Based on the failure trials, we could analyze the issues and improve the system.

Contributions of the proposed unmanned sediment sampling system are, novel design of the system to maximize the sediment sampling, system integration based on the challenges to accomplish tasks on the given environment, sediment sampling pattern analysis to collect quantitative sediment samples, and extensive field experiments evaluate the system. The proposed unmanned sediment sampling system is the first step toward the autonomous sediment sampling system that can remove the risks of human-based sampling and establish more frequent sampling for more effective sediment monitoring.

Demo video - https://youtu.be/7b2Px7zBOnc