Low-cost and Low-power System for Wave Profile and Tide Monitoring

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Introduction

With occurring climate changes, it is increasingly important to understand and monitor how costal and shore erosion affect human structures and ecosystems. Although sea monitoring is an already widespread concept, it may also be of interest to study river waves. The constant boat and ship traffic generate wakes that collide with the riverbank, which may lead to accelerated deterioration of natural or man-made structures and disturb protected areas. There is an increasing demand for in-situ real-time systems with localized or spread-out monitored areas. Most sensors capable of monitoring the wave profiles are too power-hungry and costly, have significant dimensions, and are designed for specific applications.

Pressure and Temperature Sensor

Temperature and Pressure (TP) sensors are used in many applications and are a well-known technology. These sensors are easy to install, have reduced dimensions, and can be deployed close or away from the shore.

The low-power specs are compatible with energy harvesting or renewable systems, increasing its long-term deployment time limit without user intervention. Additionally, they may have compact designs.

Depth Correction

To accurately estimate the height of a wave from the pressure measured underwater, one must consider the attenuation that the pressure suffers as it travels the water column. According to the Linear Wave Theory, the pressure at a given depth can be estimated empirically through the equations:

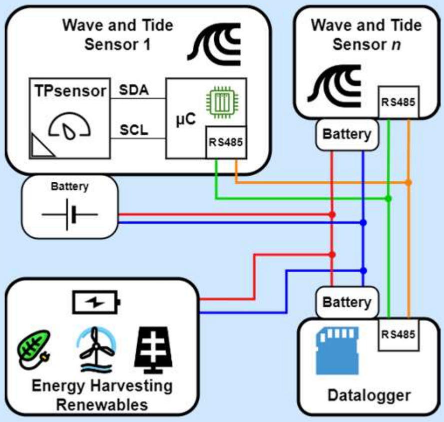
$$p = -\rho g z + \rho g \frac{H}{2} \cos(kx - \omega t) K_p(z)$$

$$K_p(z) = \frac{\cosh\{k(h+z)\}}{\cosh(kh)}$$

Using this equation, it is eventually possible to estimate the wave height and characterize the wave profile by measuring the pressure at the seafloor. However, this is an empirical theory. The pressure propagation is affected by various factors, such as the seabed's morphology. Therefore, for accurate measuring, it is essential to perform on-site sensor calibration to ensure the accuracy and reliability of the estimations.

Monitoring System

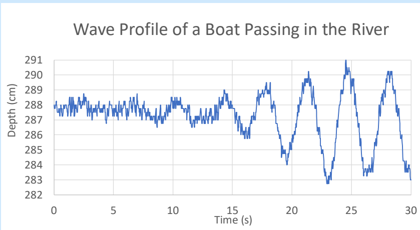
The monitoring system was designed to be modular. It can be deployed as a standalone sensor with an integrated datalogger, storing the data in an SD card for later acquisition. Furthermore, it is able to incorporate a communication module, allowing the construction of a multi-sensor network with RS485, Wi-Fi, LoRa, or ZigBee protocols, broadcasting data in real-time. A low-power microcontroller manages the TP sensor and the data, deciding whether to store or broadcast it. The sensor has a maximum sampling rate of 100 Hz and 1 cm resolution. The system was tested successfully in real-life conditions, in rivers Douro and Cávado and off the coast of Viana do Castelo.

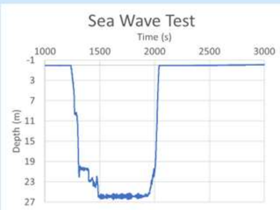


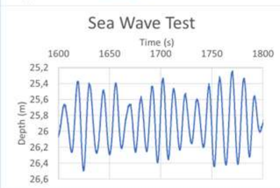
Wave monitoring

What produces waves?

-Most sea waves are caused by wind;
-Occasionally caused by tectonic plates shift (such as tsunamis);
-In lakes and river, a boat or ship passing by also produces waves.







Measuring river waves

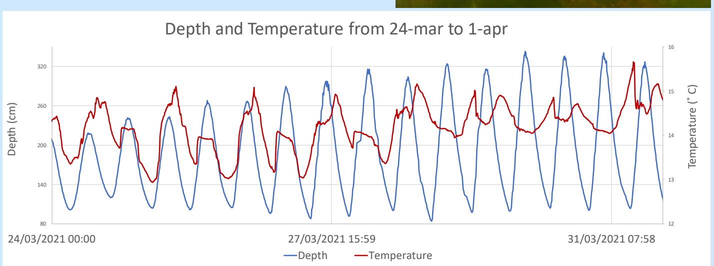
-A passing boat generates waves large enough to disturb the riverbank and accelerate erosion;
-Sensor installed 2.8 m deep;
-Waves up to 10 cm measured;
-The pressure is attenuated as it propagates down the water, making 20 cm waves seem like 10 cm.

Measuring sea waves

-Sensor dropped to a depth of 26 m;
-Wave's profile and frequency easily identified;
-The amplitude needs to be calibrated, because the pressure propagation is attenuated the deeper the sensor is installed.

Tide monitoring

-Sensor deployed in the estuary of the Cávado River;
-It was possible the distinguish the two daily high/low tide cycles, as well as the Neap tide in the first days and the Spring tide seven days later;
-Additionally, the temperature corroborates the tide cycle measured by the pressure.



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