Wave Profile and Tide Monitoring System for Scalable Implementation

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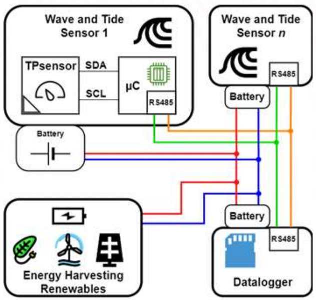
Introduction

With occurring climate changes, it is increasingly important to 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. There is an increasing demand for in-situ real-time systems. Most sensors capable of monitoring the wave profiles are 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. It can measure pressure in the range of 0 bar to 30 bar, and temperature from -20° C to 85° C.

Monitoring System



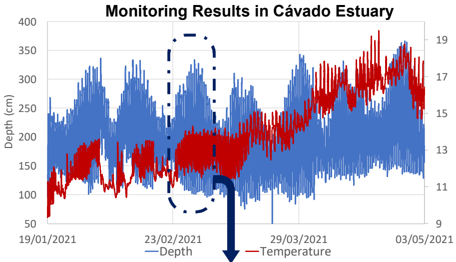
The monitoring system was designed with modularity in mind, offering standalone capabilities with an integrated with data storage. It can also integrate communication modules for real-time transmission using various protocols (RS485, Wi-Fi, LoRa, ZigBee), connecting several sensors to a datalogger and creating a multi-sensor network. A low-power microcontroller (STM32L082KZT6) was tasked with timing measurements, managing data, and communicating with the datalogger. Low-power specs are compatible with energy harvesting or renewable systems, increasing deployment time limit without user intervention. The sensor has a maximum sampling rate of 100 Hz and 1 cm resolution. Field tests in challenging environments, including rivers and offshore, confirmed its effectiveness.

Results

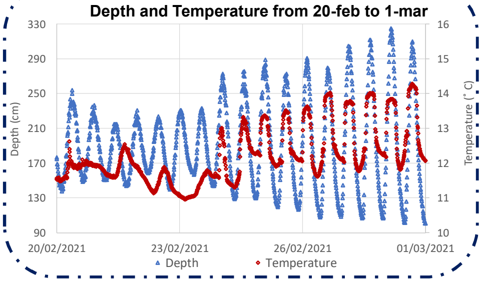
Cávado Estuary Tide Monitoring

The first test outside the lab was made in Cávado river, to monitor the tide shift, in terms of depth and temperature. The sensor was deployed at a minimum depth of 2 m, and connected to an already installed network, using RS-485 communication, converting the acquired values into a string with an identifier, and sending it to the datalogger [1]. More than three months of data were then collected and verified with information on online weather forecast.

Monitoring Results in Cávado Estuary



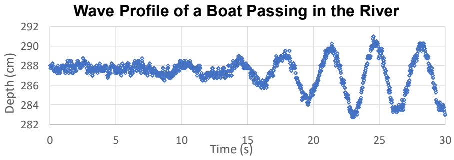
Depth and Temperature from 20-feb to 1-mar



Measuring waves generated by boats

The wave profile monitoring system was deployed at a depth of 3 meters in the Douro River, measuring the waves generated by boats passing nearby.

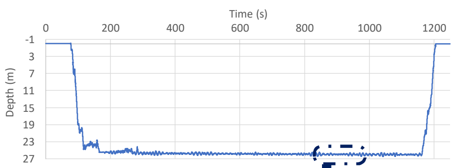
Wave Profile of a Boat Passing in the River



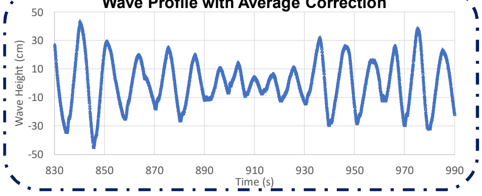
Sea wave test in Viana do Castelo

In Viana do Castelo, the sensor was dropped at a depth of 26 meters to measure the wave profile for 16 minutes.

Depth Test in Viana do Castelo



Wave Profile with Average Correction



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 [2], the pressure at a given depth can be estimated empirically through the equations:

$$p = -\rho g z + \rho g \frac{H}{2} \cos(kx - \omega t)\, K_p(z) \quad (1)$$

$$K_p(z) = \frac{\cosh\{k(h+z)\}}{\cosh(kh)} \quad (2)$$

Equation (1) may be divided into three sections: static pressure, dynamic pressure, and attenuation factor.

$-\boldsymbol{\rho g z}$ represents the static pressure, which depends on the average height of the water column;

$\boldsymbol{\rho g \frac{H}{2} cos(kx - \omega t)}$ represents the dynamic pressure, which depends on the wave profile;

$\boldsymbol{K_p(z)}$ is the attenuation factor, which mainly depends on the depth of the sensor and the frequency of the wave.

Using this equation, with special attention to the attenuation factor, it is possible to estimate the wave height and characterize the wave profile by measuring the pressure at the seafloor. However, it should be noted that this is an empirical theory, and the pressure propagation is influenced by various factors, including the morphology of the seabed. Therefore, for accurate measuring, it is essential to perform on-site sensor calibration to ensure the accuracy and reliability of the estimations.

Conclusions

Pressure sensors for wave measurement offer cost-effective potential for broad deployment, with each sensor costing just 30 EUR and consuming a maximum of 6 mW.

Calibration, involving a minimum of three sensors at various depths, is vital for accuracy. However, the sensors may be limited to shallow coastal regions due to depth constraints. Integration of underwater wireless communication, like acoustic tech, can enhance versatility and deployment ease [3], improving aquatic ecosystem monitoring and management.

References

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