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How to know what's in your river?

Comment savoir ce qu'il y a dans votre rivière?

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RÉSUMÉ

Les premières civilisations ont été façonnées par la présence de rivières et de cours d'eau. L'intensification de l'utilisation des terres, l'urbanisation et le rejet de polluants dans les cours d'eau récepteurs se sont accélérés ces dernières années, conduisant à la dégradation des masses d'eau. Afin de mieux comprendre de manière intégrée, la santé des rivières et des cours d'eau, cet article propose l'utilisation d'un capteur à moindre coût, miniaturisé, permettant l'acquisition de données en temps réel, avec un système modulaire, connecté (IoT) et programmé en open-source. Cet outil de suivi innovant doit, cependant, être compatible avec les objectifs de recherche et fournir des données valides et fiables. Cet article se concentre sur l'adaptation d'un capteur à très bas coût utilisé dans l'industrie pour le suivi des sédiments dans les rivières. L'objectif est de mettre en lumière les problèmes rencontrés par les chercheurs lors de l'utilisation de ce type de capteur et de proposer des solutions à ces problèmes.

ABSTRACT

Initial civilizations were shaped by the presence of rivers and waterways. Intensified land use, urbanization and release of pollutants to water bodies that has accelerated in recent years has put the health of these water bodies at risk. To help understand the health of rivers and streams in an integrated way, this paper proposes the use of a sensor with lower costs, miniaturization, real-time data acquisition, modularity, connectedness (IoT) and open-source programming. This innovative monitoring needs, however, to be compatible with the research goals and provide valid and reliable data. This paper focuses on the adaptation of a very low-cost turbidity sensor used in industry for sediment monitoring in rivers. The aim is to shed light on the problems encountered by researchers while developing these sensors and propose solutions to these problems.

KEYWORDS

Monitoring, low-cost, turbidity, turbidimeter, Internet of Things (IoT)

1 WATER QUALITY: A PERENNIAL ISSUE

Living near watercourses has always been a staple of humankind through various civilizations. The availability of free-flowing water allowed human settlements and the development of many major cities. Rivers were used as means to meet the essential needs for drinking water, irrigation, agriculture, transport and navigation, disposal of waste and even in cultural rituals (Adeloye, 2009). Throughout the years these settlements grew into urban centers and anthropogenic effects in rivers have been more and more impactful. Contemporary issues affecting urban and peri-urban waters relate to conservation, flood protection, run-off control, and integrated water resource management (Zingraff-Hamed et al., 2021).

Dealing with rising demands, pollution and climate change impact requires better management techniques and the preservation of the remaining water resources. Concerns about pollution gave rise to the need for monitoring and maintaining water quality, and the standards for in-stream water quality management (Macklin & Lewin, 2020).

Riverine ecosystems can be severely affected by the increase of sediments (Harrison et al., 2008). To understand river health, single measuring points and sporadic sampling does not suffice, particularly for sediment fluxes, given that catchments and channels are composed of complex interconnected systems of sediment supply, transport, and storage (Sear et al., 1994). We need to look at rivers and streams more as an integrated system rather than as isolated points. To enable an increase in the spatial and temporal resolution of data collection, we propose a network of low cost suspended sediment transport sensors, where the limiting factors in field data collection such as, number of field visits, data retrieval, sensor diagnostics and cost become smaller or even insignificant. This innovative monitoring, however, needs to be compatible with research goals and provide valid and reliable data. This paper focuses on the adaptation of a very low-cost sensor used in industry (in washing machines) for monitoring of suspended sediments in rivers. The aim is to shed light on the problems encountered by researchers while developing these sensors and propose solutions to these problems.

2 WHY SUSPENDED SEDIMENTS ?

Determining the TSS loads in rivers is critical for defining locally relevant, science-based criteria for water quality. Suspended sediments often act as carriers for components which can affect the physical, chemical, and biological properties of aquatic ecosystems, such as trace metals, semi-volatile organic compounds, and pesticides (US EPA, 2000). This parameter, although very easily identifiable presents logistical and cost challenges in order to properly characterize TSS variability. The measurement of water turbidity can be used as a surrogate to understand not only the amount but also the size, shape and even composition of the particles present in the water. It characterizes how the particles suspended in the water scatter and absorb light, rather than transmitting it (Zhu et al., 2020).

Turbidity is either acquired by laboratory analysis of samples, which can be time consuming, or by deploying sensors into environments such as streams, lakes and sewer pipes. These sensors need to be robust enough to endure harsh weather conditions without compromising the data. Currently, many commercial sensors exist in the market, but, with costs reaching five to ten thousand euros per sensor, high spatial resolution cannot be expected. There is a growing trend in the development of low-cost Internet of Things (IoT)-connected technology (Alobaidy et al, 2022). This technology is now reaching the scientific community, providing lower costs and real-time access to data.

Managing the data of a variety of field-deployed sensors can be demanding, especially if constant field visits are necessary to ensure that the sensor is performing well and retrieve data. Often, days or even weeks of data are lost due to dropouts in data collection or storage. Using IoT connected technology, the data can be transferred, stored and analyzed in real time, increasing greatly the response time for any anomalies in the data.

3 FROM THE WASHING MACHINE TO THE RIVER

We propose the use of a field turbidimeter with real-time data transmission. The entire system is constructed using Arduino components, and its main component, the sensor SEN0189 (DF Robot, 2022) was first developed to be used in washing machines. To our knowledge, this is currently the only low-cost commercially available sensor suitable for this type of measurement. The head consists of a printed circuit protected by a transparent plastic cap, on which two LEDs separated by about 1cm allow the measurement of the turbidity by operating in the near infrared light spectrum. The sensor measures how

much the emitted light is attenuated when going through the sediment filled water until reaching the receiver (Figure 1). This principle is not new, and has already been put into application by many authors (Rymaszewicz et al., 2017; Parra et al., 2018). What changes in this research in comparison to previous studies is the approach made to rectify inconsistencies in the measured data. Several challenging issues need to be solved before the deployment of low-cost turbidity sensors in the field (Table 1).

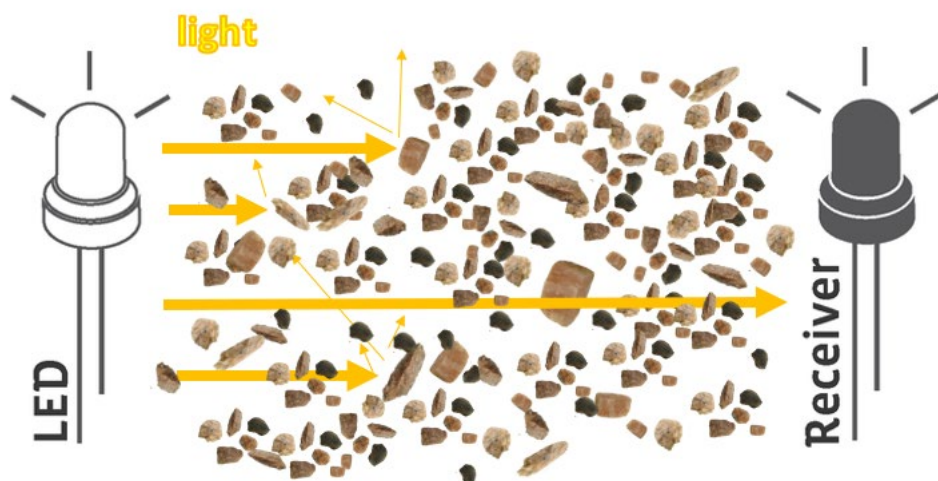


Figure 1: Emitter LED and Receiver phototransistor depicted showing the passage (blockage and dispersion) of light through suspended sediment.

Table 1: Issues and possible solutions with deploying low-cost turbidimeter

Issues	Description	How to identify it	Possible solution
Ambient light	Sun light causes overestimation of measured values because it increases the amount of light on the receiver LED.	Using control measurements with varying solar influence (in the light, shadow and completely dark)	<ul style="list-style-type: none"> • Use LED and receiver with lower sensitivity to sunlight • Develop sun protection casing for sensor • Measure sunlight influence before any measurement
Fouling	Accumulation of dirt/algae/calcareous materials blocking the passage of light between the LEDs	<ul style="list-style-type: none"> • Identify trend in measured values • Do measurements before and after cleaning the probe 	<ul style="list-style-type: none"> • Develop sensors cleaning methods (ultrasonic, mechanical) • Implement alert system when trend is identified
Accuracy	Turbidity measurement accuracy can be affected by voltage measurement method	Direct voltage measurement from the Arduino board is questionable	Use a dedicated component to accurately monitor the voltage: ADS1115
Calibration	Sensor calibration is mandatory and can be time consuming (especially when deploying many sensors)	Test different sensor calibration methods	Develop fast standard calibration procedure
Temperature variation	Variation of measured data according to temperature	Test variation in measurement with temperature (expected to occur in all turbidity measurements)	Apply correction factors specific to each sensor

Our preliminary lab experiments (in a controlled environment) showed promising results in comparison to well-established commercial sensors. The next stage was to implement some of the ideas presented in Table 1. To counter the influence of solar light, the emitters and receivers were substituted with LEDs

with a wavelength less sensitive to ambient light. According to our experiments, solar noise tends to increase measured voltage by circa 60%; the LED substitution limits the increase to circa 10%. Further steps are being taken to decrease this difference even more, such as varying light emitting times and light frequency of the emitter LED.

Experiments to assess the influence of the water temperature in turbidity measurement have shown that it is possible to compensate for temperature changes and obtain results very close to reference sensors. Once the correction factors are defined for a sensor, the temperature effects can become negligible.

Further studies need to be done on the formation of biofilms and deposit of sediments on the sensor, given that these deposits may cause erroneous measurements. Two approaches are possible in this case: either prevent the formation and deposit of substances on the sensor, or develop a way to identify and compensate the changes in the measured values.

Preliminary results encourage us to further pursue the directions taken for addressing the impacts of solar noise and temperature. The SEN0189 has proven its applicability for turbidity measurement in water-related systems. The issues we encountered and the problem-solving approach we followed can be of inspiration for other researchers aiming to use and adapt low-cost technology.

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