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MDPI

Open-Source Portable Spectroscopic Device for Rural Water Monitoring Applications

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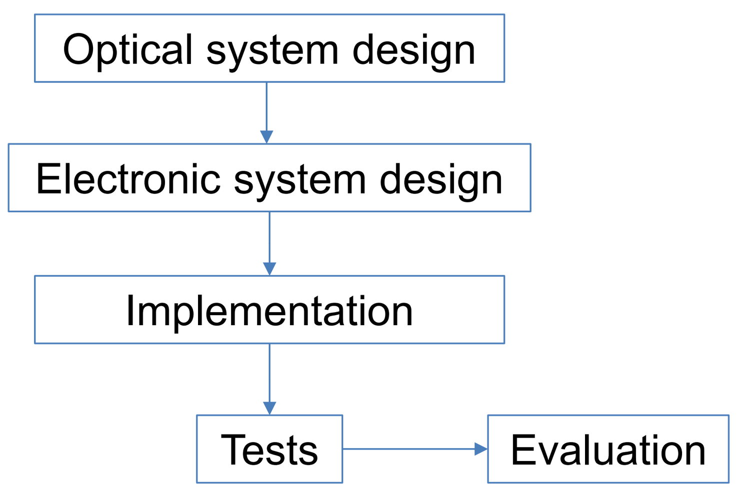
INTRODUCTION & AIM

Visible light, spanning wavelengths from 400 to 700 nm, corresponds to colors perceptible to the human eye. Spectrometers enable the separation and measurement of these wavelengths through optical components such as diffraction gratings and lenses. Although commercial spectrometers offer high precision, their cost restricts access for educational and low-budget applications. This limitation motivates the development of affordable systems capable of performing reliable spectral analysis. In this work, a low-cost portable optical device is designed to detect light intensity across the visible spectrum. The system integrates basic materials, an electronic module, and an angular scanning mechanism to enable in situ measurements comparable to commercial equipment.

METHOD

For the development of the prototype, we follow a sequential work as show in the figure below.

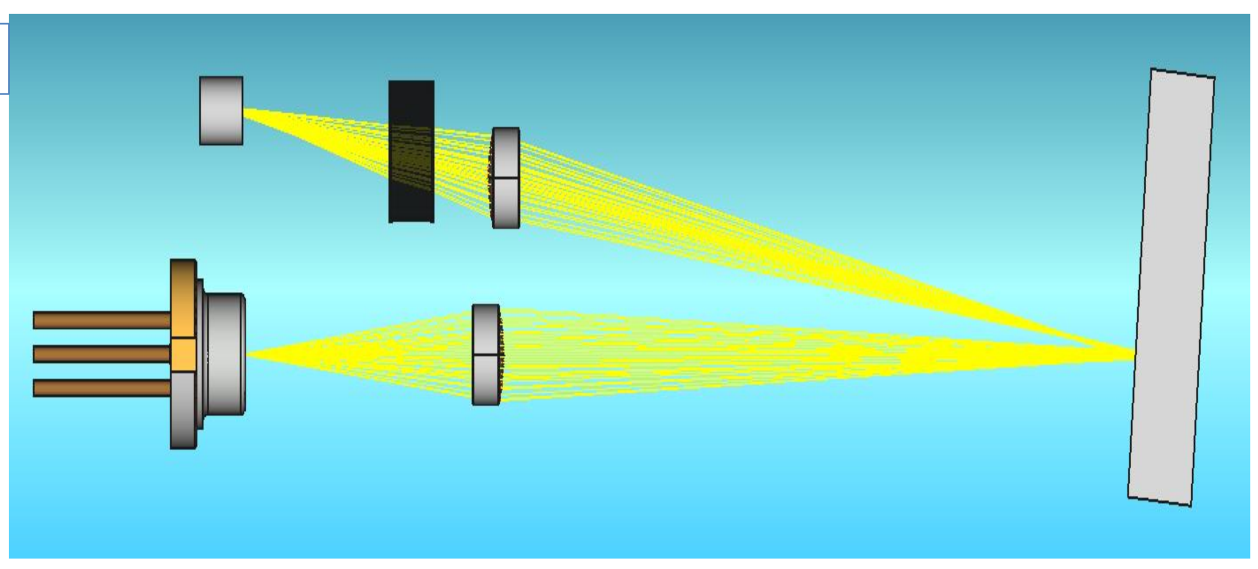


Locations for the system evaluation

Sampling point	Latitude	Longitude
Location 1	1°38'21"S	78°34'01"W
Location 2	1°38'20"S	78°35'40"W
Location 3	1°41'18"S	78°39'04"W

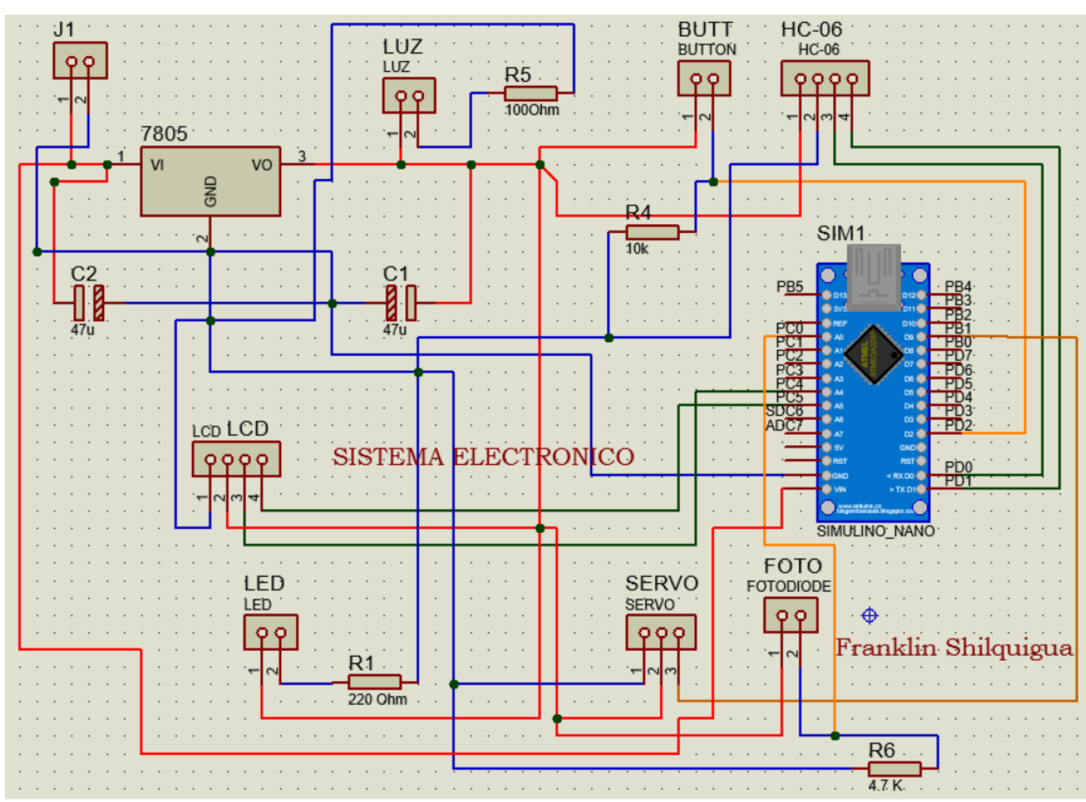
RESULTS & DISCUSSION

Optical system



A white-spectrum LED was used as the illumination source. The optical path employed two identical convex lenses: the first focused the beam onto a diffraction grating, and the second directed the dispersed light toward a 3DU33 photodetector. The analysis cuvette was placed before the detector to allow light–sample interaction.

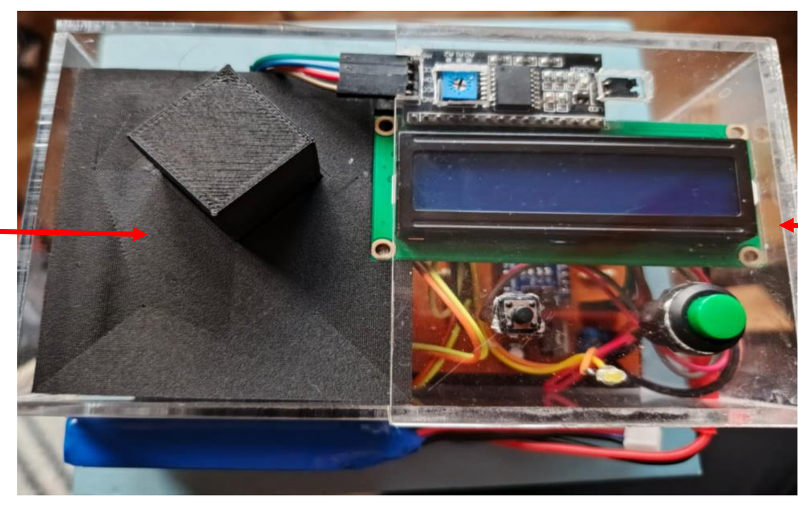
Electronic system



The system was based in the Arduino nano module. The HC-06 Bluetooth module enabled communication between the spectrometer and a mobile device, allowing real-time visualization and storage of liquid-sample data.

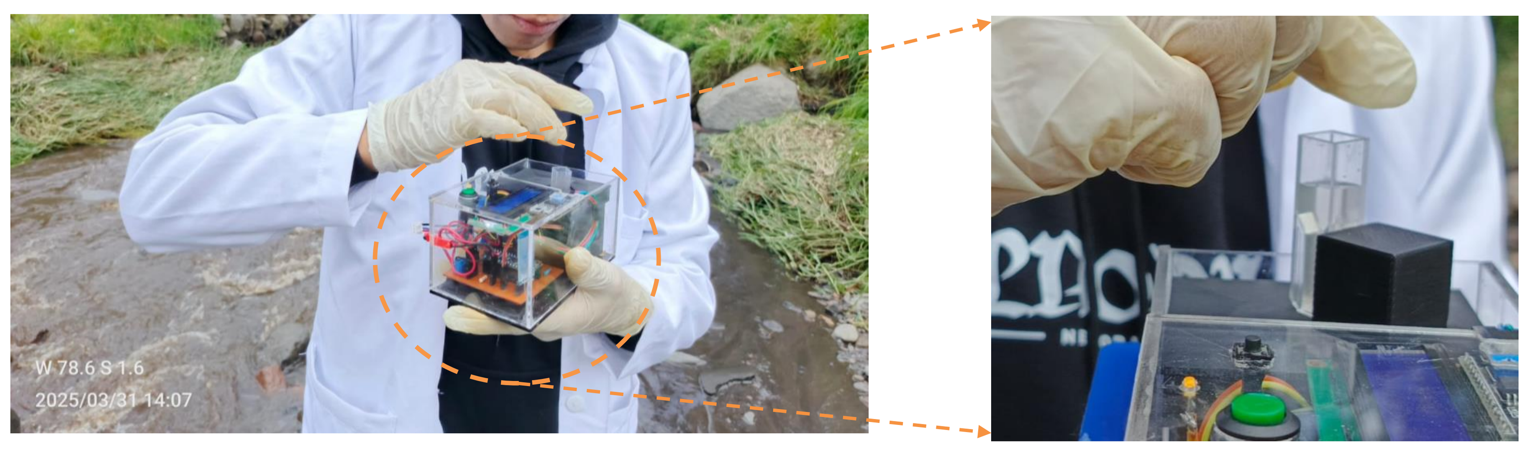
Implementation

Optical system case



Electronic system case

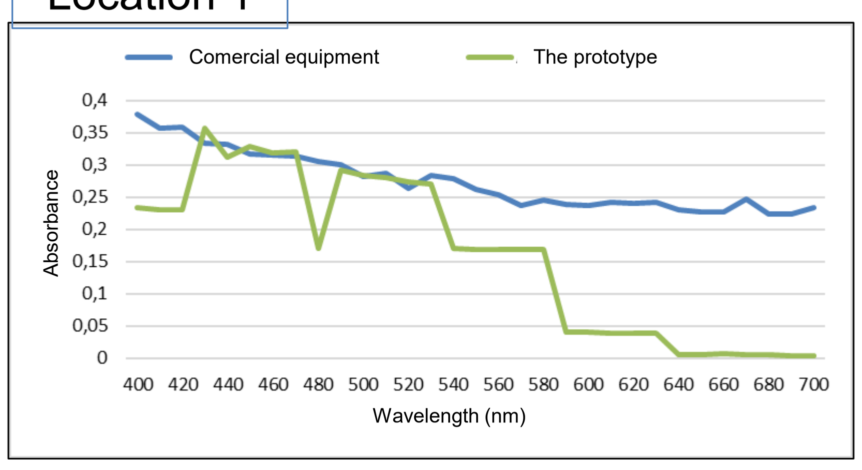
Evaluation



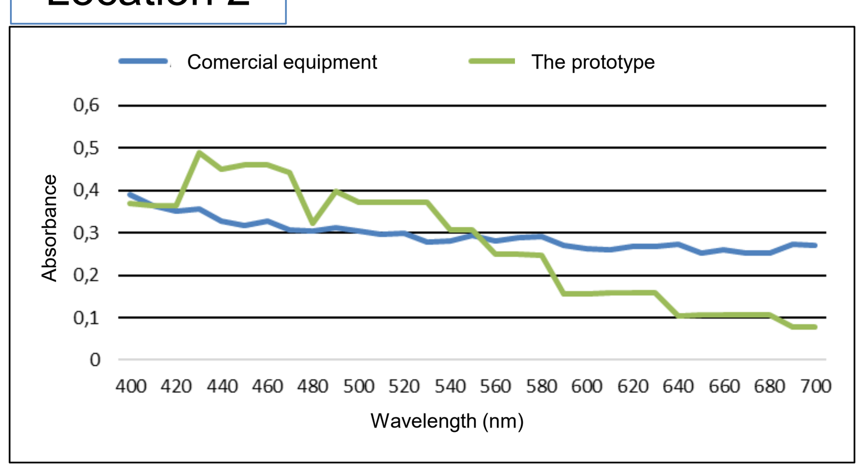
Preparation of cubettes for measures in rural areas

The map displayed in methodology allows the location for measures in situ from water sources. The proposes was validate the measures comparing with a commercial UV/Vis spectrometer. The measures obtained was compared one by one.
The figures below show a basic comparison of measures in three different locations.

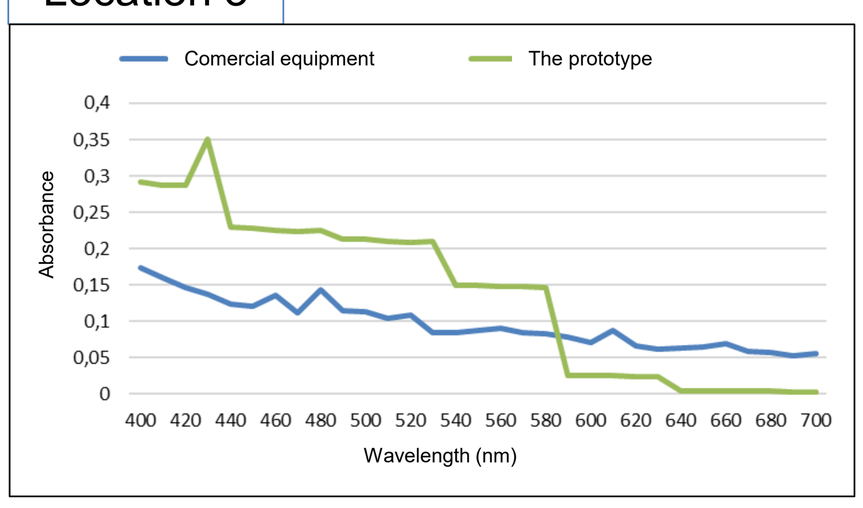
Location 1



Location 2



Location 3



The three graphs show overall decreasing absorbance with increasing wavelength for both the commercial and prototype devices. Agreement is strongest in the mid-visible region (approximately 500–540 nm), where trends closely overlap. However, the prototype consistently underestimates absorbance at higher wavelengths, especially beyond 580 nm, and presents greater variability with abrupt drops. Differences depend on the water source, indicating that prototype performance is sample-dependent and limited by its lower spectral resolution.

The quickest solution to improve resolution is to replace the improvised diffraction grating with a higher-performance one and repeat the evaluation process.

CONCLUSION

The low-cost spectrophotometer proved technically functional, successfully integrating optical, electronic, and data-processing modules into a portable device capable of in situ water analysis. The absorbance measures confirming operational versatility. Comparison with a commercial spectrophotometer showed acceptable agreement in the 500 – 530 nm range, although small discrepancies appeared at higher wavelengths (590 – 700 nm), where the prototype tended to underestimate absorbance. These differences stem mainly from the improvised diffraction grating, which limits spectral resolution. Some samples, such as Location 2 and natural spring water, revealed consistent or aceptable accurate behavior, with light variability than the commercial device.