Prototype Development and Testing of a Smart Buoy System for Coastal and Marine Ecosystems Using IBIS

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Motivation and Rationale

- ➔ Revolutionizing environmental monitoring with IoT technology.
- ➔ Introducing a Smart Buoy for coastal and marine ecosystems based in the work in [1].
- ➔ Tested with Single Board Computers and a suite of advanced sensors in the IBIS testbed [2].
- ➔ Provides real-time data to boost marine health, weather forecasting, and maritime safety.
- ➔ Early results highlight its potential to transform remote monitoring and expand research opportunities.

Prototype Integration and Testing

- ➔ Integration and testing focus on sensor functionality and data reliability.
- ➔ A master script manages data collection, storage, and transmission. Data is transferred to a remote server in the open cloud Chameleon [3].
- ➔ Sensors tested include temperature, wind direction sensors, and inertial measurement units (IMUs).
- ➔ Figures show readings from temperature sensors, wind direction, and IMU data.
- ➔ The system's performance is evaluated for accuracy and reliability.

Development Challenges and Solutions

System Compatibility: Difficulty in ensuring compatibility between various sensors and SBCs.

Solution: Developed custom adapters and interfaces.

Script Adaptation: Scripts designed for other platforms (e.g., Arduino) to work with the Raspberry Pi.

Solution: Rewrote code and implemented specific libraries to adapt scripts.

Multi-Platform Integration: Integrating resources from different hardware platforms.

Solution: Testing and validation, with detailed documentation for future maintenance and upgrades.

Approach

The modular design ensures robust monitoring and easy upgrades, providing flexibility often missing in high-cost commercial systems.

Our goal is to ensure proper operation, functionality and reliable data collection.

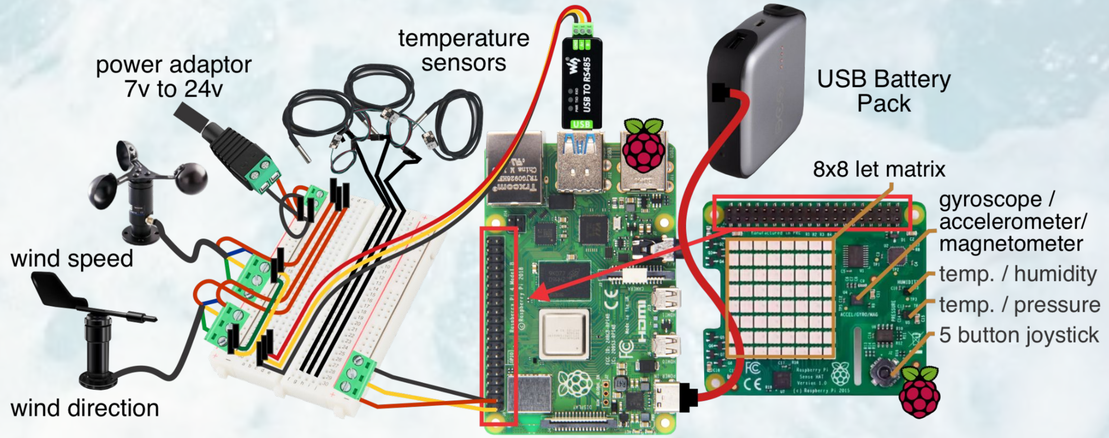


Figure 1. Schematic of internal wiring and peripheral connection.
The IBIS testbed enables complex data processing and real-time analysis.

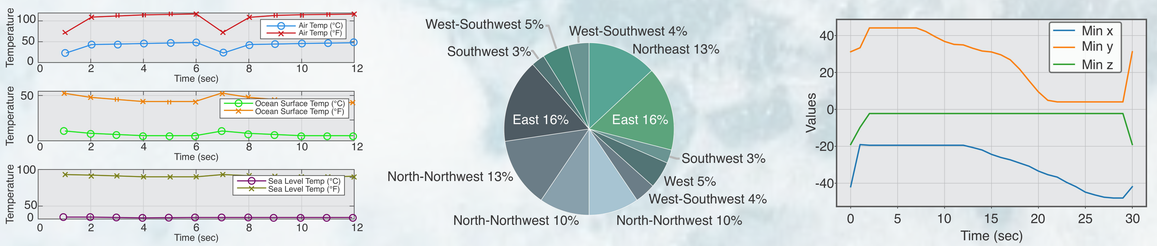
Device Parts/Mechanics

- ➔ **Affordable Prototype**: An alternative with cost-efficient components and open-source technologies. (Table 1)
- ➔ **Reduced Maintenance Expenses**: The modular design and use of widely available components cut maintenance costs.
- ➔ **Scalability**: The prototype can be deployed in multiple units at a fraction of the cost of commercial systems. It also has extensive room for modification enabling extensive monitoring at a lower price.

Table 1. *Hardware components, quantity and details used in the development of our smart buoy system.*

Components	Description and Quantity/Details
Raspberry Pi 4	Central computing unit (1)
SD Card	Storage for data (1)
Breadboard	Prototyping (1)
Jumper Wires	30 Female, 20 Male
Temperature Sensors	3 per station (DS18B20 or SMA PT-1000)
Inertial Measurement Unit (IMU)	Sense Hat for vertical acceleration (1)
Wind Speed Sensor	Open-source or commercial options
Power Supply	Voltaic with battery
Pulse-to-Digital Converter	ADS1115 Byte 4 Channel I2C
Solar Radiation Sensor	Surface light intensity (1)
Power Measurement Sensor	(1)
Networking Peripherals	Cellular or satellite (optional)

Prototype integration and initial testings



Figures (left to right) *Readings from temperature sensors in three different setups: air, ocean surface, and 1 meter below the sea level, wind direction and inertia measurements from the IMU.*

Conclusion and Future Work

- ➔ Our prototype demonstrate the capability to integrate various sensors, such as for temperature, inertia measurements, and wind conditions, ensuring effective data acquisition in marine environments.
- ➔ Initial tests confirm the system's accuracy, proving that high-performance monitoring does not require high costs.
- ➔ Future work will focus on refining the prototype and validating its performance in real-world settings, work in collaboration with the Marine Ecology & Acoustics Laboratory from the Florida International University.

References

[1] A. Babić, M. Oreč, and N. Mišković, Developing the Concept of Multifunctional Smart Buoys, OCEANS 2021: San Diego – Porto, San Diego, CA, USA, 2021, pp. 1-6.
[2] K. Keahey Z. Murry T. Sitzmann J. Zhou A. Esquivel Morel, M. Powers and P. Calyam. 2024. IBIS — An Infrastructure Management Framework for Adaptable, Multi-Sensor Data Collection in Scientific Research. ISC High Performance 2024 International Workshops (2024). https://doi.org/10.13140/RG.2.2.11758.22082 Preprint available on ResearchGate.
[3] K. Keahey, J.Anderson, Z.Zhen, P. Riteau, P. Ruth, D.Stanzione, M.Cevik, J.Colleran, H. Gunawi, C. Hammock, J. Mambretti, A. Barnes, F. Halbach, A. Rocha, and J. Stubbs. 2020. Lessons learned from the Chameleon testbed. USENIX Conference on Usenix Annual Technical Conference (USENIX ATC'20).