PRESIDENCY UNIVERSITY

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School of Engineering

A Project Report on

"Comprehensive Deep Sea Exploration Analysis and Visualisation Platform"

Submitted in partial fulfillment of the requirement for the course

Innovative Projects using Raspberry Pi (**ECE2011**)

Submitted by
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Abstract:

The Comprehensive Deep Sea Exploration Data Analysis Platform is a novel tool designed for oceanographic research, integrating a Raspberry Pi Pico-based system with a web interface built using HTML, CSS, and JavaScript. The platform offers two main features: Visualization and Analysis. Visualization allows users to explore pre-existing simulations of critical oceanic factors, improving accessibility to complex data. The Analysis section provides detailed insights such as CTD profiles, TS diagrams, transect profiles, and decade-long data trends, supporting scientific and environmental studies.

This platform stands out for its compact and cost-effective deployment using a Raspberry Pi Pico, offering a scalable solution for remote research. Its combination of embedded systems with a research-oriented front-end interface represents a creative integration of existing technologies. The platform's real-life applications include academic research, environmental monitoring, and climate studies, making it invaluable for oceanographers and climate scientists.

Introduction:

The Comprehensive Deep Sea Exploration Data Analysis Platform is a cutting-edge tool designed for oceanographic research, combining advanced technologies with accessibility and cost-effectiveness. Built around a Raspberry Pi Pico system, it features a user-friendly web interface created with HTML, CSS, and JavaScript, offering two primary functionalities: Visualization and Analysis. Visualization allows users to explore pre-existing simulations of critical oceanic factors, making complex data more accessible, while Analysis delivers detailed insights such as CTD profiles, TS diagrams, transect profiles, and decade-long data trends.

A unique addition to the platform is its AI chatbot, which utilizes historical data and machine learning algorithms to predict future trends in oceanic conditions. It provides real-time, interactive insights into scenarios like temperature shifts and salinity changes, supporting ecological impact assessments and informed decision-making. Compact, scalable, and cost-effective, this platform is ideal for remote research, academic studies, environmental monitoring, and climate resilience planning. Its innovative integration of embedded systems with predictive analytics and a research-focused interface highlights its potential for groundbreaking contributions to oceanographic studies.

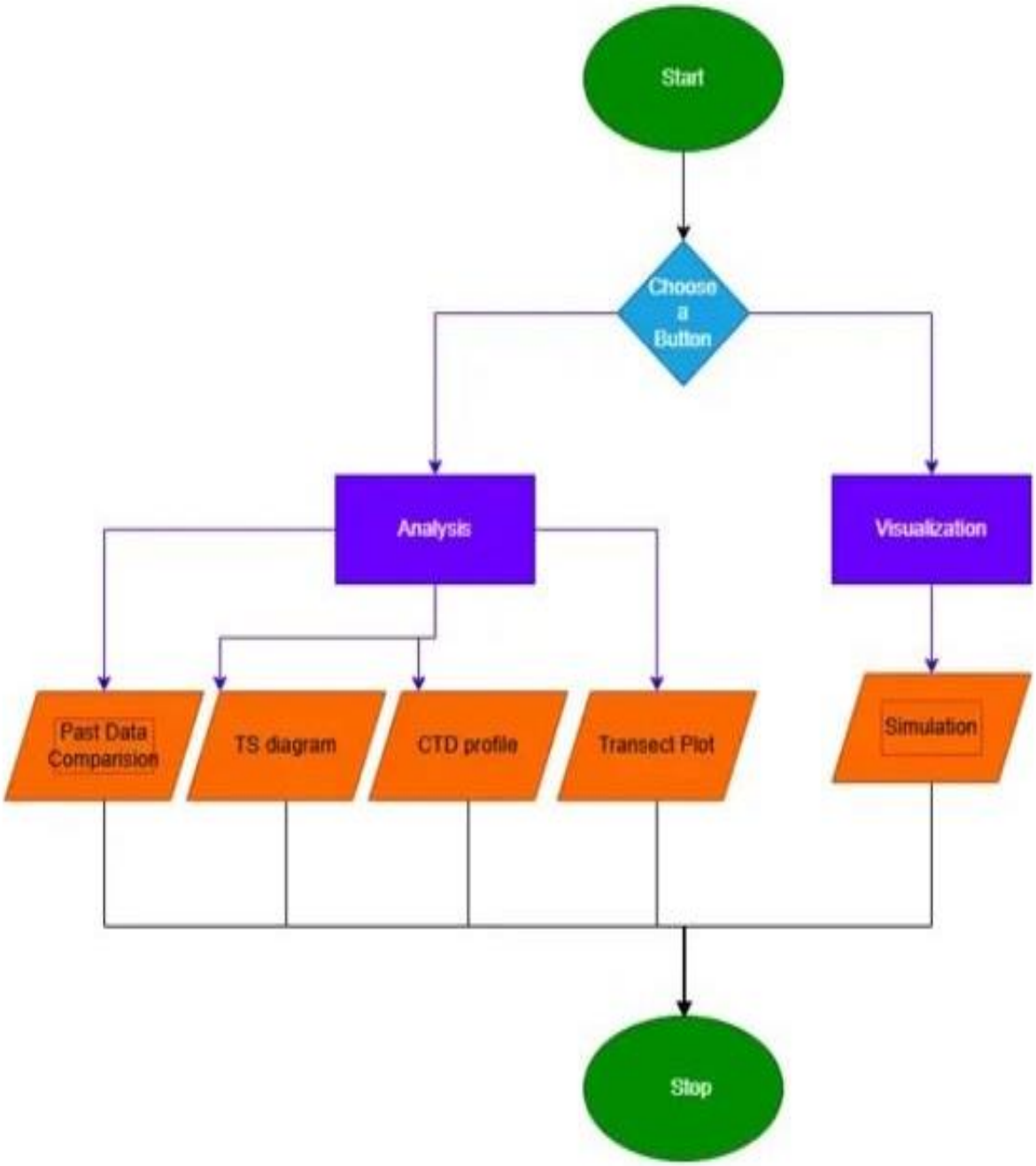
Related Work:

Oceanographic research has seen significant advancements with platforms such as NOAA's Ocean Explorer and NASA's Earth Data, providing extensive datasets for scientific analysis. However, these platforms often require technical expertise and lack user-friendly visualizations tailored for non-experts. Recent studies have emphasized the importance of intuitive data visualization in oceanography, but existing tools like Tableau and D3.js lack domain-specific features for CTD profiles or TS diagrams. While IoT devices such as Raspberry Pi have been applied in data collection, limited solutions exist for integrating APIs into scalable web platforms. This project bridges these gaps by offering an accessible ocean data visualization tool.

Existing ocean data platforms like NOAA’s Ocean Explorer, NASA’s Earth Data, and the Copernicus Marine Service have revolutionized access to oceanographic data by providing extensive datasets, interactive maps, and real-time monitoring of critical parameters such as temperature, salinity, and currents. However, these platforms often cater to highly technical audiences, requiring advanced expertise to extract meaningful insights. Additionally, they lack seamless integration with APIs for real-time data retrieval and fail to offer intuitive, domain-specific visualizations like CTD profiles, TS diagrams, and transect profiles.

In contrast, the proposed ocean data website simplifies access to oceanographic data through a user-friendly interface that integrates global APIs, including NASA's Earth Data and NOAA’s resources, while leveraging web-based technologies like Node.js and Chart.js for real-time visualization. This software bridges the gap between raw data and actionable insights by providing tailored tools that allow users to explore decade-long trends, simulate oceanic factors, and generate scientific plots with minimal technical expertise. By combining accessibility, advanced visualization, and global data integration, the platform stands out as a scalable, accessible, and effective solution for researchers, policymakers, and environmental enthusiasts alike.

Implementation:



System requirement specifications:

- Hardware Components

1. Raspberry Pi Pico
    a. Purpose: Collecting data from sensors and transferring it to ESP32.
    b. Specifications:
        i. RP2040 microcontroller
        ii. Dual-core ARM Cortex-M0+ processor
        iii. 2MB onboard flash memory
2. ESP32
    a. Purpose: Interfacing with sensors and sending real-time data to Raspberry Pi.
    b. Specifications:
        i. Dual-core Tensilica LX6 microprocessor
        ii. Wi-Fi and Bluetooth enabled
        iii. GPIO pins for sensor integration
        iv. Low-power mode for energy efficiency

-Software Components

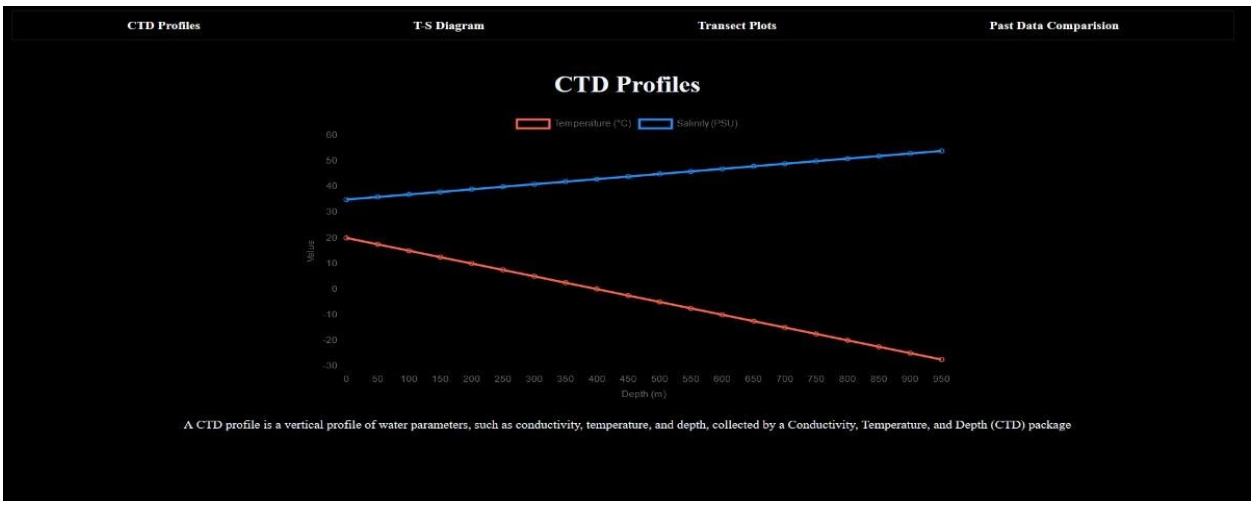
1. Operating System
    - Windows
2. Programming Languages
    a. Micro Python (for ESP32 and Pico programming).
    b. HTML, CSS, and JavaScript (for front-end development).
    c. Python (for data processing).
3. Packages and Libraries
    a. Micro Python Libraries:
        i. machine: For GPIO control.
        ii. umqtt.simple: For MQTT communication (optional).
        iii. ds18x20 & onewire: For temperature sensor handling.
    b. Web Libraries/Frameworks:
        i. Bootstrap 5: For responsive design.
        ii. Chart.js: For dynamic graphs.

iii. D3.js: For complex visualizations.

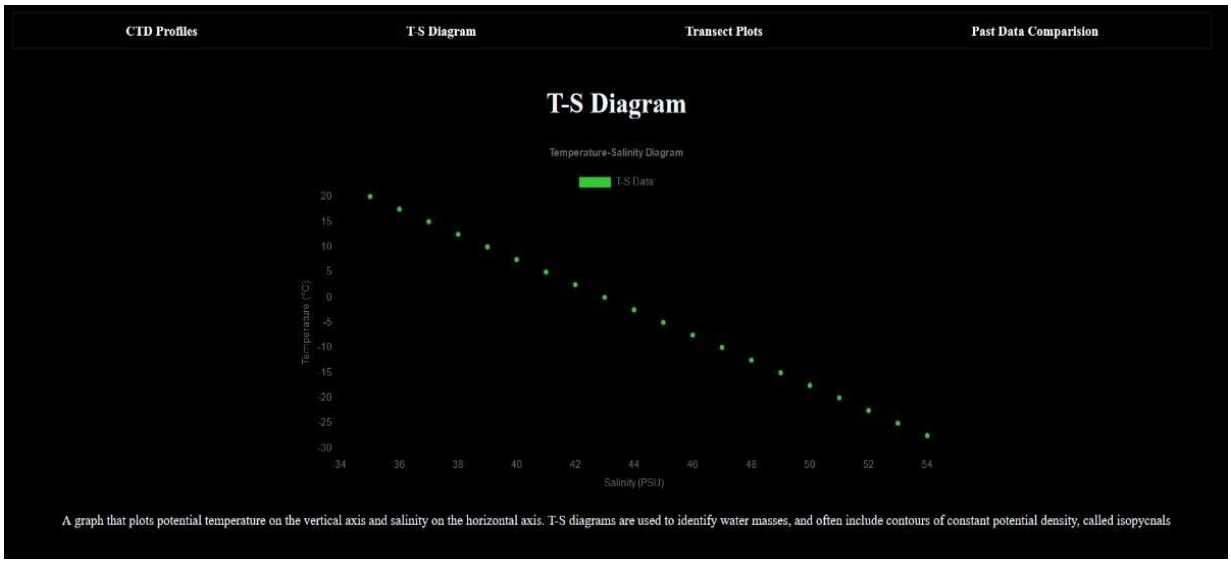
Result:


IPR-235
Report Video
DEEP SEA
DATA ANALYSIS AND
DATA VISUALISATION
Analysis
Visualisation
Chatbot

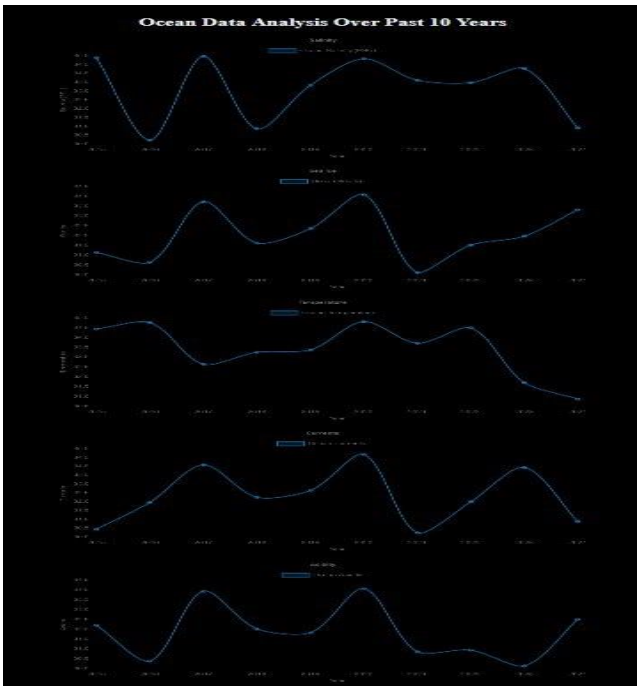

SEA ICE
Sea Ice
Salinity
Temperature
Currents
Acidity
Oxygen
Sea ice concentration (%)
1 December 2024
Arctic
Switch Poles
MyOcean LIGHT
Apr Jul Oct 2023 Apr Jul Oct 2024 Apr Jul Oct 2025

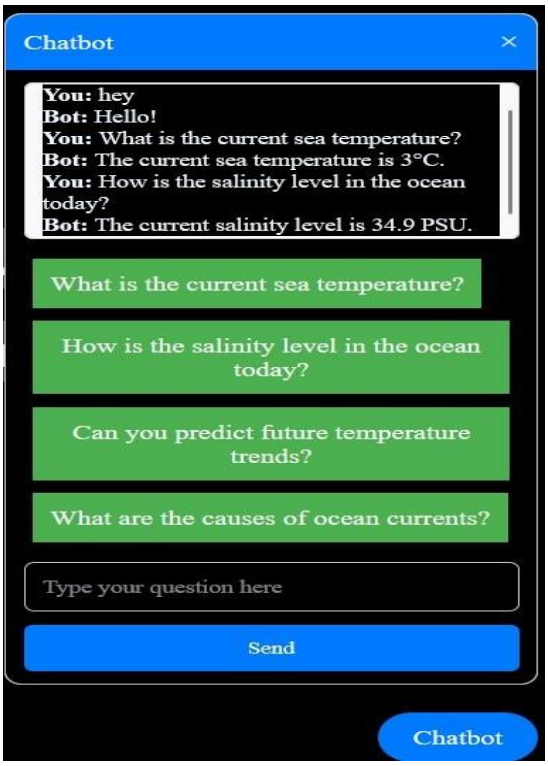

CTD Profiles
T-S Diagram
Transect Plots
Past Data Comparision
CTD Profiles
Temperature (°C)
Salinity (PSU)
Value
Depth (m)
A CTD profile is a vertical profile of water parameters, such as conductivity, temperature, and depth, collected by a Conductivity, Temperature, and Depth (CTD) package

CTD Profiles | T-S Diagram | Transect Plots | Past Data Comparision



A graph that plots potential temperature on the vertical axis and salinity on the horizontal axis. T-S diagrams are used to identify water masses, and often include contours of constant potential density, called isopycnals





This website combines data visualization, analysis, and interactive tools like a chatbot to provide oceanographic research insights. Users can explore CTD profiles, analyze temperature and salinity trends, and interact with the chatbot for queries. The buttons facilitate seamless navigation between sections for an enhanced user experience.

Conclusion:

The Comprehensive Deep Sea Exploration Data Analysis Platform represents a significant advancement in oceanographic research, combining affordable, compact hardware with powerful data analysis tools. Its unique integration of a Raspberry Pi Pico system and a research-oriented web interface makes it both scalable and accessible for remote research, supporting a wide range of applications from academic studies to environmental monitoring. The addition of AI-driven predictive analytics further enhances its utility, providing researchers with the ability to forecast trends and model ecological impacts in real-time.

By offering a cost-effective and user-friendly solution, the platform empowers oceanographers and climate scientists to make more informed decisions regarding conservation efforts and climate resilience. Its innovative approach to integrating existing technologies, including machine learning and embedded systems, highlights the platform's potential for widespread adoption and future development. Overall, the platform offers a promising tool for advancing the study of ocean ecosystems and addressing the challenges posed by climate change.

References:

1. Copernicus Marine Service - Provides interactive maps, ocean forecasts, and detailed marine data visualizations.Visit Site
2. NOAA Ocean Explorer - Delivers oceanographic maps, visualizations, and real-time exploration data.Visit Site
3. Marine Institute Ireland - Shares oceanographic data, visual reports, and maps for coastal studies.Visit Site
4. Mercator Ocean International - Offers visualization tools like MyOcean Light for global ocean observations.Visit Site
5. National Centers for Environmental Information (NCEI) - Hosts interactive tools and visualizations for ocean climate data.Visit Site
6. Argo Data System - Provides TS diagrams and global ocean profiles from autonomous floats.Visit Site
7. World Ocean Atlas - Publishes climatological data and global oceanographic trends.Visit Site
8. NASA Ocean Color - Offers satellite-derived ocean color and productivity data visualizations.Visit Site
9. Seabed 2030 - Global mapping project visualizing unexplored ocean floor data.Visit Site
10. EMODnet - European marine data visualization portal offering interactive mapping tools.Visit Site
11. Global Ocean Data Analysis Project (GLODAP) - Delivers long-term datasets for oceanographic research.Visit Site
12. World Ocean Database - A comprehensive platform for global ocean profile data analysis.Visit Site
13. Pangaea Data Repository - Provides detailed datasets and analysis tools for ocean science.Visit Site
14. MBARI Data Portal - Shares oceanographic sensor data and deep-sea visualizations.Visit Site
15. GEBCO (General Bathymetric Chart of the Oceans) - Offers global ocean bathymetric charts and tools.Visit Site
16. Schmidt Ocean Institute - Interactive maps and data visualizations from ocean expeditions.Visit Site

17. EUMETSAT Ocean Data - Satellite-based visualizations for ocean trends and forecasting.Visit Site
18. Ocean Data View (ODV) - Visualization software for ocean profiles and time-series data.Visit Site
19. ICES (International Council for the Exploration of the Sea) - Provides marine ecosystem data visualization.Visit Site
20. Australian Integrated Marine Observing System (IMOS) - Offers real-time oceanographic and climate data visualization.Visit Site