SMART INDIA HACKATHON 2025

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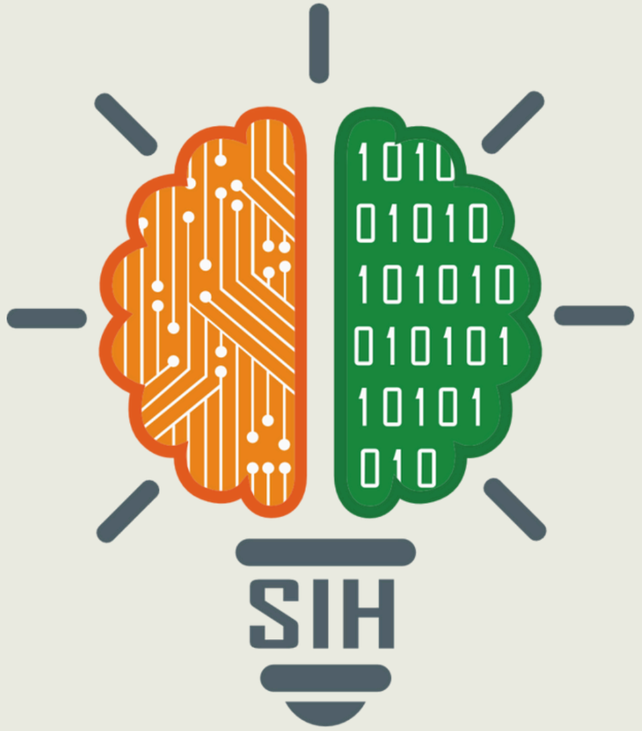
- Problem Statement ID – SIH25043
- Problem Statement Title- Embedded Intelligent Microscopy System for Identification and Counting of Microscopic Marine Organisms
- Theme - Smart Automation
- PS Category - Hardware
- Team ID - 84553
- Team Name - Visionary Vanguards



VISIONARY VANGUARDS

Our Solution - AquaLens AI

Smart embedded microscope for real-time marine analysis

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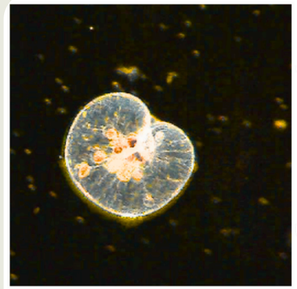
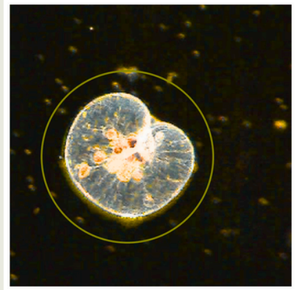
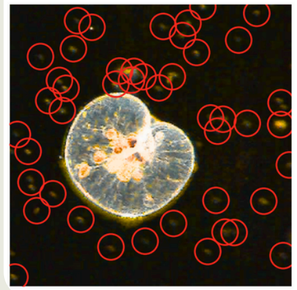
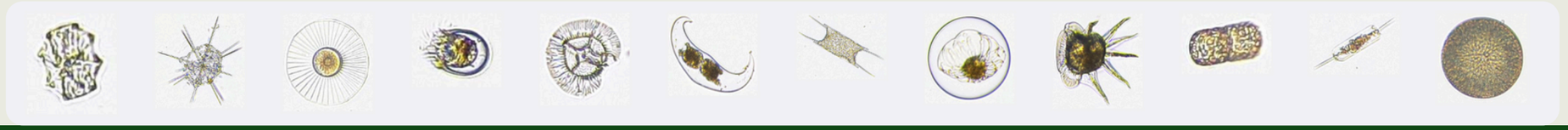
- Why Geo-Tagged Plankton Data Matters?
  - Ocean Health Indicator: Links plankton diversity with changing ocean parameters such as **temperature, salinity**, and **pH**.
  - Climate Early-Warning System: Detects trends in **warming**, **acidification**, and **carbon cycle fluctuations** through micro-organism patterns.
  - Fisheries & Food Security: Tracks plankton **abundance and migration**—critical to predicting fish stock movement and productivity.
  - AI-Driven Biodiversity Mapping: Builds India's first open, geo-referenced **marine microbe database** for global ecological collaboration.
- Proposed Solution
  - The proposed solution is an **AI-enabled portable** microscopy system that automates the **identification** and **counting** of microscopic marine organisms in real time. It captures **high-resolution** images of water samples and processes them locally using **lightweight deep-learning models** optimized for embedded deployment. With **adaptive illumination correction** and **morphology-aware segmentation**, the system maintains accuracy under varying imaging conditions. **Operating offline** with minimal computational load, it generates **geo-tagged, time-stamped biodiversity data** for large-scale, reproducible marine ecosystem monitoring.

- PROBLEM STATEMENT:
  - Marine biodiversity monitoring relies on **microscopic identification** of **planktonic organisms**, a process that remains **manual**, **time-consuming**, and **error-prone**. Variations in organism **morphology**, **overlapping specimens**, and **inconsistent imaging conditions** further reduce accuracy and reproducibility. The lack of an **automated, field-deployable system** limits **real-time analysis** and large-scale ecological monitoring, creating a critical gap in assessing marine ecosystem health and sustainability.
- Innovation and uniqueness of the solution
  - **Federated learning–ready architecture** enabling distributed model updates without sharing raw image data.
  - **Adaptive illumination and focus calibration** to ensure clarity and consistency in microscopic imaging.
  - **Explainable AI** integration (Grad-CAM) providing visual interpretability for research validation.
  - **Open, geo-tagged marine microbe data portal** fostering collaborative and transparent ecological research.
  - **Scalable and domain-flexible design** adaptable for freshwater, aquaculture, and environmental monitoring applications.


Experimental image


Noctiluca scintillans

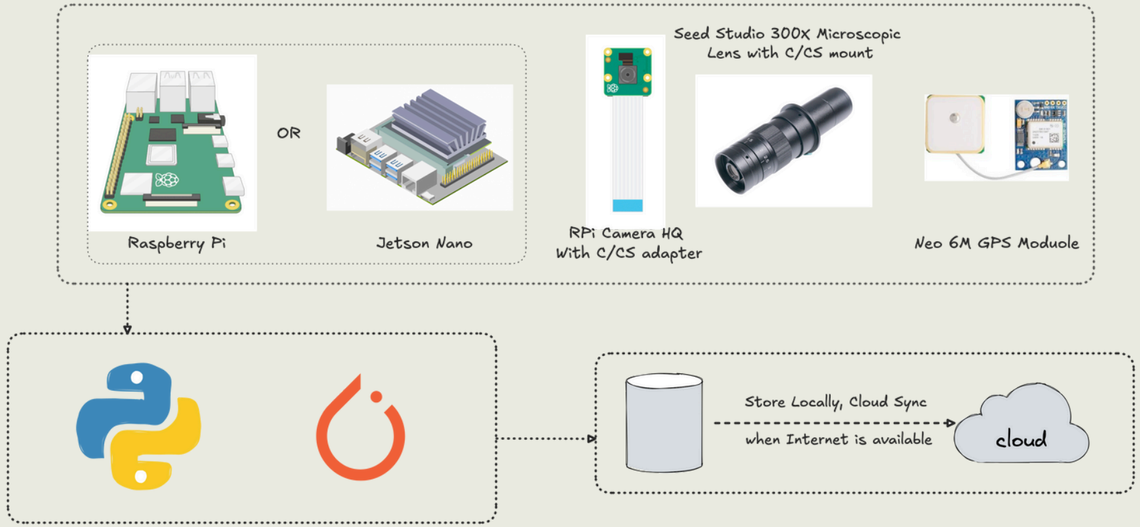

Dunaliella tertiolecta



TECHNICAL APPROACH

Hardware:
Pi 4/5 + IMX477 HQ + C-mount macro + LED backlight.

Software:
Pi OS Lite, Picamera2/libcamera, OpenCV, TensorFlow Lite / PyTorch, pandas, Streamlit / Folium, FastAPI, SQLite — supports on-device deep-learning inference (MobileNet / CNN-based models) for Edge AI microscopy and real-time classification.



Sample
Water drop on slide or flow cell

Capture
Pi HQ Camera + 300X C-mount lens
Picamera2

Preprocess
OpenCV: denoise, normalize, background remove

Detect
Segmentation to separate organisms (handle overlaps)

Identify
CNN (TFLite/PyTorch)
Species/Genus + confidence

Count
Per class count, size (µm) per pixel

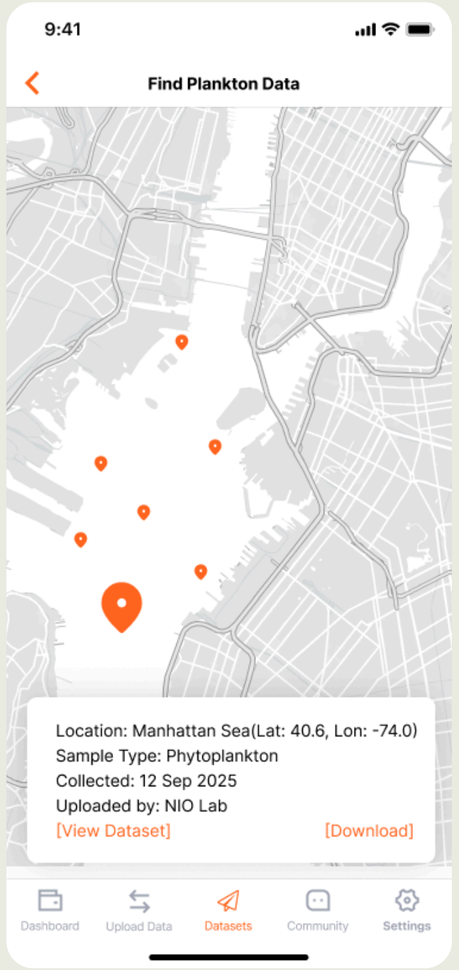
Summarize
Composition, bloom flags, diversity indices

Save/Share
CSV + image link, time, geo-tag
SD Card Now, Cloud sync later

View
Simple dashboard (charts + map preview)

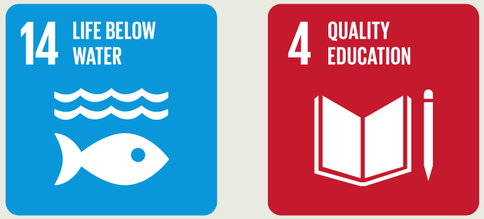
FEASIBILITY AND VIABILITY

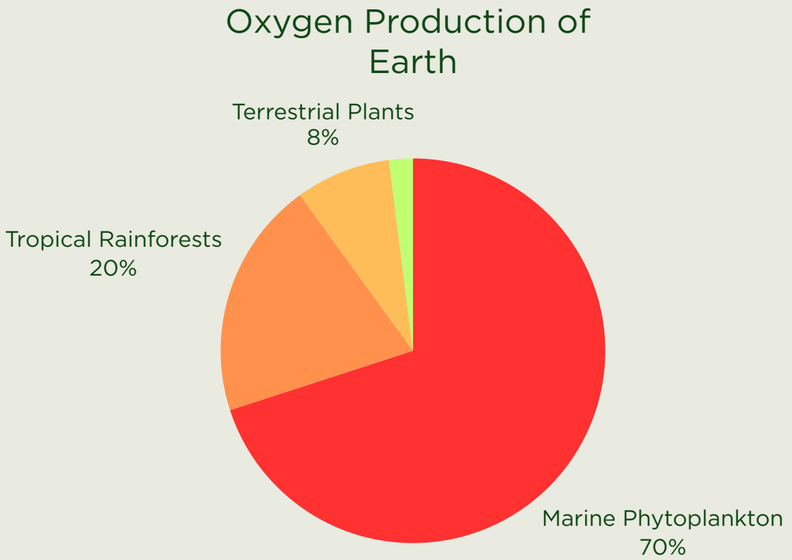
- Technical Feasibility
  - Runs offline on **Raspberry Pi 4/5** with **quantized CNN models** optimized for low power and memory.
  - The **IMX477 camera with macro lens** delivers sub-micron imaging of 10–1000 µm organisms.
  - Workflow: **capture → preprocess → segment → classify → geo-tag output.**
  - Includes **local storage**, optional GPS/RTC, and a **rugged waterproof enclosure** for field use.
- Risks
  - **Data scarcity**: Limited availability of labeled, geo-tagged plankton datasets for model training.
  - **Imaging artifacts**: Overlapping organisms, motion blur, and uneven illumination may affect detection accuracy.
  - **Environmental factors**: Field use requires power optimization, waterproofing, and thermal stability.
  - **User adoption**: Simplified UI and one-button operation essential for reliable field usability.
- Mitigations
  - Build a **custom labeled dataset** and apply **transfer learning** from related microscopy datasets.
  - Implement **adaptive preprocessing** (auto-focus, illumination correction, and threshold tuning) to minimize imaging errors.
  - Uses energy-efficient Pi/Jetson hardware with **sealed enclosures** for **durable field deployment**.
  - Provide **clear documentation, tutorials, and open-portal support** to ensure user adoption and model retraining.



IMPACT AND BENEFITS

- Potential Impact & Benefits
  - Accelerating Science: AI-powered identification of plankton and microbes **eliminates manual bottlenecks**, enabling faster, reproducible biodiversity assessments.
  - Environmental Monitoring: Real-time organism counts support **early detection** of algal blooms, invasive species, and ecosystem stress indicators.
  - SDG Alignment: Directly contributes to **SDG 14 (Life Below Water)** and **SDG 4 (Quality Education)** through accessible marine AI tools.
  - Economic & Educational: **Approximately 10× cheaper** than flow cytometers; democratizes marine biology and AI research via an open portal.
  - Social & Food Security: Plankton generate **~70% of Earth's oxygen**, sequester 2.8 B T carbon/year, and underpin $362 B fisheries supporting **520 M livelihoods**. Early bloom detection **safeguards coasts and aquaculture**.
  - India Focus: With an 8,118 km coastline, 3.5 M fishers, and **₹20,000 Cr infrastructure** lacking real-time plankton data—our system bridges this **critical monitoring gap**.





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