Sensor-Actuated 'Roboduck' Network for Marine Monitoring

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Introduction: Locating and Tracking Marine Microorganisms using Gradient information

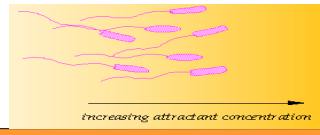
Problem Characteristics

- To locate, track and study the growth and migration patterns of harmful algal blooms like those caused by brown tide algae.
- **Assumption:** The source generates a gradient which can be sensed by the robots
- **Dynamic source:** The intensity of the gradient generated by a source may vary over time
- **Source Location:** The gradient source location may vary over time
- **Multiple Gradient Sources:** There can be multiple gradient sources near the robots
- **Applications:** Temperature, Light intensity, Chlorophyll, pH, Opacity, Salinity (conductivity), Minerals etc.

Characteristics of Bacterial Motion

- **Produced through the action of flagella**
- **Move towards nutrient sources by following gradients**
- **Move towards attractive stimuli and away from harmful substances in a process known as *Chemotaxis***

A ***straight run*** of an average duration followed by an ***uncoordinated tumble*** which randomizes the direction of the next run



Problem Description: Locate and Track Dynamic Gradient Sources (Marine Microorganisms)

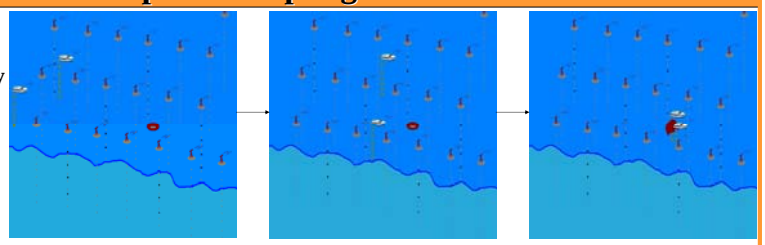
Solution Criteria

- **Simplicity**
- **Robust and adaptive to changes in environment**
- **Minimality in sensing/memory/communication/processing**
- **Insensitive to errors in sensing**
- **Should not require localization**
- **Should work in-situ**
- **Should have a small form factor and be scalable**
- **Should monitor the area constantly and investigate significant changes in detail**

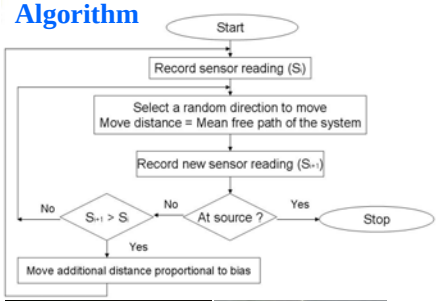
Proposed Solution: Biased Random Walk with Adaptive Sampling

Key Ideas

- **The static network (buoys) regularly monitors the water body at a lower resolution and signals any detected anomaly to the roboduck for further investigation**
- **The roboduck can move to the location of interest and perform in-situ sampling and analysis as well as collect samples for further lab analysis. Data collected by its onboard sensors helps bridge the data voids in the static network.**
- **Biased Random Walk → Directed Motion**



Algorithm



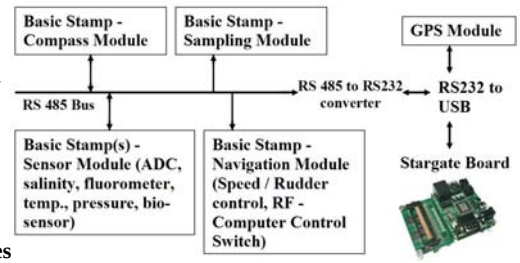
Field Tests

- **Preliminary field tests**
  - **Shelter Is., NY**
  - **Pascal Fountain, USC Campus**
  - **Balboa Lake, San Fernando Valley**
  - **James Reserve, Idyllwild, CA**

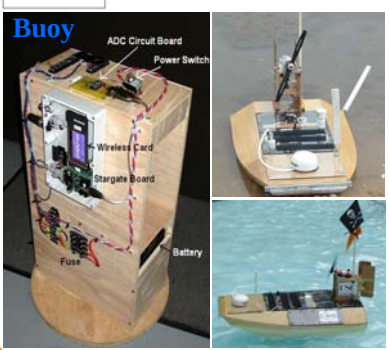
Application Areas

Ocean coast monitoring, detection of algal blooms, generating gradient profiles, distributed plume source tracking, detecting oil spill boundaries

Basic Buoy / Node - Architecture



Buoy



Deployment

Preliminary Results

- **Successful *autonomous navigation* to GPS way-points using PID control**
- **Development and initial field testing of the static stargate based buoy network for continuous and autonomous water body monitoring**

Conclusions

- **Success with single and multiple source localization**
- **Success with unattended in-situ monitoring**
- **Adapt to boundary detection**
- **Modest tolerance to errors in sensor measurements (only the difference in readings is used to make a decision, not the absolute sensor readings)**
- **Requires minimal amount of memory/sensor**