Center for Embedded Networked Sensing

Bacterial Navigation and Applications to Sensing in Marine Environments

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Introduction: Locating and Tracking Gradient Sources

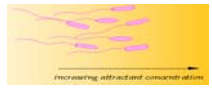
Problem Characteristics

- **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



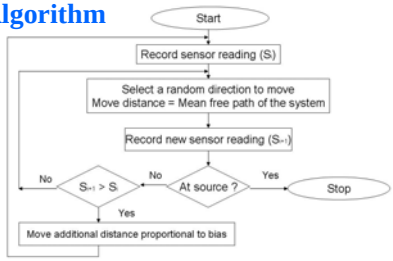
Problem Description: Locate and Track Dynamic Gradient Sources

Solution Criteria

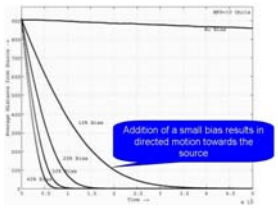
- **Simplicity**
- **Robust and adaptive to changes in environment**
- **Minimality in sensing/memory/communication/processing**
- **Insensitive to errors in sensing**
- **Should not require localization**
- **Should work in-situ**
- **Should have a small form factor and be scalable**

Proposed Solution: Biased Random Walk

Algorithm

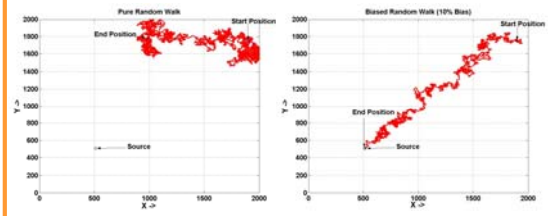


Source Localization



Phototaxis Experiments with Robomote

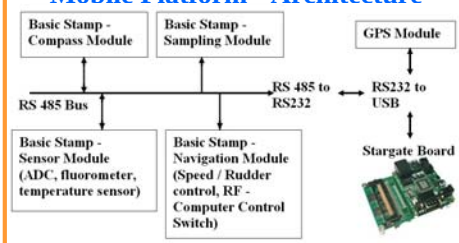
Biased Random Walk ➔ Directed Motion



Field Tests

- **Preliminary field tests**
  - **Shelter Is., NY**
  - **USC Campus**
  - **Balboa Lake, San Fernando Valley**
  - **James Reserve, Idyllwild, CA**
- **Successful *autonomous navigation* to GPS way-points**
- **Change in control architecture from RS-232 to single bus RS-485, making the system plug-n-play**
- **Addition of PID controller to navigation module**

Mobile Platform - Architecture



Conclusions

- **Success with single source localization**
- **Success with localizing multiple dynamic sources**
- **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**

Application Areas

- **Ocean coast monitoring, generating gradient profiles, Distributed plume source tracking, Detecting oil spill boundaries**

Limitations

- **The system takes time to converge to the gradient source. This makes it unsuitable for applications where the source moves rapidly**