Title

Bacteria-Inspired Motion Strategies for Robotic Sensor Networks

Authors
Amit Dhariwal
Gaurav Sukhatme
Ari Requicha
et al.

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Bacteria-inspired Motion Strategies for Robotic Sensor Networks

Amit Dhariwal, Gaurav S. Sukhatme, Aristides Requicha, David Caron

Robotic Embedded Systems Lab, USC - http://www-scf.usc.edu/~dhariwal/dpst

Introduction: Locating Gradient Sources in a Computationally Simple Manner

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
- **Gradient Types**: Temperature, Light intensity, Salinity (conductivity), pH, Opacity, 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***
  - It consists of a ***straight run*** of an average duration which is followed by an ***uncoordinated tumble*** which randomizes the direction of the next run
  - *Negative Chemotaxis* results in a random tumbling motion
  - *Positive Chemotaxis* results in an increase in the run duration

Problem Description: Locate and Track Dynamic Gradient Sources

Solution Criteria

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

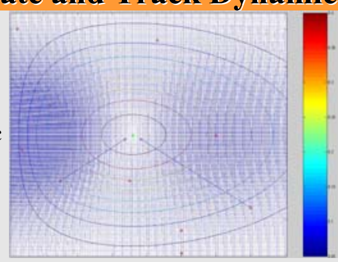


Fig 1. Gradient Source (Green); Robot Nodes (Red);

The Algorithm: A Biased Random Walk

- **Model the world as a grid of dimensions 2000 * 2000 Units**
- **Randomly initialize source(s) of gradient(s)**
- **A set of robot nodes initialized at random locations in the grid**
- **The nodes move an average distance of 10 units (also called the Mean Free Path (MFP) of the system) followed by an uncoordinated tumble (random direction change)**
- **A bias factor which determines the increase in the MFP in case a positive gradient change is observed**

Simulation Results

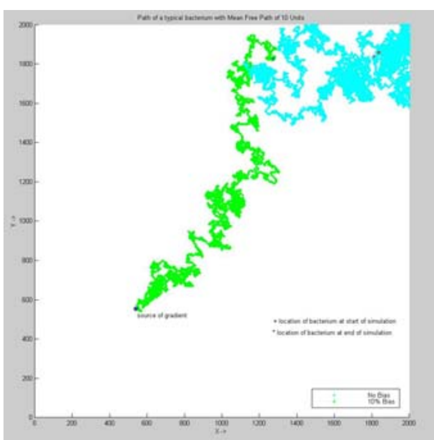


Fig 2. Random Walk vs. Biased Random Walk

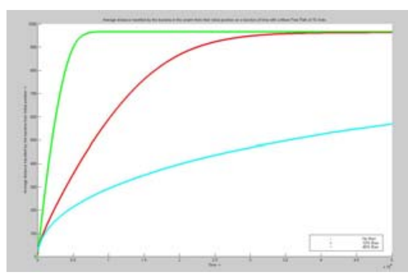


Fig 3. Distance traveled by bacteria from their initial position over time

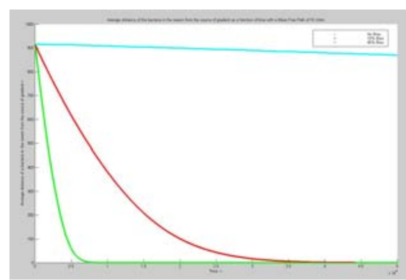
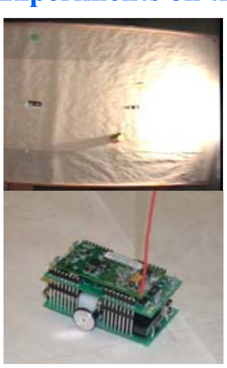


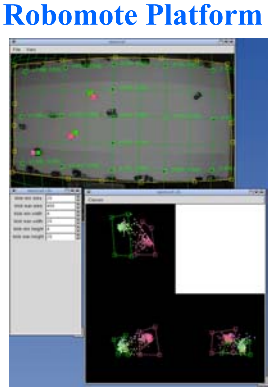
Fig 4. Progress towards the Gradient Source as a function of time under different bias conditions

Conclusions

- **Can effectively track one or more gradient sources**
- **Can adapt to dynamic and mobile gradient sources**
- **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**

Experiments on the Robomote Platform





Limitations

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

Application Areas

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

Ongoing and Future Work

•Effectiveness of Biased Random Walk in Boundary Detection

•Surface Water Experiments for Gradient Source Detection