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Boundary Detection Using Actuated Sensor Networks

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http://www.cens.ucla.edu/Project-Descriptions/Actuated_Boundary_Detection/index.html

Introduction: Control law for Gradient descent

Sensor-based Planning

- Generalized Voronoi Graphs (Choset et. al.) have been used to perform sensor-based navigation of robots (fig 1)
- Provably convergent in n-dimensions
- Control Law has been proposed for such gradient descent

$$\dot{x} = \alpha \, \mathrm{Null}(\nabla G(x)) + \beta (\nabla G(x))^{\dagger} G(x)$$

where $(\nabla G(x))^{\dagger} = (\nabla G(x))^{T} (\nabla G(x)(\nabla G(x))^{T})^{-1}$

Alpha, beta → scalar gains

$G(x) = [d_1(x) - d_2(x)]$ and

$\nabla G(x) = [(\nabla d_1(x) - \nabla d_2(x))^{T}]$

Adaptation to Sensor Networks

Control law modified to suit randomly deployed sensor networks

G(x) = (sensor reading at the mobile node) – (threshold reading defining the contour to be traced)

and $\nabla G(x) = (\nabla d_1(x) - \nabla d_2(x))$ where

d_1 → Unit vector in the direction of the steepest gradient towards the contour

d_2 → Unit vector in the direction of the steepest gradient away from the contour

Each iteration performs one query of sensor readings on all neighboring sensor nodes to compute d_1 and d_2(Fig 2)

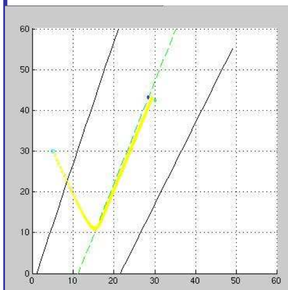

Fig 1 Robot traversing a Voronoi line using the control law

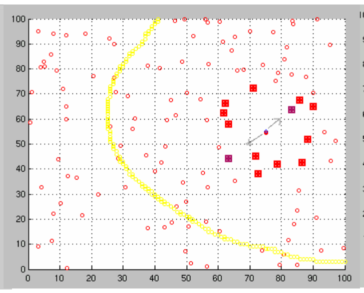

Fig 2 Gradient formation in the case of an actuated sensor node

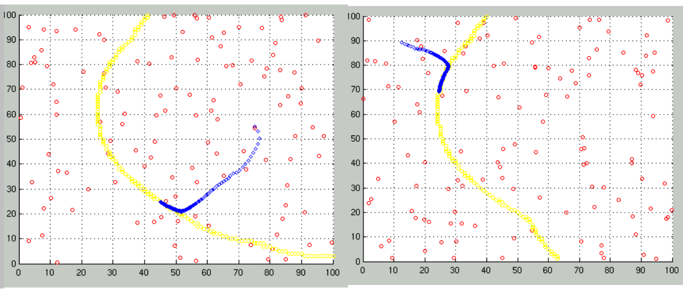

Fig 3,4: Two cases of Boundary Detection using Actuated sensor node and the adapted version of the control law

Proposed Solution: Adapt control law to perform boundary detection using actuated nodes

Assumptions

- Each node is perfectly localized
- The sensed phenomenon is assumed to monotonically degrade in a certain predefined fashion
- Algorithm not drastically affected by type of gradients

Summary of results

- Algorithm uses only local sensor information
- Saturation: Boundary detection percentage is above 80% for networks of degree > 6
- Optimality: Traversed path is within 10-20% of optimal path for networks with degree > 6
- Algorithm minimally affected by type of degradation in the gradient

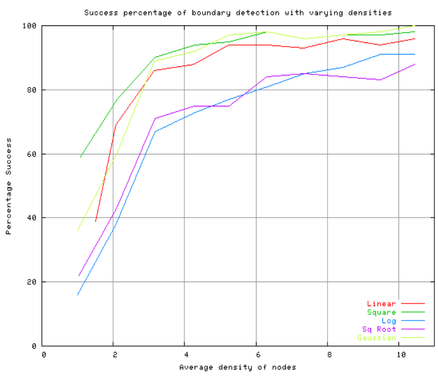

Fig 3: Percentage of success in detecting boundaries

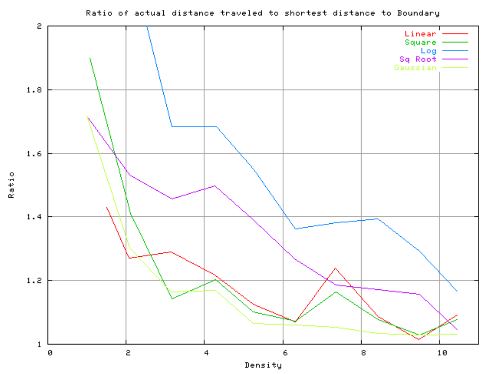

Fig 3: Optimality of path taken by the actuated sensor node