Title
Boundary Detection Using Actuated Sensor Networks

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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

\[
\dot{x} = \alpha \text{Null}(\nabla G(x)) + \beta (\nabla G(x))^T G(x)
\]
where \(\nabla G(x) = (\nabla G(x))^T (\nabla G(x))^{-1}\)

Alpha, beta \(\rightarrow\) 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

\[G(x) = \text{sensor reading at the mobile node} - \text{threshold reading defining the contour to be traced}\]
and
\[\nabla G(x) = \text{unit vector in the direction of the steepest gradient towards the contour}\]
\[d_1 \rightarrow \text{Unit vector in the direction of the steepest gradient towards the contour}\]
\[d_2 \rightarrow \text{Unit vector in the direction of the steepest gradient away from the contour}\]

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

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

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

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: Percentage of success in detecting boundaries
Fig 3: Optimality of path taken by the actuated sensor node