Title
Model-based Localized Calibration for Interacting Actuators And Sensors

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Introduction: Calibrate Interacting Sensors and Actuators Simultaneously

Global Perspectives

- Sensor-based measurements are intrinsically prone to errors
- Differentiation of systematic error and random noise
- Calibration is the process of validating and/or adjusting the accuracy of a measuring instrument so that the systematic error is calculated and the bias is corrected
- Distributed localized in-field calibration is crucial

Technical Components

- Differentiate and calibrate sensors and actuators separately
- Formulate calibration as a nonlinear function minimization instance
- Polak-Ribiere conjugate gradient method
- Three-phase localized calibration procedure that minimizes the number of multi-hop limited-sized packets
- Confidence intervals by applying resubstitution-based nonparametric statistical percentile method

Problem Description: Simultaneous Multi-sensor Fusion with Calibration

Location Discovery

Given:
- \( n \) nodes with unknown location
- \( k \) beacons with known location
- Measured distances between nodes and beacons within communication range

Solving for:
- Locations of \( n \) nodes
- Calibrate each node’s sender & receiver

Generic Location Discovery Formulation

\[
\sqrt{(x - x_j)^2 + (y - y_j)^2} = d_{ij} + f_1(d_{ij}) = \varepsilon_{ij},
\]

Obj: \( \min \sum f(\varepsilon_{ij}) \quad i=1, \ldots, n; \quad j=1, \ldots, n \)

Navigation

Given:
- An object equipped with acceleration, velocity, angle sensors and a receiver travels through a sensor network
- Sensors within radio range communicate with the object

Solving for:
- Locations of the object at any given time instance
- Calibrate object’s acceleration, velocity, angle sensor; object’s receiver; and nodes’ senders

Generic Navigation Formulation

\[
\begin{align*}
\varepsilon_{a_{i-1}} &= (v_i + f(v_i)) \Delta t + \frac{1}{2} (a_{i-1} + f(a)) \Delta t^2 \\
\varepsilon_{b_{i-1}} &= \left[ x_{i-1} + d_{(i-1)-b_{i-1}} \cos(\theta_{i-1} + f(\theta)) \right] \\
\varepsilon_{c_{i-1}} &= \left[ y_{i-1} + d_{(i-1)-c_{i-1}} \sin(\theta_{i-1} + f(\theta)) \right] \\
\varepsilon_{d_{b_i}} &= \sqrt{(x_b - x_i)^2 + (y_b - y_i)^2} - (d_{b_i} + f_{b_{i-1}} + f_{S_{b_i}}) = \varepsilon_{d_{b_i}}
\end{align*}
\]

Obj: \( \min \sum f(\varepsilon_{b_i}) \)

Proposed Solution: Conjugate Gradient-based Nonlinear Function Minimization
