Robust indoor location tracking via interval analysis

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Outline

- Motivations
- Set membership estimation
- Indoor location tracking
- Experimental evaluation
- Research directions
Monitoring for Healthcare
Motivations

- Smart home sensors + Robust data fusion
  = Indoor location tracking,
  = Activity Daily Living characterization.

- Indoor location tracking
  = set-membership state reconstruction

- Robust to sensor failures
Motivations

Set membership estimation

Indoor location tracking

Experimental evaluation

Research directions
Classical estimation is probabilistic

Yield valid results only if
- Perturbations, errors and model uncertainties with statistical properties known \textit{a priori}
- Model structure is correct, no modeling errors
Unknown but bounded-error framework

Hypothesis
Uncertainties and errors are bounded with known prior bounds

A set of feasible solutions
\[ S = \{ p \in \mathbb{P} \mid f(p) \in Y \} = f^{-1}(Y) \cap \mathbb{P} \]
State estimation with continuous systems

- Prediction - Correction / Filtering approaches
  - (Kieffer, et al., 1999) …
Set inversion. Parameter estimation

- Branch-&-bound, branch-&-prune, interval contractors …
  (Jaulin, et al. 93) (Raïssi et al., 2004)

\[ S = \{ z \in \mathcal{Z}, \ | \ f(z) \in \mathcal{Y} \} \quad \Rightarrow \ S \subseteq S \subseteq \bar{S} \]

\[ f([z]) \subseteq \mathcal{Y} \quad \Rightarrow [z] \subseteq S : \text{inner approximation} \]
\[ f([z]) \cap \mathcal{Y} = \emptyset \quad \Rightarrow [z] \notin \bar{S} : \text{outer approximation} \quad \Rightarrow [z] \subseteq \mathcal{Z} \setminus \bar{S} \]

partition …
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Binary sensors

Figure: Infra-red sensor coverage
Figure: The Living Lab: GIS Madonnah at Bourges (France)
Figure: repartition of sensors and zoning areas
\[ x_{k+1} = (p(y_{k+1}) \land (f_1(x_k) + \omega_{1k})) \lor \\
(\neg p(y_{k+1}) \land (f_2(x_k) + \omega_{2k})) \]

\[ y_{k+1} = h(x_{k+1}) + v_{k+1} \]
Predictor-Corrector Approach

Prediction step

\[ X_{k+1}^+ = (p(y_{k+1}) \land f_1(X_k)) \lor (\neg p(y_{k+1}) \land f_2(X_k)) + W_{k+1} \]

Correction step

\[ X_{k+1}^- = h^{-1}(y_{k+1} + V_{k+1}) \]
Prediction step: random walk

Figure: Prediction step
Prediction step, no motion detected

Figure: No movement detected
Use of RFID sensors

Figure: Result of three rings intersection
Figure: Correction step
q-Relaxed intersection

\[ \bigcap X_i = \bigcap X_i \]

\[ \bigcap X_i \]

\[ \bigcap X_i \]
q-Relaxed intersection
(Jaulin, 2009)
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Motivations

Set membership estimation

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Research directions
Location Tracking using binary sensors only

Figure: Reconstructed location zones
Location Tracking using binary sensors + RFID RSSI

Figure: Impact of the use of RFID sensors
Location tracking of single inhabitant (IEEE ICRA 2015)
Location tracking of single inhabitant (IEEE ICRA 2015)
Location tracking of two inhabitants (IEEE CASE 2015)
Location tracking of two inhabitants (IEEE CASE 2015)
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Research directions

- Use forward-backward predictions
- Extend to multiple inhabitants
- Use with multi-modality
- Apply to FDI (IFAC SafeProcess 2015)

- Combine set-membership and stochastic modeling of errors.
M.H. Amri, Y. Becis, D. Aubry, N. Ramdani, M. Fränzle,
Robust Indoor Location Tracking of Multiple Inhabitants Using Only Binary Sensors.
IEEE CASE 2015, Gothenburg, Accepted.

M.H. Amri, D. Aubry, Y. Becis, N. Ramdani,
Robust Fault Detection and Isolation applied to Indoor Localization.
IFAC SafeProcess 2015, Paris, Accepted.

M.H. Amri, D. Aubry, Y. Becis,
N. Ramdani, Indoor Human/Robot Localization using Robust Multi-modal Data Fusion,
IEEE ICRA 2015. Accepted.