An interval-based target tracking approach for range-only multistatic radar

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Main objective

What

Presentation of TIBA, an interval approach to solve the problem of maneuvering target tracking, using range-only multistatic radar.

Why

The radar process is plagued by several uncertainty sources that affect directly the receivers' measures. As a result, the radar system can be both imprecise and unreliable. Usually, interval methods handle uncertainty easily . . .

How

By computation of the all feasible configurations for the target which are consistent with the measures.

Summary

Scenario

Radar applications

- airspace monitoring, marine surveillance
- weather prediction, ground imaging

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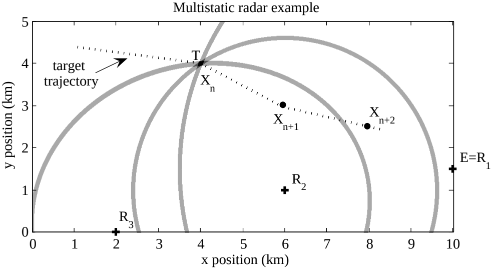
...thus, the radar system can be unprecise and unreliable.

...then, we present TIBA as an alternative to traditional tracking algorithms.

Problem description



Details

- multistatic radar
- range-only measures
- one transmitter, three receivers
- monotarget

state: $\mathbf{X}_n = [x_n, y_n, \dot{x}_n, \dot{y}_n]^t$

evolution: $\mathbf{X}_{n+1} = \mathbf{f}(\mathbf{X}_n) + \mathbf{V}_n$

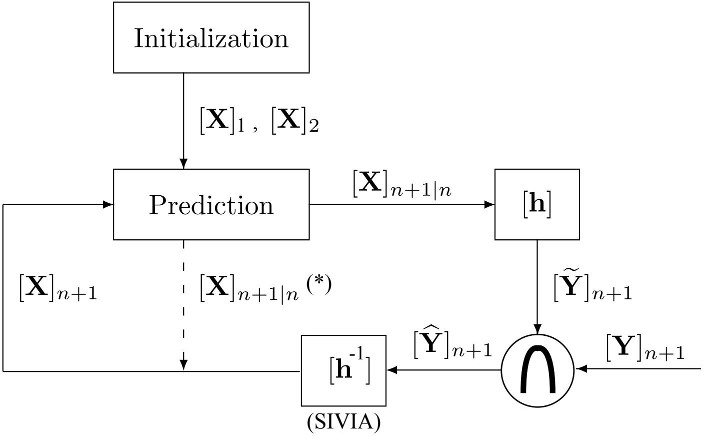
Problem description

evolution: $\mathbf{X}_{n+1} = \underbrace{\mathbf{A}\mathbf{X}_n}_{\mathbf{f}(\mathbf{X}_n)} + \underbrace{\mathbf{B}\mathbf{N}_n}_{\mathbf{V}_n},$

where matrices **A** and **B** are given by:

$$\mathbf{A} = \begin{bmatrix} 1 & 0 & \Delta t & 0 \\ 0 & 1 & 0 & \Delta t \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix} \qquad \mathbf{B} = \begin{bmatrix} \frac{\Delta t^2}{2} & 0 \\ 0 & \frac{\Delta t^2}{2} \\ \Delta t & 0 \\ 0 & \Delta t \end{bmatrix}$$

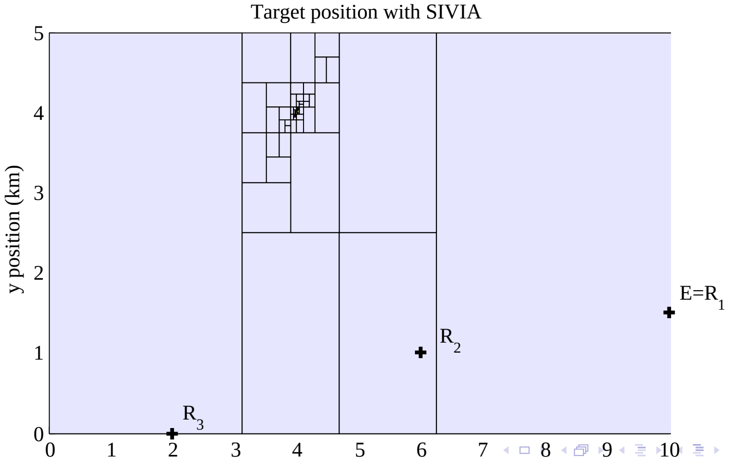
Tracking using an Interval-Based Approach (TIBA)



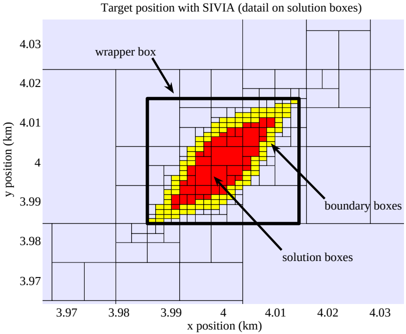
(*) used if incoherent observations

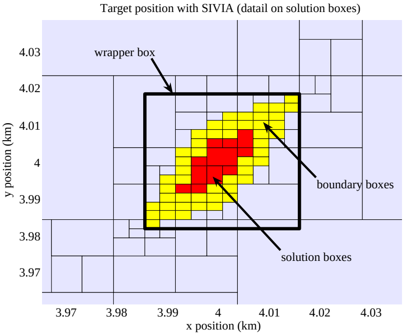
SIVIA

SIVIA to solve $[r_n^i - \epsilon, r_n^i + \epsilon] = [d]_{E[\mathbf{z}]} + [d]_{[\mathbf{z}]R_i}$



Zoom on the region where the solution lies.





(CPU time$= 0.7s$; $[\mathbf{z}] = [0, 25]km \times [0, 10]km$; $\varepsilon = 2m$, $\epsilon = 12m$)

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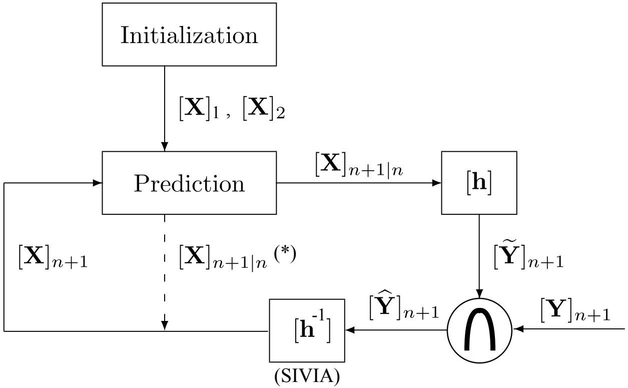

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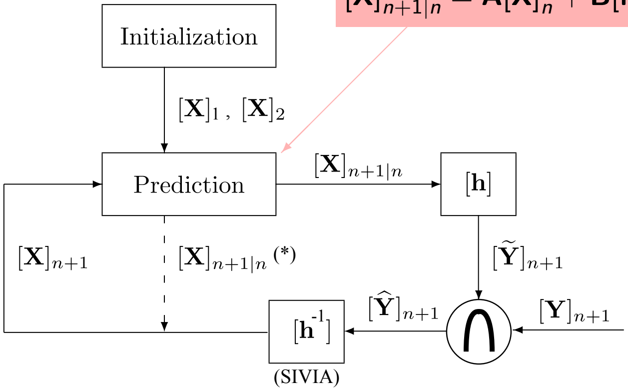
Tracking using an Interval-Based Approach (TIBA)

$$[\mathbf{X}]_{n+1|n} = \mathbf{A}[\mathbf{X}]_n + \mathbf{B}[\mathbf{N}]_n$$



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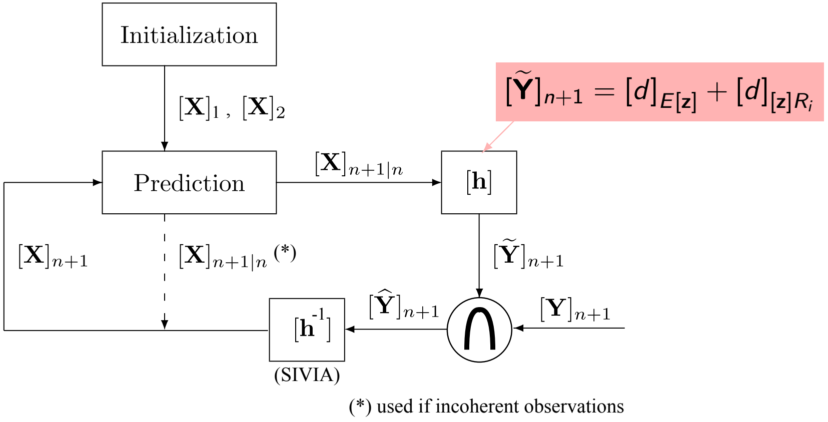

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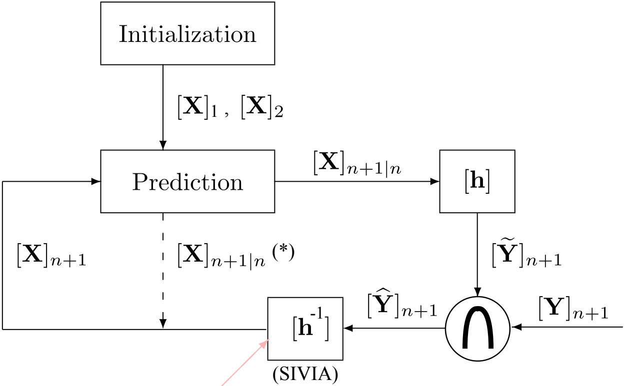


$$[\widehat{\mathbf{Y}}]_{n+1} = [d]_{E[\mathbf{z}]} + [d]_{[\mathbf{z}]R_i}$$

(*) used if incoherent observations

Experiments - simulation details

Trajectory generation

- $\mathbf{Y}_n = \mathbf{A}\mathbf{X}_n + \mathbf{B}\mathbf{W}_n$,
  - $\mathbf{Y}_n$ is Gaussian, mean 0 and $\sigma_{\mathbf{Y}} = 4m$
  - $\mathbf{W}_n$ is Gaussian, mean 0 and $\sigma_{\mathbf{W}} = 100m.s^{-2}$
- delay between the observations: $\Delta t = 0.1$
- outliers and missing measures: 10%
- sample: 1000 observations

Experiments - approaches details

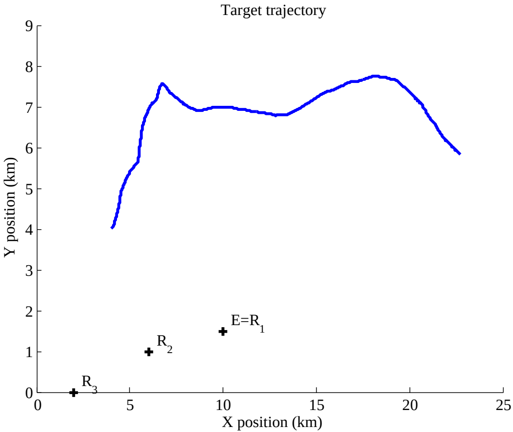
TIBA

- radar range: $[0, 25]km \times [0, 10]km$
- maximal error in measurements: $\epsilon = 12m$
- SIVIA's accuracy: $\varepsilon = 2m$
- interval noise: $\mathbf{N}_n = [-90, 90]$

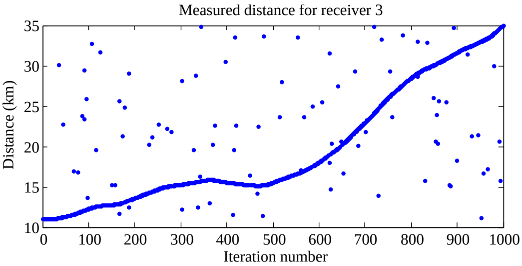
Particle filtering

- particles: 1000
- Regularization noise: $[10, 10, 10, 10]$;

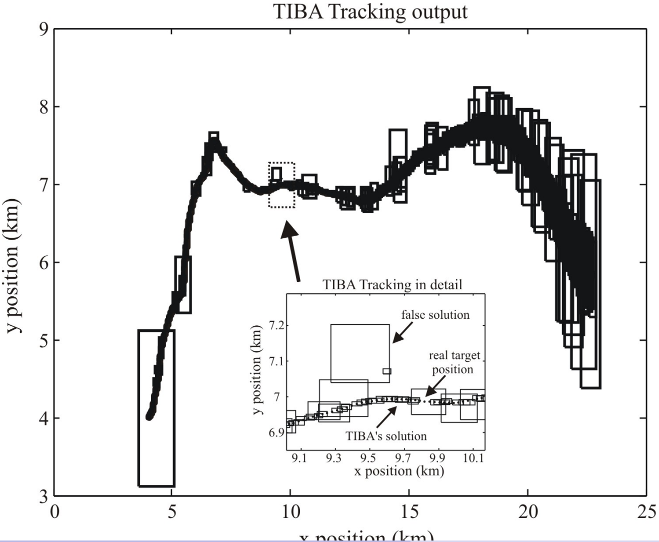
Experiments - Trajectory



Experiments - Observation example



Experiments - TIBA's output



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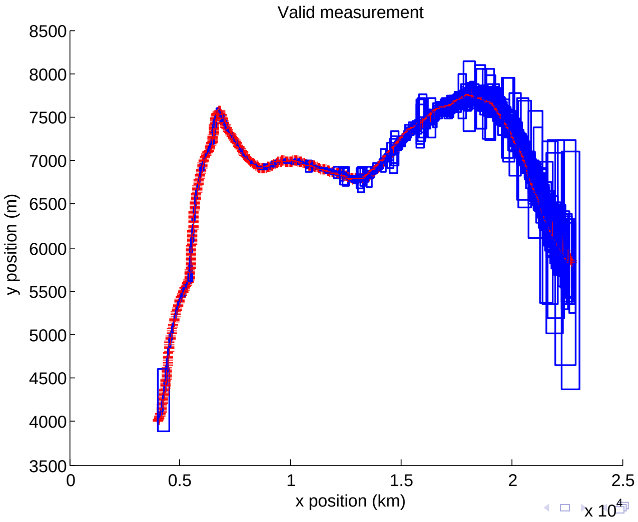
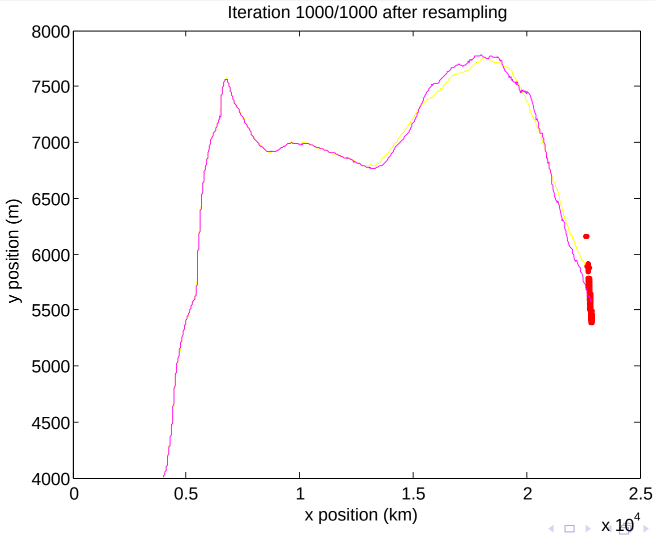
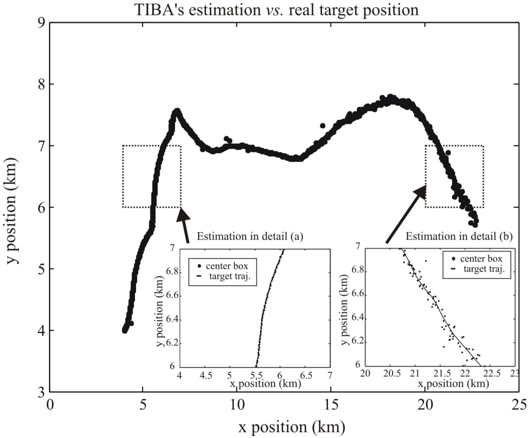


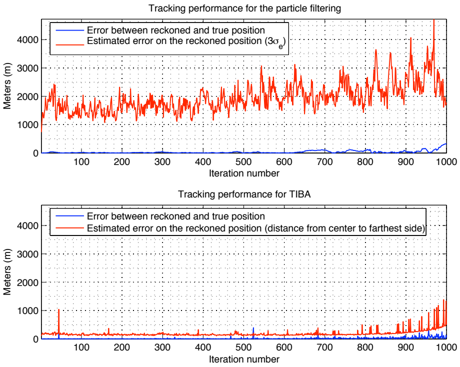
Experiments - PF's output



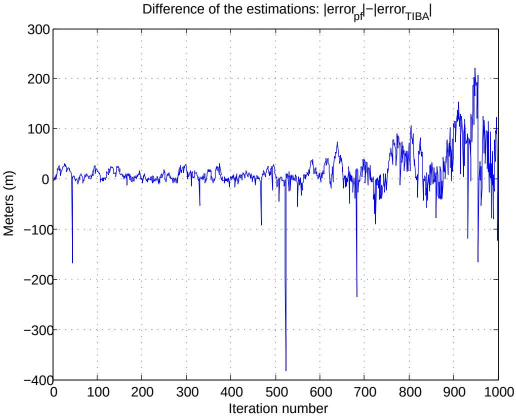
Experiments - TIBA's estimation



Experiments - TIBA x Particle filtering



Experiments - Error difference TIBA x PF



Conclusions

TIBA is a deterministic, interval-based technique while particle filtering is a stochastic method. The experiments provide the following comparison:

Criteria	TIBA	PF
fast cpu time		✓
no parameter tuning	✓	
convergence	✓	not guaranteed
small maximal error	✓	
good estimation	✓	✓