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

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Abstract

This paper investigates the use of interval analysis to solve the problem of maneuvering target tracking, using range-only measures collected by a multistatic radar. The problem consists in one transmitter, and some receivers working together as a multistatic radar. The radar process is plagued by several uncertainty sources that affect directly the receivers' measures. As a result, target tracking can be both imprecise and unreliable. This study presents the Tracking using an Interval-Based Approach *(TIBA) that computes the set of all feasible configurations for the target which are consistent with the measures. The algorithm is compared to a conventional tracking method: particle filtering.*

1. Introduction

Radar systems have been used in several fields as in airspace monitoring, marine surveillance, weather prediction, and ground imaging. We consider here multistatic radars returning range-only measurements. surveillance positioning multisensor system, robot mapping, passive coherent location systems, between other applications. The purported advantages of multistatic systems increase (for the receivers, which are passive) the potential ability to detect target that were optimized to be harder to detect for monostatic radar (stealth targets) and the ability to use sources of opportunities.

If the radar measurements are corrupted by noise, outliers or missing measures, the true position of the target becomes harder to determine, hence the radar system can be unreliable. Tracking algorithms help to reduce the uncertainty on a target's position. Intervals methods can intrisically handle uncertainty and give guaranteed results. These have motivated the development of TIBA as an alternative to traditional tracking algorithms, such as Kalman filtering or particle filtering.

2. Description of the problem

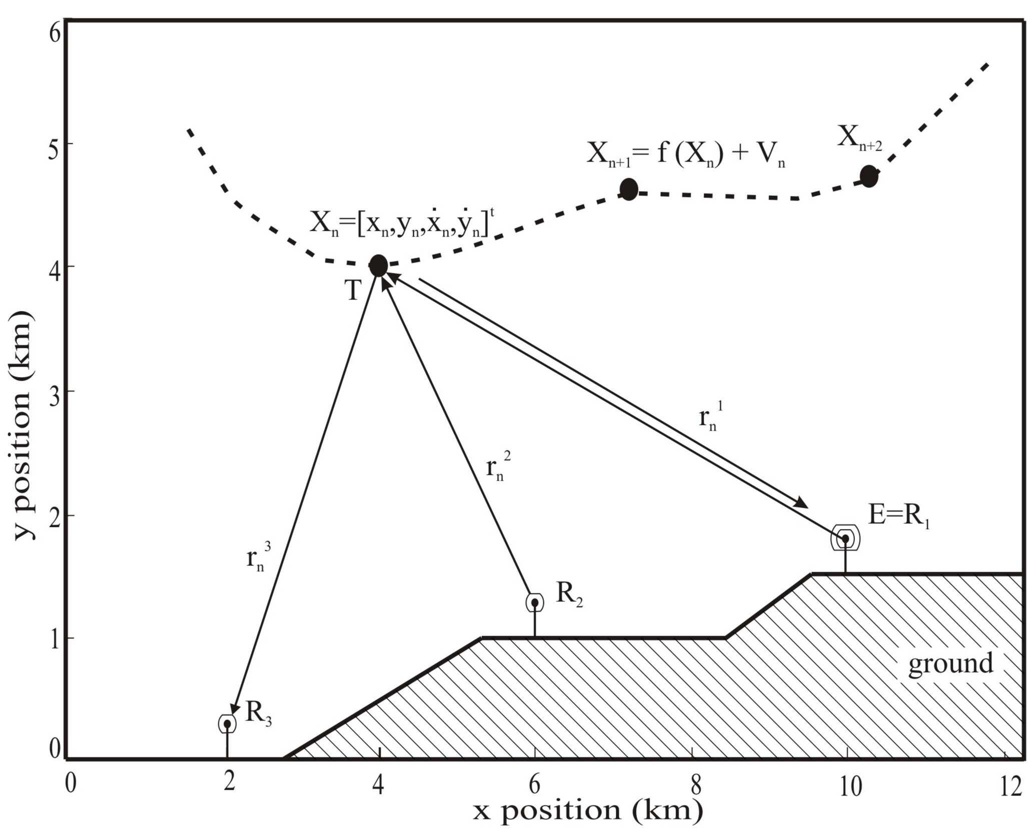

Figure 1: *Multistatic radar (2D space) with three receivers R_i, one transmitter E and one target T. Target representation: $\mathbf{X}_n = [x_n, y_n, \dot{x}_n, \dot{y}_n]^t$; target evolution: $\mathbf{X}_{n+1} = f(\mathbf{X}_n) + \mathbf{V}_n$; and measurements r_n^i.*

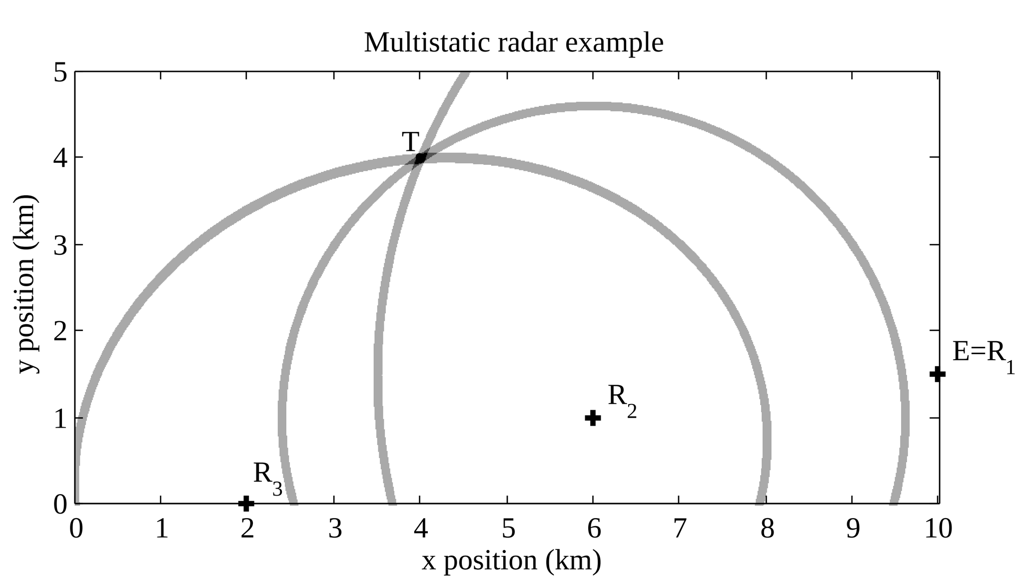

Figure 2: *The Fresnel ellipsoids' intersection define the region where the target can be.*

3. TIBA

TIBA has few parameters, and a simple structure. It outputs an interval where the target is guaranteed to be and is consistent with measurements.

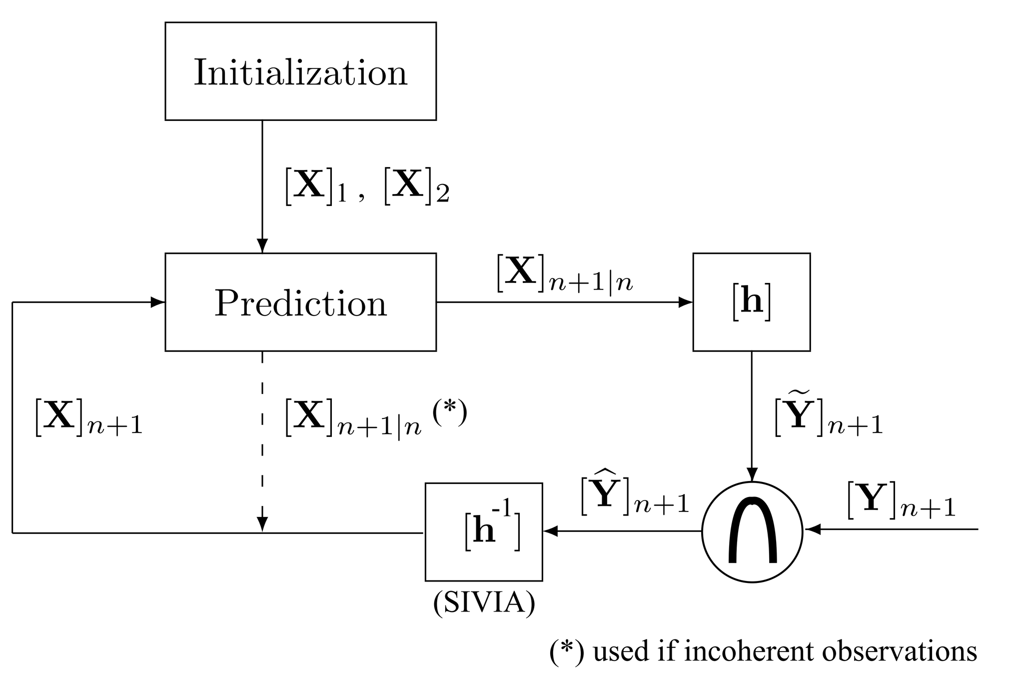

Figure 3: *Workflow of TIBA. Note that the correction step is implemented in the function space.*

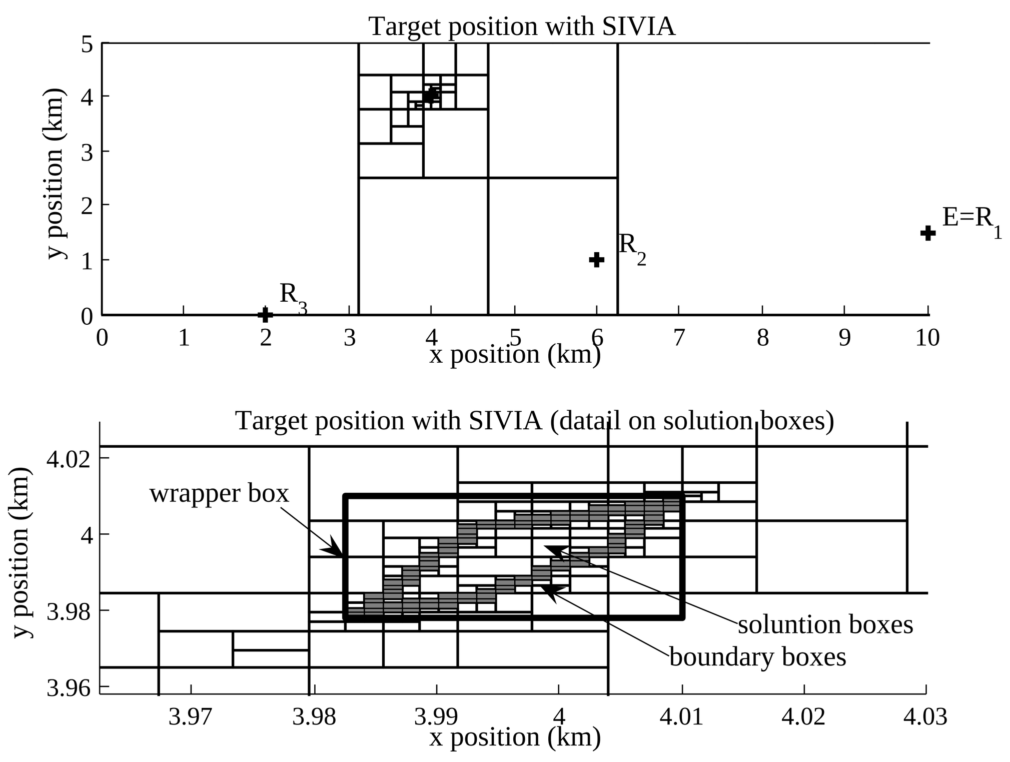

Figure 4: *Typical SIVIA graphics. Above, the convergence to a region consistent with measurements. Below, a zoom on the solution region.*

4. Comparison and experiments

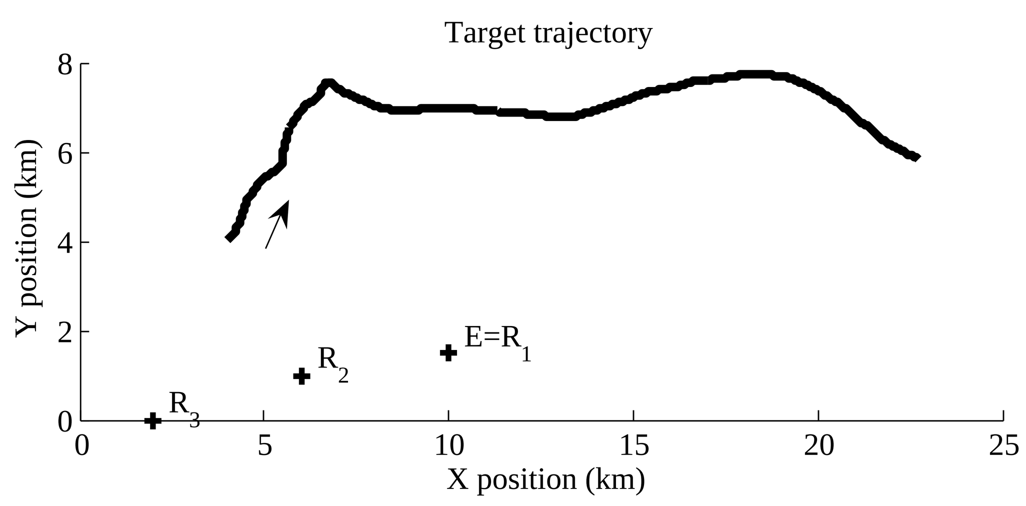

Figure 5: *True target trajectory for the experiment. The target moves from the left to the right.*

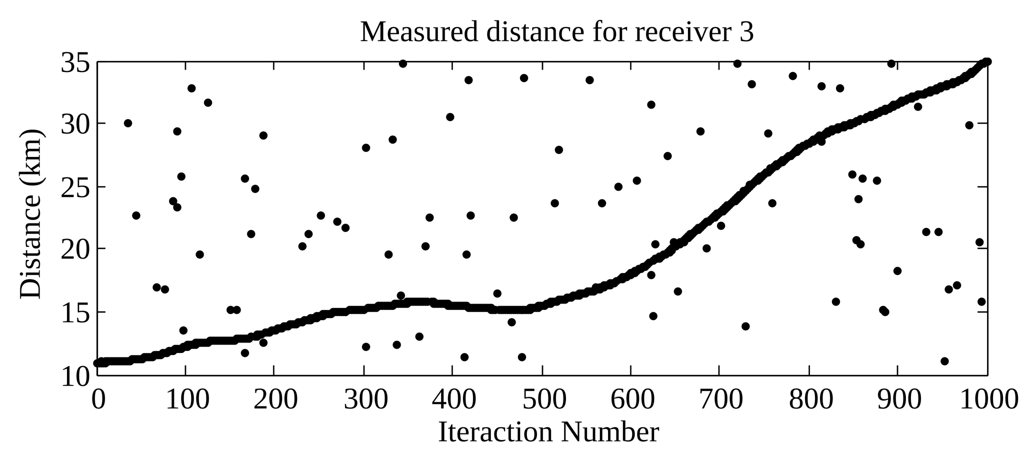

Figure 6: *Measures from the receiver 3. Outliers and missing measures occure with a 10% probability.*

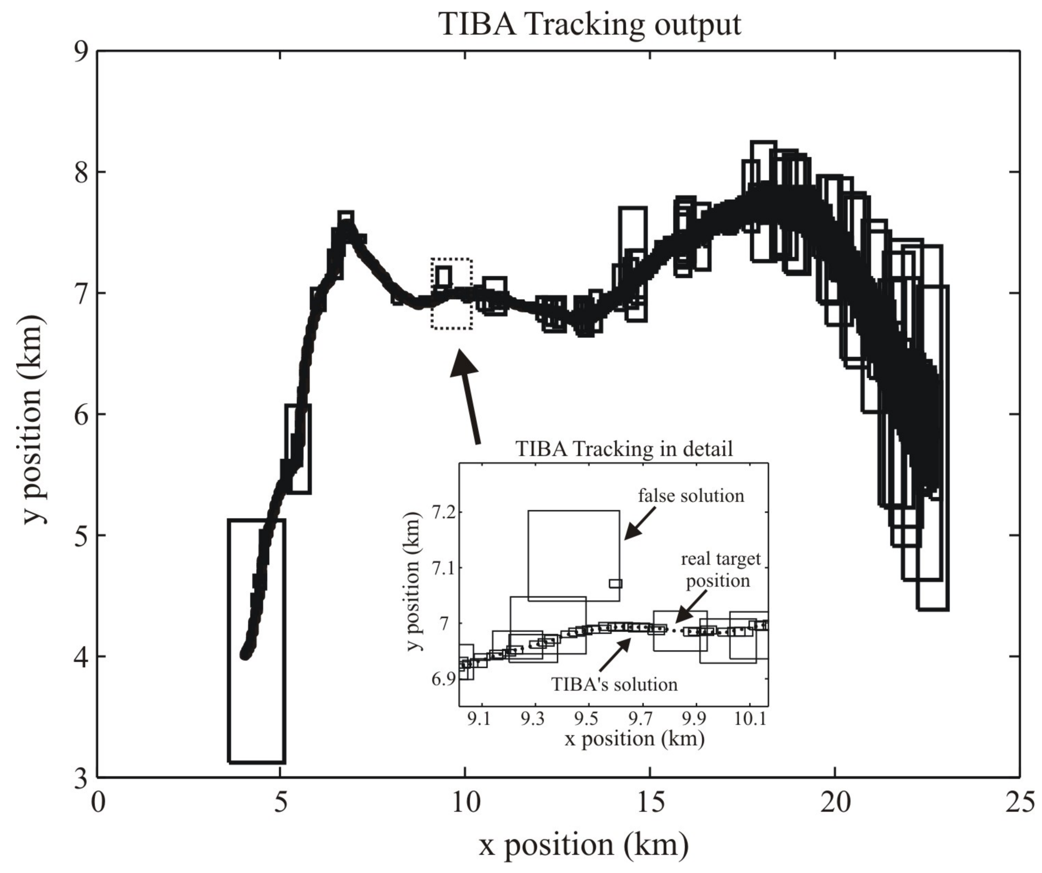

Figure 7: *Full TIBA tracking output. The target boxes, false solution boxes and the real target location are shown in the detail.*

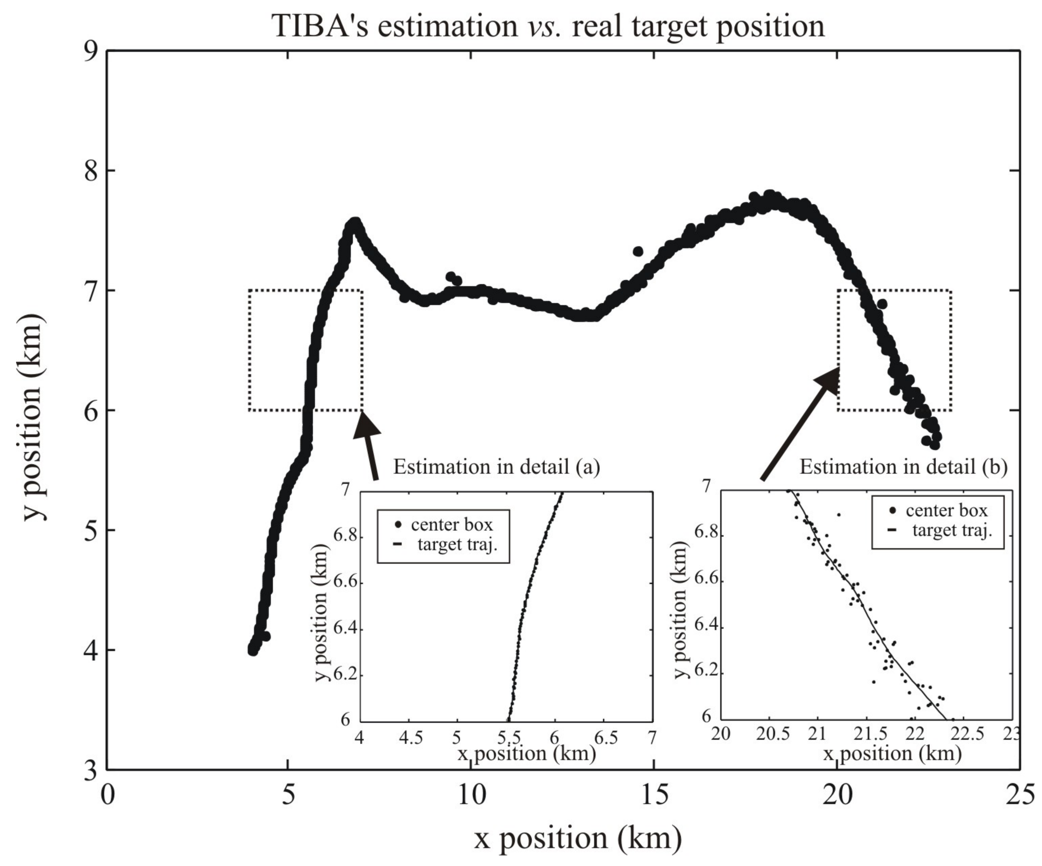

Figure 8: *TIBA's estimation of the target's location. The quality of TIBA's estimation depends on the quality of the intersection of the isorange ellipses.*

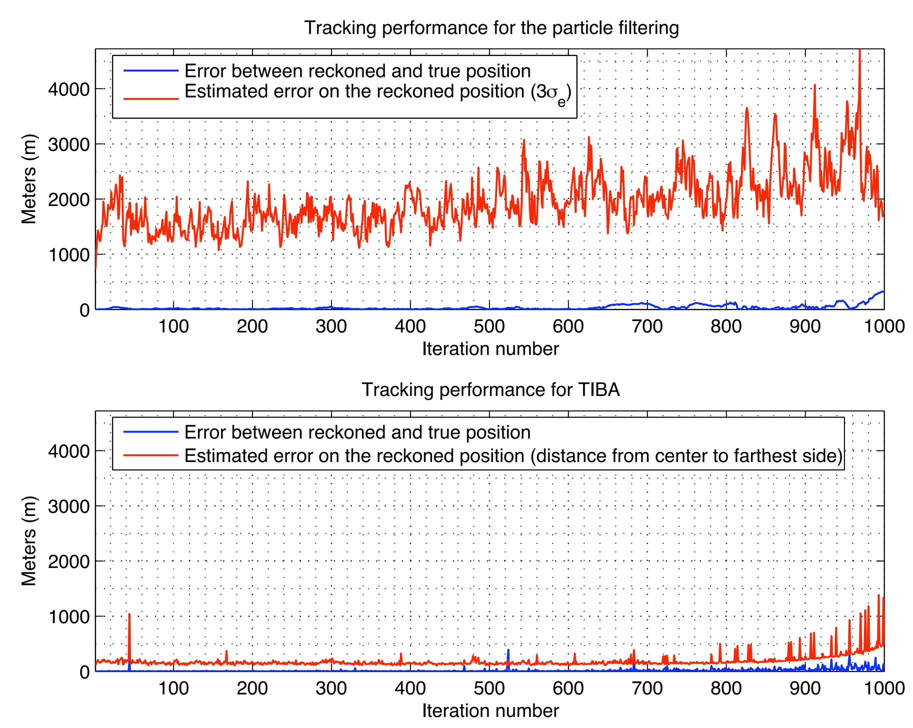

Figure 9: *Comparison between particle filtering (1000 particles) and TIBA in terms of precision and robustness.*

5. Conclusions and future outlooks

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	✓	✓

Real time applications like radar tracking need methods that give reliable and precise results using the allotted available time. In our tests, TIBA has failed the CPU time criterion. This will be fixed for next version of the TIBA by inserting an effort parameter in the SIVIA algorithm. PF is faster than TIBA and the tracking process is independent of the transmitter-target-receivers positions. On the other hand, TIBA is sensitive to large ellipsoid intersection areas. TIBA has also fewer tuning parameters than PF. Finally, TIBA always converges, even when there are only few consistent measures.

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