Robust 3D target localization using UAVs with state uncertainty

M. Zagar[1], M. Kieffer[1], H. Piet-Lahanier[2], and L. Meyer[2]

[1] Université Paris-Saclay - CNRS - CentraleSupélec - L2S, F-91192 Gif-sur-Yvette
[2] ONERA, F-91120 Palaiseau

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Introduction

This work considers the estimation of the 3D location of a target observed by several cooperating Unmanned Aerial Vehicles (UAVs). The measurement errors in the body frame of each UAV are assumed to be bounded. Moreover, the proposed approach, accounts for the UAV state uncertainty, assumed bounded, and for the presence of outliers.

Robust estimation

N UAVs observe a target located at $\boldsymbol{x}^{\mathrm{t}}$. A measurement in the frame of UAV i, expressed in spherical coordinates, is assumed to satisfy

$$\mathbf{y}_i = \mathbf{h}\left(\mathbf{x}_i^{\mathrm{u}}, \boldsymbol{x}^{\mathrm{t}}\right) + \mathbf{w}, \tag{1}$$

where $\mathbf{x}_i^{\mathrm{u}}$ is the state of the UAV only known to belong to the set $\in \mathbb{X}_i^{\mathrm{u}}$ and $\mathbf{w} \in [\mathbf{w}]$ is the bounded measurement noise. Consider a set of indexes $\mathcal{N} \subset \{1, \ldots, N\}$. The estimate of all target positions in the search domain $\mathbb{X}_0$, consistent the measurements $\mathbf{y}_i$, $i \in \mathcal{N}$, the measurement model (1), the noise bounds, and the UAV state uncertainty is

$$\mathbb{X}_{\mathcal{N}}^{\mathrm{t}} = \left\{\boldsymbol{x} \in \mathbb{X}_0 \mid \exists \mathbf{x}_i \in \mathbb{X}_i^{\mathrm{u}},\ \mathbf{h}\left(\mathbf{x}_i, \boldsymbol{x}\right) \in [\mathbf{y}_i], i \in \mathcal{N}\right\}. \tag{2}$$

Combining the Thick-SIVIA algorithm [1] and the q-relaxed intersection [2], we propose the Robust Thick SIVIA (RTSIVIA) algorithm to determine the largest sets $\mathcal{N}$ such that the set $\mathbb{X}^{\mathrm{t}}_{\mathcal{N}}$ is not empty. Starting with $q = 0$, the corresponding set estimate is evaluated as

1. Contract $\mathbb{X}_0$ using i-th measurement only to get $\mathbb{X}_i$, $i \in \{1, \ldots, N\}$.
2. Use Thick SIVIA to evaluate the set

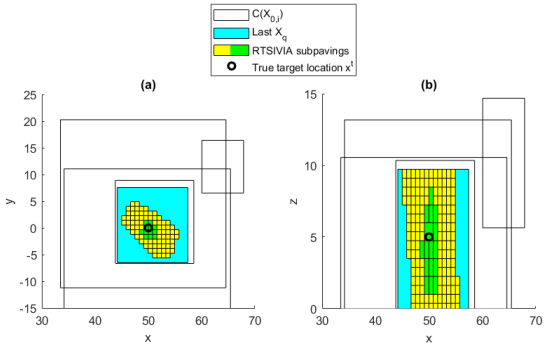
$$\mathbb{X}^{\mathrm{t}}_q = \bigcap_{i \in \{1,\ldots N\}}^{q} \{\boldsymbol{x} \in \mathbb{X}_i \mid \exists \mathbf{x}_i \in \mathbb{X}^{\mathrm{u}}_i,\ \mathbf{h}(\mathbf{x}_i, \boldsymbol{x}) \in \mathbf{y}_i - [\mathbf{w}]\} \qquad (3)$$

   of all target locations consistent with at least $N - q$ measurements.
3. If $\mathbb{X}^{\mathrm{t}}_q = \emptyset$, more outliers have to be tolerated: $q = q + 1$; Go to 2.

Results

Consider 4 UAVs getting target distance and elevation measurements (one produces outliers). UAV's position and attitude uncertainties are $\pm$1m and $\pm 2^{\mathrm{o}}$; Measurement noise is with $\pm$1m and $\pm 0.5^{\mathrm{o}}$ uncertainty.

The figure shows the results of RTSIVIA: white boxes are the $\mathbb{X}_i$s; the first non-empty $\mathbb{X}^{\mathrm{t}}_q$ is contained in the cyan box; (a) and (b) are the projection on X-Y and X-Z planes of the subpaving approximating $\mathbb{X}^{\mathrm{t}}_q$



References

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