



Cooperative Localization of Drones by using Interval Methods

Ide-Flore Kenmogne, Vincent Drevelle, Eric Marchand

► To cite this version:

Ide-Flore Kenmogne, Vincent Drevelle, Eric Marchand. Cooperative Localization of Drones by using Interval Methods. SWIM 2018 - 11th Summer Workshop on Interval Methods, Jul 2018, Rostock, Germany. pp.1-4. hal-01814760

HAL Id: hal-01814760

<https://inria.hal.science/hal-01814760>

Submitted on 13 Jun 2018

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

Cooperative Localization of Drones by using Interval Methods

Ide-Flore Kenmogne, Vincent Drevelle and Eric Marchand

Univ Rennes, Inria, CNRS, IRISA

`ide-flore.kenmogne@inria.fr`

`{vincent.drevelle, eric.marchand}@irisa.fr`

Keywords: Cooperative pose estimation, Set Inversion

Introduction

In this paper, we address the problem of cooperative pose estimation [1] in a group of N unmanned aerial vehicles (UAV), each equipped with a camera that sees landmarks with known positions. The UAVs communicate, exchange poses and measure distances with neighbours and a base station. Our aim is to compute the pose domain of each robot assuming the errors on measurements are bounded.

Single robot pose estimation

Each robot first estimates its pose domain $\mathbf{r} = (x, y, z, \phi, \theta, \psi)$ using camera and base distance constraints. To get the camera constraints, the perspective projection equation (Eq. (1), pinhole camera model) of a 3D world point ${}^w\mathbf{X}$ in the camera frame represented in normalized coordinates $\mathbf{x} = ({}^cx, {}^cy)$ is used (see [2] in camera only case).

$$\mathbf{x} = \mathbf{\Pi} {}^c\mathbf{T}_r {}^r\mathbf{T}_w(\mathbf{r}) {}^w\mathbf{X} \quad (1)$$

with ${}^r\mathbf{T}_w$ the unknown transformation matrix between the world reference frame and a frame attached to the robot and ${}^c\mathbf{T}_r$ is the known rigid transformation between the camera and the robot frames. Equation (1) is applied for each visible landmark ${}^w\mathbf{X}_i$ ($i \in 1..m$) and the

following constraints can be derived

$$C_i : \begin{cases} ({}^cX_i, {}^cY_i, {}^cZ_i) = {}^c\mathbf{T}_r {}^r\mathbf{T}_w(\mathbf{r}) {}^w\mathbf{X}_i \\ {}^cx_i = \frac{{}^cX_i}{{}^cZ_i}, {}^cy_i = \frac{{}^cY_i}{{}^cZ_i}, \\ {}^cx_i \in [{}^cx_i], {}^cy_i \in [{}^cy_i], {}^cZ_i > 0. \end{cases} \quad (2)$$

The image/range-based pose estimation problem is then defined as a constraint satisfaction problem (CSP)

$$\mathcal{H} : \begin{pmatrix} \mathbf{r} \in [\mathbf{r}], \\ \{C_i, i \in 1...m\} \\ C_{dist} \end{pmatrix}$$

Where C_{dist} is the additional distance constraint between the robot position $p = (x, y, z)$ and the base station B used to get a tighter pose estimate

$$C_{dist} : d = \|\mathbf{p} - \mathbf{b}\|_2, \quad d \in [d]$$

with \mathbf{b} the known position of the base station.

A robot R_k computes a domain in a form of an outer subpaving $\mathbb{S}_{\mathbf{r}_k}^+$, that contains all the feasible poses, using SIVIA [3] to solve \mathcal{H} .

Robots cooperation: data exchange

At each time step, once the pose domain $\mathbb{S}_{\mathbf{r}_k}^+$ is computed, the robot exchanges the bounding box of its position domain $[\mathbf{p}_k] = \square \text{proj}_{\mathbf{p}} \mathbb{S}_{\mathbf{r}_k}^+$, where \square is the bounding box operator, and $\text{proj}_{\mathbf{p}}$ is the projection onto the position space. The position $[\mathbf{p}_k]$ is transmitted to all neighboring robots R_j , $j \in \mathcal{N}(k)$, and the distances $d_{k,j}$ between R_k and R_j are simultaneously measured (with $\mathcal{N}(k)$ the neighbours of R_k).

At reception of information (position boxes $[\mathbf{p}_j]$ and bounded-error distances measurements $[d_{k,j}]$) from neighboring robots, R_k tries to refine its actual pose domain, by propagating the new distance constraints between R_k and each of its neighbours. A CSP is also built and SIVIA is used to refine the pose domain.

Experimental results

The proposed method has been tested with data acquired on Parrot AR-Drone2 UAV, with 5 landmarks represented by AprilTag markers. The image measurement error bounds are set to ± 0.5 px and the range measurement error is assumed to be within ± 5 cm.

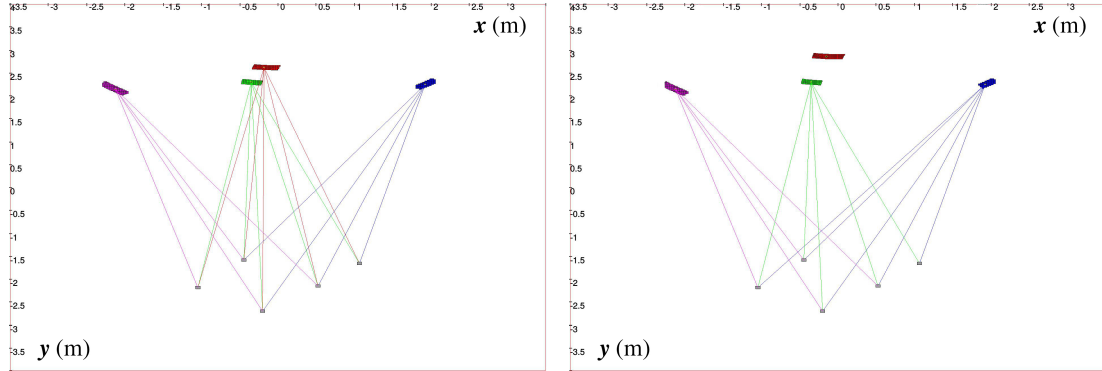


Figure 1: Pose domain for 4 robots.

The left part of Fig. 1 shows subpavings obtained when all 4 robots observe the 5 landmarks (full visibility case). The image on the right of Fig. 1 shows how cooperative localization reduces the feasible pose domain when one robot (in red) cannot clearly see the landmarks, by propagating position information of the neighbours. The average horizontal position error is less than 5 cm for each of the drones.

References

- [1] J. SPLETZER AND C. J. TAYLOR, A Bounded Uncertainty Approach to Multi-Robot Localization, *IEEE/RSJ Int. Conf. on Intelligent Robots and Systems*, 1258-1264, Las Vegas, 2003.
- [2] I. KENMOGNE AND V. DREVELLE AND E. MARCHAND, Image-based UAV localization using Interval Methods, *IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (IROS)*, 5285-5291, Vancouver, Canada, 2017.

- [3] L. JAULIN AND E. WALTER, Set inversion via interval analysis for nonlinear bounded-error estimation, *Automatica*, 29, 1053-1064, 1993.