Research context

- We envision an emergency situation (e.g., a fire) in which a team of $N$ UAVs acts as a distributed wireless sensor network to track targets (e.g., firemen) inside buildings. The UAV positions are considered a-priori known.
- Each UAV accomplishes the following tasks:
  - Exchange the gathered information only with its closest neighbors (multi-hops);
  - Fuse the collected data to infer the target position and optimize the trajectory;
- In this paper, we focus on the decentralized control of UAVs and the assessment of a trade-off between localization accuracy and convergence speed.

Information-seeking control

Goal: Each UAV estimates its own control signals in order to minimize the error in localizing the target and avoiding collisions between UAVs and obstacles.

Problem statement:

- $\mathbf{q}^{(k+1)} = \arg\min_{\mathbf{q}^{(k)}} \text{PEB}(\mathbf{p}_i^{(k)}, \mathbf{q}^{(k)})$
- $\mathbf{q}^{(k)}$: locations of all the UAVs as known by the $i$th UAV at time slot $k$; $k$ is the number of hops between the $i$th and $j$th UAV;
- $\mathbf{p}_i^{(k)}$: estimated target position by the $i$th UAV at time slot $k$.

UAV control signal: $\mathbf{u}^{(k+1)} = [\mathbf{q}^{(k+1)}] - \mathbf{p}_i^{(k)}$

Position Error Bound

Fisher Information Matrix:

$\text{PEB} (\mathbf{p}_i, \mathbf{q}^{(k)}) = \sqrt{\mathbf{J}^T (\mathbf{p}_i, \mathbf{q}^{(k)}) \mathbf{J} (\mathbf{p}_i, \mathbf{q}^{(k)})}$

Log-likelihood function:

$\lambda (\mathbf{z}^{(k)} | \mathbf{p}_i) = \sum_{j=1}^{N} \ln f (\mathbf{z}_j^{(k+1)} | \mathbf{p}_i)$

Measurement model:

$\mathbf{z}_j^{(k)} = \mathbf{d}_i^{(k)} \oplus \mathbf{v}_i^{(k)}$

Ranging model:

$\mathbf{z}_j^{(k)} = \sigma_2 d_i^{(k)} \oplus \eta_1 (\nu^{(k)}) \sigma_2$

Constrained navigation

Gradient-based solution: $u^{(k+1)} = \nabla \mathbf{P}_\mathbf{E} \mathbf{B} (\mathbf{p}_i^{(k)}, \mathbf{q}^{(k)}) - N^T (N N^T)^{-1} g$

Projection matrix:

$P = I - N (N N^T)^{-1} N^T$

Activated constraint:

$g = \mathbf{d}_i - d^*; \quad d^* = \mathbf{d}_i^{(k)} - \mathbf{d}_i^{(k)}$

2D indoor/outdoor scenario

- Blue dots: UAV initial positions;
- Green triangle: Target position;
- Gray rectangles: obstacles;
- Black line: UAV trajectory.

Success rate:

$\text{SR} = \frac{1}{N_{\text{hop}}} \sum \text{PEB}(\mathbf{p}_i, \mathbf{q}^{(k)}) < c$

Conclusions:

- An increased number of UAVs translates in a better localization accuracy and improved convergence speed.
- An increased hop allows for the collection of more up-to-date measurements, and, hence, improved performance.
- Passing from $h_{\text{max}} = 1$ to $h_{\text{max}} = 3$ (i.e., collecting more not-updated measurements from UAVs that are further away) does not improve the results.