Decentralized Control for Multi-Agent Missions based on Flocking Rules

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14th International Conference on Automatic Control and Soft Computing
Bragança

July 1-3 2020

Outline

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3. Proposed Solution
4. Simulation Results
5. Concluding Remarks

Motivation

- Multi-Agent Systems (MAS) - a network composed of mobile agents with the objective of converging to high-value positions.
- No centralized infrastructure - implies the need for a decentralized algorithm to compute the actuation.
- Applicable to surveillance - a group of vigilant robots that want to periodically visit sites to be monitored.

Traditional Solution

- Typical solutions use consensus algorithms [1] [2], can cope with asymmetric wireless links.
- Consensus algorithms can be made to work with noise in the measurements [3].

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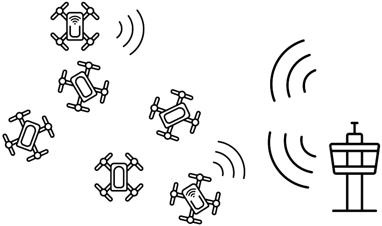
- Consensus algorithms can be made to work with noise in the measurements [3].
- Problems:
  1. Convergence is not achieve in high-value areas;
  2. Difficult to incorporate mission plane constraints;
  3. Multiple clusters if the initial topology was not connected;
  4. Possible collisions.

Scenario

- Communication towers provide localization with errors;
- Transmission resorts to directional antennae;
- Agents listen to the channel to discover neighbors.



Main issues

- Possible collisions;
- Position and velocity received with errors;
- Non-connected and unknown topologies;
- Limited unidirectional communication.

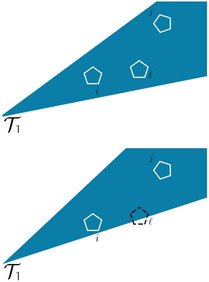


Figure: Strip centered at node i and i, j and l are neighbors (top). Strip centered at node j and only i is neighbor (bottom).

Flocking Algorithm

- Common rules:
  - Separation — nodes want to stay away of each other

$$\mathcal{U}_s = \frac{1}{|\mathcal{N}_i(k)|} \sum_{j \in \mathcal{N}_i(k)} c_i(k) - c_j(k)$$

  - Cohesion — to maintain the formation

$$\mathcal{U}_c = \frac{1}{|\mathcal{N}_i(k)|} \sum_{j \in \mathcal{N}_i(k)} c_j(k) - c_i(k)$$

  - Alignment — agents tend to move in the same direction

$$\mathcal{U}_a = \frac{1}{|\mathcal{N}_i(k)|} \sum_{j \in \mathcal{N}_i(k)} v_j(k) - v_i(k)$$

- However, these are not sufficient for the goal.

Flocking Algorithm

- Added rules:
  - Attraction — nodes gravitate towards high-utility agents

$$\mathcal{U}_{attr} = \frac{1}{|\mathcal{N}_i(k)|} \sum_{j \in \mathcal{N}_i(k)} (h_j - h_i)(c_j(k) - c_i(k))$$

  - Utility — try to maximize their current utility

$$\mathcal{U}_u = \nabla h_i(k)$$

  - Randomness — small noise values to avoid deadlocks

$$\mathcal{U}_r = \mathrm{rand}()$$

- Final movement is given as
  $u = \alpha \cdot \mathcal{U}_s + \beta \cdot \mathcal{U}_c + \gamma \cdot \mathcal{U}_a + \delta \cdot \mathcal{U}_{attr} + \epsilon \cdot \mathcal{U}_u + \zeta \cdot \mathcal{U}_r.$

Collision Avoidance

- Use of Set-Valued Observers (SVOs) [4] to estimate positions;
- The magnitude of the actuation is saturated to prevent collisions;
- Collision-free guarantees since SVOs are guaranteed to contain the true state.

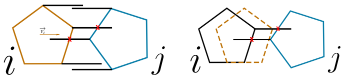


Figure: Ray tracing to detect maximum movement before collision.

Simulation Setup

Setup: With 10 agents moving in a 100×100 mission plane and strips of 8 degrees. We tested:

1. Single rendezvous point (static and moving)
2. Single escape point (static and moving)
3. Multiple rendezvous and escape points
   a. Static rendezvous areas;
   b. Static rendezvous areas and with illegal zones;
   c. Rendezvous areas whose utility value decreases when explored, and increases when not observed for surveillance missions;
   d. Rendezvous areas whose utility value decreases when explored, and increases when not observed with illegal zones;
   e. Random creation and destruction of rendezvous and escape points.

Simulation Results - Rendezvous mission

- Nodes converge to the moving rendezvous point;
- Distance among nodes cannot be zero due to the collision avoidance mechanism;
- Initial non-connected topology.

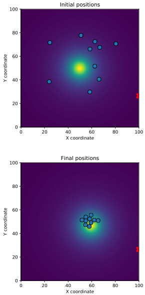


Figure: Initial configuration (top) and final (bottom) with one tower (red X).

Simulation Results - Escape mission

- Nodes move away from the threat point;
- Clusters were formed in this case;
- Nodes move as a group.

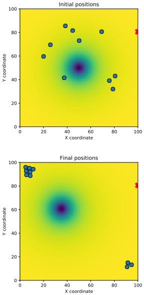


Figure: Initial configuration (top) and final (bottom).

Simulation Results - Complex mission

- Nodes stay away from the illegal zones;
- Even though the obstacles are in their path, the algorithm succeeds;
- Nodes are stuck in a rendezvous point once found.

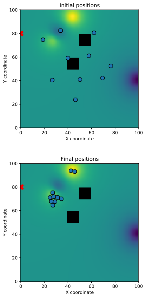


Figure: Initial configuration (top) and final (bottom) with illegal zones (black squares).

Concluding Remarks

Contributions:

- We have added additional flocking rules in order to specify mission objectives.
- Using the SVOs for position estimate and ray tracing, collision avoidance is guaranteed.
- In the journal version, we study the convergence of the proposed flocking algorithm.
- We have already extended these ideas to a fully decentralized algorithm.

References

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The end

- Thank you for your time.

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