Stabilization of MAV and MAV-UGV swarms based on a visual relative localization

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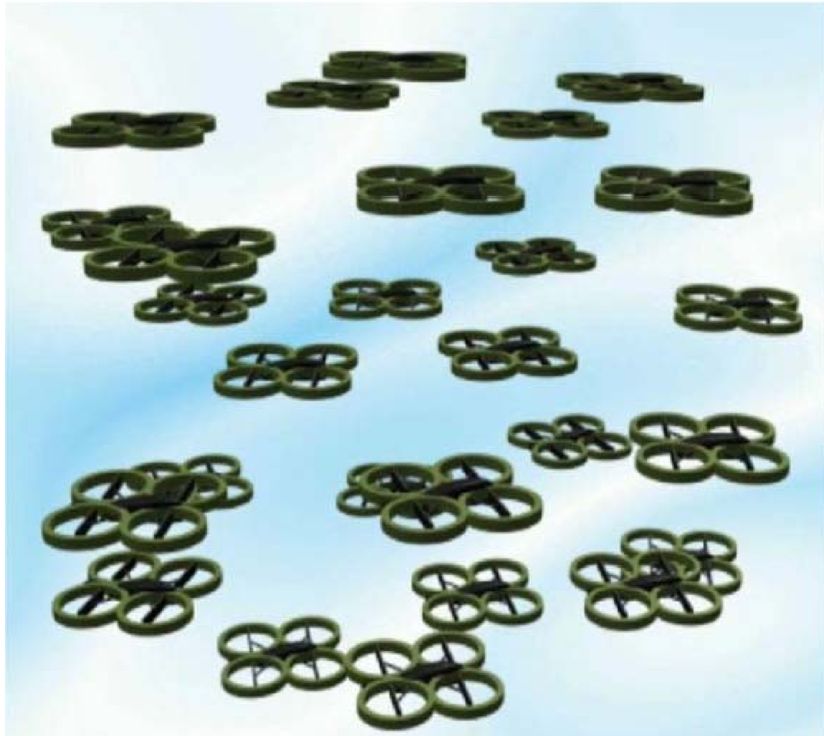

The key message

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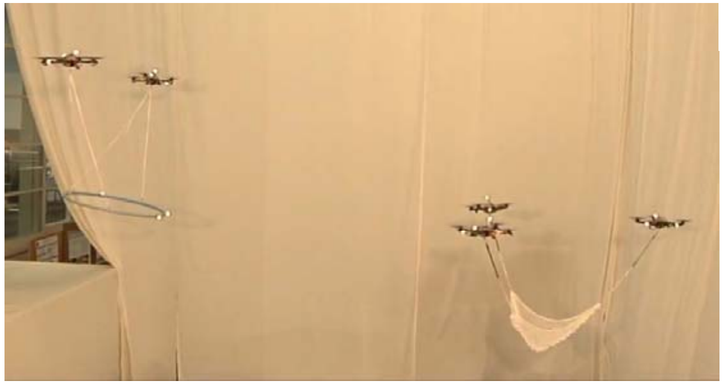

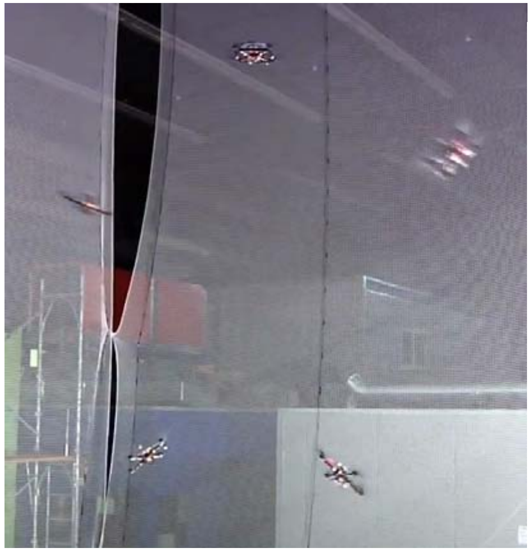

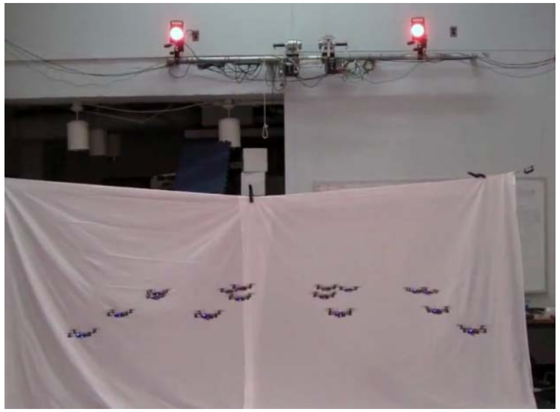

UPENN

Motto: Let’s repeat the VICON story with onboard visual localization. Let’s take the swarms outside laboratories.

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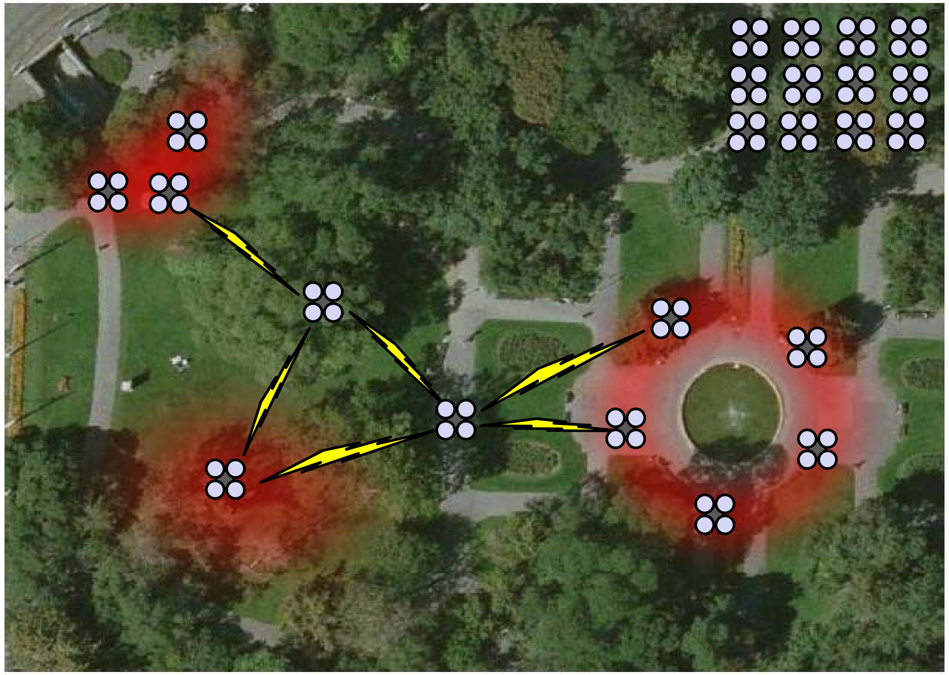
The key message

- Deployment of multiple-MAV systems outside laboratories equipped by external precise localization infrastructure
- Navigation and coordination of robots based on an onboard monocular vision system only
- Possibility of cooperation with ground unites acting as a base station → to prolong mission duration
- Various applications in demanding outdoor and indoor environments (large- as well as small-scale)
- Search and rescue missions, reconnaissance, surveillance

1st example – swarm coverage

- Deployment of swarms (MAV) in real outdoor applications
- Surveillance/presence tasks – locations of interest with different priorities

- To spread the swarm while keeping swarm constraints
  - Localization constraints
  - Motion constraints
  - Sensing constraints



- **The mission target:** Optimal static coverage of areas by spreading swarm while its constraints are guaranteed.

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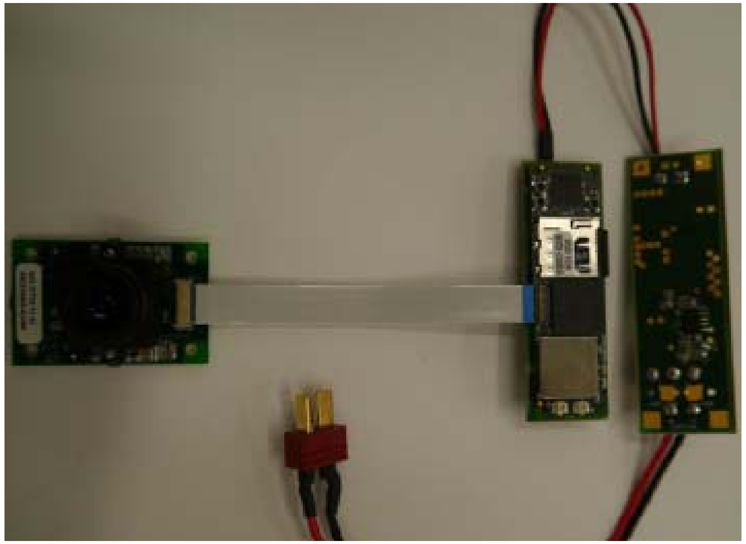
- Relative localization constraints
  - Swarm particles mutually localized using on-board camera modules and identification patterns on neighbors
  - Constraints given by range, viewing angle, mutual MAV heading & dynamic properties



- Movement constraints
  - Low-level controller constraints (μ-MAV dynamics)
  - Interactions between swarm particles (effects of air turbulences)

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Proposed approach

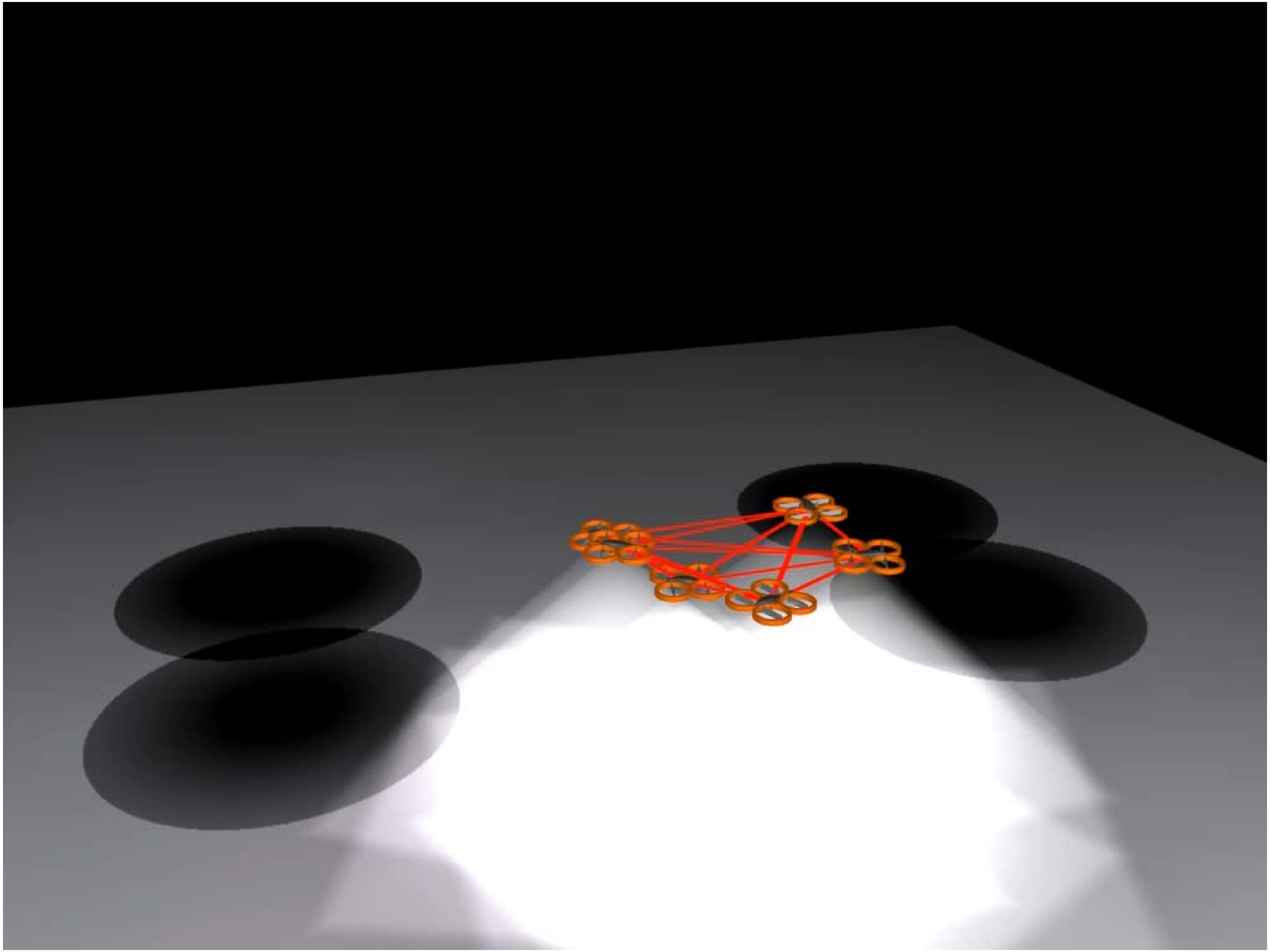
- To **find a target shape** of the spread swarm together **with trajectories** from the initial to desired configurations that are **satisfying the given constraints**

- A solution would provide:
  - **Spread swarm**- robot configurations and their assignments to the areas of interest
  - **A feasible trajectories** of MAVs from the initial to goal configurations
  - The trajectories may not be optimal, but feasibility of the solution is guaranteed.

- The idea for solving the given problem is to apply:
  - Control theory together with AI nature inspire principles
  - Particle Swarm Optimization (PSO)

Proposed approach

- Each PSO particle represents the entire swarm (string of *x*,*y*,*z* coordinates of swarm members)
- PSO fitness function correlates with the swarm coverage (coverage of each MAV depends on the altitude and sensor viewing angle)
- In each PSO iteration the feasibility (localization, motion, … constraints) of trajectory into a new solution is verified using a motion planning and movement simulation for each MAV
- Unfeasible solution is repaired or PSO iteration is restarted
- Position of the best particle together with trajectories employed during the optimization are returned as the required solution



Movie – swarm coverage

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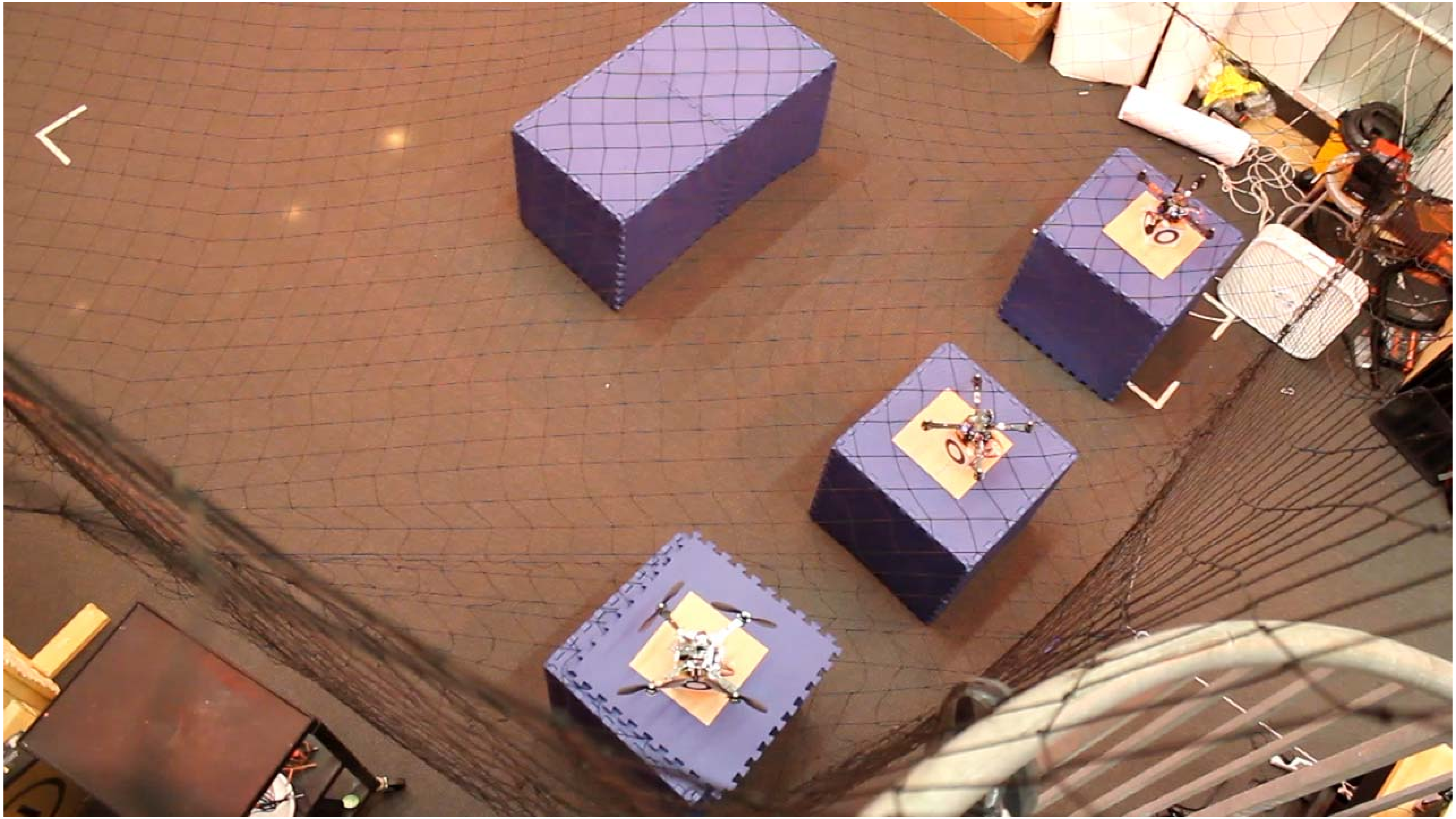

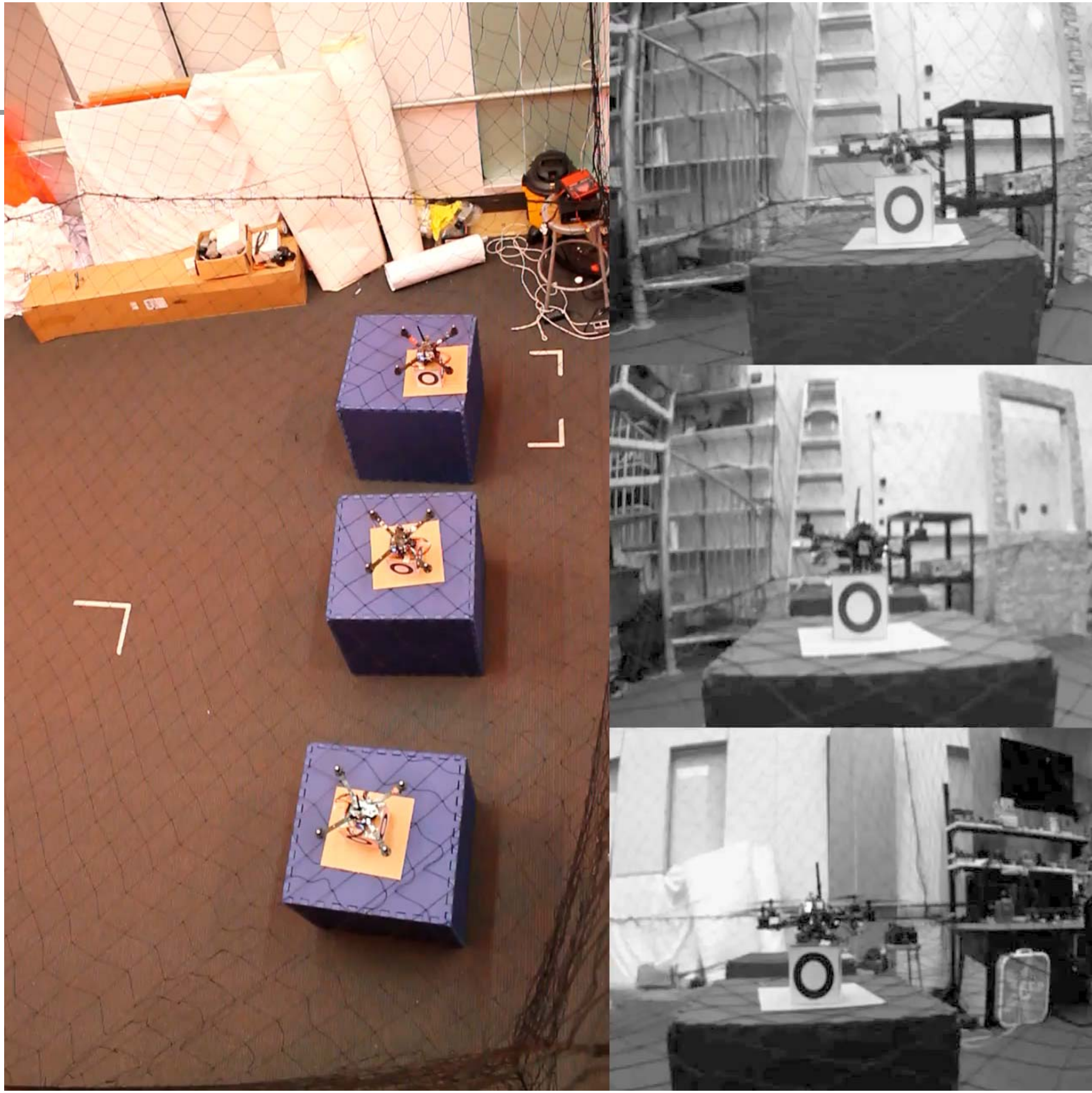

Formations for search and inspection applications

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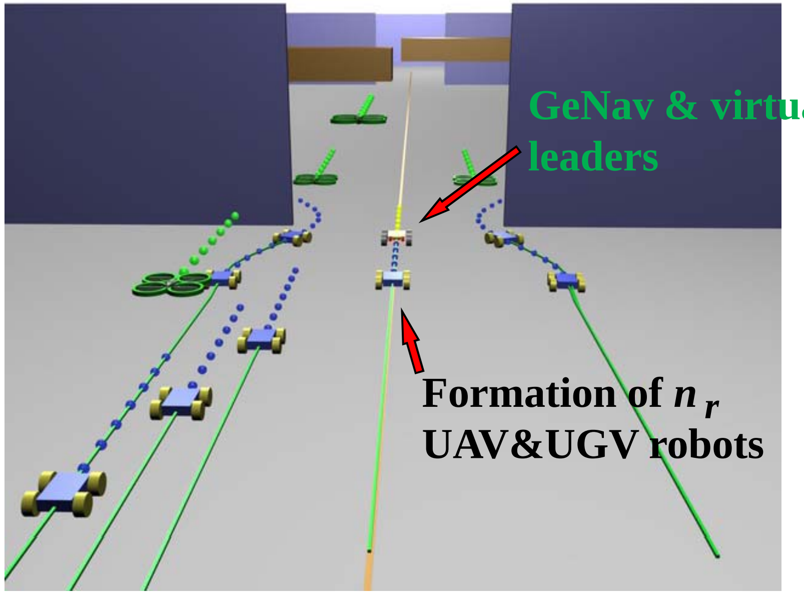
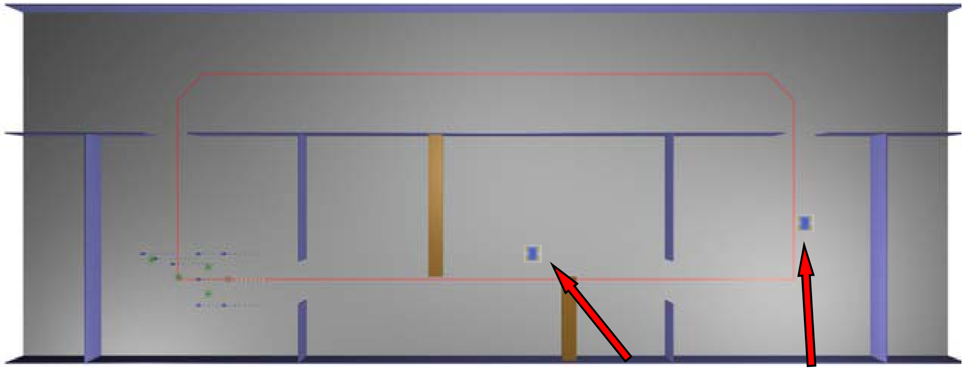
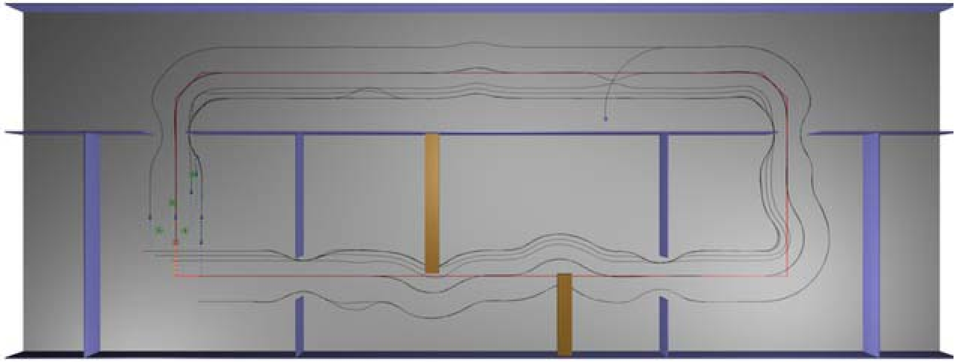




Static and dynamic obstacles



• Formation following a pre-learnt path using GeNav (surf features in images from GeNav leader's camera)

• Direct visibility between robots to provide relative localization (hawk-eye)

• Trajectory planning and optimal control for a virtual leader and followers (UGVs and MAVs) using Model Predictive Control

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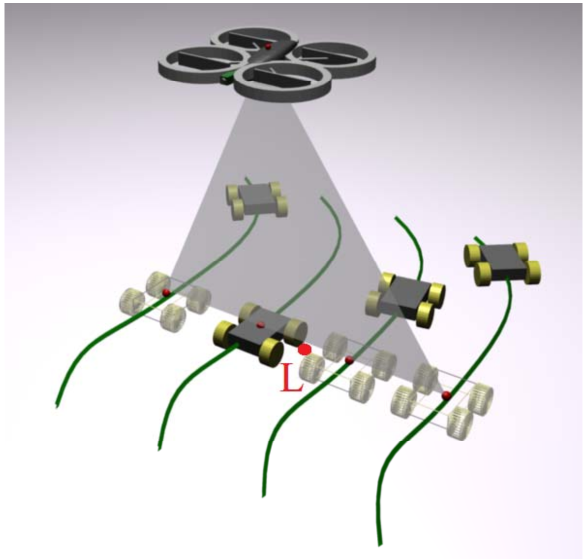
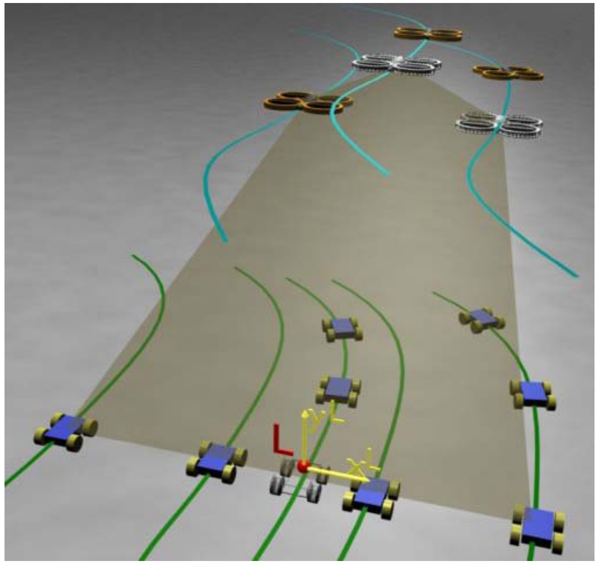
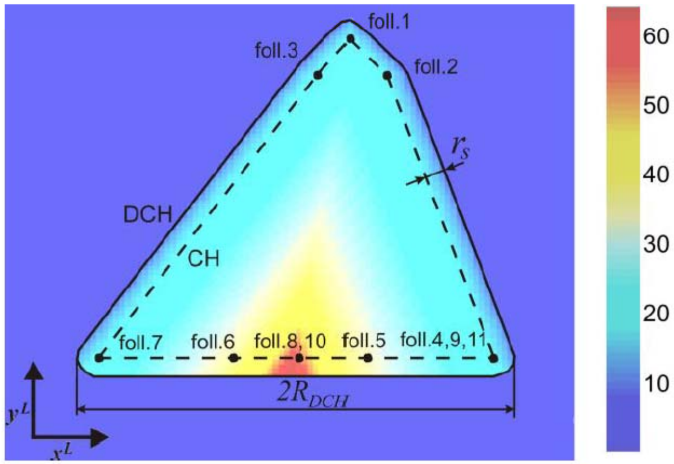
Representation of the formation for the leader's planning

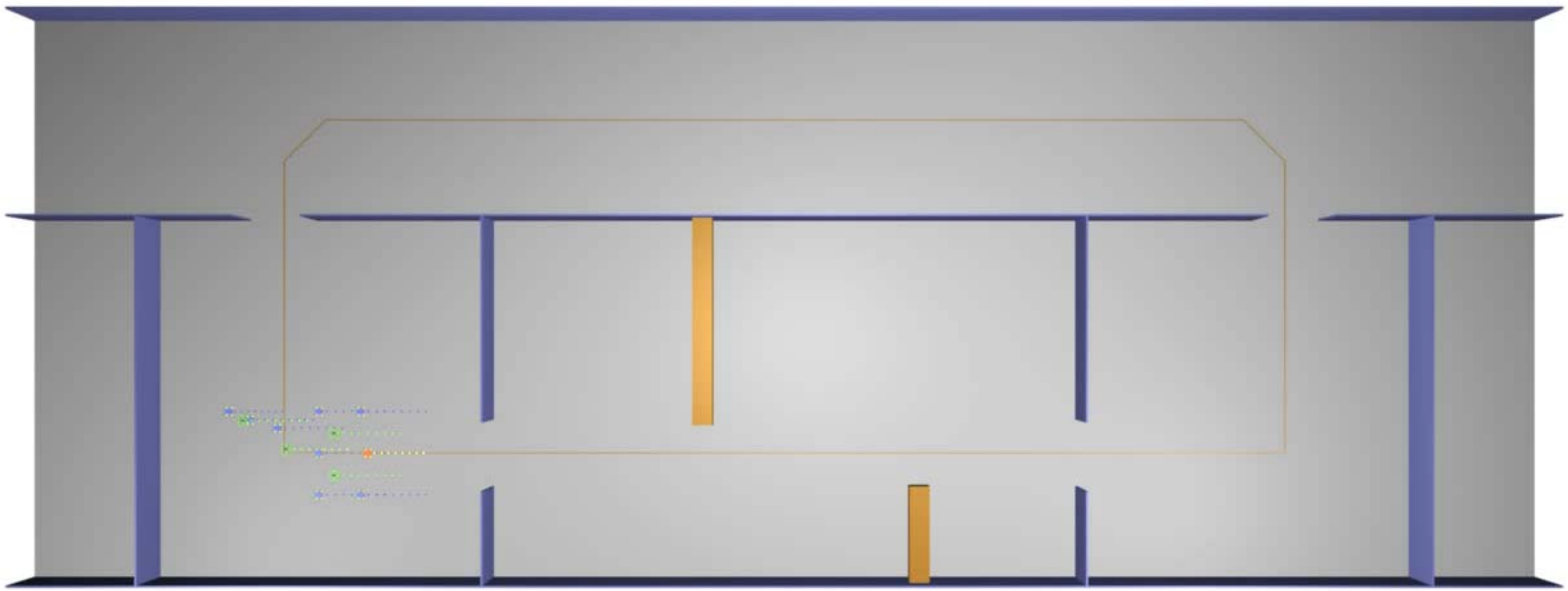




- to incorporate requirements on the direct visibility between the robots into the trajectory planning (cameras mounted on MAVs)

- convex hull of points representing positions of followers
- the positions are projected into the plane orthogonal to the trajectory of the virtual leader
- the convex hull of the set of points denotes borders of the area which should stay obstacle free





laboratory Gerstner

Saska, Krajník, Vonásek and Přeučil

Navigation, localization and stabilization of formations of unmanned aerial and ground vehicles

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Movie – swarm movement