ALPEN-ADRIA UNIVERSITÄT KLAGENFURT

From Individual Perception to Collective Behavior in MAV. A self-aware approach

Mohammad Rahmani

Pervasive Computing Group

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Swarms

Swarms are teams of homogeneous robots that

- locally perceive via sensors
- locally (re)act through actuators
- locally communicate

but are expected to

- behave collectively

to accomplish a task. (E.g collective payload delivery)

Why swarms?

- **Improved performance**: if tasks can be decomposable then by using parallelism, groups can make tasks to be performed more efficiently.
- **Task enablement**: groups of robots can do certain tasks that are impossible for a single robot.
- **Distributed sensing**: the range of sensing of a group of robots is wider than the range of a single robot.
- **Distributed action**: a group a robots can actuate in different places at the same time.
- **Fault tolerance**: under certain conditions, the failure of a single robot within a group does not imply that the given task cannot be accomplished, thanks to the redundancy of the system.

Leadership in swarms

- Static leadership
- Dynamic leadership (E.g. In collective movement: The agent closer to the destination takes temporarily the leadership)
- No leader (Most frequent in swarms. E.g. Each agent knows the final destination)

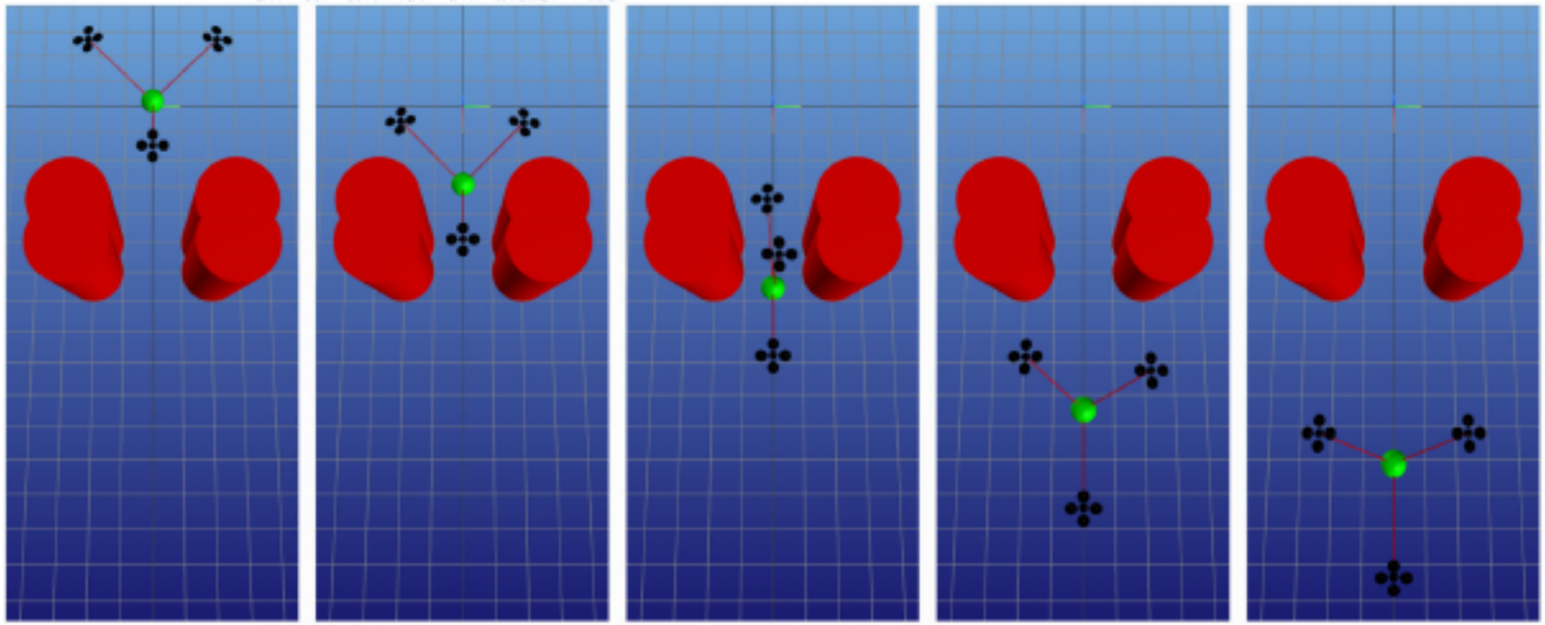
Issues in maintaining collective homeostasis conditions

The ultimate goal of self-awareness is to help an IA to maintain its homeostasis condition. One approach to achieve this is to equip an IA with

- an initial experience with which it can achieve its task
- the ability to detect new experiences
  - model, store and retrieve them back for prediction
- make appropriate decisions according to future states predictions

Issues in maintaining collective homeostasis conditions

The same can be applied to collective awareness which translates to anomaly detection in existing course of relation between agents. This course of relation can be formalized as the dynamism of vector distance between agents. (But there are other ways too[1])



[1] Baydoun, M., Campo, D., Kanapram, D., Marcenaro, L., &

Issues in maintaining collective homeostasis conditions

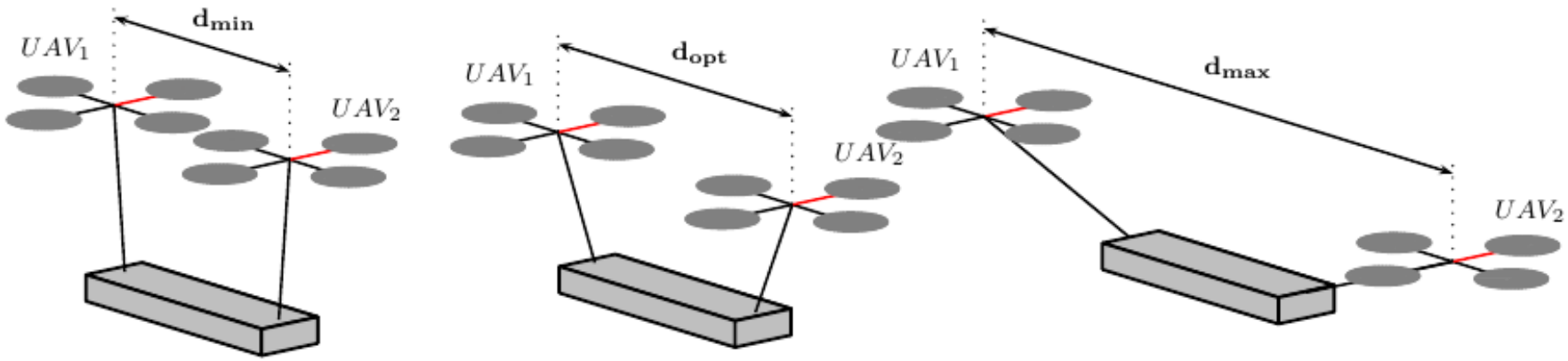
Example: Flocking (Reynolds laws of boids: how to stay in a flock)

- Move in the same direction as their neighbors
- Alignment - steer towards average heading of neighbors
- Cohesion - steer towards average position of neighbors (long range attraction)

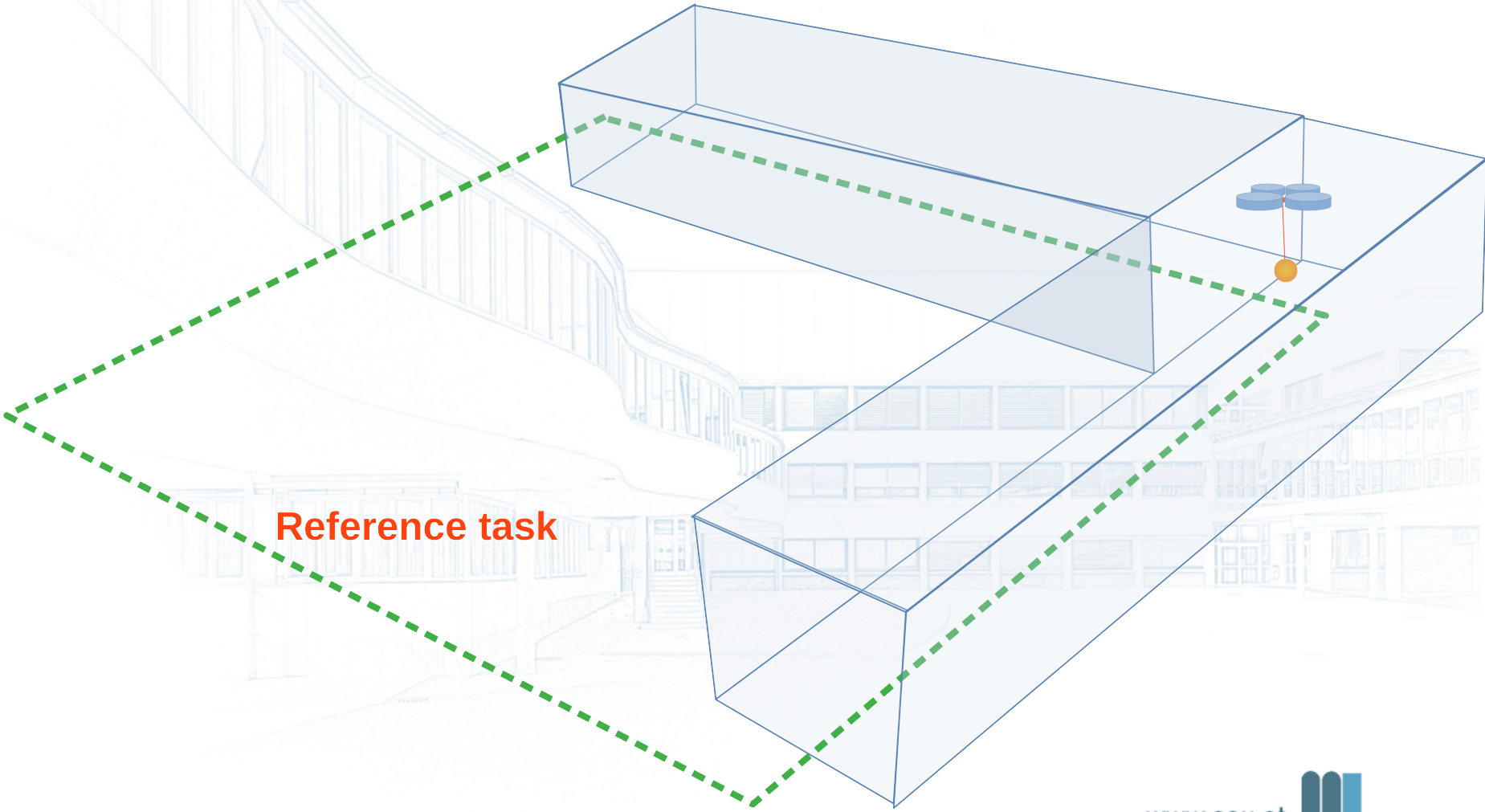
Issues in maintaining collective homeostasis conditions

Example: Collective load transportation

- If the two drones are too close, then the whole system's homeostasis level is threatened by external disturbances
- If the two drones are too far away from each other then the two drones higher energy consumption threatens the homeostasis level of the system



Dynamic Individual behavior modeling, reference task



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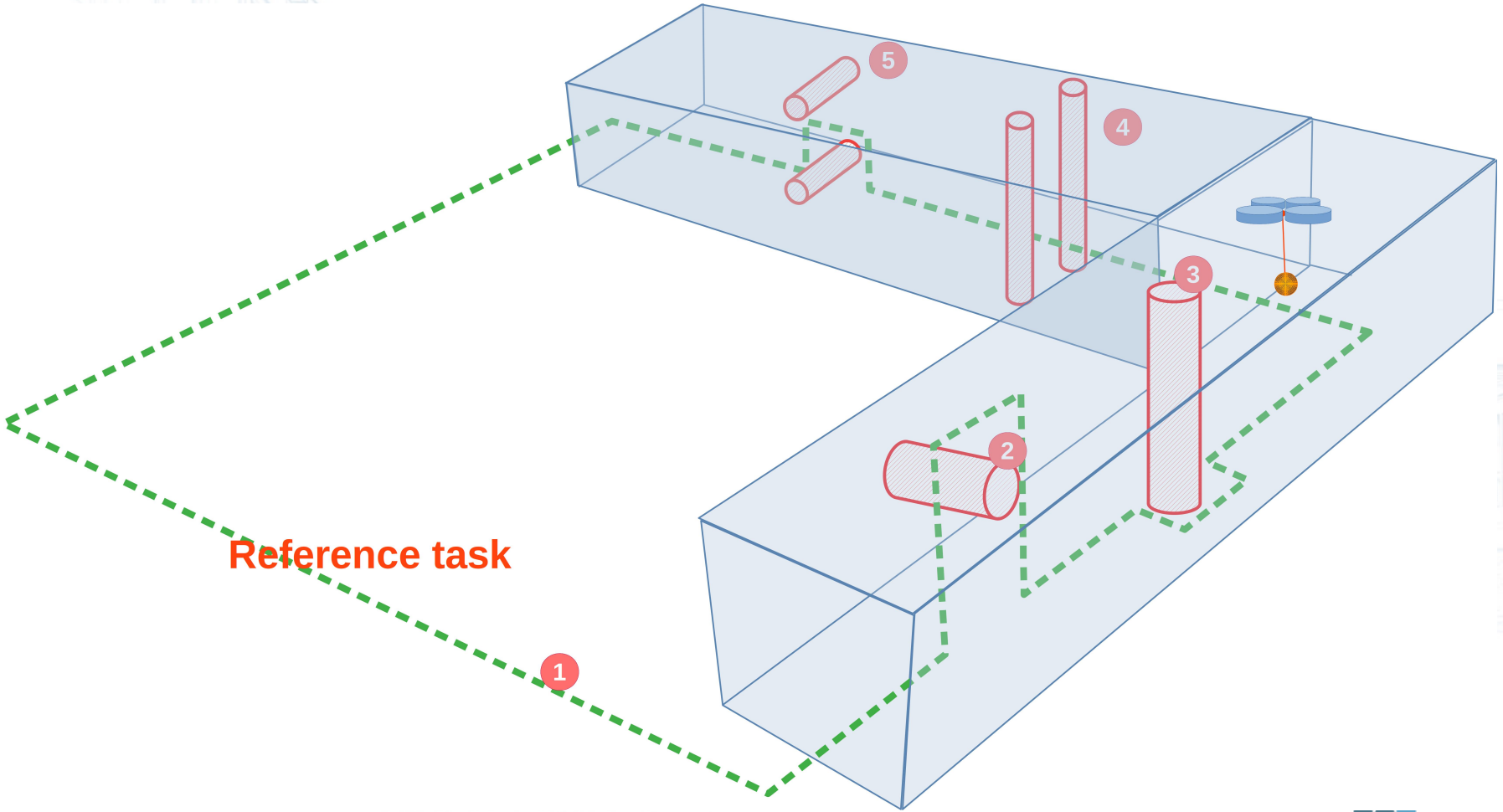
Modeling new individual experiences



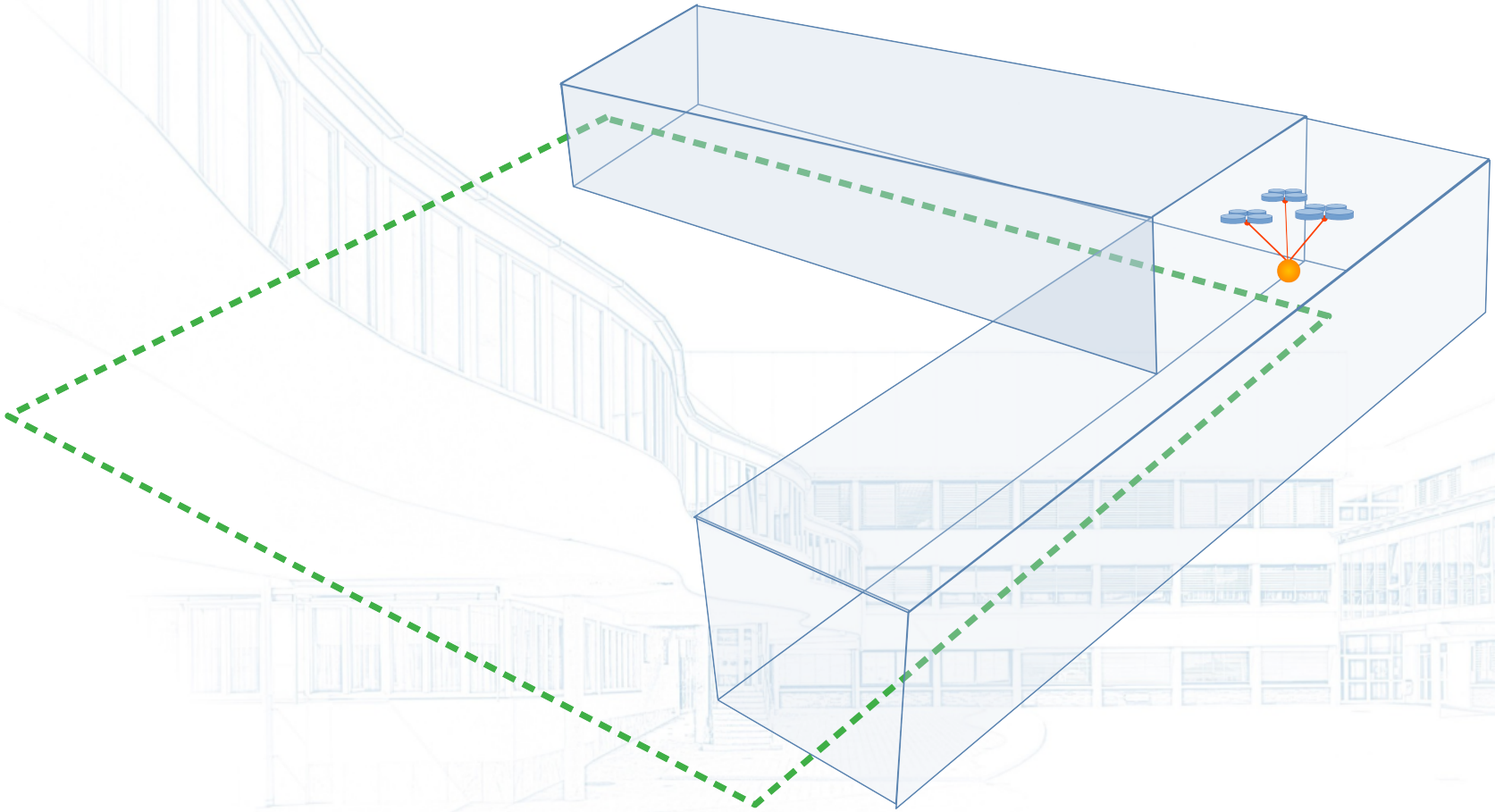
Modeling new individual experiences

Kanapram et al., 2020[2] uses words formed of different time derivative of states to train the individual DBNs.

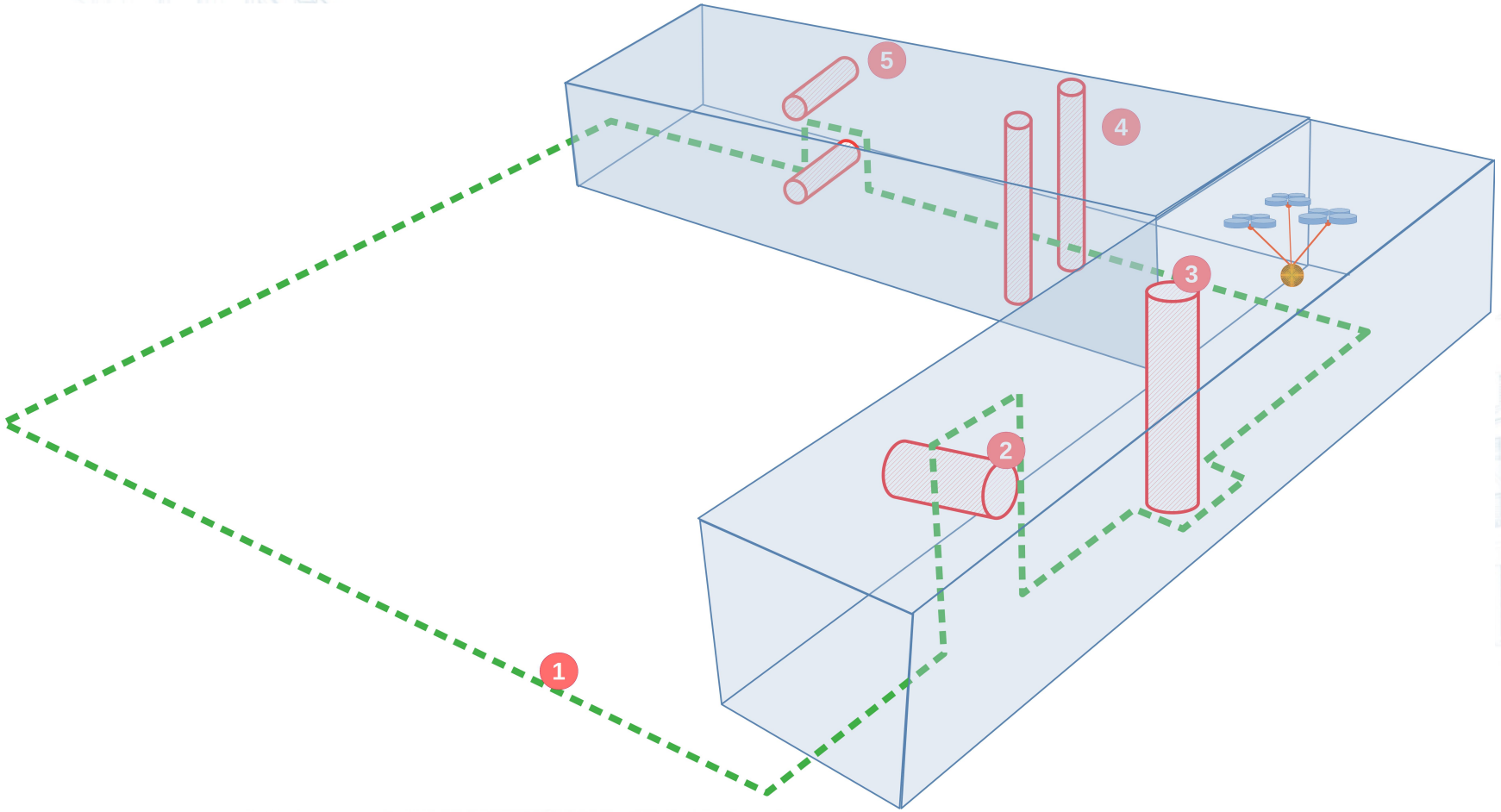
$$W_j = \{\alpha^{(0)}, ..., \alpha^{(L)}\} \tag{1}$$

[2] Kanapram, D., Patrone, F., Marín-Plaza, P., Marchese, M., Bodanese, E. L., Marcenaro, L., ... Regazzoni, C. S. (2020). Collective awareness for abnormality detection in connected autonomous vehicles.

Dynamic collective behavior modeling - reference task



Dynamic new collective behavior modeling



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Modeling new collective experiences - Training

Each experience can be modeled as mutual quasi-constant state regions proposed in Baydoun et al., 2019[3]

$$W_{ij} = \{S_i, S_j\} \tag{2}$$

$$DBN_{f_{ij}} = \{D_{f_{1_{ij}}}, ..., D_{f_{n_{ij}}}\} \tag{3}$$

For each experience we have one collective experience

$$DBNs = \{DBN_1, ..., DBN_p\} \tag{4}$$

[3] Baydoun, M., Campo, D., Kanapram, D., Marcenaro, L., & Regazzoni, C. S. (2019). Prediction of multi-target dynamics using discrete descriptors: An interactive approach.

Question

If each IA communicate its current state to its neighbors with Kanapram et al., 2020 words, how precisely can we map a set of communicated words to a collective DBN in Baydoun et al., 2019 or recognize it as a new collective experience.

- In other words can informing on individual efforts to maintain individual homeostasis help with a quicker decision of practicing an appropriate collective behavior?