

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

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# Swarms

Swarms a set of identical robots that

- locally perceive via sensors
- locally act through actuators
- locally communicate

but are expected to

- behave collectively

# An approach in collective awareness

Imagine a collection of agents navigating from a starting point to a destination (attraction) point and on their way they face repulsive forces against which they should overcome

- As the dynamism of each IA can be described in the form of a DBN, the course of their relationship over time until reaching the destination can also be described by a DBN

## An approach in collective awareness

**Formation:** Is a consensus between a set agents to maintain the distance vector between themselves over a certain amount of time i.e. if  $A$  is the set of the agents in the system

$$A = \{a_1, \dots, a_{|A|}\} \quad (1)$$

then the distance vector to form the formation  $i$  that agent  $a_j$  should be aware about  $k$  neighboring agents can be defined as

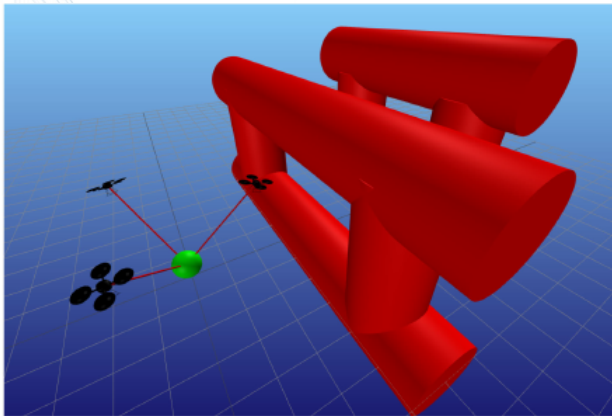
$$D_{ijk} = \{\vec{d}_{jp}(a_j, a_p) | p \in \{1, \dots, n_k\}\} \quad (2)$$

The formation  $i$  for the whole system can be defined

$$F_i = \{D_{ij} | i \in \{1, \dots, |A|\}\} \quad (3)$$

If a formation is maintained for time  $t$  then  $F_t$  will present a temporal formation.

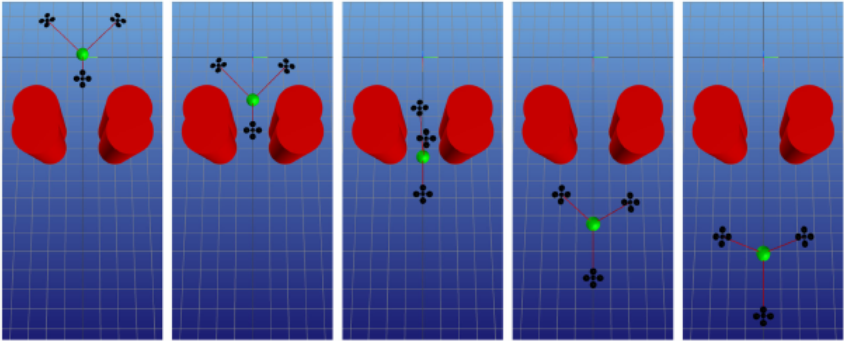
# Temporal formation



# Maneuver, Collective behavior

- **Maneuver** is changing from one formation to another over the course of time.
- **Collective behavior or a temporal behavior** is a temporal formation or a maneuver between the agents.

# Maneuver



# Predictive models for collective behavior

- Both maintaining a temporal formation or maneuver are dynamic systems which shows the **evolution of distance vector over the course of time** and hence could be formalized by a transition matrix.
- Can this transition matrix trained by repeating the temporal formation or the maneuver and be stored for future state predictions as a **model** or **experience** as a DBN similar to an individual agent state prediction model?



## Training the collective behavior DBN

- One approach is to **discretize** the **state space** of each individual agent in a collective behavior to **quasi-motion constant regions** and the temporal sequence of co-occurrence of each agent's region with another neighboring agent can form the alphabet for the words of a sentence describing the evolution of the relation between two agents. (Taking an approach similar to <sup>1</sup>)
- An **anomaly** can be defined as the **distance** above the **tolerance rate** between **expected/predicted state** in this relationship and **observed state** in comparison to practicing model.

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<sup>1</sup>Baydoun 2019 Prediction of multi target dynamics using discrete descriptors an interactive approach

## Why should we observe anomaly in a collective behavior?

- Each agent tries to **save itself** as such the intersecting quasi-motion regions will not occur as they were predicted and collective anomaly occurs.
- But if other agents do not react accordingly the whole system collapse (Systems homeostasis will collapse for the sake of maintaining an individual's homeostasis).
- **Solution:** Choosing the right collective DBN to practice according to which each individual should adjust it's motion to avoid whole system's collapse

## Probable implementation

- 1 **Discretizing** the motion state space of agents to **different derivative orders of time**<sup>2</sup>
- 2 Use the **composition** of these **different derivative orders** as **words** to communicate any **motion state change** of each agent to neighboring agents
- 3 Train a model to **map** the **words received** by an agent from its neighboring agents to a **collective behavior** defined by the words of the DBN representing a collective behavior.

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<sup>2</sup>Kanapram 2020 Collective awareness for abnormality detection in connected autonomous vehicles

## Scenario