

# From individual perception to collective behavior in drones. A self-aware approach

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31 August 2020

# Topics

- Self-awareness as a dynamic Bayesian networks approach
- Force field analysis of repulsive and attractive forces
- Variational auto encoders
- Continual/lifelong learning learning

# Intelligent Agents, Sensors and Actuators

Each intelligent agent, biological or artificial, incorporates:

- Sensors
  - Proprioceptive (Cochlea, IMU)
  - Exteroceptive (Eyes, Camera)
- Actuators (Feet, Engine)

# Self-awareness (SA)

Self-awareness incorporates agent's ability to become the object of its own attention which translates to the following abilities (See next slide) <sup>1</sup>

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<sup>1</sup>Regazzoni, C. S., Marcenaro, L., Campo, D., & Rinner, B. (2020).

Multisensorial generative and descriptive self-awareness models for autonomous systems.

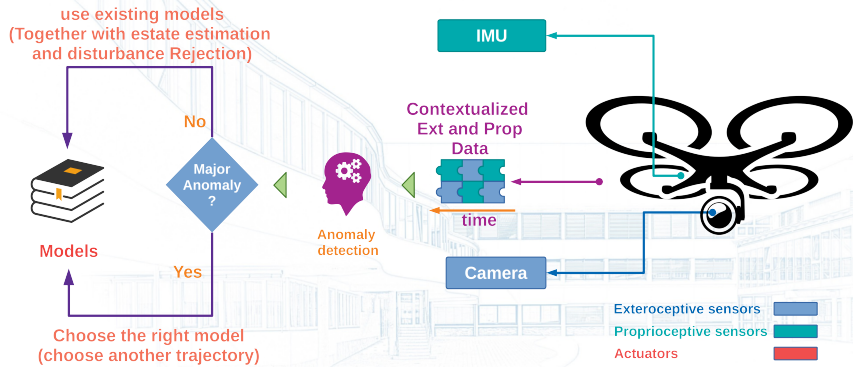
## Self-awareness (SA) - Abilities list

- **Initialization** Ability to follow a reference task over the course of time (Time-awareness)
- **Major anomaly detection and Generative Model building:** Ability to detect new experiences from exteroceptive and proprioceptive sensory data
- **Memorization and discrimination:** Ability to memorize and provoke the appropriate learned experience

## Self-awareness (SA) - Abilities list - 2

- **Decision making:** Converting anomaly signals to appropriate actions
  - **Disturbance rejection:** convert minor anomaly signals to actions such the distance between estimated states and current practicing model minimizes
  - **Changing practicing model:** changing from one model to another model in case of major anomaly detection

# Simple illustration of an SA drone



SA, sensors and actuators

# SA in Single drone navigation and aerial manipulation

The aforementioned abilities in a single drone translates to:

- Path/motion planning
- State estimation
- Trajectory tracking
  - **Minor anomaly detection** Disturbance rejection
- **Major anomaly detection** Anomaly detection: Collision avoidance
  - Corridor turning points
  - Vertical collision avoidance
  - Horizontal collision avoidance



# Collective Awareness CA abilities

In addition to individual SA abilities in the collection, CA must incorporate anomaly detection ability for

- the course of relationship/formation which should be kept along time

Our examples will be based on collective load transportation which entails keeping drones close to each other in particular formation which are either

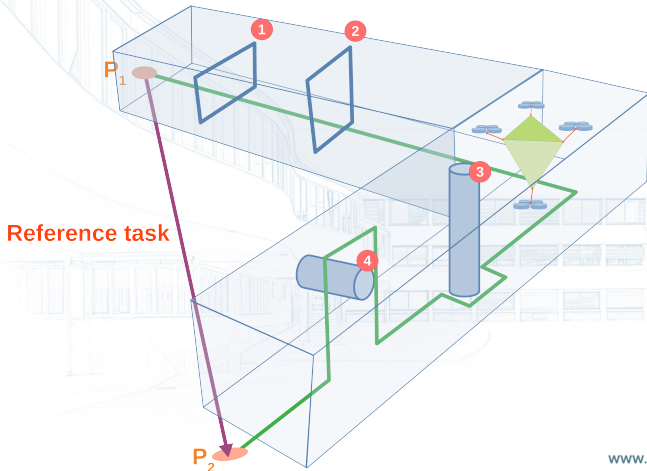
- attached to rigid loads
- suspended from a cable

# CA in multi drones navigation and aerial manipulation

- Collective path/motion planning
- Formation state estimation
- Formation Anomaly detection while individuals perform collision avoidance maneuvers and taking the right decision toward a new appropriate formation to avoid load and system collision

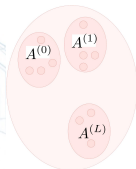
## CA scenarios

CA formation models from which appropriate actions should be practiced



## Individual semantic emergence

Discretized<sup>2</sup> generalized state for different derivatives of time forms the alphabet of words by which each individual agent can describe the experiences it is practicing to other agents<sup>3</sup>



$$w = \{\alpha^{(0)}, \dots, \alpha^{(L)}\} \quad (1)$$

<sup>2</sup>Fiser, D., Faigl, J., & Kulich, M. (2013). Growing neural gas efficiently.

<sup>3</sup>Kanapram, D., Marin-Plaza, P., Marcenaro, L., Martin, D., & Arturo de la Escalera, C. R. (2019). Cognitive dynamic systems: Perception-action cycle, radar and radio.

# Collective semantic emergence

Mutually activated discretized generalized state space for the collective language<sup>4</sup>

Words are  
synchronously  
activated  
Zones in the  
absence of  
repulsive forces



<sup>4</sup>Baydoun, M., Campo, D., Kanapram, D., Marcenaro, L., & Regazzoni, C. S. (2019). Prediction of multi-target dynamics using discrete descriptors: An interactive approach.

## Question

How should emergence and frequency of locally communicated phrases of individual agent experiences persuade an agent toward either

- **Reacting to major collective anomaly** Taking actions to perform a part of a collective behavior to keep homeostasis situation
- **Reacting to minor collective anomaly** To ignore them and devolve it to individual disturbance rejection module in each individual agent.