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

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Intelligent Agents (IA), Sensors and Actuators

Each IA, either biological or artificial, incorporates:

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

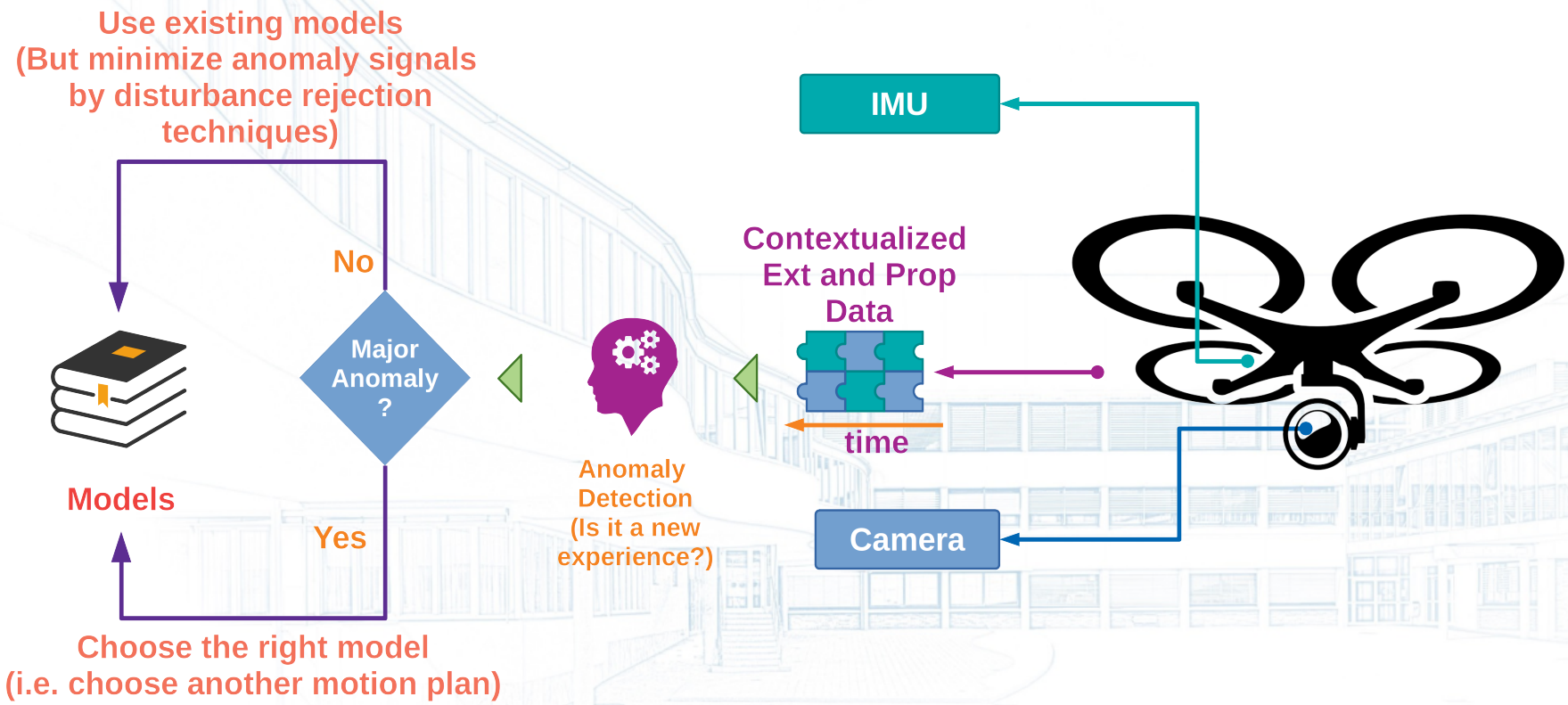
Self-awareness (SA)

SA is an approach in AI to enable IAs making a distinction between their **previous** experiences (The first one forms the initial knowledge) and new experiences observed by the sensors (**Abnormality detection**) [1] and

- build predictive generalized state models from these new experiences
- store them and retrieve them to predict and plan future motions
- make appropriate decisions such as disturbance rejection or motion re-planning via actuators

[1] Regazzoni, C. S., Marcenaro, L., Campo, D., & Rinner, B. (2020). Multisensorial generative and descriptive self-awareness models for autonomous systems.

Simple illustration of an SA drone



SA, sensors and actuators

The ultimate goal of a self-aware IA

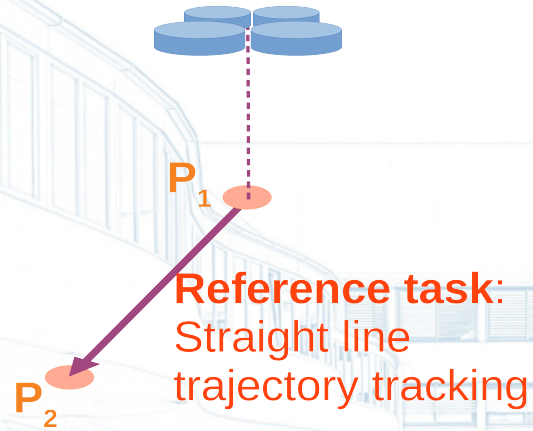
- To maintain its homeostasis condition over the course of time by taking advantage of the modeled experiences to predict future states in order to plan and act accordingly to improve
  - Resource management
  - Security
  - Safety

For this proposal embodies in Collision avoidance

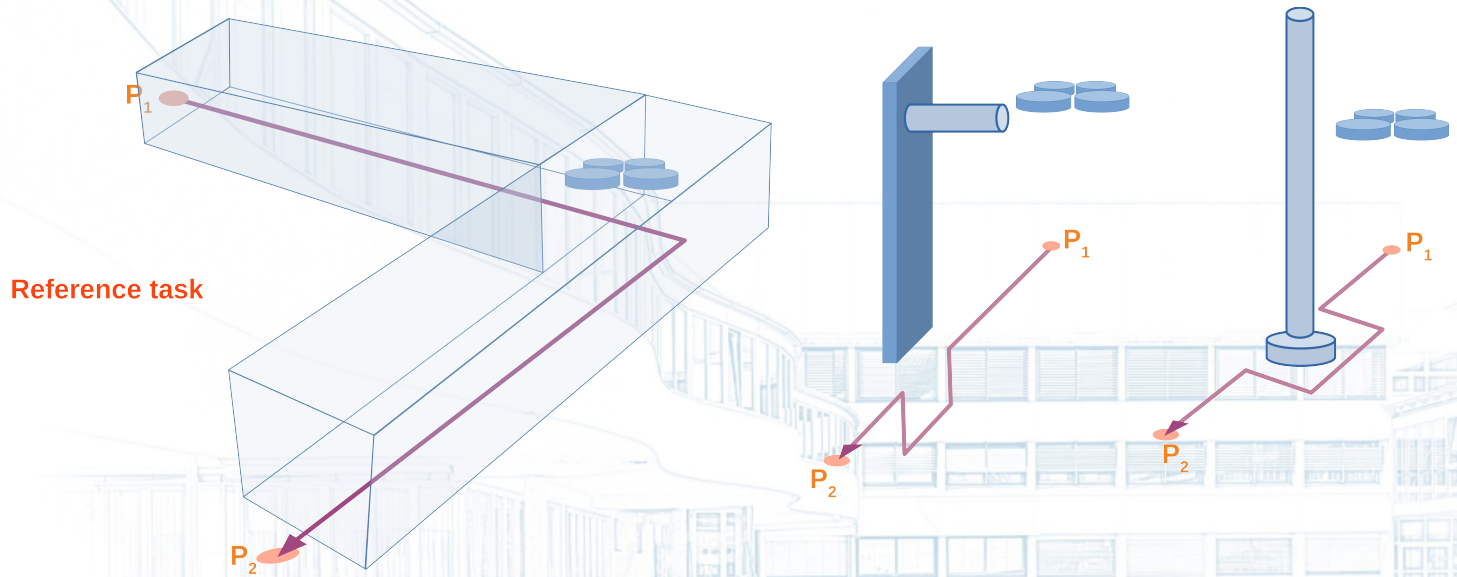
Existing dynamic models on continuous generalized state space

- DBN = A Markov chain that each of its state nodes is predicted by a bank of KFs

Reference scenario in classical models



Force field theory and the obstacles to overcome in classical mod



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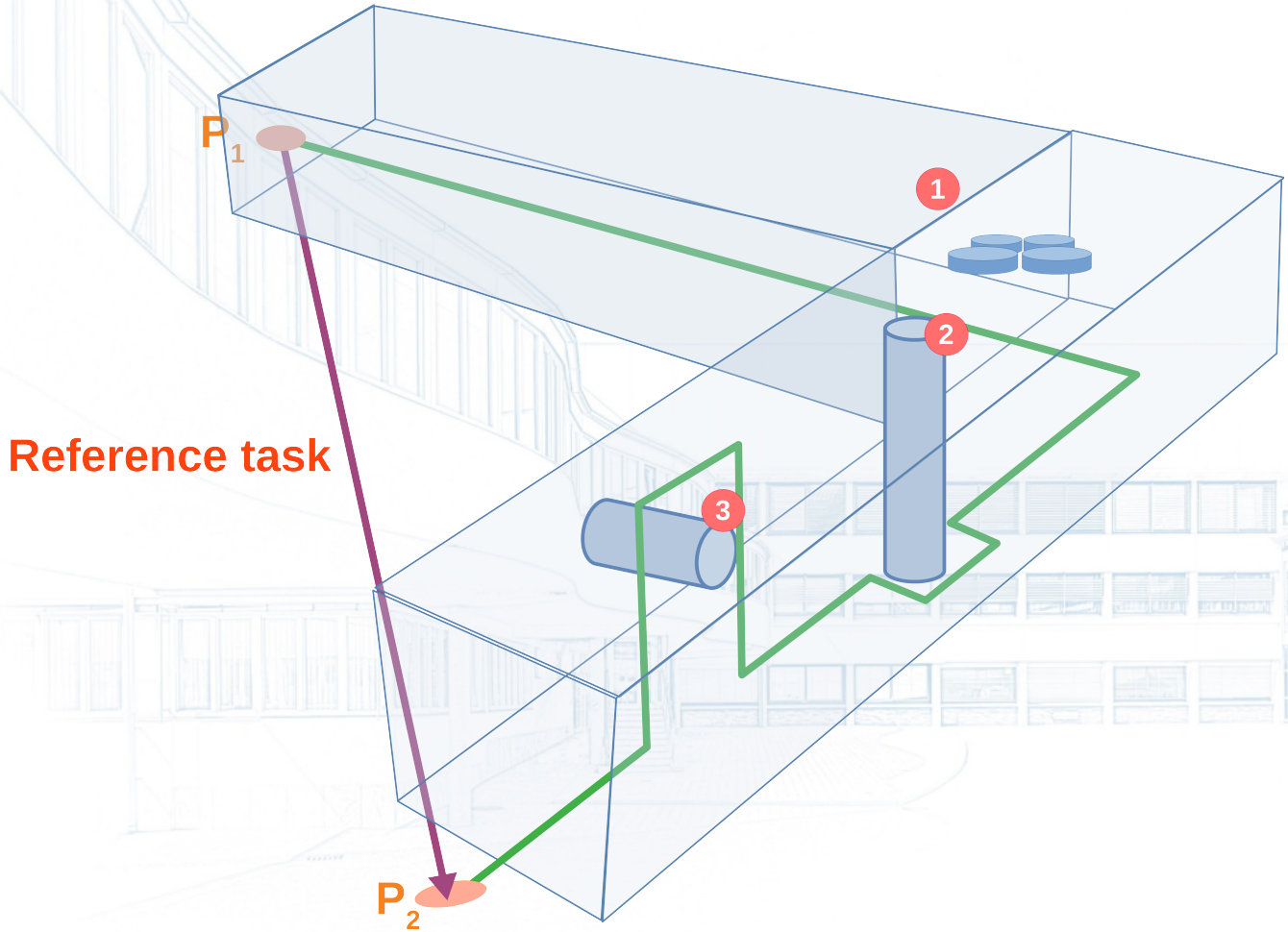
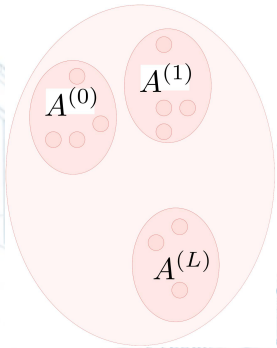
All experiences



First language: Building a switching, predictive models for each i

Discretized 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 [2]



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

[2] 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.

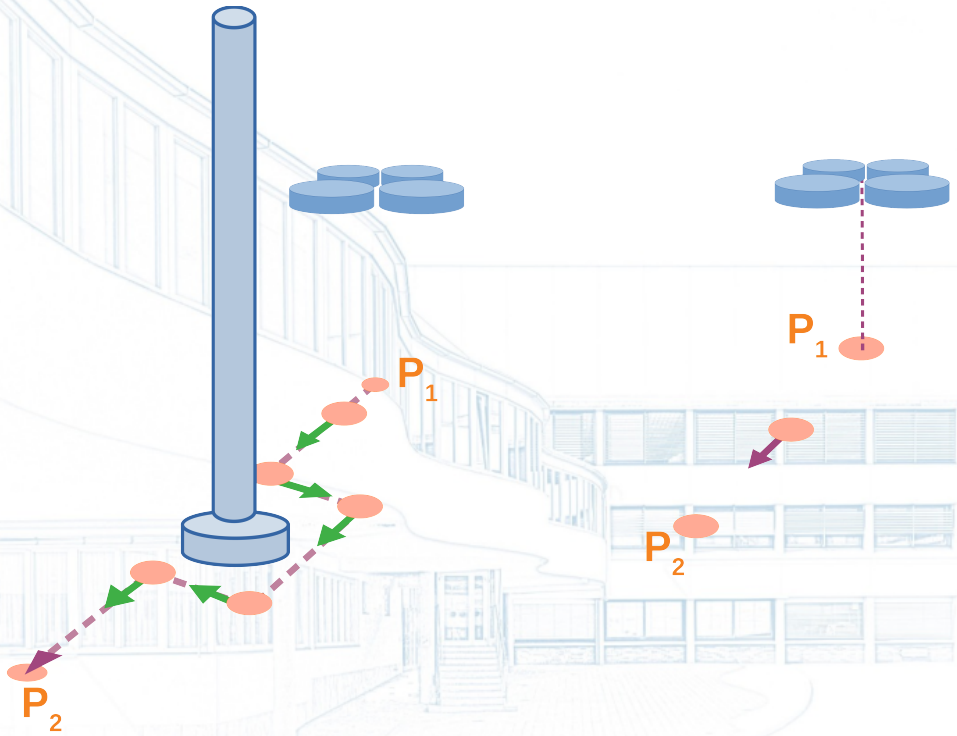
First language: Discretization technique

Discretization

- GNG[3]
  - Online

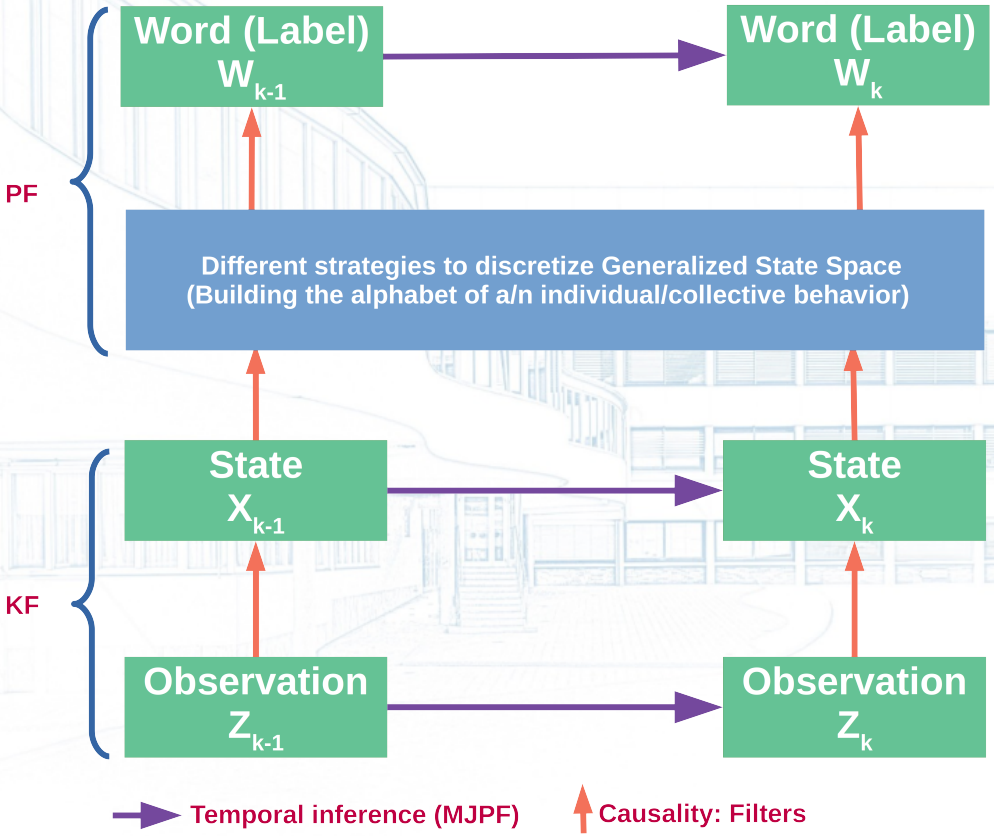
[3] Fiser, D., Faigl, J., & Kulich, M. (2013). Growing neural gas efficiently.

Reference and Vertical obstacle avoidance in the first language



A novel dynamic switching models, MJPF

- MJPF (DBN = Level 1: Bank of KF - Level 2: Bank of PF in each Markov chain state)



Collective Self-awareness (CA)

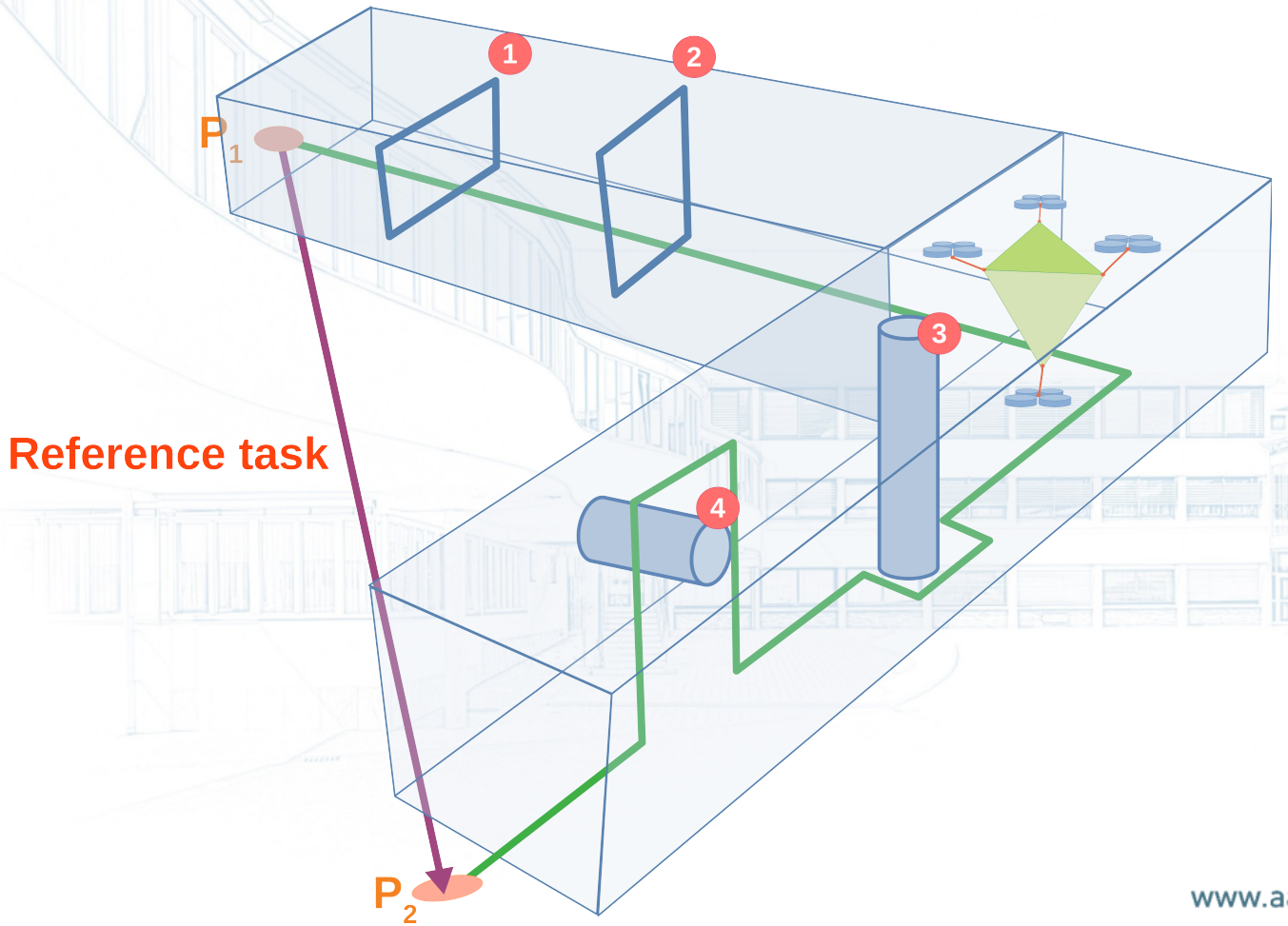
- The ability to detect abnormality in the course of relation that a collection of IAs were supposed to maintain to make appropriate decisions by the actuators to improve collective homeostasis conditions
  - **Example**: Taking an appropriate **formation** when the collection faces a factor detrimental to its collective homeostasis condition

CA in multi-MAV navigation for aerial manipulation

Not only each individual IA must be aware of new experiences observed from the environment, but also they must be able to detect anomaly in the motion of other agents in the collection.

CA scenarios

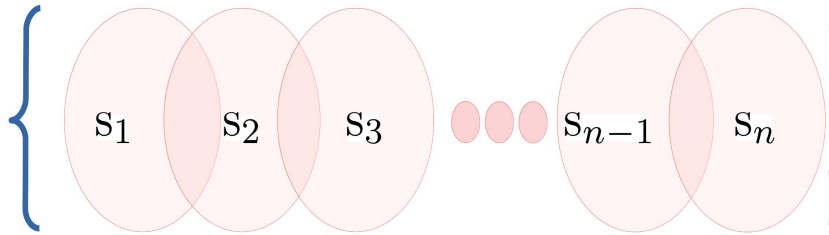
CA formation models from which appropriate actions should be practiced



Second language: Describing the course of a collective behavior

Mutually activated discretized generalized state space form the collective language which can describe the expected behavior of a collection of agents are supposed to expose over a certain course of time [4]

Words are synchronously activated Zones in the absence of repulsive forces



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

Second language: Discretization technique

Discretization

- SOM[5] or even a simple K-means
  - Offline

[5] Kohonen, T. (2001). Self-organizing maps. *Springer Berlin Heidelberg*.

Continual/life long learning for both SA and CA

- Variational Auto Encoders/Decoders (To generate different versions of the same experience)
- Continual/Lifelong learning (To include all experiences in one model)
- Define an abnormality tolerance level which adopts to newly added models

The main challenge

If each agent describes the following changes to it's neighboring agents

- Generalized state described by the first language
- Practicing predictive model trained by the first language

, then the main challenge is to train a model to

- map samples of the aforementioned populations to a sentence of the second language

to find out how efficient such model can improve homeostasis level of individual agents and the whole system.

Simulation environment

- ROS as robot simulation tool
- GAZEBO as simulation tool
- MAVLINK as communication standard
  - MAVSDK ... Python implementation