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

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Content

- Concepts and methods
  - A Dynamic Bayesian Network (DBN) approach in Self-awareness (SA) and characteristics of a self-aware Intelligent Agent (IA)
- A proposal for Collective Self-awareness (CA) application in a multi-UAV system

Intelligent Agents (IA), Sensors and Actuators

Each IA, either biological or artificial, incorporates:

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

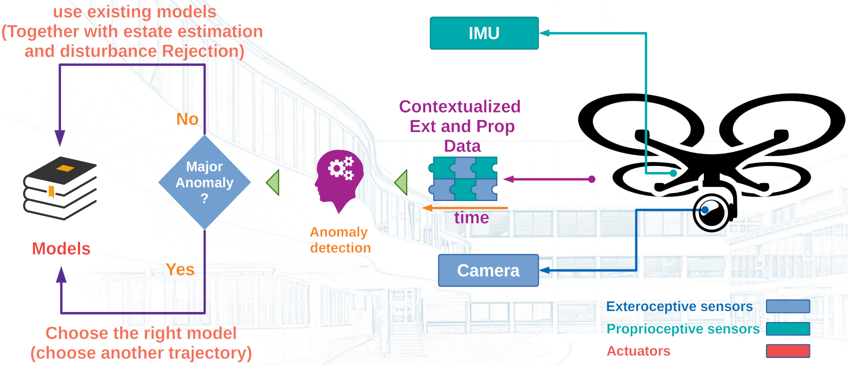
Self-awareness (SA)

SA is an approach in Artificial Intelligence to enable IAs to make a distinction between their previous experiences and new experiences observed by the sensors (Abnormality detection) [1] and

- build predictive models from these new experiences
- store them and retrieve them to predict and plan future
- Make appropriate decisions such as disturbance rejection or path re-planning

[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 improve issues such as
  - Resource management
  - Security
  - Safety

Collective Self-awareness (SA)

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

Tools and Theories to Implement SA/CA

- Dynamic Bayesian Networks such as
  - Markov Jump Linear Systems (KF+DBN) [2]
  - Markov Jump Particle (KF+PF+DBN) Systems[3]
- Force Field Analysis (Autonomous navigation)
- Variational Auto Encoders (To generate different versions of the same experience)
- Continual/Lifelong learning (To include all experiences in one model)

[2] doucet-2001-particle-filters-for-state-estimation-of-jump-markov-linear-systems
[3] baydoun-2018-learning-switching-models-for-abnormality-detection-for-autono

SA in Single UAV Navigation for Aerial Manipulation

The aforementioned abilities in a single UAV navigation in tight spaces such as buildings translates to:

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

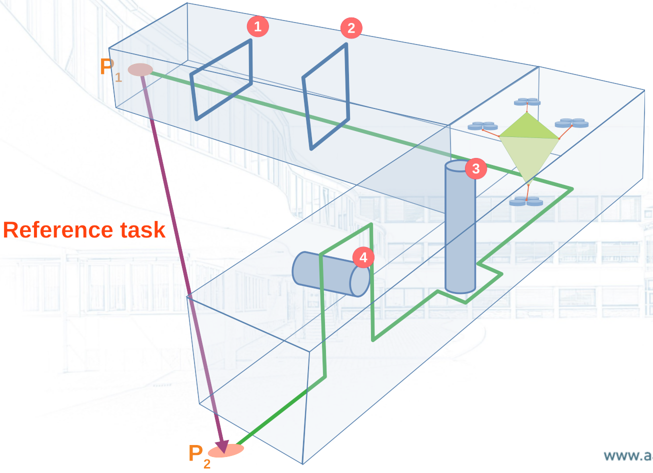
CA in Multi UAV Navigation for Aerial Manipulation

Not only each individual IA must be SA, but also the whole collection should include these abilities:

- **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

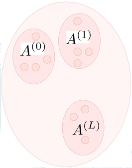
CA scenarios

CA formation models from which appropriate actions should be practiced



First Language: Individual Semantic Emergence

Discretized[4] 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 [5]



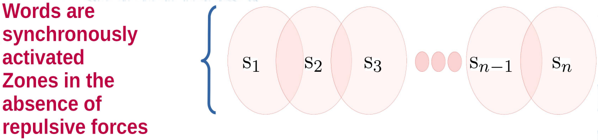
$$w = \{\alpha^{(0)}, ..., \alpha^{(L)}\} \tag{1}$$

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

[5] 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.

Second language: Collective Semantic Emergence

Mutually activated discretized generalized state space form the collective language which can describe the relation(Formation) a collection of agents are supposed to maintain over the course of time [6]



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

Future plan

How should emergence and frequency of locally communicated phrases of individual agent experiences in the first language be either

- mapped to those of the second language to form predictive models
- or used as a new anomaly detection method upon which new predictive models can be extracted

Drone hub, Klagenfurt University UAV lab

- uav.aau.at
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