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Collective Self-awareness in Multi-Robot systems

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Collective-awareness (CA) in Multi-robot systems (MRS)

Self-awareness is an intelligent agent's (IA) ability to realize that it is experiencing something new for which it may need to build models, memorize them, compare them to previous experiences and retrieve them in future for such comparison.

Difference between robots and other Intelligent Agents (IAs)

- A robot is a dynamic system acting in a dynamic environment
  - Dynamism means states change over the course time in both the robot and the environment.
- They have actuators with which they can manipulate their state space

Difference between robots and other IAs - Sensors

They have sensors with which they can observe/measure the state in which they are.

- Sensor types
  - Proprioceptive sensors: To observe/measure/assess their current state
  - Exteroceptive sensors: To observe/measure/assess the environment's current state

Difference between robots and other IAs - Sensors - 2

- The data generated from these sensors may be put together contextually **dispositional units (DUs)** [1] or even hierarchically in which each sequence of data contains another sequence of data or DUs at the leaves.
- **Sensor noise** is the difference sensor observation/measurement and the real state in which the robot is. For example the difference between the GPS sensor observation about the position of a robot and its real position.
- **Experience**: A sequence of the data perceived by these sensors can be regarded as an experience.

[1] Damasio, A. (1999). *The feeling of what happens : Body and emotion in the making of consciousness*. New York, Harcourt Brace for study

State space

Can be

- Discreet
- Continuous

A continuous space state can be discretized to

- reduce computational complexity in model creation
- form a language to enhance interaction between robots for model sharing
- to define the grammar of a relation between several robots

Self-aware robot particularities - 1

A self-aware robot needs

- **Initialization** An initial knowledge/model that it can be developed according to its comparison with new models
- **Anomaly detection / descriminative modeling** A comparing ability with which it can compare the new experience in comparison to existing experiences
- **Memorization** A memorization system with which it can store and invoke the created models for comparison against a new experience

Self-aware robot particularities - 2

A self-aware robot needs

- **(Generative) Model creation** an ability with which it can create new models when the new experience is different enough (measured by discriminative / abnormality detection models) from existing generative models predictions so that it can better predict future.
- **Decision making** An ability with which it can determine which actions to take according to the sequences of experienced and predicted states to minimize the abnormality size until the creation of a new generative model which describes the robot and the environment better.

Initial knowledge

New Experience realization always happens in comparison to previous generative models.

- The very first experience is called the **initial knowledge**.

New models will be created, compared and memorized according to this model.

Initialization methods

- Manual training (e.g. Human training)
- Reinforcement Learning (RL)
- Evolutionary algorithms

Generative, temporal-causal modeling

Generative models are better to incorporate the following two specifications:

- **Temporality**: which should predict the most probable next observation after a certain amount of time.
- **Causality**: which should predict what exteroceptive experience causes emergence of an proprioceptive experience and vise versa.

In both above cases, models may consider exteroceptive and proprioceptive experience individually or as DUs.

Anomaly detection / descriminative modeling

- **Definition**: Anomaly is the difference between the current observation/experience and the predication of generative models.

Imagine the two following scenarios:

- **Scenario A**: A drone is initially trained to autonomously fly from point A to point B (initial knowledge/experience).
- **Scenario B**: The same drone on the same mission encounters a new obstacle around which it should turn to continue it's previous path.

Learning from anomaly

- In scenario A, only one predicting model is needed to predict the future, lets call it M_1
- In scenario B, two models are needed to predict the future states together in a sequence such as M_1, M_2, M_1
  - M_1 to predict the future state in strait paths
  - M_2 to predict the future state in the curve

New Generative model creation

Without M_2, a human can take control of the drone to turn it around the building and then the drone by taking advantage of its descriminative model, detects abnormality and consequently encodes the new state transition over the course of time to M_2.The human is replaceable by to build M_2 and use it as a new model for future hybrid generative models.

- Reinforcement Learning
- Evolutionary Algorithms
- ...

Generative model types in MRS

In MRS two different kind of self-awareness can be introduced

- Single robot state change in each robot (Discussed earlier)
- Inter-relation state change
  - Two drones should directly go from Point A to Point B while keeping their interconnecting **distance** vector constant.

Sources where abnormality should be sought

- **In single RS**: Difference between new experiment and generative models
- In MRS external observation of a robot may be composed of:
  - In the difference between the generative model prediction and current experience in each single robot
  - Comparison of transmitted new experience from other robots with regard to their previously shared generative models among others
  - In the difference between generative model prediction on the course of relation between the robots and the current experience.

from which we suppose new models arise for better description of collective and individual behavior of the agents in an MRS.

Decision making

Decision making is the matter of using actuators such that abnormality is kept minimum until new generative models are made. These acting models may use

- Reinforcement learning
- Evolutionary algorithms

to act in such a way.

References I

Damasio, A. (1999). *The feeling of what happens : Body and emotion in the making of consciousness*. New York, Harcourt Brace.