Proposal: Semantic-aware swarms for object transportation

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1 Abstract

This proposal takes a collective self-aware approach to prove that semantic-awareness improved better decision making with regard to maintaining home-ostatic state of swarms who should accomplish a task. Self-awareness which is considered here as the ability of an Intelligent Agent to recognize abnormality from its initial knowledge and build, memorize and retrieve new dynamic models out of high abnormalities for further use. Semantic-awareness in this proposal is equal to Level 1: Understanding the dynamic models other agents are reviewing now and Level 2. Understanding the difference between same models appearing in different contact (i.e previous model and future model). This proposal plans to prove that the higher the level of semantic-awareness is, the better collective behavior is achieved in a local communication scheme in which agents are allowed only to communicate with neighboring agents. That is, better generative/descriminative and abnormality detection models will be generated which will result in emergence of improved collective behavior.

2 Introduction

3 Motivation

Scientific

- Set of problems which could only be solved by a collection of agents
- Requires mostly proper interaction modeling rather than individual motion modeling to solve
- A seamless framework from perception to action
- The **null hypothesis** that this proposal is trying to reject is that "Semantic awareness does not improve decision making"

Technical

- Collective load transportation

- Collective load landing
- Micro UAVs because of their low inertial

4 Related work

Collective adaptive systems

Collective object transportation

Existing object transportation with multi drone systems Jackson et al. (2020)

Existing drone swarm navigation models in tight spaces Soria et al. (2020)

Self-organizing swarms

Self-organizing drones

Dynamic systems modeling

Dynamic Bayesian Models

Semantics

- in action sequences
- in natural language

5 Methodology

From individual perception to collective behavior

- Individual perception of environmental data
- individual decision making
- creating individual generative models
- creating generative interaction model for each triples of agents with consecutive rankings (agents are aware of existence of the behind and front agents)
- messaging to neighbors through individual generative models

- creating individual descriminative model in which a messaged individual generative model and the rank of the sender may cause a decision and an action
- Collective behavior

Overview The experiment takes a collective self-aware approach in the sense that it will be first trained by an initial generative model for a reference task and then new generative and descriminative models will be generated from the data presenting the observed abnormality. The modeling starts from initial modeling of collective movements of a straight flight from one point to another and then introducing the initial flight path with obstacles such as tight flight corridors which may need a collective maneuver or column avoidance which needs a single maneuver to avoid the obstacle. From these new experiences, new models should be generated and through neighboring interactions other agents should learn to decide to either react to other manauvers or not. The goal of this proposal is to prove that if such model messages is transmitted locally but contextually, then some improvments will be observed in comparison to the base models.

Homeostatic state In thus proposal, homeostatic state is the generalized state in which the dynamic systems has the highest survival chance and comes at two levels in this proposal

1. Trying to keep the abnormality signals minimum according to the currently practicing generative model
2. Returning back from the previously practiced model to the reference model as soon as which might be one of the following tasks
   - in 2-D, middle empty/full formation of the swarms (the simplest case which will be studied most probably in this proposal)
     - Keep a regular (convex) polygon
   - in 3-D, middle empty/full formation of the swarms
     - Half-sphere Platonic solid
3. In high speeds is the formation which brings the best aero-dynamic shape.

- Each currently, collective, practicing generative model should be considered as the homostatic state to which the swarm must return by using its actuators. For example, if the path of the drone is disturbed by the wind, it should try to return back to its former formation and trajectory.

5.1 Generative models

Two generative models should be considered. One which defines

Interaction model Starting by two tasks (See Figure 4.1,2) from which, taking advantage techniques such as Bayesian reasoning, the third task should be solved (Figure 4.3).

Initial model for the reference task- constant movement between two points As a further phase, to avoid computational complexity, such models should be learned by dividing the environment to discreet regions in which mutual relation dynamism is approximately constant and such models should be trained for consecutively ranked agents and not between all agents.

5.2 Discriminative models

The models which are responsible to attribute a sequence of observations with the best fitting generative model.

For collective behavior

For individual behavior

5.3 Abnormality detection

Feature selection

Sources of abnormality detection

5.4 Generative/Descriminative Model creation

After abnormality detection, the sequence of data which represents the abnormality should be used for training a dynamic generative model.

If individual words derived from clustering methods such as Kanapram et al. (2019) which represent specific sequence of generated dynamic .

5.5 Communication

Communication rules

Ranking The one which is closer to the destination will be ranked lower and the ranking starts from 1. The leader is rank 1. The leader is rank one.

- Only with the two neighbors on the sides
- in 3/2 the neighboring ranks can do that.
- no agent can transmit the information (models/ abnormality signals) from other agents to the neighboring agent.

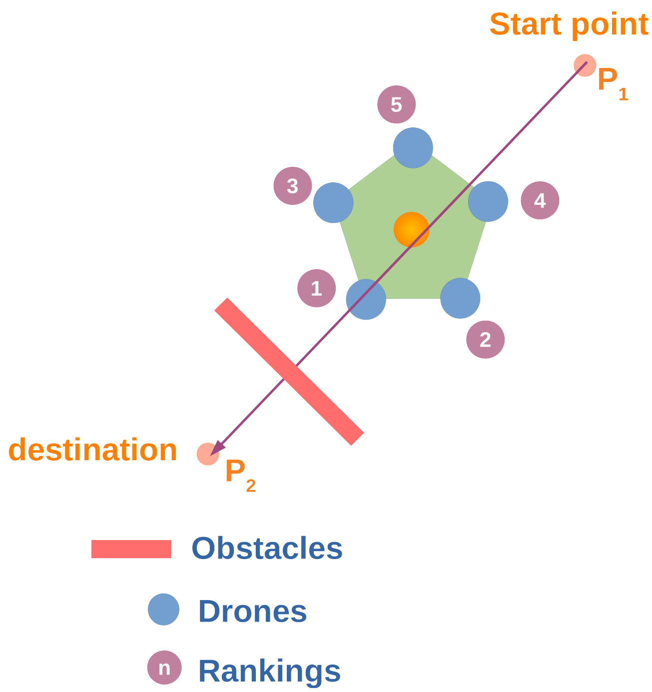

Figure 1: Closer agents to the destination take the lead. If destination of two agents is measured to some degree of tolerance equal, then random ranks will be assigned. Semantic stated interaction is only allowed between consecutive neighboring ranks.

- information transition is only allowed between one higher or one lower rank in the network.
- The messages architecture can be just two individual generative models, the last reviewed one and the one being practiced now. These messages will be considered as exteroceptive data along with agents other exteroceptive sensor data and will be used contextually to build new collective generative and descriminative models and we believe that such architecture will improve the performance of models.
- Messages can only be transmitted to neighboring nodes when the generative model an agent is practicing changes.
- no agent can propagate other agents' messages

Building the communication words Each generative model is a word.

The smallest sentence is formed of three words The interaction should include at least three temporally consecutive models. The reviewed model in the past, the one at the present and the one in which is predicted to be reviewed in future. The proposal plans to prove that such kind of awareness helps with making better collective and individual behavior and decisions.

Levels of semantic-awareness Having the ability to understand

1. the transmitted (according to the communication rules) generative models which are being practiced

2. the context in which a transmitted generative model has appeared.

5.6 Sensors

Exteroceptive

- Environmental

- From neighboring agents

Proprioceptive

- Gyroscope: For measuring pitch, role, yaw

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Heterogeneity Heterogeneity of the sensors which plays the heterogeneity for the whole system will be sought in deployement of different sensors installed independently on different agents.

Contextuality

- Active self

- Passive self

Multi-sensory approach / Fusion

Feature selection for generative and discriminative models Choosing the best set of features which captures metrics such as abnormality

Sensor precision

5.7 Decision making and control

- A model to convert abnormality signals to decisions for actuators
  - To return back the system to the best fitting, existing generative model by simultaneously making decisions that minimize the deviations from that model
  - Continuously trying to return back to the reference generative model this reference model defines the homos static state to which the whole system tries to return

6 Experimental setup

Minimum experimental requirements

- Three drones so that neighboring communication is meaningful
- Minimum two sensors to establish a relationship between heterogeneous sensors. The best of such sensors for depth and obstacle selection in low speed are active sensors (Apatean et al., 2007):
  - Lidar
  - Sonar
  - Radar

6.1 Experimental scenarios

In this section several scenarios will be presented from which both generative individual and interaction models can be learned some of these scenarios entail generalized state change from the agents while others don't. For each of these scenarios, a DBN model should be learned. Then we should prove that semantic messages composed of at least two individual generative models which represent the previous reviewed generative model and the current one improves the baseline model which only considers reception of current practicing DBN by the neighboring node.

Why frames are so important Consecutive frames in depth can represent any passage channel. Each frame also is formed of two triangles and triangles can reconstruct any surface. Each rectangular frame is formed of two triangles.

Reference collective horizontal movement See Figure 2

Reference collective vertical landing See Figure 3

Collective horizontal frame passage See Figure 4 for a few samples of similar scenarios for which collective interaction models must be built.

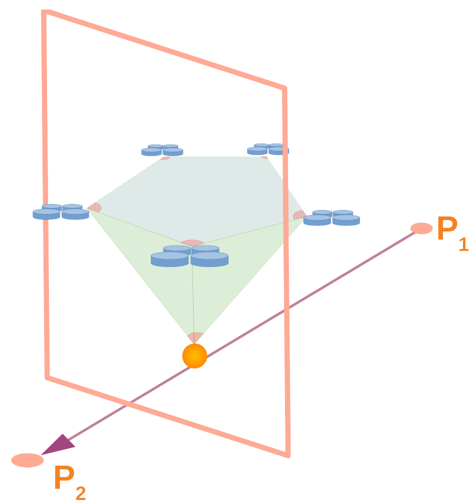

Figure 2: Reference task for which an initial model should be learned

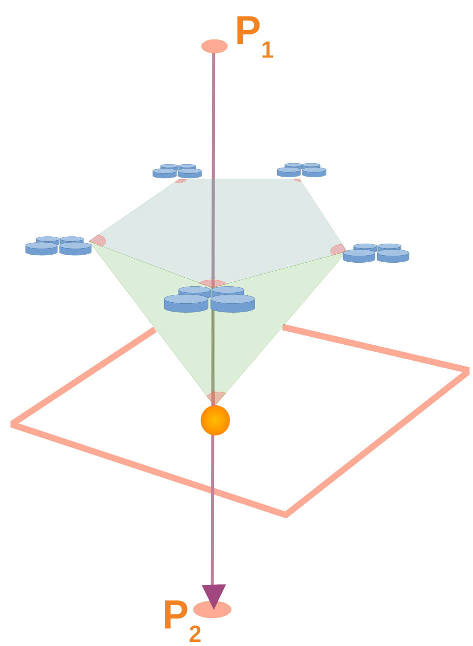

Figure 3: Reference task for which an initial model should be learned for vertical landing

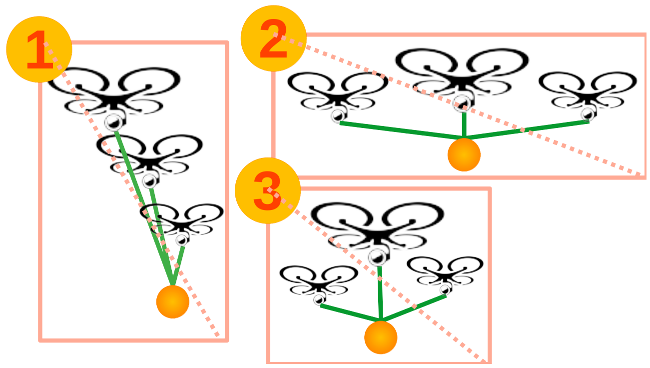

Figure 4: Learning the third collective behavior while the two first experience is are available

Collective vertical frame passage Similar to "Collective horizontal frame passage" scenarios, but the frames are places vertical

Vertical column avoidance A scenario in which changes in generalized state of one agent does not entail changes in other agents. See Figure 5

Horizontal column avoidance A scenario in which changes in generalized state of one agent does not entail changes in other agents. See Figure 6

7 Papers

Conferences

Journals Three drones - If heterogeneity is sought, it could be considered as heterogeneity of the data derived from various sensors.

References

Anca Apatean, Alexandrina Rogozan, Corneliu Rusu, and Abdelaziz Bensrhair. Sensors for obstacle detection - a survey. pages 100 – 105, 06 2007.

B. E. Jackson, T. A. Howell, K. Shah, M. Schwager, and Z. Manchester. Scalable cooperative transport of cable-suspended loads with uavs using distributed trajectory optimization. *IEEE Robotics and Automation Letters*, 5(2):3368–3374, 2020.

D. Kanapram, Damian Andres Campo, Mohamad Baydoun, Lucio Marcenaro, Eliane L. Bodanese, Carlo S. Regazzoni, and Mario Marchese. Dynamic

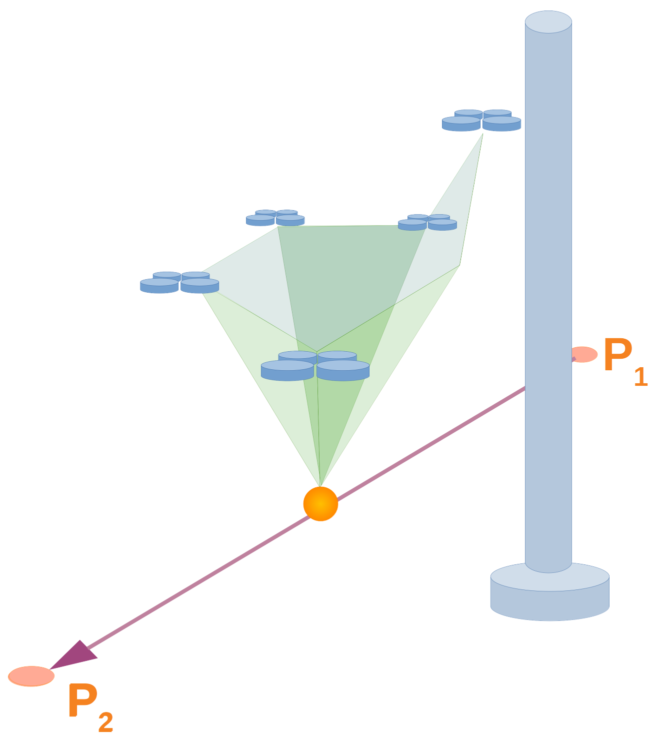

Figure 5: Vertical obstacle avoidance

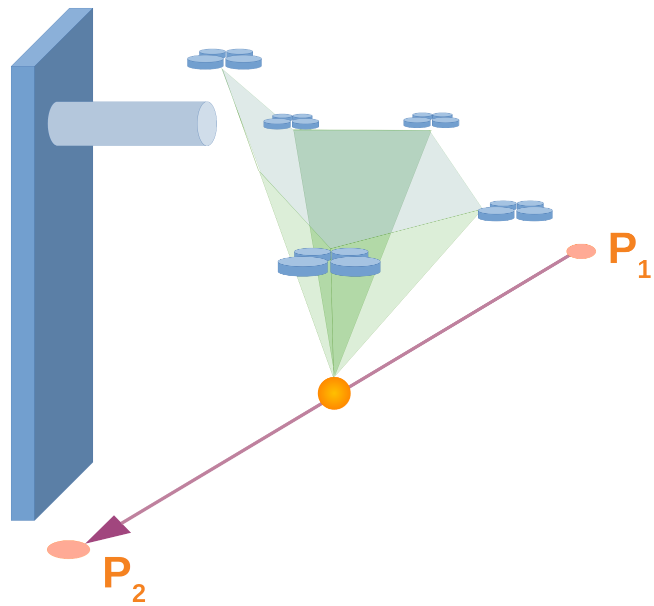

Figure 6: A scenario similar to Figure 5 from which collective behavior could be learned

bayesian approach for decision-making in ego-things. *2019 IEEE 5th World Forum on Internet of Things (WF-IoT)*, pages 909–914, 2019.

Enrica Soria, Fabrizio Schiano, and Dario Floreano. Swarmlab: a matlab drone swarm simulator. *arXiv preprint arXiv:2005.02769*, 2020.