Multi-Agent Surveillance Using Active Inference and Reinforcement Learning

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Problem Overview

Effective surveillance with multi-robot systems necessitates the detection of anomalies among a given set of processes. This project aims to integrate active inference principles for predictive anomaly detection [1], while leveraging reinforcement learning (RL) techniques, such as the Soft Actor-Critic (SAC) method [2], for dynamic task allocation and coordination among the robots.

Literature Review

Active inference, grounded in the concept of "Free Energy" minimization, offers a novel approach to anomaly detection [1]. On the other hand, reinforcement learning, particularly methods like Soft Actor-Critic (SAC) and its variants, demonstrates promise in optimizing agent behaviors in dynamic multi-agent settings [2]. While DRL has found applications in various fields, its significance in multi-robot systems, where agents learn collaboratively, is of interest [3].This project seeks to merge insights from these domains to develop a comprehensive surveillance system.

Proposed Method and Experiments

The proposed strategy encompasses:

1) **Anomaly Detection**: Robots employ active inference to anticipate and pinpoint anomalies, striving to minimize the surprise in their observations.
2) **Dynamic Task Allocation**: RL techniques, such as SAC or other suitable algorithms, will be adapted to facilitate dynamic task distribution, ensuring optimal area coverage and prompt responses to detected anomalies.

Evaluation: Quantitative measures will include anomaly detection rates, response times, and efficiency of area coverage. Qualitative assessments will gauge the system's adaptability and resilience across diverse surveillance scenarios.

Milestone and Timeline

- **Initial Phase (Week 1-2)**: Comprehensive literature review to understand the foundational concepts of active inference and RL methodologies suitable for multi-agent systems.
- **Development Phase Part I (Week 3-4)**: Begin the design and preliminary implementation of anomaly detection using active inference in a simulation environment.
- **Development Phase Part II (Week 5-6)**: Exploration of reinforcement learning techniques for dynamic task allocation. Selection and preliminary adaptation of a suitable RL algorithm for the project.
- **Integration Phase (Week 7-8)**: Combine active inference and RL methodologies. Initial testing and refinement of the integrated system in simulation.
- **Evaluation Phase (Week 9-10)**: Comprehensive testing, debugging, and performance evaluation. Refinement based on test results.
- **Final Goal**: Delivery of a flexible multi-agent surveillance system that synergistically combines active inference for anomaly detection and RL for dynamic task allocation.

Background

I bring a strong foundation in cognitive science. With prior experiences in active inference and in deep learning as well as some experience in reinforcement learning frameworks, this project is positioned to benefit from a holistic approach to the challenges of combining these domains for multi-agent surveillance. Additionally, the drafting and refinement of the language clarity in this proposal was assisted by advanced AI language models, ensuring clarity and coherence in its presentation [4].

References

[1] Joseph, G., Zhong, C., Gursoy, M.C., Velipasalar, S., & Varshney, P.K. (2020). Anomaly Detection via Controlled Sensing and Deep Active Inference. *GLOBECOM 2020 - 2020 IEEE Global Communications Conference*, 1-6. https://api.semanticscholar.org/CorpusID:233231295.

[2] Pu, Y., Wang, S., Yang, R., Yao, X., & Li, B. (2021). Decomposed Soft Actor-Critic Method for Cooperative Multi-Agent Reinforcement Learning. *ArXiv*, abs/2104.06655. https://api.semanticscholar.org/CorpusID:233231295.

[3] Orr, J., & Dutta, A. (2023). Multi-Agent Deep Reinforcement Learning for Multi-Robot Applications: A Survey. *Sensors*, 23(7), Art. no. 7. https://doi.org/10.3390/s23073625.

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