

Original Research Article

## Semantic-aware network collaborative scheduling mechanism for multi-agents

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**Abstract:** In the context of the deep integration of intelligent terminals and Internet of Things technology, the multi-agent semantic perception network, formed by the combination of multi-agent systems and semantic perception technology, is widely applied in various scenarios such as distributed information processing and intelligent collaborative perception. The efficiency of its collaborative scheduling plays a decisive role in the network's perception performance and service quality. This paper summarizes the basic characteristics of the multi-agent semantic perception network, analyzes the core problems existing in the current collaborative scheduling process, proposes an appropriate collaborative scheduling optimization mechanism, and utilizes semantic unified adaptation and dynamic scheduling strategies to resolve issues such as semantic heterogeneity and unreasonable resource allocation, thereby improving the network's collaborative efficiency and stability. This enables the network to operate more efficiently and stably in practical applications, providing strong support for the development of related fields.

**Keywords:** multi-agent; semantic perception network; collaborative scheduling mechanism; semantic adaptation; dynamic scheduling

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### 1. Introduction

With the rapid development of artificial intelligence and network technology, the perception and processing capabilities of a single intelligent agent are unable to meet the application requirements of complex scenarios. Therefore, the multi-agent semantic perception network has emerged. One of the core issues in the research of multi-agent systems is cooperative control, which refers to designing distributed control algorithms for each intelligent agent based only on the local interaction information among neighbors, to achieve the set cooperative goals. This network relies on the collaborative work of multiple intelligent agents with autonomous perception, decision-making, and interaction capabilities to achieve efficient collection, transmission, and interpretation of semantic information, breaking through the limitations of the capabilities of a single intelligent agent. However, the semantic perception capabilities of each intelligent agent vary, the semantic information is heterogeneous, and multi-agent systems have a distributed characteristic, which often leads to semantic incompatibility, uneven resource allocation, and low collaborative efficiency in the existing cooperative scheduling mechanisms, hindering the improvement of the overall performance of the network and affecting its application effect in complex scenarios.

### 2. Basic characteristics of multi-agent semantic perception network

#### 2.1. Core characteristics of multi-agent system

The distributed control algorithms of multi-agent systems generally rely on the state estimation information of interactions among individuals. Therefore, accurate estimation of individual states is the prerequisite for the realization of collaborative control in multi-agent systems. As a distributed collaborative system composed of multiple autonomous agents, the core characteristics of multi-agent systems include autonomy, interactivity, and coordination. These characteristics are the fundamental for achieving efficient scheduling. Each agent can independently complete tasks such as semantic perception, adjust according to the environment it is in, and achieve state information exchange through communication interaction, providing necessary data support for scheduling work. Compared with a single agent, multi-agent systems have greater flexibility and robustness.

They can carry out division of labor and collaboration to reduce the overall load, integrate their respective advantages to complete complex tasks, and efficiently cope with various challenges. In practical applications, they demonstrate more outstanding adaptability and problem-solving capabilities.

## **2.2. Composition and working logic of semantic perception network**

The semantic perception network focuses on the collection, transmission, and interpretation of semantic information, covering the semantic perception layer, communication transmission layer, and collaborative scheduling layer, forming a complete closed system. The semantic perception layer extracts environmental semantics from agents and converts raw data into semantic expressions. The communication transmission layer is responsible for information interaction, ensuring efficient transmission of semantics and instructions, avoiding loss and delay. The collaborative scheduling layer integrates perception resources and formulates scheduling plans based on tasks and the states of agents, allocating tasks, coordinating progress, and enabling efficient and coherent semantic perception processes. These three layers collaborate and continuously optimize to meet the various requirements of complex scenarios, demonstrating excellent adaptability and stability in different application situations.

## **3. Challenges in multi-agent semantic perception network cooperative scheduling**

### **3.1. Scheduling conflicts caused by semantic heterogeneity**

Currently, one of the core problems faced by multi-agent semantic perception network cooperative scheduling is semantic heterogeneity. This is mainly due to the differences in semantic perception capabilities, semantic encoding standards, and cognitive logic among various agents. When different agents extract semantic information, due to the different perception algorithms and encoding methods they use, there will be differences in the semantic representation of the same environmental information, making it difficult for semantic information to be effectively exchanged and shared. During cooperative scheduling, semantic heterogeneity can easily lead to scheduling conflicts, making it difficult for the scheduling layer to accurately identify the semantic information transmitted by each agent and formulate reasonable task allocation strategies. This can even result in repeated task allocation or imbalance, reducing the efficiency of cooperative scheduling, and may cause deviations in semantic perception results, thereby affecting the overall perception performance of the network. This, in turn, challenges the stability and effectiveness of the entire network's operation.

### **3.2. Inefficient resource allocation and delayed scheduling**

In multi-agent semantic perception networks, the resource reserves and workloads of each agent are in a dynamic state. However, the current cooperative scheduling mechanisms mostly employ static scheduling strategies, lacking the ability to dynamically sense and adjust the real-time status of the agents. This leads to significant problems of inefficient resource allocation and delayed scheduling. Static scheduling strategies are unable to allocate tasks based on the real-time resource reserves and workloads of the agents, often resulting in some agents having idle resources while others are overloaded. This causes resource waste and task delays, and the scheduling layer has a delay in perceiving the work status and environmental changes of the agents, making it difficult to respond immediately to changes in task requirements. In the event of agent failures or sudden environmental changes, it is unable to quickly adjust the scheduling strategy, causing the semantic perception tasks to be interrupted, which affects the stability and reliability of the network.

## **4. Multi-agent semantic perception network cooperative scheduling optimization mechanism**

### **4.1. Semantic unification adaptation mechanism**

To solve the scheduling conflict problems caused by semantic heterogeneity, a semantic unification adaptation mechanism is constructed to achieve the intercommunication and sharing of semantic information among all intelligent agents, laying a unified semantic foundation for cooperative scheduling. A unified semantic knowledge base is established, integrating the representation norms and parsing criteria of different types of semantic information, standardizing the semantic encoding mode, ensuring that the semantic information

extracted by each intelligent agent can be represented and transmitted according to a unified standard. A semantic alignment algorithm is introduced to dynamically align and convert heterogeneous semantic information transmitted by each intelligent agent, eliminating semantic differences and converting semantic information in different encoding formats into a unified style that can be recognized by the scheduling layer. A semantic verification mechanism is established to verify the accuracy of the aligned semantic information, ensuring the consistency and reliability of the semantic information, providing precise support for the formulation of cooperative scheduling strategies, enabling the scheduling work to be carried out more efficiently and accurately, effectively reducing conflicts caused by semantic issues, and improving the overall efficiency of cooperative scheduling.

#### **4.2. Multi-agent dynamic cooperative scheduling strategy**

To address the problems of unreasonable resource allocation and delayed scheduling, a multi-agent dynamic cooperative scheduling strategy is proposed, achieving dynamic matching of scheduling strategies and the real-time status, task requirements of intelligent agents. An intelligent agent state perception model is constructed to collect real-time status information such as resource reserves, workload, and perception accuracy of each intelligent agent, establishing a dynamic state database to provide real-time data support for scheduling decisions. A hierarchical scheduling architecture is adopted, with the main intelligent agent responsible for task decomposition and global scheduling decision-making, splitting complex semantic perception tasks into multiple sub-tasks, dynamically allocating sub-tasks based on the real-time status and advantages of each intelligent agent, optimizing resource allocation to prevent idle resources and load imbalance. A dynamic feedback adjustment mechanism is established to monitor the execution status of tasks, adjusting the scheduling strategy in a timely manner according to the progress of the task and changes in the status of intelligent agents, ensuring the efficient advancement of tasks, enhancing network stability and collaborative efficiency, enabling the entire scheduling system to operate more flexibly and accurately in complex and changing environments, and adapting to the constantly changing task requirements and status of intelligent agents.

### **5. Conclusion**

The multi-agent semantic perception network collaborative scheduling mechanism, as the key factor for enhancing the network's perception performance and collaborative efficiency, plays a direct and decisive role in the application effectiveness of the network in complex scenarios. This paper focuses on conducting in-depth research on the multi-agent semantic perception network collaborative scheduling mechanism. Firstly, it meticulously examines the basic characteristics of the multi-agent system and the semantic perception network. Then, it analyzes the core problems faced in the current collaborative scheduling process, such as semantic heterogeneity, inadequate resource allocation, and scheduling lag. Subsequently, it provides targeted semantic unification adaptation mechanisms and multi-agent dynamic collaborative scheduling strategies, offering practical solutions and thinking directions to address scheduling difficulties and optimize scheduling effectiveness. It is expected to have a positive and far-reaching impact in the research and practical application of this field.

### **References**

- [1] Kong Weiyang. Review on Multi-Agent Reinforcement Learning Research [J]. *Science and Industry*, 2025, 25(21): 91-105.
- [2] Yang Chengbi, Zhou Liheng, Yang Longbao. Research on Predictive Maintenance of Power System Equipment Based on Multi-Agent [J]. *China Equipment Engineering*, 2025, (20): 77-79.
- [3] Kong Deyin, Tu Yewei, Liu Chao, et al. Switching-type Load Regulation Strategy Based on Multi-Agent Consistency [J]. *Electrical Switching*, 2025, 63(05): 80-84.