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Distributed task allocation modeling based on agent topology and protocol for collaborative system

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ABSTRACT

Task allocation plays an important role in collaborative system. This paper focuses on interaction topology and protocol of Multi-agent system (MAS) for task allocation, particularly for UUV collaborative system. The corresponding relationship between UUV formation system and MAS was systematically analyzed and developed from the viewpoint of structural similarity, in which UUV is regarded as the agent member of MAS network to realize the control for task allocation, and then Extended Contract Net Protocol is present based on peer-to-peer topology to complete interactive communication, which mainly focuses on network communication to improve efficiency and quality of task completed. The experiment results demonstrate the proposed distributed task allocation model has better performance on the performance indicators, which can be a good tool to solve the task allocation in the UUV formation system.

1. Introduction

Unmanned Underwater Vehicle (UUV) Collaborative System (UCS) as underwater robots swarm has been widely used in numerous marine scientific applications [1–5]. Task allocation modeling can realize the resource optimism between the UUV and task under dynamic underwater environment, which has attracted numerous scholars, and many methodologies and technique have been proposed during the past decades [6–9]. Recently, the requirement of distributed task allocation has led the research to Multi-agent system (MAS) [10–12].

Stemming from Distributed Artificial Intelligence (DAI) [6,12,13], an agent can be perceived as a software computational entity possessing the properties including autonomy and reactivity. And MAS is a loosely coupled network of agents that interact to solve problem which is beyond the individual capacities or knowledge in a specific environment. Therefore, the MAS methodology is especially suitable for distributed task allocation modeling because of its cooperative problem solving ability. Under the MAS paradigm, UCS can be portrayed as a set of intelligent agents, each being responsible for one or more activities and interacting with other agents to accomplish the planning and scheduling tasks, by the communication interaction topology and protocol [2,4,14].

Interaction protocol can regulate relation between the agents for achieving overall goals in MAS, and interaction protocol is not independent of topology of the agent's network. Together, they determine how the task allocation is performed

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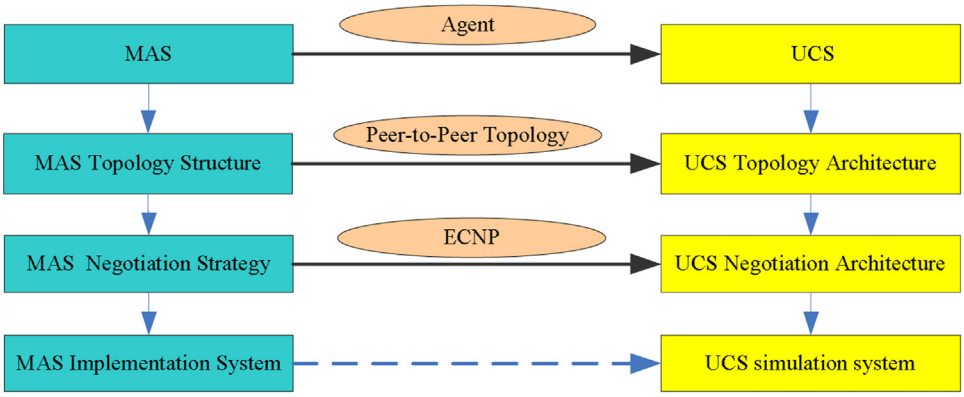

Fig. 1. Relationship between UCS and MAS for task allocation.

[15–17]. In research of the system topology, it suggests that an appropriate topology leads to a better performance, some topologies were proposed such as centralized topology and distributed topology. The research shows that weblike and starlike topologies are prevalent in distributed task allocation. Interaction protocol correlated with corresponding topology can be used to complete the coordinate the agent's individual problem solving activities. A widely interaction protocol is the well-known Contract Net Protocol (CNP)[], which is a coordination mechanism by imitating the economic behavior to achieve task allocation. In order to improve the flexibility and adaptability performance, many researchers had made much effort to refine and extend in many application domains [6,15–20].

In the background of the above analysis, this paper addresses the distributed task allocation by proposing Extended Contract Net Protocol (ECNP) based on the peer-to-peer topology [2,6,15], which reflected both the intelligent make-decision behavior of each Agent, and the organizational behavior of agent's network. The following sections of this paper are structured as follows. A brief relationship analysis between MAS and UCS is presented on the distributed task allocation in Section 2. Section 3 proposes peer-to-peer topology architecture. Section 4 designs Agent internal task allocation control model based on CNP. Section 5 puts forward ECNP as the negotiation strategy. Section 5 establishes the simulation experiment. Finally, Section 6 discusses the conclusion.

2. Problem description and relationship analysis

The MAS as the DAI modeling tool was adapted to development the agent-based distributed task allocation system, there has three main issues must need to be consider [1] expression the physical world entities by agent with specific relationship between the entity and relevant agent, [2] system structure topology of the agent's network, and [3] interaction protocol which is closely related to the topology [2,4,15]. In view of the above three issues, the corresponding relationship between MAS and UCS is established and shown in Fig. 1.

As shown in Fig. 1, many mechanisms extracted from MAS can be applied to the design the UCS [1]. The UUV in the UCS can be regarded as the UUVAgent by the Agent modeling [2]. The Peer to Peer Topology is developed to design the UCS topology. And [3] the ECNP as the Interaction protocol is proposed to complete the UUVAgent communication negotiation, which will be studied in detail below.

3. Topology architecture

There are two topology structures Centralized Topology (CT) and Distributed Topology (DT) in MAS theory [21,22]. In the CT, a top-down hierarchical centralized system for task allocation causes rigidity and confines problem-solving ability in the real world, although it can achieve the best control effect with the lower of communication requirements under the condition that the task is fixed. In the DT, each agent has completely autonomous characteristic, it is to make decisions and execute tasks according to the obtained information from communication and environment. Clearly, DT is a way to address the in flexibility of the hierarchical system.

UCS is a hybrid system that contains some discrete events and information interaction between each UUV, these events and information interactions need to be real-time and concurrent control task allocation for UCS is actually problem which seeks for an optimized solution under the dynamic environment. Therefore, the task allocation modeling can essentially be seen as a distributed problem from the both logical and physical viewpoint and can benefit form the DT. So, the Peer-to-Peer (P2P) topology is employed and shown in Fig. 2.

As shown in Fig. 2, the Distributed Peer-to-Peer topology is established based on the corresponding relationship, which can reflect chain structure of UCS. Based on autonomic computing and programming, each UUVAgent can implement dynamic task allocation through mutual negotiation.