A novel task optimal allocation approach based on Contract Net Protocol for Agent-oriented UUV swarm system modeling

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ABSTRACT

In order to improve the collaborative capability and efficiency, based on Multi-agent system (MAS) and Contract Net Protocol (CNP), a novel task optimal allocation approach Improved Contract Net Protocol (ICNP) is creatively proposed, which mainly focuses on multi-stage reducing network communication to improve the efficiency of the system and the quality of the task completed. In Task Announcement stage, regional trust degree (RTD) is introduced to decrease the communication scope; and in Bidding stage, the abilities are mainly focus to improve learning ability of contractor agent; also in Awarding stage, a least square method combination of subjective and objective is designed to evaluate the biding, which consider the subjective weight and objective weight from the analytic hierarchy process and driving principle of difference respectively. Finally in Executing and Monitoring stage, adaptive adjustment mechanism is employed to change the RTD. During this multi-level process, the Agent-oriented UUV swarm system can make dynamic task allocation based on environment change. Simulation results show the proposed ICNP can realize task optimal allocation for Agent-oriented UUV swarm system modeling.

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1. Introduction

With the increasing scientific and technological development of Unmanned Underwater Vehicle (UUV) swarm system in science and engineering fields [1–4], and because of complex underwater mission and dynamic environment [3,5], task optimal allocation has been attracted some attention. Multi-Agent system (MAS) is consisted of agents to realize the collaborative operation, those agents have a certain intelligent to independently think and reason under complex environment [6–9]. Therefore, the MAS theory and technology can solve UUV swarm system related task optimal allocation because of its cooperative problem solving ability. In order to realize the collaboration, the design of communication interaction algorithm or protocol is very important.

The communication interaction protocol [10–12] is an important part of any MAS to achieve its desired task allocation problem. In order to solve task allocation problem, various communication interaction protocols and algorithms have been proposed recently, which is mainly divided into centralized task allocation and distributed task allocation. Centralized task allocation approach was focus on linear programming method [13], blackboard model [14] and swarm intelligence algorithm [15], which can achieve global coordination in the task allocation process with faster computing speed. However, with the improvement of scale of the task to be allocated, computational complexity resulted from the huge computation, therefore it was not suitable for solving large-scale task allocation problem. Distributed task allocation approach is mainly focus on balance principle method [16], biological immune mechanism [17], and acquaintance net method [18], especially the contract net method [19–22], because of parallel computing, distributed communication, scalability and robust characteristics, which is suitable for dynamic system, which has received widespread attention [23,24].

Contract Net Protocol (CNP) [18–24] is a well known high-level protocol that was proposed as early as 1980, which has been later standardized by the Foundation for Intelligent Physical Agents (FIPA) (25). It is a kind of negotiations coordination, by imitating the economic behavior of "Announce-Biding-Award" mechanism to achieve the task allocation. The CNP as interaction protocol is suitably used for task allocation because of characteristics of swarm system [9].

In the background of the above analysis, considering advantages of MAS modeling and task allocation demand of UUV

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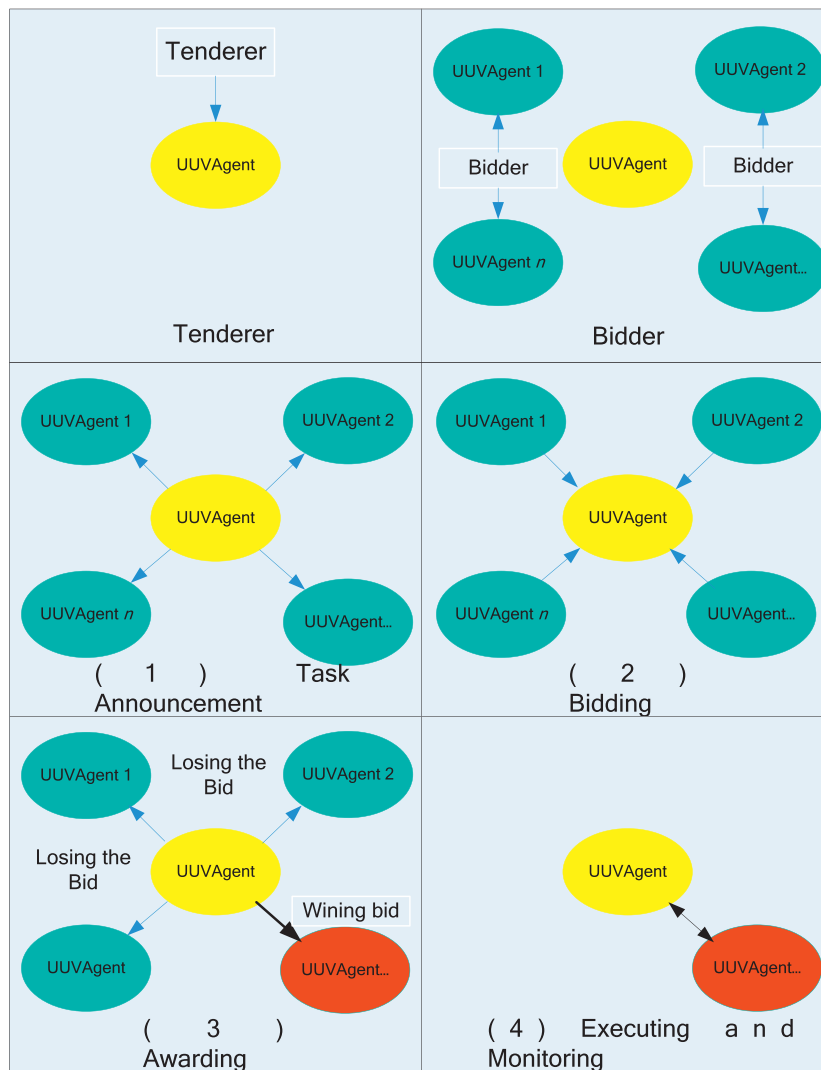E-mail address: lianghongtao.789@163.com (H. Liang).

Fig. 1. Schematic diagram of the bidding process.

swarm system [3,5,8,9,23–25], the Improved Contract Net Protocol (ICNP) based on MAS is creatively proposed to solve the task allocation in this paper. ICNP is put forward to implement negotiation strategy by multi-level negotiation in Task Announcement stage, Bidding stage, Awarding stage and Executing and Monitoring stage.

2. Improved Contract Net Protocol

In the Communication Interaction Protocol, ICNP is mainly focus on multi-stage reducing network communication to improve the efficiency of the system and the quality of the task completed [8]. In Task Announcement stage, Regional trust degree was introduced to decrease the communication; and in Bidding Stage, the abilities were mainly focus to improve learning ability of Contractor Agent; Also in Awarding stage, an evaluate algorithm combination of subjective and objective was designed to evaluate the biding, which consider the subjective weight and objective weight from the Analytic Hierarchy Process and Driving Principle of Difference; Finally, in Executing and Monitoring stage, Adaptive adjustment mechanism is employed to change the regional trust degree. In task optimal allocation of UUV swarm system, schematic diagram of the bidding process is shown in Fig. 1.

In Fig. 1, all UUVAgents are independently distributed, there has three categories: Tenderer UUVAgent (TUA), Bidder UUVAgent (BUA) and Winning bidder UUVAgent (WUA). When a UUVAgent is first to detect a target and distance d which can be shown in Fig. 2 is shortest between the UUVAgent and target location, it automatically becomes the TUA. And except the TUA, the UUVAgent becomes the potential BUA. The specific operation stages are shown as following.

2.1. Task announcement stage based on regional trust degree

When the TUA have not enough ability to handle the current task, or the new task is made by task decomposition, TUA needed help from others BUA. The important definition regional trust degree is defined by a circular area with radius R, which is shown in Fig. 2.

The size of the radius is affected by many factors, such as motion information of TUA, target motion information, threaten degree of BUA, and environmental factor. Therefore, It is used to choose the appropriate BUA to be became the potential object of task announcement issued by the regional trust degree to improve the communication quality and efficiency. And Task Document was sent to the selected BUAs by the TUA. The detail of Message Format