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Dynamic grouping of heterogeneous agents for exploration and strike missions

Key words: Multi-agent; Dynamic missions; Group formation; Heuristic rule; Networking overhead

Chen CHEN
E-mail: xiaofan@bit.edu.cn
ORCID: https://orcid.org/0000-0001-9354-6974

Background and significance

Multi-agent systems are widely used in detection and strike missions. How to organize multiple platforms to complete a mission is crucial.

The construction of multi-platform mission groups is the basis of mission planning. A reasonable grouping strategy can effectively reduce mission cost and improve the overall combat effectiveness.

Motivation

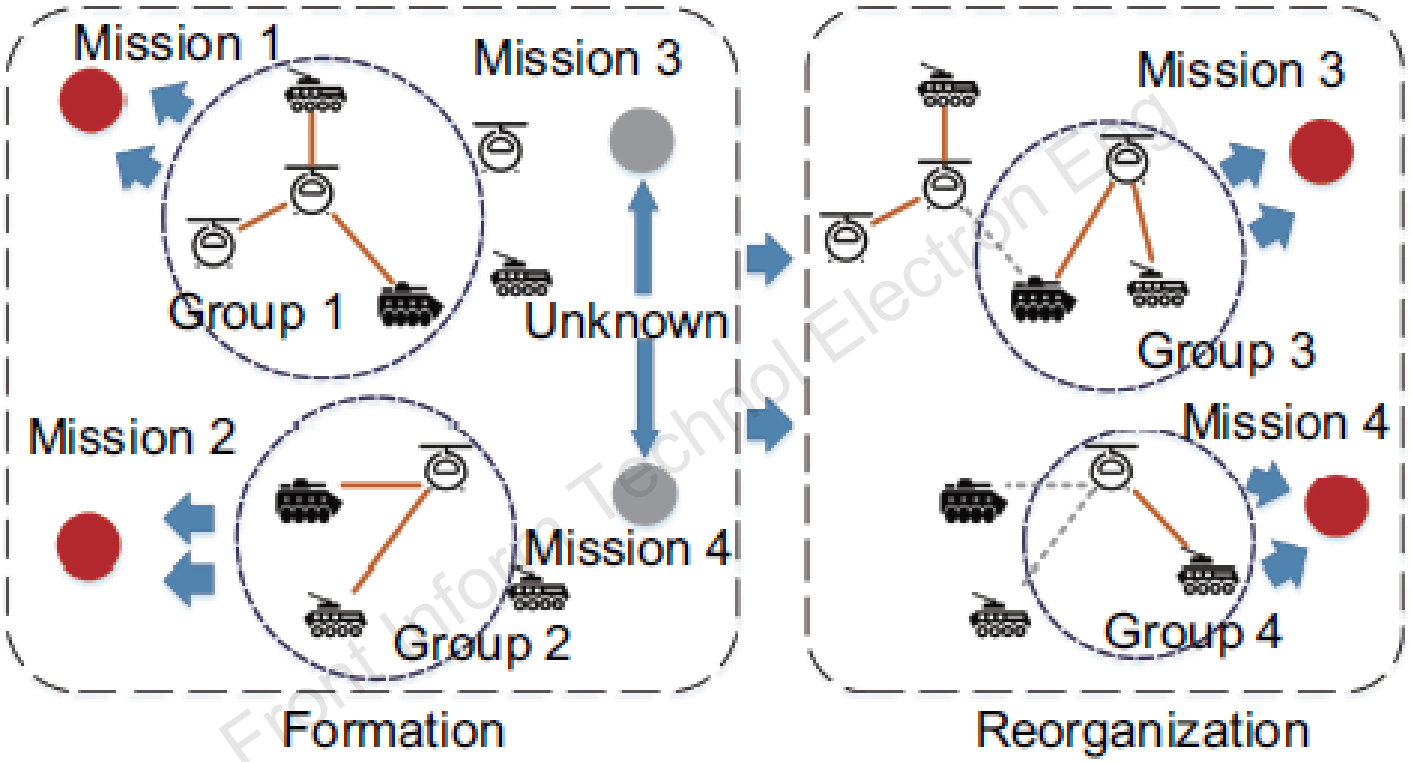
① Weapons must perform combat missions in groups.

② Complex combat missions place new requirements on the dynamics of mission team formation.

③ The development of intelligent platforms puts forward new requirements for the heterogeneity of mission groups.

- Design of mission group evaluation criteria
- Construction of the mission group formation model

Grouping scenario



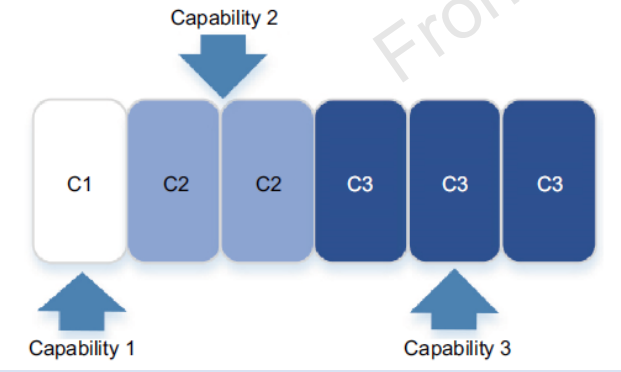
The combat scenario includes the completion of the old mission, the discovery of new missions, and the formation of new mission groups based on the new requirements.

Problem formulation

Definition of agents

- Each agent is a carrier of resource capabilities and a mission platform with certain autonomous capabilities.
- There are different types of agents with different capabilities.
- The number of agents is limited and it is not possible to perform all missions at the same time.
- Networking overhead will be generated when agents form new mission groups.

Capabilities of agents

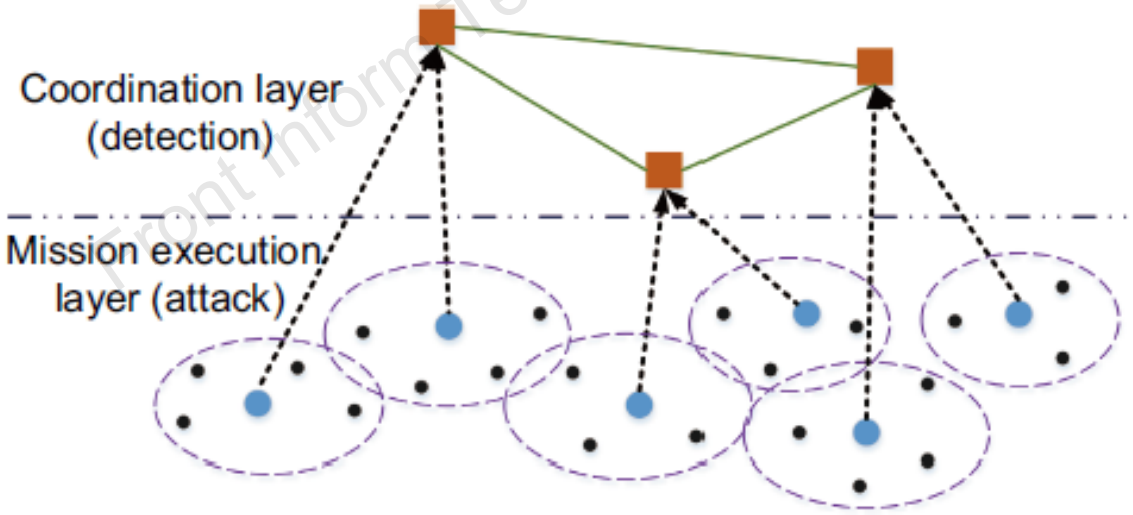


The agents' capabilities are described by a simple slot model. In the problem we study, the numbers of agent capability slots are different, and the value of each capability is also different.

Problem formulation (Cont'd)

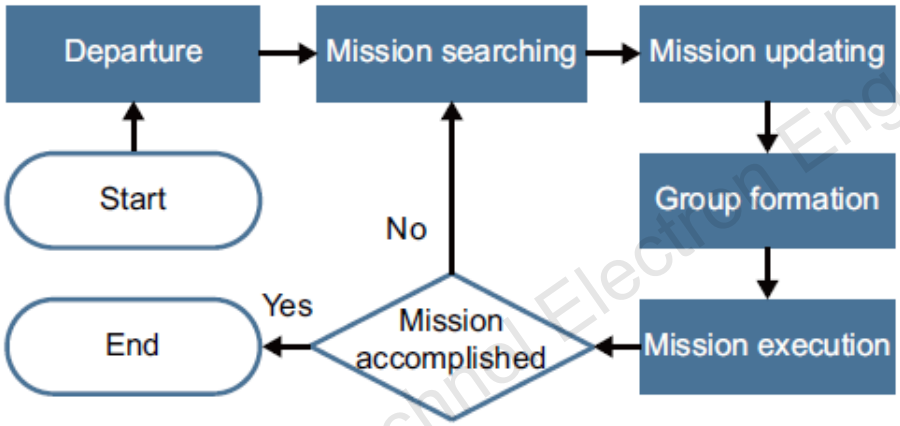
Types and topology

- Detection agent: explore new missions, coordinate among the mission groups (coordination layer)
- Attack agent: dynamically form mission groups, attack the enemies (mission execution layer)



Problem formulation (Cont'd)

Basic mission flow

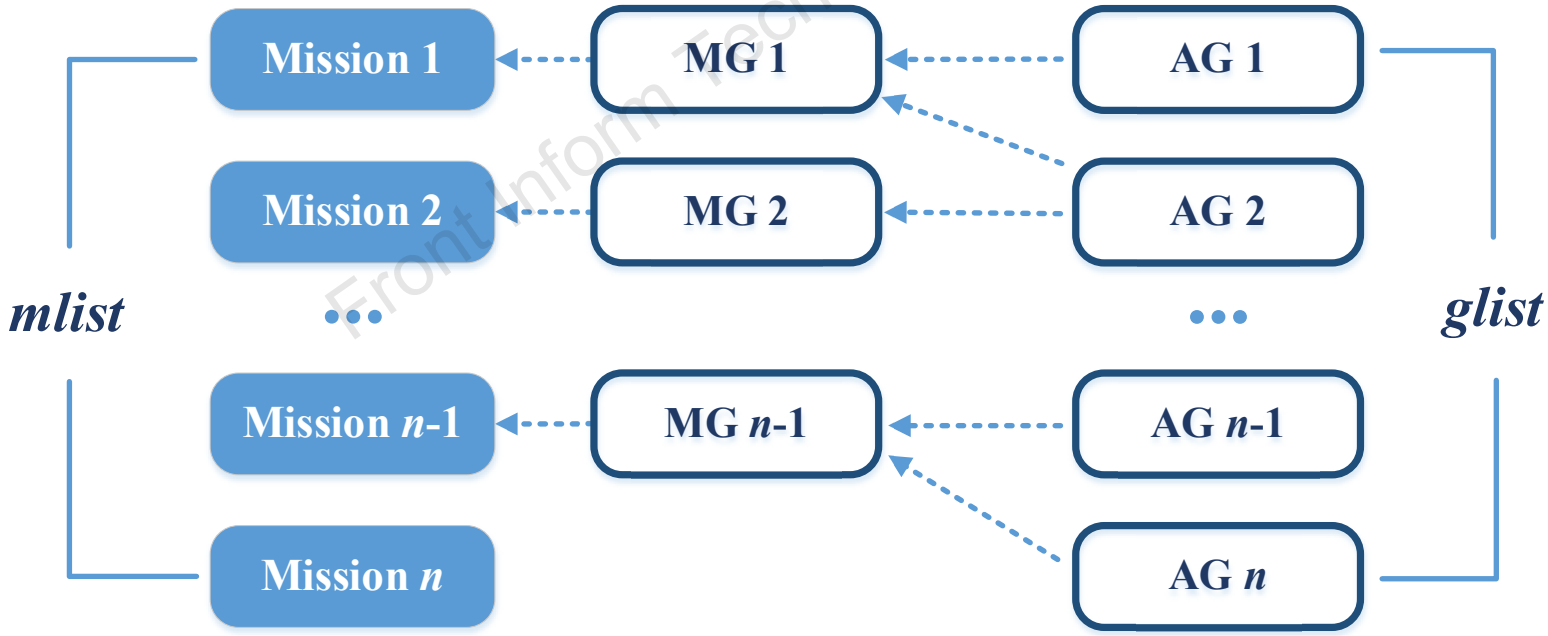


The proposed model

We give three objectives in terms of mission reward and mission cost. Among them, mission reward is expressed by the matching degree of mission requirements and group capabilities. The mission cost includes fuel cost and networking overhead.

Dynamic group formation method

This method uses two lists, mlist and glist, to store assignable missions and currently available groups (AGs). Based on mission requirements, the currently available groups are split and integrated to form new mission groups (MGs).



Dynamic group formation method (Cont'd)

In the process of group formation, a utility function is designed to calculate the matching degree between the agent and the mission, and a modified response threshold method (MRTM) is proposed to solve the group individual screening problem.

When calculating the utility value, the three factors of the urgency of the mission, the Euclidean distance, and the individual's evaluation of the mission are comprehensively considered.

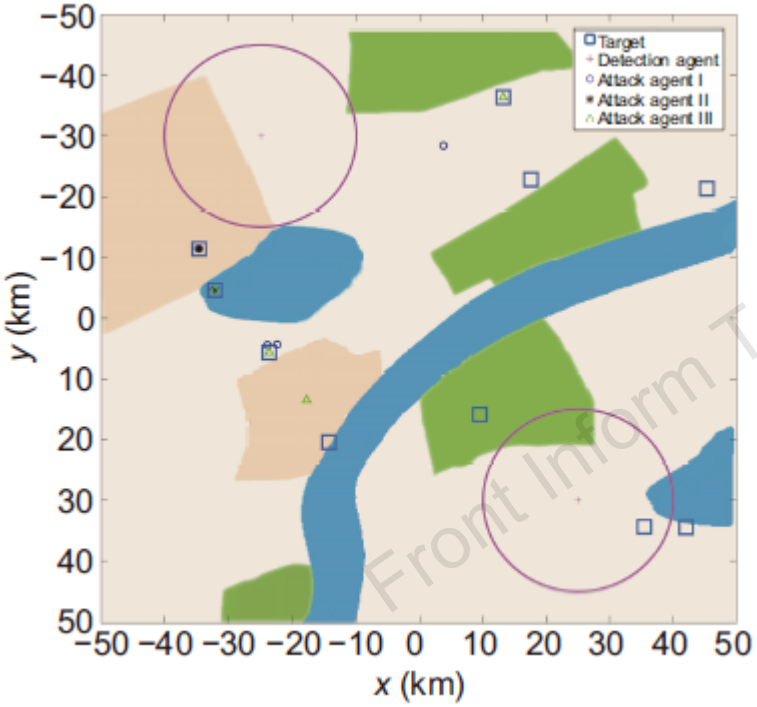
Utility function

Based on the traditional response threshold method, a new incentive strategy is designed which can more effectively screen suitable agents for the mission.

MRTM

Simulations

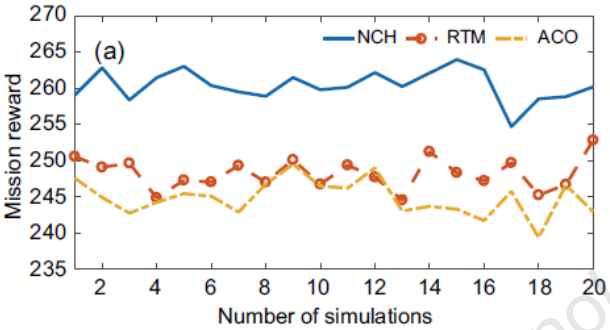
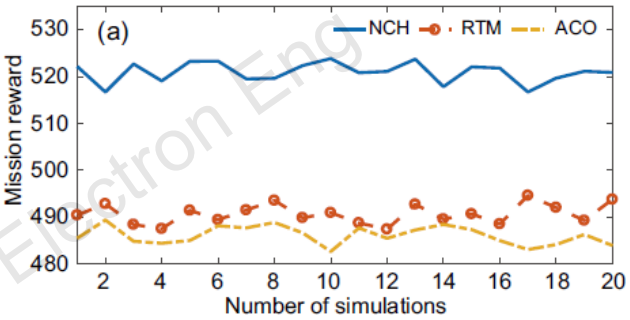
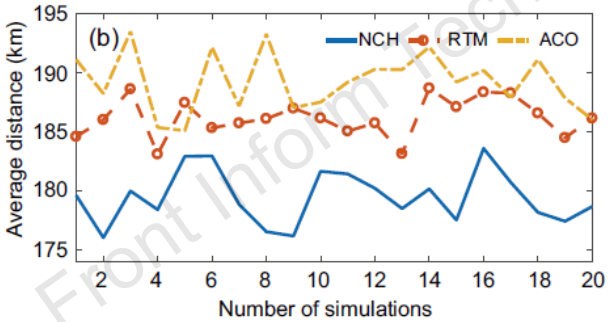
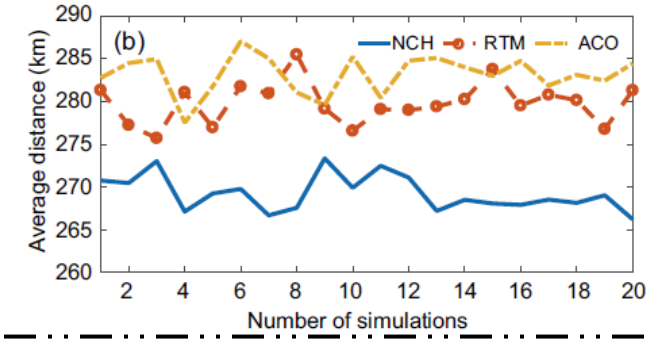
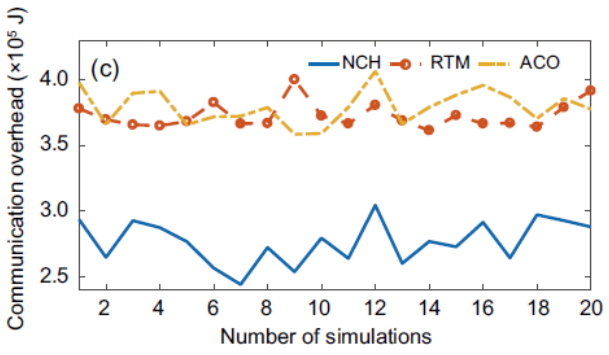
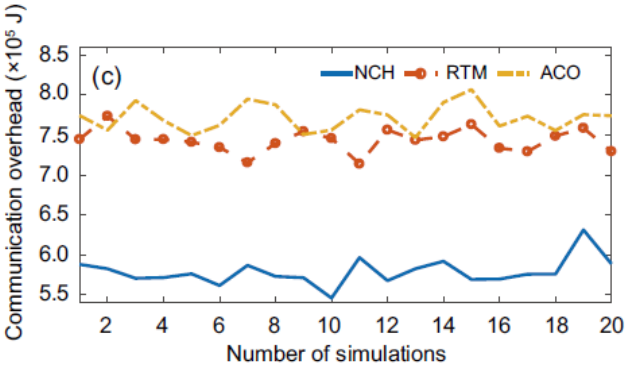
Simulation scenario



The small squares represent the enemy deployment units. The large circle indicates the detection agent and its detection range. The detection agent loops through the mission area to update the mission information. The remaining three symbols represent three types of attack agents that perform strikes based on the grouping results from the edge of the mission area.

Simulations (Cont'd)

Simulation results

	25 missions	50 missions
Mission reward		
Fuel cost		
Networking overhead		

Simulations (Cont'd)

Composition of groups

Table 5 Statistics of grouping results (scenario 1)

Method	T=10 s		T=20 s		T=30 s	
	Mission	Agents	Mission	Agents	Mission	Agents
NCH	2	3, 4, 5, 27, 28, 29, 30	1	10, 11, 12, 28	3	2, 17, 18, 19, 20, 22, 26
	4	2, 17, 18, 19, 20, 26	7	1, 13, 14, 15	10	3, 4, 5, 23, 24, 25
	5	1, 13, 14, 15, 16	8	16, 21		
	6	21, 22, 23, 24, 25	9	6, 7, 8, 9		
ACO	2	2, 4, 5, 18, 26, 28, 29	1	7, 10, 12, 13, 21	7	1, 6, 7, 8, 13
	4	3, 7, 17, 19, 20, 27	3	9, 11, 18, 19, 26, 27, 30	9	5, 10, 14, 15
	5	1, 11, 14, 23, 25, 30	8	17, 22, 29	10	3, 4, 9, 20, 24, 28
	6	6, 15, 16, 22, 24, 26				
RTM	2	1, 4, 13, 24, 27, 28, 30	1	11, 12, 16, 23	7	1, 12, 13, 17, 18
	4	2, 5, 7, 17, 19, 21, 25	3	2, 14, 18, 19, 20, 22, 26	8	11, 15, 23
	5	3, 14, 15, 16, 18	9	6, 7, 8, 9, 17		
	6	6, 20, 22, 23, 26, 29	10	3, 4, 5, 10, 13, 24, 25		

Conclusions

- We designed a series of heuristic rules to preserve the original group's organization as much as possible when forming a new group. This strategy effectively reduces the traffic generated by related steps by reducing the disconnection and reconstruction operations of links between nodes.

- Based on the ability matching principle, we have also made adjustments to the existing self-organizing algorithm and reduced the waste of agent capabilities during the grouping process.

- The simulation results have shown that the NCH method has advantages in solving this problem.

陈晨，北京理工大学自动化学院教授、博士生导师。现主要从事面向复杂系统智能优化与决策、军事运筹学方面的研究，具体包含复杂系统任务分配、布局优化、资源调度以及复杂系统建模与分布式仿真平台的设计与开发、效能评估等研究工作。在国内外学术期刊上发表SCI/EI论文40余篇。获授权发明专利20余件。近年来，主持国家自然科学基金优青项目、面上项目、国防预研、领域重点基金等科研项目多项，获国家科学技术进步奖二等奖1项，省部级技术发明奖一等奖1项，国防科技进步二等奖4项。现任中国指挥控制学会智能指挥与控制系统工程专业委员会常务委员、《火力与指挥控制》期刊编委等职。