Architecture and Algorithm of Formation control of Multi-unmanned vehicles Based on Swarm intelligence

Z Y Tian¹, B Su¹, W L Song¹, R Fu¹, P Y Lu¹, J Y Li¹, C Q Bai¹, S Xiang¹ and TY Gao¹

¹ China North Vehicle Research Institute, Beijing, 100072, China
Correspondence: bosu@noveri.com.cn(B Su)

Abstract. The main contents of this dissertation are the application of swarm intelligence to multi-unmanned vehicle system and the realization of cooperative control of multi-unmanned vehicle system. Firstly, this thesis introduces the research background and significance of multi-unmanned vehicle system and swarm intelligence. Secondly, we introduce the research contents of cooperative control of multi-unmanned vehicle system. Then the research status of cooperative control of multi-unmanned vehicle system in the domestic and overseas are introduced. Finally, this dissertation summarizes the mainstream types of architecture and algorithm of the multi-unmanned vehicle system.

1. Introduction
In recent years, artificial intelligence, sensor technology and wireless communication technology have been developing rapidly, and multi-unmanned vehicle systems composed of a large number of unmanned vehicles for specific tasks are being used more and more widely. In the industrial sector, multi-vehicle systems consisting of a large number of unmanned vehicles will be used for the handling of dangerous goods, detection and surveillance in complex environments such as underwater and land, and in the military field, a large number of unmanned vehicles are quickly arranged in sensitive areas, with the aim of implementing real-time monitoring and perception of changes in hostilities in large-scale airspace[1]. Reconnaissance and operations by multiple unmanned vehicle systems instead of the army can minimize casualties. These multi-unmanned vehicle systems are often because of their large scale, high complexity of environment and task process, so the collaborative control technology of multi-unmanned vehicle system has been paid more and more attention, and the research on multi-unmanned vehicle co-control is also a hot research topic at home and abroad[2].

2. Background

2.1. The research background of full autonomy and clustering
Full autonomy is the future development trend of multi-unmanned vehicle system, the aim is to enable multi-unmanned vehicle system to achieve cluster warfare[3]. The U.S. Department of Defense's Comprehensive Roadmap for Unmanned Systems for the 2009-2034 fiscal year shows that multi-unmanned vehicle systems are likely to be fully autonomous by 2034. Recently, the multi-unmanned vehicle system which can achieve coordinated operation by using cluster intelligent algorithm has been paid much attention, and the mainstream believes that the multi-unmanned vehicle system will be a priority to participate in the war in cluster mode in the future[4]. DarPA launched the Unmanned Cluster Challenge project in Fiscal Year 2015 and conducted a multi-unmanned vehicle system cluster algorithm study. In 2017, the "Offensive Cluster Enable Tactics" project was launched to develop a
cluster tactical ecosystem based on an open architecture, and to promote the application of multi-
unmanned vehicle cluster clusters in urban warfare by generating, evaluating and integrating multi-
unmanned vehicle system cluster tactics.

2.2. Research background of multi-unmanned vehicle system
The definition of an unmanned vehicle is a wheel, track, and wheel composite mobile robot. Multi-
unmanned vehicle systems are generally defined as systems in which multiple robots complete
specified tasks with certain rules[5]. Its main research includes:
(1) Communication problems of how to interact with information in many unmanned workshops.
(2) How to divide the overall task into the distribution of individual unmanned vehicles.
(3) How to coordinate the multi-unmanned workshop to make the status of each unmanned car
consistent problem.
(4) Multi-unmanned workshop mutual learning problems and many unmanned workshop how to
determine the logical or physical information and control relationship of the group architecture
problems.
These studies will have a crucial impact on whether multi-unmanned vehicle systems can perform
system-specified tasks more efficiently.

2.3. The research significance of multi-unmanned vehicle system
With the continuous development of multi-unmanned vehicle system research, it shows satisfactory
characteristics. The simple combination of multiple unmanned vehicles does not aptly describe multi-
unmanned vehicle systems, and multi-unmanned vehicle systems involve more complex content, with
features and features far exceeding the simple linear overlay of the function or feature effect of a
single unmanned vehicle[6]. Compared to a system with only one unmanned car, multi-unmanned
vehicle systems have many merits:
(1) Multi-unmanned vehicle system has better time and spatial distribution. Multi-unmanned vehicle
systems perform multiple unmanned vehicles in a fixed formation when performing tasks. The waste
of time or space caused by interference or obstruction caused by the autonomous movement of
individual unmanned vehicles can be reduced through the reasonable coordination and distribution of
individual unmanned vehicles in advance.
(2) The information obtained by the monomer in the multi-unmanned vehicle system is more abundant
and accurate. The transmission of information can be realized through the communication system
between the various unmanned vehicles in the multi-unmanned vehicle system, so as to realize the
effective complementarity of multiple sensor information, so that the information of the whole system
is more abundant and the information content is more accurate.
(3) The performance or function of the monomer in the multi-unmanned vehicle system is relatively
low. First of all, a single unmanned car in a multi-vehicle system can coordinate with other unmanned
vehicles even when the processing power is not strong or limited function, dividing complex tasks into
many small pieces, which greatly reduces the performance and functional requirements of the
unmanned car.
(4) Multi-unmanned vehicle system has better robustness. In the formation of multi-unmanned vehicle
systems to complete tasks, in the case of some unmanned vehicle failure, can also quickly re-form a
new formation, which greatly improves the robustness of the multi-unmanned vehicle system.
(5) Multi-unmanned vehicle system can complete more complex tasks. For example, in a round-up or
escort mission, multiple unmanned vehicles are required to cooperate with each other and be able to
coordinate what happens in the mission, and the multi-unmanned vehicle system is just able to ensure
that the task is completed effectively.
According to the advantages of the above multi-unmanned vehicle system, the research and practical
application of multi-unmanned vehicle system is of great value, and is widely used in many fields:
military applications, ocean and deep space exploration, integrated manufacturing, transportation,
assistance in post-earthquake search and rescue, removal of dangerous areas, etc. Designing a suitable
collaborative control algorithm can enable multi-unmanned vehicle systems to accomplish these tasks
more efficiently and quickly. Therefore, the research of multi-unmanned vehicle system co-control is of great practical significance[7].

2.4. Studying the background of cluster intelligence

A cluster (Swarm) is a group of entities with a common goal, and self-organizing is the coordinated behavior that occurs when the cluster acquires or attempts to acquire that goal, which does not require or require least authorization from the Control Center. Dynamically adjusts to changes in the environment based on each individual's specific tasks. The study of "swarm" began with Grasse's behavioral study of insect communities in 1953. For example, the individual structure and behavior of ants are very simple, but the groups of these simple individuals, the ant colonies, exhibit highly structured social organization characteristics and are able to accomplish complex tasks that go far beyond the individual's abilities[8]. The research shows that ants have wonderful information interaction systems, including visual signals, sound communication and more unique pheromones, based on these complex systems, ant colonies can realize the coordination of individual simple behaviors, through the emergence mechanism of large-scale clusters, showing obvious cluster intelligent behavior. The foraging behavior of the ant colony is a typical representation of this cluster intelligence.

3. Research content of the collaborative control mechanism of multi-unmanned vehicle system

3.1. Introduction

The collaborative control mechanism of multi-unmanned vehicle system is an important research content of multi-unmanned vehicle system, that is, according to the system-specific task, how to carry out the cooperative control of each unmanned workshop makes the task more effective. The cooperative control mechanism of multi-unmanned vehicle system is usually divided into explicit cooperative control mechanism and implicit coordination control mechanism[9].

3.2. Explicit co-control mechanisms

Explicit co-control mechanism refers to the multi-unmanned vehicle system has a clear coordination control mechanism for the exchange of information in the unmanned workshop. Explicit co-control mechanisms are generally divided into three mechanisms:

(1) Completely centralized coordination control mechanism: unmanned vehicles are divided into mainly controlled unmanned vehicles and controlled unmanned vehicles, controlled unmanned vehicles fully obey the orders of the master control unmanned vehicles, the master of the unmanned vehicle to complete the task of the internal planning. This mechanism is relatively simple and reduces the communication time of the negotiation process, but it is very limited and does not apply to more open or dynamic environments.

(2) Full distribution of collaborative control mechanism: the entire system of unmanned vehicles are relatively equal, the final coordination results need to be coordinated by the unmanned workshop many times, each unmanned car has the ability to deal with problems. The coordination of such a mechanism is more comprehensive and can be applied to environmental unknowns, but it is relatively complex and may take some time to coordinate.

(3) The combination of centralized and distributed collaborative control mechanism: this mechanism concentrates the advantages of the fully centralized coordination control mechanism and the full distribution of the coordination control mechanism, and the use is more reasonable.

3.3. Implicit Co-control mechanism
The implicit co-control mechanism refers to the mechanism of the unmanned vehicle to control its own motion based on local perception and local information reasoning[10]. The implicit co-control mechanism is generally divided into two mechanisms:

1) Social rules research mechanism: this mechanism provides for each unmanned car must comply with a set of pre-set rules, to ensure that each unmanned car behavior is carried out in accordance with this set of rules, and finally to ensure that the entire multi-vehicle system behavior is coordinated;

2) Filtering strategy mechanism: filtering strategy mechanism refers to the reasonable part of the optional behavior of the unmanned car according to certain rules to stay, filter out the conflicting part, so as to coordinate the behavior of the whole multi-unmanned vehicle system.

4. Conclusion

Multi-unmanned vehicle system application potential is huge, broad prospects for development, and weapons and equipment and combat mode has a subversive impact, involving control, electronics, information, communications, computers, materials, aviation, marine and many other high-tech. It could also trigger a new revolution in the robot era. However, the development and application of multi-unmanned vehicle system still faces many technical challenges, there are many problems to be solved, such as autonomy and autonomy classification standards, autonomous classification methods, multi-unmanned vehicle system acquisition, multi-unmanned vehicle system applications, especially the application of multi-unmanned vehicle system safety, Legitimacy and how to prevent it from getting out of control are the priorities to be addressed. However, despite the problems, multi-unmanned vehicle systems are still in the process of rapid equipment. The role of multi-unmanned vehicle systems in the future information war and the war on terror will become more and more prominent. It is urgent to study the mission mission of multi-unmanned vehicle system in depth, try to break through the key technologies of related disciplines, and enhance the interoperability and openness of multi-unmanned vehicle system, so as to promote the rapid development of multi-unmanned vehicle system and meet the needs of key combat tasks in the future information war.

[1] Mariana Felisa Ballesteros Escamilla,David Cruz Ortiz,Jorge Isaac Chairez Oria,Alberto Luviano Juárez. Adaptive output control of a mobile manipulator hanging from a quadcopter unmanned vehicle[J]. ISA Transactions,2019.

[2] Feres A.Salem, Ubirajara F.Moreno, Eugênio B. Castelan. Information Distributed Kalman Filter Applied to Rendezvous Problems in Cooperative Robotic Teams [J]. IFAC PapersOnLine,2018,51(25).

[3] Syed Hassan,Jungwon Yoon. Haptic assisted aircraft optimal assembly path planning scheme based on swarming and artificial potential field approach[J]. Advances in Engineering Software,2014,69.

[4] Fabio Petrillo,Yann-Gaël Guéhéneuc,Marcelo Pimenta,Carla Dal Sasso Freitas,Foutse Khomh. Swarm debugging: The collective intelligence on interactive debugging[J]. The Journal of Systems & Software,2019,153.

[5] Fukuda T, et al. Structure Decision Method for Self Organizing Robots based on Cell Structures-CEBOT [C]. IEEE Int. Conf. On Robotics and Automation, 1989: 695-700.

[6] Xiao-xu DU,Huan WANG,Cheng-zhi HAO,Xin-liang LI.Analysis of hydrodynamic characteristics of unmanned underwater vehicle moving close to the sea bottom[J].Defence Technology,2014,10(01):76-81.

[7] N.Heider,V.Denefeld,H.Aurich.Analysis of global momentum transfer due to buried mine detonation[J].Defence Technology,2019,15(05):821-827.

[8] G.Magudeeswaran,V.Balasubramanian,G.Madhusudan Reddy.Metallurgical characteristics of armour steel welded joints used for combat vehicle construction[J].Defence Technology,2018,14(05):590-606.
[9] V.Denefeld,N.Heider,A.Holzwarth.Measurement of the spatial specific impulse distribution due to buried high explosive charge detonation[J].Defence Technology,2017,13(03):219-227.

[10] S.V.S.Narayana MURTY,Sushant K.MANWATKAR,P.Ramesh NARAYANAN.Metallurgical analysis of a failed maraging steel shear screw used in the band separation system of a satellite launch vehicle[J].Defence Technology,2016,12(05):380-387.

Acknowledgments
This work has been supported by the National Natural Science Foundation (NSSF) of China under Grant 91748211.