



Research on Manned and Unmanned Collaborative Mission Planning Based on Intelligent Decision-making of the ABC (Artificial Bee Colony) Algorithm

Su Guo*, Wei Pu

Army Academy of Armored Forces, Beijing, China.

How to cite this paper: Su Guo, Wei Pu. (2024) Research on Manned and Unmanned Collaborative Mission Planning Based on Intelligent Decision-making of the ABC (Artificial Bee Colony) Algorithm. *Advances in Computer and Communication*, 5(1), 48-52.
DOI: 10.26855/acc.2024.02.008

Received: February 16, 2024

Accepted: March 13, 2024

Published: April 9, 2024

*Corresponding author: Su Guo, Army Academy of Armored Forces, Beijing, China.

Abstract

This article delves into the realm of collaborative mission planning involving both manned and unmanned systems, leveraging the Artificial Bee Colony (ABC) Algorithm. In the context of current challenges in intelligent decision-making, especially the effective coordination of manned and unmanned entities in complex systems, this research focuses on the principles and evolution of the ABC algorithm and its role in intelligent decision-making scenarios. The study begins with a detailed analysis of the ABC algorithm's basic principles, examining its potential to facilitate collaborative planning between manned and unmanned systems. This examination leads to the construction of a specialized mission planning model tailored to the unique dynamics of such collaborations. The paper then progresses to an optimization of the ABC algorithm, aiming to heighten the efficiency and effectiveness of task planning. Anticipating a breakthrough in task planning methodologies, the study proposes a system capable of achieving optimized resource allocation and heightened decision-making efficiency in environments that involve both manned and unmanned elements. A key highlight of this research is the comprehensive analysis of the ABC algorithm's applicability in complex systems. This serves as the foundation for introducing an innovative solution, addressing the nuanced challenges faced in contemporary intelligent decision-making. This innovative approach promises to advance the field by offering new perspectives and methodologies in orchestrating collaborative missions.

Keywords

Artificial bee colony algorithm, collaborative task planning, intelligent decision-making

1. Introduction

In today's era of rapid technological development, intelligent decision-making and task planning play an important role in many fields. Especially in the collaborative operation of manned and unmanned systems, effectively planning and making decisions have become key challenges. This research focuses on exploring the application of Artificial Bee Colony (ABC) in collaborative mission planning between manned and unmanned systems, aiming to provide an efficient intelligent decision-making mechanism. The ABC algorithm, as an optimization algorithm that simulates bee colony behavior in nature, has shown its excellent search capabilities and the application potential in many fields [1]. Its application in the field of intelligent decision-making, especially when dealing with task allocation and

planning problems in complex systems, shows unique advantages. The article aims to provide theoretical guidance and practical solutions for efficient and intelligent collaboration between manned and unmanned systems, and at the same time contribute a new perspective to the development of intelligent decision-making theory.

2. Theoretical basis of the ABC Algorithm

2.1 Basic principles of the ABC algorithm

The artificial bee colony algorithm is an optimization algorithm that simulates the foraging behavior of bees. Its design is inspired by the intelligent behavior of bees in the process of searching for food sources. The core of this algorithm is to imitate the division of labor and information exchange mechanism of bee society, so as to effectively explore and utilize the search space. In the ABC algorithm, bee colonies are divided into three categories: scout bees, hired bees, and follower bees. The scout bees are responsible for randomly searching for new food sources, that is, potential solution space areas; the hired bees conduct local searches around known food sources to optimize the current solution; the follower bees select food sources for further processing based on the information provided by the hired bees [2]. During the execution of the algorithm, the position of a group of bees in the search space is first initialized, representing different solutions. Scout bees randomly explore new areas, while hired bees and follower bees conduct detailed searches within these areas [3]. The quality of each food source represents the quality of the solution. Bees will decide whether to continue searching in this area or move to a new area based on the quality of the food source. In addition, when a food source has not been improved within a certain period, the scout bees will abandon the food source and search for new areas. This mechanism promotes the algorithm to maintain a balance between global search and local search, effectively avoids falling into the local optimal solution, and enhances the global search capability of the algorithm.

The distinguishing features of the ABC algorithm are its simplicity and powerful global search capabilities. By imitating the social behavior of bees, the algorithm can effectively explore and exploit the solution space to find the optimal solution or a near-optimal solution. This optimization method based on swarm intelligence shows significant superiority in dealing with complex multi-peak optimization problems and is suitable for optimization tasks of various complex systems [4]. Therefore, the ABC algorithm not only has important value in theory but also shows broad application prospects in practical applications. Figure 1 shows the basic framework of the ABC algorithm.

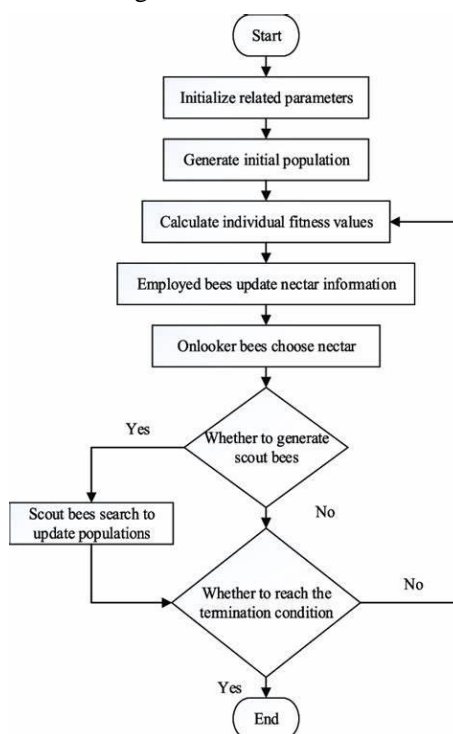


Figure 1. The basic framework of the ABC algorithm.

2.2 Evolution and development of the ABC algorithm

The ABC algorithm has experienced significant evolution and development since its introduction and has become an important branch in the field of intelligent optimization. Originally proposed by Karaboga in 2005, it was designed to simulate the foraging behavior of bee society. Since then, the algorithm has gradually developed from a simple proof-of-concept to an optimization tool with wide applications. In the early stages, the ABC algorithm mainly focused on the exploration of basic principles and empirical research on simple applications. With an in-depth understanding of algorithm performance, researchers began to work on improving and optimizing the algorithm to make it more suitable for complex practical problems. During the evolution process, the key improvements of the ABC algorithm include the optimization of the search mechanism, the improvement of parameter adjustment strategies, and the combination with other optimization techniques. In order to improve the convergence speed of the algorithm and the quality of the solution, researchers have introduced a variety of heuristic rules and adaptive mechanisms [5]. For example, by adjusting the number ratio of scout bees and hired bees, or introducing a local search strategy, the global and local search capabilities of the algorithm can be enhanced. In addition, the integration with other optimization algorithms such as genetic algorithm and particle swarm optimization algorithm has also been proven to effectively improve the performance of the algorithm. The development of the ABC algorithm is also reflected in the continuous expansion of its application scope. From the initial function optimization problem, it has expanded to many fields such as machine learning, image processing, and network optimization. In these applications, the algorithm has demonstrated its ability to handle complex problems, especially in multi-objective optimization and optimization in dynamic environments. These studies not only verified the effectiveness of the ABC algorithm but also further promoted the development of its theory.

2.3 Application of the ABC algorithm in intelligent decision-making

The application of the ABC algorithm in the field of intelligent decision-making has shown its unique advantages and wide applicability. Intelligent decision-making, as a method that relies on models, data, and algorithms to optimize the decision-making process, puts forward efficient, accurate, and reliable requirements for optimization algorithms. In this context, the ABC algorithm has become an important tool for solving complex decision-making problems due to its excellent global search capabilities and adaptability. In various decision-making problems, such as resource allocation, scheduling optimization, path planning, etc., the ABC algorithm has demonstrated its ability to optimize complex systems. For example, in supply chain management, the ABC algorithm can effectively optimize costs and balance supply and demand. In terms of network design and management, the ABC algorithm is used to optimize network layout and traffic control to improve network performance and efficiency. In addition, in the field of machine learning, the ABC algorithm is also used in feature selection and optimization of model parameters to improve the accuracy and generalization ability of the learning model. The key is that the ABC algorithm can effectively handle high-dimensional, nonlinear, and multi-constraint complex situations when dealing with these decision-making problems. The adaptability and flexibility of the algorithm enable it to find optimal or near-optimal solutions in uncertain and dynamically changing environments. This is particularly important in rapidly changing market environments and complex system decisions. Furthermore, the parallel processing capabilities of the ABC algorithm also make it particularly effective in handling large-scale problems, which is particularly critical in today's data-intensive and computing-intensive decision-making environments.

3. Collaboration theory between manned and unmanned systems

3.1 Definition and classification of manned and unmanned systems

Manned systems and unmanned systems represent two different modes of operation in modern technology. Manned systems refer to those systems that are directly controlled by a human operator or have significant human intervention. These systems are characterized by relying on human intuition, experience, and decision-making capabilities, such as traditional aviation control systems. In contrast, unmanned systems are those that rely primarily or entirely on automation technology and artificial intelligence to operate, such as driverless cars and autonomous drones. The classification of both systems is based not only on the degree of automation of operations but also on their level of autonomy in decision-making, control, and execution of tasks. Unmanned systems often show advantages in highly

complex or dangerous environments, while manned systems excel in scenarios that require human intuition and creative decision-making.

3.2 Theoretical framework of collaborative task planning

The theoretical framework of collaborative mission planning refers to a methodology for effective planning of task allocation, decision-making, and execution processes when manned and unmanned systems jointly perform tasks. This framework involves many aspects, including the identification of task types, allocation of resources, definition of roles, and coordination mechanisms during execution. Collaborative task planning needs to consider the interaction and impact between systems to ensure that tasks can be completed efficiently and reliably with limited resources. The theoretical framework also needs to include adaptive considerations for uncertainty and environmental changes, as well as assessment and response strategies for various potential risks. Effective collaborative task planning not only improves the efficiency and success rate of task execution but also plays a key role in ensuring coordination, consistency, and stability between systems.

3.3 Challenges and opportunities of manned and unmanned collaboration

Manned and unmanned collaboration face a series of challenges and opportunities when executing complex tasks. The challenge is mainly reflected in the interaction and coordination between the two systems, such as how to ensure the accurate transmission of information, consistency of decision-making, and synchronization of operations. In addition, technical compatibility, system reliability, and security are also important considerations. For example, the autonomy and predictability of unmanned systems need to be combined with the flexibility and adaptability of manned systems to handle unforeseen situations. The opportunity lies in the complementary advantages that the collaboration of the two systems can bring. For example, unmanned systems can perform high-risk tasks, while manned systems can perform complex decision-making and supervision. In addition, collaborative operations can improve efficiency, reduce resource consumption, and achieve more efficient and precise task completion in complex environments.

4. Application of the ABC algorithm in manned and unmanned collaborative mission planning

4.1 Analysis of the applicability of the algorithm

The key to the applicability analysis of the ABC algorithm is to evaluate its effectiveness and efficiency in different types of collaborative task planning. Suitability analysis usually involves the convergence speed, solution quality, and stability of an algorithm when dealing with a specific problem. For example, considering the application of the ABC algorithm to a multi-objective optimization problem, its suitability can be evaluated by the algorithm's ability to find Pareto optimal solutions. Specifically, it can be done by comparing the difference between the optimal solution set found by the algorithm and the known Pareto front. In addition, the performance of the algorithm under different scale problems also needs to be considered, for example, by evaluating the time complexity and space complexity of the algorithm on small-scale and large-scale problems. The applicability analysis also includes the sensitivity of the algorithm to different parameter settings, that is, the stability of the algorithm performance when parameters change.

4.2 Construction of mission planning model

When building a mission planning model, the problem can be formalized as an optimization problem. For example, if the goal is to minimize the total time to complete a task, the objective function can be defined as:

$$\min Z = \sum_{i=1}^n t_i$$

Among them, n is the total number of tasks, t_i is the completion of the i -th time required for each task. In this model, the decision variable can be the assignment matrix of tasks, indicating which tasks are assigned to manned systems and which to unmanned systems. Constraints can include resource limits, time windows, etc. The application of the ABC algorithm in this model is to optimize the above objective function by iteratively searching for different task allocation schemes.

4.3 Algorithm optimization and performance evaluation

When optimizing and evaluating the performance of the ABC algorithm, it usually involves adjusting the algorithm parameters and measuring the performance of the algorithm on a specific task. For example, a key parameter of the algorithm is the number of bees, N , which can be adjusted to observe the impact on performance. Performance evaluation can be performed by calculating the difference between the optimal solution found by the algorithm and the known optimal solution:

$$\Delta = \left| f(x_{\text{algorithm}}) - f(x_{\text{optimal}}) \right|$$

In addition, the convergence speed of the algorithm can be measured, that is, the number of iterations required to achieve a certain solution quality. Through these methods, the application effect of the ABC algorithm in specific task planning can be comprehensively evaluated and optimized.

5. Conclusion

This study conducts an in-depth discussion on manned and unmanned collaborative mission planning based on the ABC algorithm. By analyzing the basic principles, evolution, and development of the ABC algorithm and its application in intelligent decision-making, this article establishes a complete theoretical framework. Furthermore, based on the theory of collaboration between manned and unmanned systems, we discussed the construction method of the mission planning model and the optimization application of the ABC algorithm. The findings of this study show that the ABC algorithm shows significant advantages when dealing with complex collaborative task-planning problems, especially in optimizing resource allocation and improving decision-making efficiency. Future research can focus on further optimization of the algorithm, such as combining machine learning technology to improve the adaptability and intelligence of the algorithm. At the same time, exploring the performance of algorithms in a wider range of application scenarios, especially in dynamic and uncertain environments, will be a direction worthy of attention.

References

- [1] Tang J, Duan H, Lao S. Swarm intelligence algorithms for multiple unmanned aerial vehicles collaboration: A comprehensive review [J]. *Artificial Intelligence Review*, 2023, 56(5): 4295-4327.
- [2] Zhou Y, Rao B, Wang W. UAV swarm intelligence: Recent advances and future trends [J]. *IEEE Access*, 2020, 8: 183856-183878.
- [3] Qiming Z, Husheng W, Zhaowang F. A review of intelligent optimization algorithm applied to unmanned aerial vehicle swarm search task [C]//2021 11th International Conference on Information Science and Technology (ICIST). IEEE, 2021: 383-393.
- [4] Sun W, Hao M. A Survey of Cooperative Path Planning for Multiple UAVs [C]//International Conference on Autonomous Unmanned Systems. Singapore: Springer Singapore, 2021: 189-196.
- [5] Cheng Y, Li D, Wong W E, et al. Multi-UAV Collaborative Path Planning using Hierarchical Reinforcement Learning and Simulated Annealing [J]. *International Journal of Performability Engineering*, 2022, 18(7).