Swarm Slam Optimization of the Bionic Working Mode of the Robot

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Abstract. How swarm slam robots work in unknown environments is one of the key research topics today. Researchers have found that in the case of optimization of bionic working mode, there is still a research gap on how to obtain more direct and accurate information in an unknown complex environment and how to reduce the working cost of robots. In this study, researchers start with ant colony robots. In terms of bionic working mode, they first adopt the arrangement mode of ant colony incubation to improve the utilization rate of multiple robots to the environment, and then collect and transfer environmental information by means of DCPSLA which solves the problem by means of chain robots. The researchers carried out a series of optimization from the aspects of multi-robot work cost, safety guarantee, work efficiency and so on. Therefore, through consulting papers and collecting knowledge, the research topic of this paper is optimization of the bionic working mode of swarm slam robots.

Keywords: Swarm Slam, Release Algorithm, Multi-robot Way of Working.

1 Introduction

Swarm Simultaneous Localization and Mapping (Swarm SLAM) is a technology that uses swarm robots for simultaneous positioning and map construction.

Swarm SLAM The robot needs to accurately perceive the surrounding environment and locate it. However, swarm robots are often limited by sensors, such as sensor accuracy, sensing range, and reliability of sensor data. Therefore, how to improve the perception and positioning ability of robots, and how to handle the noise and uncertainty of sensor data is an important research direction [1].

When the swarm robot performs simultaneous map construction, it needs to deal with a large amount of sensor data and the data matching problem between the robots. With increasing group size, algorithms for map construction need to have efficient processing capacity and good scalability. In addition, how to reduce the accumulation of errors during large-scale map construction is also a challenge. The algorithm of Swarm SLAM needs to have high efficiency and real-time performance to meet the needs of group robots in practical applications [2]. How to design and optimize the algorithm, and adopt appropriate distributed computing and communication strategies

Y. Wang (ed.), *Proceedings of the 2024 International Conference on Artificial Intelligence and Communication (ICAIC 2024)*, Advances in Intelligent Systems Research 185,
https://doi.org/10.2991/978-94-6463-512-6_11

to improve the performance and efficiency of the algorithm is an important research direction. Although Swarm SLAM has many potential application scenarios, such as environmental monitoring, rescue missions, etc., it still faces some challenges in practical application. For example, in complex and dynamic environments, swarm robots need to be highly intelligent and adaptive to cope with different situations and task requirements [3].

This paper adopts the method of review research in group robots, they face a variety of problems. From the early layout and for obstacle avoidance, information transmission and assist the contract to solve the problem, to achieve the research purpose, and use the robot communication in a concise way to solve the problem.

2 The Preliminary Work Layout of The Group Robot

2.1 Bionic Definition of A Swarm Robot

Research in swarm robotics is often inspired by observations of social insects Researchers soon realized that understanding the functions of system-level features of social insects, such as robustness to individual failure, flexibility to adapt to environmental changes, and scalability over large group sizes, could provide insights into how to achieve this desirable ability in multi-robotic systems. Biologists, computer scientists, and robotics experts collaborate to transfer their knowledge of social insect behavior to the design of multi-robotic system controllers, as shown in Fig 1 [4].

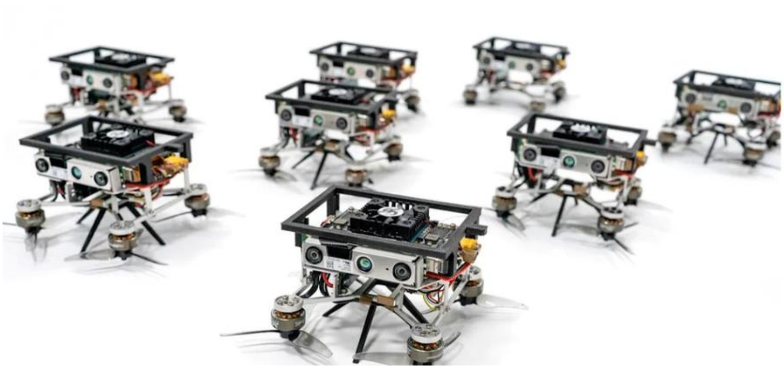

Fig. 1. The aerial independent group robot [4]

2.2 An Early Layout of Group Robots

This multidisciplinary joint effort has spawned the field of research known as group robotics. There are already too many terminologies marking different styles of multirobotics research, such as "collective robotics", "distributed robotics", and "robotic colonies", which often have vague and overlapping meanings. Ants will order the larval eggs according to their hatching degree, and the more hatched eggs are placed in peripheral positions to obtain more space and resources, which can be regarded as a circular sorting problem.

Assuming that in a working environment, the swarm robot cannot expand in large areas in a narrow working environment, which can imitate the working characteristics of the ant colony. The ant incubation process presents an orderly arrangement behavior, and its larvae can be roughly arranged in three layers of rings, as shown in Fig 2 [5].

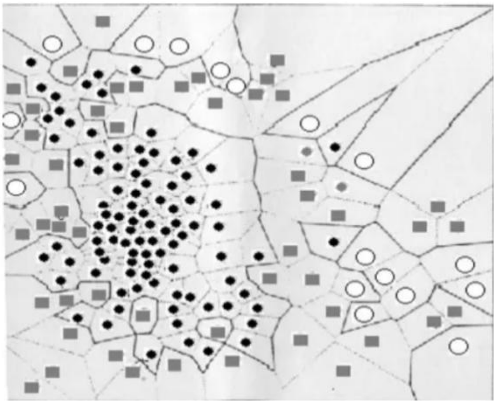

Fig. 2. The sequence of the ant hatching distribution[3]

The researchers explored the idea of classifying targets with simple rules, early only in simulation and recently on real robots, such as clustering single types of targets and classifying two different types of targets. The researchers used the mechanism for circular classification of any number of type targets and defined a cluster as a set of objects, with no target more from any other target than an individual's diameter. Each robot uses simple mechanical structures and sensing mechanisms, as well as simpler strategies to allow for more robust and cheaper robotic units.

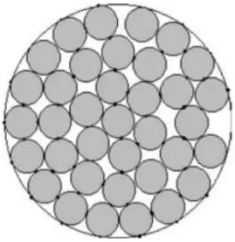

Fig. 3. The estimated filling scheme of the Donavan algorithm[3]

Hence, on the basis of the collective robot is classified, as suitable for collecting information robot distribution in the periphery, at the same time according to the division of work, with high precision lam "worker" to collect information, collected through local area network information to the next layer of robot, they are responsible for the field thickness and a series of conditions in the center of ants "queen" robot. The degree of compactness indicates whether it is compressed to the smallest possible range to improve space utilization, regardless of the spatial stacking case, and estimates the minimum radius as well as the filling scheme, as shown in Fig 3.

3 The way the Group Robots Work

3.1 Collection and Processing of Information

The DCP-SLAM technique is shown in Fig 4 below. Unknown obstacles are shown in gray. Once the robot's onboard sensor detects an obstacle (or a part of it), it is red in the figure. (A) Original setup, the launch pad of the launching robot, and the display of unknown obstacles.(B) The robot 1 examines an obstacle while navigating to the target. The first robot broadcasts the information to the next robot. (C) Robot 1 part examines the second obstacle, and the second robot navigates to the navigation point placed from the first robot. (D) The first robot gets the unimpeded path leading to the target, and the second robot navigates from the other side of the obstacle while broadcasting the information. (E) Robot 2 finds the unimpeded path to the target. The next robots choose the best path [6].

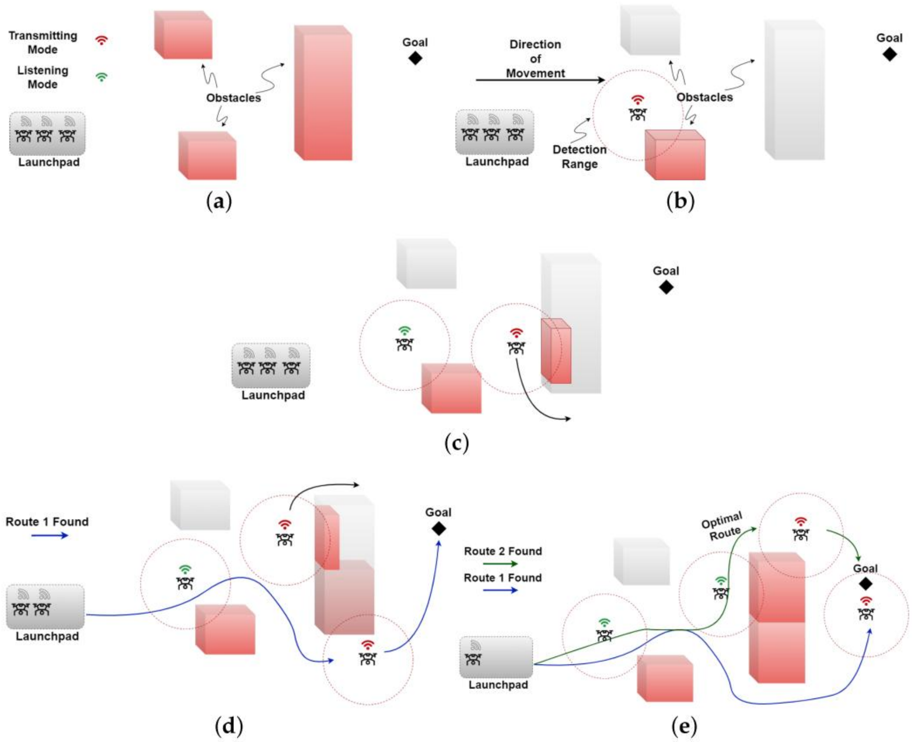

Fig. 4. The system developed by the DCP-SLAM technology [6]

3.2 For Map Navigation and Obstacle Avoidance

Navigation and obstacle detection get a common pseudocode through algorithm 1. Agents execute this top-level algorithm locally using their off-machine processing units. At the beginning of the mission, the agents were assigned an ID and established a connection between them in the leader and follower system. In the initialization phase of the algorithm, a global leader is declared, and the corresponding followers are connected to the corresponding followers of each leader in a hierarchical manner. Then, if the corresponding agent does not reach the specified destination, navigation is started. During the navigation phase, if the agent has not reached the specified goal, navigation begins. If the agent detects an obstacle, the properties of the obstacle are stored in a list of obstacles. The agent then calls a function called Merge Objects to check if these obstacles have been detected by other agents that may be navigating the same path.

3.3 Crash Prevention and Map Construction

When the agent is started, it executes an obstacle avoidance algorithm to reach the destination using the shortest path. It chooses the nearest inflection point as its temporary target or navigation point, and moves to the navigation point, while constantly sensing the hitherto invisible obstacles in its environment. If it is detected on the way to the navigation point, the intelligent experience will perform anti-collision and publicize the coordinates of the newly discovered obstacle part. All agents update their respective maps by adding newly collected information and running merge object algorithms to merge multiple parts of the same obstacle into a single one. After the agent leaves it, repeat the process of choosing the navigation point towards the target until it completes the task.

4 Task assignment for multi-robots

Group intelligence (SI) is an innovative computing and behavioral metaphor, used to solve the problem of distribution, its inspiration from biological examples provided by social insects. In multi-robot SLAM, robots can collaborate in a decentralized manner without requiring central processing centers to capture their locations and more precise maps of the environment. In these environments, most robots not only have gaps for algorithms but also gaps for how to work. Given seeing a few papers I think of using the work of ants, for example, when urban pipeline problems, artificial cannot do further, send more robot cooperation, because carrying all the cost of accessories is expensive, can let the queen robot carrying problems possible all functional accessories, let the worker robot to collect information, problems such as all detection, the queen to solve all the problems, to achieve efficient and the lowest cost.

After the early collection of workers, the system will use the chain robot structure to protect the queen and transmit the required processing information to the queen robot through the wireless network. In the chain structure, each robot is a fully autonomous mobile robot, capable of performing basic tasks. In addition to these functions, one-bot is able to communicate with other s-bot, physically shown in Fig 5. Graphical visualization shows how rigid handles can be used to connect a robot in a safe way, thus forming chains that overcome large barriers or holes. Connect them in a flexible way to form the so-called swarm robots. Such robotic entities are capable of performing individual robot tasks with major problems, such as exploring, navigating, and transporting heavy objects on very rugged terrain. The scene itself is divided into four stages [7].

Fig. 5. The chain robotic system[8]

In the first stage, a group of robots search for a weight, seize it, and begin to move it collectively. At the same time, another group of robots is dispersed throughout the environment looking for targets. In the second stage, the robot creates a path for the object connecting the initial position to the target position. In the third and fourth stages, the robots transporting objects had to move through a narrow channel by configuring their position around the object. This scenario highlights swarm robot concepts, robustness, versatility, and rough terrain navigation.

The issue of robustness to physical damage plays a crucial role in unstructured and unstable environments. For example, after a disaster, as shown in Fig 6. Large rocks, holes in the ground, obstacles and other hazardous materials can cause damage to the robot system. The system must be fault-tolerant to ensure the efficient execution of tasks [8].

Fig. 6. Unstructured and unstable environments [8]

5 Optimization of Bionic Working Mode with Integrated Multi-robot Operation

This paper presents a method to find the best navigation mode for a group of autonomous robots. This method is used to make observations using only local airborne sensors in an environment without pre-prepared maps and to share observations. By using the Donavan algorithm to estimate the minimum radius, The group robot in a small working environment as small as possible, When all the robots are in place, The worker ant robot will use the path algorithm provided by the DCP-SLAM radar to move forward and process the collected information through the algorithm, Using the Internet to deliver to the next episode of the worker ant robot, After all the worker robots have collected the information, Transfer all addressed issues to the queen robot in the colony center, The queen robot will calculate calculations based on previous paths, At the same time, the queen robot accessories focus on handling the corresponding problem, For path processing mainly through the chain robot working structure, The one-bot is able to communicate with the other s-bot, Using a rigid grip to connect the robot in a safe way, Thus forming chains that overcome large barriers or holes. Connecting them in a flexible way to create so-called swarm robots, not only protecting the queen robots but also reducing the energy consumption of the queen robots. In the overall working mode, the division of labor and cost of the group robot is considered, so that the worker robot with a single working nature can explore the terrain and collect information, and the queen has rich functions to solve problems, which can optimize the work efficiency and reduce the work cost.

The robot navigates towards the goal using the suggested technique, detecting and avoiding nearby objects with the help of its airborne range sensor. The technique optimises the remaining robots in the swarm's route by leveraging the map data created by the leading robots. Therefore, any gaps due to loss of information are quickly filled by followers. Situations in which many different objects obstruct the straight path to the destination are simulated. In this way, it is also shown that the environment is learned in sufficient detail through the channels of some leading robots so that the remaining members of the cluster can find the best path.

Therefore, given that the entire swarm takes the best path, some leading robots will eventually take longer routes and discover the hidden parts from partially found obstacles. This additional information will be shared with other members of the group and choose routes more wisely by following the robot. This selects the best path for the follower and saves up to 13% for the individual robot. Moreover, using the proposed method, the distance travel efficiency is up to 11% [9].

Bulk robots can benefit from multi-range and multi-mode sensors to sense and exchange signals at different levels and environments. However, the actual interference is more, for example, the detection range of infrared proximity sensors is short. In contrast, a camera is a passive sensor that can use features extracted from an image for distance sensing. The control structure of swarm robots adopts distributed control based on local information and simple self-organizing rules inspired by ant colony behavior.

Although this control algorithm does not require much computing power, it requires fast pre-processing and efficient control because the robot is equipped with a network of multiple processors, each of which is responsible for a specific subtask in the system. The main processor is responsible for system management and communication with the base station for monitoring purposes. These processors run the standard Linux operating system, allowing the use of standard development tools and easily customized robot development tools. Finally, the robot is also equipped with a radio connection to the base station, but only for monitoring rather than control.

The environments in which robots must move in extreme exploration applications include plenty of obstacles of any kind. Robots designed to deal with many features are likely to be challenged by other robots. It is possible one task begins with one goal and ends with another. For example, a task could begin with the exploration step and end with a transport task [10].

6 Conclusion

This paper introduces the concept of swarm robotics, where swarm intelligence mechanisms utilize collective interactions that go beyond the control layer. This means adding new mechanical functions to a single robot, as well as new electronic devices and software to manage it. The new feature can solve complex mobile robot problems. In future work, we aim to further develop the proposed approach and refine our methods for adapting to dynamic environments with moving obstacles. At the same time, researchers have found that there are certain research gaps in the construction of map information, the construction of information channels, and the protection of robots. The algorithm adopts the ant colony bionic working mode to improve the robot system. At the same time, there are some problems in the completeness of information search, the efficiency and accuracy of information transmission, robot movement, and work efficiency. The researcher will conduct in-depth research and improvement in the future.

References

1. Cao, H., Liu, Q.: SLAM algorithm based on semi-direct method. Journal of Engineering **44**(11): 3345–3358 (2023)
2. Pei, F., Wu, X., Yan, H.: Distributed SLAM system using particle swarm optimized particle filter for mobile robot navigation. In: 2016 IEEE International Conference on Mechatronics and Automation, pp. 994–999. Harbin, China (2016)
3. Sun, T., Feng, Y.: Research on indoor mapping of lidar assisted by inertial sensor. Industrial Control Computer **35**(10): 121–123+153 (2022)
4. Bailey, T., Durrant-Whyte, H.: Simultaneous localization and mapping (SLAM): part II. IEEE Robotics & Automation Magazine **13**(3): 108–117 (2006)
5. Zhou, R.: A visual slam algorithm based on multi-feature optimization for indoor environments. In: 2023 42nd Chinese Control Conference (CCC), pp. 3929–3934. Tianjin, China (2023)

6. Mahboob, H., Yasin, J. N., Jokinen, S., Haghbayan, M. H., Plosila, J., Yasin, M. M.: DCP-SLAM: distributed collaborative partial swarm slam for efficient navigation of autonomous robots. Sensors (Basel) **23**(2):1025 (2023)
7. Xu, Z., Wu, J.: A study of RBPF-SLAM model. Surveying and Mapping Science **48**(06): 112–118. (2023)
8. Li, Z., Cui, G., Li, C., Zhang, Z.: Comparative study of slam algorithms for mobile robots in complex environment. In: 2021 6th International Conference on Control, Robotics and Cybernetics (CRC), pp. 74–79. Shanghai, China (2021)
9. Qian, R., Guo, H., Chen, M., Gong, G., Cheng, H.: A visual SLAM algorithm based on instance segmentation and background inpainting in dynamic scenes. In: 2023 38th Youth Academic Annual Conference of Chinese Association of Automation (YAC), pp. 132–136. Hefei, China (2023)
10. Zhang, S.: The Research of RBPF-SLAM Accuracy under the Influence of Depth Camera Noises,2020 International Conference on Computing and Data Science (2020).