



Review on Flocking Control

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Abstract. Nowadays, significant changes have taken place in the field of information technology and industry and robot research is also deepening. The realization of multi-robot flocking control problem has far-reaching significance. This paper mainly introduces the development status of flocking control at home and abroad and summarizes several commonly used distributed flocking control strategies. In this paper, on the basis of summarizing the development of flocking research at home and abroad, forecasts its development prospect in the field of aviation and so on.

Keywords: Multi-robot · Flocking control · Distributed

1 Introduction

With the development of robot technology and the further improvement of social needs, people's requirements on robots are no longer limited to a single robot, but more and more interested in the system composed of multiple robots. This is not only because some tasks cannot be undertaken by a single robot, but more and more examples show that for some dynamic and complex tasks, the development of a single robot is far more complex and expensive than the development of multiple robot systems. At the same time, with the emergence of robot production line, the desire of autonomous operation of multiple robot systems becomes more and more strong. In the late 1970s, some robotics researchers applied the multi-agent theory of artificial intelligence to the research of multi-robot systems, thus starting the research of multi-robot technology in the field of robotics. Multi-robot system is not a simple stack of a single robot, but an organic combination of multiple robots. It effectively avoids the shortcomings of a single robot and gives full play to the advantages of group robots. With the continuous deepening of robot research and the continuous development of military, security, industrial production and other application fields, as one of the important bases and research directions of multi-robot cooperation and coordination, the realization of multi-robot crowd control problem plays an increasingly important role.

Multi-robot system research began in the 1970s, since then many foreign universities and research institutes extensively studied the multi-robot system, they

Supported by National Nature Science Foundation under Grant 61203335, and partly by National Natural Science Foundation of China (Nos. 61603150).

set up specifically for multi-robot system research project, MARTHA (Multiple Autonomous Robots for Transporting and Handling Application) in [12]. Under the study of foreign experts and scholars, this kind of flocking control has been widely applied in network topology, obstacle avoidance of autonomous mobile agents and other aspects. After nearly 40 years' research, flocking control has been well developed. In recent years, Chinese researchers have also begun to have a strong interest in studying robot swarm motion control. Flocking control has achieved remarkable results in military and other aspects.

2 Research and Analysis

Flocking control has been paid great attention by intelligent system theorists at home and abroad. Formation control refers to the control technology that multiple mobile robots maintain a certain formation while adapting to environmental constraints (such as the existence of obstacles or physical restrictions of space) when they reach the destination. Through research and development and practical application, the great application prospect of this technology in industrial and agricultural production, flexible manufacturing, unmanned exploration (ocean, space, nuclear environment), especially in the national defense industry is gradually reflected. These areas include moving large objects in fixed formations, encircling/capturing intruders in arcs, and completing space missions. Autonomous formation control is also applied to vehicles, mainly in formation movement according to the specified path, including collision avoidance between vehicles. This multi-robot formation is also used in exploration, rescue and environmental monitoring of unknown environments [17].

2.1 Flocking Control Based Leader-Follower

In the follower-leader formation, one robot plays the role of leader and has absolute control, coordinating with other robots, while other intelligent robots play the role of follower. The navigator is responsible for sending commands and navigation information to other robots, and then leads other robots to maintain a formation so that the robots in the formation will not collide with each other. At the same time, the artificial potential field method is used to maintain a certain distance and angle between the robots. The downside of this approach is that we don't get enough information, navigation information only, cannot obtain the following information such as the position and posture, and the lack of information communication between followers. It can cause the connectivity between the two is not good, when the navigator and followers have a communications problem between, both will lose connection, which can cause the failure of the formation, and are more prone to local minima. But the advantage is to the communication request is not so high, the real time is strong. A fuzzy controlled multi-agent distributed control is adapted in [1].

Due to the poor stability of the traditional formation method of leaders and followers, for example, when the communication between the leader and the

following robot goes wrong, the formation of the whole robot will be wrong. In order to solve this problem, a method of re-electing leaders is proposed in [16]. The method of connection problems when the formation of the leader and other robots, the system will calculate the average energy of the whole robot team formation to level, and based on the energy level of each robot in the robot to elect a leader in the group, then discard leader of problems before, this will greatly improve the stability of the robot formation, significantly reduce formation error. The method in this paper is based on the leader follower control method proposed in [19].

A distributed control method for aggregation and formation of machine fish is proposed in [8]. Leaders in this approach have no external input. In this case, the fish inside need of attraction and repulsion method is introduced to avoid the fish within the collision, the number of leaders is far less than the follower, and the leader is not affected by followers, thus caused the unidirectional communication between leader and followers, in order to improve the school internal stability and avoid collisions, has also taken by reducing the speed and increase the intensity of potential function of individual fish.

The advantage of this method is that the behavior of the whole robot formation can be controlled only by the behavior and trajectory of the given navigator, and the control is simple. The disadvantage is that the navigator is not easy to get the tracking error feedback of the follower. If the leader moves too fast or the follower is blocked by the obstacle, the formation may be damaged, which will affect the quality of task completion in severe cases. In the case of leader failure, if the design is not fully considered and simply relies on it, the consequences will be very serious. Usually, this requires the adoption of strategies such as designated alternate leader and leader replacement according to the situation in the design process to improve the system capacity.

2.2 Behavior-Based Approach

Different from the traditional formation method, the behavior-based architecture does not need to be modeled, but directly outputs the expected speed and direction through sensors to feel the external stimuli, which has the advantages of fast response speed and strong adaptability to the environment. The behavior-based approach consists of three parts. When the robot movement through its positioning module for current position, and then through the communication module for data broadcasting, the robot for leadership position information of the whole system, finally, following its own position information and the position of the leader and by motion control module to realize their own update speed and angle. The triangle control method of multi-intelligent aircraft cluster is described in [11]. The whole aircraft group has the leader and the following aircraft. The leader is the center of the whole aircraft group, and the other following aircraft keep the relative position with the center aircraft. The standard linear quadratic method is adopted to design the final following aircraft of the aircraft group.

In [2], Olfati Saber algorithm is adopted, and the change of constant formula and Gronwall inequality proves that the whole swarm system will increase the probability of collision within the swarm if the distribution of robots is too dense.

There is a self-triggering distributed control algorithm in [7]. Each agent can determine the adaptive sampling time, thus reducing communication time and controlling behavior time. Dynamic decoupling can also be carried out between multiple agents, so that each agent has a local controller, so as to alleviate the problem of irregular position distance and unstable speed between robots. This method makes the formation of the group more stable, and also alleviates the problem of collision between robots to some extent.

In [18], they focused on the Cucker-Smale multi-intelligence model prediction cluster control scheme, and mainly studied the cluster prediction problem of the model in the discrete time domain. The velocity can be changed by adjusting the control force, so that the velocity of the group can be unified and the movement of the group can be relatively stable. The disadvantage of this method is that the group behavior is not clearly defined, it is difficult to carry out mathematical analysis and it is difficult to ensure the stability of formation.

2.3 Flocking Control Without Leader

A formation control of amigobot robot has been proposed in [10], which is a discontinuous cluster control for tracking γ -agent. The formation control of five robots was realized by tracking the trajectory of five γ -agents. The asymptotic stability of this approach has been demonstrated by treating a classical non-intact robot system as α -agent and then tracking γ -agent.

Haibo studied the flocking problem for flying robots in three-dimensional space in [9]. Each robot's attitude dynamics is considered. Motivated by consensus algorithms, they propose a distributed control law to achieve the flocking of flying robots. Each robot is regarded as an agent which makes decisions just based on limited neighbours' information. Under the condition of undirected and connected communication topology, every robot moves in the same direction and same speed finally.

The advantage of this method is that it is easy to specify the behavior of the robot group (virtual structure behavior), and can make formation feedback. The disadvantage is that it requires the formation to be a virtual structure, which is relatively fixed and rigid, so it cannot consider the overall obstacle avoidance problem. Therefore, it is generally applied in the barrier-free environment.

2.4 Formation Control Algorithm

In view of amigobot, a nonlinear and incomplete system, Newton method is proposed for the cluster control and formation of robots. In [3], a method can help the artificial potential field method to jointly complete the adjacent robots to maintain a certain distance and avoid obstacles by acting together with the attractive and repulsive forces. It makes the swarm control and motion control

of the robot more regular. This method makes the robots in the group react quickly and swarm well, but it is more affected by the environment.

Many previous clustering algorithms (including MPC clustering algorithm [21]) have involved the acquisition of robot position and speed state, but not all robots are equipped with speed sensors. Some studies have explored algorithms that only need location information. MPC clustering algorithm based on global measured location information is proposed in [22]. This not only saves the high cost of communication, but also improves the performance of the cluster.

In [6], it presents a distributed model predictive algorithm for a multi-agent system with communication delays between agents. Considering a multi-agent system in the presence of communication delays, we have proposed a novel DMPC in [5] based flocking algorithm by introducing the waiting mechanism to cope with communication delays. In the proposed flocking algorithm, the communication cost is greatly reduced because all the agents do not have to exchange information at each discrete sampling step. However, the proposed algorithm does not involve the external disturbances, which is another issue urgent to be solved.

Most of the methods to achieve multi-agent clustering control require the location and speed information of the robot, but Lu proposed a method of speed estimation and driving based on local location measurement in [13], which is conducive to cluster control and solving the problems of cluster speed estimation.

Previous cluster control did not do very well in terms of connectivity between robots. MAO proposed a distributed cluster control strategy with self-maintenance function for connectivity in [14]. Different from the previous method of fixing one edge, this method can allow any edge to be destroyed. It can be seen that this method improves the stability and flexibility of the whole system and makes the connectivity between robots better.

2.5 Formation Control Method Based on Virtual Structure

In [15], a network pinning strategy was proposed by analyzing the topological structure of the flocking agents and based on the knowledge of graph theory and control, which could greatly improve the clustering control of the flocking agents. This method applies the information transfer matrix to the multi-agent network topology. By using PBH criterion to set up specific nodes, a cluster control strategy is designed to improve the control of robot crowd.

In [4], it addresses the bipartite flock control problem with or without a virtual leader. In such a collective motion, the whole group separates into two clusters, in each of which all individuals move with the same direction. Meanwhile, every pair of agents in different clusters moves with opposite directions. Moreover, all agents in the two separated clusters approach a common velocity magnitude, and collision avoidance among each cluster is ensured as well.

A distributed event-triggered hybrid control is proposed in [20] to investigate flocking problem with a virtual leader in multi-agent systems. In the proposed control algorithm, the continuous relative position information are used while

the relative velocity information are sampled at the instant determined by event-triggered mechanism. A distributed event-triggered hybrid control algorithm is proposed to investigate the flocking problem, in which continuous position and sampled-velocity information are utilized. The main contribution of this paper is that neighbors' information are transmitted only at discrete event-triggered instants for each agent. This method can ensure the connectivity of the system, make the speed of the robot in the system reach the same, and improve the stability of the system.

3 Discussion

Multi-robot distributed flocking control has been a hot topic in the field of robot research and it has been paid more and more attention by academic circles. Formation of robot swarm movement is still the focus and difficulty in the field of robot research, and it is necessary to further improve the autonomy and adaptability of robots, as well as enhance the communication and collaboration ability between multiple robots. Flocking control has been used in many fields: unmanned aerial vehicles, aerospace, logistics and transportation. Multi-robot path planning is an important research direction of navigation and control at any time. Autonomous formation control is also applied to vehicles, mainly in formation movement according to the specified path, including collision avoidance between vehicles. This multi-robot formation is also used in exploration, rescue and environmental monitoring of unknown environments. According to group of coalescence behavior rules, the robot has developed some control algorithm, the network topology, flocking in future studies should play a bigger role, especially in unmanned combat aircraft flight control algorithms, and it will greatly improve the operational capacity. Someday in the future, it can coordinate to complete the mission of the fleet and reduce the casualty rate and time. It is very useful.

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