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INFORMATION DISTRIBUTION METHOD FOR MULTI-AIRCRAFT COOPERATION BASED ON COLLABORATIVE FILTERING ALGORITHM

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Abstract

The information interaction in the formation tasks has higher and higher requirements on the timeliness of the communication system, but the electromagnetic environment in the confrontation environment is extremely unfavorable for the communication channel. Therefore, the high speed, high bandwidth and information interaction environmental interference, security, and cyber defense are the main contradictions in information interaction in systemic joint operations. The core task of the information distribution system is to maximize the compression of information content and reduce the pressure on information distribution to the communication system under the premise of ensuring the information needs of the node. The information distribution system mainly improves the periodic information distribution to distribution on demand, and global broadcast to accurate information push, realizing optimized information distribution. The information distribution algorithm based on collaborative filtering can effectively reduce the acquiring time, improve the accuracy of information for nodes, reduce communication bandwidth, and improve the information interaction efficiency of informationized operations.

Keywords: Information distribution, collaborative filtering algorithm, environment confrontation, data communication

1. Summary

The network characterized by information interaction is an important force in the progress of human society. The development level of network also shows the advanced degree of an organization or group from another aspect. The core of networking is to improve the speed of information transmission between different individuals, so how to maximize the use of network capabilities has always been one of the hot spots of research. A variety of network configurations, such as star connection, bus connection and complex network connection, have been developed. Different network configurations support different information distribution modes, which is inevitable, It leads to the transmission efficiency of information between different networks. In the confrontation environment, the competition for network channel is very fierce. Everyone wants to transmit as much information as possible with the minimum communication bandwidth[1]. In the environment of confrontation and game, people use each step change to express a binary bit, and use each bit of each fixed position to express a fixed meaning. Fixed location data transmission mechanism not only makes information transmission efficient, but also limits the flexibility of data transmission, because the data type of each transmission is fixed, resulting in the information is always updated periodically.

There is a problem of information distribution among the members of a collaborative body composed of multiple members. A large number of researchers have studied the methods of maintaining efficient collaborative information distribution in different fields, and achieved a lot of meaningful results. Literature 2 analyzes the multi-user information transmission method of data link from the perspective of service. Literature 3, an information distribution method supporting edge computing is proposed. The method of multi-dimensional information distribution using fuzzy time series method is given in reference 4. Literature 5, an information distribution method and evaluation model for multi UAV

cooperative work are given. Literature 6 gives a method of information distribution for physical attack is given. Literature 7 gives a method of information distribution in automatic driving scenario. These studies in the field of information distribution have partially solved their problems, but for how to flexibly use the communication channel for data transmission, so that users can automatically transmit different data according to their needs in different scenarios.

Aiming at the problem of information distribution in the scenario of changeable tasks, this paper establishes the database of data requirements of different tasks, and maps them according to the characteristics of tasks to form the database of task benchmark data requirements. For different task phases, the cosine distance between the current task and the task features in the benchmark database is calculated, and the packets with the smallest distance are distributed. The method of calculating the distance according to the task characteristics and distributing the information according to the minimum distance is called collaborative filtering information distribution algorithm. This algorithm changes the fixed format and fixed information content transmission system in the traditional data link information distribution for the first time, and realizes the dynamic distribution strategy of different information in the confrontation environment.

The structure of this paper is as follows. The first chapter introduces the research status of information distribution and the key content of this paper. The second chapter describes the characteristics of information distribution in detail. The third chapter gives an information distribution framework. The fourth chapter gives a collaborative filtering algorithm model. The fifth chapter gives a simulation example based on the algorithm proposed in this paper. The sixth chapter summarizes it.

2. The method of information distribution in the confrontation environment

Information warfare is one of the core symbols of modern warfare. Distributed Combat equipment is coordinated through information interaction to realize the ability aggregation of systematic warfare. In the process of formation operation, information interaction has higher and higher requirements on the timeliness of communication system, but the electromagnetic environment in the confrontation environment is extremely unfavorable to the maintenance of communication channel. Therefore, the main contradiction of information interaction in systematic joint operation is the high speed and high bandwidth of information interaction and the interference of battlefield environment, security, Cyber Defense, etc. The core task of information distribution system is to maximize the compression of information content and reduce the pressure of information distribution on the communication system under the premise of ensuring the information demand of nodes[8,9]. The information distribution system mainly realizes the optimal information distribution by adjusting the periodic information distribution to the on-demand information and the broadcast information to the accurate information push. The information distribution algorithm based on collaborative filtering can effectively reduce the time and accuracy of information acquisition, reduce the communication bandwidth, and improve the information interaction efficiency of information warfare.

The traditional information distribution is a human-in-the-loop request-response mechanism. The node using information submits requests to the service center according to its own needs. The service center pushes operational information to the requester according to global information. The process involves two layers of transformation. It consumes much time, and in the complex environment where people participate, the response information cannot be guaranteed to be the optimal information. In order to solve this problem, some researchers propose to push the operational information by means of periodic push or global broadcast, but it consumes much channel bandwidth, resulting in wasted resources, which often interfere with the distribution of truly useful messages. The information distribution system studied in this paper mainly solves the environmental information, which includes situational information and physical information. The situational information is the operational information in specific airspace operational process during a certain period of time, involving the airborne flight target location, target attributes, information such as target motion attributes, distance between targets, and target motion trends. The physical information includes atmospheric information, terrestrial information, sea area information, electromagnetic radiation information, and altitude

information of a specific airspace.

3. Information distribution framework

In the current command and control node centric multi aviation platform task coordination architecture, the command and control node needs to control the task requirements of no node in the whole environment, and use the data communication network between multi aviation platforms for information distribution. Each aviation platform uploads the information obtained by its own sensors in real time. Only the command and control center can grasp the global information. Moreover, the command and control center will also have the command information, the global environment information and the global confrontation information of the higher level control center. The transmission of information in the network is not the more the better, but needs a task appropriate and appropriate information, which can not only reduce the pressure of communication network data transmission, but also reduce the processing pressure of each aviation platform. The information distribution architecture shown in the figure below is just the information distribution mode of multi aviation platform with the command and control node as the center[10-12]. The command and control center node integrates the information perceived by each individual in the formation, and combines the environment information and task information to form a global unified situation. Each member uses the data sent by the command and control center to form a local decision input and carry out individual actions. In the process of command and control task with human participation, commanders manually distribute information to each individual. Due to the limitation of human processing ability, they usually distribute information at the same rate. As a result, the most important information can not be sent to the individuals in need in time.

The best information distribution strategy is to use the experience information to analyze different situations and get the optimal information demand of each individual in each situation. The command and control center sends information to different individuals according to the situation information. In this paper, the collaborative filtering algorithm is used to classify and save the historical situations, and the historical event experience value is formed in the situation space, When the situation in the process of multi aviation platform cooperation is digitized and compared with the experience value in the situation space, the group of information distribution information with the minimum multi-dimensional distance value is searched, and the information distribution instruction of the current command and control center is given.

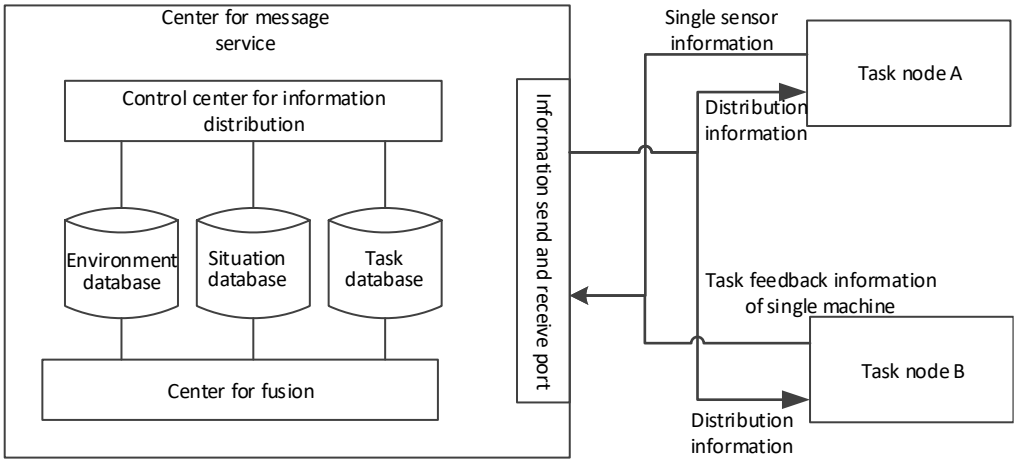

Figure 1. Information distribution architecture of multi-aircraft cooperation.

4. Description of collaborative filtering algorithm

According to the task information of the current node, the distance calculation is performed with all

the tasks in the task library, and the information corresponding to the previous tasks m is summed, and the maximum information value is obtained. The information queue is the current optimal information demand queue, and the information service center distributes all information. The detailed algorithm is as follows.

This paper adopts the collaborative filtering algorithm as the decision rule generation algorithm of the information service center, and uses the calibrated combat mission and combat information pair as the training data set I_d. Training data set $I_d = \{W, S\}$, According to the task classification W determined by the command and control center, each task number corresponds to all data pairs that can characterize the task, $W = (item_1, item_2, \mathrm{L}\ , item_n)$, $item_i$ represents the first eigenvalue. The eigenvalues handled in this paper need to describe a complete task, so the value of each eigenvalue needs to be normalized. For the time type feature value, the time absolute value is used; for the geographic location type, the feature value takes the latitude and longitude ratio with respect to the reference point origin; for the subjective feature value such as the task importance, the equal value absolute value of 1 to 10 is used; The eigenvalues use the absolute value of the probability, and the specific task eigenvalues need to be processed according to the actual use situation.

Find the task with the highest similarity to the current combat node task in the task library. The similarity uses the cosine distance of the multi-dimensional vector as the criterion.

$$sim(i,j) = \frac{W_i \cdot W_j}{|W_i| \cdot |W_j|} = \frac{\sum_{v \in n} \left(W_{i,v} \times W_{j,v} \right)}{\sqrt{\sum_{v \in n} W^2_{i,v}} \sqrt{\sum_{v \in n} W^2_{j,v}}} \tag{1}$$

Which $W_{i,v}$ represents the feature i of the task v.

According to the task information of the current node, the distance calculation is performed with all the tasks in the task library, and the information corresponding to the previous tasks m is summed, and the information of the largest front-middle task is summed, and the information maximum value is obtained. The information queue is the current optimal information demand queue, and the information service center distributes all confidence. The detailed algorithm is as follows.

Collaborative filtering information distribution algorithm

Input: Enter the task status data of the current node;

Output：A list of information required by the current node.

Step1. Normalize the task N status data of the node;

Step2. for $i \in n$

calculate $sim(N,i)$；

Step3. save $sim(N,i)$ in the queue of distance L；

Step4. $\max\limits_{top-m \in L} sim(N,i)$；

Step5. $S = \sum_{i=1}^{m} S_i$。

以上提到的算法，理论上能够解决多航空平台协同任务中的信息分发问题，但是面对高维度和高数据量的问题会出现数据稀疏的问题。在实际应用过程中，指挥控制中心需要对每一个任务平台的态势与

5. Simulation analysis

For the sake of simplicity, we assume that in a strategic airdrop mission, the main delivery aircraft

carries four escort aircraft. In the whole mission execution process, it can be divided into three stages, namely, takeoff phase, cruising phase and air drop phase, At the same time, the main delivery aircraft also needs to receive the meteorological information, task number information, waypoint information, etc. pushed by the ground command and control center. In cruising stage, the main delivery aircraft needs to transfer position information, target information, control information and so on with the escort aircraft. In the air drop phase, the main delivery aircraft needs to send delivery information to the ground command and control center and interact with the ground personnel. It can be seen that the content of information transmission includes periodic information and trigger information, and the content of information transmission will change according to the transformation of task stage. The algorithm proposed in this paper is used to distribute information and record the amount of information exchange data in the whole task simulation cycle. The amount of data between the two methods was recorded and compared. In order to facilitate comparative analysis, the information distribution process of this paper adopts different strategies, one is manual distribution for the whole process, and the time consumption and information type of each stage are recorded, and the other uses the collaborative filtering algorithm proposed in this paper. The simulation shows that the proposed algorithm can cover 95% of information requirements while ensuring task execution.

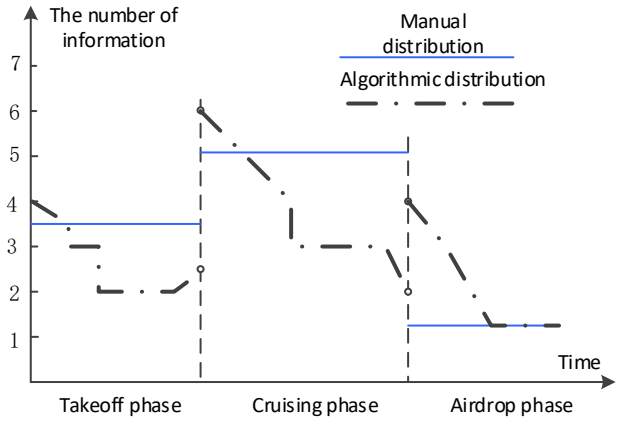

Figure 2. The simulation result

The analysis indicates that the algorithm meets the information needs of the operational nodes, and can greatly reduce the pressure of information transmission on cooperative operation communication. This method can not only provide decision support for the command and control operators of the information service center. Meanwhile, it can be used in the information distribution on drones by human-machines in the process of unmanned operation.

6. Conclusion

The effect of information distribution in the countermeasure environment is directly determined by whether the proportion of data needs is met or not. The frequency and dimension of data distribution can be dynamically adjusted when needed, which will effectively reduce the pressure of communication channel. Especially in the case of communication interference, the available effective bandwidth is very limited. If the necessary information is not transmitted in different ways in the network, It will hinder the transmission of useful information, and then affect the mission completion between multiple aircraft. The calculation of the distance between tasks proposed in this paper determines the historical data to cut the information distribution content and frequency of the current task, which can meet the needs of the current data transmission to the maximum extent, effectively reduce unnecessary data transmission, and effectively use the communication bandwidth. It is an effective information distribution method.

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