Design of track fusion system for anti-aircraft gun fire network system

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Abstract. Anti-aircraft gun fire control networking can improve the whole battle efficiency of anti-aircraft gun fire system. Aiming at the data processing need of fire control network, a gun fire control network track fusion system is designed. The system is realized by C programming language, which can be applied to the fire control computer. The flow diagram of the track fusion system is given. It mainly described the method of track correlation, track fusion, track management and threat estimation in the system. The system could realize the real-time processing of multi-batch target data in gun fire control network, and could provide basis for the subsequent target strike.

Introduction

Anti-aircraft gun system is one of the main anti-aircraft weapons, which is mainly responsible for the fight against low-altitude flying targets. To improve the overall operational efficiency of anti-aircraft gun system, an important research direction is to networking all anti-aircraft fire control system. By fire control networking, the air situation information could be shared, and the system target discovery and capture capabilities could be improved [1].

As a distributed mode fire control [2], fire control node in the network can send its own target tracking data to the network. There will be dozens of targets in the network, which need multi-sensor data fusion technology to manage track information [3]. In this paper, a track fusion system is designed, which could meet the target information processing needs after the fire control system network and achieve real-time management.

The fire control network system is equipped with fire control computer, in which the multi-source information processing, firing element solver, data transmission, artillery and actuation functions are realized. The designed track fusion system is applied to the fire control computer, and is implemented by the C programming language, which is mainly to complete several groups of target data fusion. Its ultimate goal is to get a system track by processing the trajectory of each node in the fire control network. Track Fusion system needs to complete the track correlation, track fusion, track management and target threat estimation processing.

System Design

The design flow of track Fusion system is shown in Fig. 1. After receiving the node data, and completing the coordinate conversion and other operations, the system finishes the track parameters initialization. By filling the target data and node error, and calculating the statistic distance, the track correlation is completed. After the track fusion, the system track is get. For the obtained multiple tracks, track management is needed, such as track numbering and etc. And based on the final track fusion results, the system completes threat estimation, which could provide basis for the subsequent fire strike.

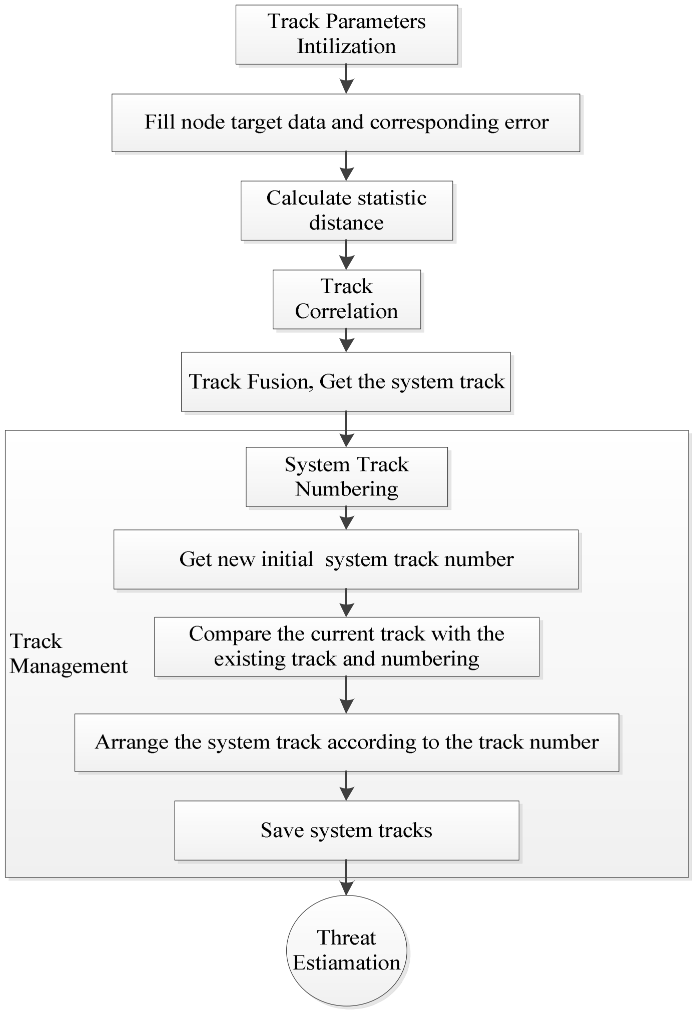

Fig.1 Flow diagram of track fusion system

In the design of track fusion system, combining with the needs of anti-aircraft artillery fire control network, the methods of track correlation, track fusion, track management and target threat estimation are chose, which are detailed below.

Track Correlation. In fire control network, multiple nodes at different locations are capturing the same target. Each node generates the corresponding node track. The track fusion system carries out track correlation with these node tracks at first. Here a weighted correlation algorithm is used in the system.

During the track correlation, two sets of data are compared at one time. When the two sets of data are related, the system will retain one set of data, and discard the other set of data. The retained data will be compared with other groups target node receives data again until all node tracks are compared. The number of the final retained track data should be equal with the number of the targets.

Track Fusion. After the target correlation, the phenomena that one target has multiple tracks is eliminated. But there are errors in the retained track data, it is necessary to eliminate target data errors by track fusion. Variance weight fusion algorithm and equal weight fusion algorithm are adopted in the design system. According to the actual situation, the system can choose between the two algorithms.

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Assuming the track $\hat{X}_i(k)=\left[x_i(k), y_i(k), z_i(k)\right]^T$, $i=1,2,....,N$, N is the number of the node track of the same target at time k, $P_i(k)=\left(p_{i,11}(k), p_{i,22}(k), p_{i,33}(k)\right)$ is the corresponding error variance.

With variance weight fusion algorithm, the fusion track $\hat{X}_F(k)$ is

$$\begin{aligned}\hat{X}_F(k) &= \left[\sum_{i=1}^{N} P_i(k)^{-1}\right]^{-1} \sum_{i=1}^{N} P_i(k)^{-1} \hat{X}_i(k) \\ &= \left[\frac{\sum_{i=1}^{N}\frac{x_i(k)}{p_{i,11}(k)}}{\sum_{i=1}^{N}\frac{1}{p_{i,11}(k)}}, \quad \frac{\sum_{i=1}^{N}\frac{y_i(k)}{p_{i,22}(k)}}{\sum_{i=1}^{N}\frac{1}{p_{i,22}(k)}}, \quad \frac{\sum_{i=1}^{N}\frac{z_i(k)}{p_{i,33}(k)}}{\sum_{i=1}^{N}\frac{1}{p_{i,33}(k)}}\right]^T \end{aligned} \tag{1}$$

With equal weight fusion algorithm, the fusion track $\hat{X}_F(k)$ is

$$\hat{X}_F(k)=\frac{1}{N}\sum_{i=1}^{N}\hat{X}_i(k)=\left[\frac{1}{N}\sum_{i=1}^{N}x_i(k), \quad \frac{1}{N}\sum_{i=1}^{N}y_i(k), \quad \frac{1}{N}\sum_{i=1}^{N}z_i(k)\right]^T \tag{2}$$

When the system can get real-time data, the target data can be used for real-time Kalman filter [4]. Each target batch get its own Kalman filtering error variance, which can be used to realize the variance weight fusion. In this way, each node can get more accurate target information. Variance weighted fusion algorithm is a suboptimal algorithms in maximum likelihood sense. The algorithm is simple and has small calculation amount, which is beneficial for real-time solving.

If the fire-control nodes cannot provide real-time track filter error variance to the fire control network information fusion system, the system can only use the equal weight fusion.

Track Management. The track Fusion system carries out track fusion processing at each sampling point continuously. If there are more than one system track in the system, it is necessary to do track numbering. The flow of track numbering in the system is shown in Fig 2.

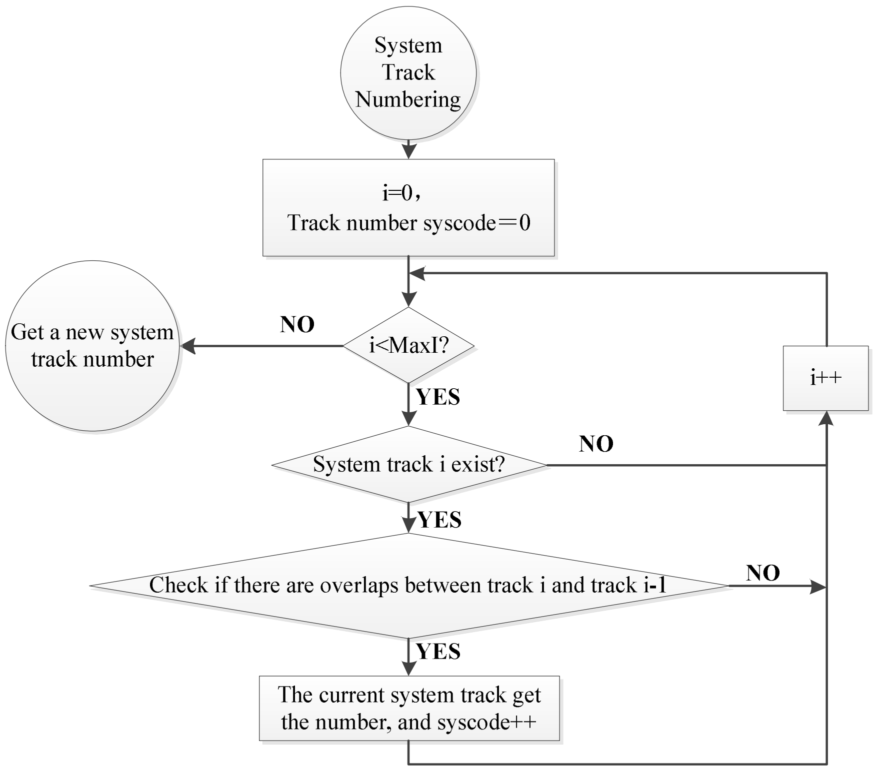

Fig.2 Flow diagram of system track numbering

When track numbering, the system will compare the current system track with the existing track batch to at first. If the target batch exists, the track number is given to the current system track. If not, the system generates a new track number.

Threat Estimation. In order to implement a strike, it is necessary to analyze the target data and finish threat estimation, which can determine the target threat level.

To accomplish the goal threat estimation, the threat level judgment threshold is determined at first according to the anti-aircraft gun type. Then the threat degrees are calculated for each batch. The biggest one is chose as the system automatically track target. The main considerations of threat estimation are including flight distance, target speed, flying time and other factors [5]. The flow of threat estimation is given as follow:

(1) When the target is approaching flight, but is still out of the anti-aircraft gun firing range, the target in this area has the highest priority ordering. When multiple targets simultaneously granted in this distance range, calculate the relative position of each batch of target flying time. The minimum time is determined as the greatest threat degree.

(2) When all targets are not in the range of (1), check whether there is target in the anti-aircraft gun firing range. If so, the target with the highest airspeed is determined as the priority target.

(3) When all targets are flying away and the target in the shooting range antiaircraft valid, the target threat degree are determined according to the size of the shortcut route. The target with the smaller route shortcut gets a higher threat degree.

(4) Otherwise, the threat level is zero.

Conclusions

A track fusion system for anti-aircraft gun fire network system is designed, which is realized by the C programming language. The practical application verifies that the track fusion system can complete the relevant target processing operations to meet the needs of the fire control network. It provides basis for the subsequent implementation of target strike. The performance of the track fusion system can be improved by using better track processing algorithms in the following studies.

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