

## Firing Calibration Decision System of Artillery Reconnaissance Radar Based on Data Fusion

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**Abstract.** Aiming at improving the decision ability of artillery reconnaissance radar by map work and field reconnaissance, A decision evaluation system of networking artillery radar was realized. Basic principle, hardware structure and software structure of the system were discussed. This system is then developed with tools of VC++6.0 and SQLServer. According the principle of Least Squares and weight value of radar precision, the data fusion algorithm of exploding point data based on several networking radar was designed. The shooting results show that the system improves the automatic command ability and measure precision of exploding point.

**Keywords:** artillery radar, decision system, model

### 1. Introduction

We design a correction fusion evaluation system for the artillery radar networking with the tool of VC++ and SQLServer2000 based on the technology of radar networking and data fusion. The system can transform the information in real time and visualize the battlefield situation. The development of the system can not only advance the command level of campaign system and networking, but also provide the real-time decision information for commanders, which enables the command organ, commanders and operation platform to obtain current firing conditions<sup>[1,2]</sup>.

### 2. Algorithm of Data Fusion

Because of different positions of various radars, the target observation data are different from each other. Therefore, what should be done first is to unify the different data from various radars in space and in time, which contributes to processing the target observation data from various radars in united coordinate system<sup>[3]</sup>.

When working in multiple radars networking mode, because of the difference of start time and observation principia, we must calibrate the time of observation data. Usually, we take some radar as the standard processing time, and then unify other radars' time. Another method is to make use of the value-inserting method to unify all the radars' time in a time axis.

After unifying the time of radars, we adopt the optimized fusion estimation method to fuse the data of the burst point. According to the norm time  $kT$ , we can obtain  $N$  independent two-dimension position estimations  $\bar{Z}_i$  from  $N$  radars. In order to simplify the deduction, we consider that  $\bar{Z}_i$  is a target true position without error and the square error is  $R_i$  respectively.

According to the principle of the minimum square error, we adopt weighted averaging method. Namely, we distribute the weighting value according to different precision of radars, and optimize and fuse those  $N$  estimation values. Then we get  $\tilde{Z} = W_1\bar{Z}_1 + W_2\bar{Z}_2 + \dots + W_N\bar{Z}_N$ .

In the above formula,  $W_i, i=1,2,\dots,N$  is the weighting crossing matrix, and  $W_1 + W_2 + \dots + W_N = I$ ,  $I$  represents the unit matrix<sup>[4,5]</sup>.

The optimized fusion estimation  $\tilde{Z}$  should meet two requirements: The one is that  $\bar{Z}_i$  is a target true position without error; the other is that the value of the square error matrix is a minimum. Namely,  $R_g$  is less than  $R_{ii}$ .

First considering  $N=2$ , namely the weighting value is distributed when there are two radars.

$$\tilde{Z} = W_1 \bar{Z}_1 + W_2 \bar{Z}_2 = \bar{Z}_1 + W_2 (Z_2 - Z_1) \quad (1)$$

Therefore,

$$\tilde{Z} - \bar{Z} = (1 - W_2)(\bar{Z}_1 - \bar{Z}) + W_2(\bar{Z}_2 - \bar{Z}) \quad (2)$$

The optimized estimation square error is as following.

$$R_g = E[(\tilde{Z} - \bar{Z})(\tilde{Z} - \bar{Z})^T] \quad (3)$$

Put the formula (2) into the formula (3), and we will get the following result.

$$R_g = (1 - W_2)(1 - W_2)^T R_{11} + (1 - W_2)W_2^T R_{12} + W_2(1 - W_2)^T R_{21} + W_2W_2^T R_{22} \quad (4)$$

Because  $\bar{Z}_1$  and  $\bar{Z}_2$  are irrelevant,  $R_{12} = R_{21} = 0$ . And we consider that the weighting proportion of  $\bar{Z}_i$  is same in x-dimension and y-dimension, namely  $W_i = W_i^T$ .

And then the above formula can be simplified as following.

$$R_g = (1 - W_2)^2 R_{11} + W_2^2 R_{22} \quad (5)$$

In the formula (5),  $R_g$  can be regarded as a function of  $W_2$ . Now, let's take the differential coefficient of  $W_2$ .

$$\frac{\partial R_g}{\partial W_2} = -2R_{11} + 2W_2(R_{11} + R_{22}) \quad (6)$$

When the value of the formula (6) is 0, we can get the following result.

$$W_1 = \frac{R_{22}}{R_{11} + R_{22}} \quad (7)$$

$$W_2 = \frac{R_{11}}{R_{11} + R_{22}} \quad (8)$$

When taking the formula (7, 8) back to the formula (5), we can get the following result.

$$R_g = W_1^2 R_{11} + W_2^2 R_{22} = \frac{R_{11}^2 R_{22} + R_{11} R_{22}^2}{(R_{11} + R_{22})^2} = \frac{R_{11} R_{22}}{R_{11} + R_{22}} \quad (9)$$

Therefore,

$$R_g - R_{11} = -\frac{R_{11}^2 (R_{11} + R_{22})}{(R_{11} + R_{22})^2} = -\frac{R_{11}^2}{R_{11} + R_{22}} \quad (10)$$

Because both  $R_{11}$  and  $R_{22}$  are not less than zero,  $R_{11} + R_{22} \geq 0$ . Therefore, we get  $R_g - R_{11} \leq 0$ .

Namely,  $R_g \leq R_{11}$ ; similarly, we can obtain  $R_g \leq R_{22}$ . Hereto, we have proven that the square error of the fusion estimation is less than each single-radar square error in the weighting matrix, which illuminates that the precision of the fusion data is improved.

From the formula (3) and (9), we can get the following result.

$$\tilde{Z} = \frac{R_{22}}{R_{11} + R_{22}} \bar{Z}_1 + \frac{R_{11}}{R_{11} + R_{22}} \bar{Z}_2 = \frac{R_{11}^{-1} \bar{Z}_1 + R_{22}^{-1} \bar{Z}_2}{R_{11}^{-1} + R_{22}^{-1}} \quad (11)$$

$$R_g = \frac{R_{11}^2 R_{22} + R_{22}^2 R_{11}}{(R_{11} + R_{22})^2} = \frac{R_{11} R_{22}}{R_{11} + R_{22}} = \frac{1}{R_{11}^{-1} + R_{22}^{-1}} \quad (12)$$

Similarly, we can get the following fusion formula of the burst point coming from  $N$  radar stations.

$$\tilde{Z} = \frac{\sum_{i=1}^N R_{ii}^{-1} \bar{Z}_i}{\sum_{i=1}^N R_{ii}^{-1}}, \quad \text{and} \quad R_g = \frac{1}{\sum_{i=1}^N R_{ii}^{-1}}$$

### 3. Constitution and Function of System

Simulation evaluation system can realize the whole simulation training operation process of position selection for artillery reconnaissance radar. Three parts such as scenario creation and management module, position selection and field reconnaissance module, position evaluation and ordering module constitute the system. Connection between each department is shown in Fig.1. Thick real rectangle line indicates system modules, real line arrow indicate system operation flow, and broken line arrow indicate visitation to each library. It can be seen from Fig.1 that the constitution of system includes scenario creation and management, position selection and field reconnaissance, position evaluation and ordering, etc.

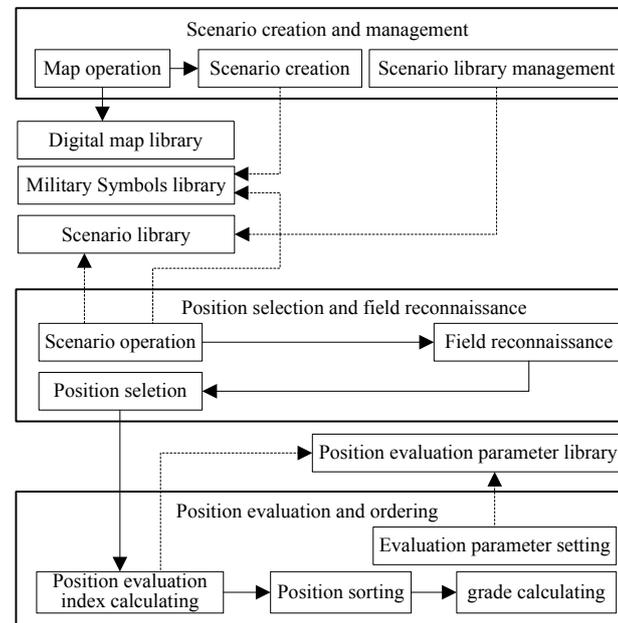


Fig. 2: Chiefly constitution of the system

Scenario creation and management module is chiefly composed of three modules such as map operation, scenario creation and scenario library management. Map operation module can complete the operation for digital map such as open, zoom in, zoom out, roam and so on; According to the digital map opened; scenario creation module can protract the artillery position and radar preparatory position, come into being scenario file, save into scenario library; Scenario library management can delete, load, save as the scenario etc, and the operation objects is the scenario file in library.

Position selection and field reconnaissance module is composed of three modules such as Scenario operation, field reconnaissance, and position selection. Scenario operation

module can read and display the scenario file, mark the preparatory radar position and save scenario file etc, so as to provide number of preparatory position and data of the position coordinate; Field reconnaissance module establish 3D terrain real-time scene according to the serial number of preparatory radar position, change the position of observer in simulation scene if needed, and change the observational mode and preparatory position; Position selection module confirm the serial number of radar position according to the result of field reconnaissance.

Position evaluation and ordering is composed of four parts such as evaluation parameter setting, position evaluation index calculating, position sorting and grade calculating. Evaluation parameter setting module confirm the evaluation criterion and power coefficient of each evaluation index; Position evaluation index calculating module acquire and input of each property data, calculate each independence index and integration index; Position sorting module sort order of the position by the integration index; Grade displaying module give the training grade according to the position serial number selected by the manipulator and the sorting result.

#### 4. Software Structure of System

The software structure of the system consists of the data input module, the system update module, the correction fusion module, the map managing module and the specialist system maintenance module, as is shown in Fig.2.

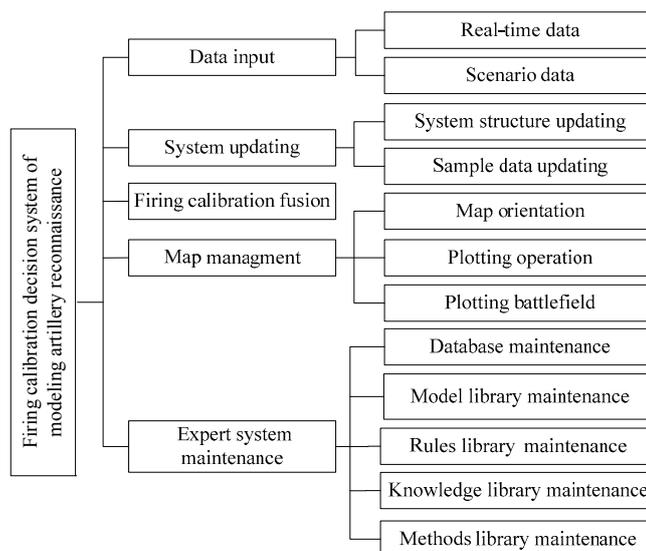


Fig. 2: Software structure of the system.

The data input module includes the data in real time and the data in the problem exercise. The data in real time is the data of the burst points that are input via the communication lines and the radar data interface. The data in problem exercise is the data that are designed by commanders or controllers according to various operational missions, including relevant data information coming from the mission types and correction requirements, as well as relevant parameters that might affect the performance of the radar network. The system update module is composed of the updating system structure and the updating sample data, and the latter is mainly used to update the data when the inputting content isn't changed.

The correction fusion module can select corresponding algorithm to finish corresponding data fusion of the burst points according to the data in real time or the data in problem exercise.

The map managing module can load the map of operational areas, and fulfill the map orientation, plotting operation and radar position plotting. The specialist system maintenance module serves for the management of the current data base, model base, rule base, knowledge base and method base..

## 5. Conclusion

In this paper, the simulation evaluation system was developed, large terrain scene roaming was realized by the method in the article on common computer. The research of the artillery networking correction estimation system can not only fulfill the distribution and share of firing correction information, but also improve the comprehensive response capability and meet the requirement of the artillery precision strike.

## 6. References

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