Journal of Applied Sciences

ISSN 1812-5654

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 14 (15): 1775-1780, 2014
ISSN 1812-5654 / DOI: 10.3923/jas.2014.1775.1780

Research on Key Technologies of Virtual Test System

[1]Xiao-Wen Yang, [2]Yan-Min Ma and [1]Xie Han
[1]School of Computer and Control Engineering, North University of China, Taiyuan, China
[2]Shijiazhuang Army Command College, Shijiazhuang, China

Abstract: Virtual test is a new testing method that makes the tested data visualize through the computer to get analysis, processing and expression. It researches on virtual test based on the exterior ballistic test system from the range and analyzes the framework of the virtual test system. According to the framework it mainly research on the introduction reason for the collaborative test from some test equipment, guiding from the radar to the photoelectric theodolite in the process of collaborative test, fusing the tested data and building the mathematical models to position the targets. In order to obtain the better tracking results for the targets it must optimize the layout of the collaborative test equipment and then it adopts the genetic algorithm to do it and get the simulation results based on MATLAB. The simulation results show that the fitness of the coordinate information from the positioning target by the optimization is better than the simple layout of stations.

Key words: Virtual test, collaborative test, genetic algorithm, optimization of the layout

INTRODUCTION

Virtual trial is a new and comprehensive test technology with the development of computer network technology, computer modeling and simulation technology, software engineering and virtual instrumentation technology (Case *et al*., 2014). Virtual trial combines the virtual reality technology with the virtual test technology. According to the test program it uses the test equipment to track the tested targets and makes the visualization of the test process and the test results get analysis, processing and expression to provide reliable technical support for the improvement of the weapon design (Vergara *et al*., 2014; Zhang *et al*., 2013). The study analyzes the framework of virtual test system, builds the mathematical models to position the targets and optimizes the layout of the collaborative test equipment through the genetic algorithm to obtain the better tracking results.

FRAMEWORK OF VIRTUAL TEST SYSTEM

The virtual test system researches on the exterior ballistic test from the range and realizes the real-time tracking for the target and the test of relative parameters (Young *et al*., 2013). According to the requirement of the exterior ballistic test from the range, virtual test system needs to achieve the following functions.

- It can achieve the testing function for the virtual test equipment to collect the information and transport data in real time
- It can store and analyze the data and make the visualization of the results
- It has interoperability function among the different equipment to work collaboratively
- It should have a clock synchronization function to ensure a uniform time reference among the equipment
- It has other function such as operating tips, self-test and fault location.

According to the above functional requirements from the virtual test system its functional structure is shown in Fig. 1 and the whole testing process as Fig. 2.

According to Fig. 1 and 2, in the implementation process of virtual test system, the key problems that must be solved are the clock synchronization and the testing data collection from the range. In the actual testing process, the clock synchronization may use the precision clock synchronization based on IEEE1588 but in the process of the virtual test the virtual test system that is composed by several computers simplifies the clock synchronization and can solve the clock synchronization only by the clock consistency among multiple computers. So, the key problem to be solved is the collection of test data from the range in real time.

RESEARCH ON KEY TECHNOLOGIES OF COLLABORATIVE TEST FROM VIRTUAL TEST SYSTEM

According to Fig. 1 and 2, in the process of testing data from the range, virtual test system involves the application of the radar and the photoelectric theodolite.

Corresponding Author: Xiao-Wen Yang, School of Computer and Control Engineering, North University of China, Taiyuan, China

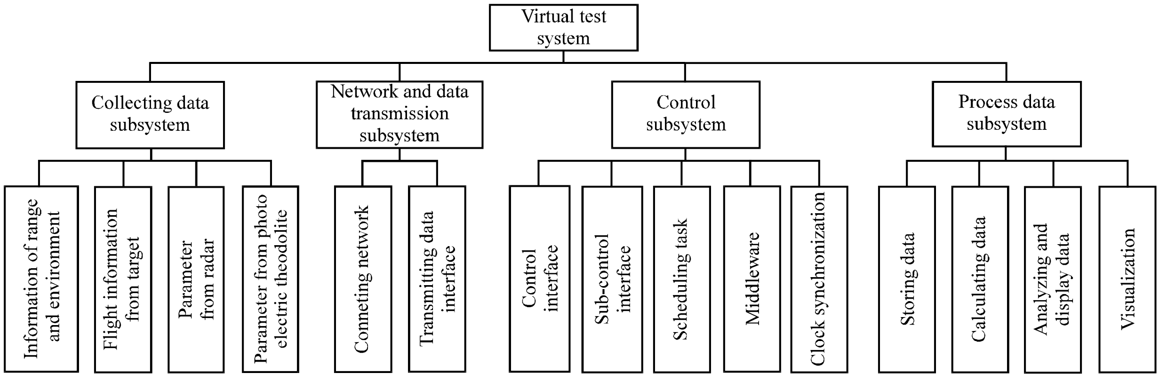

Fig. 1: Functional framework of virtual test system

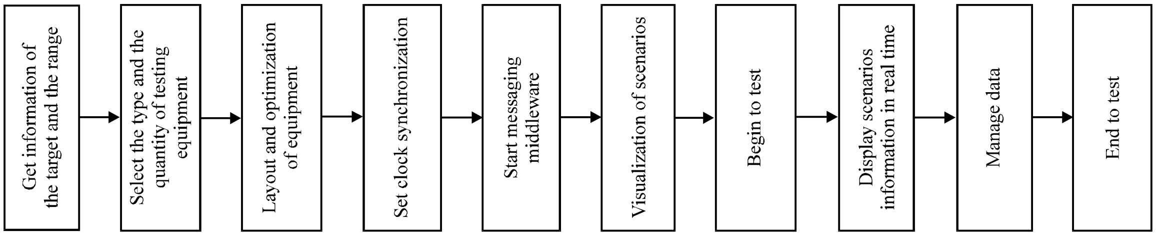

Fig. 2: Testing process of virtual test system

In order to ensure the data consistency and availability these devices must be collaborative to test and get the best test results.

Introduction reason of collaborative test: In the virtual test system, the radar can detect the target, resolute the target, measure the target and identify the target, yet the photoelectric theodolite can test the ballistic data and the posture, record live flight and measure physical parameters (Karam and Safa, 2013).

In a low altitude measurement such as the range, the radar is widely used and can track the targets in general. The radar can provide the speed and the distance of the target at the high precision, is strongly mobile, flexible networking, wide applications, etc. However, the radar has low accuracy for the information of testing angle, can't get the target image and is vulnerable to noising jamming. So, the radar can't meet the requirements for the positioning accuracy of the target.

In the test of the range the photoelectric theodolite only can measure the angular information of the target in the local coordinate system, yet a small number of the photoelectric theodolite that add the device to measure distance can't get the satisfactory effect. According to the tracking mode of the photoelectric theodolite it is influenced by the distance and the weather conditions to poor tracking effect. If you can guide the photoelectric theodolite to track targets through other test equipment, the test results will be better in the tracking and testing process to reduce the failure rate of the tracking and improve the stability of the tracking. In this case, the use of radar to guide the photoelectric theodolite can complete the collaborative test from the range.

Collaborative test technology: The collaborative work from the test equipment mainly includes the inter-guiding among the test equipment and the fusion process for the tested data. The collaborative work from the radar and the photoelectric theodolite not only improves the tracking ability from the photoelectric theodolite but also may obtain the more ballistic coordinates by the data fusion under the unfavorable case of the tracking of the photoelectric theodolite (Li *et al*., 2012).

Radar to guide the photoelectric theodolite: The current radar can select master-slave operation mode. Under this case the radar not only can complete the normal test but also may use the second output port to send the ballistic data to guide the other test equipment to work in real time.

The exterior ballistic measurement system by the photoelectric theodolite consists of a central station, two measuring stations and the corresponding microwave communications systems. Two measuring stations are mainly used to capture and record the ballistic image from

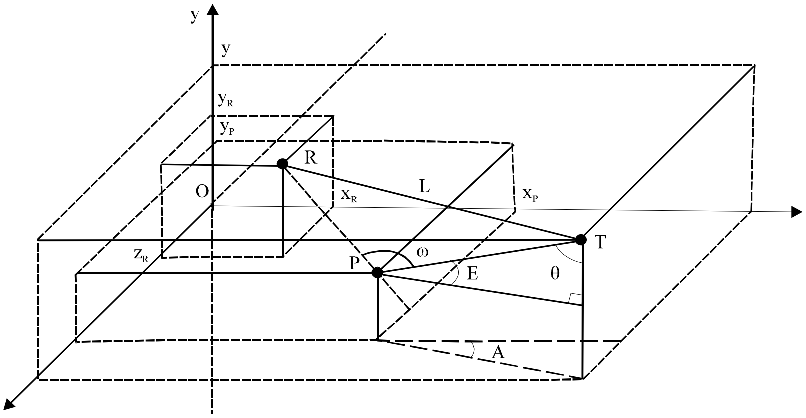

Fig. 3: Special positioning principle of the radar and the photoelectric theodolite

the target in the testing process. The central station is responsible for receiving the external guiding signals from the base command center or other test equipment in real time, the tested data from the photoelectric theodolite and the status of the equipment and get fusion process such as getting rid of outliers, coordinate conversion, track formation, smoothing filtering and track forecasting to guide the photoelectric theodolite to capture the target or intercept the target again when the target is lost in the process of the tracking.

The system uses the certain ranging radar and places the precise ranging radar near to the photoelectric theodolite limited to tens of meters. It applies the photoelectric theodolite that has high-precision to measure angle and the radar that has high-precision to measure distance. The radar provides the distance of the target and the guidance of azimuth for the photoelectric theodolite and the photoelectric theodolite provides the guidance of pitch angle for the radar. Then the ranging data from the radar will get fusion with the angle data from the photoelectric theodolite to achieve the precise positioning method for the target through the mutual cooperation. In the process of real test from the range, the collaborative test has certain practical value.

Fusion of the tested data: The data fusion is to take advantage of multiple data sources, uses and disposes rationally for these data of data sources and combines multiple data sources according to the criteria of the redundancy in space or time or some complementary data to get the consistency of the explanation or description for the tested target. So, the whole information system obtains more favorable performance than some subsystem (Song *et al.*, 2013).

The prerequisite of data fusion is that the tested data should be simultaneous, the same field with the targets, the same dimension of the targets. Because the tested data from the different ballistic test equipment can't coincide exactly in the time and the number of the dimension it must standardize those data such as the difference of the coordinate system and the sampling cycle to do data fusion. Secondly it should differentiate the homogeneous data and the heterogeneous data. If it is homogeneous data it will be processed directly; else it must convert the structure for the data fusion.

Mathematical model of the positioning: The combination positioning from the radar and the photoelectric theodolite uses the spatial relationship among the radar, the photoelectric theodolite and the target to build model (Qian, 2013). In the process of solving the model algebraic calculus is only used in general, so the process is complicated. If the model is converted to the spatial geometry model and make full use of the geometric relationships and other information to make positioning more quickly and accurately.

According to Fig. 3, the coordinate of the tested target T is marked by (x, y, x), the coordinate of the radar R is marked by (x_R, y_R, z_R), the coordinate of the photoelectric theodolite P is marked by (x_p, y_p, z_p), the azimuth and pitch angle measured from the photoelectric theodolite are marked as A and E and the relative distance from the radar to the target is marked as L in the coordinate system of the range as O-XYZ.

The coordinate of T needs to meet the following relationship such as Eq. 1-3:

$$\tan A = \frac{(z\text{-}z_p)}{(x\text{-}x_p)} \tag{1}$$

$$\tan E = \frac{y - y_p}{\sqrt{(z - z_p)^2 + (x - x_p)^2}} \tag{2}$$

$$(x\text{-}x_R)^2+(x\text{-}x_R)^2+(x\text{-}x_R)^2 = L^2 \quad (3)$$

Solving the above three equations in joint is shown in Eq. 4:

$$\begin{cases} x = [(-b+\sqrt{b^2-4ac})/2a]\cos A + x_p \\ y = [(-b+\sqrt{b^2-4ac})/2a]\tan E + y_p \\ z = [(-b+\sqrt{b^2-4ac})/2a]\sin A + z_p \end{cases} \quad (4)$$

Among them:

$$\begin{cases} a = 1+\tan^2 E \\ b = 2[(x_p - x_R)\cos A + (y_p - y_R)\tan E + (z_p - z_R)\sin A] \\ c = (x_p - x_R)^2 + (y_p - y_R)^2 + (z_p - z_R)^2 - L^2 \end{cases}$$

Because these parameters such as (x_R, y_R, z_R), (x_p, y_P, z_p), A, E and L are known, Eq. 4 can get the coordinate as (x, y, z) of the target.

The analysis of the above Eq. 4 can get to know that the coordinates from the radar and the photoelectric theodolite can be exactly measured to ignore their effect and main effect is from A and E from the photoelectric theodolite and L from the radar. These values are measured separately. Under the circumstance that their standard deviations as σ_A, σ_E and σ_L are known, the random errors that are identified with σ^2_x, σ^2_y and σ^2_z can be quantitatively evaluated for the coordinate of the target according to the error transferring theory and are shown in Eq. 5:

$$\begin{cases} \sigma_x^2 = (\frac{\partial x}{\partial A})^2\sigma_A^2 + (\frac{\partial x}{\partial E})^2\sigma_E^2 + (\frac{\partial x}{\partial L})^2\sigma_L^2 \\ \sigma_y^2 = (\frac{\partial y}{\partial A})^2\sigma_A^2 + (\frac{\partial y}{\partial E})^2\sigma_E^2 + (\frac{\partial y}{\partial L})^2\sigma_L^2 \\ \sigma_z^2 = (\frac{\partial z}{\partial A})^2\sigma_A^2 + (\frac{\partial z}{\partial E})^2\sigma_E^2 + (\frac{\partial z}{\partial L})^2\sigma_L^2 \end{cases} \quad (5)$$

It make x, y and z from Eq. 4, respectively do the partial derivative and be simplified, get into Eq. 5 to obtain σ_x^2, σ_y^2 and σ_z^2 and get measurement accuracy that is marked by f as Eq. 6 for the collaborative positioning model between the radar and the photoelectric theodolite:

$$f = \sqrt{\sigma_x^2 + \sigma_y^2 + \sigma_z^2} \quad (6)$$

Through the analysis of Eq. 6, the positioning accuracy is higher if the value of f is smaller.

Layout optimization: When the exterior ballistic test system of the range uses the radar and the photoelectric theodolite to work collaboratively, the positional relation between the radar and the photoelectric theodolite can affect the test results in the testing process (Moreira *et al*., 2012). Therefore, in order to ensure the optimal results of the collaborative test, the layout for the radar and the photoelectric theodolite need to optimize. Firstly it needs to consider the constraint of the layout. Secondly it selects the rational modern optimization algorithm to optimize it.

Constraint of the layout for the station: When it carries the layout for the radar and the photoelectric theodolite, the constraints of the layout area are as follows:

- The layout area should be on land and can't be unfit for human habitation such as the swamps and the deserts
- The area of the layout must meet the requirements of the measurement for the equipment
- The area nearby can't have light or electromagnetic interference to avoid the blocking effect on the observed surface features

Modern optimization algorithms: Now commonly used optimization algorithms include genetic algorithm, artificial neural networks, ant colony algorithm and simulated annealing algorithm. The introductions of optimization algorithms are as follows.

Genetic algorithm is a class of randomized search method for the reference of the biological evolution law and a global optimization algorithm. It provides common framework of optimization problems to solve complex system, doesn't depend on the specific region of the problems, has low requirement to the optimization function and has robustness for all kinds of intelligent problems. It is widely used in computer science, engineering technology and social sciences and other fields (Yin, 2013).

Artificial neural network is a mathematical model that processes the information through the application which is similar to the structure of the brain synaptic coupling. And it is a calculation model that is formed by the mutual connection among the large number of nodes or neurons. Among them, each node represents a specific output function that is called by activation function and the connection between the two nodes represents a weighted value that is called by the weight by the connection signal and equivalent to the memory of artificial neural network. So, the output of the network varies from the connection type of the network, the weight and the activation function.

Ant colony algorithm is a new type of the simulation for the evolutionary algorithm that firstly is proposed by the Italian scholar M. Dorigo in recent years. The algorithm can solve the traveling salesman problem, assignment problem and job shop scheduling problem and make a series of better results.

Simulated annealing algorithm is an extension to local search algorithms. In the every process of modifying the model, the algorithm may randomly generate a new status model and select the status that has bigger power in its neighbor at a certain probability. The algorithm that can accept new model evolves into a global optimal algorithm and has been validated in the theory and practical application.

According to the compare of the above optimization algorithm it adopts the genetic algorithm to optimize the layout in order to obtain a global optimal solution and faster convergence rate.

Optimization of the layout based on the genetic algorithm: According to the implementation of genetic algorithm it needs to set the parameters to generate a random initial colony, then begin to code and perform the fitness calculation to select the best individual. The following highlights individual coding, calculation for the fitness and exclusion for the abnormal results.

Individual coding: According to the constraint condition, the test equipment is set in the area that is 40 km in the length and 40 km in the width in the range coordinate system and in the horizontal plane such as XOZ. Therefore, the coordinates of the equipment should meet the condition as Eq. 7:

$$\begin{cases} 0 \le x \le 40 \\ y = 0 \\ -20 \le z \le 20 \end{cases} \tag{7}$$

The search accuracy is 0.001 km and the distance between the radar and the photoelectric theodolite must be no more than 0.01 km. Thus, Eq. 8 should be met:

$$\sqrt{(x_R - x_p) + (z_R - z_p)^2} \le 0.01 \tag{8}$$

Since, the layout of the radar and the photoelectric theodolite is within the range of 15 km at a certain direction they can obtain higher accuracy. Therefore, it needs to select three groups for the radar and the photoelectric theodolite to complete the testing tasks.

In the case of getting the original site of the photoelectric theodolite it adopts genetic algorithm to code by the binary for the six value of the coordinate where each value need the number of the bit that is marked by m to meet Eq. 9:

$$2^{m-1}-1 \le (U_i-L_i)\times 10^k \le 2^m-1 \tag{9}$$

Here, k is the digits after the decimal point for the search precision, here k is equal to 3 and U_i and L_i are, respectively the upper and lower limits of the area. It can calculate that m is equal to 16, so three radars and three photoelectric theodolites, respectively need 96 bits that is 16 multiplied by 6.

Calculation of the fitness: Because the positioning accuracy for the target at a random point x_k is shown as Eq. 6 in the process of the entire ballistic test. So the optimization function of the layout g is shown as Eq. 10:

$$g = \sqrt{\sum_{k=1}^{N} f_{xk}^2} \tag{10}$$

where, N is the number of the entire ballistic test data. The fitness function can be expressed as Eq. 11:

$$\text{fitness} = \frac{1}{g} \tag{11}$$

The value of the fitness function is higher, thus the positioning accuracy of the layout geometry is higher and the layout geometry is more excellent.

Optimizing: Because they have randomness that is generating the initial colony and the operation of the crossover and mutation for the colony, the fitness can be complex in the process of calculation. Thus this will affect each optimization results.

RESULTS AND DISCUSSION

If it can obtain a group of the layout coordinates in Table 1. However, in order to find the optimal solution it needs to process the complex. It replaces the complex with the real to get rid of the complex and retain the original colony.

In the experiment it simplifies the ballistic mathematical model as a straight line that is shown in Eq. 12:

$$\begin{cases} x = 0.2t \\ y = 6 \\ z = 10 \end{cases} \tag{12}$$

Table 1: Layout coordinates on XOZ

Groups	Radar (x, z)	Photoelectric theodolite (x, z)
First	(10.7166, 2.9966)	(4.7525, 4.6690)
Second	(13.8742, 10.9435)	(21.0695, 5.8366)
Third	(33.0091, 3.6747)	(34.5410, -2.2586)
Optimal fitness	1.5295	

Table 2: Layout coordinates on XOZ

Groups	Radar (x, z)	Photoelectric theodolite (x, z)
First	(8.4961, 5.1145)	(8.0285, 6.1120)
Second	(18.2353, -1.7661)	(18.8875, -1.4715)
Third	(36.1156, 7.2422)	(36.7544, 7.9750)
Optimal fitness	1.8320	

In general, the ranging precision of the radar σ_R is equal to 0.003 km, the angle precision of the photoelectric theodolite such as σ_A and σ_E are equal to 18°, the scale of the colony n is set to 20, the genetic algebra ger is equal to 200, the crossover probability pc is equal to 0.65. It selects 100 test points in the whole ballistic test. The optimization results for Table 1 is shown in Table 2. The fitness from Table 2 where the layout is optimized is better than it from Table 1 where the layout is not optimized. Clearly, in Table 2 the simulation where the real replaces the complex obtains the better fitness results, gets rid of the complex.

CONCLUSION

In this study, the virtual test researches on the test system of the exterior ballistics in the range and gives the framework of the virtual test system. On the basis of the framework it research on the collaborative test in the virtual test in depth. And it optimize the layout of the radar and the photoelectric theodolite through the genetic algorithm in the process of the collaborative test in order to obtain the better test results and get simulation results in MATLAB. The simulation results show that the fitness of the coordinate information from the positioning target by optimization is better than the simple layout and the algorithm is simple to improve the operation efficiency.

ACKNOWLEDGMENT

This study is supported by the National Science and Technology Support Program (2013BAH45F02), Scientific Research Project of Shanxi Province (201001011023-1).

REFERENCES

Case, F., A. Beinat, F. Crosilla and I.M. Alba, 2014. Virtual trial assembly of a complex steel structure by Generalized Procrustes Analysis techniques. Autom. Constr., 37: 155-165.

Karam, M. and H. Safa, 2013. Towards collaborative testing of workflows in WMVC-based web applications. Proceedings of the International Conference on Collaboration Technologies and Systems, May 20-24, 2013, San Diego, CA., USA., pp: 324-331.

Li, X., Q. Gao, Z. Zhang and X. Huang, 2012. Collaborative virtual maintenance training system of complex equipment based on immersive virtual reality environment. Assembly Autom., 32: 72-85.

Moreira, J.C., E. Miguez, C. Vilacha and A.F. Otero, 2012. Large-scale network layout optimization for radial distribution networks by parallel computing: Implementation and numerical results. IEEE Trans. Power Delivery, 27: 1468-1476.

Qian, K.C., 2013. Self-identification method and application of measuring equipment under conditions of close arrange stations. Adv. Mater. Res., 706: 995-999.

Song, W., L. Lou, M. Chai and S. Hu, 2013. The research and application on fusion location algorithm of theodolites and radar associated measurement. J. Projectiles Rockets Missiles Guidance, Vol. 33

Vergara, D., M.P. Rubio and M. Lorenzo, 2014. Interactive virtual platform for simulating a concrete compression test. Key Eng. Mater., 572: 582-585.

Yin, Z.X., 2013. Simple average for linear combined forecasting weights method. J. Applied Sci., 22: 5186-5191.

Young, S., P.R. Bakic, K.J. Myers, R.J. Jennings and S. Park, 2013. A virtual trial framework for quantifying the detectability of masses in breast tomosynthesis projection data. Med. Phys., Vol. 40 10.1118/1.4800501

Zhang, P., D. Zrnic and A. Ryzhkov, 2013. Partial beam blockage correction using polarimetric radar measurements. J. Atmos. Oceanic Technol., 30: 861-872.