Design Method of Multi-source Aerial Target Information Fusion Platform Based on Message Communication

Jie Zhang¹*, Haiyan Lv¹, Kai Liu¹, Yaqi Cui¹

¹ Naval Aeronautical University, Yantai, China

*Corresponding author e-mail: zhangjie9886@126.com

Abstract. Against air targets multi-source asynchrony and heterogeneous nature of data problems, the paper puts forward a way of using message communication, realizing the information transmission of each source monitoring platform using message library pipeline mode by Xml message format for data transmission. To improve the data transmission and interaction ability, it establishes a multi-threaded data pipeline transfer mode, and support real-time access and exit of multi-source monitoring. The target data fusion adopts method of the Euclidean distance with least-square method of quadratic curve fitting method for the correlation operation, and effectively guarantees the same target correlation fusion and target attribute fusion. Target identity information can be passed to the comprehensive target recognition, providing a reliable data basis and guarantee for subsequent aerial situation and threat assessment.

1. Introduction

With the increasingly complex battlefield environment, especially in military combat readiness, a single source of air target tracking is limited by detection range, detection performance, factors such as spatial resolution, and the air target tracking based on multi-source sensor has improved significantly in target discovery performance, positioning accuracy and recognition, but air situation information sources are usually deployed in different areas on many types of sensors[1]. With increasing air targets monitoring data, for example, each source detection node is relatively independent, the monitoring of the target data is likely to be the same air targets, it is necessary to carry out the monitoring data fusion, identify the same air targets tracking information, first it is necessary to transmit data to the multi-source target detection platform through the network, and to provide data support for the air situation data fusion.

This paper proposes using ZeroMQ messaging libraries for the target track monitoring information transmission, and builds a platform with functions of monitoring platform dynamic registration, track monitoring information transmission, information storage, target tracking information building, track correlation and fusion, the fusion data forwarding, and other functions, to reduce the information redundancy track, comprehensive complementary and capture the collaborative information, such as multiple source of air monitoring data fusion and storage for a higher level of data processing, target recognition, situation assessment and intelligent decision-making.

2. System Overall Design

Given the multi-source monitoring nodes generally have characteristic of heterogeneity and diversity, which requires a cross-platform way of monitoring data transmission, at the same time the platform...
should support equipment dynamically join and exit, such as alternative should provide specifications after fusion data forwarding functions. Based on the above analysis, in combination with ZeroMQ message communication libraries possess the characteristics of real-time and reliability of data transmission, and reduces the complexity of network programming. The advantages of the implementation is relatively simple and feasible by ZeroMQ message to establish an efficient, reliable, transparent, cross-platform data communication platform. A lightweight data-interchange format Xml is adopted to complete multi-source monitoring data transmission between the devices and platforms.

![Monitoring platform design framework.](image)

The functional modules of platform mainly include:

a) data reception
   Its function includes formulating unified data interchange format, track data sending, receiving, forwarding function. Firstly it registers target monitoring source (equipment), and then the monitoring device can transmit data in accordance with the unified, standardized format, sending and receiving air track point data by ZeroMQ message. The platform supports source monitoring node dynamic access and exit, and greatly improve the platform's adaptability.

b) data fusion
   First of all, the following functions have been implemented: the pretreatment of air situation track, filtration of abnormal data monitor node sending, building the tracking information, including the knowledge based on the correlation calculation form for air tracking information pretreatment. The platform establishes a cache track, obtaining air target tracking data, and according to the route cache of track data of the target number, and update cache tracking information, in order to reduce the amount of calculation and storage space consumption by cutting track with too many points, which can greatly improve the correlation and fusion calculation efficiency. The track correlation operation is the core part of platform, which has functions of achieving target multiple tracking information fusion, generating different batch number the same target correlation table, correlation operation, and the associated computational results pretreatment module for real-time feedback to track the follow-up tracking information on the basis of related knowledge base to merge.

c) data forwarding
   The platform sets the specified data interface, and the fused data can be sent to the specified device port by ZeroMQ message, which can be used for higher level air situation data analysis system.

3. Implement Key Technologies
The core function of the tracking processing platform completes the transmission of data information of multi source monitoring nodes, through the operation of the data association of the platform track data and the fusion of track properties and so on, and realizes the data retransmission after the fusion, and the key technologies are mainly included:

3.1 monitoring target data exchange standards
In view of the heterogeneity of multi-source monitoring and structural inconsistencies in the exchange of track information, the data must be converted into an unified format. The method is to use a text format, which is completely independent of programming language to store and express. Xml is a
lightweight data exchange format. The simple and clear hierarchical structure makes XML an ideal data exchange language, which inherits the advantages of scalability, structure, and verifiability, and uses a structured way to describe the data itself and support the use of the data[3].

By analyzing the air monitoring data, the parameters and attributes closely related to the track correlation and subsequent situation assessment are abstracted, and the unified monitoring data exchange XML format is generated. The format is defined as follows:

```xml
<?xml version="1.0" encoding="UTF-8"?>
<data>
  <MonitorDevice>Ks</MonitorDevice>
  <Target>
    <Number>870124</Number>
    <Type>AIR</Type>
    <Country>CN</Country>
    <Character>Military</Character>
  </Target>
  <Location>
    <Property name="Lon">125.01214478</Property>
    <Property name="Lat">29.508333333333</Property>
    <Property name="Alt">123.55422</Property>
  </Location>
  <Time>
    <Property name="PositionTime">1524911182000</Property>
    <Property name="ReceiveTime">1524911182000</Property>
  </Time>
</data>
```

3.2 Multi source device message communication implementation

In order to ensure the real-time and reliability of the communication between the source detection nodes, and supporting join and exit of the multi-source node in real time, the platform uses the ZeroMQ message communication library to complete the transition of the monitoring data. It is a multithreaded network library based on message queuing, which abstracts the underlying details of socket type, connection processing, frame and even routing, and provides sockets across multiple transport protocols. It is a network communication intermediary between the application layer and the transport layer, and a scalable layer that can run in parallel, distributed among distributed systems.

![Message communication working modes](image)

**Figure 2.** Message communication working modes

a) Pub-Sub mode, the publisher distributes data, and does not guarantee whether all the information is sent to the subscriber. If the publisher begins to publish information, the subscriber is not connected, the information is discarded directly, the subscriber is only responsible for receiving, and can not be fed back, and the data will be accumulated at the subscriber's port when subscriber's consumption is slower than the publisher.
b) Pipe mode, when multiple Pull ends are connected to the Push end, the Pusher has a load balancing internally, using an average allocation algorithm to distribute all the message equilibrium to the Pullers; when multiple Pushers connected to the Puller, we call this structure a fair team column, and the Puller is understood as a queue. Each Pusher sends the data to the queue continuously. Compared with the Pub-Sub model, the Pipe model will not be consumed (the Pusher will be blocked) without the consumer; in the case of insufficient consumer ability, it can provide a multi consumer parallel cancellation solution. The model is mainly used in many cases, e.g. Task parallel processing\[^4\].

3.3 Track correlation fusion processing

Track association is to associate the track of the same target, and classify the sensor data according to the target. Since each track is composed of track points, and each point contains information of time, position, speed and so on. In many existing target association methods, the position information is the most important attributes\[^5\]. In addition, the trajectory of any target can be approximated by a polynomial of order to any longitude. Based on this idea, this paper uses the least square method of two times curve fitting to estimate the track correlation by calculating the point trace Euclidean distance between the tracks.

a) The set of track points is three tuple \(t = (T, \text{lon}, \text{LAT})\), which are composed of position time, longitude and latitude (Because the altitude error of air target is large, it is not a reference attribute)\[^6\]. The first two tracks T1 and T2 should have the intersection time \(\Delta T\) (and \(\Delta t > \text{threshold T}\)), and select the set of points in the cross time: \(U_1 (P_1, P_2, \ldots, P_N)\) and \(U_2 (P'_1, P'_2, \ldots, P'_M)\), we choose the more dense tracks (assuming T1) to use the least square method and the two order curve fitting to get the two curve of the track.

\[
\begin{align*}
    x &= a_{11} \cdot t^2 + b_{11} \cdot t + c_{11} \\
    y &= a_{12} \cdot t^2 + b_{12} \cdot t + c_{12}
\end{align*}
\]

b) select K track points of track T2 in \(\Delta T\), and obtain a set of 2-D vector set \(\alpha\), according to the time information of selected K track points (T1, T2, T3, TK), get the fitting values of longitude and latitude of track T2 track on the curve, and use the matrix to represent the set of vectors.

\[
\alpha = \begin{bmatrix} x_1 & y_1 \\ x_2 & y_2 \\ \vdots & \vdots \\ x_k & y_k \end{bmatrix} \quad \delta^T = \begin{bmatrix} x'_1 & x'_2 & \ldots & x'_k \\ y'_1 & y'_2 & \ldots & y'_k \end{bmatrix}
\]

c) according to the Euclidean distance formula, the real value of the point-i and the distance between the pseudo value are obtained. The mean value of the Euclidean distance between the two vector sets and the point trace of the corresponding vector is solved.

\[
\eta_i = \sqrt{(x_i - x'_i)^2 + (y_i - y'_i)^2}
\]

\[
\mu = \frac{1}{K} \sum_{k=1}^{K} \eta_k
\]

When the \(\mu\) value is less than the threshold M, the track T1 and T2 are identified as the same track. Because the monitoring equipment is limited to detection range, detection performance, and spatial resolution, from a monitoring equipment, there may be intermittent between tracks. Multi-source monitoring can be transmitted between track association relations. This operation is called the association structure, for example, track T1 and track T2 have been successfully associated, track T2 and track T3 has been successfully associated, and then he track T3 is associated with track T1, and the main track is determined by track attribute. The algorithm for track association aggregation is as follows:
a) the state of \(<t', t'\) is set as Unprocessed, and stored in L(a List), creating an empty set of tracks associated with U to start traversing List;

b) get a state that is unprocessed from L, \(<t_1, t_2>\), create track association aggregation \(U'\), add \(<t_1, t_2>\) to \(U'\) in subsets, and mark \(<t_1, t_2>\) state is processed;

c) find out whether the track in \(U'\) is included in the other correlation result pairs in List, if there is \(<t_1', t_2'>, <t_1', t_2'>\) is added to the \(U'\) in the subset, and \(<t_1', t_2'>\) is processed;

d) if it does not exist, continue (b) operation until all the track association results in List are processed.

4. Design and implementation of Platform

When using the ZeroMQ message library to communicate with other source monitoring node, the monitoring point or equipment is taken into real time and exit, and ensure that the track can be processed in time when the monitoring data is large. The platform uses the ZeroMQ distributed message by Pub-Sub and pipeline mode. The flow of information transmission is as follows:

a) when the new monitoring equipment is connected to the platform, the equipment information should be registered at the control terminal of the platform. After the registration is completed, the PUB socket is created to the device terminal. After the device SUB socket is connected to this end, the aerial target data can be sent, and the control terminal of the platform can also send other control signals, such as the removal and change of the equipment.

b) multiple monitoring registered devices send data through push sockets, and the platform handles the receiving and processing of each air data through the task collector pull socket. When the number of monitoring equipment is too large or the speed of data transmission is too fast, a distributed processing procedure process can be added after the data collection(Pipeline mode), in the end, the associated data processing data can be published by Pub-Sub message for other systems or platforms to subscribe. In order to improve the data concurrency processing capability, the communication module uses multithreading by pipeline mode.

Figure 3. Design of platform data transition

5. Experimental Analysis

In the experiment, 5 monitoring devices are connected with the tracking platform for data transmission and interaction. The data received through the platform shows that the ZeroMQ distributed messages can achieve the load balance within the Server end (such as the Pull end), and the average allocation algorithm can be used to balance the Push socket of each detection device (client). The puller end, instead of receiving all the data sent by a device, take turns to receive data from multiple devices. In addition, the experiment shows that when the monitoring device sends data faster than the integrated platform data processing and receiving capability, the data transmission is blocked in Push end.
6. Conclusion

In order to ensure the high speed communication between the monitoring nodes and the tracking processing platform, a communication mode based on ZeroMQ message is proposed in this paper, in view of the heterogeneity and location of the target multi-source monitoring equipment, and the data format is not uniform and the data generation speed is different. The data interaction of platform works in two modes, and extracts key information from transmission data and exchanges data with Xml, setting up multi-thread pipeline data mode and supporting the real-time access and exit of each source monitoring, which improves the ability of data exchange processing. The above methods are dealing with data interaction and communication with high data volume and high real-time requirement. Moreover, this model is of universal applicability and translatability. In addition, this paper uses the Euclidean distance least square method of curve fitting to carry out track association operation. This method has high correlation success rate when dealing with good track continuity and the existence of time cross between tracks. The algorithm is simplified but the premise is too strict[6], and it does not to consider the speed, horizontal height and monitoring equipment error of the target track, it is difficult to deal with the track bifurcation and cross track, and the correlation operation is insufficient in this case.

References

[1] Hua Wan, research into Multi-sensor cooperative location technology [J],Shipboard electronic countermeasure,2014,37(3)30-37
[2] Quan Pan, Basic methods and progress of information fusion, Control Theory & Applications, [J], 2012, 29(10)1231-1241
[3] Lili Qiu, Design and implementation of dynamic interaction platform for hierarchical data[J], Computer Applications and Software, 2013, 30(3)182-185
[4] Information on http://zeromq.org/
[5] Wenchao Li, A Survey of Target Data Association [J], Computer Simulation, 2014, 31(3)1-6
[6] Zhang Zhang, A new track correlation algorithm based on statistics [J], Computer Applications and Software, 2012, 29(8)269-271