Single-station Passive Reconnaissance Target Location Based on Intelligent Technology

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Abstract. At present, passive reconnaissance target location usually adopts multi-station direction-finding cross or multi-station time difference method, which has the disadvantages of complex scenes, large resource consumption, long time consumption and low positioning accuracy. In this paper, intelligence technology is used to perform machine learning and predictive evaluation of target radiated power in battlefields, and combined with the electromagnetic propagation model to complete the estimation of target approximate position of single-station passive reconnaissance. The results show that after training with a certain sample, the method can quickly complete the estimation of the target position, and has high positioning accuracy.

1. Introduction

Passive reconnaissance of target location is a popular technology for military applications. It uses radar signals and radio communication signals to complete the calculation and estimation of the target position on the battlefield. Compared with radar detection, it has the advantages of good concealment, strong identification ability and fast positioning speed. Since the 1970s, the research direction of passive reconnaissance target location technology includes multi-station coordinated target location and single-station target location \cite{1,2}. Common methods for multi-station coordinated target location include multi-station direction-finding cross or multi-station time difference. The multi-station cross-location method is applicable to various combinations of shore-ship coordination, ship-aircraft coordination, and satellite-ship coordination. It adopts the feature parameter matching method to fuse the data of multi-station and perform cross-bearing positioning on the matching screening data. The multi-station time difference positioning method uses the time difference and azimuth information of signals arriving at different stations, and calculates the specific position of the target through the time difference positioning model algorithm. Passive reconnaissance single-station target location is still in the initial stage of research. The biggest drawback is that when performing target positioning calculations \cite{3,4}, it is necessary to provide reference point positions for target positioning correction. At present, this method is very limited, and it is only suitable for signals using special modulation by TDMA \cite{5}.

With the rapid development of artificial intelligence and machine learning technology, it has gradually been widely used in engineering development, which has brought about great changes in machine cognition and artificial empowerment, and has injected new impetus into the research of single-site passive positioning. The main difficulty of the single-station passive reconnaissance target
location method is to estimate the equivalent radiated power (ERP) of the emitter and the atmospheric propagation loss. Atmospheric propagation losses can be obtained through calculation of atmospheric propagation models, where current meteorological environmental parameters are obtained by atmospheric environment assessment equipment. The ERP of a single radiation source varies greatly in different functional modes. Therefore, the intelligent machine learning technology is used to establish an ERP training model composed of signal parameters, target azimuth distance, meteorological conditions, and transmission loss. The model training accumulation is used to form the target equivalent source power ERP sample set under real conditions, which provides input for the source ERP estimation in single-station passive reconnaissance target location [6][7].

2. Rough Estimate of Target location

2.1. Target location estimation model

The passive reconnaissance station obtains the target radiation source's direction through the direction-finding device, and can estimate the target's position by estimating the target distance. The principle is as shown in Figure 1.

![Figure 1. Target location calculation principle block diagram.](image)

Among them, \( \text{Pos}^M \) is the current geographic location of the reconnaissance station, \( \text{Az} \) is the target's direction relative to the reconnaissance station, \( d \) is the estimated distance between the target and the reconnaissance station, and \( \text{Pos}^T \) is the target position, which satisfies the following calculation model:

\[
\text{Pos}^T = \text{Pos}^M, \text{Az}, d
\]

\( \text{Pos}^M \) data set acquisition method: Real-time acquisition by satellite positioning and navigation equipment at the passive reconnaissance station.

\( \text{Az} \) data set acquisition method: the bearings of radiation source signal obtain by direction-finding device at the passive reconnaissance station;

The specific method for obtaining the target distance \( d \) dataset is shown in Figure 2:

![Figure 2. Schematic diagram of target distance acquisition.](image)

Single-station passive reconnaissance can obtain three types of information: target orientation, signal parameters, and receive signal level. According to the actual space electromagnetic propagation Okumura-Hata empirical model, the target distance estimation formula is as follows:
\[ L_p \ dB = 69.25 + 26.16 \lg f_{MHz} - 13.82 \lg h_1 - a \ h_2 + 44.9 - 6.55 \lg d_{Km} - K \]  \hspace{1cm} (2)

\[ a \ h_2 = 1.1 \lg f_{MHz} - 0.7 \ 1.56 \lg f_{MHz} - 0.8 \]  \hspace{1cm} (3)

\[ K = 4.78 (\lg f_{MHz})^2 - 18.33 + 40.94 \]  \hspace{1cm} (4)

\[ L_p \ dB = \text{ERP}_{dBm} - L_v_{dBm} \]  \hspace{1cm} (5)

\[ d_{Km} = \arclg (\text{ERP}_{dBm} - L_v_{dBm} - 69.25 - 26.16 \lg f_{MHz} + 13.82 \lg h_1 + a \ h_2 + K / 44.9 - 6.55 \lg h_1) \]  \hspace{1cm} (6)

Where \( L_p \ dB \) is the path loss, \( \text{ERP}_{dBm} \) is the target equivalent radiated power, \( L_v_{dBm} \) is the receive signal level collected by the reconnaissance station, \( f_{MHz} \) is the signal frequency, \( a \ h_2 \) is the correction factor for the antenna height gain of the open area, \( h_1 \) is the equivalent height of the antenna of the reconnaissance station, and \( K \) is the correction factor for the coverage area of the open area.

### 2.2. ERP intelligent estimation model

The typical reconnaissance scenario of passive reconnaissance against ship and aircraft targets as shown in Figure 3. ERP value meet the stable detection conditions to be valid estimates, there are two main points of judgment. The first is passive reconnaissance station stably tracks target, at this time the reconnaissance antenna beam is directed at the target carrier radiation source, the target radiation source tracks the reconnaissance station, and the amplitude of the signal is stable. The second is to continuously collect or detect signals in unit time, at this time the target radiation source performs airspace scanning, and the signal amplitude of the reconnaissance station has a typical periodic scanning characteristic.

![Figure 3. Block diagram of a typical reconnaissance scenario.](image)

The ERP intelligent estimation model is mainly support for machine learning training and intelligent estimation of \( \text{ERP}_{dBm} \) in the rough target location estimation model. Aiming at the targeted individual radar radiation source and communication radiation source, combined with active detection and passive reconnaissance methods, the active detection target track and passive reconnaissance signal parameters are comprehensively used to establish an intelligent learning training model. The principle structure is as shown in Figure 4.

![Figure 4. Overall block diagram of ERP intelligent estimation model.](image)
According to the intelligent estimation model, the target individual radiation source is trained based on the reconnaissance scene, and an ERP estimation sequence is generated for a single radiation source. The target azimuth distance is calculated by the track information acquired by the radar detection equipment, and the signal reconnaissance parameter information is directly detected by the reconnaissance station equipment. Usually there is a corresponding mapping relationship between the radiation source signal parameters and ERP, so according to the target distance estimation formula, the ERP estimation model is as follows:

\[
\text{ERP}_{\text{d humili}} \approx 69.25 + 26.16 \log f_{\text{MHz}} - 13.82 \log h_1 - a h_2 + 44.9 - 6.55 \log h_1 \log d_{\text{Km}} - K + \text{Lv}_{\text{d humili}}
\]  

(7)

2.3. Single-Station Passive reconnaissance target rough location estimation process

According to the training model, the radiation source ERP is estimated to form the target radiation source training knowledge base. The corresponding workflow is shown in the figure.

Figure 5. ERP estimation training flowchart.

Corresponding to the real geospatial environment, according to the target approximate location estimation model and the radiation source training knowledge database, and then calculate the approximate position of the target that meets the conditions. The corresponding workflow is shown in the figure.
Radar signal or communication signal detection processing

Start

Radar ERP training knowledge database comparison matching

Is it matches?

No

Yes

Radar ERP training knowledge database comparison matching

Is it matches?

No

Yes

Signal parameters

Transmission loss estimation

Target distance estimation

Target rough position calculation

Target bearing(AZ)

End

3. Target location Training and Experiment

Construct training and test scenarios under good weather conditions, including three types of battlefield targets, which are simulated early warning aircraft, fighter aircraft, and destroyer ship. The settings and requirements of other relevant parameters in the scenario are shown in Table 1.

| Type             | Radiation source parameters | Training scene | Experiment scene |
|------------------|-----------------------------|----------------|------------------|
| Early warning aircraft | Radar:RF=3500MHz PRI=1000us PW=1us | Tracking | Scanning         |
|                  | Communication:RF=360MHz Pattern=FM Type= Fixed frequency | Omnidirectional | Omnidirectional |
| Fighter aircraft | Radar:RF=9500MHz PRI=100us PW=2us | Tracking | Scanning         |
|                  | Communication:RF=380MHz Pattern=FM Type= Fixed frequency | Omnidirectional | Omnidirectional |
| Destroyer ship   | Radar:RF=3100MHz PRI=2000us PW=1.5us | Tracking | Scanning         |
|                  | Communication:RF=390MHz Pattern=FM Type= Fixed frequency | Omnidirectional | Omnidirectional |

The dynamic interaction requirements for training test scenarios are:

1) Training scene: the target is 300 kilometers away from the reconnaissance station, the target moves according to the randomly planned route, the radiation source continues to track the reconnaissance station;

2) Experiment scene: The target is 300 kilometers away from the reconnaissance station. The target moves according to a randomly planned route. The radiation source scans the reconnaissance station periodically.

The positioning accuracy of approximate position estimation is expressed by the circular distance error. Extract three types of target data for rough position estimation under stable conditions. Among them, the approximate position error of the early warning aircraft is 2.5%, the approximate error of the fighter aircraft is 5.7%, and the approximate error of the ship target is 1.3%.
4. Conclusions
In this paper, the artificial intelligence technology is applied to passive reconnaissance target location, it supports the construction of training models and approximate position estimation models under typical reconnaissance scenarios. The Model application experiments show that it can achieve high accuracy acquisition of target ERP and target location under stable detection conditions. In general, this method can make up for the deficiency of single-station passive reconnaissance location capability. At the same time, it effectively enhances the combat platform's situational awareness capabilities under the condition of electromagnetic silence.

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