Target Association and Management Engineering Application of Photoelectric Detection of Ground Mobile Platform

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Abstract. On the basis of the current detection methods and the target information obtained of ground mobile platform, this paper constructed the architecture of target management of mobile platform, put forward the target association and management solution based on image recognition, tracking, laser ranging, and situation sharing, initially completed the engineering realization through position association algorithm, and installed on a special unmanned vehicle by computer simulation, verified this software, the verification results show that this architecture can complete the functions of multi-source target management in mobile platform, it could access the mobile platform software architecture of existing models, could realize the target position association and had good engineering application value.

Keywords: ground mobile platform, target association, target management.

1. Introduction
The target fusion and situation management of ground mobile platform are practical problems that need to be solved urgently for mobile platform, they are the prerequisites for vehicles to realize threat assessment, weapon allocation, and autonomous attack, and they are also the important foundation for realizing multi-vehicle situation management and coordination in the future. At present, data association and fusion technology are widely used in multi-target tracking, multi-source target fusion and other practical problems, scholars at home and abroad have conducted in-depth research on target association and fusion methods [1], from the earliest proposed nearest neighbor (NN) to the later probabilistic data association (PDA), joint probabilistic data association (JPDA), D-S evidence reasoning algorithm, etc., all have achieved good results.

Given the existing software and hardware conditions of the vehicle, photoelectric detection is the main method of vehicle detection at present, image recognition based on passive detection and laser ranging based on active detection are important sources for vehicles to obtain target information, according to the current detection methods of vehicles, this paper constructed the architecture of target management of mobile platform, proposed target association and management solution based on image recognition, tracking, laser ranging, and situation sharing, initially completed the engineering implementation and functional verification through the nearest neighbor, realized unified management, numbering and preliminary redundancy removal of the acquired target information, and provided basis for the application and verification of target association algorithm in the mobile platform in the future.
2. The Overall Idea of Target Association and Management of Photoelectric Detection

Under the existing software and hardware conditions of the vehicles, the target information and accuracy are obtained by the vehicles' current inertial navigation positioning, target image recognition, laser ranging and other means to achieve target association and unified management, as shown in Fig.1, the overall idea and steps are as follows.

Fig. 1 the overall idea of target association and management of photoelectric detection

(1) Information flow acquisition. By the white light/infrared watching device, laser ranging device, image recognition and tracking system, inertial navigation positioning device, etc., the target type and other attribute information, the pixel information of the target in image, the target distance information, the vehicle attitude and the position information are obtained, the northward angle, pitch angle, latitude and longitude, and other information of target are further obtained by calculation, the information flow from image recognition, automatic tracking, and laser ranging are formed. Information flow acquisition is not the focus of this paper, and it is taken as the known.

(2) Target association and matching. Target association and matching are conducted on the information obtained from the three-way information flow, data association is conducted from the information flow obtained from image recognition and northward angle and pitch angle of the known
target in the target library, target position information is continuously obtained from automatic tracking, the target database information of the known tracked target is directly updated; target information is obtained from laser ranging, first, the target with the longitude and latitude information in the target database is matched, the target without successfully matching and the target without latitude and longitude in the target library conduct data association of northward angle and pitch angle of known distance.

(3) Generation and management of target library According to the results of target matching, if there is no matching target, the target library adds new target entry, and if it matches existing targets, the target attribute is updated in accordance with a certain modification attribute priority.

3. Target Association and Matching Method

According to the overall plan, the target matching interval is preliminarily divided for different information sources, and the target association calculation is conducted on the targets entering into the target matching interval.

3.1. Target matching interval

1) Matching interval based on northward angle and pitch angle

Since the images acquired by twitching device of the mobile platform have higher sampling frequency, the time interval between two frames of images is relatively small, it is set to be $\Delta t$. Under this interval, the continuously moving target drives at the maximum travel speed $V_{\text{max}}$ of the mobile platform under the conventional detection distance $D$ of the mobile platform, according to $y$ triangle conversion, the maximum moving northward angle $A$ of the target within $\Delta t$ time can meet.

$$\tan(A/2) = \frac{(V_{\text{max}} \cdot \Delta t + L)}{2D}$$

Among them: $D$, $L$, $V_{\text{max}}$ are constants, $D$ is the conventional detection distance of the mobile platform (m), $V_{\text{max}}$ is the maximum driving speed of the mobile platform (m/s), and $L$ is the target vehicle length (m).

The northward angle error of the same point at the conventional detection distance $D$ of the mobile platform acquired by two frames of images is:

$$X_{\Delta} = M_{\Delta} + J_{\Delta} + I_{\Delta} + X_{\Delta}$$

Among them: $\Delta M$ is the measurement error of the sight position, $\Delta J$ is the calculation accuracy error, $\Delta I$ is the image recognition error, $X_{\Delta}$ is the system error.

Because $A > B$, the probability $P_i'$ where target $r'$ in the measurement space is associated with the target $P_i$ in the known space can be set to meet the following inequality:

$$P_i' = \begin{cases} 1 & (x_i - A) < x^j < (x_i + A) \\ \text{Indeterminacy} & (x_i - B) < x^j \leq (x_i - A) \\ \text{Indeterminacy} & (x_i + A) \leq x^j < (x_i + B) \\ 0 & (x_i + B) \leq x^j \text{ OR } x^j \leq (x_i - B) \end{cases}$$

Then for the range where the northward angle of measurement target $r'$ in $(x_i - B) < x^j \leq (x_i - A)$ or $(x_i + A) \leq x^j < (x_i + B)$, it is considered that the measurement target $r'$ has entered into the matching interval of the known target $P_i$.

2) Target matching interval of northward angle and pitch angle based on known distance information
For the matching between the target from laser ranging or first entering into automatic tracking and the target known from image recognition, since the distance is known, therefore, the constant D in the interval boundary A is calculated as the true measured distance of the target, and the matching interval is the same as above.

(3) Target interval based on latitude and longitude

For the matching between the target from laser ranging or has entered into automatic tracking and the target with known distance, latitude and longitude information, the state space is changed from northward angle and pitch angle to latitude, longitude and elevation information, interval boundary:

\[ A = B = \Delta G + \Delta J + \Delta X \]  

Among them: \( \Delta G \) is the measurement error of positioning device, \( \Delta J \) is the calculation accuracy error, and \( \Delta X \) is the system error.

Then \( P_i \) meet:

\[
\begin{cases}
\text{Indeterminacy} & \text{if} \quad (x_i - A) < x^j < (x_i + A) \\
0 & \text{if} \quad (x_i + A) \leq x^j \text{ or } x^j \leq (x_i - A)
\end{cases}
\]  

For the range where the north angle of the measurement target \( r_i^j \) in \( (x_i - A) < x^j < (x_i + A) \), it is considered that the measurement target \( r_i^j \) enter into the matching interval of the known target \( p_i \).

3.2. Target association calculation

Problem description: all the existing targets are regarded as the known space, and all the targets obtained from the same frame of image are regarded as the measurement space; the characteristic quantity which conducts target association is regarded as the state space, solve the correlation between each variable in the measurement space and the known space in accordance with the characteristic quantity of the state space, and there are the following propositions.

Proposition 1: the same target in the known space corresponds to at most one target in the measurement space.

Proposition 2: the same target in the measurement space corresponds to at most one target in the known space.

Definition 1: the set of all targets in the known target library is known space \( P = \{p_1, p_2, \cdots, p_n\} \), \( p_i \) represents the i-th target in the known space; all the targets acquired at the next moment are the current measurement space, it is denoted as \( R = \{r_1, r_2, \cdots, r_m\} \), \( r^j \) represents the j-th target obtained at the next moment; the target feature space of the known space and the measurement space is denoted as \( X = \{x_1, x_2, \cdots, x_k\} \).

Explanation: regarding the measurement space, the measurement space obtained by image recognition is all targets of the same frame of image, and the number of targets in the measurement space obtained by ranging is \( m=1 \), it is the current ranging target. Regarding the characteristic space, target matching based on northward angle and pitch angle, target northward angle data and pitch angle data as characteristic space variables of target; target matching based on latitude and longitude, and elevation of target as characteristic space variables of target.

The similarity characteristic of nearest neighbor [2] can be used for conducting target association. The Euclidean distance between each target in the measurement space and each target in the known space is calculated, the smallest distance is considered to be the same target. Moreover, it is guaranteed to meet the above-mentioned proposition 1 and proposition 2.
Specifically, the Euclidean distance \([3]\) between the target in the measurement space and the target in the known space \([3]\) is:

\[
D_i^j = \sqrt{(x1_i - x1^i)^2 + (x2_i - x2^i)^2 + ... + (xk_i - xk^i)^2}
\]  

The distance defined by the above formula is normalized to obtain the relative similarity function of the following movement position:

\[
s(D_i^j) = D_i^j / \sum D_i^j
\]

Among them: \(\sum D_i^j\) represents the sum of Euclidean distances between the target \(r^i\) recognized by the image \(f_k\) and all targets in all known spaces.

The similarity function \(s(D_i^j)\) shows the similarity of the target movement, the smaller \(s(D_i^j)\), the more similar the movement, the smallest known target in the matching interval is selected as the associated target of this measurement target.

4. Generation and Management of Target Library

4.1. Target encoding mechanism

The purpose of target matching is to ensure the consistency and uniqueness of the vehicle code; therefore, the target code adopts method combining counting and target source code, as shown in Fig.2.

\[ \text{Fig. 2 target encoding} \]

4.2. Modify the target mechanism

For different target sources, after the targets are successfully associated, the target attributes are updated according to the following priority.

\[ \text{Table 1. Target modification priority} \]

| Target type     | Target northward angle, pitch angle | Target distance | Latitude, longitude and elevation of target |
|-----------------|-------------------------------------|----------------|---------------------------------------------|
| Image recognition source | 3 | 2 | 2 | 2 |
| Ranging source  | 2 | 1 | 1 | 1 |
5. Test Verification

5.1. Simulation verification

On the PC with Windows 7 operating system, the C++ programming of target association and management software is realized by VisualStudio2008 tool, and the simulation debugging environment is established by the MFC interface simulation tool. Under this simulation environment, the target source data is simulated for conducting simulation test.

1) Functional test and static target test. The test case is shown in Table 2. The test results show that this software can realize addition, deletion, modification and match of targets, etc., and can realize the association matching of static targets.

| Test item | Test result |
|-----------|-------------|
| Addition and matching of image recognition | ✓ |
| Image input normal value data-addition | ✓ |
| Image input new data edge value and breaking bound value-add and range judgment | ✓ |
| Image input value of original target error range-matching | ✓ |
| Image input value outside original target error edge-matching and addition | ✓ |
| Addition and matching of ranging | ✓ |
| Control terminal input the new target normal value-addition | ✓ |
| Control input new target edge value-range judgment | ✓ |
| Control input value within the error range of original recognition target-match northward angle | ✓ |
| Control input value outside original recognition target -match and add northward angle | ✓ |
| Control input value of the error range outside original ranging target -match and add latitude and longitude | ✓ |

2) Moving target test. Under 160ms sampling frequency condition, this test simulates target input data of the target (person) moving at 2m/s and 8m/s lateral speed within 500m, simulate the target (vehicle) driving at 25km/h and 30km/h lateral speed within 1000m, simulate the target (vehicle) driving at 25km/h and 30km/h lateral speed within 2000m, simulate the target (vehicle) driving at 25km/h and 30km/h lateral speed within 3000m, respectively, and carry out test. The test results show that this algorithm can achieve association matching for the above targets.

5.2. Installed verification

On a special unmanned vehicle platform, a certain type of system is embedded to conduct installed verification, the verification results are shown in Fig.4 and Fig.5. The No.4 target shown in Fig.4 and the No.32 target in Fig.5 are moving targets, test shows that this software can carry out correlation of
moving targets to a certain extent, but it is limited by the stability of target recognition, the oneness of associated data and the limitation of association algorithm, its matching accuracy for moving targets is not high enough.

![Fig. 3 Installed verification case 1](image1)

![Fig. 4 Installed verification case 2](image2)

6. Conclusion
According to the existing detection methods and acquired information of vehicles, this paper constructed the architecture of target management in mobile platform, and put forward solution of target association and management based on image recognition, tracking, laser ranging, and situation sharing, initially completed project realization and functional verification by the nearest neighbor, achieved unified management, numbering and preliminary redundancy removal of the acquired target information, and provided basis for the application and verification of the target association algorithm in the mobile platform in the future. The accuracy of dynamic target association has a lot to do with the stability of target recognition, the diversification of associated data, and the associated algorithm by test, therefore, the next step will use image recognition and other means extract and mine characteristic information of target, then conduct comprehensive matching in combination with the relative position and absolute position information of the target, moreover, optimize the multi-feature target association algorithm, further improve the correlation accuracy of dynamic target.
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References
[1] Yang Lujing, Yu Hua. Multi-source Information Fusion Theory and Its Applications [M]. Beijing: Beijing University of Posts and Telecommunications Press, 2006.
[2] Nie Xuan, Chen Huaimin. Track Multiple Objects with Feature-correlation Algorithms [J], Application Research of Computers, Master's Thesis, 2009, 26(9), 3545-3547.
[3] Chang Tianqing, Hao Na. Target Management and Passive Location Based on Information Fusion [J]. Systems Engineering and Electronics, 2017, 39(9), 1921-1935.