Target Optical Property and Multi-target Information Fusion Processing Algorithm in Target Tracking System

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Abstract
To improved photoelectric detection performance and enhance the target recognition rate in photoelectric detection system, this paper set up target optical property model in photoelectric detection area based on the theoretical knowledge of illumination, analyze the influence factor of detection system, give the calculation and deduction; set up the D-S data fusion reasoning model and research target recognition algorithms for data fusion and Multi-sensors signal fusion algorithm. Through experiment and calculation, when the sky background luminance is greater, the detection performance is weaken in photoelectric detection system, the new D-S evidence reasoning method can effectively improve target recognition rate.
Keywords: PHOTOELECTRIC DETECTION, TARGET OPTICAL PROPERTY, D-S EVIDENCE REASONING, TARGET RECOGNITION RATE

1. Introduction

In recent years, with the development of technology, target tracking and detection technology at home and abroad has made new breakthroughs, it is also research hotspot[1-2]. Development and application of infrared technology in particular has the broad application prospect, which promote weapon guidance, infrared warning and real-time surveillance and other aspects of reform. Target tracking is a classical problem in computer vision, its basic task is to determine or estimate the position, velocity and effective features on interested targets of video sequences[3].

In the civil context, the application of target tracking such as video coding, intelligent transportation and video surveillance, provide oversight and supervision role for travel safety to avoid the occurrence of accidents. To effectively identify the target information, we must master and analyze the target feature, tracking dynamic feature, target information recognition and processing, and so on[4]. So, Data association is a kind of information processing of multi-source sensor network technology. Through the analysis and extract of the relationship between multi-source data, it can be obtain the target information that from a single sensor can not to get. The way of multi-source heterogeneous detection has the principle of complementarities by itself, in this way; through the associate information sensors can solve the problem that original detection system cannot to solve. It provides a broader method and ideas for information fusion technology, D-S evidence reasoning method is based on the detection of independent sensors[5].

In many practical applications, although the probability assignment function of each sensor is independent, and they may detect the target at the same time, but their information related to certain. This information is not reflected in the traditional evidence reasoning, which does not make full use of multi-source information. The establishment of data association method between the sensors will make full use of the related information, in order to improve the system's target recognition probability. To improve the performance of the photoelectric detection system, this paper studies the target optical property and the multi target information fusion processing method.

2. Target optical property in photoelectric detection system

2.1 The basis principle of photoelectric detection system

Figure 1 is the schematic diagram of photoelectric detection system. photoelectric detection track rotating platform includes angular-encoder and rotational structure, the rotational angle can be show in computer, synchronous trigger provide a trigger signal to the image acquisition module, under synchronous trigger control, computer processing system can gather target image and dispose it by image processing techniques, at last, synchronous tracking target information can be gained.

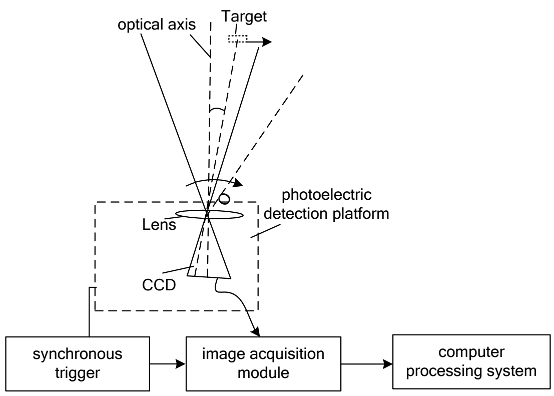

Figure 1. The schematic diagram of photoelectric detection system

2.2 Target optical property calculation model

According to the optical detection principle of photoelectric detection system[6], assuming that the background light spectral irradiance is $E_b(\lambda)$, the optical detection system of radiation luminance is E_1.

$$E_1 = \int_{\lambda_1}^{\lambda_2} E_b(\lambda) d\lambda \tag{1}$$

In (1), λ_1 and λ_2 are the spectrum wavelength range of the optical system imaging CCD detector response, according to the effective aperture of optical lens, optical detector total luminous flux of photoelectric detection system is ψ.

$$\psi = \frac{1}{4} \cdot \pi D^2 \cdot \int_{\lambda_1}^{\lambda_2} E_b(\lambda) d\lambda \tag{2}$$

D is the aperture diameter of optical lens. If tracking platform optical lens light transmittance is τ, then spectral flux obtained on the photosensitive surface of the CCD detection element is

$$\psi = \frac{1}{4} \cdot \pi D^2 \cdot \tau_0 \cdot \int_{\lambda_1}^{\lambda_2} E_b(\lambda) d\lambda \tag{3}$$

Assuming that CCD exposure time is t_0, the total radiation on CCD detector element sensitive surface is

$$M = \int_0^{t_0} \psi(\lambda, t) dt = \frac{1}{4} \cdot \pi D^2 \cdot t_0 \cdot \tau \cdot \int_{\lambda_1}^{\lambda_2} E_b(\lambda) d\lambda \tag{4}$$

According to the detection principle of CCD photoelectric couplin, assuming that the CCD detector spectral quantum efficiency is $\eta(\lambda)$, then the photo generated electron number of CCD photosensitive surface is:

$$N(\lambda) = \frac{1}{4} \cdot \pi D^2 \cdot t_0 \cdot \tau \cdot \int_{\lambda_1}^{\lambda_2} \eta(\lambda) \frac{\lambda}{hc} E_b(\lambda) d\lambda \tag{5}$$

In electro-optical tracking system, if the target imaging covering energy is divided equally by n pixel of CCD, each pixel photo generated electron number is:

$$N^{'}(\lambda) = \frac{1}{n} N(\lambda) \tag{6}$$

Then the output voltage value of CCD photosensitive device is

$$V = \frac{e \cdot \delta \cdot t_0 \cdot \tau}{C \cdot G} \cdot \frac{1}{4M} \cdot \pi D^2 \int_{\lambda_1}^{\lambda_2} \eta(\lambda) \cdot \frac{\lambda}{hc} E_b(\lambda) d\lambda \tag{7}$$

In (7), δ is the total charge transfer efficiency, G is the amplifier gain, C read the equivalent capacitance, e is the electron charge[7].

Through the relationship between the natural numbers and the target signal detection circuit noise signal output voltage, photoelectric detection ability of the tracking system can be obtained.

3 Target recognition algorithms for data fusion

Established on the basis of the underwater target recognition, in order to obtain the real target signal, we need to identify and the relevant data reason the underwater target detecting sensor network , and provide a reliable identification for underwater detection system[8]. Assuming that $P(x_1)$ and $P(X_2)$ are two independent underwater sensor evidence emerged of target recognition probability, $P(Ax_1)$ and $P(AX_2)$ is a probability that the evidence of two sensors and associated evidence. Also determined probability of the target, when the given correlation values appear, namely β_i. the conditional probability can be gain by formula (8),(9) and (10).

$$p(A|x_1) = p(A|x_1)/p(x_1) \quad (8)$$

$$p(A|x_2) = p(A|x_2)/p(x_2) \quad (9)$$

$$\beta_i = p(A|x_1)/p(x_1) + p(A|x_2)/p(x_2) \quad (10)$$

According to (9), because of detection sensors with independent probability assignment function and sensors associated independent from each other in multi-sensor photoelectric detection system, β_i can be used as independent judgment evidence, as the basis of D-S evidence reasoning. In this way, the multi-sensor photoelectric detection system can obtain *p*+*q* evidences, *q* is the number of relevance of evidence. Because in assuming that the sensors have independent probability assignment function, and sensors associated independent each other, so the system of *q* associated criterion can be directly through the laws of D-S evidence reasoning synthesis[10]. Although, β_i independent each other, compare with the original sensor output information is not independent, so β_i and the original sensor criterion mi cannot directly synthesis with the laws of the D-S evidence reasoning. At the same time β_i must be alone based on D-S evidence reasoning rule of synthesis.

Suppose, a detection system contains P sensors, the detection probability assignment of each sensor to target is W_i. The sensor P_i and $q(q \le p-1)$ sensors associated. So, when every association evidences appears, it will give support to the sensor P_i of target detection probability assignment[11-12]. Let the ratio of correlation information of real measured relevance and the setting relevance to K_i, at the same time ,setting the impact factor of related information to be λ_i. According to the relevant information, it can give out the revision value of W_i.The modified calculation method of W_i can be expressed by formula (11).

$$W_i' = (1 + \sum_{i=1}^{p-1} \lambda_i K_i) W_i \quad (11)$$

W_i' is the revision value of W_i. When P_i does not correlate with another sensor, $K_i = 0$.

Based on (11), Sensor modified detection probability assignment still meets the application conditions of D-S evidence reasoning method; it can be synthesized by D-S evidence reasoning synthesis method.

4 Multi-sensors signal fusion algorithm

Assume that there are *m* numbers of evidence; for each of the evidence, there is a basic probability assignment function of *M*. *M* is a mapping from *0* to 1, at the same time satisfies the formula (12).

$$\begin{cases} M(\Phi)=0 \\ \sum_{A\subseteq\Theta} M(A)=1 \end{cases}, \quad 0 \le M(A) \le 1 \quad (12)$$

Suppose there are *q*+1 sensors exist two independent associations, according to the formula (12) calculate the threshold value of correlation probability of target assignment, its corresponding basic probability assignment function is $M(A)$, and meet the D-S evidence reasoning conditions.

$$M(A) = M_1(A) \oplus M_2(A) = \sum_{X\cap Y=A} \frac{M_1(X) \times M_2(Y)}{K} \quad (13)$$

In (13), $K = \sum_{X\cap Y\neq\Phi} M_1(X) \times M_2(Y)$, $A \neq \Phi$.

After obtain *M(A)*, system obtained under the two combined evidence reasoning results, at this time as well as the results of the two reasoning according to the conditional probability calculation to merge, it also can continue to according to D-S evidence reasoning to approximate synthesis the combination of evidence reasoning results.

5 Calculation and experiment analysis

5.1 Detection ability calculation and analysis

According to the calculation principle mentioned above, we chose the optical lens focus is 85-125mm in the design of photoelectric detection system, and the conversion response rate of the photoelectric detector is $(3 \sim 4.5) \times 10^{-6} us$. Based on the SNR’s formula of photoelectric detection system, the detection signal-to-noise ratio change curve of the photoelectric detection system in different sky background luminance can be obtained under the condition of the changeless solar altitude angle in the sky-screen detection area, when the target luminance is 5 star magnitudes and 6 star magnitudes. The figure 2 shows the change curves SNR versus sky background luminance.

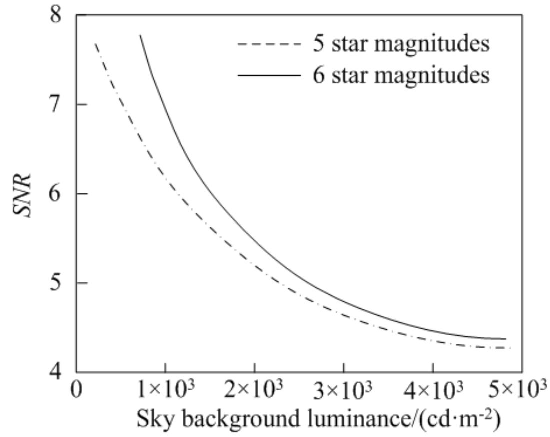

Figure 2. The varied curve of *SNR* under different sky background luminance

It is known from figure 2 that the SNR decreases with the increases of the sky background luminance, when the photoelectric tracking optical detection system design parameters are changeless. The *SNR* is less than 5.6 when the sky background luminance is greater than $2.0\times10^{3} cd/m^{2}$, which is lower than the photoelectric detection system steady working requirement. It means photoelectric detector output saturation and the photoelectric detection system cannot detect and recognize the target information; when the sky background luminance is greater than $2.0\times10^{3} cd/m^{2}$, it will results in abnormal working of the photoelectric detection system.

To improve the detection sensitivity of the photoelectric detection system in the strong background illumination effectively, the sky background luminance should be $(0.5\text{-}2.0)\times10^{3} cd/m^{2}$, it is conducive to the improvement detection performance of the photoelectric detection system, and the dynamic information capture rate of space target is very high.

Figure 3 shows the different caliber targets detection capability curve in different background illumination. From figure 3, we know if photoelectric detection system detects the same caliber target, with the increase of the background luminance, the SNR reduces and the detection ability also decreases, and it illustrates that this condition is not conducive to detect targets. When the target caliber increases, the photoelectric detection system detection ability improves, which is mainly reflected in that the detection area of the space target increases, then the light energy obtained by the electro photonic detector increases.

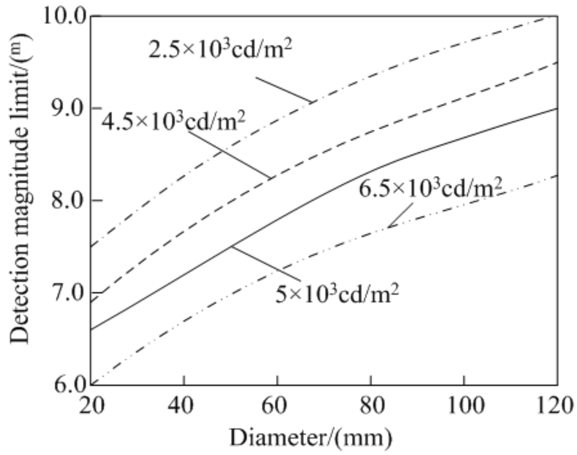

Figure 3. The varied curve of detection magnitude limit and different diameter at different background luminance

5.2 The experimental analysis on data fusion recognition processing

Based on D-S evidence reasoning, if a framework for target recognition is $Q=\{n_1, n_2, n_3\}$, the detection system uses four kinds of sensors to design photoelectric detection system, we calculate and analyzed their measure data by different multi-sensors detection system. The basic probability assignment function corresponding to a sampling period is shown in Table 1, which represents the basic probability assignment function of uncertain proposition. There is a correlation between the two groups of sensors corresponding. $y_1 \sim y_4$ are four sensors target recognition probability under Q.

Table 1. The basic probability assignment value of four kinds sensors

Target recognition probability	n_1	n_2	n_3	Q
y_1	0.21	0.26	0.28	0.191
y_2	0.25	0.27	0.15	0.302
y_3	0.17	0.31	0.22	0.385
y_4	0.24	0.18	0.34	0.351

Table 2 is target judgment probability under the calculation of a given correlation value. In table 2 , σ_{12} represent sensor 1 and sensor 2 correlation degree, σ_{34} represent sensor 3 and sensor 4 correlation degree. Based on table 1 and table 2, we assemble y_1, y_2 y_3 and y_4,and obtain the correlation value. Without considering the correlation information y_1, y_2 y_3 and y_4, the four kinds of evidence synthesis probability can be calculated, the result can be shown in table 3.

Table 2. Target judgment probability under the calculation of a given correlation value

correlation degree	n_1	n_2	n_3
σ_{12}	0.221	0.035	0.047
σ_{34}	0.023	0.031	0.029

Table 3. Four kinds of evidence synthesis probability

evidence synthesis probability	n_1	n_2	n_3	Q
κ_{12}	0.31	0.36	0.27	0.154
κ_{123}	0.24	0.32	0.21	0.143
κ_{1234}	0.38	0.32	0.36	0.122

In table 3, κ_{12} and κ_{1234} is target recognition probability on the sensor 1 respectively with other sensors' evidence synthesis. Such as, κ_{12} is sensors 1 and sensor 2 synthesis recognition probability. κ_{123} is sensor 3 and κ_{12} synthesis recognition probability under certain condition, κ_{1234} is sensor 4 and κ_{123} synthesis recognition probability under certain condition. Through calculation and analysis, we can calculate target determine probability β_i under the condition of a given relational values, table 4 is the value of target determine probability.

Table 4. Target determine probability β_1 and β_2

target determine probability	n_1	n_2	n_3	Q
β_1	0.26	0.27	0.26	0.158
β_2	0.33	0.29	0.38	0.131

We combine β_1 and β_2 by using D-S evidence reasoning method, and get the probability distribution of four sensors after combining, Table 5 is total recognition rate.

Table 5. Total recognition rate of four target fusion

total recognition rate	n_1	n_2	n_3	Q
P	0.44	0.40	0.26	0.128

Through the comparison and analysis, D-S evidence reasoning method can improve recognition rate. Strong correlation original goal was to improve the probability of detection, conversely, if target signal are not correlation, the target detection recognition rate will weaken.

From the whole experiment process, the D-S evidence reasoning method that based on the data association has two cores. First, it is how to get the correlation information from multi-source sensor data. Second, it is how to make full use of the correlation information, to form a correct judgment for the target. The method mainly is use the application of the correlation function to get the target detection probability and the correlation information. And this method solves the problem of the extraction and application for the correlation information in multi-targets recognition. At the same time, the method effectively combines the D-S evidence reasoning method, and greatly improves the overall detection performance of detection system.

6. Conclusions

According to the principle of photoelectric detection system, this paper set up target optical property model in photoelectric detection area, analyze the influence factor of detection system, give the calculation and deduction, the result shows when the sky background luminance is greater, the detection performance is attenuated, so, We must use reasonable extinction technology to weaken strong background luminance influence. In addition, these papers set up the D-S data fusion reasoning model, and give calculation and analysis; D-S data fusion reasoning can effectively improve the recognition rate of photoelectric detection system. Through experiment and calculation, after the introduction of correlation information through the appropriate approach, multi-source sensor detection system of target recognition accuracy than traditional D-S evidence reasoning method had obvious increase, at the same time, the uncertainty of the system is also greatly reduced.

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References

1. Wan min, Su Yi, Yang Rui (2003) Improvement of signal to noise ratiao in astronomical objects detection in daytime. *High power laser and particle beams*, 15(12), p.p.1151-1154.
2. Hanshan Li (2014) Research on photoelectronics properties of array emitting diode and its light energy distribution in detection screen, *Optik*, 125(3), p.p.1096-1100.
3. Lanterman A D, Sullivan J A O, Miller M I. (1999) Kullback-leibler distances for quantifying clutter and models. *Optical engineering*, 38(2), p.p.2134-2146.
4. Hanshan Li (2015) Limited magnitude calculation method and optics detection performance in a photoelectric tracking system. *Applied Optics*, 54(7),p.p.1612-1617.
5. K. Sirlantzis, S. Hoque, M. C. Fairhurst (2008) Diversity in multiple classifier ensembles based on binary feature quantisation with application to face recognition, *Applied Soft Computing*, 8(1), p.p.437-445.
6. Hanshan Li, Zhiyong Lei (2013) Calculation Research on Infrared Radiation Characteristic on Flying Projectile in Sky-Screen. *IEEE sensors journal*, 13(5), p.p.1959-1964.
7. Zhou Bingyu, Lu Ye, Li Zhuang, Wu Haining (2007) D-S Evidence theory method in the application of target recognition. *Photoelectric technology application*, 22(5), p.p.67-70.
8. Liu Tongming (1999) Fuzzy reasoning based on evidence theory of multi-sensor information fusion target recognition in the sea. *Pattern recognition and artificial intelligence*, 2(1), p.p.25-31.
9. Hanshan Li (2014) Research on a new photoelectric detection method to anti-muzzle's flame or light disturbance and projectile's information recognition in photoelectric detection target. *Optoelectronics and advanced materials-rapid communications*, 8(7-8), p.p.653-658.
10. Liao Chongda, Gao Guiming (2008) D-S Evidence theory in the application of radar target recognition. *Radar and against*, 3(3), p.p.32-34.
11. Han Zhenyu, Shen Xujuan, Shi Zhanglin (1999) The multi resolution signal analysis and its application in noise elimination. *Journal of Sichuan Union University*, 3(1), p.p.52-58.
12. Fu Yanjun, Sun Kaifeng, Shi Chao (2008) D-S Evidence theory and its application in target recognition. *Air force engineering university journal*, 9(4), p.p.50-52.