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Simulation Research on Marine Image Recognition Based on Bionic Infrared Compound Eye Vision Perception

Mingshuai Wang, Mingjie Zhong, He Wu, Wentao Cheng

School of Marine Engineering, Jimei University, Xiamen, Fujian, 361000

Keywords: Imitating infrared compound eye system, compound eye structure, infrared image recognition

Abstract: Ship navigation requires strict maritime image recognition, and maritime image recognition is extremely important for ship safety. Traditional monitoring equipment is limited by different factors such as geographic environment, weather conditions, and real-time. Traditional single-aperture optical systems for ships have unsatisfactory performance in the field of identifying targets and detection at sea, and are affected by factors such as maritime radiation and foggy weather. It is becoming more and more difficult to achieve clear image recognition, which poses a challenge to current maritime image recognition. This paper studies the use of a bionic infrared compound eye system to identify maritime images, imitating the fly's compound eye structure to design an infrared optical system. Then the optical design software Zemax is used to simulate and analyze the optical structure of the infrared compound eye, and its field of view, focal length, resolution and other parameters are compared through the simulation analysis. Ensuring the quality of maritime image recognition during ship navigation is an important reference for the promotion and application of infrared systems on ships. Finally, use matlab to simulate the infrared image to improve the integrity of the bionic infrared compound eye system for image recognition.

1. Introduction

When a ship is sailing, the surrounding environment is also a considerable challenge for the ship to use visual perception for image recognition at sea. Especially in foggy weather or dark night, it is of great significance for ships on the ocean to be able to detect and identify them in a timely and accurate manner.

Literature [1] used the features of accurate fly-eye positioning to create a model and took up to 1,320 photos clearly at the same time. Hu Xuelei et al [2] proposed a large field of view curved bionic compound eye optical system designed by using the spaced circumferential layered microlens array arrangement, and used an imaging scheme that combines a revolving system and a microlens array, the problem of mismatch between the curved surface imaging of the microlens array and the flat detector is solved. Guo Ping [3] and others proposed that the ant colony algorithm is applied to the maritime image recognition system. Its advantage is that it can search globally and intelligently, at the same time, it has good adaptive feedback ability and excellent robustness characteristics.

Ships in navigation often encounter the influence of factors such as heavy fog, dark night, cloudy and rainy weather, and obstacles. This article based on the image target recognition of the infrared optical system, just solves these problems. The bionic infrared compound eye system designed in combination with the principle of bionic compound eye can more accurately recognize the target image.

2. Analysis of the structure of bionic infrared compound eye

2.1 Insect compound eye structure

The structure of insect compound eyes is usually studied by paraffin sectioning and transmission electron microscopy. This paper collects several common insects and performs partial shearing. The relevant parameters are obtained by simulating the structure of the compound eye. Comparing the partial images, we can find that the compound eye structure is evenly arranged on the curved surface with each sub-eye. The structure under the microscope is shown in Figure 1.

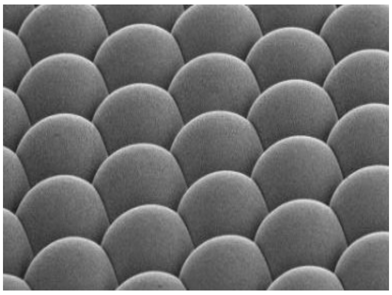


Figure 1: Microscopic partial view of insect compound eyes

It can be seen that the compound eye structure of an insect is composed of many sub-eyes. After comparison, it can be concluded that the arrangement of the compound eye sub-eyes of different insects is roughly the same. This article analyzes the special structure of insect compound eyes, and simplifies the structure of its compound eyes, and analyzes the field of view of its sub-eyes and compound eyes. The simplified compound eye model is shown in Figures 2 and 3.

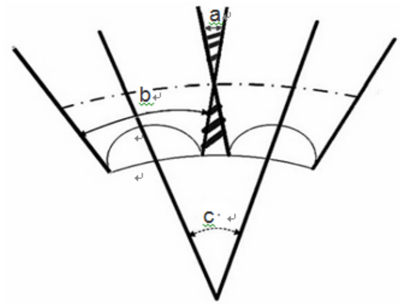


Figure 2: Simplified analysis diagram of compound eye

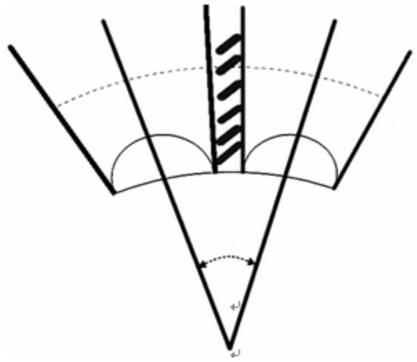


Figure 3: Simplified analysis diagram of compound eye when a=0

The analysis results are as follows:

As shown in Figures 2 and 3, let a be the angle formed by the edges of adjacent sub-eyes in the compound eye, and b represents the field angle of the compound eye's sub-eyes, c is the angle between the optical axes of adjacent sub-eyes of the compound eye, where b and c should satisfy a certain relationship.

Since each sub-eye in the simplified model of the bionic compound eye has the same field of view b, it can be clearly seen: $a=b-c$. First, when $a=0$, that is, $b=c$, as shown in Figure 3, adjacent sub-eyes on the bionic compound eye will have a certain imaging blind zone at the edge of the sub-eye field of view; Secondly, when $a=c$, that is, $b=2c$, as shown in Figure 2, the edge of the field of view of the bionic compound eye is exactly parallel to the optical axis between adjacent sub-eyes, at this time, the adjacent sub-eyes on the bionic compound eye will just cover the blind area above the object plane (dotted line) completely; Above the object plane in Figure 2, there will be an overlap between the adjacent sub-eyes of the bionic compound eye, that is, the shaded part above the object plane in Figure 2, and the overlap angle is a. At this time, in order to ensure that the overlapped part is not too large and lose the advantages of the large field of view of the bionic compound eye optical structure, and the images outside the edge of the field of view of each sub-eye of the bionic compound eye are seriously lost, it is generally required for optical design to $c<b<2c$.

2.2 Analysis of Infrared Optical Structure Parameters of Bionic Compound Eye

2.2.1 Calculation and Analysis of Optical Parameters of Bionic Infrared Compound Eye

As shown in Figure 4, after arranging the eyes of the bionic compound eyes according to the simplified model, the distance between the edges of adjacent compound eyes is q.

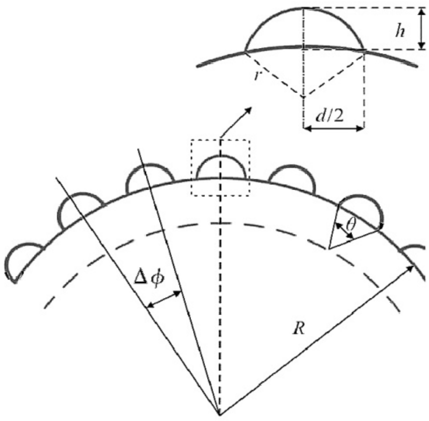


Figure 4: Bionic infrared compound eye structure diagram

Then there is a geometric relationship between the eyes of adjacent bionic infrared compound eyes:

$$tan\Delta\phi = \frac{\mathrm{d+q}}{R} \tag{1}$$

Where: $\Delta\phi$ is the angle between two adjacent bionic compound eyes; *d* is the aperture of the bionic compound eye; *q* is the straight line distance between the edges of the adjacent bionic infrared compound eyes; *R* is the radius of curvature of the bionic infrared compound eye.

According to the geometric relationship of the eye of the bionic infrared compound eye in Figure 4, we get:

$$(\mathrm{r-h})^2 - \mathrm{r}^2 = (\frac{d}{2})^2 \tag{2}$$

For the sub-eye of the bionic infrared compound eye, according to the optical principle, the focal length formula of the sub-eye is:

$$\frac{1}{f} = \frac{(n-1)^2 h}{nrR} + (n-1)\left(\frac{1}{r} - \frac{1}{R}\right) \tag{3}$$

Where: *f* is the focal length of the sub-eye of the bionic infrared compound eye; *r* is the radius of curvature of the sub-eye of the bionic infrared compound eye; *h* is the thickness from the center of the bionic infrared compound eye to the surface of the compound eye.

The number of sub-eyes arranged unidirectionally on the surface of the bionic infrared compound eye is *N*, the aperture *d* of each compound eye and the number of photosensitivity *v* corresponding to each compound eye. So for the bionic infrared compound eye structure with *M* pixels and pixel width *L*, the equation should be satisfied:

$$M = Nv \tag{4}$$

$$L = \frac{d+q}{\mathrm{v}} \tag{5}$$

The field of view ω of the bionic infrared compound eye structure is:

$$\omega = 2(\alpha\Delta\phi + \theta) \tag{6}$$

In the formula: ω represents the field of view of the bionic infrared compound eye structure; θ is the field of view of the released infrared compound eye; α refers to the number of circumferences of the bionic infrared compound eye structure distributed on the surface of the bionic infrared compound eye according to the circumference of the insect compound eye structure except for the center sub-eye.

In this paper, the field of view of the bionic infrared compound eye structure is set to 150°, and the distance between the edges of the compound eye is q=0.5 mm. According to formula 1, it can be calculated: d=2.0 mm.

In order to better match the infrared image recognition system, this paper selects the material of the bionic infrared compound eye lens H-K7, its refractive index n=1.507, and the focal length of the bionic infrared compound eye lens f=4.3mm. It can be solved according to formulas 2 and 3: $h\approx0.25$ mm, $r\approx2.1$ mm.

According to the data selected in this article, combined with formulas 4 and 5, the number of unidirectionally arranged bionic infrared compound eye sub-eyes is 9, and each bionic infrared compound eye sub-eye contains 270×270 pixels, the total number of eyes in the bionic infrared compound eye is 81.

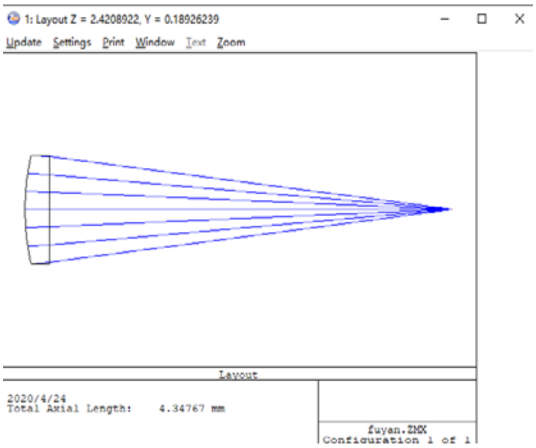
In the designed bionic infrared compound eye structure, a=4. According to the relationship between the angle $\Delta\phi$ between the center optical axis of the bionic infrared compound eye and the field angle θ of the child eye, formula 6 can be obtained: $\Delta\phi$ is 14°, θ is 20°, The field angle setting $\omega=2\times(14\times4+20)=152°>150°$ of the above-mentioned design of the bionic infrared compound eye structure is satisfied.

2.2.2 Bionic infrared compound eye eye simulation and optimization

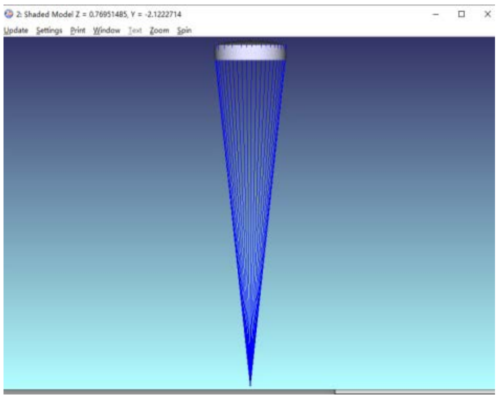
Using the initial structure parameters of the sub-eyes of the bionic infrared compound eye structure calculated by the above parameters, input the initial parameters of the sub-eye structure of the bionic infrared compound eye into the ZEMAX optical simulation software for simulation analysis, 2D and 3D images of ray tracing and spot patterns can be obtained.

By observing the ray tracing 2D and 3D images of the initial structure of the bionic infrared compound eye, as well as the dot pattern and other graphics, the possible aberrations in the 0° field of view are analyzed. Analyzing the spot pattern, it is found that the concentric beams emitted from the points on the axis cannot converge at the same point after passing through the lens; the rays at different angles from the optical axis passing through the lens have different degrees of deviation from the ideal image point; The dot pattern is distributed in a circular ring with a root mean square radius of 1.804μm. It is known that there is a certain spherical aberration phenomenon in the system. The even sub-aspheric surface and spherical aberration correction function are used to correct the eyeball aberration of the bionic infrared compound eye, and the sub-eye structure parameters obtained after simulation analysis.

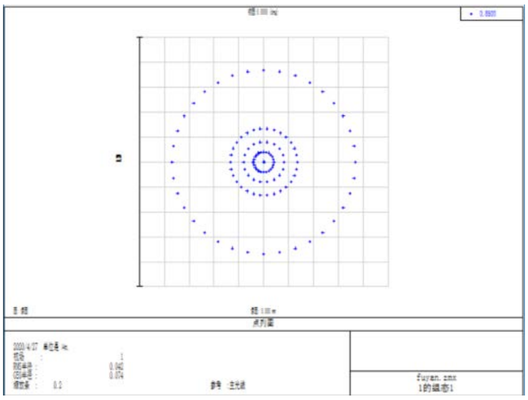
After analysis and optimization, the obtained 2D and 3D ray tracing images of the bionic infrared compound eye and the dot pattern are shown in Figure 5.



a. Optimized sub-eye ray tracing 2D image



b. Optimized sub-eye ray tracing 3D image



c. Optimized sub-eyepoint pattern

Figure 5: The simulation diagram of the optimized bionic infrared compound eye

After optimization, the spherical aberration correction effect of the bionic infrared compound eye is very obvious, and the root mean square radius obtained is 0.042μm, which is smaller than the size of a single pixel (1.12μm). At this time, it can meet the matching requirements of the optical system and the detector, that is, the optimal design parameters. The two parameter comparisons are shown in Table 1.

Table 1: Comparison table of initial setting parameters and optimization

	Initial calculation parameters	Simulation optimization parameters
Material	H-K7	H-K7
Surface type	Standard surface	Even aspherical surface
Radius of curvature	2.10	2.07
Thickness	0.25	0.25
Half diameter	0.5	0.5
Cone coefficient	0	-0.262
Root mean square radius of dot plot	1.804	0.024

3. Marine infrared image recognition simulation

3.1 Infrared image preprocessing

The preprocessing of infrared images includes infrared image segmentation, infrared image enhancement, infrared image filtering and noise suppression. The preprocessing of the infrared image not only improves the relevant data of the image, but also suppresses irrelevant features, and can further improve the accuracy of infrared image recognition. Since the use of matlab for image feature learning also needs to be segmented, this article only performs sharpening enhancement and noise suppression processing for the preprocessing of infrared images.

3.1.1 Infrared image sharpening enhancement

First, sharpen and enhance the collected maritime infrared image, which can make the recognition target more prominent. As shown in Figure 6.

(a) Initial infrared image (b) Infrared image after enhancement

Figure 6: Infrared image enhancement map

After the infrared image is sharpened and enhanced, the feature resolution of the enhanced infrared image is enhanced.

3.1.2 Infrared image noise processing

Although the optical system with the bionic infrared compound eye structure can obtain infrared images with less noise, a certain amount of noise will also cause errors in the recognition of infrared images, so the infrared image is processed for noise reduction. The processed image is shown in Figure 7.

(a) Infrared image after enhancement (b) Infrared image after noise reduction

Figure 7: Infrared image noise reduction map

After the enhanced infrared image is processed for noise reduction, the infrared image with obvious characteristics of the sea image can be obtained, which is more conducive to the recognition of the image in the next step.

3.2 Infrared image recognition simulation

3.2.1 Infrared image segmentation and classification

As shown in Figure 8, using Matlab's built-in APP: OCR Trainer, the image is automatically cut or manually framed and cut and classified. In this step, the relevant pictures are saved in multiple copies. The advantage is that the image features can be extracted more accurately, making the recognition system more efficient and more accurate.

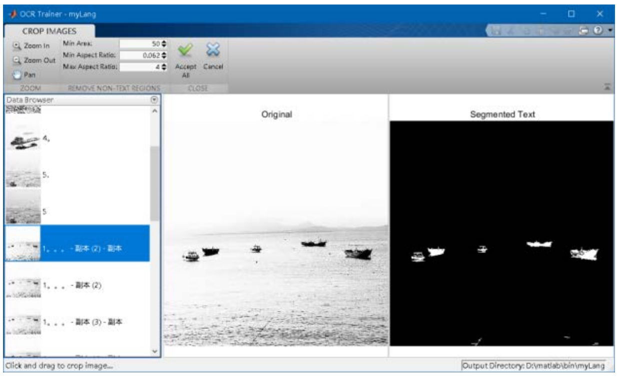


Figure 8: Infrared image segmentation

3.2.2 Infrared image recognition simulation

Using the algorithm obtained by OCR Trainer in MATLAB to simulate and simulate, you can get as shown in Figure 9.

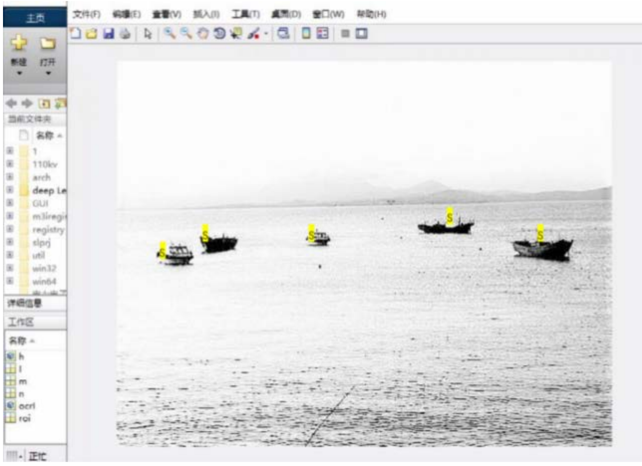


Figure 9: Matlab simulation diagram

In this paper, the marine image recognition of the ship sailing scene uses the simulation MATLAB to simulate, the infrared image is preprocessed and then the image is further cut and classified by OCR Trainer, a series of feature maps are obtained, and the required algorithm for image recognition is obtained through training. The results show that the algorithm can identify well.

4. Conclusion

This article mainly draws three conclusions as follows:

1) The even-order aspheric surface and spherical aberration correction function are used to correct the spherical aberration of the bionic infrared compound eye. After optimization, the spherical aberration correction effect of the bionic infrared compound eye is very obvious, and the root mean square radius is 0.042μm.

2) The distance between the position of the sub-eyes of the compound eye structure on the lens with large curvature needs to be adjusted appropriately by calculation to prevent the overlapping of the sub-eyes' field of view from causing unnecessary waste, and it is more concise and beautiful.

3) There are not just two or three factors that affect the navigational obstacles encountered by the ship during navigation and the precise identification of the maritime identification system. Considering that the ship needs to sail for a long time and the route is uncertain, it needs to be comprehensively considered based on experience and actual conditions.

References

[1] Di Si, Xu Hongkui, Du Ruxu.The new development of artificial compound eye imaging system [J]. Optics and Optoelectronics, 2008 (4).

[2] Hu Xuelei, Gao Ming, Chen Yang. Design of Bionic Compound Eye Optical System with Large Field of View [J]. Infrared and Laser Engineering, 2020 (1).

[3] Guo Ping. The application of ant colony algorithm in sea surface image recognition system [J]. Ship Science and Technology, 2015, (4).