Sensor Modeling Realization Based on Fruit Fly Optimization Algorithm

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Abstract: The structural parameter optimization model of binocular stereo vision sensor was first built using the optimum regression design to improve its measurement precision in this study. Then, the optimization model was solved by Fruit Fly Optimization Algorithm (FOA). The measurement precision of binocular stereo visual sensor has been greatly improved through FOA optimization. Thus, it can obtain better results than traditional methods.

Keywords: Binocular stereo visual sensor, Fruit fly algorithm, Optimum regression design, Population size, Iterative times.

1. Introduction

Visual sensor has been more widely used with the continuous development of computer vision technology. Stereo visual sensor especially has many advantages such as intuitive principle, simple structure, and easy use, high measurement precision and high speed. Thus, it has been extensively used in industrial inspection, target identification, work piece positioning, robot guidance and other fields [1].

Binocular stereo visual sensor is usually composed of two cameras located in the same plane with certain angle between them. Moreover, their structural parameters have a direct effect on measurement precision. The structure building of most binocular stereo visual sensors selects structural parameters on the basis of people's experience, and there are few theoretical bases [2].

The structure-parameter optimization model of binocular stereo visual sensor was first built using optimal regression design in this study to improve such sensor measurement precision. Then, the optimization model was solved by FOA to improve the measurement precision of binocular stereo visual sensor.

2. Parameters of Binocular Stereo Visual Sensor

Binocular stereo visual sensor is composed of two CCD cameras, shown in Fig. 1. The two cameras were horizontally placed across each other. The o and o' are the perspective centers of two cameras, respectively, and the origin of coordinates was set as o. The projection of spatial point p (x, y, z) was p' in the plane xoz. The image coordinates of left and right cameras were O1X1Y1 and O2X2Y2, respectively. Line through the center O1 of left image plane and the lens center o was the optical axis O1o of camera on the left side. Line through the center O2 of right image...
plane and the lens center o' was the optical axis O₂₀' of camera on the right side. The angles between optical axes of two cameras and baseline were α₀ and β₀, respectively. The connecting line oo' of two cameras lens centers was the baseline, and baseline distance was recorded as B. The focal lengths of cameras are f₁ and were f₂, respectively, and the vertical distance between measured object to baseline was H [3].

Fig.1. Structure of binocular stereo visual sensor.

The structural parameters of binocular visual sensor included following s according to the above analysis: They are angles between two camera optical axes and baseline, baseline distance, effective focal lengths of cameras and vertical distance between measured object and baseline. Moreover, they are not independent variables, but there is a certain constraint among them [4]. Two cameras are symmetrically placed in this study, and the angles of optical axes of two cameras and the baseline are the same, i.e. α₀=β₀=α. The focal lengths of two cameras are fixed values, and there is f₁=f₂=25 mm. Therefore, parameters needing optimization are: the angles between camera optical axes and baseline, baseline distance and vertical distance from measured object to baseline.

3. Optimum Regression Design Model

The structure analysis on binocular stereo vision sensor shows that three parameters need optimization, so 311-A scheme in the optimum regression design was used for the experiment. The different assigned values of three factors (i.e. parameters x₁, x₂ and x₃) divided into 11 groups to form 11 experiments in the scheme. The assigned values of the three parameters were determined using coded values in each experiment [5-8]. The coded values of optimum regression design: 311-A program are shown Table 1.

Linear coding substitution was performed in accordance with the coded values of three factors x₁, x₂ and x₃ for experimental parameter values. Moreover, the regression relationship of dependent variable y to independent variables was transformed into the coded value relationship of y to x₁, x₂ and x₃. Thus, the regression equation of y with x₁, x₂ and x₃ [9-13] was established:

\[ y = b_0 + \sum_{j=1}^{3} b_j x_j + \sum_{i<j} b_{ij} x_i x_j + \sum_{j=1}^{3} b_{jj} x_j^2 \]  

where b₀ is the constant term; b_j is the regression coefficient of one degree term; b_ij is the regression coefficient of interaction term; b_jj is the regression coefficient of quadratic term.

Table 1. Coded values of optimum design.

<table>
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<th>No.</th>
<th>Factor</th>
<th>1</th>
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<th>3</th>
<th>4</th>
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<th>6</th>
<th>7</th>
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<th>9</th>
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<td></td>
<td>X₂</td>
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<td></td>
<td>X₃</td>
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<td>1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>-1</td>
<td>0</td>
</tr>
</tbody>
</table>

4. Parameter Model Building of Binocular Stereo Visual Sensor

Angle α between camera optical axis and baseline, baseline distance B and distance H from measured object to baseline were taken as experimental factors in this study. The height measuring value of gauge block with a height of 9 mm was taken as experimental index. The assigned value range of each parameter was determined according to the used binocular stereo visual sensor as follows: B: 34~46 cm; H: 28.5~34.5 cm; α: 56°~60°.

The value of B was denoted by x₁, H value was denoted by x₂, α value was denoted by x₃. The regression equation between the measuring height of gauge block and the structural parameters of sensor was established according to the experimental design data in literature [14]:

\[ y = 8.607 + 0.121 x₁ + 0.007 x₂ + 0.036 x₃ - 0.106 x₁^2 - 0.218 x₂^2 + 0.004 x₁ x₂ - 0.039 x₁ x₃ - 0.059 x₂ x₃ + 0.058 x₁ x₂ x₃ \]  

Data in Table 1 were substituted into the regression equation to make regression effect
verification after was created, and $X^2 < X^2_{0.05}(10)$ was obtained. Therefore, the regression effect of created regression equation is remarkable, which means that the regression equation can reflect variation between B, H, α and y.

5. Structure Parameter Optimization of FOA Binocular Sensor

5.1. FOA Overview

FOA is a new, evolutionary computation method proposed by Taiwan's young teachers: Pan Wenchao in 2011 [11]. The olfactory and visual superiority of fruit fly is shown in Fig. 2. Fruit fly uses its own keen vision to find food and companions' gathered position and finally fly towards food position after searching food sources in the air. Therefore, this method considers that fruit fly first searches the approximate location of food by olfactory and then determines the correct position of the food by vision. The method is a new, global optimization method deduced on the basis of the foraging behavior of fruit fly.

5.2. FOA Steps

FOA can be divided into seven steps, and the concrete steps are as follows:

1) Fig. 1 shows the location initialization of fruit fly populations, and the result is Init X-axis; Init Y-axis;

2) The random search distance of drosophila individual can be obtained by the following formula after the search direction $RV_x$ and $RV_y$ are set:

$$
Xi = Init X \text{ axis} + RV_x
$$

$$
Yi = Init Y \text{ axis} + RV_y
$$

3) The position of food is unknown. Therefore, it is necessary to estimate the distance $Disti$ between the current position of drosophila individual and origin and then calculate flavor concentration determination value $Si$. Moreover, the determination value of taste concentration is equal to the reciprocal of the distance.

$$
Disti = \sqrt{Xi^2 + Yi^2}
$$

$$
Si = \frac{1}{Disti}
$$

4) Taste-concentration determination value is substituted into taste-concentration determination function to calculate the current position taste concentration of this drosophila individual.

$$
Smelli = Function(Si)
$$

5) The best taste concentration of fruit fly population can be obtained by the following formula:

$$
[bestSmell, bestIndex] = \max(Smelli)
$$

6) The best taste concentration value in drosophila population and the x-coordinate and y-coordinate corresponding to concentration are retained. Moreover, drosophila population locates food source through their own vision and then fly to the location of the food source.

$$
Smellbest = bestSmell
$$

$$
X_{\text{axis}} = X(bestIndex)
$$

$$
Y_{\text{axis}} = Y(bestIndex)
$$

7) Iterative optimization begins. Iterative steps (2)-(5) are repeated, and whether taste concentration is better than the previous iterative taste concentration is determined. If it is right, then step (6) is performed.

5.3. Establishing Structural Parameter Optimization Model

The smaller the difference between measured value and true value is in the measurement, the higher the measurement precision is. Therefore, the function was established with the difference square of measuring height value $y$ and actual height value $h$ ($h=9\text{ mm}$) of gauge block as objective. The following optimization model was established with the assigned value ranges of three parameters as constraints:

$$
\text{min } Z = (y-h)^2 = \text{min } 8.607 + 0.121x_1 + 0.007x_2 + 0.004x_3^2 + 0.039x_4 - 0.059x_5 + 0.058x_6 - 9
$$
5.4. Optimization Based on FOA

FOA optimization procedure was compiled using Matlab software. The corresponding parameters were set: population size was 20, and the number of iteration was 1000. The optimal results were obtained by simulation. \( x_1=0.0665, x_2=0.2876, x_3=0.9917 \), and the convergence picture of solved results is shown in Fig. 3.

The structure parameters of visual sensor were adjusted according to the combinations of parameter values optimized by fruit fly algorithm, and verification experiment was done. The measured height value of gauge block was 8.901, and the measurement precision is greatly improved compared to that in the reference [14].

6. Conclusion

The structural optimization model of binocular stereo visual sensor was first built using the optimum regression design to improve the measurement precision of this visual sensor. Then, the structural optimization model was optimized using FOA to obtain the optimal solution. The measurement precision of binocular stereo visual sensor has been greatly improved through FOA optimization.

References


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(http://www.sensorsportal.com)