Research on Three-dimensional Modeling Method of High Speed Flying Object Based on Image

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Abstract. Aiming at the three-dimensional modeling problem of dynamic objects, a fast modeling method of three-dimensional model of high speed flying object based on image was proposed. Firstly, using high-resolution CCD camera to obtain multiple images of flying object, and the image was processed by OpenCV to obtain the data information of the key point of the flying object. Secondly, create three-dimensional graphics by calling the Open Flight API library function and write the FLT file to generate the three-dimensional contour of the flying object. Finally, the model was refined to realize the three-dimensional reconstruction of the high-speed flying object. Through the comparison of examples, the proposed method can quickly and efficiently realize the reconstruction of three-dimensional model of high-speed flying object.

Introduction

Image-based modeling is a research hotspot in the field of computer graphics and computer vision. It studies how to use a variety of clue information in a single image, image sequence or video to restore a three-dimensional model of an object or scene. The technology has a wide application prospect in the field of intelligent human-computer interaction, digital special effects production, real-time monitoring and so on.

There are three general modeling methods for 3D reconstruction: three-dimensional models are constructed using modeling software (Auto CAD, 3dsMax, Maya, Creator, etc.); The use of three-dimensional scanning equipment (such as laser scanners, depth scanners, etc.) to scan the real object, directly to get the information of the object point to reconstruct the model; The model is reconstructed by two or more images of the real object taken by the camera and the digital camera from each angle of view[1]. In [2], a three-dimensional reconstruction based on digital camera images was proposed, which can complete non-contact measurement of objects, simplify the complexity of the solution; In [3], the three-dimensional modeling method based on multiple depth images was proposed. Reference [4] proposed a new algorithm for three-dimensional reconstruction of scene images with two orthogonal constraints, the method did not need to pre-calibrate the parameters of the camera to achieve the restoration of three-dimensional structure from the two scene images of artificial rules; Reference [5] proposed a rapid modeling method of three-dimensional model which based on mobile laser scanning point cloud data and remote sensing image, using multi-source data to realize three-dimensional modeling of buildings and improving the efficiency of
modeling; Reference [6] designed and realized the three-dimensional reconstruction system of striped structured light, using pixel index value as a medium for triangle network processing of the point cloud so as to achieve three-dimensional reconstruction of the model. In the conventional method, the time of computer CPU is too long and cannot meet the current requirements of development. The research on the automatic modeling technology of surface data information based on high speed flying object is still in the theoretical exploration stage.

In the present study, this paper presents an automatic modeling method of high-speed flying object based on image, according to image information extracted by CCD camera, calling the Open Flight API function, completing segmentation and automatic modeling of the image information of the flying object surface, requiring a three-dimensional model of the flying object. The method can reduce the running time of the computer, which provides a engineering reference for automatic modeling technology of surface information of the high speed flying object in the future.

**The Model Structure of Open Flight**

Open Flight is a database defined by Multigen Corporation that is used to fully describe the visual simulation model. Open Flight format is a tree-like hierarchical structure, any of the elements in the scene can be quickly and easily edited, modified and controlled, which is suitable for real-time system to achieve a variety of traversal operations. Figure 1 shows the data structure of Open Flight.

![Figure 1. The Open Flight hierarchical data structure.](image)

The Open Flight API is a C programming language library that contains header files and link libraries that provide an interface to access the Open Flight database and the Creator model system. API can be used for the conversion of Open Flight model, real-time simulation, automatic modeling, and the expansion of the Creator function in the form of plug-ins.

Using the Open Flight API can quickly and easily complete the operation of the flt model database files, from the construction of the three-dimensional model to the model color, material, texture, and lighting settings, all of these can be achieved by operating a variety of related records set provided by the database. Compared with the traditional language of three-dimensional graphics drawing, the construction technology of three-dimensional model based on Open Flight API makes users do not need too much about the underlying hardware and computer graphics based on basic knowledge, which is convenient to construct 3D models in their applications.
The Acquisition and Processing of Image

The Acquisition of Image

The flying speed of the high-speed flying object is very high, the pitch angle, the yaw angle and the centroid is in the unceasing change, in order to carry out the three-dimensional reconstruction of the high-speed flying object, the image information of the object in different angles at the same time is needed. In this paper, two high-resolution CCD camera orthogonal image system is used to collect images, the structure of the system is shown in Figure 2.

![Figure 2. The system diagram of two camera orthogonal scheme.](image)

Image Processing

**Image Graying.** The collected images of digital ballistic range shadowgraph system are RGB images, in order to extract the contour to the surface of high speed flying object, image graying is needed firstly, that is \( R = G = B = Y \), there are a variety of methods to calculate the value of \( Y \), in OpenCV, cvCvtColor() function uses weighted method to calculate the value of Gray so as to achieve the convert from color image to gray image. The value of the weight coefficient is as follows:

\[
Y = 0.299R + 0.587G + 0.114B
\]  
(1)

Where \( Y \) is the gray value, which ranges from 0 to 255. The gray image is shown in Figure 3.

![Figure 3. The image after graying.](image)

**Binarization Image.** In order to further reduce the amount of computation, choose appropriate threshold value of the gray image to carry out binarization processing, the method is named Threshold. The binarized image can carry out analysis and feature description using geometry concept, which is faster and more convenient than the gray image. There are many methods of image segmentation, in view of the large difference
between the gray value of the high-speed flying object and the gray value of the background image, this paper uses threshold segmentation algorithm to achieve image binarization, the principle is assign each pixel of the gray image to the white \((Y=255)\) or black \((Y=0)\) in a specific range, the mathematical model is:

\[
g(x, y) = \begin{cases} 
255 & f(x, y) \geq t \\ 
0 & f(x, y) < t 
\end{cases} 
\]  

(2)

Where \(t\) is the threshold; \(g(x, y)\) is the binarized gray value; \(f(x, y)\) is the gray value before binarization.

The \texttt{cv Threshold} function in OpenCV can achieve the binarization operation for the gray image. Its principle is to compare each element in image array with set threshold to complete related processing, (2) can be achieved through threshold type selection of function, which can be expressed as:

\[
dst_i = (src_i > t) \, ? \, 255 : 0 
\]  

(3)

Where \(dst_i\) is the \(i\)-th pixel value after processing, \(src_i\) is the \(i\)-th pixel value of the original image, and \(t\) is the set threshold. Which is obtained by the function \texttt{cvThreshold}, as shown in Figure 4.

**Surface Outline Feature Extraction of High Speed Flying Body.** Roberts operator, Sobel operator, Prewitt operator, Laplacian operator, LOG operator, Canny operator are commonly used edge detection operators [7]. The Canny operator is used in this paper, because of the high SNR and high positioning accuracy, and can also adjust its parameters according to the specific requirements to identify the different characteristics of the edge, the deviation between the edge obtained and the real edge is very small, less false edge detection, the rate of failure detection is small. The implementation process of the algorithm is: (1) smooth image, suppress noise; (2) calculate the gradient of the image; (3) non-maximum suppression; (4) hysteresis threshold.

Canny edge extraction using \texttt{cv2.Canny()} function in OpenCV, the first threshold is set as 100, the second threshold is set as 200, the size of the Sobel convolution kernel of graphics gradient calculation is set as 3, and the results of edge extraction are shown in Figure 5.
The final information of the image is marked into a two-dimensional array by image processing unit, which can be used to extract the characteristics of the high-speed flying object, and reconstruct the surface profile.

**Three-Dimensional Modeling of High Speed Flying Object**

**Automatic Modeling of High Speed Flying Object Based on Open Flight API**

The prerequisite of high speed flying object modeling is to read the contour information of flying object from the image of high-resolution CCD camera. The data of the projectile and the groove are read. With many line segments, the curve line part in the surface of the flying object is described approximately, and then to calculate the coordinates of the key points according to data information of image composed of geometric size of high speed flying object, ultimately, the complete data that describes the contour surface of flight body is obtained.

The basic model node hierarchy of the high-speed flying object is set in Creator software, to import all the corresponding surface profile data information of the image, in the VC environment, call the Open Flight API library function to create a model for the high-speed flying object surface contour. In this paper, the method of "direct connection and Boolean elimination" is used to generate the outer contour image of the flying object ignoring the groove on the projectile in the process of the formation of the high-speed flying object, the effect is shown in Figure 6 (a). To establish the model of the groove according to the data information of the groove, to call the Boolean tool in Creator, carry out Subtract Boolean operations, so as to achieve modeling of high speed flying object, as shown in Figure 6 (b).

**Model Refinement and Optimization**

The model of high speed flying object built automatically by Open Flight API can only display the outline, cannot fully reflect the loss of high speed flying object during the flight, it needs to be refined by the effective algorithm to generate the three-dimensional model of the realistic graphics. In this paper, an improved tree Z-buffer algorithm is used, making full use of the coherence of the image space and the coherence of the time, a complex scene of tens of thousands of polygons is showed. To reduce the number of scanned polygons in hidden judgment by using tree partition method, the Z Pyramid algorithm is used to reduce the time consuming of the scan.
conversion of octree cube, the model is refined by analyzing the degree of light and shade on the surface of the object to determine its concavity and convexity. The effect of different angles of the model is shown in Figure 7.

![Diagram after model refined](image)

(a) The positive renderings  (b) The side renderings

Figure 7. The diagram after model refined.

The complexity of the model after Z-buffer algorithm processing is much more than that of the graphics system hardware, which seriously affects the real-time rendering speed of scene simulation. In order to ensure the communication speed of system, the objects are usually stored by the level of detail LOD (Level of Detail), generation of LOD model through the normal folding edge two vertex angle control. Different simplification conditions can generate different hierarchical model in detail, as shown in Table 1.

<table>
<thead>
<tr>
<th>Levels of LOD</th>
<th>High</th>
<th>Middle</th>
<th>Low</th>
</tr>
</thead>
<tbody>
<tr>
<td>Count of polygons</td>
<td>3648</td>
<td>1274</td>
<td>416</td>
</tr>
<tr>
<td>Visible range</td>
<td>0-12500</td>
<td>12500-187500</td>
<td>187500-25000</td>
</tr>
<tr>
<td>Three-dimensional model</td>
<td><img src="image" alt="Model" /></td>
<td><img src="image" alt="Model" /></td>
<td><img src="image" alt="Model" /></td>
</tr>
</tbody>
</table>

The model is composed of three different levels model in details. The rougher model is used in the far distance, and the fine model is used when the distance is near.

**The Analysis of Three-dimensional Modeling Results**

Compare the three-dimensional modeling method in this paper with the conventional three-dimensional modeling method; the results are as shown in Figure 8.

![Results of three-dimensional modeling](image)

(a) The proposed method  (b) The conventional method

Figure 8. The results of three-dimensional modeling.

It can be seen that the two modeling methods can both realize the three-dimensional reconstruction of the object, the accuracy of the model after reconstruction is similar, but the method in this paper has the advantages of low cost, fast construction speed,
strong sense of reality, high degree of automation, and is more convenient to be used in
the virtual environment, which has broad application prospects.

Conclusions
This paper proposed a method for automatic modeling of high speed flying object. The
method can use the high-resolution CCD camera to obtain the image of the high-speed
flying object in the course of flight, and carry on a series of processing of the obtained
images, use the image processing algorithm to extract the data information of the
desired contour, the model is automatically constructed by calling Open Flight API
through C++ language, and the model is optimized, not only makes the model more
realistic, but also improve the speed of rendering. At the same time, it is convenient to
build the object model with more complex modeling methods and write the generated
model directly into Vega Prime for real-time simulation.

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References
images [J]. Journal of University of Shanghai for Science and Technology, 2005,
[3] Zhang Qing, Guo Wei. Depth images-based approach for three-dimensional
reconstruction [J]. Journal of Huazhong University of Science and Technology, 2008,
reconstruction using spatial orthogonal constraints [J]. Journal of Xi’an Jiaotong
three-dimensional buildings from mobile laser scanning point clouds and remote
Chinese.
[6] Sun Qingke, He Yuntao, Chen Ruiqiang, Jiang Yuesong. Research of
three-dimensional point cloud reconstruction based on structured light [J]. Application
[7] Dong Hongyan. Research on several techniques of edge detection [D]. Chang Sha: