

Using IDL to Visual Analyse the Point Clouds of the Surface of Crayfish*

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Abstract: The digital measurements of surfaces of the crayfish were carried out by using the LSV 50 laser scanner, a non-touch three-dimensional laser scanner, and point clouds were the scanning digital data of the surface of crayfish. The work described in this paper represents a method for visual analyse the point clouds of the surface of crayfish in IDL (Interactive Data Language), which integrates a powerful, array-oriented language with numerous mathematical analysis and graphical display techniques. IDL provides a high level of flexibility to access, analyse and visualize the data with different methods. Point clouds of the surface of crayfish were imported, reconstructed and feature analysed by using iTools, the IDL Intelligent Tools. Polynomial regression equation of the surface of crayfish in selected cross section was also derived by programming in IDL. Detailed information about the LSV 50 laser scanner were also inverse deduced in iTools. Methods and results presented in this paper prove to be potentially useful for visual analyzing the feature of biological prototype, optimizing the mathematical model and affording deformable physical model to bionic engineering, those works would have great implications to the research of biological coupling theory and technological creation in bionic engineering.

Key words: Visualization; Analyse; Point clouds; Surface; Crayfish; IDL

DOI: 10.3968/j.ans.1715787020110401006

* The authors are grateful for the financial support by the National Natural Science Foundation of China(Grant No.50635030) and the opening foundation of Key Laboratory of Engineering Bionics (Jilin University), Ministry of Education, grant No. K201105)

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‡ Received April 30, 2011; accepted June 1, 2011.

INTRODUCTION

Bionics is a science for studying the structures, characters, elements, behaviour and interactions of biological systems in order to provide new design schemes, working principles and system structures for engineering (REN et al., 2001; Vincent & Mann, 2002; LU, 2004; Yoseph Bar-Cohen, 2006). Results of 個 biological coupling research show that, Soil animals such as earthworm and dung beetle can move efficiently in mud or moist soil without soil sticking to them; the lotus leaf can repel water, remove contaminants and clean its surface (REN et al., 2001; YAN & JI, 2008). Biological functional surfaces of those living things are formed from the synergy of many factors including biological surface morphology, structure in surface layer, and the materials to obtain the best adaptability to the environment. Bionic engineering takes the results of the evolution of living things as references for technological creation, imitates not directly duplicates features and characteristics of living things (QIAN et al., 2009).

Biological prototype, mathematical model and physical model are three inter-related aspects in bionics. Visual reconstruction and feature analysis of the three-dimensional surface of a biological prototype would not only play an important role in building and optimizing the mathematical model of Biological prototype, but also be useful to study the influences of morphology, structure and the materials on the biological function, reveal multifactor coupling law and mechanism, build the deformable physical model and design principle of biological coupling.

In recent years, significant progresses have been made on visual reconstruction and feature analysis of the three-dimensional surface of living things (XU et al., 2008; ZHANG et al., 2008; WU et al., 2006; LI et al., 2010). The reverse engineering technology was adopted to obtain the surface geometrical information of the head of wild boar and tergum of Mole cricket. Software, such as SURFACER, CATIA (Computer Aided Three Dimensional Interactive Application), AutoCAD and MATLAB, have been used to reconstruct and analyse the three-dimensional surface of those living things.

IDL, the Interactive Data Language, is a self-contained computing environment for the interactive analysis and visualization of data. IDL integrates a powerful, array-oriented language with numerous mathematical analysis and graphical display techniques, thus providing a high level of flexibility, and supporting OpenGL-based hardware accelerated graphics (LI, 2007; TANG et al., 2005; Neicu et al., 2005; Marschallinger, 2001; Chatziioannou, 1994). The iTools (IDL Intelligent Tools) are a set of pre-built visualization tools that combine data analysis and visualization with the task of producing presentable quality graphics. Based on the IDL Object Graphics system, the iTools are designed to maximize the utilization efficiency of the data. The iTools allows one continue to benefit from the control of a programming language, while enjoy the convenience of a point-and-click environment.

The crayfish was selected to study the feasible methods in the visual reconstruction and feature analysis of the three-dimensional surface of living things in this paper. The digital measurements of surfaces of the crayfish were carried out using the LSV 50 laser scanner, a non-touch three-dimensional laser scanner. Point clouds, the scanning digital data of the surface of the crayfish, were imported and analyzed in the iTools of IDL. Detailed information about the LSV 50 laser scanner were also inverse deduced by iTools, the IDL Intelligent Tools, Effective method of visual reconstruction and feature analysis to point clouds are expected in this paper.

1. ACQUISITION OF POINT CLOUDS

Digital measurements of the surface of the crayfish were carried out by using the LSV 50 laser scanner, a non-touch three-dimensional laser scanner. Samples of crayfish were set at the scanning platform of this laser scanner, and the body of crayfish were kept paralleled to the lateral moving direction of the two CCD cameras (Fig. 1). The maximum scanning range of length, width and height in this laser scanner was 80 mm × 70 mm × 30 mm, and the scanning precision was 0.05 mm.



Figure 1
Laser Scanner and the Crayfish

For simplicity, only abdomen and tail, the back part of crayfish were scanned and the scanning precision was set in 0.2 mm. Point clouds, the scanning data of the three-dimensional surface of the crayfish were saved as files of ASCII format. Fig. 2 shows the point clouds of the back part of crayfish which was imported and displayed in the Digitized Shape Editor of CATIA. Compare with the digital picture of the back part of crayfish in Fig. 3, point clouds in Fig. 2 shows a good coincidence with real shape of the back part of crayfish. It could be used in the visual reconstruction and feature analysis of the back part of crayfish.

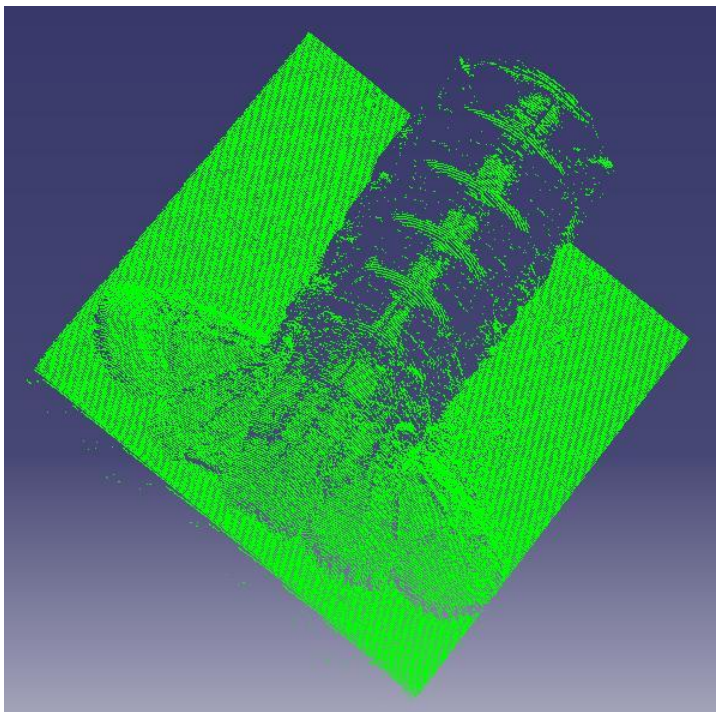


Figure 2
Point Clouds of Back Part of the Crayfish



Figure 3
Back Part of the Crayfish

Point clouds consist of three-dimensional coordinate values of measured points to the surface of the crayfish. Rich information about the point clouds can be received by viewing and analysing, such as noise data introduced from extraneous vibrations and secular reflections, data correspond to the scanning platform contained in point clouds.

In order to analyse the detail information in the point clouds, a three-dimensional coordinate system was preset to reconstruct and analyse the point clouds of the surface of the crayfish, the origin point, *X*-axis and *Y*-axis were on the scanning platform of the laser scanner, *Z*-axis was in the vertical direction the scanning platform. The origin point was the start point of scanning; *X*-axis and *Y*-axis were point to the lateral and longitudinal moving and scanning direction of two CCD cameras.

One of those ASCII files correspond to the point clouds of the back part of crayfish was selected as an example to show the process of visual reconstruction and feature analysis, it was named as *Bio_ASC*. *Bio_ASC* consisted three-dimensional coordinate values of measured points to the surface of the crayfish. In the main time, noise data introduced from extraneous vibrations and secular reflections data correspond to the scanning platform also contained in *Bio_ASC*. The size of *Bio_ASC* was up to 3.76 MB. If we opened *Bio_ASC* by Notepad, the programming in Windows, we could found a great amount of data which was arranged as 3 columns with many rows; the number of row was too much and made it not easy to be obtained in Notepad. If we want import data of *Bio_ASC* into Microsoft Excel, a warn of failed to import all the data would be shown in Excel. The largest number of the rows in one sheet of Excel is 65536, so the number of the rows in *Bio_ASC* are more than 65536.

To a certain extent, visual feature analysis the point clouds of the surface of the crayfish is a process whereby the point clouds were transformed into a visual form to augment the process of discovery and analyse the feature of the three-dimensional surface of the crayfish. Visual study of the point clouds would be helpful to reconstruct and analyse the surface of crayfish.

2. VISUAL FEATURE ANALYSE IN IDL

2.1 IDL Environment

IDL, the Interactive Data Language, is an ideal computing environment for the interactive analysis and visualization of scientific and engineering data. It integrates a powerful, array-oriented language with numerous mathematical analysis and graphical display techniques, thus providing a high level of flexibility to access, analysis and visualize the data by different methods, such as programming in editor window or

calling iTools directly. IDL programs run across all major platforms: UNIX, Macintosh and Microsoft Windows.

2.2 Importing the Point Clouds

IDL provides built-in support for the data sources, data types, file formats, and file sizes. IDL was used to access common formats like TIFF, JPEG, and DXF, hierarchical scientific data formats like HDF, HDF-EOS, CDF, and netCDF, as well as custom binary and ASCII formats.

As we known, data was arranged as 3 columns and a large number of rows in *Bio_ASC*. Those 3 columns maybe correspond to the three-dimensional coordinate values of measured points of the surface of crayfish, but which columns correspond to *x*, *y* or *z* coordinate values of measured points could be found directly in Notepad.

The iTools of IDL are a set of pre-built visualization tools that combine data analysis and visualization with the task of producing presentable quality graphics. Based on the IDL Object Graphics system, the iTools are designed to maximize the utilization efficiency of the data. The iTools allows one continue to benefit from the control of a programming language, while enjoy the convenience of a point-and-click environment.

Bio_ASC was imported into IDL by using the “ASCII Template” dialog windows and defining type and range of ASCII data. In this process, 155758, the number of rows of the data in *Bio_ASC* could be obtained by clicking “Get next 50 Lines” optional button in the “ASCII Template” dialog windows.

Being an array-oriented language, IDL could import *Bio_ASC* entirely (without using loops) into a matrix, named as *Bio_MATRIX* [3, 155758], with 3 columns and 155758 rows. This work could be carried on “editor window” with the volume of column and row being set in advance.

2.3 Analysing the Point Clouds

The iPlot tool of iTools could be used for any type of two- or three-dimensional plot, including scatter plots, line plots, polar plots, and histogram plots. As the *Bio_MATRIX* [3, 155758] was the importing data of *Bio_ASC*, point clouds, stored in the matrix of *Bio_MATRIX* [3, 155758], could be displayed and analysed with great flexibility. In order to get the correspondence between the three columns of the *Bio_ASC* with the *x*, *y*, *z* coordinate values in the three-dimensional coordinate system which we had set before, first and second columns of *Bio_MATRIX* [3, 155758] were plotted by using iPlot tool.

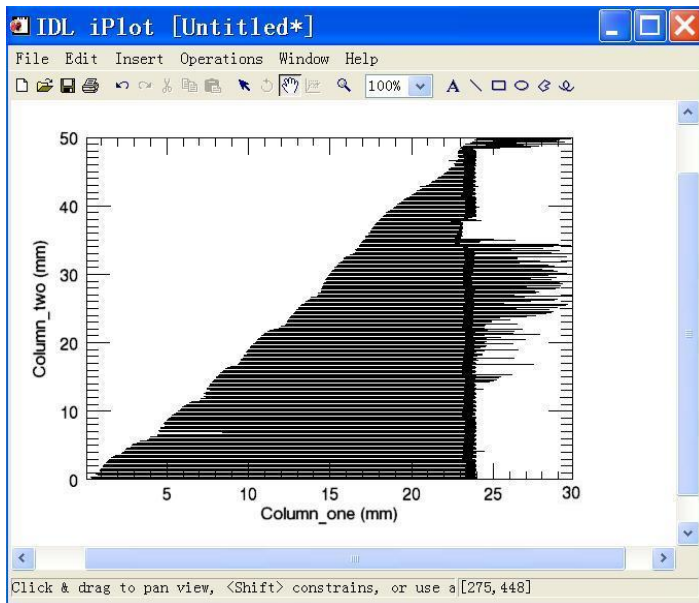


Figure 4
First and Second Columns of Original Point Clouds Being Plotted in Iplot Tool

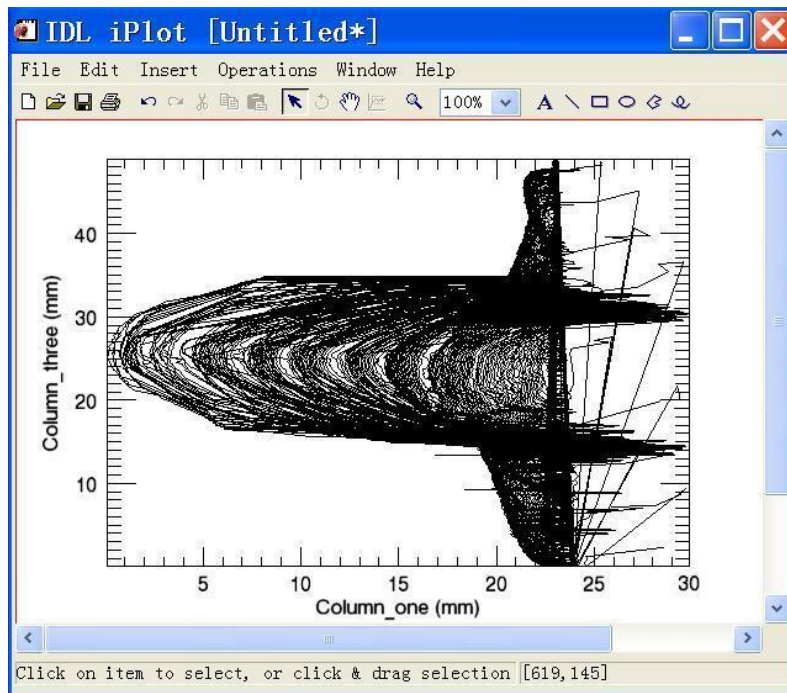


Figure 5
First and Third Columns of Original Point Clouds Being Plotted in Iplot Tool

Fig. 4 showed the relationship between first column and second column of *Bio_MATRIX* [3, 155758], the relationship between first column and second of *Bio_MATRIX* [3, 155758] was shown in Fig. 5 by same methods.

By comparing Fig. 4 and Fig. 5 with Fig. 1 to Fig. 3, we received the corresponding relationship between three columns of the *Bio_MATRIX* [3, 155758] and the x , y , z coordinate values in the three-dimensional coordinate system. The first, second and third columns of the *Bio_MATRIX* [3, 155758] stored the z , x and y coordinate values of the measured points of crayfish. Unwanted data, such as scanning platform, was shown as those data of which volumes were larger than 24 mm in “Column_One” of Fig. 4. This conclusion could also be confirmed by analysing the relationship of first and second columns in Fig. 5. In the main time, we could found the value of the highest point of the back of the crayfish is nearly 0.00 mm in Column_one of *Bio_MATRIX* [3, 155758], the Z -axis of the preset three-dimensional coordinate system. By comparing Fig. 5 with Fig. 1 and Fig. 2, we known that Column_one of *Bio_MATRIX* [3, 155758] stored the distances between the highest point that the scanner could measured and the surface of crayfish. In the main time, the fact that the maximum scanning range of height in this laser scanner was 30 mm could also be inverse deduced. Fig. 6 was the scatter plot of point clouds in IDL, which is similar with Fig. 2, point clouds of body of the crayfish shown in CATIA.

Moreover, the results obtained by iPlot tool could be modified by adding elements such as error bars, legends, and axis titles. The data range also could be altered in the data space properties of the iPlot tool if the data contained more data than wanted. After removing those unwanted data, such as data of the noise and scanning platform, three-dimensional surface of the body of crayfish was reconstructed in IDL. Fig. 6 was the scatter plot of the surface being reconstructed in iPlot tool, which was similar with Fig. 2, point clouds of body of the crayfish shown in CATIA.

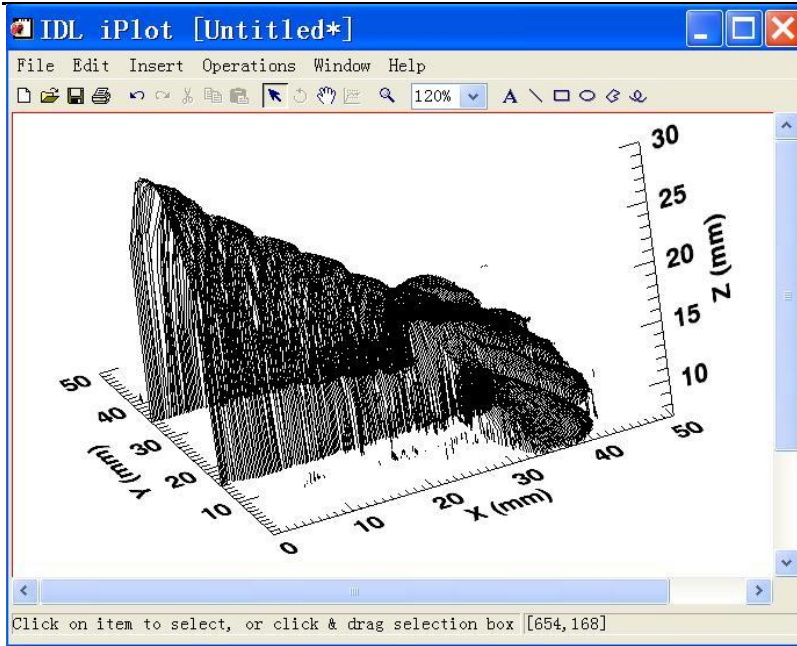


Figure 6
Scatter Plots of the Surface of Crayfish In Iplot Tool

In the process of analysing the point clouds, the data used for feature analysis were selected and stored in the matrix. On the other hand, matrix subscripting syntax of IDL could be used to simply limit the range of data when the plot display was created in analysing the feature of the surface. Fig. 7 showed the result of limiting the range of X-axis from 5.0 to 6.0 mm in Fig. 6. The preset scanning precision, 0.2 mm could be inverse deduced by analysing information in Fig. 7. In the main time, it confirmed the fact that CCD cameras moved in lateral direction along the X-axis of the preset three-dimensional coordinate system.

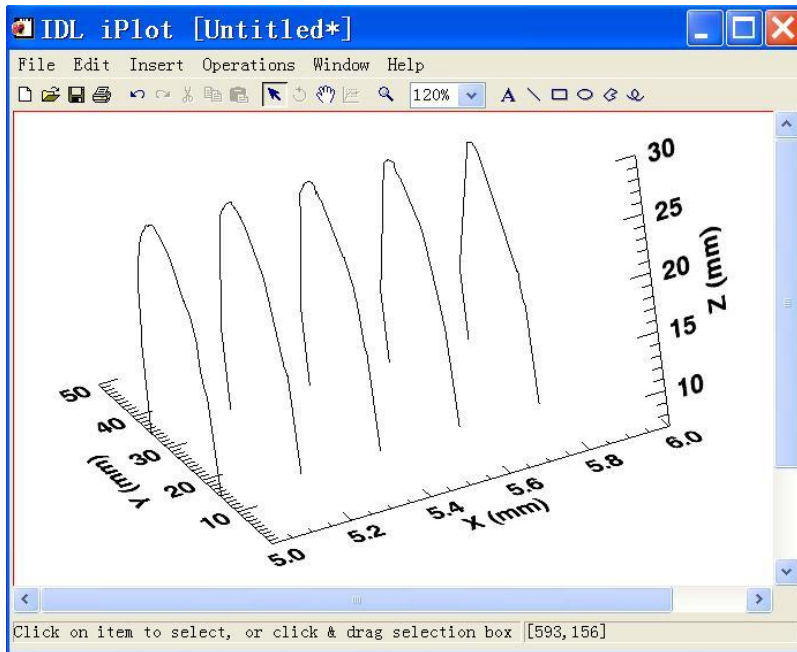


Figure 7
Scatter Plots with the Range of X-Axis from 5.0 to 6.0 Mm

3.4 Analysing Feature of the Surface

One of the main purposes to analyse the point clouds is obtaining the feature of the surface of crayfish. It would play an important role in the study of the relationship between the function and shape of the surface of crayfish. It would be helpful in the process of discovering the relationship between the function and shape of the surface of crayfish.

IDL has an extensive library of built-in math and statistics routines. Additional mathematical and statistical functionality can be added quickly and easily to an IDL application with the aid of the IDL Advanced Math and Stats Module. For example, if we want obtained the polynomial regression equation of the surface of crayfish in YZ plane ($x=5.2$ mm), we could choose point clouds that the value of second column of *Bio_MATRIX* [3, 155758], calling the iPlot tool and selecting “Quadratic” model in “Curve Fitting” operation. Polynomial regression equation of the surface of crayfish in YZ plane (the longitudinal plane, $x=5.2$ mm) would be derived as Eq. (1).

$$z = -46.91 + 5.72y - 0.11y^2 \quad (1)$$

where, y and z are coordinates of the measured points in the three-dimensional coordinate system. This result was also shown in Fig.8.

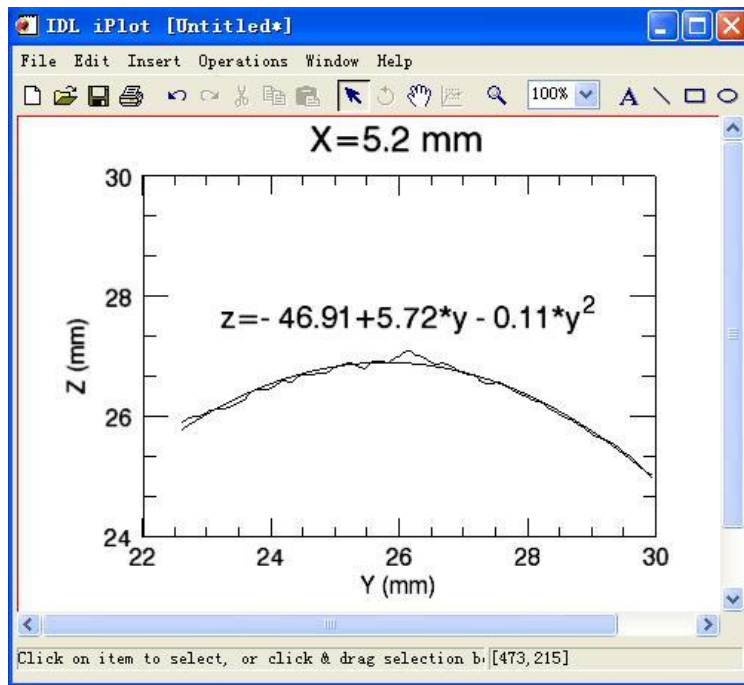


Figure 8
Polynomial Regression Equation in YZ Plane (X=5.2 Mm)

3. RESULTS AND DISCUSSION

Digital measurements of the surface of the crayfish were carried out by using the LSV 50 laser scanner, a non-touch three-dimensional laser scanner, and point clouds, the scanning data of the three-dimensional surface of the crayfish were saved as files of ASCII format. Corresponding to the preset three-dimensional coordinate system, the first, second and third columns of the point clouds stored the z , x and y coordinate values of the measured points of crayfish, and the first column stored the distances between the highest point that the scanner could measured and the surface of crayfish.

IDL is an ideal computing environment for the interactive analysis and visualization of scientific and engineering data. It has numerous mathematical analysis and graphical display techniques, thus providing a high level of flexibility to access, analyse and visualize the data by different methods. It is easy to import, reconstruct and analysis the point clouds by calling the iTools, a set of pre-built visualization tools that combine data analysis and visualization with the task of producing presentable quality graphics. Detailed information about the laser scanner, such as the preset scanning precision and the maximum scanning range of height in this laser scanner could be inverse deduced by analysing the point clouds in iTools. Main while, Polynomial regression equation of the surface of crayfish in selected cross section could be derived in IDL. Point clouds can be easily displayed and analysed by resizing, rotating and zooming in IDL.

CONCLUSION

Visual feature analysis of the point clouds of the surface of the crayfish were realized in IDL. With powerful capabilities of visualization and interactive analysis, IDL is suitable to carry out the research of visual reconstruction and feature analysis of point clouds of the surface of the living thing. Methods and results presented in this paper are of great use to analyze the feature of biological prototype, optimize the mathematical model and provide deformable physical model to bionic engineering; they promise great implications to the research of biological coupling theory and technological creation in bionic engineering.

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