Lovell Charts User Manual

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contents

0. Introduction of software

Lovell Charts (LC) is a 3D scientific research drawing software. This software is developed based on Java language and has an independent 3D drawing engine. It has the ability to draw most common 3D scientific research graphics. In view of the need to perform complex computer language input or process complex interactive interfaces when using many related software, this software will try to simplify related operations. In order to make it convenient for ordinary people who do not have computer programming experience to use this software, **LC** adopts a simple data and function input method, and also adopts a flexible and convenient interactive interface for the feature adjustment and result output of the graphics. This software is suitable for various scientific research drawing scenarios, especially for scientific researchers in colleges and universities and relevant staff of enterprises and institutions.

The current version of **Lovell Charts** is **1.2**.

1. Introduction to main functions

1.1. Graphics categories

LC can draw 3D area charts and cumulative area charts, 3D bar charts and cumulative bar charts, various 3D line charts, 3D bubble charts, 3D pie charts, torus charts and pyramid-type 3D charts, various scatter plots, surface charts, vector field charts, and 3D function charts with parameter variables. In addition to the above graphics, LC can also draw general 3D shapes, point-line structures, and visualize common point cloud files.

1.2. Color selection

LC not only has customized gradient and fixed color selection functions, but also has hundreds of commonly used color systems built in. Users can preview and choose to use them through tables.

1.3. Access method

LC's basic graphic data can be input through txt text files. When the graphics produced can be associated with a given function, **LC** provides a panel for directly inputting functions. Users can draw graphics by entering the specific formula of the function.

The final graphics drawn by **LC** can be saved as files in **png, jpg, svg** and **pdf** formats.

1.4. Dynamic Simulation

LC provides dynamic drawing functions for curve trajectory graphs and function surface graphs. The above functions can become an effective system status simulation display tool.

2. Specific functions

2.1. Drawing of various scientific research graphics

The images that Lovell Charts can draw are summarized as follows:

- *Area chart*: multi-series area chart, single-line multi-series cumulative area chart, multi-line multi-series cumulative chart
- *Bar chart*: multi-series bar chart, single-line cumulative bar chart, multi-line cumulative bar chart, bar chart with error bars
- *Pie chart*: simple pie chart, doughnut pie chart, doughnut chart, pyramid 3D chart, bar chart that can mark specific data
- *Line chart*: 3D line chart with width and thickness, line chart presented by point and line combination, curve trajectory chart with projection, dynamically drawn curve trajectory chart, multi-series line, series line chart with error bars (or error strips), multi-series line chart with waterfall lines (or waterfall surfaces)
- *Bubble chart*: 3D bubble chart with multiple coloring aspects
- *Scatter chart*: Scatter plots that can change the 3D shape of the sequence, scatter plots with logarithmic axes, scatter plots with specific area marks, scatter plots with projections, scatter plots with droop lines, and scatter plots with error bars
- *Surface plots*: 8 ways to present a single function surface: surface plots, point plots, grid lines, single-direction line plots (two types), single-direction strip plots (two types), surface plots that consider normal information
- *Vector field plots*: regional vector field plots with variable overall color and variable arrow size, vector field plots of given faces
- *Function graphs with parameter variables*: various common 3D surface plots with parameter variables
- *Point-line three-dimensional network structure graphs*: 3D graphs with point-line connected three-dimensional network structures, such as truss structure graphs
- *Point cloud graphs*: common ply, stl, and obj files can be visualized. Material and point normal vector information in the data can be considered.

2.2. Flexible interactive control

LC has flexible output control, and the final graphics can be saved as png, jpg, pdf, and svg format files. PNG and jpg format files can be used for further processing in other software later, while pdf format can achieve high fidelity effects, and svg can be used for web page production.

LC can implement appropriate dynamic control of graphics. Images can be scaled, moved, and rotated by moving the mouse on the interface. The above functions can also be achieved by clicking the relevant buttons. The overall style of the graphics or the specific coloring scheme can be changed through the drop-down menu.

For specific categories of images, LC provides flexible feature adjustment control schemes. By selecting the basic or advanced feature items in the drop-down menu, you can open the relevant control panel to modify the basic features of the graphics, such as title, axis identification, legend position, etc., or advanced features, such as axis type, image presentation type, and related feature parameters.

In addition to the above functions, LC also provides effective overall image control functions, such as coordinate system presentation, axis value range adjustment, system light source and observation angle adjustment, etc.

2.3. Data and function input

For the basic data of drawing graphics, LC can obtain it by reading txt text files. The txt file has a concise and clear structure, and does not require users to perform tedious operations.

If specific functions need to be processed, users can interact with LC by directly entering formulas.

3. Features

3.1. Diversity and convenience of color selection

LC provides tabular presentation and selection of fixed colors, gradient colors and hundreds of common color systems.

3.2. Convenience of function input

Through the function input panel provided by LC, users can easily input functions directly into LC.

3.3. Coordination of graphic quality and drawing efficiency

LC uses internal control to enable users to achieve coordination of graphic quality and drawing efficiency when processing different types of graphics.

3.4. Simple and comprehensive interactive control

Through a few menu selections and panel operations, users can achieve comprehensive interactive control of drawn graphics.

4. Introduction to the software's window menu and operation interface

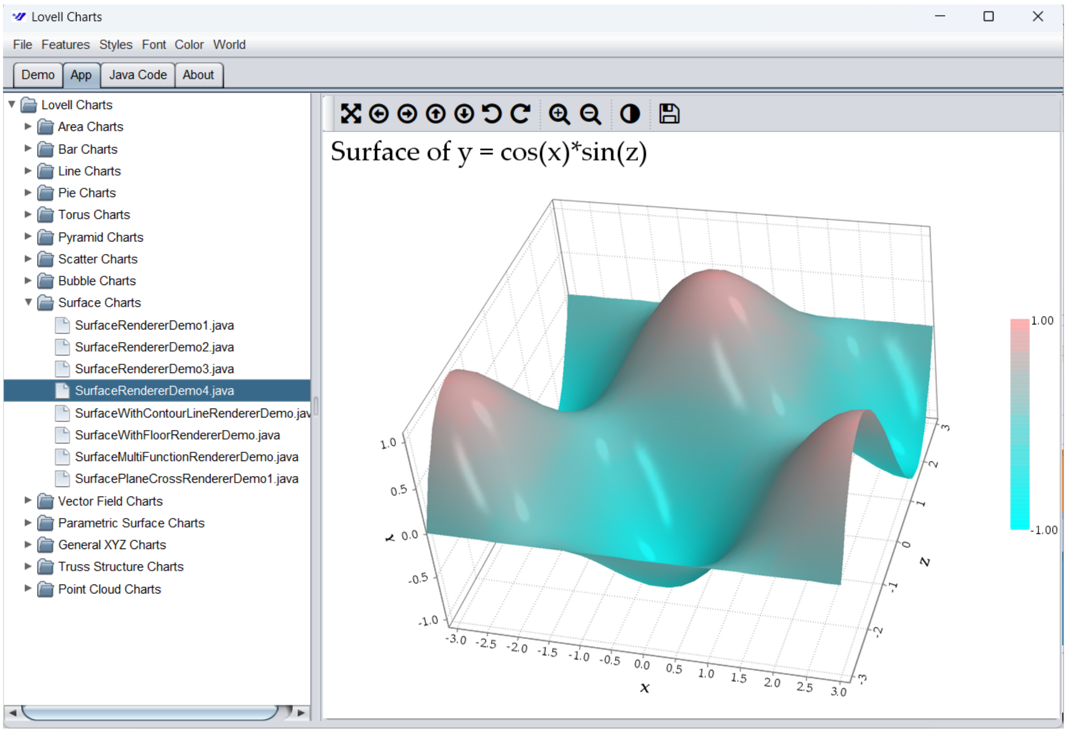


Figure 4.1. Main operation interface of Lovell Charts.

Figure 4.1 is the main operation interface of Lovell Charts.

The menu bar is located above the main operation interface, and the panel with different labels is located below. The layout of the **Demo** tab page is the same as that of the **APP** tab page; the difference between the two is that the **Demo** tab page does not have the data input function, and the drawing of the graph depends on the default data of the software. On the **APP** tab page, users can input data and functions. The **Java Code** tab contains the relevant Java source code. **Note**: This part will not appear in the publicly released version, so it will not be introduced. The **About** tab is a brief introduction to the Lovell Charts software.

Taking the **App** tab page as an example, users can select the type of graph to be drawn by clicking the tree menu on the left side below. When a specific menu item is selected, the software will prompt the user to select the method of inputting data, reading a txt file, entering the specific formula of the function, or directly using the default data of the software. When using the default data, the user can get the result that is basically the same as the selection under the **Demo** tab; therefore, the menu selection under the **App** tab also has a display function. After the software reads the data or enters the function, it will draw the graph on the right side below the main interface. The graphics drawn here will use the system's built-in default settings, such as the default shading style. Related settings can be adjusted and optimized later through menu selection and mouse operation.

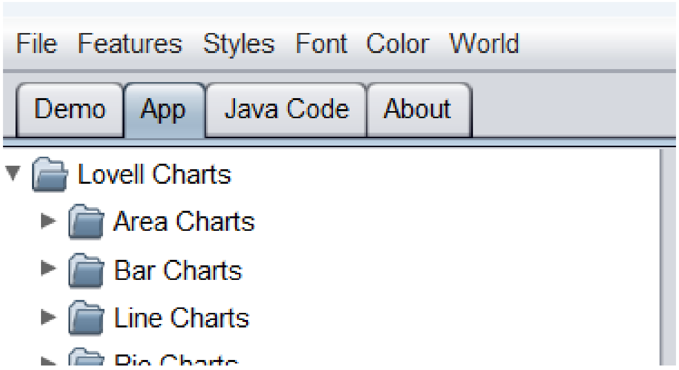


Figure 4.2. Menu bar.

The menu bar of LC is shown in Figure 4.2. The **File** menu has the function of shutting down the system or opening a Notepad. Notepad can be used to process input data files. Other menu items are used to adjust and control the characteristics of the graphics.

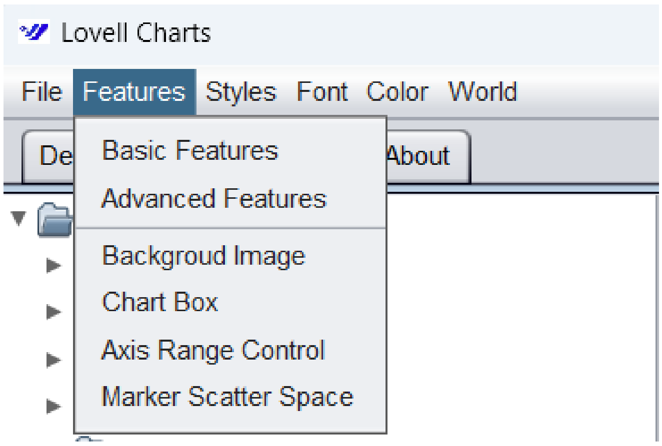


Figure 4.3. Menu bar of features.

Figure 4.3 shows the specific contents of the **Features** menu. **Basic Features** and **Advanced Features** are used to adjust the basic and advanced features of the graph, respectively. By clicking the above menu, LC will pop up the corresponding panel. Note that the specific panel content will vary with the current graphics category. Generally speaking, the basic feature panel will process features such as the title, legend, axis label, and grid lines of the coordinate system; while the advanced feature panel is generally used to process graphics features and advanced coordinate system features related to specific graphics categories.

The **Background Image** under the **Features** menu is used to open a graphics file as the background for drawing graphics. The **Chart Box** menu is used to select whether to present only the outline of the graph, whether to use a colored non-transparent coordinate box, and whether to present the coordinate system. By clicking the **Axis Range Control** menu, the user can adjust the coordinate axis range of the graph through the pop-up slider. Finally, the **Marker Scatter Space** menu can mark specific areas of the scatter plot and highlight related data.

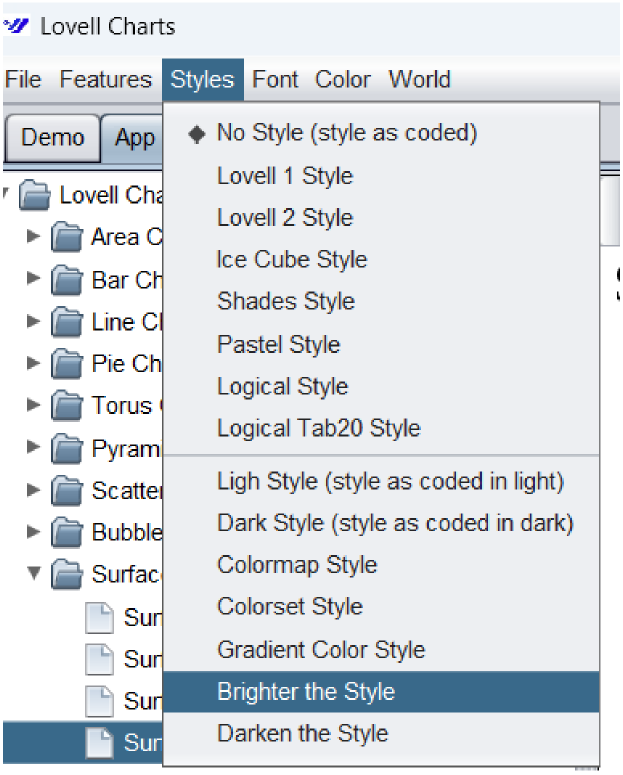


Figure 4.4. Graphics style adjustment menu.

Figure 4.4 shows the specific options of the graphics style menu in the menu bar. Users can adjust the overall style of the currently drawn graphics by clicking the relevant menu items above the menu dividing line. The menu dividing line below this menu item provides a richer graphics coloring scheme. **Light Style** and **Dark Style** will change the background color of the graphics to white or black. **Brighter the Style** and **Darken the Style** options will make the current style color brighter or darker. By clicking the **Gradient Color Style** menu, LC will pop up a color selection panel to let users select the start and end colors of the gradient color system. **Colorset Style** provides some commonly used separation color combinations. The **Colormap Style** option uses a table to present hundreds of common color systems for users to choose. The specific Colormap selection panel is shown in Figure 4.5.

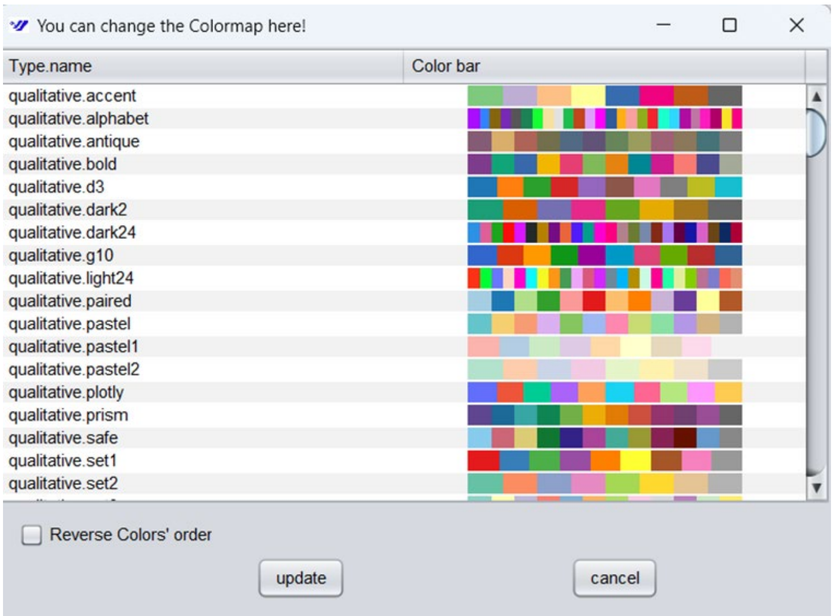


Figure 4.5. Colormap panel.

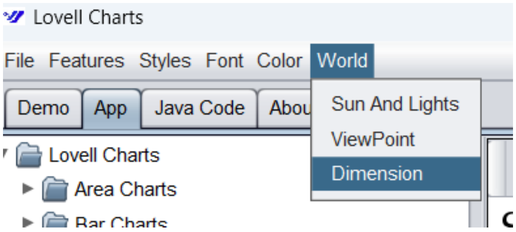


Figure 4.6. Contents of World menu.

Figure 4.6 shows the options of the **World** menu. Among them, the option **Sun and Lights** provides options for adjusting the characteristics of the light source in the system. The **View Point** option provides the basic 3D graphics viewing point. Of course, the graphics viewpoint can also be dynamically changed by rolling the mouse on the graphical interface. The **Dimension** menu item provides the function of modifying the relative length of each coordinate axis.

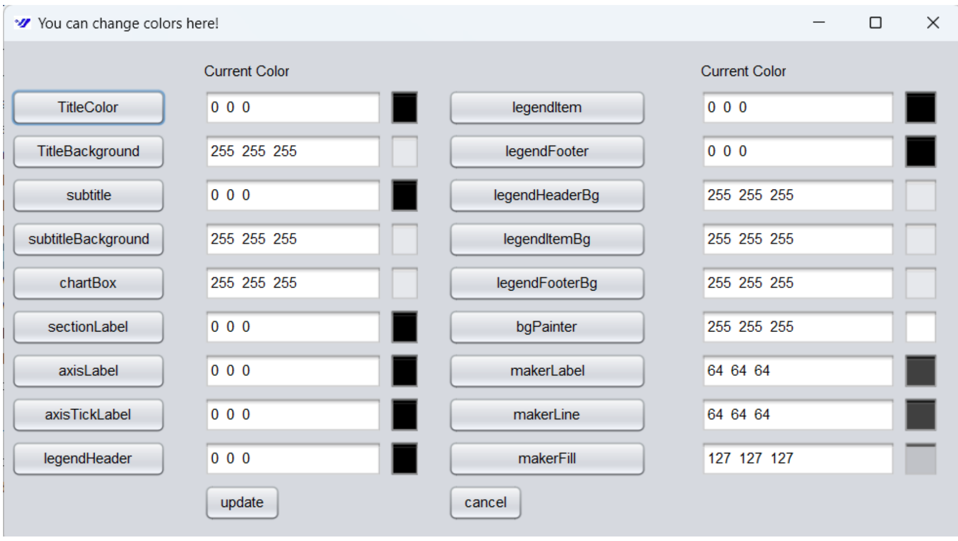


Figure 4.7. Adjustment panel for various specific colors of the current style

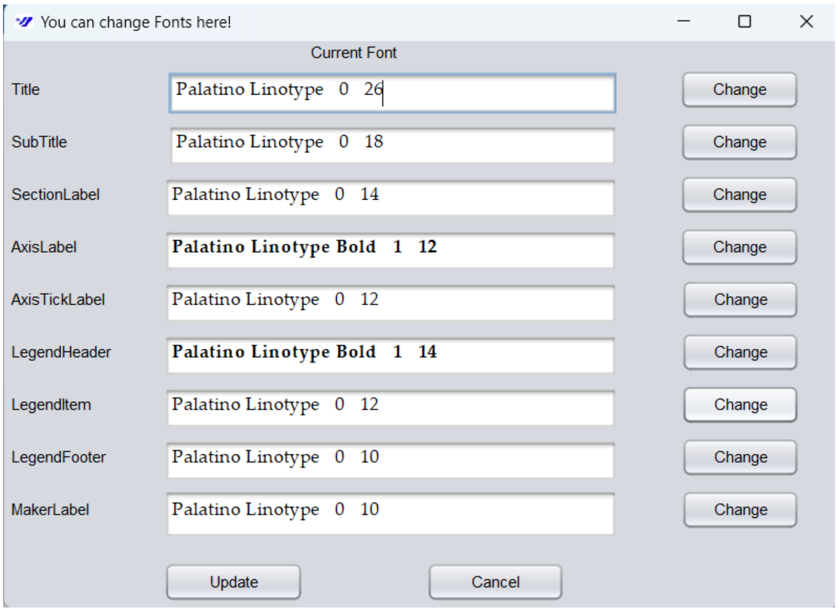


Figure 4.8 Font adjustment panel for the current style

Figure 4.7 shows the color selection panel related to the graphic style. The color selection here mainly refers to the colors of the coordinate system, legend, title and other related components that constitute the graphic. You can click the button on the left side of the relevant color option line to select the color in the pop-up color selection panel. The selected color will display its RGB value in the text box of the relevant item, and the specific color will be displayed in the following box. Users can also directly enter the RGB value of the color in the above-mentioned related text box to adjust the color.

Figure 4.8 is the font selection panel of the relevant graphics. Users can select the relevant font through the pop-up font selection panel by clicking the button after the corresponding line of the relevant font. The results of the above selection will be displayed in the text box of the corresponding line. Of course, users can also directly modify the relevant font features in the corresponding text box.

5. Interactive Graphical Interface Introduction

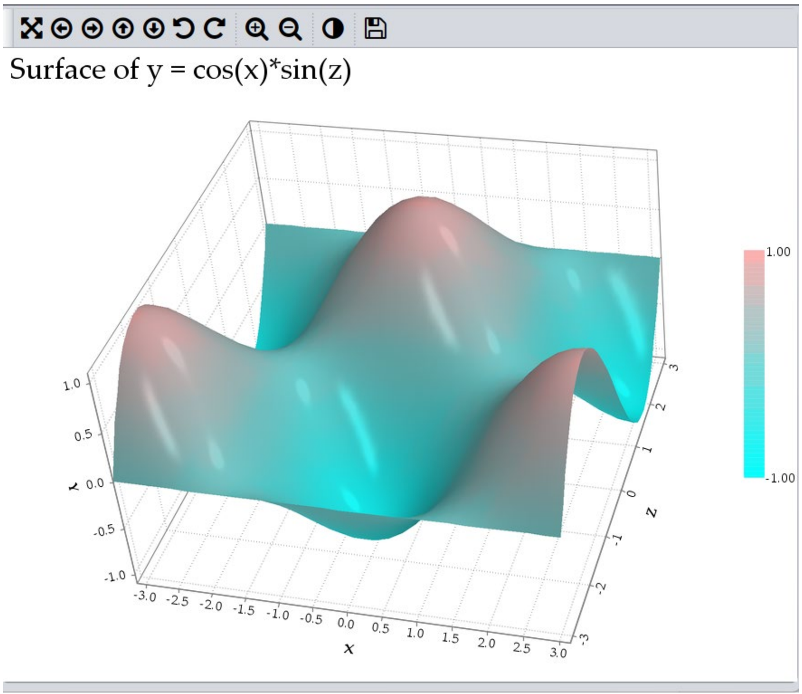


Figure 5.1 Dynamic interactive control and presentation area of graphics

Figure 5.1 is the mouse interactive control and presentation area of the graphics. Users can realize interactive dynamic control of the graphics by clicking the buttons above this area. By clicking the first button above, the size of the graphics can be adapted to the current interface size. The second to fifth buttons above can respectively control the rotation of the graphics to the left and right sides or up and down. By clicking the sixth and seventh buttons, the graphics can be rotated counterclockwise or clockwise around the center position.

The second button from right to left above this area is the coloring color or overall style adjustment button of the graphics. Clicking this button will pop up the menu shown in Figure 5.2. The content and function of this menu are the same as the style adjustment menu above the main operation interface area, and the operation method is the same. The difference between the two is that the operation of this menu item only affects the current graphics, while the menu operation above the main operation interface area will affect all subsequent graphics drawn with default settings.

The rightmost button above the dynamic interaction area is the storage button for the final graphics. By clicking this button, the menu options shown in Figure 5.3 can be popped up. Click the relevant menu item, and LC will pop up the file storage panel. The user can select the file storage path in the pop-up panel, enter the file name, and store the current graphic in the corresponding file format.

The above button options can also be selected by right-clicking the mouse in the dynamic interaction area and selecting operations in the pop-up menu list. The relevant pop-up menu list is shown in Figure 5.4.

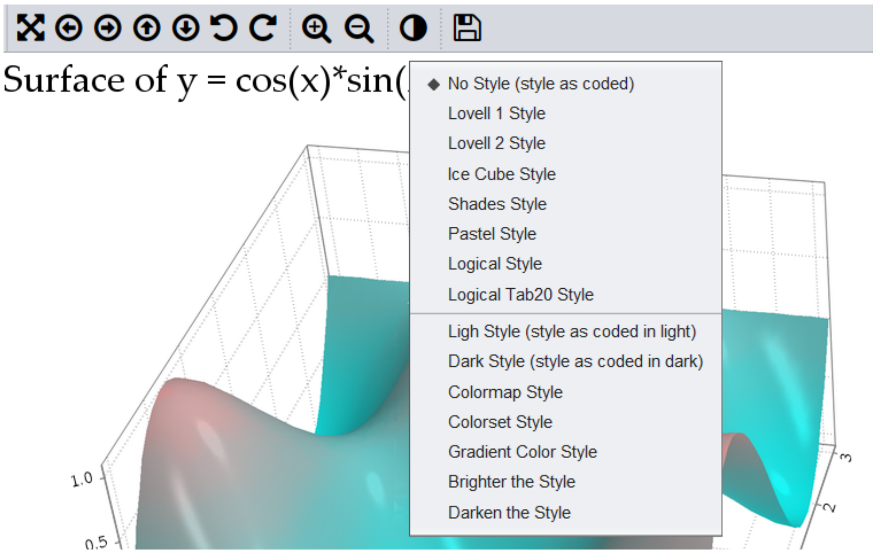


Figure 5.2 Style button pop-up menu in the graphics presentation area

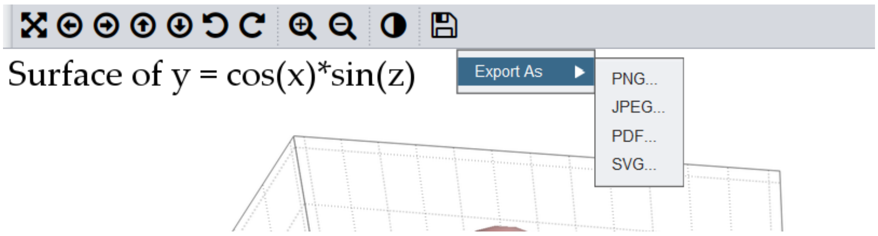


Figure5.3 Graphics output button pop-up menu content in the graphics interaction area

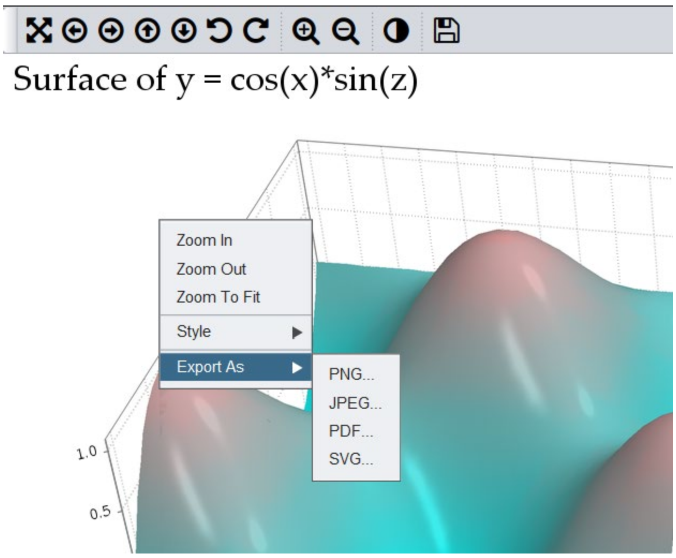


Figure 5.4 The menu that pops up when you right-click the mouse in the graphic interaction area

In addition to the above interactive controls, users can also zoom in and out by rolling the mouse in the interactive area; press the left mouse button and drag the image to rotate it in various ways. In addition, by pressing the **alt** key on the keyboard and the left mouse button at the same time and moving the mouse, the image can be moved up, down, left, and right in the interactive area.

6. Application example - taking 3D bubble chart as an example

6.1. Drawing target

Taking the creation of a 3D bubble chart as shown in Figure 6.1 as an example, the following introduces the basic operation process of applying **LC** drawing from four aspects: data preparation, data loading and drawing, graphic property modification and image storage.

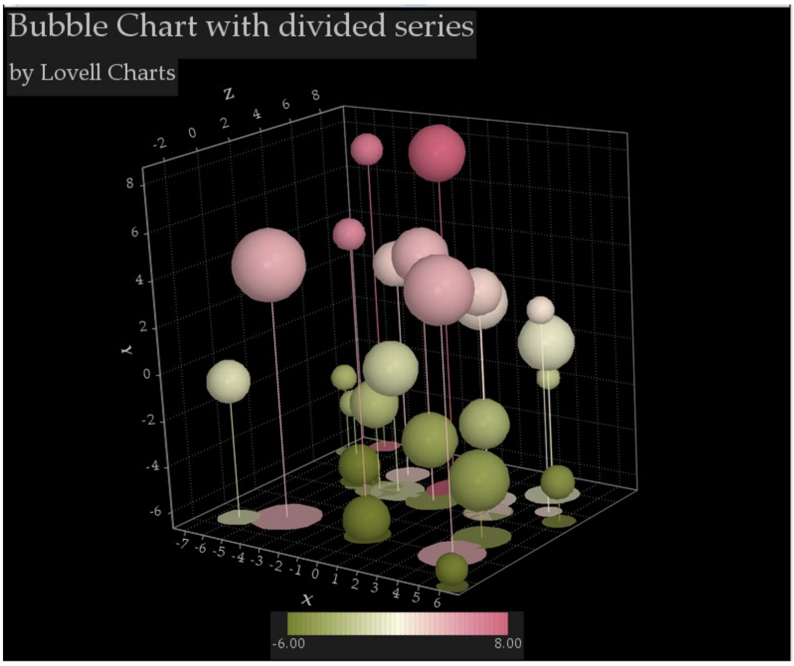


Figure 6.1 The target 3D bubble chart that needs to be drawn

6.2. Prepare data

When drawing a bubble chart, you need to know which series each bubble belongs to (and the data group it belongs to), the spatial position of the bubble (and its x, y, z coordinates), and the relative size of the bubble. Therefore, each bubble corresponds to 5 values, which are a string (representing the key value or name of the series to which it belongs), an x coordinate value, a y coordinate value, a z coordinate value, and the relative size value of the bubble. The following four values are double numeric types. For example, a set of values separated by spaces **Series1 0.0 8.0 6.0 50.0** (or separated by commas **Series1, 0.0, 8.0, 6.0, 50.0**) indicates that the bubble belongs to the series **Series1**, its (x, y, z) coordinates are (0.0, 8.0, 6.0), and its relative size value is 50.0. Put the relevant data of all bubbles into a txt file, with the value of each bubble occupying one line of the file, and you can get the bubble data file required by LC. The bubble data file required to draw Figure 13 is as follows:

```
Series1 0.0 8.0 6.0 50.0
Series1 -2.0 -1.2 4.7 50.0
Series1 3.2 -2.0 8.7 -50.0
Series1 2.0 2.0 5.7 50.0
Series1 -7.0 -3.2 7.7 -40.0
Series2 5.0 2.0 5.7 -40.0
Series2 -4.0 -3.0 4.5 -40.0
```

Series2 -2.82842712474619 -2.82842712474619 4.5 30.0
Series2 0.0 -4.0 4.5 50.0
Series3 2.82842712474619 -2.82842712474619 4.5 30.0
Series3 4.0 0.0 7.5 50.0
Series3 2.82842712474619 2.82842712474619 4.5 20.0
Series3 0.0 4.0 4.5 50.0
Series4 -2.82842712474619 2.82842712474619 6.5 20.0
Series4 -6.0 7.0 9.0 -20.0
Series4 -4.242640687119285 -6.0 5.0 10.0
Series4 -6.0 -4.0 9.0 -20.0
Series4 -6.0 -0.7071067811865475 -1.0 10.0
Series5 0.0 -6.0 0.0 20.0
Series5 4.242640687119285 -4.242640687119285 2.0 60.0
Series5 6.0 -5.0 5.0 -20.0
Series5 4.242640687119285 4.242640687119285 0.0 80.0
Series5 0.0 6.0 0.0 -30.0
Series5 -4.242640687119285 4.242640687119285 0.0 100.0
Series6 -3.0 -5.2 8.7 -40.0
Series6 6.2 -6.0 -2.7 -30.0

With the above data files, **LC** can draw graphs.

6.3. Upload data and draw

First, as shown in Figure 6.2, select the **App** tab in the main operation interface and enter. Then, in the tree menu on the left below the tab, as shown in Figure 6.3, select the **Bubble Charts** menu and select the menu item "**ScatterBubbleChartsDemo1.java**" under it. In the pop-up information confirmation window, press the **Confirm(Y)** button to enter the data txt file selection window, as shown in Figure 6.4. After finding the corresponding data file bubbleData.txt, click the **Open** button to get the bubble chart shown in Figure 6.5 in the graphic presentation area of the main operation interface.

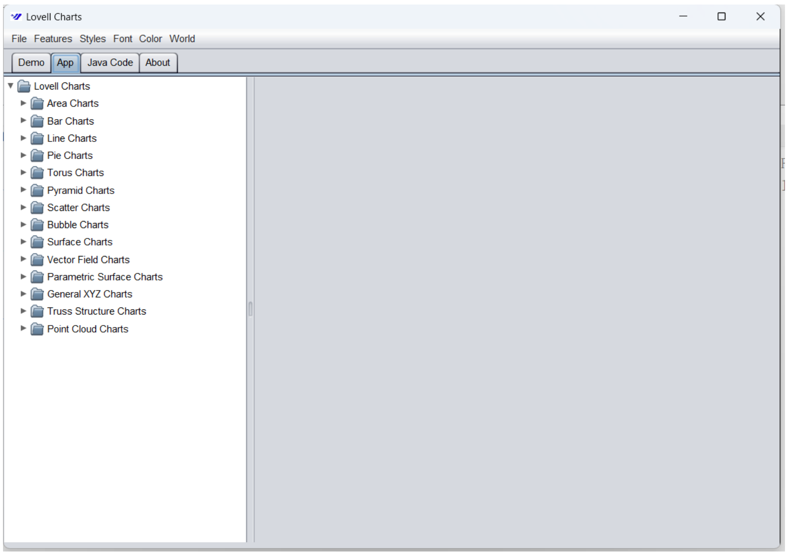


Figure 6.2 Select the App tab

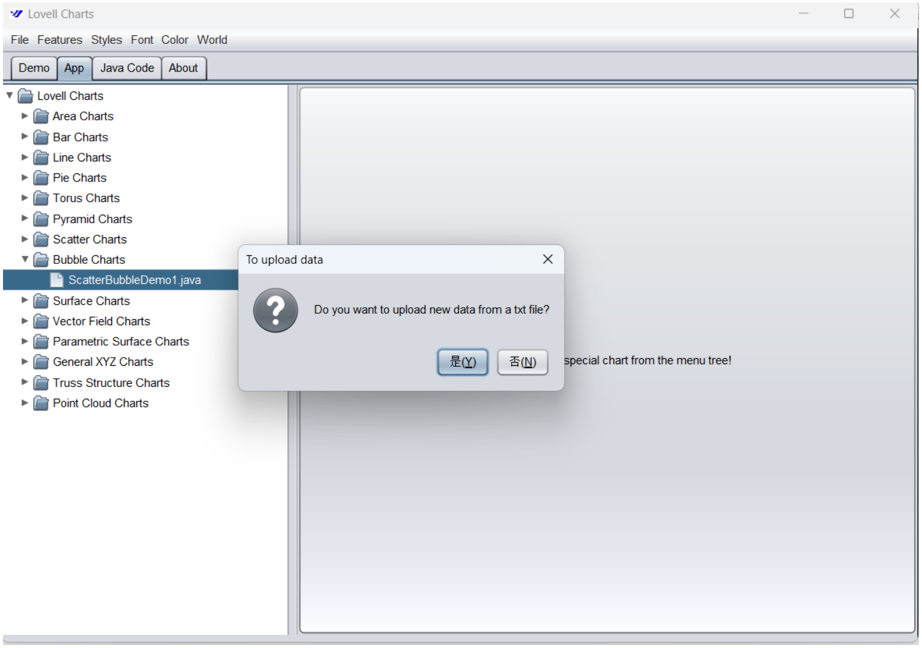


Figure 6.3 Select the ScatterBubbleDemo1.java menu item under Bubble Charts

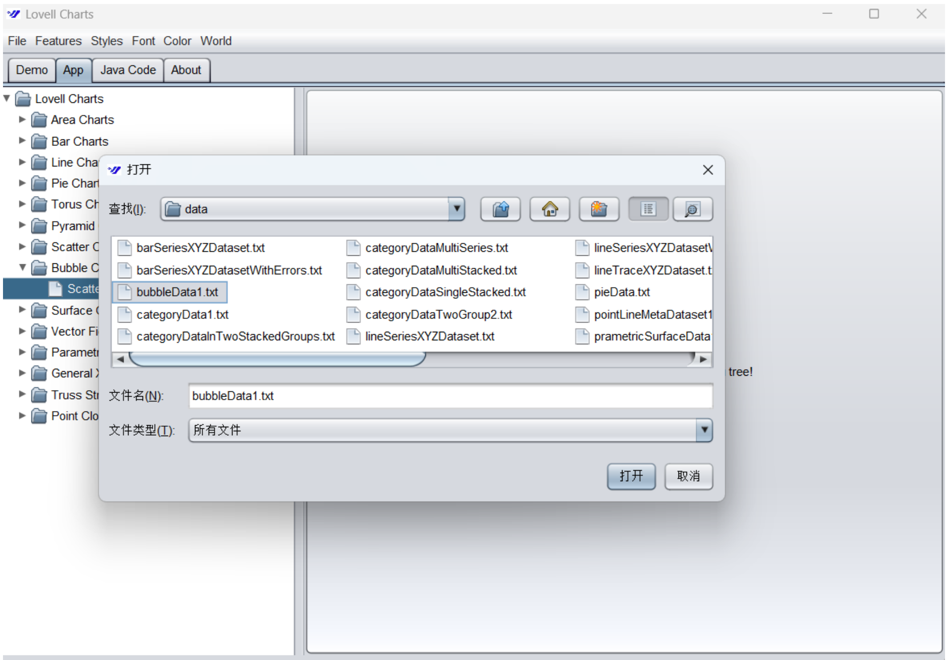


Figure 6.4 Find the txt file of bubble data

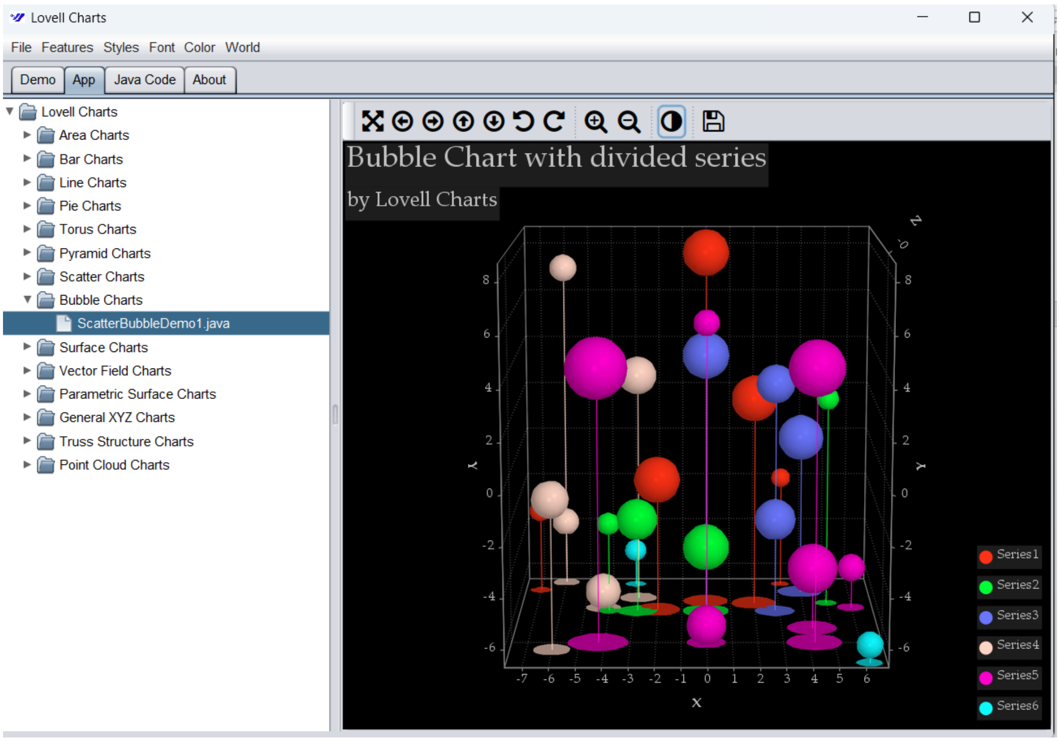


Figure 6.5 Bubble chart obtained under default settings

6.4. Modify graph features

After obtaining the bubble chart shown in Figure 6.5, its basic features can be modified. As shown in Figure 6.6, select the main operation interface menu **Features**, and select the **Basic Features** menu item under it. **LC** will pop up the bubble chart related basic feature adjustment panel as shown in Figure 6.7.

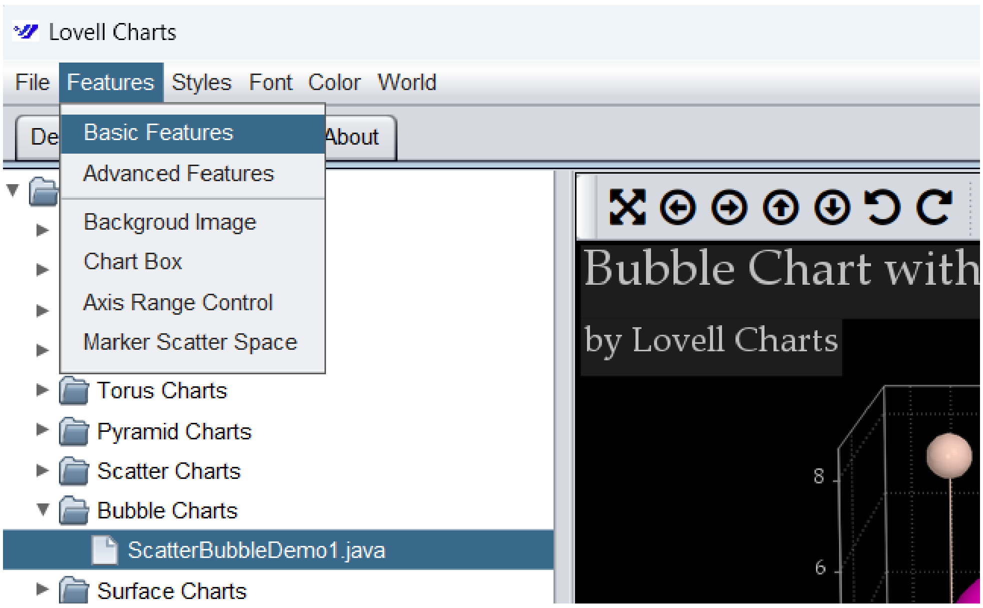


Figure 6.6 Select Basic Features from the Features menu above the main operation interface.

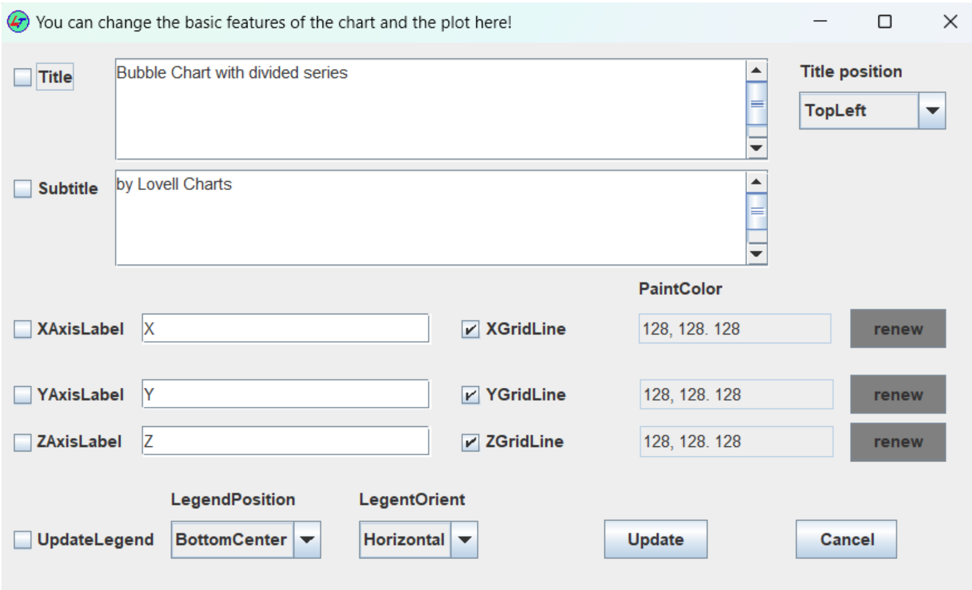


Figure 6.7 Basic feature adjustment panel of bubble chart

The basic feature panel of the bubble chart can adjust and change the content of the main and subtitles of the graph (the text box behind the **Title** and **Subtitle** check buttons) and the position (the drop-down list below **Title position**), the labels (and names) of the coordinate axes, the colors of the grid lines on each coordinate plane, and the position and layout direction of the legend. The panel that is now open will display the main and subtitles of the current graph. When you need to adjust any of the above features, you need to select the corresponding check button. The following is an introduction to the corresponding operation by taking the modification of the y-axis grid line color of the coordinate box as an example. First, click the **renew** button behind the row where the **YGridLine** check button is located, and **LC** will pop up the color selection panel as shown in Figure 6.8. You can select the required y-axis grid line color in this panel. Here, we assume that we need white grid lines and confirm it. The RGB value of the selected color will be displayed in the text box behind the row where the **YGridLine** check button is located, as shown in Figure 6.9. At the same time, we select this check box.

Suppose we also need to adjust the position of the legend. You can select the required legend position and layout direction in the drop-down selection bar under **LegendPosion** and **LegendOrient**, as shown in Figure 6.9. By selecting the **UpdateLegend** checkbox, make sure to use the above adjustment values when drawing the graph later. Finally, click the **Update** button on the panel to complete the modification of the basic characteristics of the bubble chart. **LC** will present the modified graph shown in Figure 6.10. Observing Figure 6.10, we will find that its y-axis grid lines have become white and clearer, and the position and layout direction of its legend have also changed as expected.

Figure 6.8 Coordinate system grid line color selection panel along the y-axis

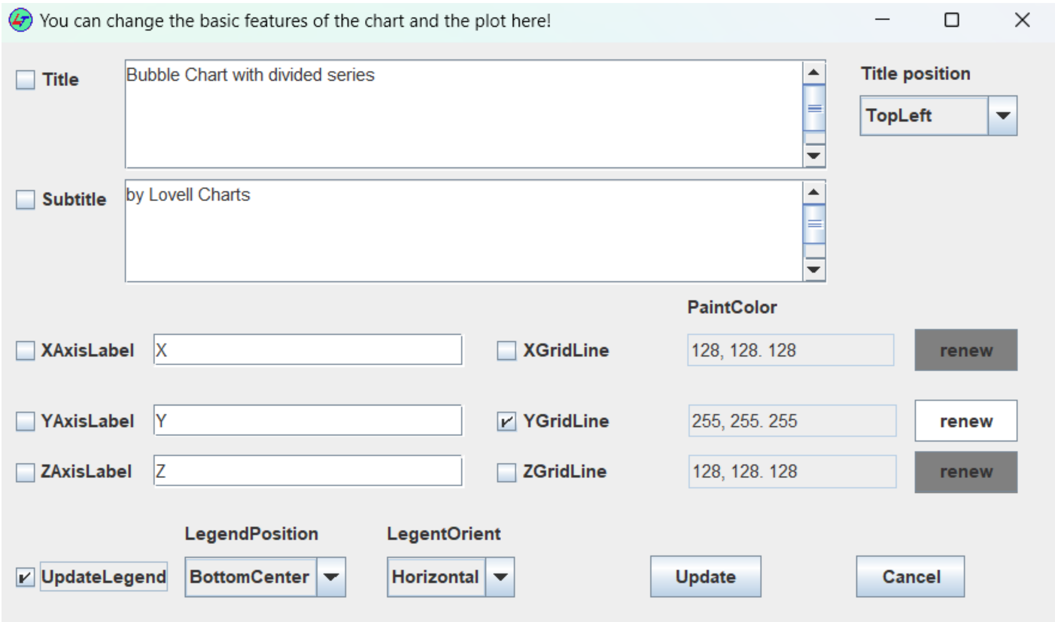


Figure 6.9 Bubble chart basic feature adjustment panel after determining the adjustment value

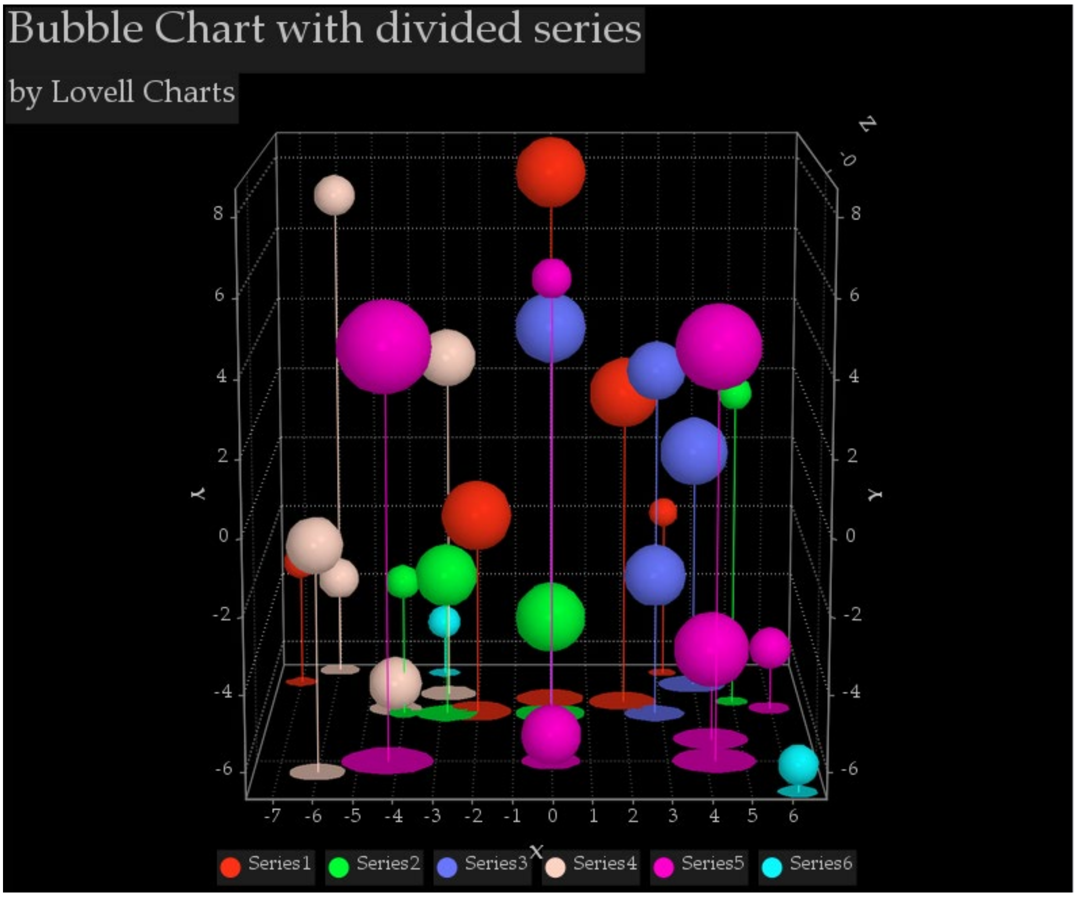


Figure 6.10 Bubble chart after changing some basic features

Next, we modify some of the advanced features in Figure 6.10 to obtain the final desired graphic result. As shown in Figure 6.11, select the **Advanced Features** menu item under the graphic **Features** menu. At this time, **LC** will pop up the bubble chart advanced feature adjustment panel as shown in Figure 6.12.

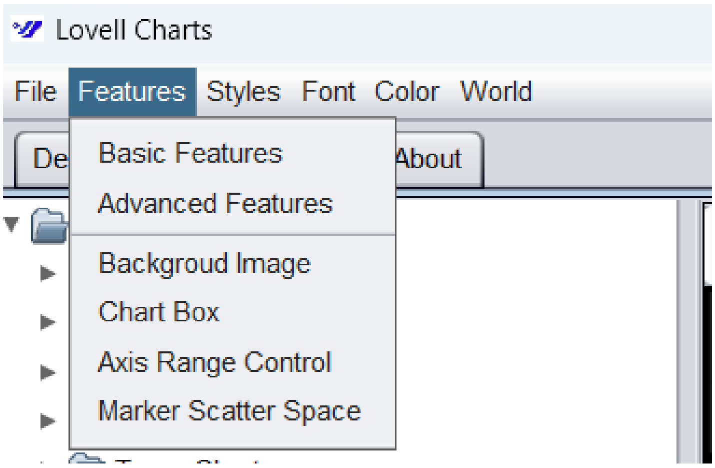


Figure 6.11 Select the Advanced Features Adjustment Panel for the Graphic

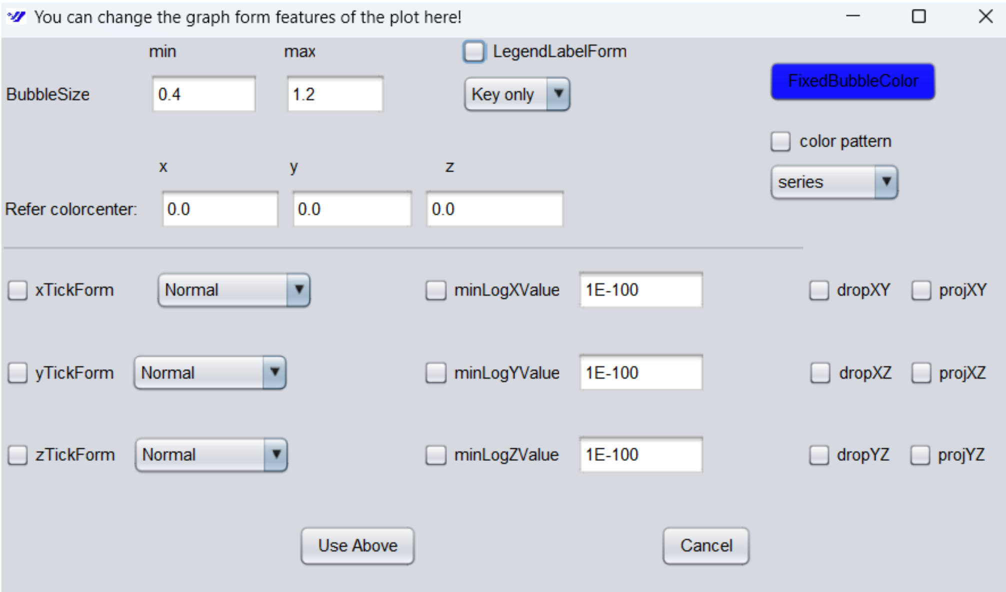


Figure 6.12 Bubble Chart Advanced Feature Adjustment Panel

In the advanced feature adjustment panel of the bubble chart, you can confirm or adjust the size range of the bubbles, the coloring method of the bubbles, the category of the coordinate system, and whether to draw the dropping lines and projections in various directions. The specific adjustment methods of each item will be analyzed in detail when introducing the graphics drawing of the classification later, and will not be further expanded here.

Suppose we need to change the bubble coloring scheme from the default sequential coloring to the y-axis direction, which changes according to the y value of the bubble position. We need to select the **color pattern** checkbox and select the **y-direction** option from the drop-down options below it. In addition, suppose we need to draw the bubble projection of the **XZ** coordinate plane and the bubble dropping line to the plane, we need to select the **dropXZ** and **projXZ** checkboxes. The result of the above selection is shown in Figure 6.13. Click the **Use Above** button on the advanced feature adjustment panel to confirm all changes, and **LC** will draw a new bubble chart, as shown in Figure 6.14.

The newly drawn bubble chart uses the default color scheme, not the coloring scheme we need. We can get the coloring scheme we need by changing the style characteristics of the graphics. To do this, as shown in Figure 6.15, select the **Colormap style** option in the **Style** menu on the main operation interface. As shown in Figure 6.16, **LC** will pop up the corresponding color selection panel. On this panel, you can see other available color schemes by scrolling the scroll bar. Select the **diverging armyrose** color scheme and confirm. The newly drawn bubble chart is shown in Figure 6.17. By selecting **Dark Style** under the **Style** menu, you can get a bubble chart in dark mode with a black background. In the interactive control area, you can get the graphics presentation perspective and size we need by scrolling the mouse, as shown in Figure 6.18. This is the final graphic we need to draw.

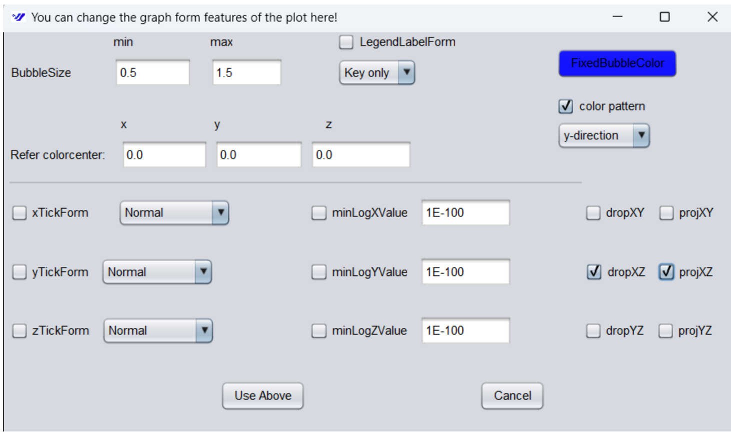


Figure 6.13 Panel with confirmed adjustments to advanced features

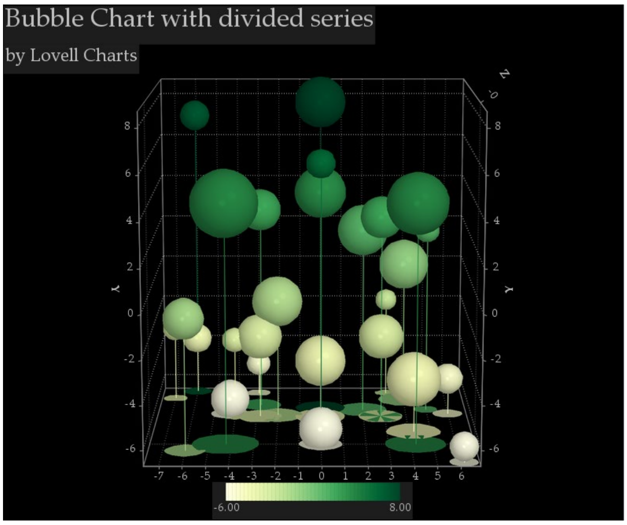


Figure 6.14 Bubble chart based on adjusted high-level features

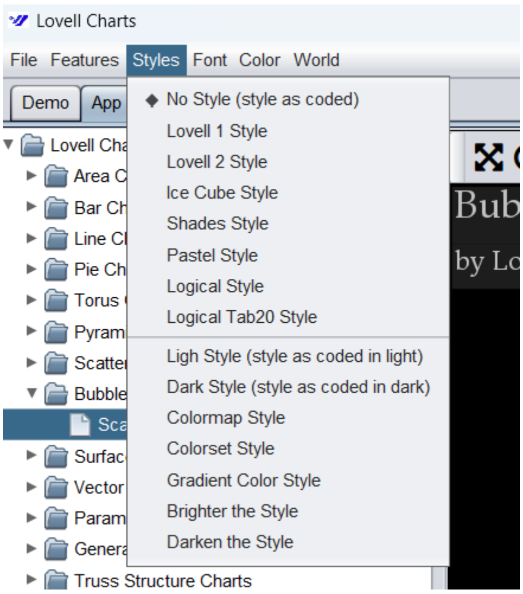


Figure 6.15 Select the style menu for the graphic

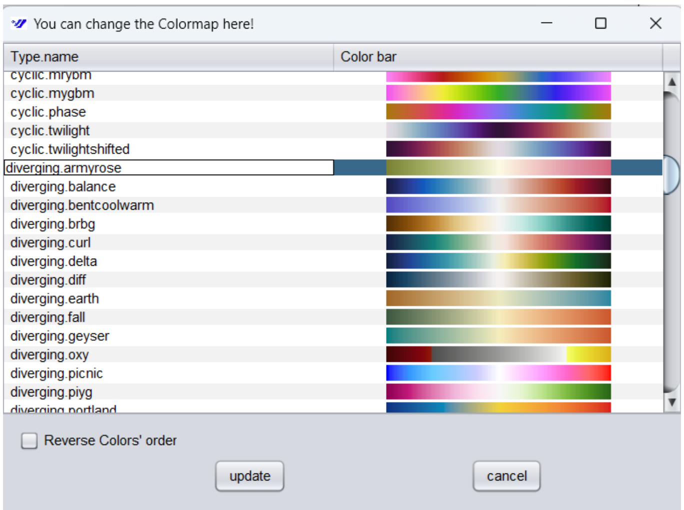


Figure 6.16 The corresponding Colormap selection panel

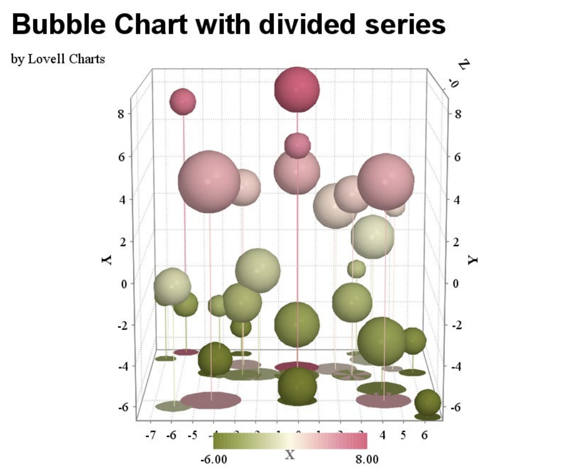


Figure 6.17 Bubble chart drawn according to the new color scheme

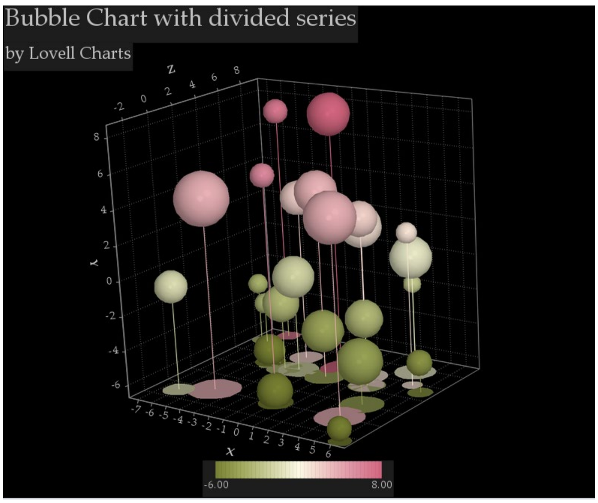


Figure 6.18 Bubble chart after changing to dark mode

6.5. Save graph

The last step in making the required bubble chart is to store the chart as an image file in the format we need. First, click the file storage button above the image presentation area, and the file storage menu shown in Figure 6.19 will pop up. Select the required image file format **pdf**, and **LC** will pop up the file storage panel, as shown in Figure 6.20. On this panel, we select the path for document storage, give the file name, click the **Save** button, and complete the file storage.

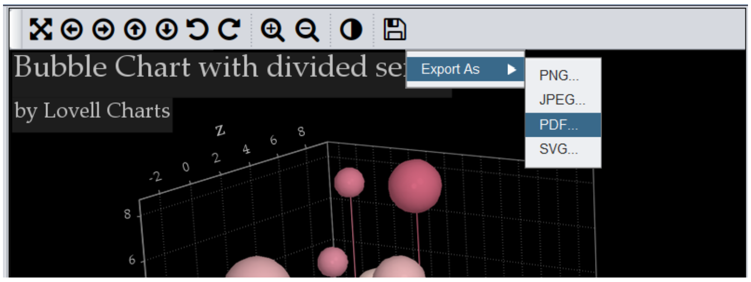


Figure 6.19 Bubble Chart Storage Menu Selection

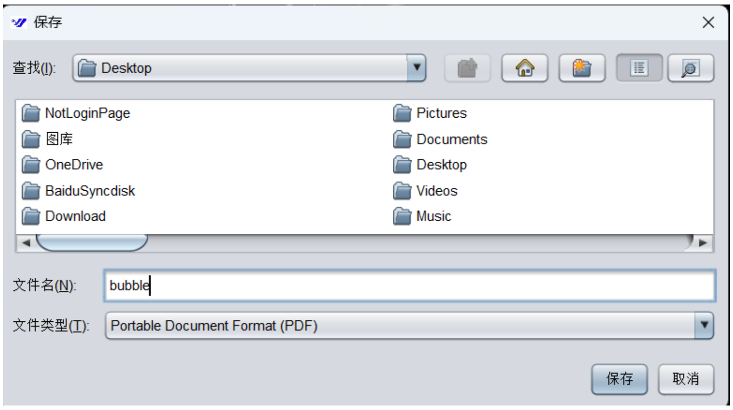


Figure 6.20 Bubble chart file storage path and name determination panel

You can find the file in the location where the file is stored and open it to verify. Suppose we store the file on the computer desktop with the name bubble. As shown in Figure 6.21, we find the file on the desktop and click to open it. The file opened in **Adobe** is shown in Figure 6.22. It can be observed that it is the bubble chart we stored earlier.

Figure 6.21 Bubble chart file stored in pdf format on the desktop

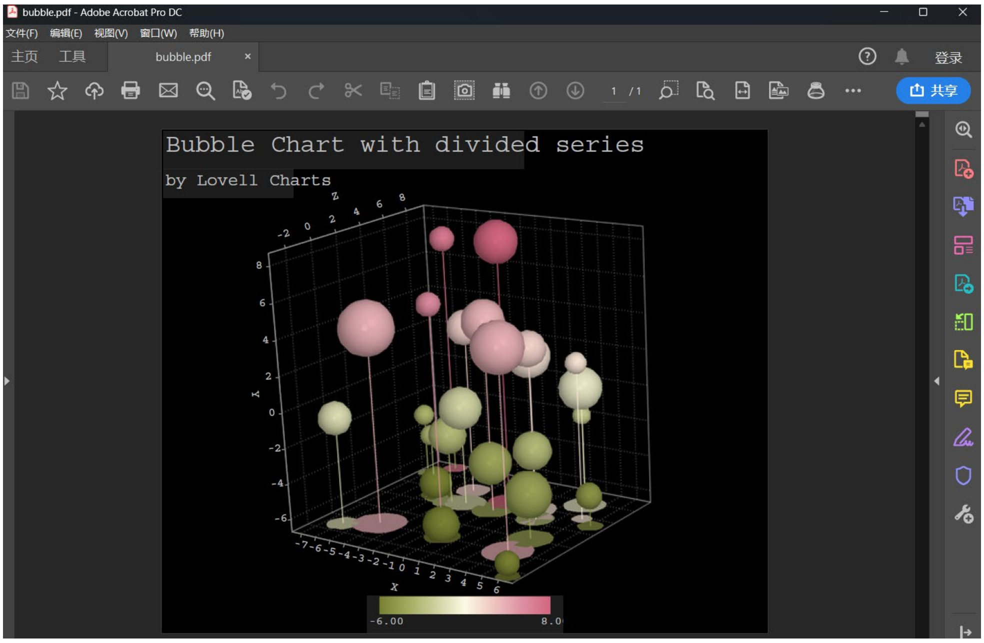


Figure 6.22 Bubble image pdf file opened in Adobe

A simple bubble chart drawing process is now completed. Users can follow the above operation process and draw bubble charts of various styles by trying various control options.

7. Input data file format specification

7.1. Data definition and classification

The input data of Lovell Charts only contains three basic data types, namely **string**, **integer** and **real** number. The above three data types correspond to the **String**, **int** and **double** data types in the **Java** language respectively.

Common data separators include **space** and **comma**. **Lovell Charts** fully supports data separated by space, and only partially supports data separated by comma. This limitation may change in the future!

In the basic data **String**, **Lovell Charts** stipulates that the above two separators cannot be included.

Lovell Charts mainly includes three types of data combination structure types, namely **key-value data**, **XYZ data** and **matrix data**. Key-value data combination generally contains two or more string data and one real number data. XYZ data generally consists of a string basic data and multiple real numbers or integer data. Matrix data combination generally consists of a group of real numbers, and a group of matrix data combination together constitutes a data matrix. Matrix data is generally used for drawing function surface graphs.

In **Lovell Charts**, we call a row of data in a txt file a **data entry**. That is, each data entry occupies one line of the txt file. The three data combination structures mentioned above can all become a data entry.

Since the data in the txt file are in lines (i.e. one data entry), any number of blank lines can be spaced between any two data entries without affecting the result. The above blank line processing allows the data to be separated by category in the preparation stage, increasing the readability of the data.

The data file consists of a large number of data entries. There are two points to note when preparing data: first, the data must be entered in English input status, otherwise it may not be read; second, in addition to the basic data entries, some explanatory data entries must be given in sequence according to regulations.

7.2. Main data file format

The content of the data file generally contains two parts, namely **the specific feature data** at the beginning of the file and **the main data**. The specific feature data is used to explain certain specific features of the required drawing graphics, and generally there are only a few lines of such data entries. Not all data files have specific feature data entries. The main data consists of a large number of data entries with the same data combination structure.

The following introduces several main data file structures, and other special data files will be explained in detail when introducing specific types of graphics drawing.

7.2.1. Single-key single-value data file

The first type of data file can be used to draw pie charts, torus and pyramid-type 3D graphics. This type of file only has the main data part, and each data entry consists of a string and a real value. Such a data combination structure can be called a **single-key single-value data combination**, and the corresponding data entry can be called a **single-key single-value data entry**. The following is a part of a single-key single-value data file:

Na 10625
Mg 7124
Li 2060
Ca 4823
…

7.2.2. Key-value data files

The main part of the second type of data files is composed of key-value data combinations, and generally does not include specific feature data entries. The following is a fragment of this type of data file, in which a data entry contains two string key values and a real value:

s1 c1 2
s1 c2 4
s1 c3 3.3
s1 c4 5.32
s2 c1 3.9
s2 c2 3.21
…

In the above data file, the first key value, that is the first string, is the name of the sequence where the relevant value is located, or the key value of the sequence. The sequence key value here is generally also the row key corresponding to the row where the real value is located. The second key value is the column key corresponding to the real value. The last real value of the data entry is the datum associated with the previous key values. When making related graphics, such as bar charts, the above sequence key and column key are equivalent to the Z and X coordinates in the XYZ coordinate system, and the real value is equivalent to the Y coordinate.

The following introduces another common key-value data file. Compared with the first type of key-value data file, the data entry of the second file adds a key value to identify the group where the corresponding real value is located. A group is generally composed of several sequences. The data of a sequence generally belongs to the same group. When drawing cumulative area charts and cumulative bar charts, we will need the concept of groups. The key value of the group, that is, the first string value of the data entry corresponds to a row of the graph, which is equivalent to the Z coordinate in the XYZ coordinate system. The other subsequent data items are explained in the same way as the first type of data file of this type. Of course, the sequence key value here is not in the row of the corresponding coordinate. Note that when drawing a cumulative area chart or a cumulative bar chart, if the opened data file is the first key value file, we assume that the group key value of each data entry is the same as its sequence key, that is, one sequence corresponds to one degenerate cumulative group.

g1, s1, c1, 2
g1, s1, c2, 4
g1 s1 c3 3.3

```
g1 s1 c4 5.32
g1 s2 c1 3.9
g1 s2 c2 3.21
…
```

7.2.3. XYZ data combination data file

The data entries of the third type of data file are composed of XYZ data combination. A data entry consists of a string key value and multiple real values. When the number of real values contained in each entry is 3, the three real values correspond to the x, y and z axis coordinates of the midpoint in the XYZ coordinate system. The following is a fragment of this type of data file:

```
Series1 1.0 5.0 1.0
Series1 2.0 6.0 1.0
Series1 3.0 7.0 1.0
Series1 4.0 15.0 1.0
Series1 5.0 12.0 1.0
Series1 6.0 7.0 1.0
Series2 1.0 8.0 2.0
Series2 2.0 18.0 2.0
…
```

When a data entry of this type of data file contains more than 3 real values, the first three data still represent the coordinates of the X, Y, and Z axes; and the specific meaning of the real values after the fourth needs to be determined according to the specific graphic category. The last three real values of a common data entry containing six real values represent the error of the first three real values corresponding to the entry. When drawing a graph with error values, we assume that the x, y, and z values of the data all have errors, so even if the corresponding error value is zero, it needs to be clarified in the data file with the real number 0.0. The following is a fragment of this type of data file, in which the data only has data errors in the y direction:

```
Series1 1.0 5.0 1.0 0.0 1.3 0.0
Series1 2.0 6.0 1.0 0.0 1.0 0.0
Series1 3.0 7.0 1.0 0.0 3.5 0.0
Series1 4.0 15.0 1.0 0.0 2.5 0.0
Series1 5.0 12.0 1.0 0.0 1.8 0.0
Series1 6.0 7.0 1.0 0.0 1.8 0.0
Series2 1.0 8.0 2.0 0.0 1.0 0.0
Series2 2.0 18.0 2.0 0.0 1.0 0.0
Series2 3.0 12.0 2.0 0.0 3.0 0.0
…
```

7.2.4. Matrix data combination data file

When drawing a function surface graph, we will use the fourth type of data file. The main part of this type of file is composed of a large number of matrix data combinations, that is, matrix data entries. Since the X and Z coordinate ranges and sampling numbers of the drawn surface graph need to be described, this type of file contains data entries that describe specific features.

When there is only one function drawn, the data file contains two specific data entries. The first specific feature data entry corresponds to the X axis; the second specific feature data entry corresponds to the Z axis. Each specific feature data entry contains three values. The first two are real values, corresponding to the minimum and maximum values of the coordinate range respectively. The third is an integer value, indicating the number of data sampling points in the value range on the corresponding axis. The main part of the data file starts from the third data entry and is composed of a large number of matrix data entries. The following is a fragment of this type of data file that captures two matrix data entries:

```
-3.14159265 3.14159265 65
-3.14159265 3.14159265 65
1.2246467991473532E-16 0.09801714032956083 0.19509032201612 86 0.2902846772544624
0.3826834323650899 0.47139673682599786 0.5555702330196022 0.6343932841636455
0.7071067811865476 0.7730104533627371 0.8314696123025455 0.881921264348355
0.9238795325112867 0.9569403357322089 0.9807852804032304 0.9951847266721969 1.0
0.9951847266721968 0.9807852804032304 0.9569403357322089 0.9238795325112867
0.8819212643483549 0.8314696123025453 0.773010453362737 0.7071067811865475
0.6343932841636454 0.5555702330196021 0.47139673682599775 0.3826834323650898
0.2902846772544623 0.19509032201612847
0.09801714032956071 -0.0 -0.09801714032956071 -0.19509032201612847 -
0.2902846772544623 -0.3826834323650898 -0.47139673682599775 -0.5555702330196021 -
0.6343932841636454 -0.7071067811865475 -0.7730104533627368 -0.8314696123025453 -
0.8819212643483549 -0.9238795325112865 -0.9569403357322089 -0.9807852804032304 -
0.9951847266721969 -1.0 -0.9951847266721969 -0.9807852804032304 -0.9569403357322089 -
0.9238795325112866 -0.881921264348355 -0.8314696123025455 -0.7730104533627368 -
0.7071067811865476 -0.6343932841636458 -0.5555702330196022 -0.47139673682599786 -
0.3826834323650903 -0.2902846772544624 -0.1950903220161286 -0.0980171403295604 -
1.2246467991473532E-16
…
```

When there is more than one function to be drawn, the number of specific feature data entries of this type of file will change. Assuming that the number of functions to be drawn is n, the number of specific feature entries of this type of data file is $1 + 2 + 3n$.

The first data entry contains only one integer value, representing the number of functions to be processed. The second and third specific feature data entries each contain two real values, corresponding to the lower and upper limits of the value range of the x-axis and z-axis, respectively.

The subsequent 3n data entries correspond to one function each, and each entry contains two integer values. These two integer values correspond to the number of numerical sampling points of the corresponding function on the X-axis and Z-axis, respectively.

The following is a fragment of this type of data file containing 3 functions, one of which is a 3D plane.

```
3
-3.14159265 3.14159265
-3.14159265 3.14159265
60 60
50 50
50 50
-9.693456950543455 -11.755078808109255 -13.317069350117908 -14.100253297399256 -
13.964651827262927 -12.934501052068805 -11.193920287854711 -9.054004325337356 -
6.897221316640281 -5.10905406871323 -4.009102526125016 -3.793961527779607 -
4.50208332204772 -6.006904978947049 -8.039469040114273 -10.2364944075231 -
12.205305739169514 -13.59401649133671 -14.154421760412198 -13.786360058067508 -
12.555615219569521 -10.682158829018269 -8.500834598189805 -6.401511597814263 -
4.759402781450576 -3.868003003841322 -3.8866325521927685 -4.8119617588648325 -
6.478606114381063 -8.588685515939876 -10.765064513512334 -12.61875790015472 -
13.818454214757745 -14.149731190002168 -13.553379541606676 -12.135985470605696 -
10.150880463217415 -7.9528632392260565 -5.934786415613216 -4.457341779855685 -
3.78459368289099 -4.036782697712478 -5.1688349671341145 -6.978418274761948 -
9.14210497394774 -11.27317835800441 -12.990750712873812 -13.987839551293899 -
14.086234732206172 -13.268350040226231 -11.680366377908612 -9.606104786624758 -
7.416298982901429 -5.502333952845405 -4.206293535774096 -3.759819624209059 -
4.242710703193047 -5.568659430806557 -7.500678388597789 -9.69345695054345
…
```

When there is more than one function to be drawn and a given 3D plane is considered to be cut, the number of specific feature data entries of this type of file will change. Assuming that the number of functions to be drawn is n except for the given 3D plane, the number of specific feature entries of this type of data file is $1 + 2 + 3n + 1$.

The first data entry contains only an integer value n, which represents the number of functions to be processed. The second and third specific feature data entries each contain two real values, corresponding to the lower and upper limits of the value range of the X-axis and Z-axis, respectively.

The subsequent $3n$ data entries correspond to n functions, each of which contains two integer values. These two integer values correspond to the number of numerical sampling points of the corresponding function on the X-axis and Z-axis, respectively.

The next data entry consists of 4 double real numbers and two integers. We assume that a 3D plane has a function form of $ax + by + cz + d = 0$, where x, y, z are variables and a, b, c, d are parameters. The first 4 real values of this data entry correspond to the a, b, c, d parameter values of the relevant 3D plane. The last two integers represent the number of numerical sampling points of the given 3D plane on the X-axis and Z-axis respectively. Note that when parameter $b = 0.0$, the given plane is perpendicular to the X-Z coordinate plane. At this time, the number of numerical sampling points on the above X-axis and Z-axis will not affect the result. If the given plane needs to be drawn, **LC** will draw the corresponding plane with a given single color under the above special conditions; otherwise, the color of the given plane is adjustable.

Below is a fragment of such a data file containing 3 functions and a given 3D plane.

```
3
-3.14159265 3.14159265
-3.14159265 3.14159265
60 60
50 50
50 50
-11.0 0.0 5.0 60 60
-9.693456950543455 -11.755078808109255 -13.317069350117908 -14.100253297399256 -
13.964651827262927 -12.934501052068805 -11.193920287854711 -9.054004325337356 -
6.897221316640281 -5.10905406871323 -4.009102526125016 -3.793961527779607 -
4.50208332204772 -6.006904978947049 -8.039469040114273 -10.2364944075231 -
12.205305739169514 -13.59401649133671 -14.154421760412198 -13.786360058067508 -
12.555615219569521 -10.682158829018269 -8.500834598189805 -6.401511597814263 -
4.759402781450576 -3.868003003841322 -3.8866325521927685 -4.8119617588648325 -
6.478606114381063 -8.588685515939876 -10.765064513512334 -12.61875790015472 -
13.818454214757745 -14.149731190002168 -13.553379541606676 -12.135985470605696 -
10.150880463217415 -7.9528632392260565 -5.934786415613216 -4.457341779855685 -
3.78459368289099 -4.036782697712478 -5.1688349671341145 -6.978418274761948 -
9.14210497394774 -11.27317835800441 -12.990750712873812 -13.987839551293899 -
14.086234732206172 -13.268350040226231 -11.680366377908612 -9.606104786624758 -
7.416298982901429 -5.502333952845405 -4.206293535774096 -3.759819624209059 -
4.242710703193047 -5.568659430806557 -7.500678388597789 -9.69345695054345
…
```

8. Introduction to Function Formula Input

Lovell Charts users can directly input the formula of the required function through the text box. **LC** can automatically recognize and compile the input formula, so it is very convenient to handle complex functions.

8.1. Variable Settings and Constants

When using **LC**, the relevant function input panel has defined the available variable names, and the name range is as follows: x, y, z, t, u, v. Users must strictly input the variable names according to the regulations.

When the input formula contains the constant π and the natural constant e, their corresponding values must be replaced by **MathPI** and **MathE** respectively. The case of the letters in the above regulations is mandatory.

8.2. Supported Basic Functions

Lovell Charts supports basic operations such as addition, subtraction, multiplication and division, and their corresponding formula input symbols are: +, -, *, /。

Lovell Charts supports most basic functions, including: $sin()$, $cos()$, $tan()$, $exp()$, $sqrt()$, $ln()$, $log()$, asin(), $acos()$, $atan()$, $sinh()$, $cosh()$, $tanh()$, $random()$, $signum()$, $ceil()$, $floor()$, $rint()$, $pow(,)$, $max(,)$, $min(,)$, $hypot(,)$, $abs()$。

In the formula input text area of LC, enter the corresponding function in the form given above.

The brackets of the above functions are mandatory. If it is a binary operation, the comma is also mandatory. For example, $max(,)$ means comparing two numbers and taking the larger value. For example, $max(x, y)$ means taking the larger value represented by x and y as the result. Note that the above functions must be entered in lowercase letters.

The function $random()$ does not require parameters and gives a random variable value that follows a uniform distribution in the range of 0 to 1.

The function $signum(x)$ means that when $x > 0.0$, its value is 1.0; when $x = 0.0$, its value is 0.0; when $x < 0.0$, its value is -1.0.

The function $rint(x)$ means taking the integer value closest to x. The functions $ceil(x)$ and $floor(x)$ respectively represent rounding x up and down.

Function h$ypot(x, y)$ gives the value of $\sqrt[2]{x^2 + y^2}$.

8.3. Input standards and features

There are the following basic rules when entering formulas:

Bracket standards: large, medium and small brackets {} [] () can be used interchangeably and can be replaced with each other without affecting the results;

Regardless of whether the formula is entered across lines, spaces in the formula input will be automatically ignored;

The square and cube of the variable x can be simply entered as: xx and xxx respectively;

The omission standard of the multiplication sign is the same as the usual handwriting method, such as $3xyz$ and $(1 + xy)xsin(2y)$.

9. Introduction to the data structure and control functions of graphic classification drawing

9.1. Area chart drawing

9.1.1. Area chart classification

3D area charts can generally be divided into two categories: general area charts and cumulative area charts. General area charts draw the area with thickness of a series of data as a row; while cumulative area charts divide the series in the data into different groups, each group contains one or more series of data, and one row of the area chart corresponds to one data group. Although the data processing methods and drawing results are different, the drawing process of the two types of area charts is basically the same.

9.1.2. Input data file structure

The data file of a general area chart is composed of data entries. A data entry occupies one line of the txt file. Each data entry contains three metadata, namely two string data and one real value data. The first string is the sequence key value of the real value data, or the sequence name; the second string is the data column identifier of the real value under the entry, that is, the column name of the data, or the key value of the column. The three metadata are separated by spaces. Both strings are not allowed to contain spaces and commas. For specific examples, see the introduction to key value data files in **Section 7.2.2**.

The data file of the cumulative area chart is also composed of many data entries with the same format. Unlike the data entries of the general area chart, the data entries of the cumulative area chart add a string that identifies the data group where the real-valued data element belongs, and put it at the beginning of each data entry, separated from other data elements by a space. For specific examples, see **Section 7.2.2**. In addition, when each data series is a group in itself, the data file of the cumulative area chart can be read in the data format of the general area chart.

9.1.3. Feature Adjustment Panel

Generally speaking, each graph has two feature adjustment panels: the basic feature adjustment panel and the advanced feature adjustment panel. The way to open the panel is the same as the bubble chart drawing example in **Section 6**.

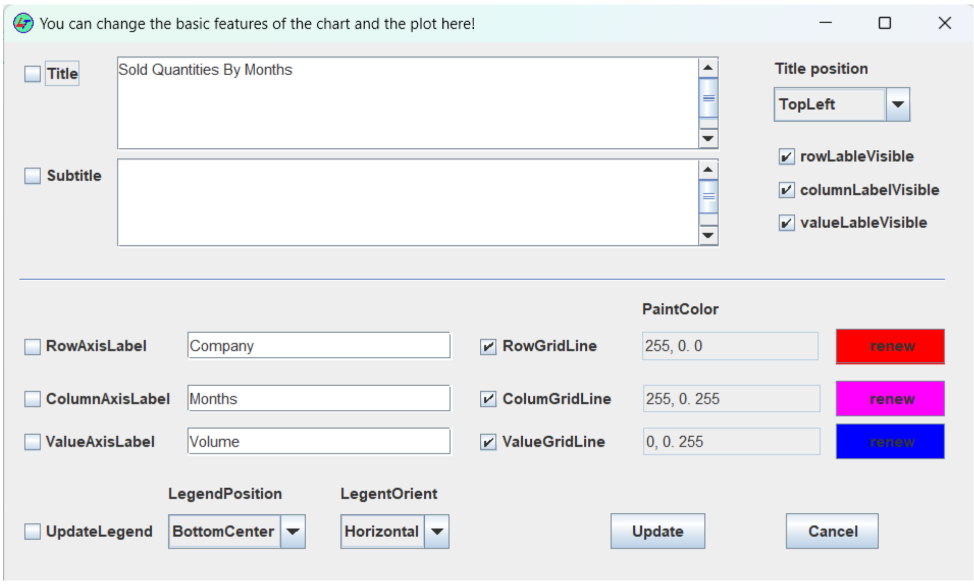


Figure 9.1.1 Basic feature adjustment panel of area chart

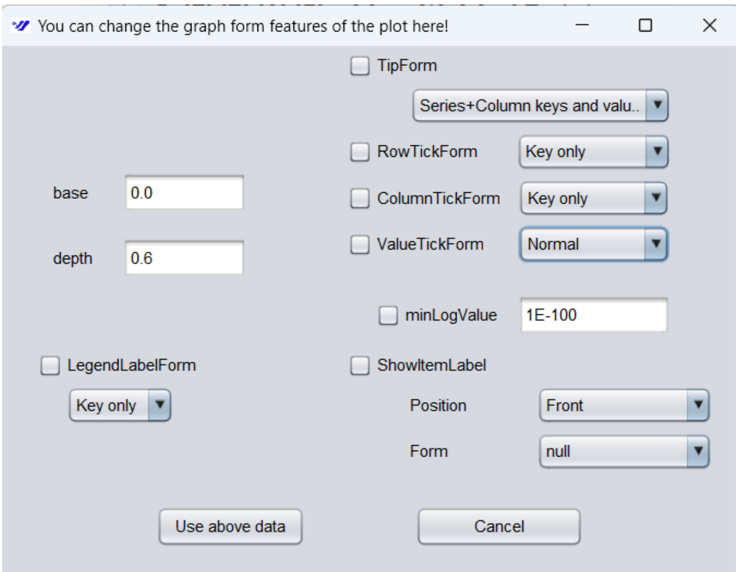
Figure 9.1.1 is the basic feature adjustment panel of the area chart. This panel is mainly used to adjust and modify the title content, title position, coordinate axis label content, control whether the coordinate label is visible, the grid line color of the coordinate box, and the layout position and display direction of the legend. The following describes how to implement the above functions one by one.

The title of the graph can be divided into the main title and the subtitle. The content of the main and subtitles can be directly entered and modified in the text box to the right of the **Title** and **Subtitle** check buttons; whether to use the newly revised main and subtitles can be achieved by checking the **Title** and **Subtitle** check buttons. The position of the title in the graphic display area can be selected through the drop-down list under the **Title position** label. **LC** provides 9 positions to choose from, including: top left corner (**TopLeft**), top center (**TopCenter**), top right corner (**TopRight**), center left (**CenterLeft**), center (**Center**), center right (**CenterRight**), bottom left corner (**BottomLeft**), bottom center (**BottomCenter**), bottom right corner (**BottomRight**).

The modification of the label content of the coordinate axis is similar to the modification of the title. This can be achieved by selecting the check buttons **RowAxisLable**, **ColumnAxisLabel** and **ValueAxisLable** and modifying the content of the text box behind them. Whether to visualize the coordinate axis label content can be achieved by selecting the check buttons **rowLabelVisible**, **columnLabelVisible** and **valueLableVisible**. The above three check buttons are checked by default.

In the default state, the coordinate box is drawn when it is behind the line of sight of the 3D system. The advantage of this treatment is that it will not block the graphics to be drawn. The color of the grid lines on the visible surface of the above box can be adjusted by the user. The modification method is to click the **renew** button on the right side of the text box and select it through the pop-up color selection panel. The RGB value of the color selected through the panel will be automatically updated to the text box on its left.

After completing the desired modification, you can visualize the adjustment selection to the newly drawn graphics by clicking the **Update** button on the basic feature adjustment panel. If you select the **Cancel** button, it means that this modification is abandoned and the graphics will not be changed.



9.1.2 Area Chart Advanced Feature Adjustment Panel

Figure 9.1.2 is the advanced feature adjustment panel of the area chart. The following describes the adjustment functions of this panel one by one. Users can change the base value of the area chart by modifying the value in the text box on the right side of the **base** label. Specifically, if the data value is less than the base value, the area chart is drawn downward with the plane where the base value is located as the base plane; if the data value is greater than the base value, the area chart is drawn upward. Users can adjust the area depth of each row of the area chart by modifying the value in the text box on the right side of the **depth** label. The value of depth here needs to be between 0 and 1, otherwise, the relevant area will disappear or overlap!

If the **LegendLableForm** checkbox is selected, the label display content of the legend can be changed according to the option selected in the drop-down list below it. Three options are available, including **Key only**, **Total**, and **Total2DP**. Key only means that only the name of the data series will appear; Total means that a bracket will be added after the name of the data series, and the integer in the bracket is the integer form of the sum of the values of the relevant series; the difference between the Total2DP and Total options is that the sum of the values of the former is displayed in the form of retaining two decimal places.

The checkboxes and drop-down lists related to **TipForm** are used to adjust the display of the data at the mouse position when the mouse is on the graph. The checkboxes and drop-down lists related to **RowTickForm** and **ColumnTickForm** are used to adjust the display of row and column coordinates. The options and processing methods of the above three functions are similar to the previous legend adjustment, so they will not be described in detail here.

The **ValueTickForm** checkbox and the drop-down list on its right are used to select the type of numerical coordinates. Three types are available, including **Normal**, **NormalPercent** and **Log**. Normal is a regular numerical axis; NormalPercent's coordinates will be displayed as percentages; Log changes the axis to a logarithmic axis. When the Log option is selected, the data values to be processed should all be greater than 0, otherwise they cannot be processed! When the Log option is selected, the minLogValue checkbox and the text box to its right can be used to change the minimum value of the Log axis. The default value is 1e-100.

The last function of the Advanced Features Adjustment Panel of the Area Chart is to control whether the data item content is displayed on the drawn graph and where it is drawn. The

ShowItemLabel checkbox and the two drop-down lists below it work together to achieve the above functions. The drop-down list on the right side of the **Position** label provides 4 options, namely **Front**, **Back**, **Center**, and **Font+Back**. Font+Back means that the corresponding data item content will be drawn before and after the data item position. The **Form** label provides the format for displaying the data item content. Figures 9.1.3 and 9.1.4 show the results of observing the data item label content before and after displaying it on the graph.

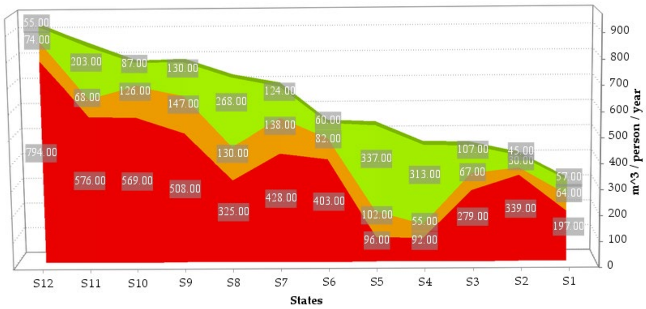


Figure 9.1.3 Data item labels showing their values

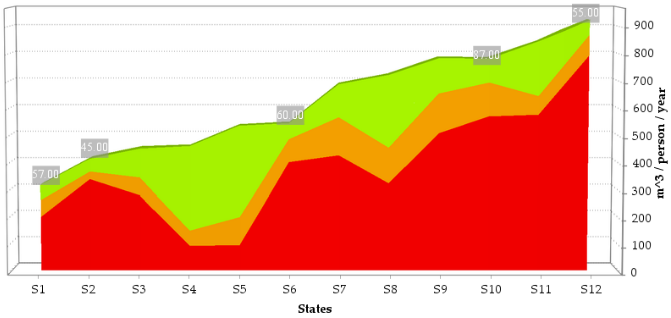


Figure 9.1.4 The data item label shows its value after the graphic is rotated 180 degrees

9.1.4. Area Chart Drawing Examples

Area charts can handle richer data and give attractive 3D displays. As examples, Figures 9.1.5, 9.1.6, and 9.1.7 show three different area charts.

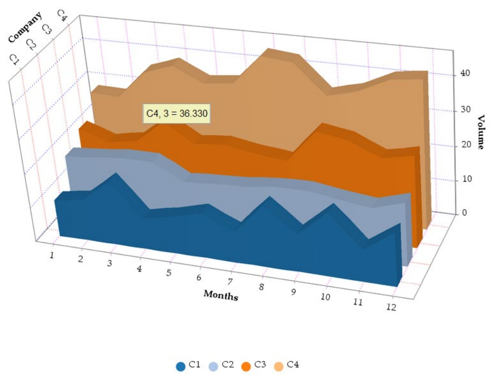


Figure 9.1.5 Area chart with four data series

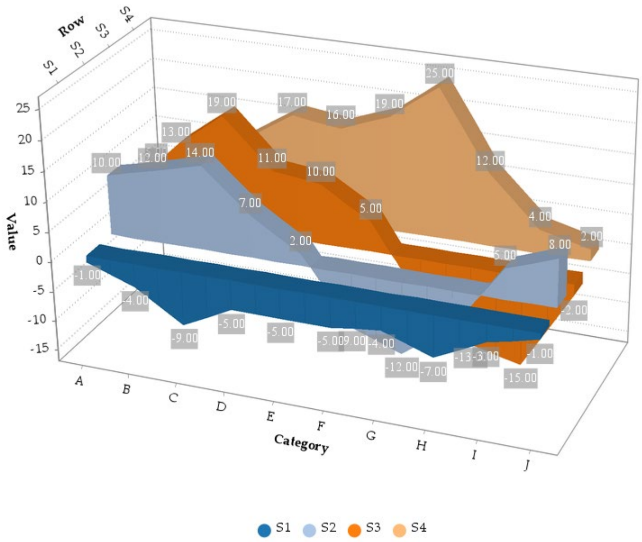


Figure 9.1.6 Area chart with positive and negative data based on 0.0 as the base value

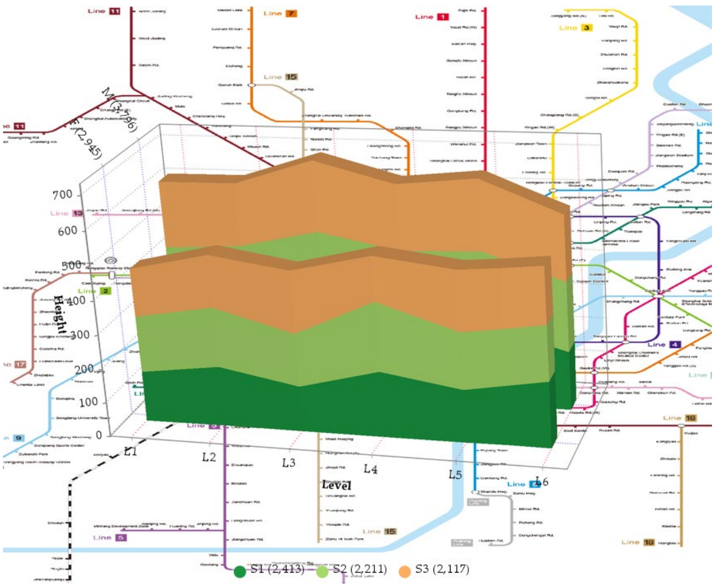


Figure 9.1.7 Cumulative Area Chart with Background

9.2. Bar chart drawing

9.2.1. Bar chart category

Bar charts can be divided into two categories according to the data type used. One uses key-value data, and the other uses XYZ data type. The data processed by the bar chart using key-value data is basically the same as that of the area chart, but it is presented in a different way. The bar chart using the XYZ data type can generate a bar chart with error bars. Since the bar chart represents the data as independent data elements or data elements combined as basic data units, it can highlight specific data.

9.2.2. Data file structure

The bar chart uses two types of data files. The key-value data structure file is exactly the same as the data file format processed by the area chart, so users can refer to the relevant introduction in Section 9.1. When the data to be processed is XYZ data, the data file can be further divided into two categories according to whether it contains error information. For an introduction to the two types of XYZ data combination files, see **Section 7.2.3**.

9.2.3. Feature Adjustment Panel

The panel for basic feature adjustment of bar charts is the same as the basic feature adjustment panel for area charts, so please refer to the relevant introduction in 9.1.3. The following only introduces the two types of advanced feature adjustment panels involved in bar charts.

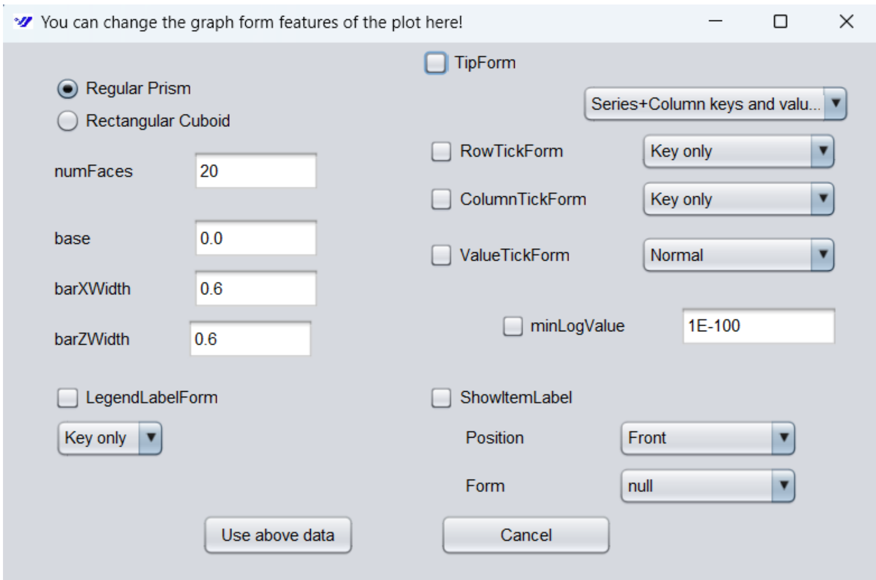


Figure 9.2.1 The first type of advanced feature adjustment panel for the histogram

Figure 9.2.1 shows the advanced feature adjustment panel provided by **LC** when the data processed by the bar chart is a key-value data combination. Most of the adjustment functions provided by this panel are the same as those provided by the advanced feature adjustment panel provided by **LC** when processing area charts, so we will only introduce the different parts here.

Two mutually constrained radio-shaped buttons appear on the upper left side of the panel. The two buttons represent the shape of the bar chart to be drawn. If the **Regular Prism** button is selected,

LC will draw the corresponding regular polygon upper and lower base cylinder according to the number of sides of the cylinder given by the user in the text box to the right of the **numFaces** label below the button. The radius of the upper and lower base of the cylinder is determined by the minimum of the two values given by the user in the text box to the right of the **barXWidth** and **barZWidth** labels. The range of the above two values is (0.0,1.0). If it is less than 0, the cylinder will disappear, and if it is greater than 1, the cylinder may overlap.

When the user selects the **Rectangular Cuboid** button, **LC** will draw a cylinder with two sides parallel to the X and Z axes, respectively. The bottom side length of the column is determined by the two values given by the user in the text boxes to the right of the **barXWidth** and **barZWidth** labels.

Except for the above differences, the advanced feature adjustment panel has the same functions as the advanced feature adjustment panel provided by **LC** when processing area charts.

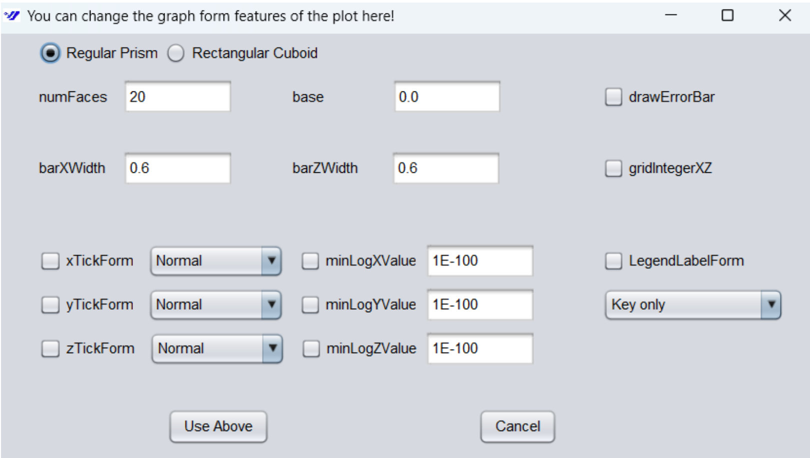


Figure 9.2.2 The second type of advanced feature adjustment panel for the histogram

Figure 9.2.2 is the bar chart advanced feature adjustment panel provided by **LC** when using XYZ data. This panel provides advanced image properties that users can control when processing XYZ data combinations. When we process key-value data, we can select the category of the value axis; like the above selection, when processing XYZ data, **LC** provides similar category selection functions for the three coordinate axes. These functions are implemented by the checkboxes, drop-down lists and text boxes at the bottom of the panel. For example, when the user needs to process the X-axis, the drop-down list in the row where the checkbox **xTickForm** is located, the **minLogValue** checkbox and the text box that follows it can be used to operate.

If the drawn data contains error information in the y direction, the user can select the **drawErrorBar** checkbox to make **LC** draw the corresponding error bar on the top of the column. When the data does not contain error information, the operation of this function will not have any actual effect.

Considering that the columns we deal with are generally distributed on a regular grid in the XZ coordinate plane, that is, the x and z coordinates of the XYZ data are the grid node coordinates on the XZ plane, when drawing the bar chart graph, the coordinates of the X and Z axes can only identify relevant integers. The above function can be achieved by selecting the **gridIntegerXZ** checkbox on the advanced panel.

In fact, Lovell Charts can use any data series distributed on the XZ plane to draw relevant bar charts!

9.2.4. Highlight settings and operations for marking specific data

The independent column display feature of the bar graph for independent data elements allows us to highlight specific data. For the convenience of users, **Lovell Charts** places the relevant function modules below the presentation area of the drawing graph. Users can achieve the above functions by selecting three buttons and clicking the mouse. Figure 9.2.3 shows the relevant operation interface. There are two check boxes and a button below the graphic interactive control area.

When the user clicks the bar menu item with the marking function and opens a data file, an interface similar to Figure 9.2.3 will appear. When the **Remove Highlight?** check box below the interface is not selected, the user can select or change the bar to be highlighted by clicking on the specific bar in the image. When the highlighted bar exists, the user can select **Show item labels?** to display the relevant data of all bars in the row and column where the highlighted bar is located. If the user needs to change the color used for highlighting, click the **HighLightColor** button, and **LC** will pop up a color selection panel for the user to select a new color. After the highlight color is selected, the drawn graphics will automatically change their highlight color.

If you want to clear the above highlight mark result, or keep the highlight operation invalid, the user can easily achieve it by selecting the **Remove Highlight?** checkbox.

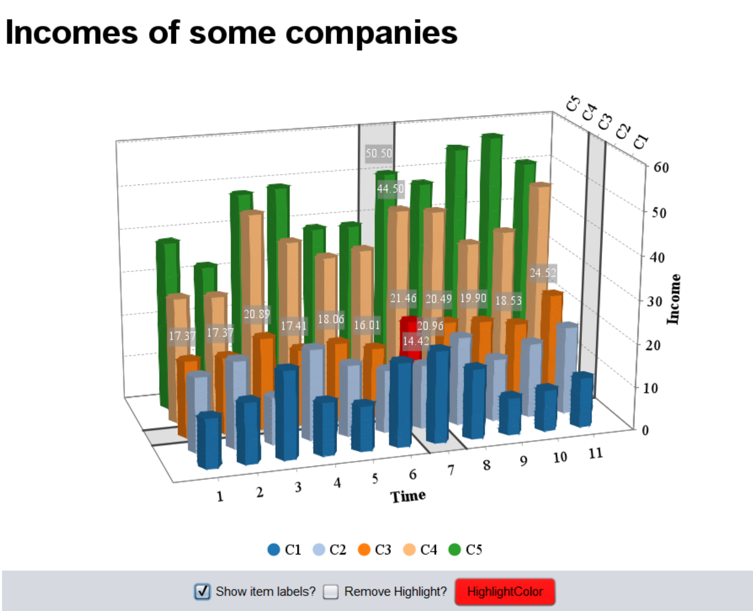


Figure 9.2.3 Histogram with highlighted data item controls

9.2.5. Histogram Example

Histogram is a widely used 3D chart. Histograms are rich in expressiveness, and users can draw a variety of customized histograms through **Lovell Charts**. Figures 9.2.5, 9.2.5, and 9.2.6 are three representative histograms drawn by using **LC**.

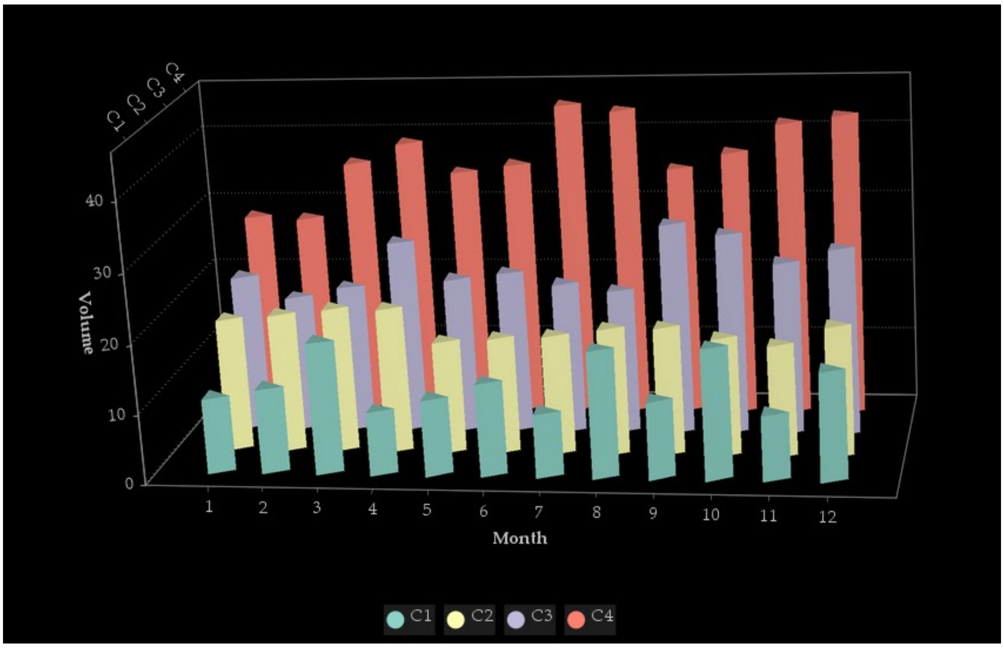


Figure 9.2.4 Triangular column chart with 4 rows of data series

Stacked Bar

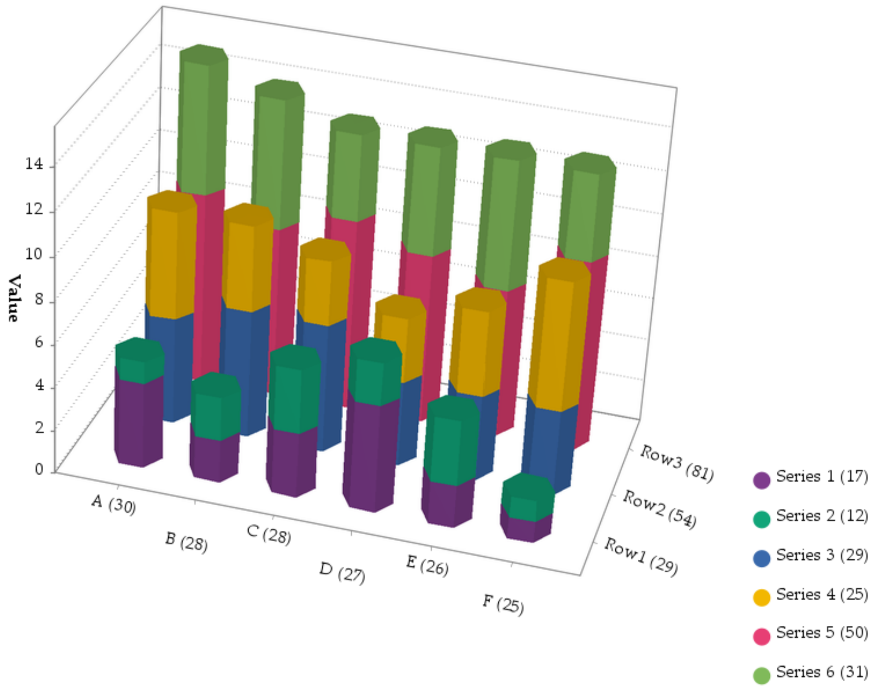


Figure 9.2.5 Histogram with 6 data series and 3 groups

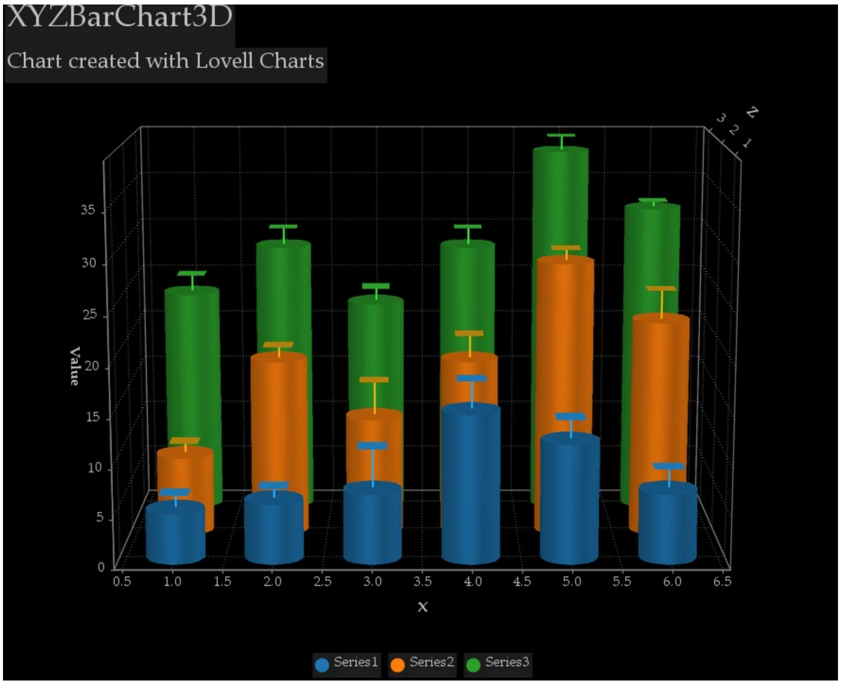


Figure 9.2.6 Histogram with error term based on XYZ data type

9.3. 3D Line Graph Drawing

3D line graph is a general term for various 3D graphs that mainly display data in the form of lines. 3D line graphs have very wide applications in reality. This section will introduce how to use **Lovell Charts** to draw three types of 3D line graphs.

9.3.1. Three types of 3D line graphs

The first type of 3D line graph deals with key-value data. The lines given by this type of line graph have 3D geometric dimensions, that is, in addition to length, the lines have width and thickness. Figure 9.3.1 is an example of this type of line graph.

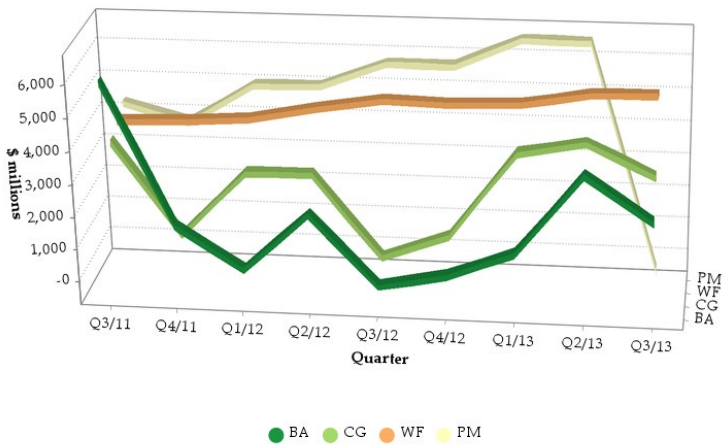


Figure 9.3.1 Example of the first type of 3D line graph

The second type of 3D line graph mainly deals with 3D curves and 3D curve trajectories with parameters. The data type processed by this type of line graph belongs to XYZ type data. Usually, data preparation is required by directly inputting the parameter function formula of the 3D curve. Figure 9.3.2 is an example of this type of 3D line graph. In this example figure, the projection of the 3D curve trajectory on the XY coordinate plane is also drawn at the same time.

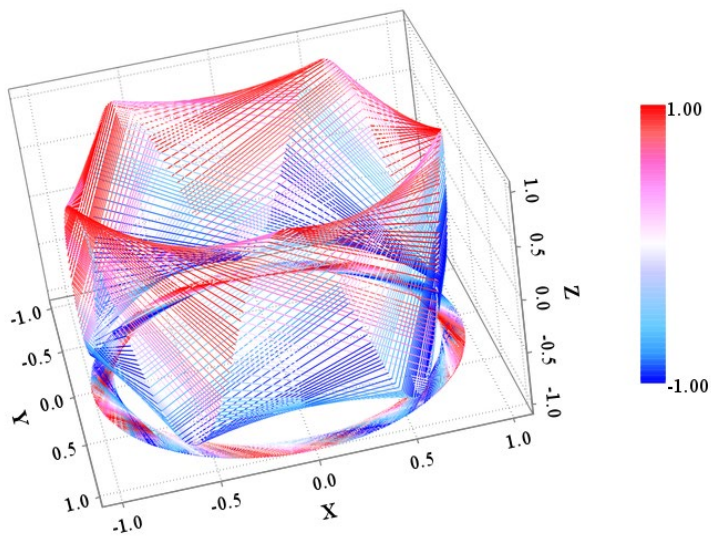


Figure 9.3.2 Example of the second type of 3D line graph

The third type of 3D line chart mainly deals with serialized XYZ data. Each sequence of data may be generated by a function or a group of data with the same interval and span. Figure 9.3.3 is an example of this type of line chart. If this type of chart is projected onto an appropriate coordinate plane, a 2D graph can be obtained. Lovell Charts not only provides the projection function, but also facilitates the above conversion by setting the range of the corresponding coordinate axis in the coordinate system.

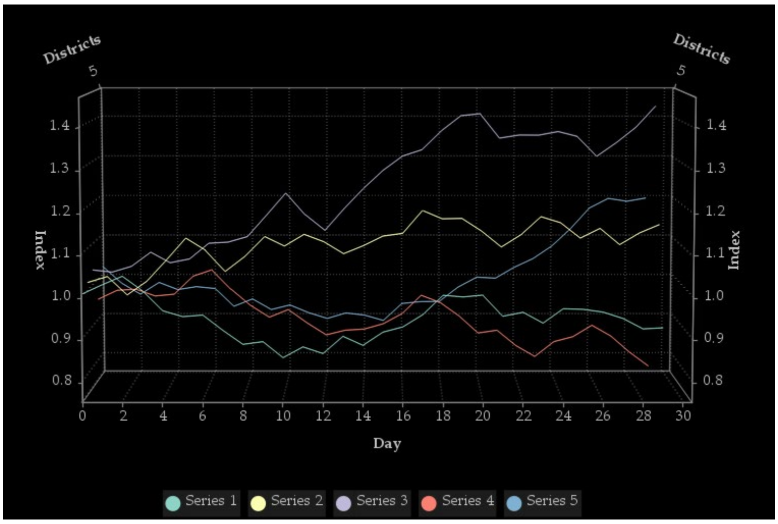


Figure 9.3.3 Example of the third type of 3D line graph

9.3.2. 3D line graph based on key-value data

The data type required for the first type of 3D line graph belongs to key-value data, and each sequence forms a group. For the relevant data files, please refer to **Section 7.2.2**.

The basic feature adjustment panel of this type of graphics is the same as the area graph introduced above, please refer to the relevant introduction.

The advanced feature adjustment panel of this type of 3D line graph is shown in Figure 9.3.4. Most of its functions have been introduced in detail in the relevant parts of the bar chart and area chart. Here, it is only necessary to specify that the text box after the **Width** and **Height** labels on the panel needs to enter the width and thickness of the line that the user wants to draw. The width value must be in the interval (0,1). If the width is greater than 1, the lines may overlap; if it is less than 0, the lines will disappear.

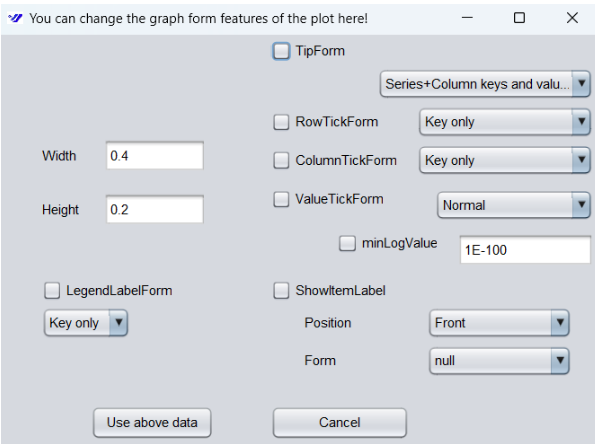


Figure 9.3.4 Advanced feature adjustment panel for the first type of 3D line graph

9.3.3. Space Curve Trajectory Diagram

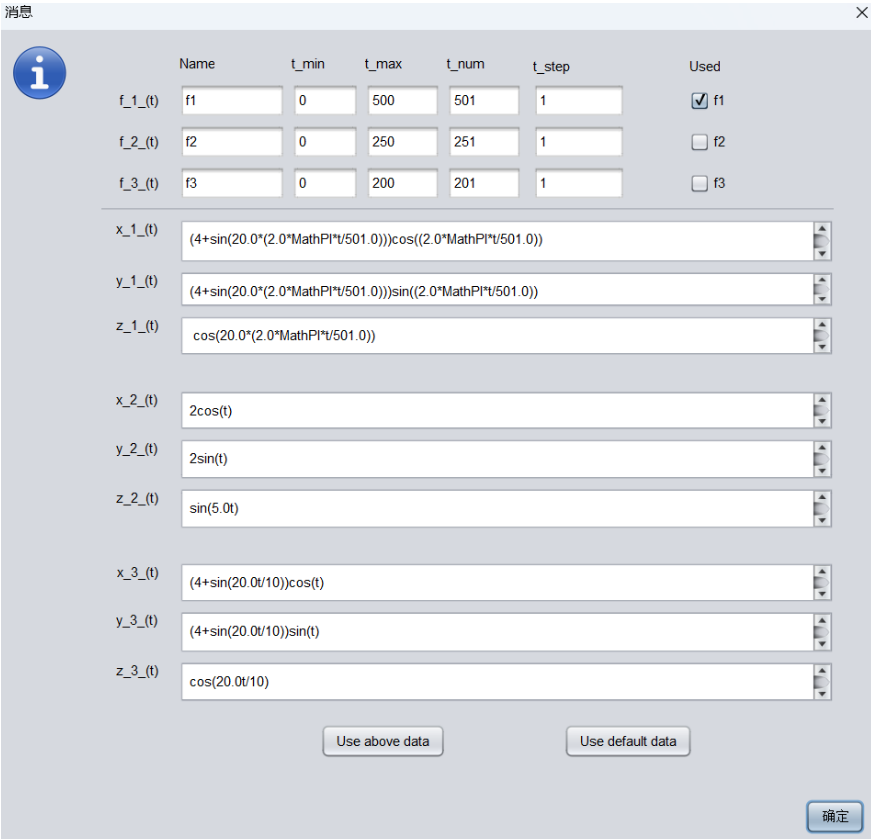


Figure 9.3.5 Function formula input panel for the second type of 3D line graph

When the user clicks the tree menu item corresponding to the second type of 3D line graph, **LC** will ask the user whether he wants to open a txt file to upload data or directly use the panel to enter the function formula. When the user chooses to enter the function formula directly, **LC** will pop up the formula input panel shown in Figure 9.3.5 for the user to use. When using the panel, the user can enter up to three function formulas with parameters at the same time, that is, draw the trajectory lines of three functions at the same time. **LC** assumes that the parameter of the three functions is t, but the three functions can have different parameter value ranges and number of sampling points. The x, y, and z coordinate values corresponding to each function vary with the value of the parameter t.

Above the formula input panel given in Figure 9.3.5, the user can enter the name of the function, the upper and lower limits of the parameter value, the number of sampling points, and the interval between adjacent sampling points. Note that **LC** will use the lower limit of the parameter value, the number of sampling points, and the interval between two adjacent sampling points in actual calculations, and will ignore the upper limit of the parameter value. The three functions entered can be used selectively by checking the corresponding function checkbox under the **Used** label on the right side of the panel.

Each function needs to input the corresponding formula $x(t)$, $y(t)$ and $z(t)$ for its three coordinates, i.e. x, y, z. The input method and specifications of the function are detailed in **Section 8**. After the formula is entered, the user confirms by clicking **Use above data**, or clicks **Use default data** to abandon the current input and use the **LC** built-in data, and finally clicks the confirmation button to draw the 3D line graph.

When adjusting the features of the second type of 3D line graph, the basic feature adjustment panel provided by **LC** is the same as the area chart and bar chart discussed above, so the user can refer to the adjustment of the above image for operation.

For this type of 3D line graph, **LC** provides an advanced feature adjustment panel as shown in Figure 9.3.6. This panel has some new functions that need to be explained here. First, the text box on the right side of the label **Object size** provides the user with the radius of the circumscribed sphere of the 3D geometry that visualizes these points when drawing the line.

Because there may be multiple function trajectories that need to be drawn at the same time, the geometry of the visualized sampling points on each trajectory can be different. **LC** provides 6 geometries for users to choose from. There are 6 drop-down lists in a row below the button **Series of Object Types**, each of which has 6 types of geometries to choose from. The selections in the 6 drop-down lists form an ordered set, and **LC** will draw the sampling points of the curve trajectory to be drawn in sequence according to the order and characteristics of the geometries in the set. When the number of trajectory lines is greater than 6, **LC** will start to reuse the geometries in the above set. If you need to use the selection in the drop-down list, the user also needs to select the button **Series of Object Types**.

The two check boxes named **drawPoints** and **drawLines** provide users with the function of choosing whether to draw trajectory points (i.e. sampling point geometries) and lines between sampling points in the graphics. Users can check both boxes as needed, or only check one of the above two check boxes.

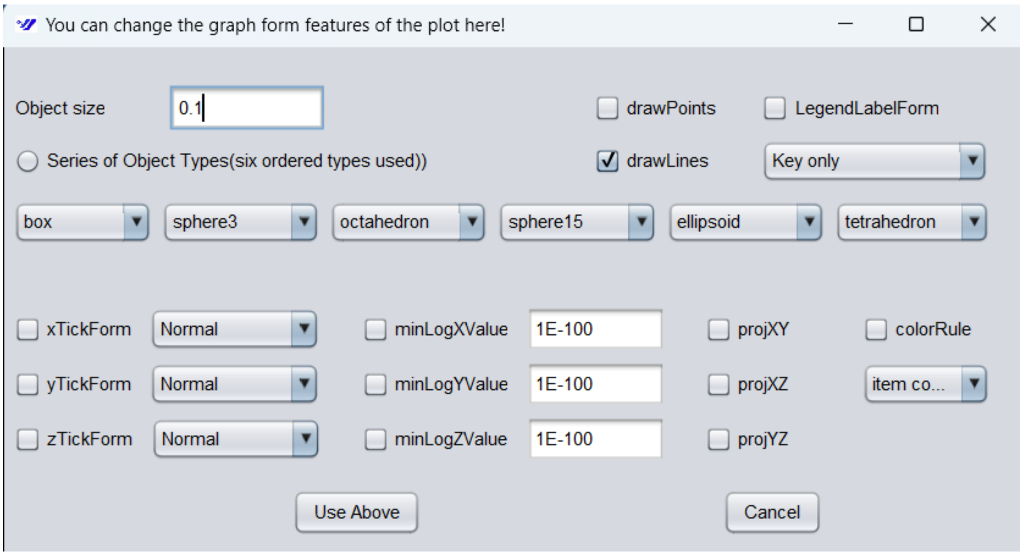


Figure 9.3.6 Advanced feature adjustment panel for the second type of 3D line graph

Lovell Charts also provides the function of drawing the projection of the curve trajectory on the coordinate plane. Users can decide whether to draw the coordinate plane projection and to which coordinate plane the projection is projected by checking the **projXY** checkbox, the **projXZ** checkbox, and the **projYZ** checkbox.

Another function of the advanced feature adjustment panel of the second type of 3D line chart is to adjust the coloring method of the 3D trajectory line. When there are two or more trajectory lines to be drawn at the same time, users can choose to change the color of each trajectory through the **Styles** menu. Here, a trajectory will be drawn in a specific color. However, when there is only one trajectory line to be drawn, **Lovell Charts** provides a more distinctive coloring scheme. Users can change the trajectory coloring scheme by selecting an option in the drop-down list below the **colorRule** checkbox. There are 4 options in the drop-down list, namely: x value, y value, z value, item count. The x value option means that the color of the points and lines on the trajectory is determined by the size of its x coordinate value; similarly, the y value and z value options respectively mean that the color of the points and lines on the trajectory is determined by the size of its y or z coordinate value. The option item count means that the color of the points and lines on the trajectory is determined by the cumulative value of the number of sampling points, that is, it changes with the actual spatial length of the trajectory. The user can select the above option and check the **colorRule** checkbox to implement a new coloring scheme. Note that when you need to draw two or more trajectory lines at the same time, the above operation is invalid.

9.3.4. Drawing of Sequential XYZ Data Line Chart

The third type of 3D line chart generally draws multiple XYZ sequence data with the same data volume and interval into spatial curves. The data input of this type of graphics can be either a txt data file or a set of functions directly input through the panel. Figure 9.3.7 shows the function input panel provided by **LC** when making this type of graphics. **LC** presets that up to 6 3D curves can be drawn simultaneously by inputting mathematical formulas. It is assumed that the independent variable of all functions is t, the value range and sampling number of all function independent variables, and the independent variable interval between adjacent sampling points are the same. The above characteristics of the independent variable can be adjusted and modified at the top of the panel in Figure 9.3.7. Note that **LC** will not use the upper limit **t_max** of the independent variable in actual calculations!

At the bottom of the function input panel shown in Figure 9.3.7, users can enter up to 6 function names and corresponding formulas. To select a specific formula, you need to check the checkboxes marked from **s1** to **s6**.

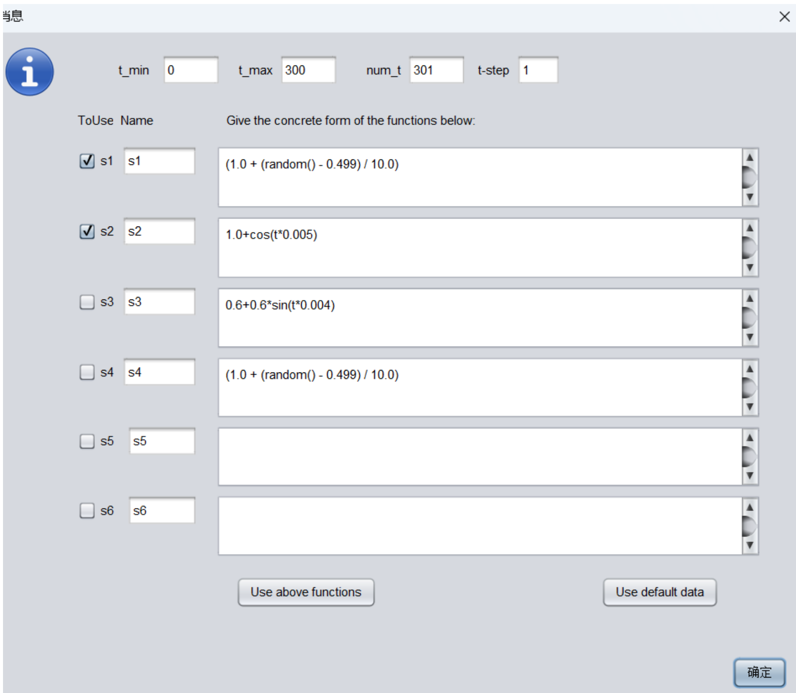


Figure 9.3.7 Function formula input panel for the third type of 3D line graph

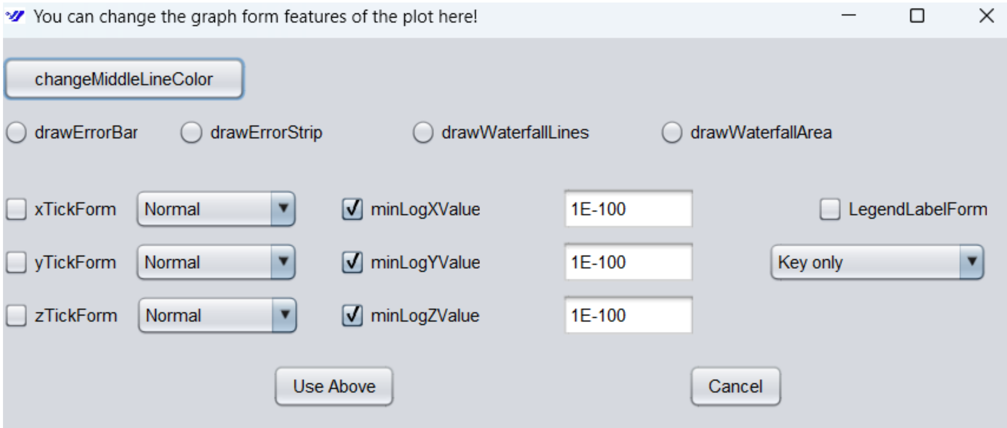


Figure 9.3.8 Advanced feature adjustment panel for the third type of 3D line graph

For the third type of 3D line chart, **Lovell Charts** provides an advanced feature adjustment panel as shown in Figure 9.3.8. The functions of the button and four radio buttons above the panel need to be explained here. When drawing the third type of 3D line chart, users can choose to draw waterfall lines or waterfall surfaces that droop from the trajectory line. If the provided XYZ data contains error data in the y direction, users can also choose to draw error lines that intersect the trajectory line and are perpendicular to the XZ coordinate plane at the sampling point, or error strips with the height of the error line at the sampling point as the half width. When drawing error strips, the center line of the strip, that is, the color of the original trajectory line can also be customized. The selection of drawing error lines, error strips, drooping waterfall lines, and drooping waterfall surfaces can be determined by checking the four radio buttons **drawErrorBar**, **drawErrorStrip**, **drawWaterfallLines**, and **drawWaterfallArea**; and the color of the middle line of the error strip can be achieved by clicking the button **changeMiddleLineColor** through the color selection panel provided by **LC**.

9.3.5. Dynamic drawing instructions and 3D sample graphs of trajectories

3D line graphs are widely used in reality. **Lovell Charts** also provides the function of dynamically drawing the second type of function trajectory. Users can select the corresponding tree menu option and check the default drawing to clarify the menu option with dynamic drawing capabilities. By entering from the corresponding menu, **Lovell Charts** will automatically dynamically draw the corresponding function trajectory. At present, **Lovell Charts** does not provide speed control for dynamic drawing of function trajectories. Subsequent versions may provide more comprehensive dynamic drawing control functions.

Figure 9.3.9 shows the result of drawing three function trajectories at the same time; and Figure 9.3.10 shows the result of drawing the Lorenz system using Lovell Charts.

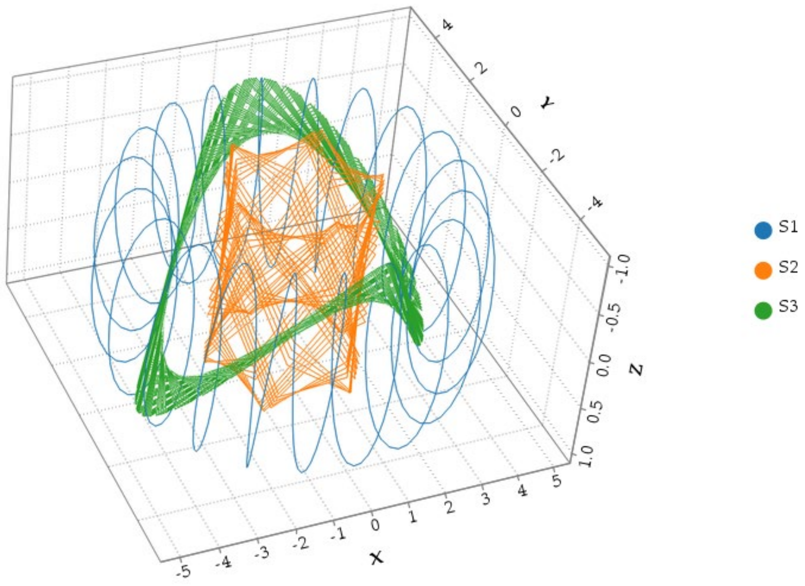


Figure 9.3.9 Simultaneous drawing of three trajectory lines

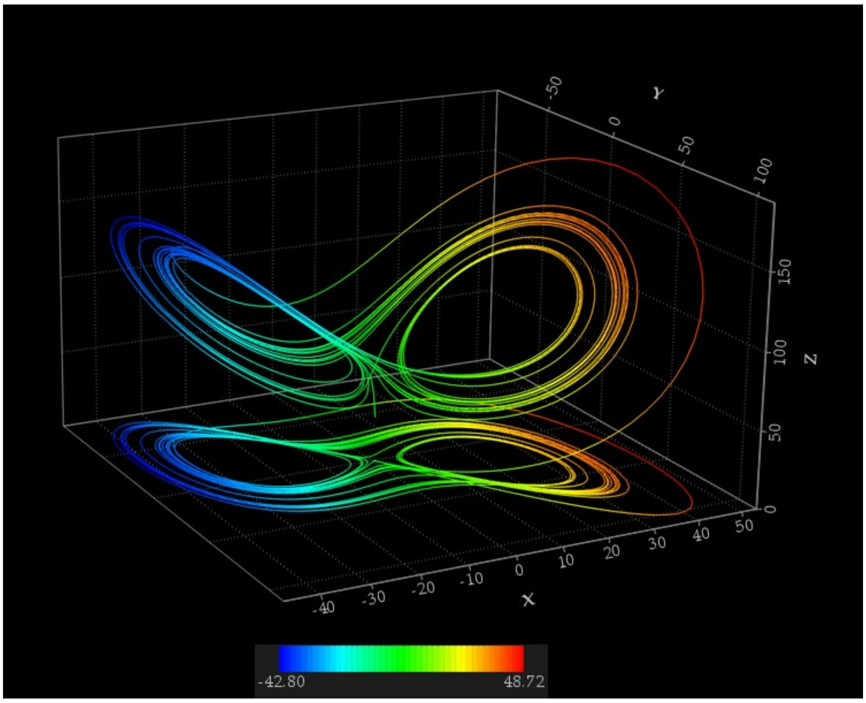


Figure 9.3.10 Simulated 3D line graph of the Lorenz system

9.4. Drawing of pie charts, torus charts and pyramid 3D charts

9.4.1. Data files

The basic data required for pie charts, torus charts and pyramid 3D charts are in the same format. The related single-value single-key data files are composed of a series of data entries with the same structure, each of which is composed of a string data and a real number value. Please refer to **Section 7.2.1** for the introduction of the structure of this type of data and the data files that constitute it.

9.4.2. Common basic feature adjustment panel

The three types of graphics have the same basic feature adjustment panel as shown in Figure 9.4.1. Compared with the basic feature adjustment panels of other types of graphics that have been introduced, this panel has removed the functions related to the coordinate axis. This is because pie charts, torus charts and pyramid 3D charts are directly presented without any visual coordinate system. For an introduction to the functions of this panel, please refer to the introduction of the area chart related panels in **Section 9.1.3**.

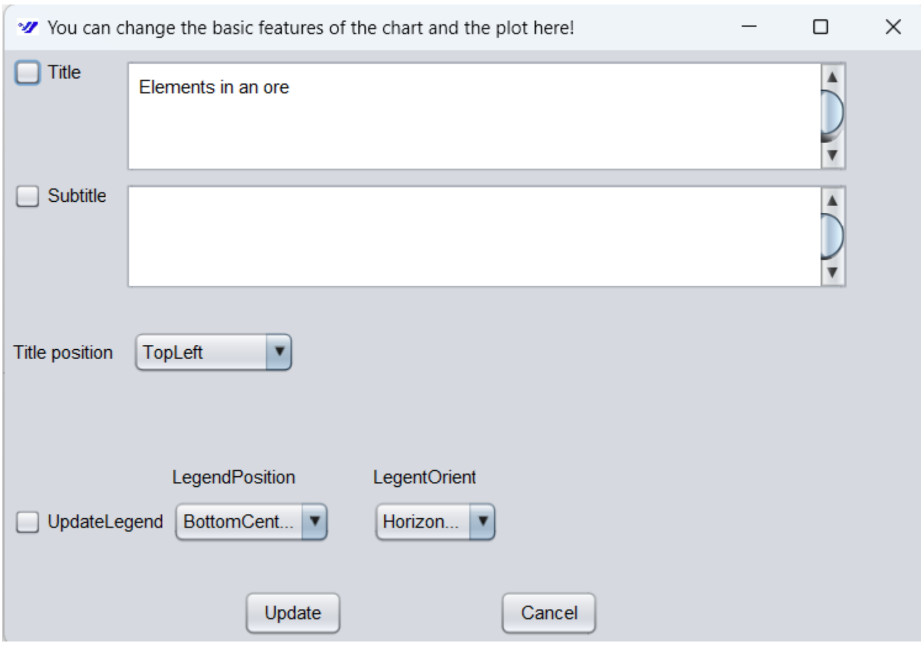


Figure 9.4.1 Basic feature adjustment panel common to the three types of graphs

9.4.3. Different Advanced Feature Adjustment Panels

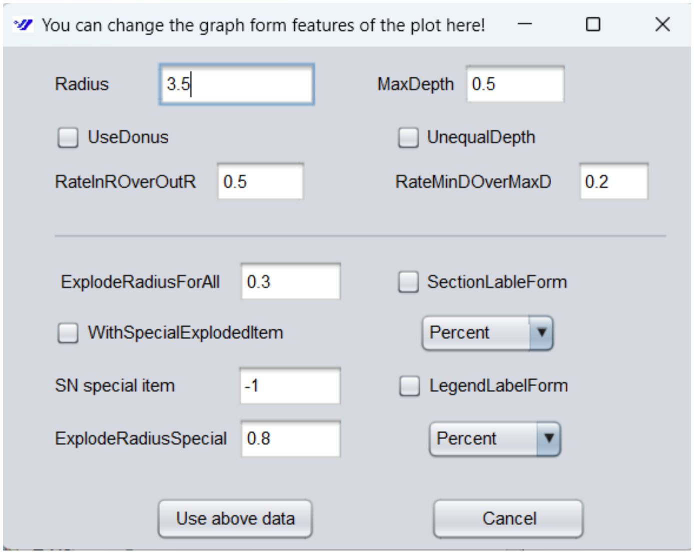


Figure 9.4.2 Advanced feature adjustment panel for pie chart

Figure 9.4.2 is the advanced feature adjustment panel of the pie chart. Users can enter the radius of the pie chart in the text box to the right of the **Radius** label. If you need to draw a donus-type hollow pie chart, you can enter the ratio of the inner radius to the pie radius in the text box to the right of the label **RateInROverOutR**. The ratio should be in the interval (0,1.0). At the same time, check the checkbox **UseDonus** to complete the confirmation of drawing a donus-type pie chart.

Users can enter the maximum thickness of the pie chart in the text box to the right of the **MaxDepth** label. If you need to draw a pie chart with unequal thickness, you need to check the checkbox **UnequalDepth** and enter the ratio of the minimum thickness to the maximum thickness in the text box to the right of the label **RateMinDOverMaxD**. When drawing a pie chart with unequal thickness, **Lovell Charts** will determine the thickness of the corresponding pie block between the minimum and maximum thicknesses according to the relative size of different data items.

If you need to have gaps between the pie blocks, you can enter the distance value for all pie blocks to move outward in the text box to the right of the label **ExplodeRadiusForAll**. If you need to highlight a specific pie, you can enter the corresponding data number in the text box on the right side of **SN special item**, and enter the specific distance value of the pie to move outward in the text box on the right side of the label **ExplodeRadiusSpecial**. Finally, check the checkbox **WithSpecialExplodedItem** to complete the selection of the specific pie. Note that when the input data number is -1, the system defaults to no specific data being selected.

In the lower right corner of the advanced feature adjustment panel of the pie chart, you can select the format of the label (**Section Label**) on the pie and the label (**Legend Label**) of the legend. Both have the same optional formats. If you want to select the label format of the pie, the user needs to check the checkbox **SectionLabelForm**, and select the required format from the drop-down list below the checkbox. The specific format can be seen in Figure 9.4.3. The meanings of the five formats are as follows: **Key only** means that only the key value of the data is displayed; **Percent** displays the percentage of the key value and the real value; **Percent2DP** displays the percentage of the key value and the real value with two decimal places; **Value** will only display the key value and the real value; **Value2DP** displays the key value and the real value with two decimal places.

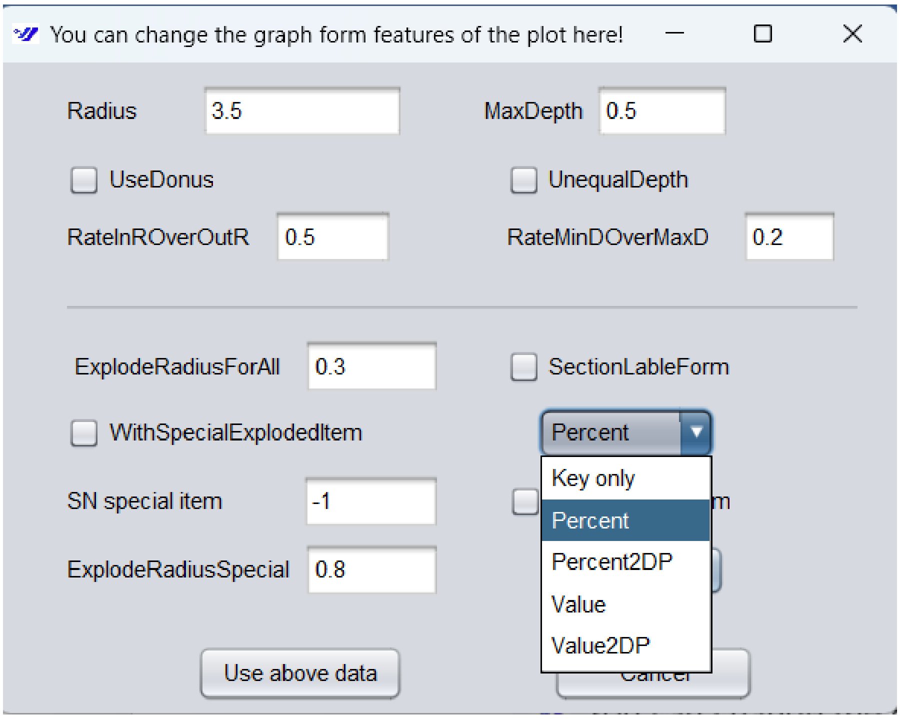


Figure 9.4.3 Label selection in the Advanced Feature Adjustment Panel

Compared with the advanced feature adjustment panel of the pie chart, the corresponding panel of the torus chart is relatively simple, as shown in Figure 9.4.4. The text box to the right of the label **NumFaces** can be used to enter the number of faces separating the small ring of the torus chart. If the input value is large, the image will appear in an arc shape; otherwise, it will appear in a polyhedron shape. However, large values require a large amount of calculation. In addition, on the advanced feature adjustment panel of the torus chart, users can enter the radius values of the large and small circles of the torus chart in the two text boxes to the right of the labels **RadiusBig** and **RadiusSmall**.

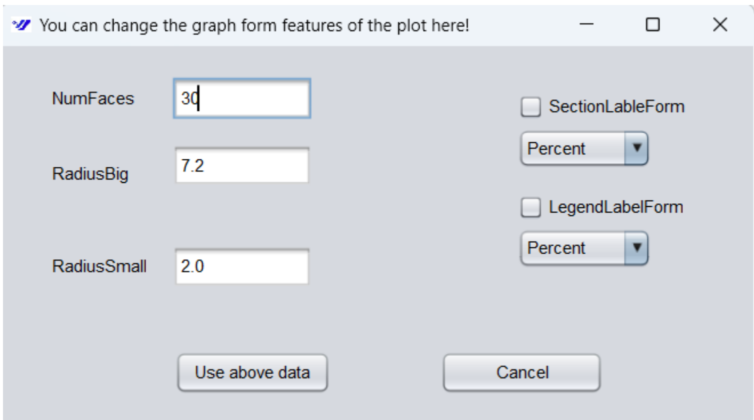


Figure 9.4.4 Advanced feature adjustment panel for Torus graph

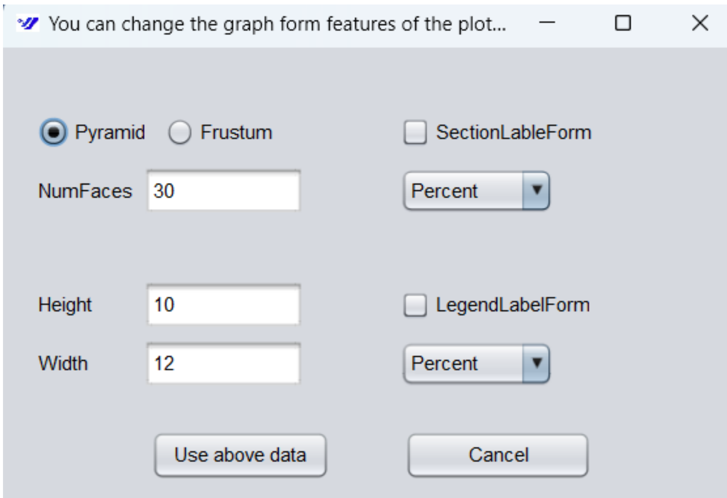


Figure 9.4.5 Advanced feature adjustment panel for pyramid 3D graph

Figure 9.4.5 is the advanced feature adjustment panel of the pyramid 3D graph provided by **LC**. Users can modify or adjust the height and bottom diameter of the drawn pyramid structure through this panel, and control the number of sides of the structure. When the user selects the **Pyramid** button, a standard pyramid structure with four sides will be drawn; and when the **Frustum** button is selected, a polyhedral cone with a given number of sides can be drawn. Users can enter the number of sides of the polyhedral cone in the text box to the right of the label **NumFaces**; enter the height and bottom diameter of the pyramid structure in the two text boxes to the right of the labels **Height** and **Width** respectively. The other functions of this panel are the same as the related operation methods of the previous pie chart and torus chart.

9.4.4. Example picture display

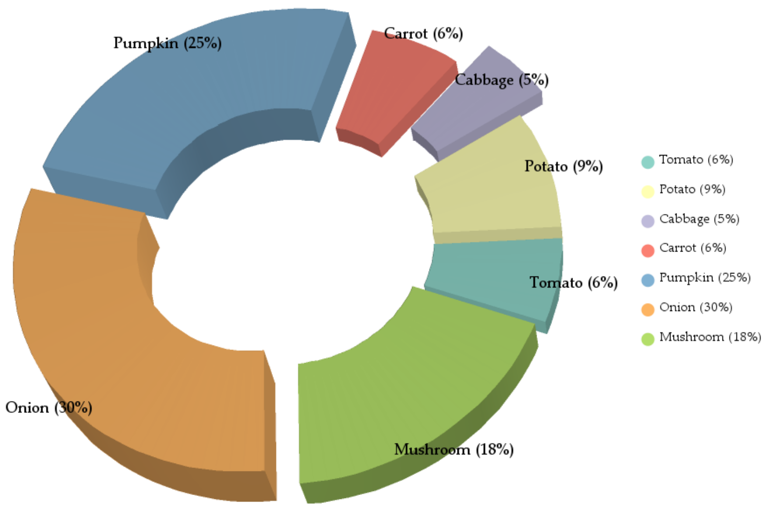


Figure 9.4.6 Pie chart with thickness differences and specific data bulging outwards

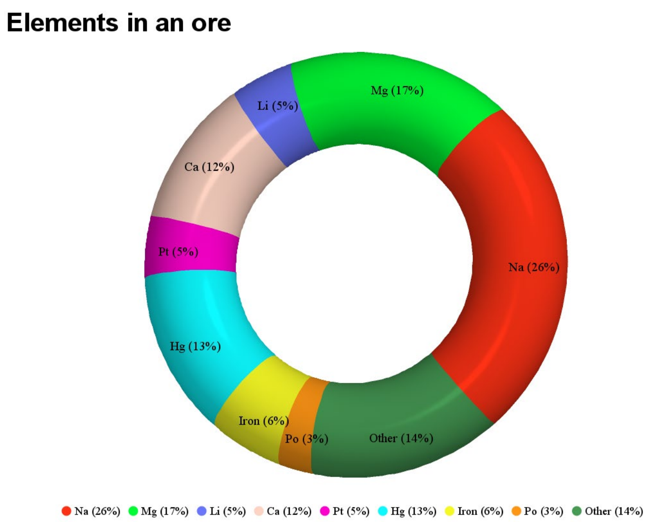


Figure 9.4.7 An example of a torus graph

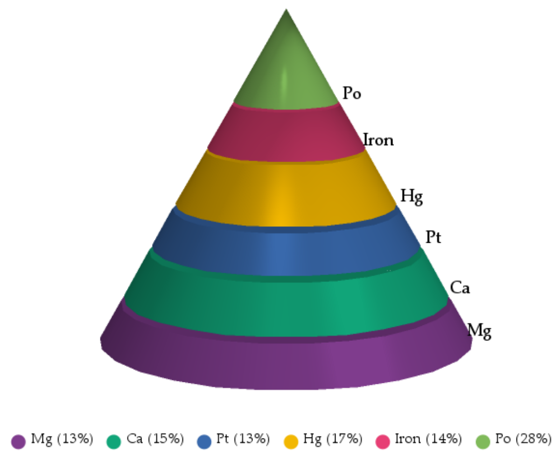


Figure 9.4.8 Pyramid-shaped 3D graph with cone shape

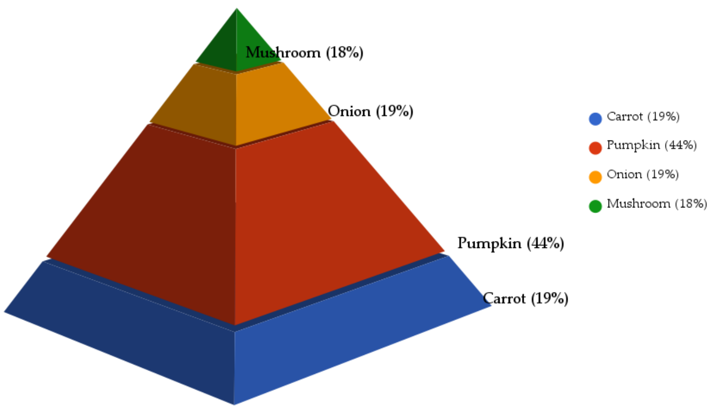


Figure 9.4.9 Pyramid-shaped 3D graph with four sides

With **Lovell Charts** software, users can draw a variety of expressive pie charts, doughnut charts and pyramid-type 3D graphs. Figures 9.4.6-9 are four representative graphs drawn using **LC**, from which users can see the actual effectiveness of **LC**.

9.5. Scatter plot

9.5.1. Scatter plot data format

Scatter plot visualizes XYZ data. According to the difference in the processed data content, scatter plots can be divided into scatter plots without errors and scatter plots with error lines. If the processed XYZ data contains error data, a scatter plot with error lines can be drawn. For the introduction and examples of XYZ data files with error information and without error information, please refer to the relevant content in **Section 7.2.3**.

9.5.2. Scatter plot advanced feature adjustment

LC can draw scatter plots according to the default settings using txt file data. For scatter plots drawn according to the default values, users can select the Features menu above the main operation interface to adjust their basic features and advanced features. The operation method of the scatter plot basic feature adjustment panel is the same as the related operation of the basic panel of the area 3D charts introduced earlier, so it will not be repeated here. The following describes how to operate the corresponding advanced feature adjustment panel when drawing general scatter plots, scatter plots with droop lines, and scatter plots with error lines.

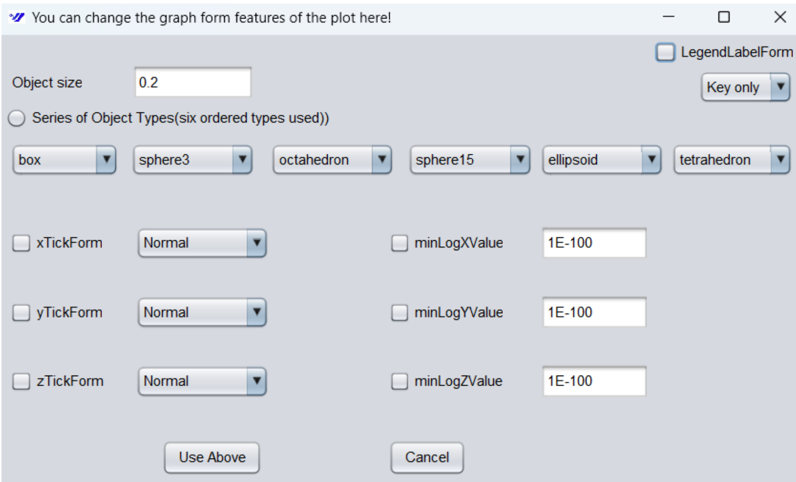


Figure 9.5.1 Advanced feature adjustment panel for general scatter plot

The advanced feature adjustment panel of a general scatter plot is shown in Figure 9.5.1. The data in the scatter plot corresponds to the position of a spatial point, and **LC** will draw a specific geometry to display the data. The geometry representing a point can be selected from a set of 6 basic geometries. At the same time, since the XYZ data processed by the scatter plot may belong to different sequences, different geometries can be used to distinguish data belonging to different sequences. **LC** assumes that an ordered set of six geometries is given. When **LC** draws points of different sequences, it will select geometries from the above set in turn to visualize the points of the same sequence. When the number of sequences is greater than 6, **LC** will reselect from the first geometry in the above geometry set. **LC** also assumes that the radius of the circumscribed sphere of all geometries in the same scatter plot is the same.

Based on the above assumption, the user can enter the diameter of the circumscribed sphere of the geometry in the text box to the right of the **Object size** label on the feature adjustment panel shown in Figure 9.5.1. Select the button **Series of Object Types**, and select 6 geometric shapes for the ordered set of geometric bodies in the 6 drop-down lists below the button to complete the adjustment of all geometric bodies for the visualization of sequence data.

In addition to the above functions, the advanced feature adjustment panel of the general scatter plot also provides the functions of modifying the legend format and selecting the type for each axis. The operation of these functions has been introduced in the drawing of other types of graphics, and will not be repeated here. One thing to note is that when a logarithmic coordinate is selected for a specified axis, the value range of the axis should not include negative numbers and zero values, otherwise it will violate the logarithmic operation principle.

When drawing a scatter plot with a droop line, **Lovell Charts** provides an advanced feature adjustment panel as shown in Figure 9.5.2. You can determine whether to draw a droop line perpendicular to the XY, XZ and YZ coordinate planes by checking **dropXY**, **dropXZ** and **dropYZ**. And by checking **projXY**, **projXZ** and **projYZ**, you can determine whether to draw projections on the XY, XZ and YZ coordinate planes. The advanced feature adjustment panel of the scatter plot with error bars is shown in Figure 9.5.3. You can determine whether to draw error bars in the x, y, and z directions by checking **xErrorBar**, **yErrorBar**, and **zErrorBar** on this panel.

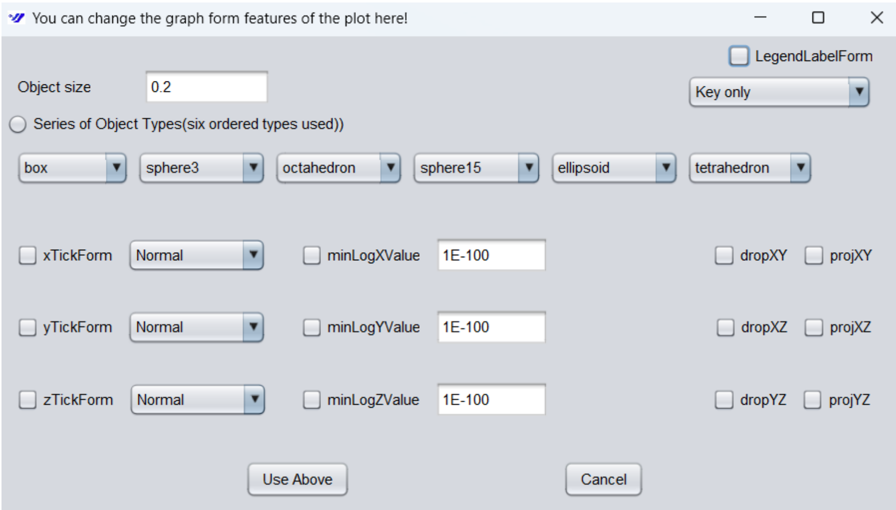


Figure 9.5.2 Advanced feature adjustment panel for scatter plot with droop lines

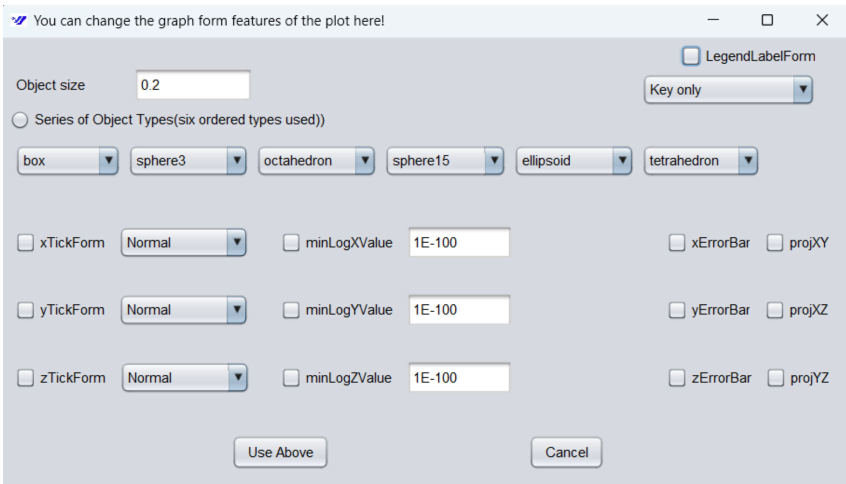


Figure 9.5.3 Advanced feature adjustment panel for scatter plot with error bars

9.5.3. Highlighting a specific area in a scatter plot

When drawing a scatter plot, it is often necessary to highlight the data (or points) in a specific area to facilitate observation of related data. **Lovell Charts** provides a corresponding highlighting tool. Users can open the Features menu on the main operation interface and select the **Maker Scatter Space** menu item from the bottom of the menu to open the highlighting control panel for the scatter plot. The location of the highlighting menu item is shown in Figure 9.5.4, and the pop-up highlighting control panel for the scatter plot is shown in Figure 9.5.5. The highlighting control panel of the scatter plot can be used to select the value range of each coordinate axis corresponding to the area to be marked, the fill color within the marked range on the corresponding coordinate plane, and whether to display the label and label position of the marked range in the figure. At the same time, the geometric bodies in the highlighted area can also be marked with specific colors.

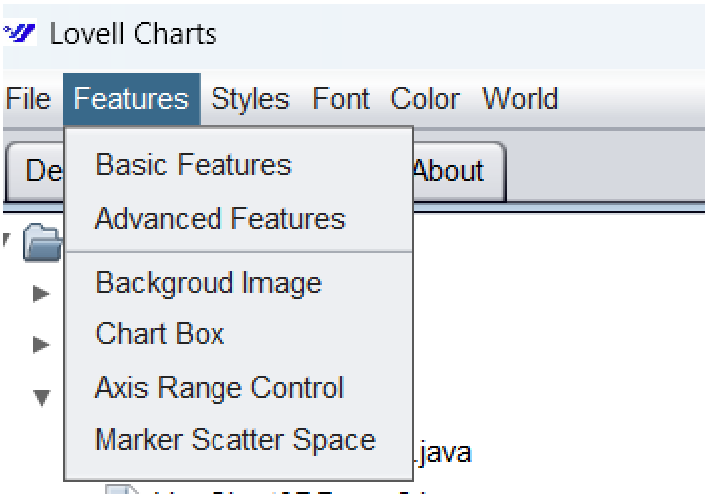


Figure 9.5.4 Highlighting the menu item selection

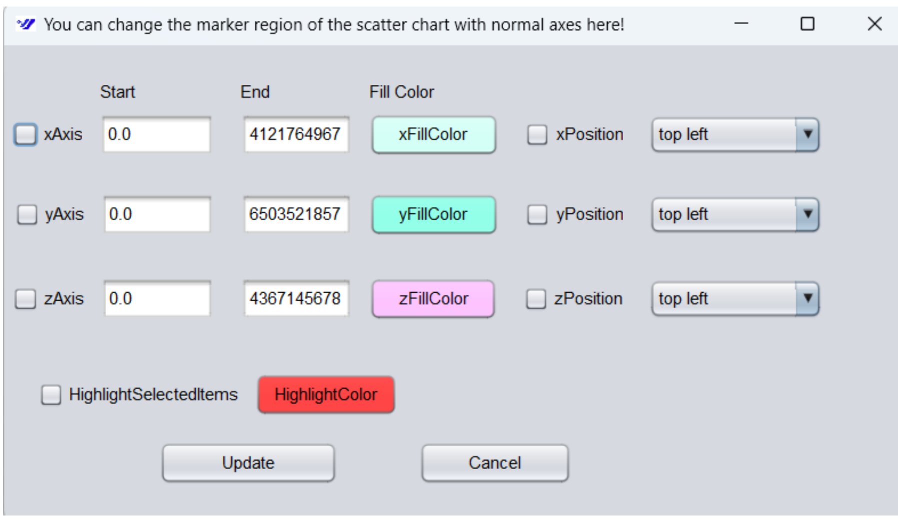


Figure 9.5.5 Control panel for highlighting specific areas of a scatter plot

Taking how to set the highlight range of the x-axis as an example, first check the **xAxis** checkbox, then enter the coordinate range to be highlighted in the two text boxes to the right of the checkbox, and then click the **xFillColor** button to select the fill color of the coordinate plane related to the range through the pop-up color selection window. If you select the **xPosition** button and select the corresponding position type in the drop-down list to the right of the button, you can complete the determination and modification of the position of the label of the relevant highlight range. The operation of other axes is the same as above. If you need to change the mark color of the points in the highlight area, you can check the **HighlightSelectedItems** checkbox and click the button behind it to select the required color from the pop-up color selection panel. The initial value of the highlight range of each axis in the highlight control panel is the value range of the corresponding axis.

9.5.4. Scatter plot illustrations

Scatter plots are a common type of 3D graph. Figures 9.5.6-9 are several scatter plot illustrations drawn using **Lovell Charts**.

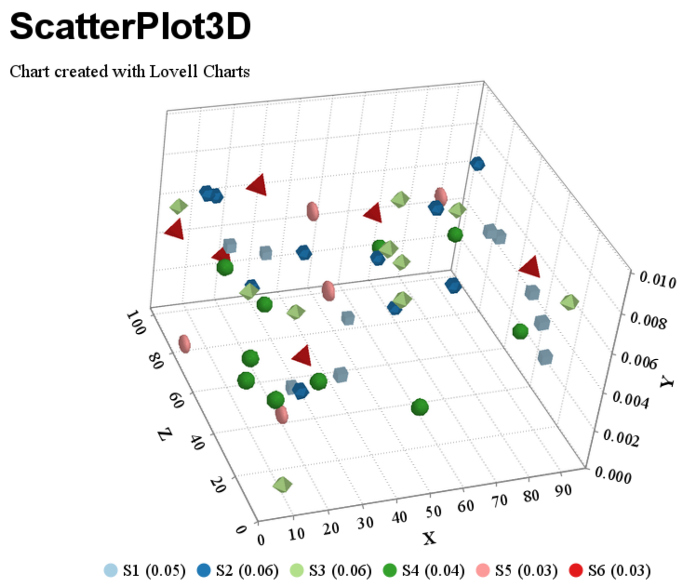


Figure 9.5.6 Scatter plot with 6 series

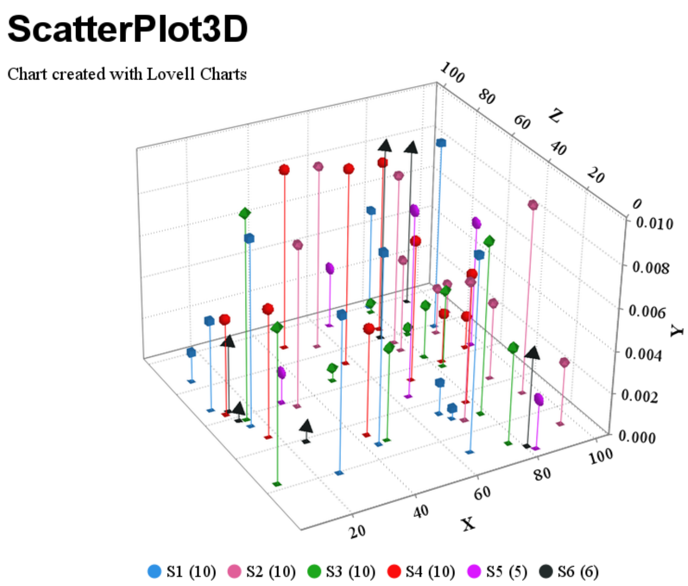


Figure 9.5.7 Scatter plot with drop line and projection

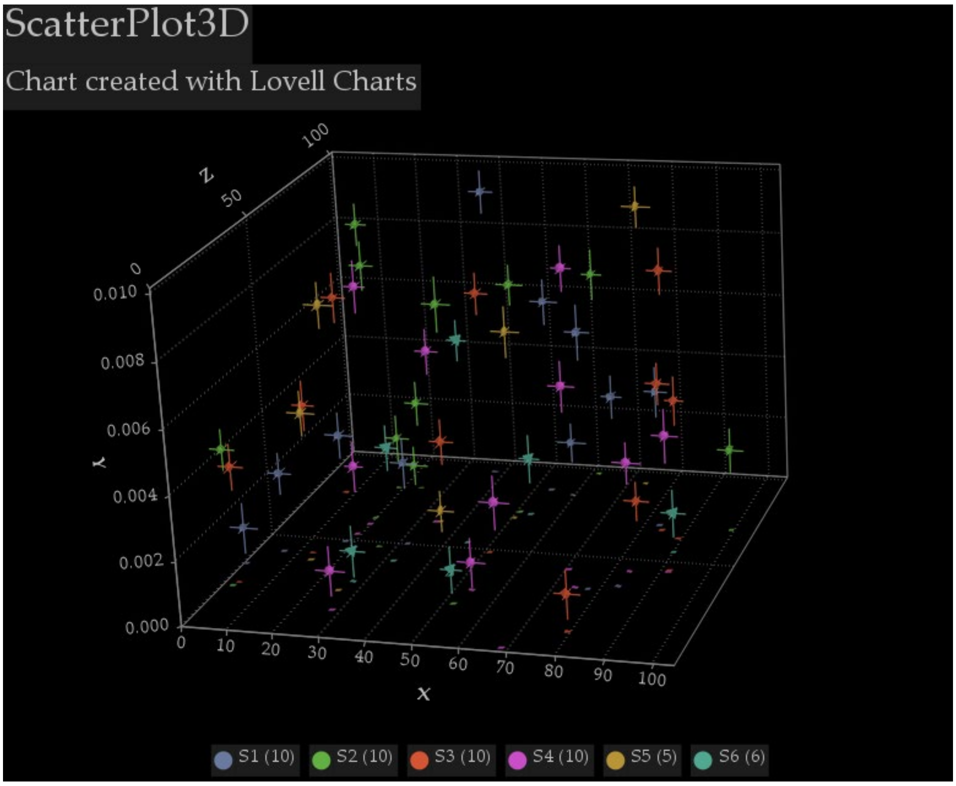


Figure 9.5.8 Scatter plot with error bars and projection

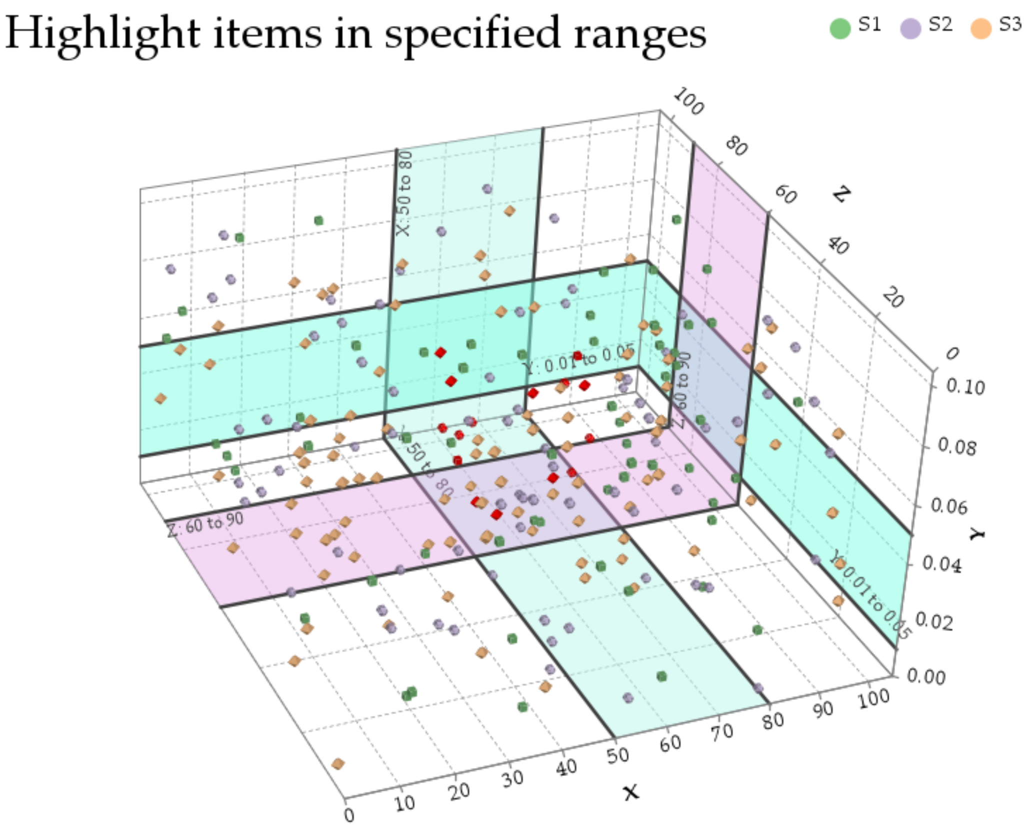


Figure 9.5.9 Scatter plot with highlighted areas

9.6. Surface Graph Drawing

9.6.1. Surface Graph Data Format

In **Lovell Charts**, the data structure of surface graph visualization is different from other 3D graphics. The matrix data structure is the standard data format for surface graph visualization. For more information about the matrix data structure and related data file formats, please refer to **Section 7.2.4**.

9.6.2. Surface Graph Function Formula Input

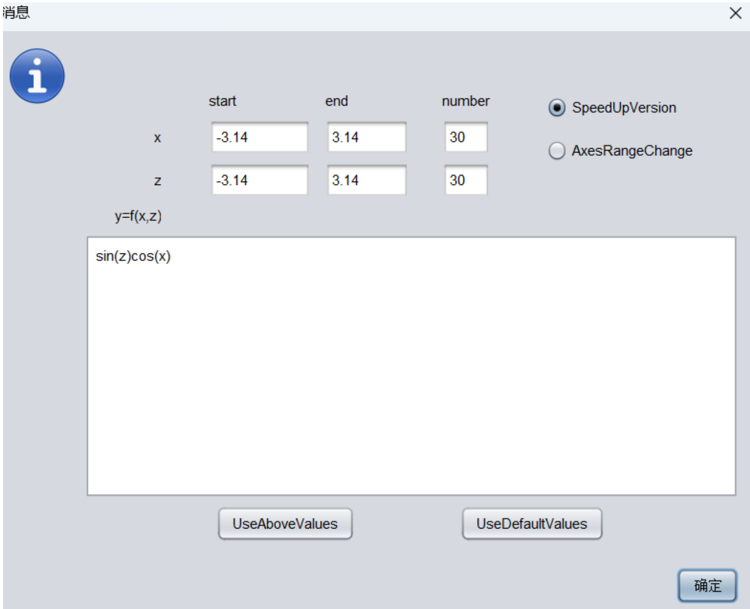


Figure 9.6.1 Single function formula input panel for surface plot

Figure 9.6.1 shows the panel provided by **LC** when entering a single function formula. At the top of the panel, the user can enter the value range of the function on the x and z axes, as well as the number of sampling points. The specific function formula with x and z as independent variables can be entered in the text box below the label $y = f(x, z)$. If the button **SpeedUpVersion** on the upper right of the panel is selected, it means that there is no need to adjust the range of the coordinate axis after drawing the graph, so the software's acceleration algorithm can be used to process the data; and when the button **AxesRangeChange** is selected, it means that the value range of the coordinate axis needs to be changed in the later modification of the graph. In this case, **LC** will not use the acceleration algorithm to process the data in order to ensure the quality of the later graph drawing.

Figure 9.6.2 shows the input panel when multiple function formulas need to be entered. The operation of this panel needs to be explained in two cases. The first case is that only multiple functions need to be drawn without considering the intersection of the surface and the 3D plane. In this case, the user only needs to consider entering the value range of the x and z variables in the upper left corner of the panel, and enter up to 4 optional function formulas in the lower part of the panel, and give the number of sampling points within the value range of x and z on the right side of the input formula. The coefficients a, c and d related to the 3D plane formula in the upper right corner of the panel are not editable and do not need to be processed.

The second case of multiple function formula input is to draw the intersection line and coordinate plane projection of a given 3D plane and other function surfaces. It is the user who needs to fill in the specific values of the parameters a, b, c and d of the given 3D plane function formula $ax + by + cz + d = 0$ into the corresponding text box in the upper right corner of the formula input panel. At the same time. Fill in the number of sampling points within the value range of x and z of the 3D plane function in the upper right corner of the panel.

For the specifications to be followed when entering function formulas, please refer to $Section$ 8. In general, the input should follow the common mathematical formula input rules, and unnecessary multiplication signs can be omitted. Pi π and the natural constant e need to be replaced by **MathPI** and **MathE**. Note that the above letter case format is mandatory.

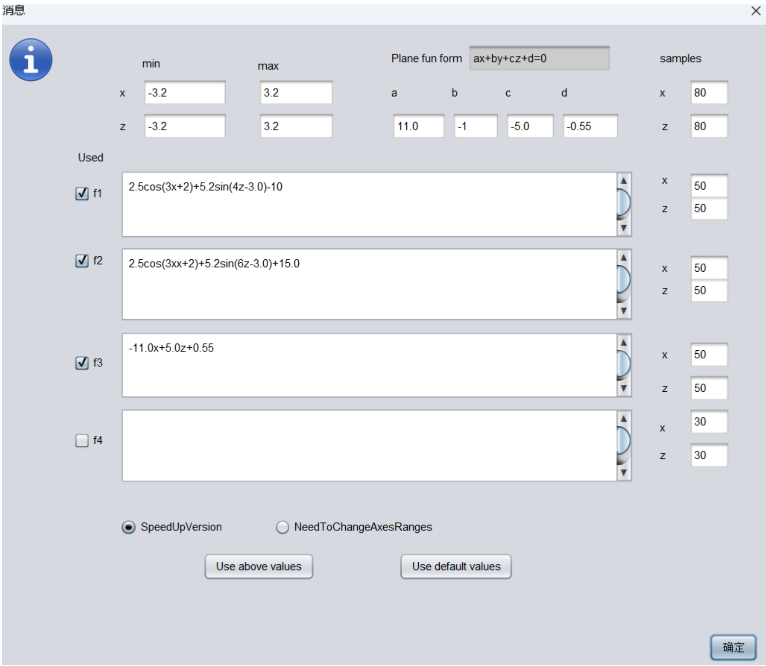


Figure 9.6.2 Multiple Function Formula Input Panel for Surface Graph

9.6.3. Advanced feature adjustment panel in surface plotting

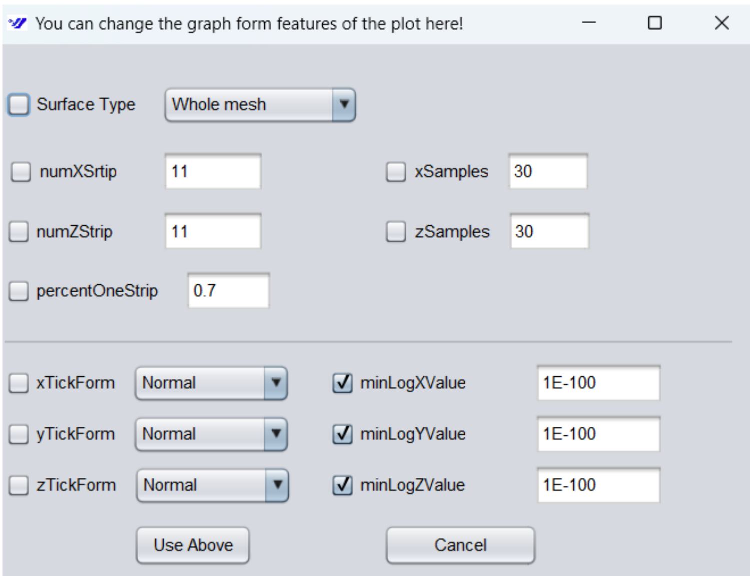


Figure 9.6.3 Advanced feature adjustment panel for a single function surface plot

When the user only needs to draw a surface graph of a single function without considering contour lines and coordinate plane projection, **LC** provides an advanced feature adjustment panel as shown in Figure 9.6.3. The top of the panel provides functions for selecting the surface drawing type, modifying the number of sampling points, and the number of strips and the proportion of strip width when drawing a strip chart. **Lovell Charts** provides 8 visualization forms of surface graphs, including: drawing the entire surface, drawing only the sampled points, grid lines in the x and z directions, x-direction lines, z-direction lines, x-direction strips, z-direction strips, and surfaces considering surface normal vectors. Users can achieve the above functions by checking the checkbox **Surface Type** and selecting the required surface visualization form in the drop-down list to the right.

Users can adjust the number of sampling points of the x variable by checking the checkbox **xSamples** on the panel and entering the number of sampling points of x in the text box to the right of the checkbox; similarly, the number of sampling points of the z variable can be adjusted using the checkbox **zSamples** and the text box behind it. When you need to draw a strip chart, the checkboxes **numXStrip** and **numZStrip** and the two text boxes following them can be used to set the number of strips in the x and z directions. The user can enter the ratio of the strip width to the corresponding variable value range in the text box to the right of the checkbox **percentOneStrip** to determine the width of the drawn strip.

Below the advanced feature adjustment panel is the selection of the axis type. This part is the same as the selection of the axis type when making other types of 3D charts using XYZ data, so it will not be repeated here.

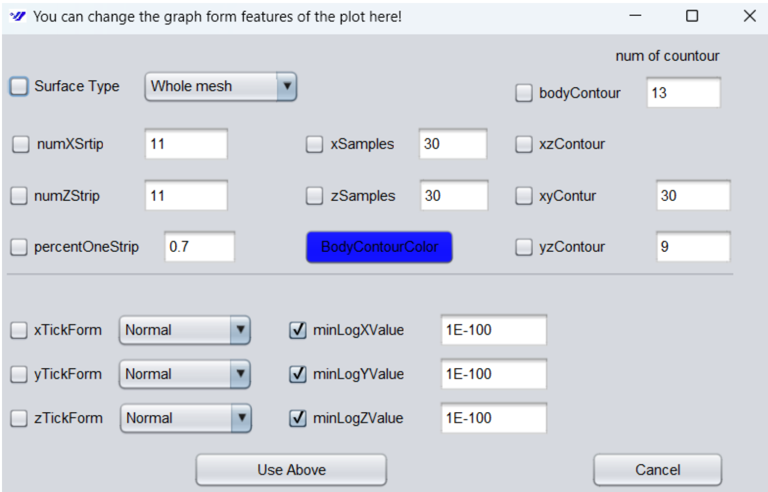


Figure 9.6.4 Advanced feature adjustment panel for a single function surface plot taking into account contours

When it is necessary to draw contour lines of the surface and their related projections, the advanced feature adjustment panel provided by **LC** is shown in Figure 9.6.4. This panel adds control over the number of contour lines drawn and the color of the contour lines. Specifically, by selecting the check boxes **BodyContour**, **xzContour**, **xyContour** and **yzContour**, determine whether to draw body contour lines on the surface, as well as contour line projections in the XZ coordinate plane, XY coordinate plane and YZ coordinate plane. The user can enter the number of related contour lines and projections in the text box to the right of the above check boxes. **LC** assumes that the number of body contour lines is the same as the number of contour lines projected on the XZ coordinate plane. By clicking the **BodyContourColor** button, the user can select a new contour line color in the pop-up color selection panel; by default, the color of the contour line and its projection is the same as the color of the corresponding position point on the surface.

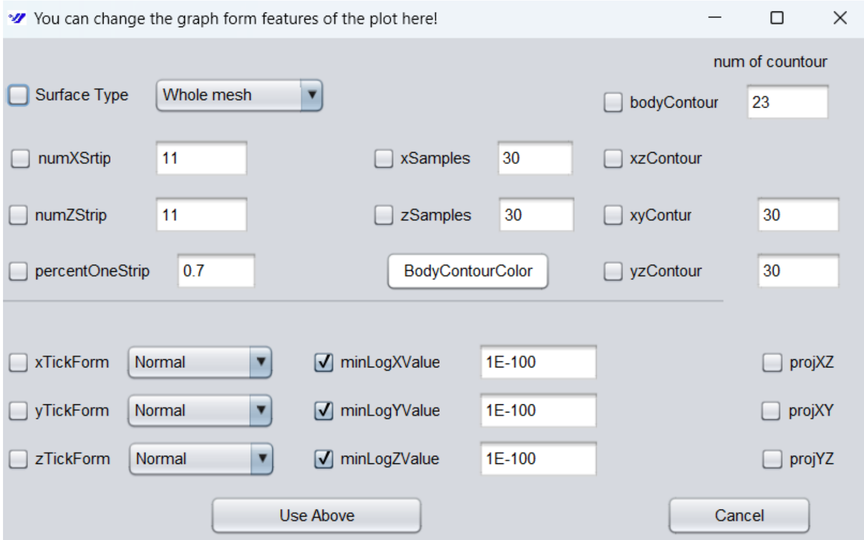


Figure 9.6.5 Advanced feature adjustment panel for single function surface plot considering surface projection

When you need to draw the projection of a surface on a coordinate axis plane, **LC** provides an advanced feature adjustment panel as shown in Figure 9.6.5. By checking the checkboxes **projXZ**, **projXY**, and **projYZ** on this panel, the user can specify which coordinate plane to project to.

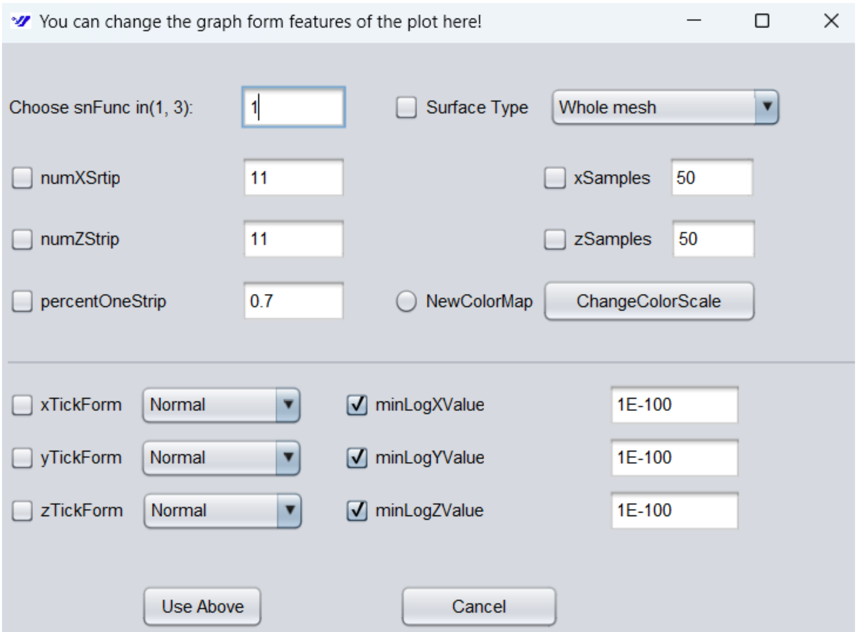


Figure 9.6.6 Advanced feature adjustment panel for multiple function surface plots

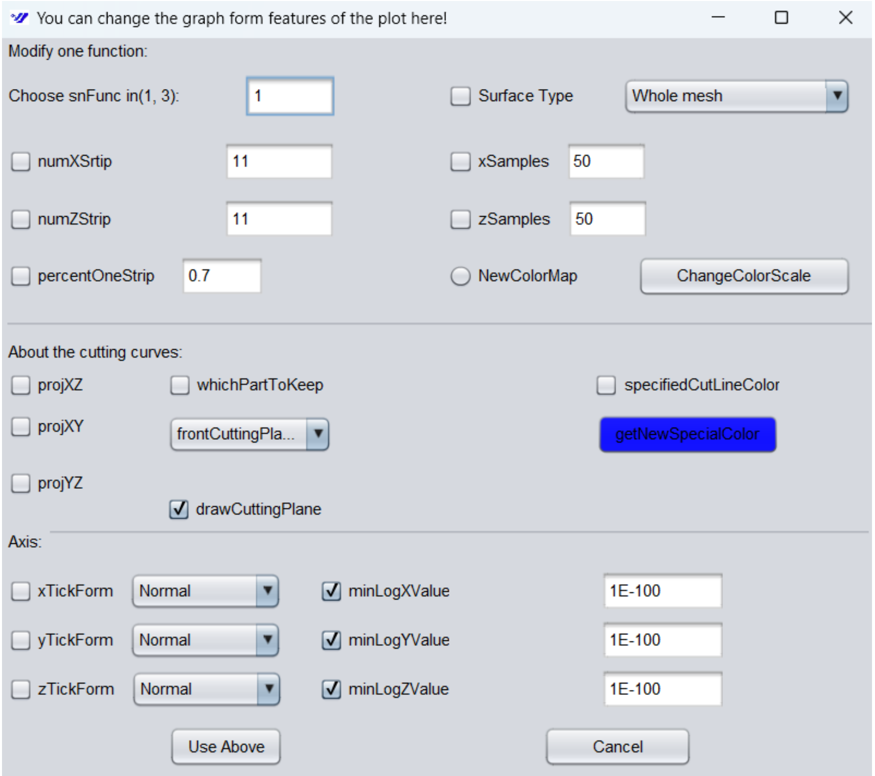


Figure 9.6.7 Advanced feature adjustment panel for multiple function surface plots considering plane intersections

When drawing multiple functions at the same time, if the intersection with the plane is not considered, LC provides an advanced feature adjustment panel as shown in Figure 9.6.6; when the intersection with a given plane needs to be considered, **LC** provides an advanced feature adjustment panel as shown in Figure 9.6.7. Since the panel content given in Figure 9.6.7 includes the content of the panel in Figure 9.6.6, only the use of the panel in Figure 9.6.7 is introduced here.

The panel shown in Figure 9.6.7 is divided into three modules: the upper module processes the features of the selected function; the middle module processes the content related to the plane intersection; the lower module is a functional module for selecting the coordinate axis type.

In the upper module, by entering the function number in the text box to the right of the label **Choose snFunc**, you can adjust its features in this module. LC will automatically display the serial number range of existing functions after the label **Choose snFunc** for user reference. In this module, users can select the button **NewColorMap** to determine the use of the newly revised color scheme in the newly drawn graphics. The new color scheme can be selected by clicking the button **ChangeColorScale** and selecting it from the pop-up color scheme selection list. The functions of other buttons and text boxes in the upper module have been introduced in the previous processing of similar advanced feature adjustment panels, so they will not be repeated here.

The middle module contains the relevant operation functions for plane intersections. Users can check the checkboxes **projXY**, **projXZ** and **projYZ** in this module to specify whether to draw the projection of the intersection line on the corresponding XY, XZ and YZ coordinate planes. By checking the checkbox **whichPartToKeep**, and selecting the desired option in the drop-down list below the checkbox, specify which part of the surface cut off by the plane needs to be retained in the subsequent drawing. There are three options: retain all, retain the part in front of the plane and retain the part behind the plane. Users can check the checkbox **drawCuttingPlane** to specify whether to draw the cutting plane itself in the subsequent drawing. In addition, you can select a specific color as the intersection line color of the plane and the surface by checking the checkbox **specifiedCutLineColor** and clicking the button **getNewSpeacialColor** to obtain the color selection panel. By default, the color of the intersection line and its projection is the same as the surface color of the intersection point between the surface and the plane.

9.6.4 Example of making a surface graph

Surface graph is a widely used type of 3D scientific drawing. Figures 9.6.8-11 are four examples of surface graphs drawn using **Lovell Charts**.

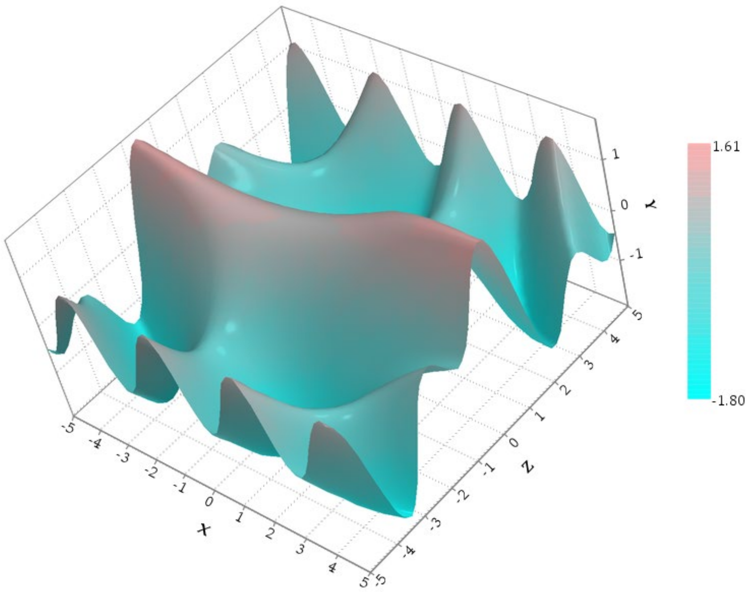


Figure 9.6.8 Surface plot considering the surface normal vector

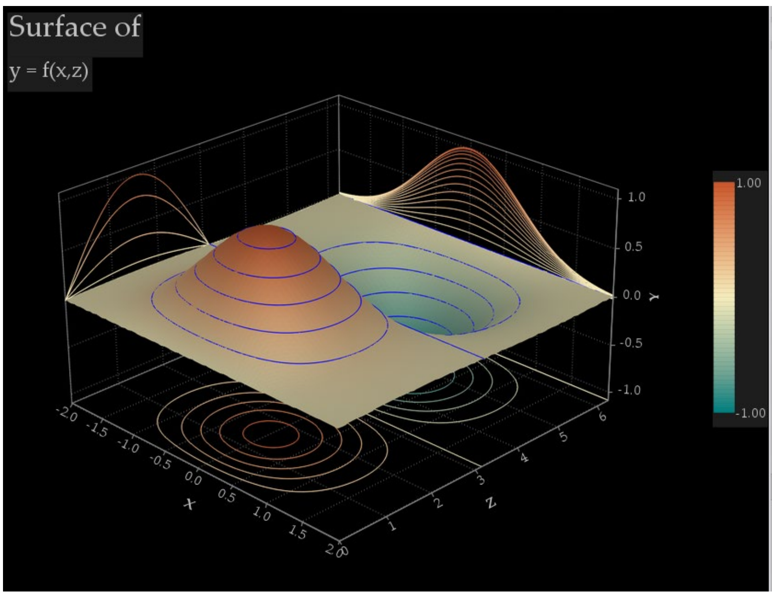


Figure 9.6.9 Surface plot with contour lines or contour projection

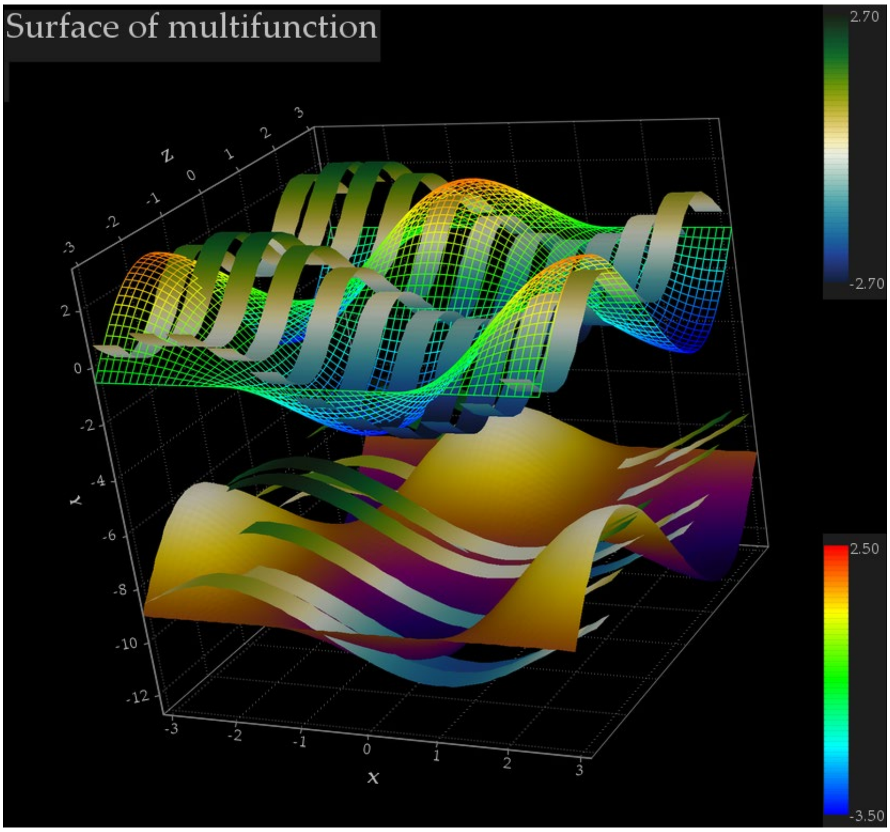


Figure 9.6.10 Surface plots of multiple functions with different visualization forms

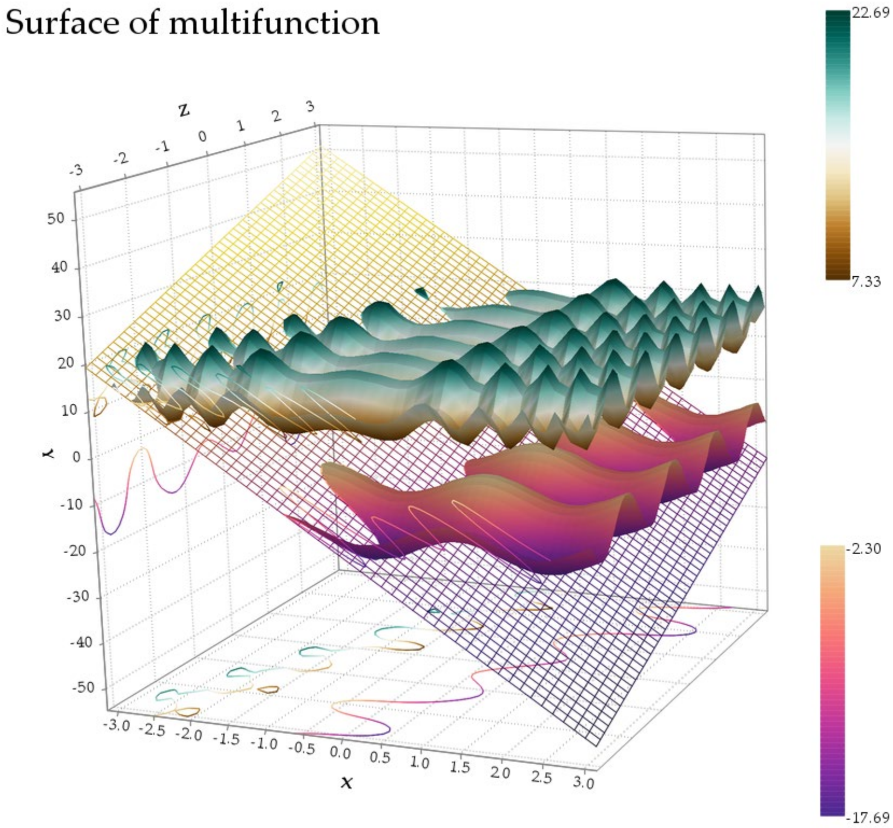


Figure 9.6.11 Surface plot considering 3D plane intersection and intersection projection

9.7. Drawing of function surfaces with parameters

9.7.1. Data file format of function surfaces with parameters

If you need to use a txt data file to input data to draw function surfaces with parameters, the corresponding txt file must comply with the following regulations:

- The first line of the file is a string, whose value can be true or other strings.
- When the string in the first line is true, it means that the information of the subsequent points contains normal vector information; otherwise, it does not contain it.
- The second line of the file is two integers, which respectively represent the number of points and triangular planes required to construct the surface.
- The file starts from the third line, and contains the data information of points and triangles in turn.
- The information of the point consists of three real numbers or 6 real numbers; when the information of the point consists of three real numbers, they are the x, y and z coordinates of the point respectively; when the information of the point consists of 6 real numbers, the first three are the x, y and z coordinates, and the last three are the normal vector components of the point.
- The information of the triangular plane consists of 3 non-negative integers representing its vertex numbers.
- The information of a point or a triangular plane occupies one line of the file.
- The data are separated by spaces.

The following is a fragment of a related data file, which contains information about 5 points and 5 triangles. The information about other points and triangles is ignored. As can be seen from the true string in the first line, the point information includes the normal vector information of the surface at that point.

```
true
10404 10404
2.0 0.0 1.0 -0.0 -1.0000001654807489 2.000000165480742
2.122888290664714 0.0 0.9924205096719357 0.260878273558136 -0.9924195620413864
2.106795693367206
1.939593872070019 0.4878274402167543 1.2463994238109641 0.24391379824561413 -
0.9697976558198794 2.0000014607631558
2.0587705598312382 0.5178015803505442 1.2388199334829 0.49506371769516927 -
0.8988139955480353 2.1067966175494095
2.122888290664714 0.0 0.9924205096719357 0.260878273558136 -0.9924195620413864
2.106795693367206
…
0 1 2
1 3 2
2 1 0
2 3 1
4 5 6
…
```

9.7.2. Introduction to the Function Formula Input Panel

When drawing a function surface with parameters, data preparation can also be completed by directly entering the function formula. When the user chooses to import information by directly entering the function formula, **LC** provides the function input panel shown in Figure 9.7.1. **LC** presets u and v as two independent variables, and the x, y and z coordinates of the points on the surface are all functions of u and v. The user can enter the minimum and maximum values of the independent variables and the number of samples between the minimum and maximum values at the top of this panel. The text box to the right of the label para1 is not used yet and can be ignored by the user. Since the calculated surface normal only corresponds to one side of the surface, the drawn figure may not be able to well show the other side that the user needs. Therefore, LC provides a checkbox Reverse the normals to allow the user to use the normals on the other side of the surface instead of the original normals. There are no special requirements for the input of the function in this panel, as long as it meets the specifications in **Section 8**.

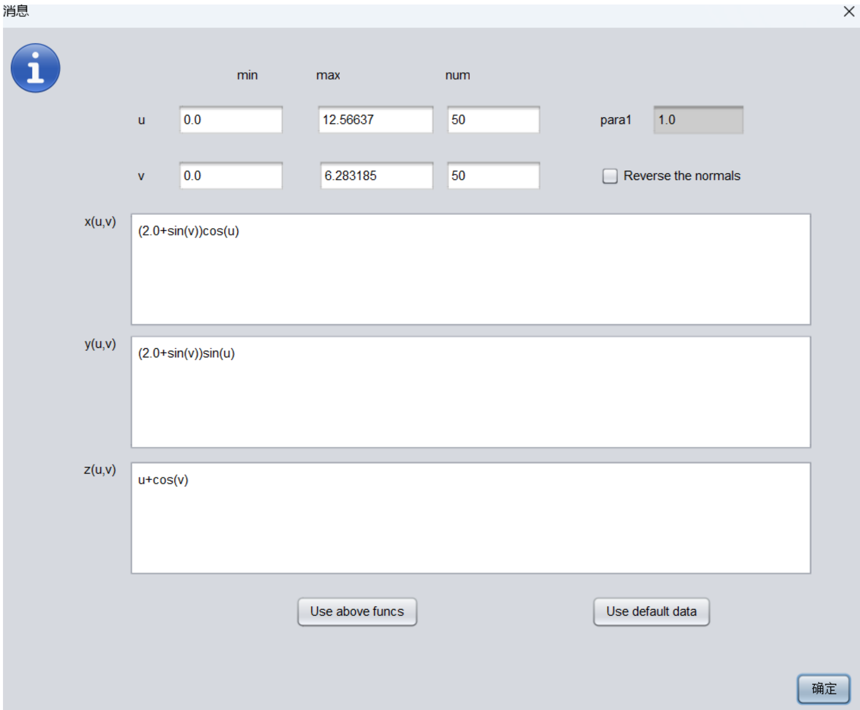


Figure 9.7.1 Function formula input panel with parameter function surface drawing

9.7.3. Adjusting the coloring scheme in the basic feature adjustment panel

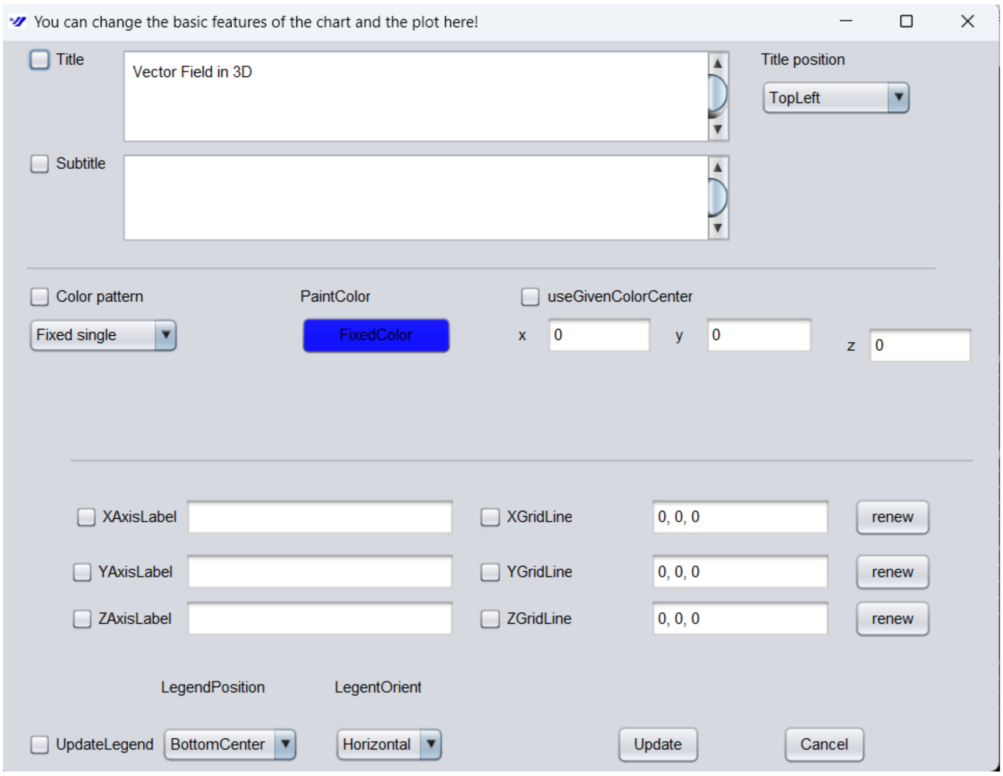


Figure 9.7.2 Basic feature adjustment panel for surfaces with parameter functions

For the drawing of function surfaces with parameters, **LC** provides a basic feature adjustment panel as shown in Figure 9.7.2. Different from the basic feature adjustment panels of other types of graphics, the panel shown in Figure 9.7.2 adds the selection of the overall coloring method of the graphics. Users can explicitly use the new coloring method by checking the checkbox **Color pattern**. Users can select a specific coloring method in the drop-down list below the checkbox. The optional coloring included is shown in Figure 9.7.3. Among them, **Fixed single** means drawing the surface with a single color; **xDirection**, **yDirection** and **zDirection** respectively indicate that the color of the point is determined by the size of the x, y and z coordinate values of the point on the surface; **distance to center** means that the color of the point is determined according to the distance of the point on the surface from the given point; **Object size** means that the color of the point is determined according to the size of the given point's size feature value; **Series** determines its color according to the sequence to which the point belongs. Note that when drawing function surfaces with parameters, the last two coloring methods are invalid and will not affect the current surface coloring after selection. Users can click the **FixedColor** button on the panel to select the specific color when coloring with a single color through the pop-up color selection panel. When the user selects the distance to center shading method, the checkbox **useGivenColorCenter** can be selected to explicitly use a given point as the reference center for shading. The x, y, and z coordinates of the shading reference center can be entered in the corresponding positions below the checkbox **useGivenColorCenter**. By default, the shading reference center is the centroid determined by all points on the surface.

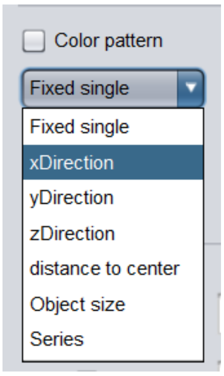


Figure 9.7.3 Optional coloring methods for surfaces with parameter functions

Currently, LC does not provide an advanced feature adjustment panel for plotting function surfaces with parameters.

9.7.4. Example of a parametric function surface

Using the function formula input panel, **LC** can draw most 3D parametric function surfaces. Figures 9.7.4 and 9.7.5 are two parametric function surfaces drawn using **LC**.

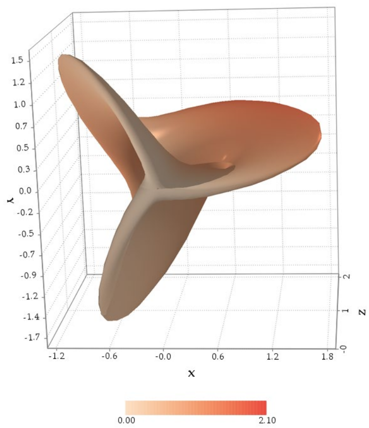


Figure 9.7.4 The first example of a surface with a parameter function

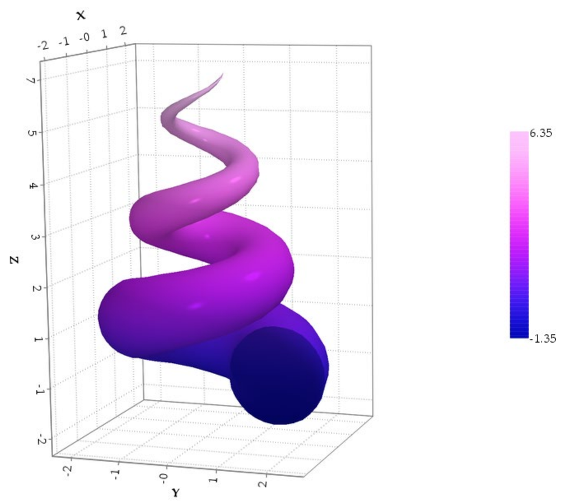


Figure 9.7.5 The second example of a surface with a parameter function

9.8. 3D visualization of vector field

9.8.1. Data file structure of vector field

Lovell Charts software uses directed line segments with arrows to depict the changes of vector field in three-dimensional space. Each sampling point in three-dimensional space corresponds to a direction vector and a directed line segment with arrows of a specific size. If you draw a 3D vector field graph by reading data from a txt data file, there are two basic formats of the data file. The first data file does not contain the RGB value of the color of the sampling point, while the second includes the RGB value of the color of the sampling point.

The first line of any data file must be a string. The string is either true or another string. If the string is true, it means that the data file contains the RGB value of the color of the sampling point; otherwise, it does not contain it.

When the RGB value of the color is not included, the data file consists of 9 real values starting from the second line. These real values are separated by spaces, and each line of data corresponds to a sampling point. The meanings of the 9 real values are: the length of the directed line segment, the diameter of the bottom circle of the arrow contained in the directed line segment, the height of the arrow contained in the directed line segment, the x coordinate of the sampling point, the y coordinate of the sampling point, the z coordinate of the sampling point, the x value of the direction vector of the sampling point, the y value of the direction vector of the sampling point, and the z value of the direction vector of the sampling point.

When the data file contains the RGB value of the color of the sampling point, the data file consists of 12 real values in each line starting from the second line. The meaning of the first 9 real numbers is the same as that of each line of data without color. The 10th to 12th real numbers are the RGB values of the color of the sampling point.

The following is a data file fragment that does not contain the RGB value of the color of the sampling point. This fragment contains data for 3 sampling points.

```
false
0.4571428571428571 0.03809523809523809 0.09142857142857143 -1.4285714285714286 -
1.4285714285714286 -1.4285714285714286 1.0 -1.0 -0.35714285714285715
0.41838022161485877 0.03809523809523809 0.09142857142857143 -1.4285714285714286 -
1.4285714285714286 -0.8571428571428572 1.6666666666666665 -1.6666666666666665 -
0.2142857142857143
0.39701295718521096 0.03809523809523809 0.09142857142857143 -1.4285714285714286 -
1.4285714285714286 -0.2857142857142858 4.999999999999998 -4.999999999999998 -
0.07142857142857145
…
```

The following is a data file fragment containing the RGB values of the sample point colors. This fragment contains data for three sample points.

```
true
0.4571428571428571 0.03809523809523809 0.09142857142857143 -1.4285714285714286 -
```

1.4285714285714286 -1.4285714285714286 1.0 -1.0 -0.35714285714285715 0 0 255
0.41838022161485877 0.03809523809523809 0.09142857142857143 -1.4285714285714286 -
1.4285714285714286 -0.8571428571428572 1.6666666666666665 -1.6666666666666665 -
0.2142857142857143 0 0 255
0.39701295718521096 0.03809523809523809 0.09142857142857143 -1.4285714285714286 -
1.4285714285714286 -0.2857142857142858 4.999999999999998 -4.999999999999998 -
0.07142857142857145 0 0 255
…

9.8.2. Direction function input panel for vector fields

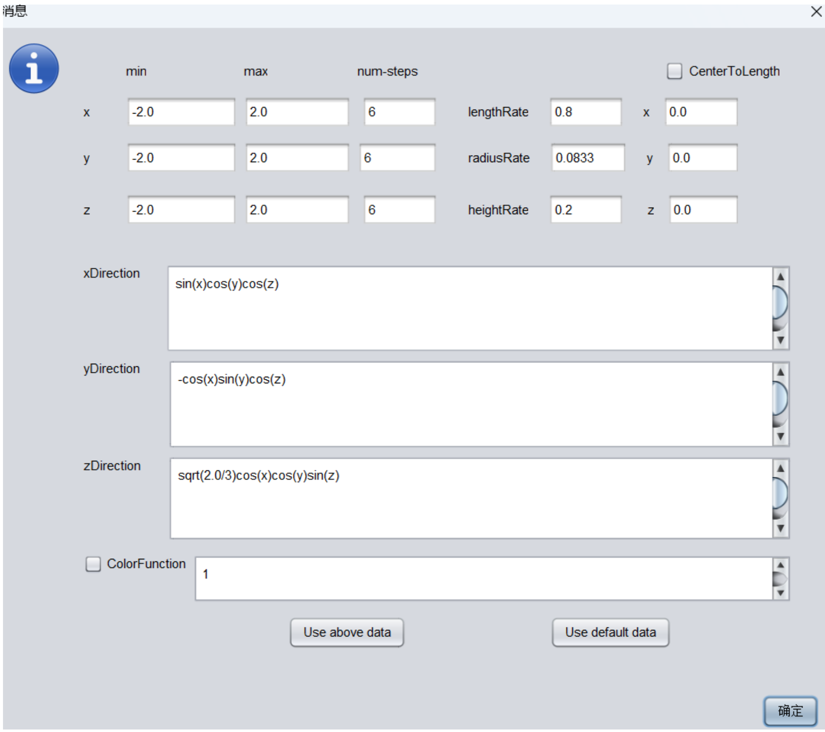


Figure 9.8.1 Vector field function formula input panel

The change of vector direction of the vector field can be obtained by directly inputting the relevant function formula. Figure 9.8.1 is the vector field direction function input panel provided by **LC**. Assume that the vector direction is a function of the coordinates of the point location. In the upper left corner of the panel, the user can enter the upper and lower limits of the x, y and z values of the three-dimensional space where the vector field needs to be drawn and the number of sampling points within the value range. Below this panel, you can enter the direction vector function of the vector in the x, y and z directions that depends on the sampling point location coordinates in turn. Note that **LC** has not yet enabled the **ColorFunction** checkbox and the text box to the right of it.

In order to avoid overlapping of the displayed directed segments, **LC** assumes that the maximum length of the finite segment is less than the minimum sampling interval in the x, y and z directions. In the text box to the right of the **lengthRate** label, the user can enter the ratio of the desired maximum directed segment length to the minimum sampling interval in the x, y and z directions. The user can enter the ratio of the diameter of the bottom circle of the 3D arrow contained in the desired directed line segment to the maximum directed line segment length in the text box to the right of the **radiusRate** label above the panel, and enter the ratio of the height of the 3D arrow contained in the directed line segment to the maximum directed line segment length in the text box to the right of the **heightRate** label above the panel. Here, a 3D arrow is actually a 3D cone.

At the far right of the vector field function input panel, the user can check the checkbox **CenterToLength** to specify whether to determine the length of the directed line segment based on the distance from the given point. **LC** assumes that the closer the distance to the given point, the shorter the directed line segment. The minimum directed line segment length is the height of the arrow. The x, y and z coordinates of this given point are entered in the corresponding text boxes below the checkbox **CenterToLength**.

9.8.3. Vector Field Graph Examples

Figures 9.8.2-4 show three different types of vector field graphs created using **Lovell Charts** software.

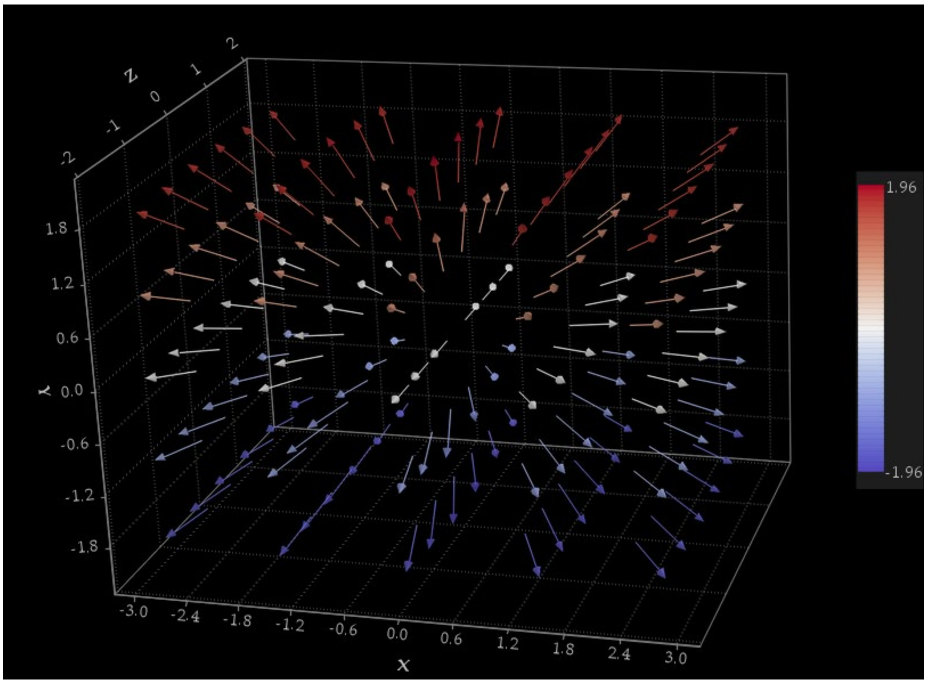


Figure 9.8.2 Central divergence vector field

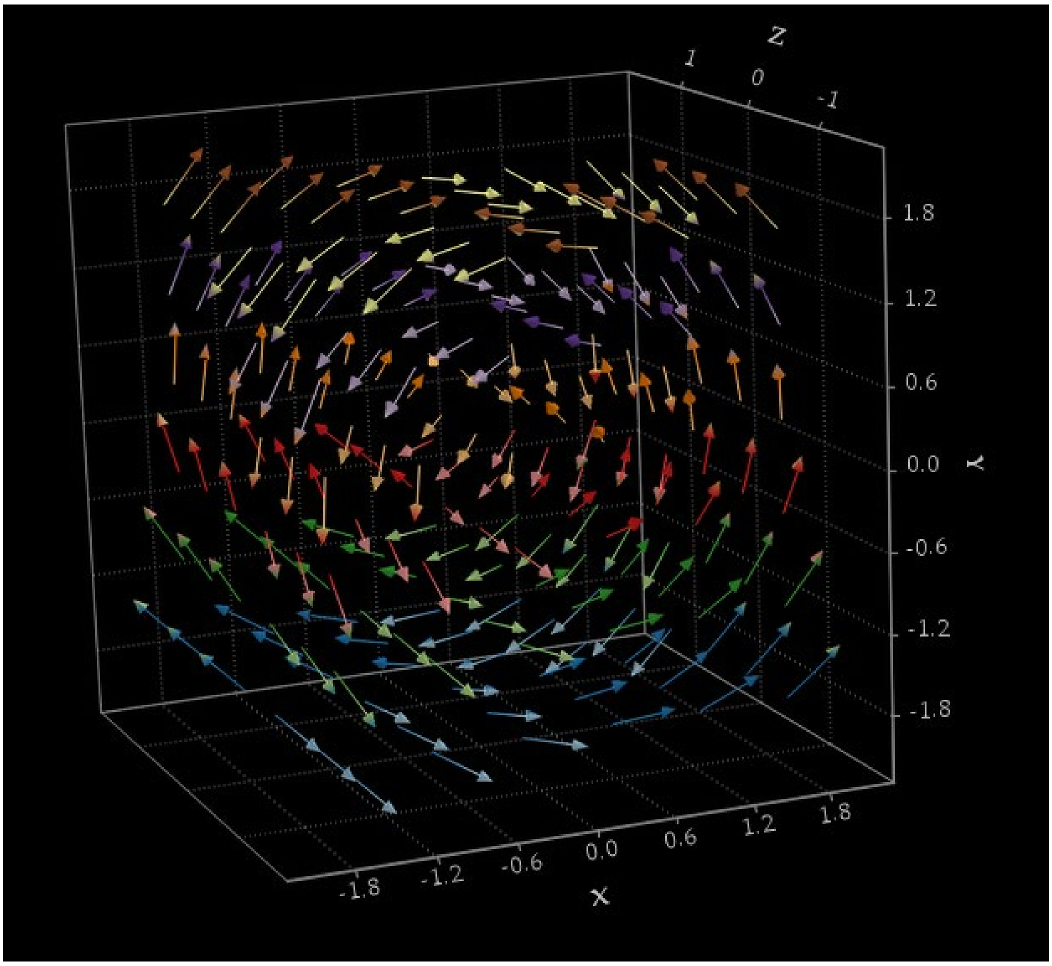


Figure 9.8.3 Roller-type vector field

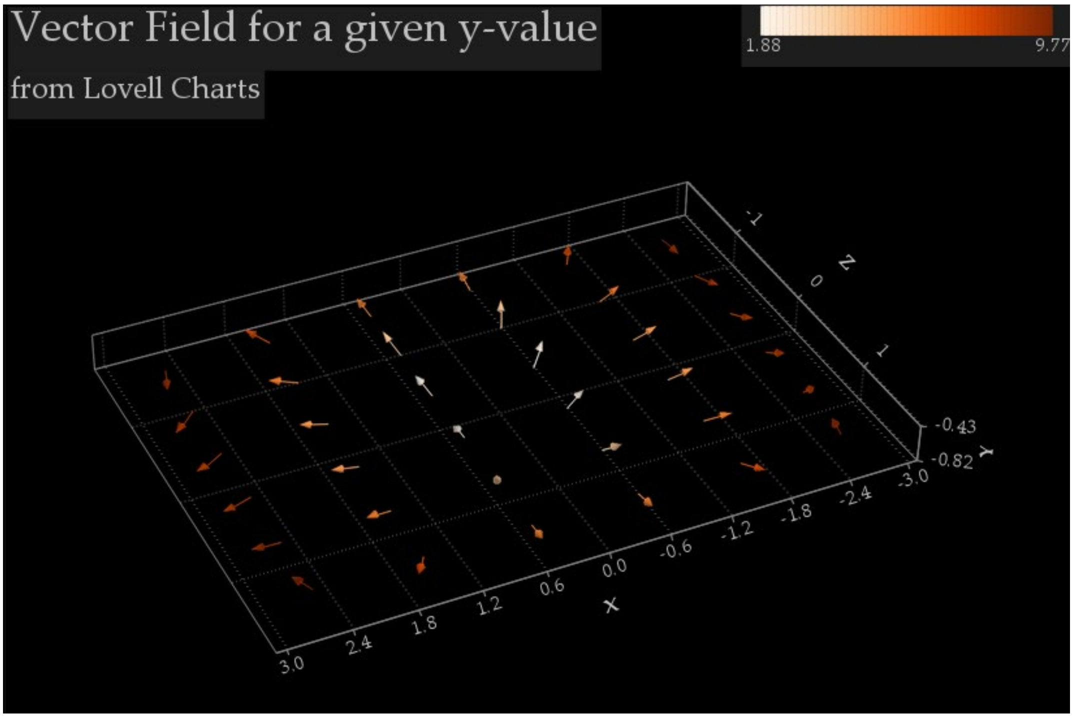


Figure 9.8.4 Vector field with given y value

9.9. Drawing of point-line associated 3D network structure

The point-line associated 3D network structure has a wide range of applications in reality. Currently, **Lovell Charts** provides basic drawing functions for this type of 3D structure. The characterization of related advanced features will be implemented in subsequent versions.

9.9.1. Data file format of point-line associated 3D network structure

The data file of the point-line 3D network structure contains three parts. The first part contains the first two lines of the txt file. Among them, the first line consists of two integers. When the first integer is 1, it means that the thickness value of the line is included; when the second integer is 1, it means that the characteristic value of the color of the line is included. When the above two integers are not 1, it means that no relevant information is included. Here, the thickness of the line and the color control characteristic value are both relative values of the relevant quantities. When drawing the specific graphics, **LC** will determine the specific value of the drawing according to the line thickness range and color system provided by the user. The second line of the file in the first part is also composed of two integers. The two integers are the number of points and the number of lines in the 3D network respectively.

The second part of the data file is the coordinate information of the point in the 3D network. Each line corresponds to a point and contains three real values, which are the x, y and z coordinates of the corresponding point.

The third part of the data file is the endpoint information of the line in the three-dimensional network. Each line in this part corresponds to a line, which consists of the serial numbers of the two endpoints of the corresponding line, the thickness of the line, and the characteristic value controlling the color of the line. The endpoints are points in the network, and the serial numbers of the endpoints are consistent with the order given by the coordinate information of each point in the second part of the data file. The first point given in the second part has a serial number of 0; the second point given has a serial number of 1; and so on, the serial numbers of other points can be obtained. In the data entry of a line, the serial number of the line endpoint is represented by an integer, while the thickness and color control items of the line are represented by double real numbers.

The following is a fragment of a data file containing 49 points and 120 lines. This fragment only lists the specific information of the first 5 points and the first 5 lines, and does not contain the thickness and color control characteristic values of the line.

```
0 0
49 120
0.0 0.0 7.0
6.94 0.0 5.85
6.010216 3.47 5.85
3.47 6.010216 5.85
0.0 6.94 5.85
…
0 1
0 2
0 3
```

```
0 4
0 5
…
```

The following is a snippet of a data file containing 20 points and 72 lines. This snippet only lists the detailed information of the first 5 points and the first 5 lines, and contains the line thickness and color control feature values.

```
1 1
20 72
0.0 0.0 6.096
3.048 0.0 6.096
3.048 3.048 6.096
0.0 3.048 6.096
0.0 0.0 4.572
…
0 4 2.4698492897644373 29.59576077506408
1 5 2.9262489877237807 20.334094408439903
2 6 3.9910473727534823 13.321609071439767
3 7 3.632998940243815 15.746252431446138
0 5 3.4369171072123414 20.33707549070864
…
```

9.9.2. Feature Adjustment in Point-Line Association 3D Network Structure Drawing

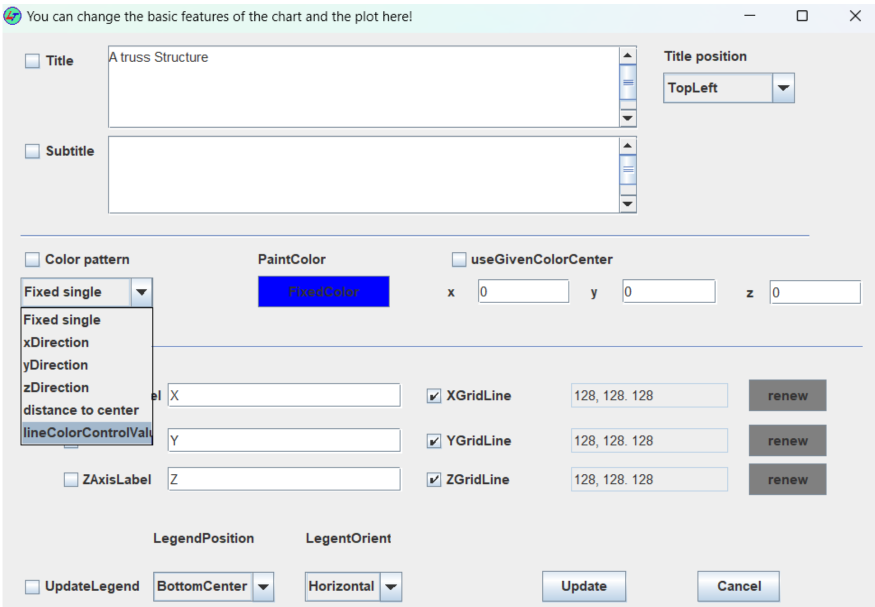


Figure 9.9.1 Basic feature adjustment panel of point-line stereo network

Figure 9.9.1 is the basic feature adjustment panel of the point-line network. The only difference from the basic feature adjustment panel given in Section 9.7 is that the options in the drop-down list under the color pattern checkbox are changed, as shown in Figure 9.9.1. The meanings of the first five options are consistent with those in Section 9.7. The sixth item, **lineColorControlValue**, indicates that the color of the drawn line needs to be determined by the relative size of the color control feature value of the line. The other operations of the panel are the same as those in **Section 9.7**.

Figure 9.9.2 is the advanced feature adjustment panel of the point-line network. At the top of this panel, the user can check the checkbox **Size of points** and enter the diameter of the sphere (or the side length of the cube of the corresponding points) used to visualize the corresponding points in the network in the text box to the right of the checkbox. The user can also check the checkboxes **projXZ**, **projXY** and **projYZ** to specify whether to include the projection of the solid network on the coordinate axis planes XZ, XY and YZ in the subsequently drawn graphics. Check the checkbox **Shape of points** and select the geometric shape of the corresponding points in the drop-down list to the right of it to change the geometry of the representative points in the drawn graphics. Here you can choose between sphere and cube. The **LineThickness** checkbox and the two text boxes after the labels **min** and **max** can complete the setting of the thickness range of the line in the drawing. The unit of measurement of the line thickness value is pixel.

The bottom of this panel provides the selection of coordinate axis categories. Its operation method and function have been explained in the previous introduction of other advanced feature adjustment panels, so I will not repeat them here.

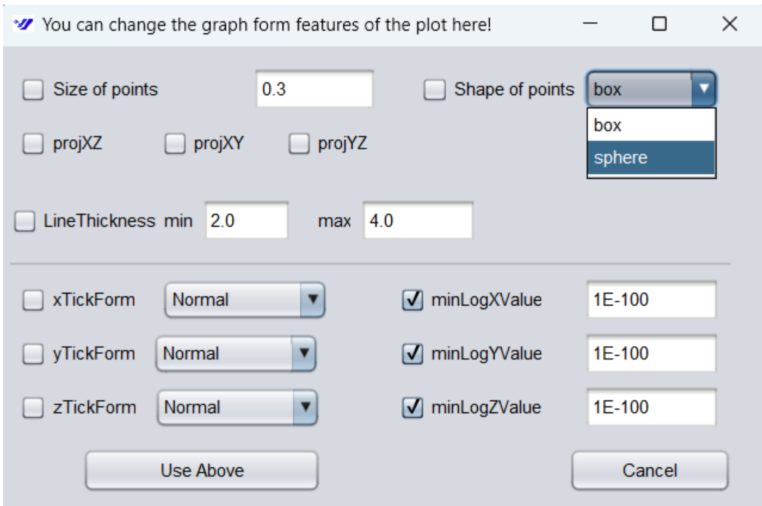


Figure 9.9.2 Advanced feature adjustment panel for point-line associated 3D network structure

9.9.3. 3D graphics example of a three-dimensional network structure with point-line association

Figures 9.9.3 to 9.9.5 are two three-dimensional truss structures drawn using **Lovell Charts**.

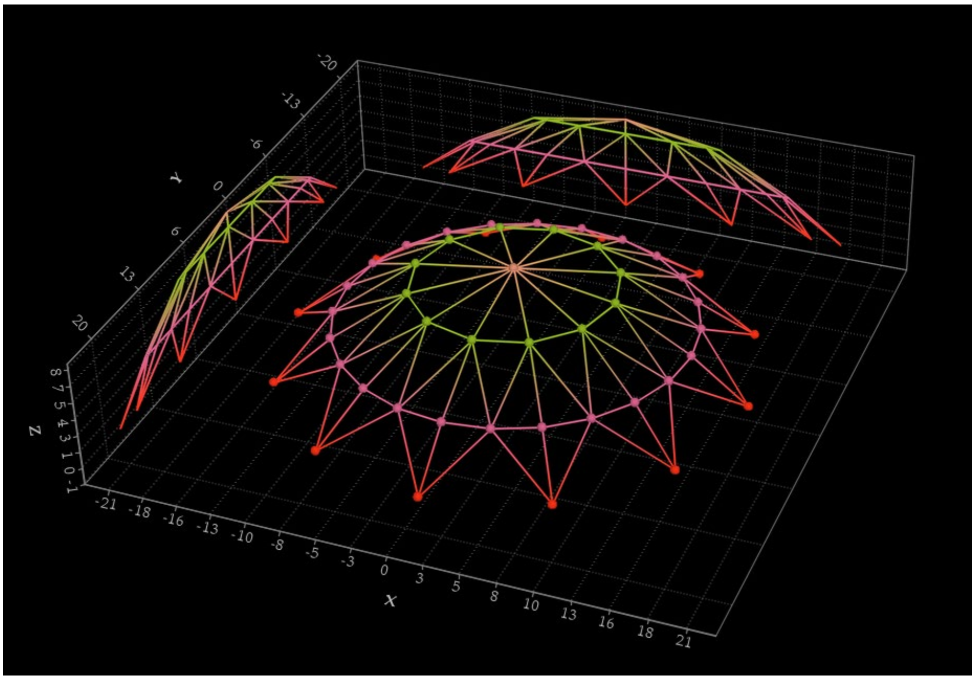


Figure 9.9.3 Point-line three-dimensional network structure considering the projection on the coordinate plane

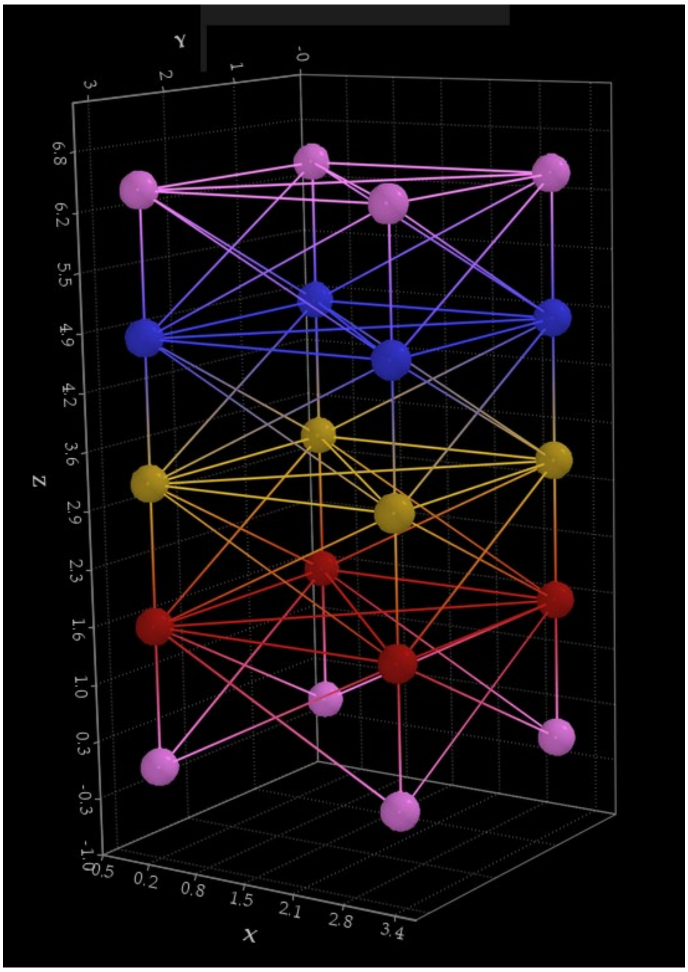


Figure 9.9.4 A simple 4-layer truss structure

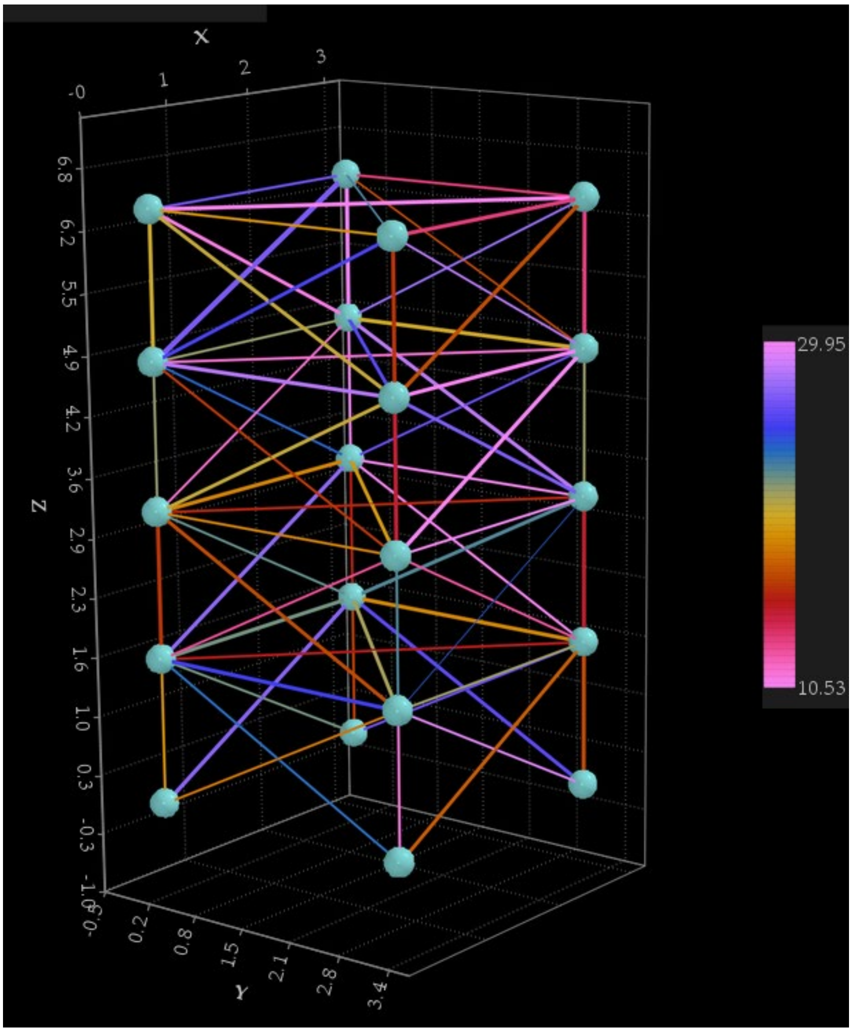


Figure 9.9.5 A 4-layer truss structure with line thickness and color determined by given characteristic quantities

9.10. Visualization of point cloud files

There are many formats of point cloud files. Currently, **Lovell Charts** supports visualization of point cloud files in three common formats. The three types of files are **ply** files, **stl** files, and **obj** files. Considering that the data size of many point cloud files is huge, and the calculation and display of **Lovell Charts** is based on the computer CPU rather than the GPU, **LC** is not currently suitable for visualizing point cloud files with large amounts of data. In order to ensure the quality of display and the smoothness of operation, the number of points or faces contained in the point cloud data suitable for **LC** visualization should generally be less than 50,000. Of course, the above restrictions are also related to the specific configuration of the computer.

9.10.1. Loading obj files with material and normal vector information

LC provides a visualization interface specifically for **obj** format point cloud files. Users can get the final graphics by reading in the material file (i.e., texture file, stored in various common graphics file formats) and the **obj** file in sequence. If the material file is read in at the beginning, **LC** assumes that the user does not need to modify the graphics color later, so the subsequent adjustment of the graphics coloring scheme will be invalid. If the user does not import the material file at the beginning, the color of the graphics can be adjusted in subsequent operations.

9.10.2. Simple loading of stl, ply and obj point cloud files

LC also provides a general interface for opening **stl**, **ply** and **obj** files. When the user selects the relevant tree menu item, **LC** will prompt the user to open the relevant point cloud file; at this time, the user can select the file format that needs to be visualized and open the data file. If you choose to use this general interface, the user can modify the coloring scheme of the graphics in subsequent operations.

The user can perform various interactive operations on the successfully drawn point cloud file, such as zooming in and out, rotating, translating, changing the coloring scheme, implicit coordinate axis, etc.

9.10.3. Example of point cloud file visualization

Figure 9.10.1-4 is a point cloud map drawn using **Lovell Charts**.

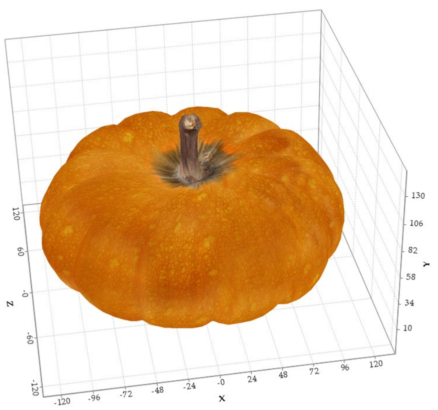


Figure 9.10.1 Pumpkin Picture

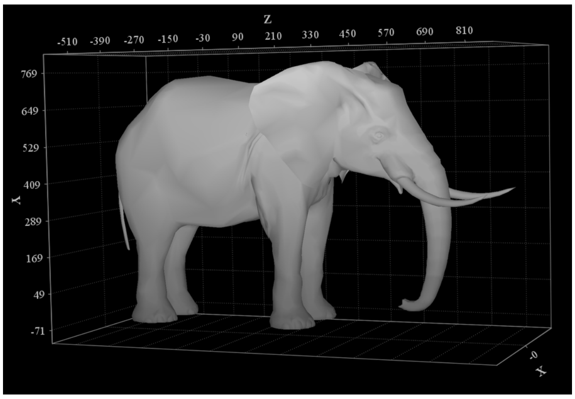


Figure 9.10.2 3D image of an elephant

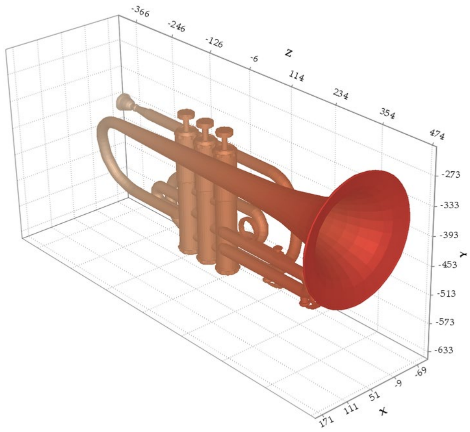


Figure 9.10.3 3D image of a trumpet

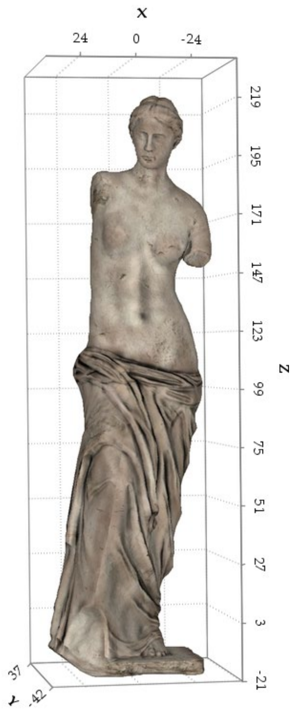


Figure 9.10.4 Sculpture of Venus