OVM
(including OVM Pro)
Manual

Optical Vision Measuring
Geometric Measuring
Image Measuring
Statistics Management

3DFAMILY TECHNOLOGY CO., LTD
2005.5.27 Revised
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Thank you very much for buying OVM visual measuring system. To insure the safe and efficient use of this system, please read this manual carefully before starting to operate. And notice the following points of attention:

- Please put the product in safe and smooth place. Do not put it in place, which is either uneven or likely to cause the drop of the product.
- Do not use accessories or fittings that are not provided by the original manufacturer, such as inferior power line or USB signal line, etc.
- Do not change or dismantle the parts of the products by yourself.
- Please put the product in place with good ventilation.
- The product enjoys one-year’s free repair and maintenance from the company. However, troubles or failures that are caused by accident, war or maloperation are excluded.
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Chapter One
System Introduction

- Introduction to OVM

- How to use this manual
OVM is a powerful image-based measuring system whose major functions includes geometric measuring and image measuring. The system is professional software for 2D measuring. It is very simple to operate and is compatible with CAD/CAM or Microsoft Word, Excel for result processing.

Some features of the system include:

1. Offering image measuring tools so that measuring point, line, arc, circle etc can be quite simple
2. Powerful math calculating ability; able to remove rough edge so as to obtain accurate measuring result
3. The measuring image and result can be directly displayed on the computer screen
4. Image tools offer quick work on 2D profile points scan
5. Using figure to display the measuring objects; the figure can be saved, printed or changed into Microsoft WORD (*.doc), EXCEL (*.xls) or AUTOCAD (*.Dxf) file format
6. Able to do tolerance analysis, and effective quality test
7. The object-based design allows you do direct calculations on the work piece
8. Compatible in XP operating system

The system can be used in the following industries: 2D measuring, cell-phone, automobile parts, wrist-watch, precise measuring, electron, mould, puncher, spring, screw, props, plastics, rubber, stopping valve, camera, bicycle parts, PCB board, conductive rubber, wire shelf, electronic part group.
How to use this manual

This manual can be used for the edition above OVM 3.0.

A major characteristic of OVM is that it can do 2D measuring quickly. Considering the 2D measuring process, we provide two means here to help you to shorten the time of processing: one is to provide user-friendly interface in OVM; the other is to list in detail in this manual various kinds of functions, working techniques of the system as well as all possible questions that you may meet when use this system.

When you use the manual for the first time, you’d better browse the contents first to get a quick view of all the information offered and then read the parts that you are interested in. If you want to inquire about single function of the software, you can the get to the part by using the contents.
This chapter introduces the computer system requirement and specifications for OVM. Through the introduction, you will understand the function of every part in OVM system. In addition, this chapter will guide you to install the software and hardware required by OVM system step by step.

The focuses of this chapter are:

- System Demand for OVM
- Installing hardware
- Installing OVM
- Installing drivers
System Demand

OVM is a specialized system that combines software and hardware. A proper computer must be matched to give full play to the system. Before installing OVM system, it is strongly suggested that you confirm in advance that your computer accords with the following minimum demands. Otherwise, the efficiency of the system may be reduced.

Hardware Demand

<table>
<thead>
<tr>
<th>Demand</th>
<th>Specification</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPU</td>
<td>Pentium grade or above (better Pentium III or above)</td>
</tr>
<tr>
<td>RAM- memory</td>
<td>64MB at least (better above 128MB)</td>
</tr>
<tr>
<td>HD- hard disk</td>
<td>at least 50MB surplus storage space</td>
</tr>
<tr>
<td>Printer-</td>
<td>(optional equipment, but essential if you want to print the report data)</td>
</tr>
<tr>
<td>OS- operating system</td>
<td>Windows 2000 or XP</td>
</tr>
<tr>
<td>32 bit color quality of the screen is needed</td>
<td></td>
</tr>
<tr>
<td>Export device</td>
<td>USB Serial port X1 (manual edition)</td>
</tr>
</tbody>
</table>

Software Demand

Professional measuring software: OVM

The image Picking driver card (3DFAMILY image Picking card)
Optical ruler driver

The installation procedure of the above drivers will be discussed under Installing Hardware Drivers
Hardware Installation

Image Picking Card

1. A **Image Picking Card** is included in the system
2. Insert in place this card in the PCI slot of the computer. Better not insert other hardwares in the adjacent PCI slot.

Platform Installation Diagram
Installing OVM (in Windows XP)

Software Installing

1. Start your computer to enter Windows XP
2. Put the installing disk into the ROM, the installing program will run automatically. In case auto-installing fails, you can enter “my computer” and click the ROM, then double click setup.exe to install.

3. You will see the installing interface like below, click “next” to continue.

4. click “next” again to continue.
5. Select “I accept the above regulations”, and then click “next”.

6. Enter user’s name and company name, and click “next” to continue.

7. You can click “change” to change the installing directory or directly click “next” to install the software into the default directory.
8. Click “install” to start installing.


10. Installing completes. Click “finish” to complete the installation.
When you finish the installation, a shortcut will be displayed on your screen desk. Double click the shortcut will run the program, or you can follow `start | all programs | 3DFAMILY | OVM | OVM measuring system` to run the system.

Uninstalling the System

1. **Auto uninstalling**
   1. Select in turn `start | all programs | 3DFAMILY | OVM | uninstall OVM measuring system`
2. Choose “yes” to uninstall the system.

3. Uninstalling in progress.

2. Removing the system manually
   1. Select “Start | Control Panel".
2. Choose “Add or Remove Program” under "Control Panel".

3. Find in the list "OVM measuring system", and click “remove”

4. Choose “yes” to confirm that you will remove this system.

5. Removing in progress.
Hardware Driver Installing

Installing 3DFAMILY image Picking card

1. Make sure that 3DFAMILY image Picking card has been correctly inserted in the computer PCI slot.
2. Start the computer
3. A prompt, “find new hardware 3DFAMILY IMGV1, WDM Video Capture” will appear, chose “installing from list or specific directory” and click “next” to continue.
4. Choose "Do not search, I will choose the driver to be installed", then click “next” to continue.
5. Choose “sound, video and game controller”, then click “next”, and then choose “to install from the CD-ROM” and find “3DFAMILY_IMAGE” directory in the installation CD of OVM, select “Bt848.inf” and click “next” to continue.

6. Installing 3DFAMILY IMGV1, WDM Video Capture driver in progress.

7. Click “finish” to complete the installation.
8. A prompt, "find new hardware 3DFAMILY IMGV1, WDM Audio Capture" will appear,

Choose "installing from list or specific directory" and click "next" to continue.

9. Choose "do not search, I will choose the driver to be installed", and click "next" to continue.

10. Choose "to install from the CD-ROM “and find “3DFAMILY_IMAGE “ directory
in the Installation CD of OVM, select “Bt848.inf” and click “next” to continue.

11. Installing 3DFAMILY IMGV1, in WDM Audio Capture driver in progress.

12. Click “finish” to complete the installation.
13. A prompt, “find new hardware 3DFAMILY IMGV1, WDM Crossbar” will appear, choose “installing from list or specific directory” and click “next” to continue.

14. Choose “do not search, I will choose the driver to be installed”, click “next” to continue.

15. Choose “to install from the CD-ROM” and find “3DFAMILY_IMAGE”
catalogue in the installation CD of OVM, select "Bt848.inf" and click “next” to continue.

16. Installing 3DFAMILY IMGV1, WDM Crossbar driver.

17. Click “finish” to complete the installation.
18. Restart the computer.

19. Open the “Device Controller” window, you will find the drivers for 3DFAMILY IMGV1, WDM Audio Capture, 3DFAMILY IMGV1, WDM Video Capture, 3DFAMILY IMGV1, and WDM Crossbar.

When installing the Image Picking card, the installation procedure will register 3DFAMILY_SDK.ax (make sure that DSStream.dll can be found automatically by the system)

To run regsvr32.exe 3DFAMILY_SDK.ax under DOS mode, you have to make sure you are using a correct directory.
For example if 3DFAMILY_SDK.ax is in C:\ (you can COPY it here first), then you have to change your directory to C:\, and then run regsvr32.exe 3DFAMILY_SDK.ax

Installing optical ruler scale counter card driver

1. Installing USB optical ruler scale counter card driver
   1. Insert the USB line of VMP in the computer.
   2. The prompt, "detect new hardware" will appear.
   3. Click “next” to continue.
4. Installing the driver of the optical ruler scale counter card.

5. Click “finish” to complete the installation.
6. If installation fails, then please choose in the third step "To install from the inventory or specific position".

7. Locate the directory "Scale _ Driver" in the installation CD of OVM, select SCALEUSB.INF and click “next” to continue.

8. If the following dialogue box appears, click “Browse” and navigate to “Scale_driver” in the installation CD of OVM, select GUbdD.sys and click “next” to continue.
9. Installing the driver of the optical ruler scale counter card.

10. Click “finish” to complete the installation.

2. Installing PCI optical ruler scale counter card driver

   1. Choose the second item “To install from the inventory or from specific position”.
2. Click “browse” and locate the directory to PCI_Scale counter card under OVM installation CD, then click “next”.

3. Driver installation in progress.

4. Click “finish” to complete the installation.
5. From the Device Controller you will see "3Dfamily pci counter Card ".

1. Installing Password Lock driver

   1. Locate "KeyPro" folder in TPM software CD, then run

   ![InstDev.exe](Image)

   2. When you see the welcome window, click "Next". See below.
3. Do not select "Install parallel driver", then click "Next", see below.

4. Click "Complete".
Installing Move Card driver

Installing ELITE move card driver

1. Choose “to install from the inventory or specific position” under “hardware installation wizard”, then click “Next”.

2. Choose “do not search, I will choose the driver to be installed”, and then click “Next”.

![Image of wizard window showing completion message]

![Image of wizard window showing options for installation]

![Image of wizard window showing completion message]
3. Choose " to install from the CD-ROM "

4. Click “Browse ”, and locate to “Elite_driver “ in OVM installation CD, then double click “ELITE.inf " , and "confirm".

5. Driver installation in progress.
6. Installation completes.

7. Open the “Device Controller”, you can see that ELITE driver has been installed successfully.
The driver installation steps of PCI-1240 and Galil move cards are simpler, so we will not elaborate the procedure here. You only need to navigate to folder "PCI-1240" and "Galil-driver" in the installation CD of OVM and run the corresponding program, then always select "Next" in the later steps. Finally, you click "finish" to complete the installation, and restart the computer to complete the installation (the procedure is similar to the installation of OVM software).
Chapter Three
OVM User Interface

This chapter presents you the first step to using OVM system. By learning this chapter, you will be able to understand the layout and functions of OVM.

The focuses of this chapter are:

- Knowing OVM interface
- The function lists of OVM
The OVM interface is composed of main menu, pulldown menu and pop-up dialog box which are very simple to use. This chapter introduces Image Measuring first.

1. Pull down main menu
2. Coordinate indicates the position and unit of the measurement
3. Light control adjusts the surface light or rimming light of the object
4. The object list displays all the attributes and units of the measurement
5. Geometric Measuring area displays the workpiece’s geometrical construction
6. Image Measuring area displays the actual image of the workpiece
7. The shortcut key icons place the commonly used functions
8. Detection function enables the user to record a macro or do SPC etc

DRO Coordinate Display

Cartesian Rectangular Coordinate
X: X-coordinate. Double click to set the X-coordinate to 0 or 1/2

Y: Y-coordinate. Double click left mouse to set the Y-coordinate to 0 or 1/2

Z: Z-coordinate (Len’s height)

Polar System

R: Radius

θ: angle

\(X, Y\) Switch to Cartesian rectangular coordinate
\(r, \theta\) Switch to polar system
\(\text{mm}\) Switch to metric system: centimeter; millimeter
\(\text{in}\) Switch to Inch system: inch
\(\text{deg}\) Switch to decimal scale angle
\(\text{dms}\) Switch to degree, minute, second

Home Return (Manual)
   To move the measuring platform manually to find the absolute origin
\(\text{Absolute/Relative}\) Switch between absolute and relative coordinates (press the button down to switch to relative coordinates)

\(\text{Set X and Y}\) Set the current X and Y-coordinate to 0 to establish the relative coordinate system
\(\text{Relative/Absolute}\) Switch from relative coordinate to absolute coordinates

\(\text{Select Point}\) Setting the point number in multipoint mode

The number before the semicolon is the point number, the number after is the object number.

For instance, when pressing the button \(\text{Center to Center Distance}\) (Center to Center Distance under Geometric menu),

\(0/6/07\) Will display, which means you need to input 2 objects, which require 6 points.
If you press Point to Line Distance icon \(\perp\) under Geometric menu,

\(0/3/02\) Will display which means you need to enter two objects, which require 3 points.
Object List

A tick before an object means that the data of this object will be exported to Word and Excel, while the same data of those without this tick will be not exported to Word or Excel.

Left click any object in the object list, the corresponding attributes of the object will be displayed in the left.

Right click on object list, the following menu will display:

- Delete
- Delete All
- Undo
- Call Out to Input
- Detail...

Delete: from the object list, click on the object you want to delete (multi-selection is not allowed), right click to show the quick menu, choose Delete from the menu to delete the object.

Delete all: right click on the object list to display the quick menu, then choose Delete all to delete all the data. Restore function cannot restore the data deleted this way.

Undo: right click on object list to show the quick menu, then choose Restore (or
Ctrl + Z) to cancel the previous steps. You can cancel as many steps as you like because no limitations are set on the times of restoration.

Callout Input: from the object list, click on the object you want to add, then right click to show the quick menu, choose Callout Input from the menu to add the object.

Details: under this menu, you can not only set tolerance control of physical dimension but can also do shape position tolerance analysis of the measuring elements. Left click to select the object you want to do tolerance analysis, and right click to choose the Details.

To do form tolerances analyses, directly put normal value in the tolerance column, then the over tolerance value will be displayed in the out-of-tolerance column.

To do shape position tolerance analysis, you should first choose the basis of reference in reference object, and do the following in the same way as in form tolerance analysis.

The following shape and position tolerance analysis are provided:

- Linearity
- Roundness
- Parallelism
- Verticality
- Inclination
- Concentricity
Image Measuring

Image measuring window shows the real time and actual image of the workpiece to be measured. With different workpiece, you can choose to use rimming light or surface light Image Measuring to achieve optimal measuring effect. Rimming light Image Measuring should be always the first choice in measuring. However, when this method fails to achieve the measuring effect, the surface light Image Measuring is a second option. The steps are: first, choose a light, and use the mouse to drag the light bar to adjust the brightness. To turn off the light, click on the OFF button besides the corresponding light.

- Rimmed Light Image Measuring

The Rimmed Light Image Measuring should be used when there are through-holes in the workpiece.

- Surface Light Image Measuring

The Surface Light Image Measuring should be used when there are no through-holes in the workpiece.
**CCD Setting**

**Camera setting**

Sync type: You can choose NTSC or PAL according to the specification of your CCD. The irregularities of image will be displayed if you choose a wrong Sync type.

Image type: Choose color or black and white.

Gain / Offset: Adjust the brightness of CCD.

**Camera**

To display the workpiece’s real time image in the Image Measuring window

**Capture Still Image**

To capture an image from Image Measuring window (the still image when capture is made) and save it as bmp or jpg format, if you continue to measure, select Camera again

**Object Measuring**
Object Point Clouds Measuring: left click on Image Measuring window, OVM will automatically display data of point clouds on the window (only one group of point clouds is shown, but consisting of many points)

Left click on the left circle to get the data of point clouds of the circle. (See picture below)

Left click on the black part will get the data of point clouds of one big circle and the four small ones.

Object Line Measuring: left click on Image Measuring window, OVM will automatically find the edges, and data within the edges will be regressed into a line. See the picture below for instance.

Left click on any part of the white area, OVM starts to find the edges which are in red. The blue line with the edges is the regressed line.

Left click on the black line, OVM automatically finds the edge which is in red. The blue line with the frame is the regressed line.
When measuring, we usually enlarge the workpiece big enough so that only a small part of the workpiece is shown in the Image Measuring window. **Object Line Measuring** is designed to measure long workpieces that have sharp black/white contrasting edges. For such workpiece, only black and white parts are displayed in the Image Measuring window. The red box area below is the actual area displayed in the Image Measuring window. The measuring speed of **Object Line Measuring** is quicker than other methods.

![workpiece](image1)

If you measure a Non Line data with **Object Line Measuring**, the result may be not desirable. For instance, if you click on the circle below, OVM will produce a mid-split line of the circle based on the edges it finds.

![circle](image2)

If you click on the ellipse below, OVM will produce a mid-split line of the ellipse based on the edges it finds.

![ellipse](image3)

If you click on the white part of the irregular image below, OVM will produce a line of the ellipse based on the edges it finds.

![irregular](image4)

**Object Circle Measuring**: left click on **Image Measuring** window, OVM will automatically find the edges, and produce a circle based on the data within the edges.
Left click into the white circle will get the data of the circle.

**Object Ellipse Measuring:** left click on Image Measuring window, OVM will automatically find the edges, and produce an ellipse based on the data within the edges.

Left click into the white circle will get the data of the ellipse.

**Object Centroid Measuring:** left click on Image Measuring window, OVM will automatically find the edges, and produce an centroid based on the data within the edges.

Left click on the white area will get the data of the centroid (a point).

**Rectangular Select Measuring**
Rectangular Select Measuring produces the regression based on the black and white edges within the rectangular select.

**Rectangular Select Point Clouds Measuring:** Use left key of the mouse to create a yellow box selection on Image Measuring window, OVM will automatically calculate and display the data of the point clouds (only one group of point clouds...
data shown, but consist of many points) within this box.

**Rectangular Select Line Measuring:** Use left key of the mouse to create a yellow box selection on Image Measuring window, OVM will automatically calculate and display the data of all the lines within this box.

**Rectangular Select Circle Measuring:** Use left key of the mouse to create a yellow box selection on Image Measuring window, OVM will automatically calculate and display the data of all the circles within this box. This method is most efficient to measure an image with many circles.

**Rectangular Select Ellipse Measuring:** Use left key of the mouse to create a yellow box selection on Image Measuring window, OVM will automatically calculate and display the data of all the ellipses within this box.
Rectangular Select Arc Measuring: Use left key of the mouse to create a yellow box selection on Image Measuring window, OVM will automatically calculate and display the data of all the arcs within this box.

Auto Tool of Measuring

Auto Tool of Point Measuring: automatically searches the highest black-white contrast value by means of image processing, and add the point data.

Auto Tool of Line Measuring: automatically searches the points that have highest black-white contrast value by means of image processing, and adds the line data.

Auto Tool of Circle Measuring: automatically searches the points that have highest black-white contrast value by means of image processing, and adds the circle data.

Auto Tool of Ellipse Measuring: automatically searches the points that
have highest black-white contrast value by means of image processing, and adds the ellipse data.

Auto Tool of Arc Measuring: automatically searches the points that have highest black-white contrast value by means of image processing, and adds the arc data.

Point Measuring Tool: click in the Image Measuring window to create a small yellow box, click elsewhere to create another. You can use your mouse to drag the yellow box to adjust the position. Left clicking on the yellow box will change the direction of the red arrow. To enter the point data, right click your mouse. The software automatically gets the point on the first border along the arrow direction.

Line Measuring Tool: adding line data

First you create two yellow boxes in the same way as in point measuring tool, and then drag either of the two points to find the optimal line. You can also drag the dashed line beside to change the range of the regression. Left click on the dashed line will change the direction of the red arrow. Right click to get the data of the line. The measuring method is the same as in point measuring. (Not repeated hereafter)
**Circle Measuring Tool:** click your mouse to create three yellow boxes. Drag the three points to find the ideal circle. You can also drag either of the dashed circles to change the range of the regression or direction of the red arrow. Then right click to get the data of the circle.

**Arc Measuring Tool:** click your mouse to create three yellow boxes. Drag the three points to create the ideal arc. You can also drag either of the dashed arcs to change the range of the regression or direction of the red arrow. Then right click to get the data of the arc.

**Ellipse Measuring Tool:** click your mouse to create three yellow boxes. Drag the three points to create the ideal ellipse. You can also drag either of the dashed ellipses to change the range of the regression or direction of the red arrow. Then right click to get the data of the arc.
Depth Measuring

You can measure depth by using Depth Measuring Wizard.

1. Change Z position, and observe Focus indicator.
2. Change Z position to high peak of focusing curve.
3. After fixed, Press 'Next'.

Locking Regression Object

If the object to be measured is too big to be displayed within one screen, press this button to tell the computer that it is dealing with the same measuring object. This function is usable only after function is activated.
**Point Clouds Measuring**

Click your mouse to create two yellow boxes. Drag the two points to find the desired edge. You can also drag the dashed line beside to change the range of the regression. Then right click to get the data of the point cloud.

**Edge Point Measuring**

Left Click to create two boxes, drag the two ends to find the suitable edge points, right click to get the data.

**Black White Exchange**

To exchange Black and White color collected by CCD during Image processing; the change is not displayed on the screen.

**Image Process Configuration**

Different configuration should be applied to different workpiece.

Two options, Filter Noise and Non Filter, are available under Noise Filter Control. Select Filter Noise will do noise filter, select Non Filter keeps the raw data.

Filter Tolerance: to filter the noise according to the tolerance setting. Noises that are beyond the tolerance will be filtered. This setting is very useful in dealing with rough edge.
**Gray Scale Control**: applying different gray scale.

**Manual**: manually selects a gray scale.

**The Measure Area Control**: Delete data less than this set value.

**Sampling Control**: to set the percentage of point you want to keep.

**Sensitive Area**: to adjust the yellow box size of the measuring tools. Tick the Show Area can show or hide the yellow box.

**Delay Time**: sets the speed of auto measuring when moving the measuring platform to the position indicated by direction indicator.

To set the reticle to dashed, solid or different color.

Other settings will be discussed in the IUI chapter.

**Clear Image**

Clear the objects in **Image Measuring** window.

**Show Ruler**

Show or hide the Red Cross ruler in **Image Measuring** window. Press Shift and left click to move the Red Cross ruler in **Image Measuring** window. When the ruler is shown, press Space Bar will input the center point’s coordinate of the reticle.

**Plane Calibration**

To do measuring on bevel, you have to do Plane Calibration first. The steps are very simple; you just need to select a few points on this bevel, and be careful to get a clear focus on the intersection.

**Delete Data**

This function is designed to delete the wrongly created points.

**Disable/Enable Callout Input**

Enable/Disable IUI function

**Real Time Object Plot**

Use this tool to enable or disable real time plot in Image window

**Geometric Measuring**

Geometric Measuring window displays geometric forms of the workpiece. In Geometric Measuring window you can calculate the distance, angels etc based on the data of point, line, circle, arc etc you get from the Image Measuring window

You can get the data of the object by clicking on the object in Geometric Measuring window.
CAPE—TRE—E

Undo
To restore the deleted data in the object list

Select View
To expand you’re selection to the maximum in Geometric measuring window

Fill View
To view the whole image in Geometric Measuring window

Delete
With this command, when move your mouse to an object in Geometric Measuring window, it will turn into red. Press Delete key then will delete the object.

Rectangular Select Delete
With this command, the selected object will turn into yellow; Press Delete key then to delete the object.


Point
To input or call out a point to calculate it’s coordinates. Select •, you will see in the Coordinate Display window which means you need to input a point to let
OVM get this object (a point). There are two ways to create this point: one is to left click in the Image Measuring window to input a point, the other is to right click in Geometric Measuring window to call out a point.

Object Information: X Coordinate, Y Coordinate

Line
To call out two points to generate a line, and calculate the distance between the two points. Press \( \overline{\text{L}} \), you will see information like \( \overline{0.240} \) which means you need to input two points to create this object (a line).

**Left click in the Image Measuring window to input two points, and right click to generate the line.**

Object Information: Length, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate)

Circle
To call out at least three points (not along a line) to generate a circle. Press \( \overline{C} \), you will see the information \( \overline{0.304} \) which means you need to input three points to create this object (a circle).

**Left click in the Image Measuring window to input three points, and right click to produce the Circle.**

Object Information: Center’s X Coordinate, Center’s Y Coordinate, Diameter, Radius, Big Radius, Small Radius, Roundness, Area.

Arc
To input or call out at least three points to generate an Arc. Data like, center, radius, arc length and angle can be calculated. Press \( \overline{A} \), you will see the information \( \overline{0.304} \) which means you need to input three points to create this object (an Arc).

\( \overline{\text{C}} \) Use \( \overline{9} \) to change the points you need to input.

Object Information: Center’s X Coordinate, Center’s Y Coordinate, Diameter,
Radius, Start Angle, End Angle, angle, and arc length.

Ellipse
To input or call out at least five points (not along a line) to generate an ellipse. Press \( \text{Ellipse} \), you will see the information \( 0:5:0:1 \) which means you need to input five points to create this object (an ellipse).

Object Information: Center’s X Coordinate, Center’s Y Coordinate, long axis, short axis and area.

B-Spline
To input or call out at least five points to produce a B-Spline. The more points you input the more accurate the B-Spline is. Information like, B-Spline length, smoothness and B-Spline type can be calculated. Press \( \text{B-Spline} \), you will see the information \( 0:3:0:1 \) which means you need to input three points to create this object (a B-Spline).
◎ Use \( \text{B-Spline} \) to change the points you need to input or call out.
◎ Press \( \text{B-Spline} \) twice, a dialog box will appear which allow you to adjust the smoothness of the B-Spline. The higher the value, the smoother the line is.

Object Information: Step number and Smoothness

Regression Line
Randomly input three points, a regression line will be generated automatically. Press \( \text{Regression Line} \), you will see the information \( 0:3:0:1 \) which means you need to input three points to create this object (a Regression Line).

◎ Use \( \text{Regression Line} \) to change the points you need to input or call out.

Object Information: Length, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate).
Coordinate), average deviation, maximal deviation, minimal deviation.

**Points Cloud**
To input at least three points to make a points cloud. Press ◼ you will see the information [3:0:1], which means you need to input three points to create this object (a Points Cloud).

◎ Use ▼ to change the points you need to input or call out.

Object Information: Point number

**Line Midpoint**
To input or call out a line, and calculate the distance between the two ends and coordinates of the midpoint. Press ← you will see the information [2:0:1], which means you need to input two points to create this object (a point).

Object Information: X Coordinate and Y Coordinate of the midpoint

**Point to Line Distance**
First input or call out one point (point A), then input or call out a line (line B) or two points (which can generate a line), length of line B or the distance between point A and line B can then be calculated and obtained. Press ↓ you will see the information [3:0:2], which means you need to input three points to create two objects (a point and a line).

Object Information: Length, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate)

**Point Tangent Line to Circle**
Input or call out a point first, then input or call out a circle or more than three points (not along a line to generate a circle). You will be able to calculate the point tangent line to this circle. Press ⊕ you will see the information [4:0:2], which means you need to input four points to create two objects (a circle and a point).
Use to change the points you need to input or call out.

Object Information: Length, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate)

Line Intersection
First input or call out one line, then a second, based on which the intersection’s coordinates, inclination, and supplementary angle can be calculated. Press you will see the information which means you need to input four points to create two objects (two lines).

Object Information: X Coordinate and Y Coordinate of the intersection, inclination, 180º supplementary angle, 360º supplementary angle.

Central Line
First input or call out two points (point 1, 2) to generate a line, then input or call out another two points (point 3, 4) to make another line. The software will find the midpoints between point 1 and 3, point 2 and 4, and make a line by the two midpoints. Press you will see the information which means you need to input four points to get two objects (two lines).

Object Information: Length, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate)

Average Width
First input or call out one line, then another. The software will calculate the average width between the two lines. Press you will see the information which means you need to input four points to get an objects (a compound object composed of two lines and line to line distance of the two lines).

Object Information: Length of line one, Start Point X Coordinate, Y Coordinate,
End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate); Length of line two, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate)

**Circle and Line Distance**
First input or call out a line, then a circle. The software will calculate the distance between the circle and the line. Press 🆕 you will see the information 📊 which means you need to input five points to get two objects (a circle and a line).

◎ Use 📊 to change the points you need to input or call out.

Object Information: Length, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate)

**Circle and Line Intersection**
First input or call out a line, then a circle. The software will calculate the intersection of the circle and the line. Press 🆕 you will see the information 📊 which means you need to input five points to get two objects (a circle and a line).

◎ Use 📊 to change the points you need to input or call out.

Object Information: X Coordinate and Y Coordinate of the Intersection

**Circles Intersection**
First input or call out a circle, then another. The software will calculate the intersection of the two circles. Press 🆕 you will see the information 📊 which means you need to input six points to create two objects (two circles).

◎ Use 📊 to change the points you need to input or call out.
Object Information: X Coordinate and Y Coordinate of the Intersection

- **Center-to-Center Distance**
  First input or call out a circle, then another. The software will calculate the center-to-center distance of the two circles. Press \( \text{ } \) you will see the information \( \text{ } \) which means you need to input six points to create two objects (two circles).
  \( \text{ } \) Use \( \text{ } \) to change the points you need to input or call out.

Object Information: Length, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate)

- **Two Circles Tangent Lines**
  First input or call out a circle, then another. The software will calculate the tangent lines of the two circles. Press \( \text{ } \) you will see the information \( \text{ } \) which means you need to input six points to create two objects (two circles).
  \( \text{ } \) Use \( \text{ } \) to change the points you need to input or call out.

Object Information: Length, Start Point X Coordinate, Y Coordinate, End Point X Coordinate, Y Coordinate, DX (deviation in X Coordinate), DY (deviation in Y Coordinate)

- **Input Coordinates**
  To manually input the coordinates of point, line or circle.
**IUI**
Enable or disable IUI function

**Display Data Group Number**
Show data group number

Hide data group number

**Show Cross Mark**
Show Cross Mark

Hide Cross Mark

**Switch between relative and absolute coordinates of the cross mark in Geometric window**
Calculation Setting
1. To set the distance to be calculated when measuring Circle-to-Circle Distance or Circle to Line Distance.
   - Circle to Circle Distance
     - Center-to-Center Distance
     - Maximal Distance
     - Minimal Distance
   - Circle to Line Distance
     - Center to Line Distance
     - Maximal Distance
     - Minimal Distance
Export Format

Select the data to be displayed for convenience of viewing and exporting to Word or Excel

DRO Decimal Setting
To set the decimal number for Metric system or British system based on your own needs. OVM will remember your setting next time when you start it.
Pulldown Main Menu

File

**Create Project**
Delete the currently measuring data and create a new project, with the extension name VMF.

**Open Project**
Open an existing VMF project from the computer.

**Save Project**
Save the current project with the current filename.

**Save Project As**
Use a new filename to save the current project as another file.

User Interface
User interface setting allows you to define your Pulldown Main Menu and to show or hide the Quick Key panel, so as to hide those uncommonly used functions.

Click on the setting items under Pulldown Main Menu or Quick Key, OVM will apply your setting immediately. You will see the changes of the interface meanwhile.

Click on Select All or Select None, and apply to change the look of the interface.

Click on Save to save your setting so that next time when you open the software, it will automatically use this setting.

**Import DXF**
To import DXF and compare it with the actual workpiece.

**Export DXF**
Save the file as DXF file so that it can be open by CAD/CAM for future editing.
CHAPTER—THREE
Export Word
Open a Word window, and transfer the measuring results to Word.

Export Excel
Open an Excel window, and transfer the measuring results to Excel.

Exit
Exit the system

**Coordinates Transformation**

Before measuring an object, you have to setup a coordinate first, the origin of which should be based on your view mode.

**Default Origin**

When you press \[ \text{Default Origin} \], the software default origin will replace your self-set coordinates system origin.

**Coordinates Move**

Press \[ \text{Coordinates Move} \] and call out a point to replace the old coordinates system’s origin with this point.

For example

After you press \[ \text{Coordinates Move} \] and right click on point C, point C becomes the origin of the new coordinates system.

**Two Points Defined X axis**

Press \[ \text{Two Points Defined X axis} \] and call out a point \( (1) \) to make it the origin of the coordinates. Call out another point \( (2) \), then the line goes through \( 1, 2 \) will become the X-axis, whose positive directions is from \( 1 \) to \( 2 \).

For example

Press \[ \text{Two Points Defined X axis} \] and right click on point B to make it the origin of the coordinates. Then right click on point C, by doing you will establish a X axis along the line that connects point B, C, the positive direction being B to C.
Two Points Defined Y axis

Press \[ \text{Select Point} \], and call out a point (1) to make it the origin of the coordinates. Call out another point (2), then the line goes through 1, 2 will become the Y axis, whose positive directions is from 1 to 2.

For example

Press \[ \text{Select Point} \], and right click on point B to make it the origin of the coordinates. Then right click on point C, by doing you will establish a X axis along the line that connects point B, C, the positive direction being B to C

Coordinate Rotate

Press \[ \text{Coordinate Rotate} \] and then call out two points (point 1,2) based on which to rotate the coordinates. The line connects the two points becomes the X-axis, while the origin remains the same.

For example

Press \[ \text{Coordinate Rotate} \], and right click on point B, then right click on point C, the coordinate will rotate to the extent that the line connects points B and C becomes the X axis, while the origin remains the same.
Machinery Origin
**Point and Line Intersection**

Press $\text{ \textbullet }$, and call out a point (point 1) to make it a point in the Y axis, then call out another two points (point 2, 3) to make the line through them the X axis whose direction is from point 2 to 3. From point 1, go vertically down to reach the X-axis, the point reaches become the origin, and the vertical line becomes the Y-axis.

For example

Press $\text{ \textbullet }$, and right click on point B, then right click on point C, the coordinate will rotate to the extent that the line connects points B and C becomes the X axis, while the origin remains the same.

**Point and Line Intersection 2**

Press $\text{ \textbullet }$, and call out a point (point 1) to make it the origin, then call out another two points (point 2, 3) to make the line connect them the parallel line of the X-axis whose direction is from point 2 to 3. A new coordinates system will be established whose origin is point 1 and X-axis is the parallel line.

For example

Press $\text{ \textbullet }$, and right click on point B to make it the origin, then right click on point C and point A. Line CA then becomes the parallel axis of the X axis whose positive direction is from C to A. A new coordinates system will be established whose origin is point B and X-axis the parallel line.
**Two Points Midpoint**
Press and call out two points to establish the X-axis whose direction is from point 1 to point 2. A new coordinates system will be established whose origin is the midpoint, and Y-axis the line that goes through the Midpoint and vertical to line 1,2.

For example
Press and right click on point C and point A in turn to make line CA the X-axis whose positive direction is from C to A. The Y-axis of the new coordinates system will be the line that goes through the Midpoint of line CA and vertical to it, the origin is the Midpoint.

**Two Lines Intersection**
Press and call out two points (1, 2) to establish the X-axis whose direction is from point 1 to point 2. Input another two points (3, 4) to make a line, then the intersection of Line 12 and Line 34 becomes the origin. The Y-axis will be the line that vertical to X-axis.

For example
Press and right click on point C and point D in turn to make line CD the X-axis whose positive direction is from C to D. Right click on point B and point A to
make line BA. The intersection of Line BA and Line CD will be the origin and the Y-axis will be the line that goes through the origin and vertical to Line CD.

Move Coordinates Again

After transforming the coordinates in other ways, press again and call out a point. A new coordinates system will be established whose origin becomes the callout point.

For example

First you transform the coordinate based on Y-axis. Then press and right click on point A to make it the origin.

Coordinates Setting

Coordinates Setting allows you to move or rotate the coordinates. Any settings (except for Default Origin, Coordinates Rotate, Coordinates Moving, Coordinates Re-moving) of the coordinate will generate this dialog box. If you mark the Preset Value box, then the coordinates will move or rotate this default value each time after you transform the coordinates.
Calibration

- **Linear Calibration**: to calibrate the image
- **Load Calibrated File**: to load a group of files with specific focus

For calibration:
- Load Calibrated File 1.
- Load Calibrated File 2.
- Load Calibrated File 3.
- Load Calibrated File 4.

- **Save Calibrated File**: Save the currently calibrated file
- Save Calibrated File 1.
- Save Calibrated File 2.
- Save Calibrated File 3.
- Save Calibrated File 4.

Function Setup
In Execution Method label (under Learning Function Setting), three solutions are provided in case Auto Measuring fails,

1. To resume the program without prompt when no object is detected by Auto Detection
2. In case no object is detected during Auto Detection, pause the program to let the user adjust and fix the object, then resume the program to continue measuring.
3. To exit the program when no object is detected by Auto Detection

Two delete methods are available under Delete Methods label:
1. To delete after confirmation, namely, the software will pop up a confirmation prompt each time before you delete a learning step.
2. To delete directly, i.e., delete the learning steps without any prompt.

Language

English
To switch to English interface
Traditional Chinese
To switch to Traditional Chinese (Big5) interface

Simplified Chinese
To switch to Simplified Chinese (GB) interface

Help

OVM Help
To view user manual

About 3DFAMILY TECHNOLOGY CO. LTD.
To open www.3dfamily.com.cn or www.3dfamily.com if you are collected to Internet

About OVM
To check the version information
This chapter provides you with the basic knowledge about OVM system. By learning this chapter, you can understand the window environment and function of OVM clearly which serves as the foundation to learn the later chapters.

The focuses of this chapter are:

- Knowing the window environment of OVM
- The function List of OVM
Notice: when a picture is selected, the surrounding lines become wider.

Basic element

Point

Move the mouse to a point in the image window, then double click right mouse key, the software will display the coordinates of the point you select. (You can check the accuracy of the coordinates)

Line

The operation is similar to the case with Point. Double click right mouse key will display the length of the line, and the
coordinates of the two end points. Double click again will cancel the display (if you right double click at the end points, only the coordinates of the point will be displayed).

Move the mouse to the middle part of the line, the software will show the position of the midpoint with thick line. Double click right key will generate the individual data of the midpoint of this line.

After generating the midpoint, you can also right click the line and the midpoint in turn to produce the perpendicular bisector.
Circle

Coordinates of the center and radius of the circle can be obtained by using this circle tool (the detailed operation will not be explained hereafter).

Arc

The data that can be shown is similar to that of circle.
Ellipse

The coordinates of a specific point is shown

Compound Function

Point - Point
Right click on two points sequentially; you will get the distance between the two points

**Point – Line**

We can select a point first, and then click on the line. By clicking on different position on the line you will produce different figures whose meaning is also different.

a. If you right click on the end point of the line, you will get the distance between the point and the two end points of the line.

b. If you right click on the line, you will get the distance between the point and the line.

c. If you right click on the midpoint of the line, you will get the distance between the point and the midpoint the line.
Point - Circle

Similar to point-line, you first select an individual point and then select another point on the circle. Different position of the latter point will get different result.

a. Right click the center of the circle, you will get the distance between the point and the center.

b. Right click on the circle, if the position you click is near to the individual point, you will get the shortest distance between that point and the circle.

c. Right click on the circle, if the position you click is farther to the individual point, you will get the longest distance between that point and the circle.

d. Right click on the circle, if the position you click is within side parts of the Circle (as referred to that individual point), the result produced is the tangent line of the Circle.

Point - Arc

The information that can be obtained is similar to that in Point-Circle.
Point - Ellipse
The distance between the individual point and a specific point on the Ellipse can be calculated.

Point - Point Cloud
Similar to Point-Point

Line - Line
Line and point-point combination is the simplest.
Then you select a point and a line to get the distance between the point and the line.

When the contained angle of the two lines is quite small or the two lines are parallel, you can select the line to produce the distance between the two lines and select the midpoint of the two lines to get the midline of the two lines.

If the contained angle of the two lines two is greater, you can select the line to get the contained angle of the two lines (the angle is one that produced in counterclockwise direction). By selecting the midpoint of the two lines you can get the angle bisector of two lines.
In other words, if the angle is bigger than a specific value, the software will calculate the contained angle of the two lines. If the angle is smaller than a specific value, the software will calculate the distance between the two lines. This specific value can be adjusted under Image Measuring - Image Processing Setup – Angle Set.

Notice: you first select the line midpoint, then select another line. Note that the figure produced varies according to the position of the line.

a. If you want to get the distance between the point and the line, you should select a line that is near to the axle.

b. If the position clicked is too far, the result will be the contained angle between the two lines.

**Line - Circle**

Select the line first, and then take it as the reference. By selecting different position on the Circle, you can get the shortest distance (close to the line), distance to center and farthest distance (far from the line).
If the Circle line is crossing, you can calculate the intersection by click on the line and then the circle.

**Line - Ellipse**

The combination of line and ellipse are as follows
Line - Arc

The combination of Line - Arc is similar to Point - Arc

Line - Point Cloud

Select the line first, and then by selecting Point Cloud in different positions, you will receive different results.

a. Take the line as the reference; if you select a Point Cloud that is relatively far from the line, you will get the maximal distance between the two.

b. Take the line as the reference; if you select a Point Cloud that is relatively near from the line, you will get the minimal distance between the two.

Circle - Circle
Selecting different position of the Circle will produce different results. Some of the particular points on the circle include the point that allows you to get the shortest Circle - Circle distance, the point that allows you to get the farthest Circle - Circle distance, the point that you get the tangent line and the center of the circle.

When two Circles are crossing, you can ask calculation the point of intersection, whose method is similar to the case in line - Circle.

Notice: after the calculation regarding the circle, you will get a few specific points on the circle that are related to the calculation you just made for the convenience of future reference.

Circle - Arc, Circle- ellipse, Ellipse- Ellipse, Ellipse - Arc, Arc- Arc
The calculations between the above elements will not be discussed in details here.

Cross line function is added under Image Processing

a. The size marking decides whether to show the digital size or not.

b. When you select the edge finder, and approach the cross line to the edge, its color will change (see the following picture)
Coordinates Transformation and Undo Function

See the picture below. There are a Circle and a Line on the picture. Right click on the circle, you will get a small circle (with a number 1 in it) on the upper left corner of the picture. The small circle represents the element you just selected and the number 1 is the serial number of this element.

Right click on the small circle will generate a dialogue box. “Clear” means cancel the selection. “Coordinates selection,” means transform the coordinates. “Cancel” means to do nothing. Here if we choose “coordinates selection”, then in the same way, we do “coordinates selection” to a line, then the coordinates will transform.
Transforming rule: the center or point will serve as the new origin. The direction from the starting point to the ending point becomes the positive direction of the new X-axis.

**Import DXF**
Before loading this DXF picture file, you should set up a coordinates like this picture by measuring an object corresponding with the drawing in the software.

You can load the drawing by using Import DXF from the File menu.
Like this you can compare the workpiece with its drawing and see if there are big inconsistencies (you can compare in image window or geometric window). You can find out the inconsistencies in the following picture. This detection method is quite simple, quick and convenient.
This chapter is an introduction to the basic operation of OVM system. In this chapter you will know the software and hardware of OVM system and get an overall understanding of the system.

The focuses of the chapter are:

- Operation Procedure of OVM
- Calibration of OVM
Preparation before Measuring

Start the System

The proper order should be:

- Turn on the computer
- Activate the measuring platform
- Run the program

Turn on your computer and enter Window XP. The measuring platform will be activated. You can double click the  on your screen desk or choose «Start | All Program | 3DFAMILY | OVM | OVM Measuring System» to run the system.

You will see the interface like below:

![Interface Image]

After you see this window, you can start using the system.

Finding absolute origin of optical ruler

The purpose is to ensure that you are using the same origin each time you enter the system.

1. Click on [Q], you will see a popup box like below. Press “Confirm” and follow the prompt to shift the platform left or right quickly to find the absolute origin of X-axis.
2. If you see the picture below, it means the absolute origin of X-axis has been located. Press “Confirm” to continue.

3. You will see a box like below. Press “Confirm” and level shift the platform forward or backward quickly to find the absolute origin of Y-axis

4. If you see the picture below, it means the absolute origin of Y-axis has been located. Press “Confirm” to finish.
Image Calibration

Linear Calibration
1. Put the calibration box on the scan platform.
2. Press “Image Measuring | Camera”
3. Press “Calibration | Image Calibration | Linear Calibration”
4. Decide the size of enlargement, and set the focus.
5. Select a proper size circle on the calibration box and click on the circle.
6. Move X axis to let the standard circle leave its original position and click on the circle.
7. Move Y-axis to let the standard circle leave its original position and click on the circle.
8. Repeat step 6 and 7 to try to let the standard circle appear on all the four corners of the screen.
9. After letting the circle appear in at least three different positions, right click your mouse key.
10. A prompt “calibration succeeds” will appear.
Chapter Five

Exit

The proper order should be:

- Close the program (save necessary file first)
- Shut the platform
- Shut the computer

After all the measuring, you can click \( \times \) or press ALT+F4 or through the menu File | Exit to exit the system. Note to save the useful file before you exit.

The following box will pop up when you exit:

If you press “Yes”, the system will save the project to OVMTEMP directory (if you installed the system under \ Program Files\3DFAMILY\OVM\OVMTEMP) will the filename OVM (year,month.day.hour, and minute). vmf, for example OVM2003_1_1_13_15.vmf. If you press “No”, it will return to the system, and no project will be saved. Remember to shut the platform before shut the computer.

Operations before Measuring

- Load measuring data: you can select File | Open an existing file to open an existing file.
- Clear measuring data: you can select File | New Project to clear all measuring data (the system will ask you whether you will save the present project or not)
- Delete Single Measuring Object: if a measuring error is found on a single object, you can call it out (the color of the object will turn into purple) and delete it by pressing Delete button.
- Change Unit: Press \( \text{in} \) or \( \text{mm} \) will switch between metric and

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English unit system. Press \( \theta \) or \( \ominus \) can switch between “Degree” and “Degree, Minute, Second”. The result will be displayed in “Object List”.

Start Measuring

Before measuring, you may measure different elements, such as point, line, circle, midpoint, Bspline, etc based on your needs.

Measuring Method Setup: you can select between Geometric Measuring and Image Measuring from the Main Menu or from the quick tool menu.

After that, you can start measuring.

Save Measuring Data

You can save the project during or after the measuring for future use. To do this, you just select “File | Save Project”.

You can also export the data to Word or Excel instead of saving the data. Just use the menu File | Export Word or File | Export Word. Using the menu File | Export DXF will save the project to DXF format so that it can be used in AutoCAD.

Note: as the Geometric Measuring window only shows observable image (i.e., no all objects is on the image), you need to press \( \Theta \) first before you can export all the objects to WORD or EXCEL.
This chapter introduces the checking function. You can use the Checking function in OVM to measure the workpiece. In addition, you will also know the different use of automatic and manual operation.

The focuses of this chapter are:

- Scanning
- Focusing
- Checking
- SPC
Scanning (OVM Pro)

In Step Control, you can drag the bar to adjust the value for each axis, or you can adjust the value subtly by pressing the arrows beside.

In positioning area, you select an axis first and adjust the value using to move the platform based on the current positioning of the platform. Or you can use to move the platform based on the zero point of the current coordinates.

Find the default origin for the platform.

When moving the platform you can use this button to stop it.
Focusing (OVM Pro)

In Focusing window, select Enable Focusing, you will see a yellow box on the image window. Move the platform then to place the edges within the box.

Click , the platform will automatically do the focusing.

You can use the default setting to do the focusing if you are under a low enlargement. Otherwise, you should mark “accurate” and use the biggest value (drag the bar to the right) under “sensitivity” before auto-focusing.

Focusing Indicator
Select “start”, you will see a yellow box on the image window. Move the platform to place the edges within the box. Move the Z-axis, you will get a graph in the focusing indicator window. If this graph is very disorderly, then you may need to click reset and move the Z-axis to get a graph until it looks normal. Next, you move the Z-axis in the opposite direction and aim the green vertical line at the blue little cross line (the peak of the wave). By doing this, you will get a clear focus.

Checking

Quick Access

1. Click 📋 to start learning (the following steps will be recorded).
2. Select a learning model.
3. Define a mechanical datum plane. If you choose to use clamping, that means you do not define the mechanical datum plane.

4. Measuring the object.

5. Double click the project you want to control in the “Object List” to load SPC.

6. Press \( \text{\textasciitilde} \) will delete a checking step.

7. Click \( \text{QUIT} \) will exit the learning.

8. Click \( \text{MOVE} \) to move the platform to the position of the indicator, then click in the Image window, OVM will automatically load data till finishing all the learning steps.

9. Click \( \text{CHECK} \), the platform will start the checking in loop until you click \( \text{STOP} \) to stop.

10. Press the "Path" button to select an existing filename that SPC has exported. If you have ticked "add to file", then the statistical data by SPC will be added to the final part of the original file. If "add to file" is not selected, the software will empty the previous data and then add the new data in; if you want to create a new file, you simply need to name (use English letter) it after choosing the path. Press "clear" will clear the path. Ps: The format exported by SPC can only be opened by Q-PLUS.

**Level Shift Copy and Rotate Copy**

- Level Shift Copy: to copy the selected object (can be more than one) along the horizontal line.

Level Shift Copy is only usable under learning model.

For Example:

Input two circles on (0,0) and (3,0), like below:
In the Checking box, you will see the following picture. Click “geometrically or manually input circle”, and press 

Set the value like the picture below and press “confirm”.

![Image of checking box with geometrically or manually input circle option]
In Geometric window you will see the following picture, which tells that the movement in Y direction is 3 and the copy number is 5.

![Diagram of circles in Geometric window]

Rotate Copy
Rotate copy the selected object (can select more than one).

Rotate Copy function is usable only under learning model.
For instance:
Input two circles on (0,0) and (3,0), like below:
In the Checking box, you will see the following picture. Click “geometrically or manually input circle”, and press 😊.

Set the value like the picture below and press “confirm”.

In Geometric window you will see the following picture, which tells that the rotated angle is 60° and the copy number is 5.
Explanation on the Detailed Procedure

Suppose that the object that you are to measure is a slice of circuit board, please operate according to the following steps.
1. Fix the first circuit board (as reference to the following measuring position) to the platform (use a clamping apparatus to fix so as to prevent the circuit board from slipping. You can use clay to help fixing too).

- Define the datum plane

![Diagram showing the first circuit board and measuring position]
If you use cross line to locate, the second and subsequent circuit board should always be vertical or horizontal to the first circuit board.

- vertical or horizontal shift
- rotate
Do not reverse the first circuit board (the front and back side might not be the same)

2. With the first circuit board, what we should do first is to define the datum plane, but what’s the role of defining the datum plane? Because as we have no clamping apparatus at hand, the position of each circuit board on the platform can be the same, so we must tell the computer: Which position is the standard position so that to avoid wrong judgments of the program which are caused when rotating the circuit board.

3. Without clamping apparatus, we have the following five means to define the datum plane: cross line positioning, object circle positioning, Point Group circle positioning, Point Group circle and Point Group line positioning, Point Group line positioning.
4. Presses Shift key, use the left mouse key to drag the Red Cross line and let it aim at the right angle edge, and then right click to finish defining the datum plane.

5. Find the circle to the left first, the right click to define the first datum point; then find a circle to the right, right click to define the second datum point. The line connects the first datum point and the second datum is the X-axis we defined.

- Picture of the first circuit board.
6. In the same way, we can find hole B and right click to define the first datum point; and then find Hole A, right click to define the second datum point. The line connects the first datum point and the second datum point (Line BA) is the Y-axis we defined.
7. After defining the datum plane, start learning from the hole to be measured in the first circuit board. Click will exit learning.

8. Take the first circuit board away from the platform and put the second circuit board on the platform.

9. After manual learning, click or to find the datum point on the second circuit board (use the same cross line or hole as the first circuit board). Then you will see direction mark like to help you move the platform. Stop moving when the red circle turn into green and twinkling state. OVM will automatically measure the object.

10. After inputting the datum point (line), you can move the platform to the correct position according to the data of the indicator, click the image window again, OVM will load the data automatically till finishing all learning steps.

11. Press to exit checking.

SPC

Step

1. Input the data that you want to analyze into SPC. You must enter Learning model before you can use SPC.

2. The data that measures will have different attributes. Double click on that attribute will list it in SPC controlling.

3. Enter a name for control item. For example: radius or R1. Input desired value in standard value box, positive and negative tolerance box.

4. Stop the learning model by clicking . Click or will measure again the previously learned objects till the end.

5. Press F4 to see results in SPC window.
Function Key of SPC

- Create SPC Project: to clear all SPC data and create a new SPC project.
- Open SPC Project: to open an existing SPC project.
- Save SPC Project: save the current SPC project
- Export To Excel: export the current SPC data to Excel.
- Export To Word: export the current SPC project to Word.
- Delete last group of data (including 2 to 6 sets of data)
- Delete the last set of data
- X-R Chart: Switch to Mean and Range Control chart.
- Xm-R Chart: Switch to Median and Range Control chart.
- X-Rm Chart: Switch to Specific Value and Mobile Range Control chart.
- X-S Chart: Switch to Mean and Tolerance Control chart.

Three functions are available when right clicking on the control chart:

Full View: To show the graph with best size.
3D View: To draw the graph in 3D effect.
2D View: To draw the graph in 2D effect. (The default setting)

2D View
3D View

Practice on Real Example

In order to explain how to use SPC do statistics analysis, we take the process of measuring the radius of two circles as an example.

1. Start the program
2. Select from the menu Image Measuring | Camera.
3. Enter learning model 📚, and press 🎈 to start Image Measuring.
4. Click on the first circle. The measuring results will be display in “Object List”. Double Click on radius on the list.
5. Enter a name for control item. For example: radius or R1. Input the desired value in standard value box, positive and negative tolerance box (if the positive and negative tolerance are equal, just click on negative tolerance box, you will get the same value as in positive tolerance box automatically).

6. Repeat step 4 to step 7 to set R2 as the control item of the second circle.

7. Press \( \text{ } \) to stop learning model. Click \( \text{ } \) or \( \text{ } \) and select in turn the first circle and the second circle, till the end.

8. Press F4 to check the result in SPC window

Data Analysis

Data form is divided into 3 parts in Data Analysis window: the upper part lists the Data Analysis and some commonly used process norms, such as \( \text{Ca} \), \( \text{Cp} \) and \( \text{CpK} \). The middle part lists the accuracy, precision of process, and process ability index. The lower part lists the order number, item, standard value, and number of data, unqualified number and its ratio.
Graph Data

Mean and Range Control chart (X-R)

If the quality data can be reasonably grouped, use X control chart to analyze the process and use R control chart to process variation.
Median and Range Control chart (Xm-R)

Similar to X-R Control chart, but X control chart checking efficiency is lower while the computation is simpler.

Specific Value and Mobile Range Control chart (X-Rm)

1. If the quality data cannot be reasonably grouped, use X-Rm control chart under the following situations:

   Only one data (such as manufacture efficiency and consuming rate) can be collected at one time.

   When the Process quality is very even so that no need to sample many times, such as liquid density.

   When it is time-consuming and involves high cost to get the measuring value, such as complicated chemical analysis and destructive inspection

2. If the quality data can be reasonably grouped, use X-R control chart to enhance checking efficiency.
Mean and Range Control chart (X-S)

Similar to X-R Control chart, but the S Control chart is more efficient than R Control chart in term of its checking ability while the computation is more complicated.

Use R Control chart if the sample number is less 10, otherwise use S Control chart.
Data Form

Data Form falls into two parts: the upper part shows the result of each set of measuring (each row 2-6 samples) with their mean and range. The lower part displays the order number of control data, the control item, standard value, and number of data, unqualified number and its ratio.
Before measuring, you should first acquaint yourself with the basic function of OVM. By learning the process of measuring a real example in this chapter, however, you can be more familiar with the measuring procedure.
Handphone Shell Data Picking (Rimming light)

1. Start the system.
2. Open rimming light and shut surface light.
3. Press the menu “Image Measuring | Camera”.
4. Press quick tool 😃.

5. Click in the Image Measuring window, the system will use black and white to display the image, while the edges are in red. The “Object Full View” window displays the relative position of the measuring object in

6. If you move the object, the edging line that you got before moving (in blue) will move along.
7. After measuring, you will see the point data in “Geometric Measuring” window.

Handphone Shell Inner Edge Data Picking (surface light)

1. Start the system.
2. Open surface light and shut rimming light.
3. Press the menu “Image Measuring | Camera”.
4. Press quick tool \* to mark the feature points of the object under Measuring.
5. Press “File | Export DXF” for later use.

- Surface light is used when the object has no big contrasting color and is opaque. While rimming light can only be used on object that has big contrasting color. If the object has big contrasting color like black and white, you can also use \* to find the edge.

Circuit Board Checking

When measuring, two situations are distinguished: with or without clamping apparatus. If the clamping apparatus is available, we do not need to define the datum plane. Otherwise, we have the following five means to define the datum plane: cross line positioning, object circle positioning, Point Group circle positioning, Point Group circle and Point Group line positioning, Point Group line positioning.
With Clamping Apparatus

First, we will demonstrate the checking of circuit board with clamping apparatus.

1. Before checking, make sure that settings about power supply, return home, and calibration have all been done.
2. Fix the circuit board to the clamping apparatus.
3. Press on checking window.
4. The dialogue box “Define machine datum plane” will pop up, press and click “Next”.
5. Start learning (including SPC setup).
6. Press to end learning.
7. Take out another circuit board, and fasten it to the clamping apparatus.
8. Press or to start checking.

Without Clamping Apparatus

Cross line Positioning

1. Before checking, make sure that settings about power supply, return home, and calibration have all been done.
2. Use clay to fasten the circuit board to the measuring platform.
3. Press on checking window.
4. The dialogue box “Define machine datum plane” will pop up, press and click “Next”.
5. Press “Image Measuring | Show Ruler”
6. Press down Shift key and meanwhile use the mouse to use the Red Cross line until aiming it at the square edge, then right click to finish defining the datum plane.
7. You will see the picture below after right click.

8. Start learning (including SPC setup).


10. Take out another circuit board, and fasten it to the measuring platform.

11. Press ⬆️ or 🌈 to start checking.

12. Find the same position of datum cross line of the first circuit board, then right click to complete defining the datum plane. After that, the checking will start.

13. Repeat step 1 and step 2 each time you put a circuit board on
CHAPTER-SEVEN

the platform.

Workpiece Circle Positioning

1. Before checking, make sure that settings about power supply, return home, and calibration have all been done.

2. Use clay to fasten the circuit board to the measuring platform.

3. Press \[ \text{on checking window} \]

4. The dialogue box “Define machine datum plane” will pop up, press \[ \text{and click “Next”} \]

5. Right click on the first hole to make it the origin; you will see information in Checking window as below.

6. Right click on the first hole to make direction of the X-axis; you will see information in Checking window as below.

7. Start learning (including SPC setup).
8. If you want to do SPC analysis, just double click on the desired items on the Object List. The instance here is the “center to center distance”.

9. Set SPC like the picture below.

![SPC Setup](image)

10. If you want to delete one step, just select that item and press . Note that when you delete a step, the data items that are originated from that step will be changed. For instance: if you delete the circle in step 6, the “center to center distance” which is based on this circle cannot be obtained. So before you delete a step, you must consider in advance whether you need the data that is evolved from that step.

11. Press \( \square \) again to end learning.

12. Take out another circuit board, and fasten it to the measuring platform.

13. Press \( \angle \) or \( \triangle \) to start checking.

14. Find the same position of datum hole of the first circuit board, then right click to complete defining the origin and X-axis direction of this circuit board. After that, the checking will start.

15. Repeat step 1 to step 5 each time you put a new circuit board on the platform.

**Point Group Circle Positioning**

1. Before checking, make sure that settings about power supply, return home, and calibration have all been done.

2. Use clay to fasten the circuit board to the measuring platform.

3. Press \( \square \) on checking window.

4. After the dialogue box “Define machine datum plane” pops up, press \( \bigcirc_1 \) and \( \bigcirc_2 \) and click “Next”
5. With the lower hole, use the right key of your mouse to input at least 3 points, and then right click to make a circle, the center being the origin. See below:

6. With the upper hole, use the right key of your mouse to input at least 3 points, then right click to make a circle, the line connect the origin and the center being X axis. See below:

7. Start learning (including SPC setup).
8. Press 📞 to end learning.
9. Take out another circuit board, and fasten it to the measuring platform.
10. Press 🔽 or ⬆️ to start checking.
11. Find the same position of datum hole of the first circuit board, define the datum plane of this first circuit board and then start checking.
12. Repeat step 11 each time you put a new circuit board on the platform.

Point Group Circle and Point Group Line Positioning

1. Before checking, make sure that settings about power supply, return home, and calibration have all been done.
2. Use clay to fasten the circuit board to the measuring platform.

3. Press 🔄 on checking window.

4. After the dialogue box “Define machine datum plane” pops up, press 🔄 and click “Next”.

5. With the lower hole, use the right key of your mouse to input at least 3 points, and then right click to make a circle, the center being the origin. See below:

![Diagram of a circuit board with a circle and points labeled 1 and 2.]

6. Left click to input at least two points, and then right click to make a line, whose direction becomes the direction of X-axis.

7. Start learning (including SPC setup).

8. Press 🔄 to end learning.

9. Change a circuit board, and fasten it to the measuring platform.

10. Press 🔄 or 🔄 to start checking.

11. Find the same position of datum hole of the first circuit board, define the datum plane of this first circuit board and then start checking.

12. Repeat step 11 each time you put a new circuit board on the platform.

**Point Group Line Positioning**

1. Before checking, make sure that settings about power supply, return Home, Calibration has all been done.

2. Use clay to fasten the circuit board to the measuring platform.

3. Press 🔄 on checking window.

4. After the dialogue box “Define machine datum plane” pops up,
press \( \text{and click "Next".} \)

5. Left click to input at least two points, then right click to make a line, whose Direction becomes the direction of X-axis.

6. Left click to input at least two points, and then right click to make a line. The Intersection of this line with the first line becomes the origin.

7. Start learning (including SPC setup).

8. Press \( \text{to end learning.} \)

9. Change a circuit board, and fasten it to the measuring platform

10. Press \( \text{or } \) to start checking.

11. Find the same position of datum hole of the first circuit board, define the Datum plane of this first circuit board and then start checking.

12. Repeat step 11 each time you put a new circuit board on the platform.
Chapter Eight
Troubleshooting

This chapter provides you with solutions to some problems or failures of the system, so that you can do basic maintenance to the system. A good operating habit can add to the service life of the machine.

If you cannot find the solution to your problem here, please provide with us the machine model, software version and operation system of your computer as well as the detailed description of the problem.
Why can’t I start the program?

► Make sure that platform is properly connected to the computer.
► Make sure the power supply of the platform is connected
► Make sure that USB line is usable.

► if the computer fails to detect USB device, try to plug in the line again.
► if the USB still fails, please reinstall the USB driver.
► Refer to 2-22 (Optical ruler scale counter) for Driver installation.

1. When you see the prompt “image picking device error”
► Make sure that the driver has been installed (see picture below), otherwise you should install the image picking card driver first.

► Make sure that the Image Picking Card is firmly placed in the PCI slot.
► Remove the existing driver. Pull out the Image Picking Card and insert it into another PCI slot, then reinstall the driver.
2. Why there is no image on the screen?
► Make sure that the power switch on Control panel is on.
► Check the power supply of the light or the brightness of the light.
► Make sure that the Image line is connected to the AV1 port of the Image Picking Card.
► Make sure that you have press “Image Measuring | Camera 📸”

3. Why can’t I read the data from the optical ruler?
► Make sure the USB line is properly connected. If there is only one axis whose data can’t be read, then please replug the line of it.

4. Why does the measuring result differ too much with the real size of the workpiece?
► Make sure what kind of unit system you are using, Metric system or British system.
► Check if you adjusted the enlargement of the lens, but forget to readjust when measuring.
► Check whether the workpiece is firmly fastened to the platform.
► Check the light of Calibration, if the light is too strong, the measuring result will be bigger, otherwise it will be smaller.

5. Why the lighting on the platform fails to light?
► Check whether you have switched the power on or not.
► Check the brightness setting of the light.
► Check the power connection of the control panel.
► Check the power switch on the control panel.
6. Why does Image Measuring fail to work?
   ► Make sure you use a moderately bright light.
   ► Make sure you get a clear image.

7. Why there are many vertical bars on the image of the workpiece in Image window?
   ► Check the CCD, see whether it’s PAL or NTSC. And use the same setting for it by set CCD setup—Camera 1.

8. Why it says loading CoInitialize fails when exporting to Word or Excel.
   ► Make sure you have installed Word or Excel in your computer.

9 Abnormal startup of the software.
   ► Remove the OVM and reinstall to fix the problem.
The focuses of this chapter are:

- Operation Environment
- Maintenance
Operation Environment

Temperature

A temperature of $20^\circ\text{C} \pm 2^\circ\text{C}$ (including $2^\circ\text{C}/8\text{hrs}$ variance) is optimal to the accuracy of measuring.

The measuring accuracy will be undermined under extreme temperature. Do not adjust the accuracy of the machine under bad temperature, otherwise even the accuracy under $20^\circ\text{C}$ may also be affected.

Humidity

Humidity has no direct influence on the accuracy of measuring. However, as the machine may rust under high humidity and thus affects the level shift. It is necessary to keep the measuring humidity between 55% and 65%.

Vibration

Vibration of the machine affects the accuracy of the measuring. If the frequency is less than 10Hz, the amplitude of vibration should be kept under $2\mu\text{m}$ (peak-peak variance). If the frequency is between 10Hz and 50Hz, the acceleration should be kept under 0.4Gal.

An anti-vibration device is needed, if the vibration under measuring is bigger than the above value.

Dust

Delicate devices such as optical ruler, etc must be kept away from dust. Measuring device should be cleaned periodically even though an anti-dust covering is used.
Maintenance

Precautions:

1. Do not put the device in places with too much dust, big vibration or sharp-contrasting temperature.

2. Clean the lens or computer screen with clean cotton paper. Do not touch them with your hands or clean them with water or oil dipping cloth.

Machine Shell

If the shell gets dirty, it won’t affect the measuring accuracy. However, it’s possible that it brings the dirt to more delicate parts like linear slipping rail or measuring platform, so do clean the shell (with soft cloth) once it’s dirty.

Linear Rail

Linear Rail is the base of all kinds of movement. Grease it every three-month.

Measuring Platform

Take care not to hit or break the glass plane when handling the workpiece. Sometimes the plane may be covered with a layer of water or oil, and then you need to clean it with detergent.

Optical Ruler

The Optical Ruler on each axis has already been protected with anti-dust covering or install in place that prevents dust. Contact the company if they fail to get correct results.
Chapter Ten
Appendix

The focuses of this chapter are:

- Geometric Measuring
- Image Processing
- Introduction to SPC
- Introduction to Control chart
Geometric Measuring

Unit

2. Length Unit
   1 mm = 0.03937 inch
   1 inch = 25.4 mm

3. Angle Unit
   Degree system
   The Degree system uses sexagesimal system. It divides a circle into 360 even parts with each part called 1 degree (°). A degree is further divided into 60 even parts, called 1 Minute (´). A Minute is also further divided into 60 even parts, called 1 Second (¨).

   The circumference angle of a circle is 360°. One half of it will be 180°, which is also called horizontal angel, such as the angle between two parallel lines. One fourth of the circumference angle is 90°, which is also called square angel, such as the angle between two lines that are vertical to each other.

Degree Conversion Table

<table>
<thead>
<tr>
<th>Degree (°)</th>
<th>Minute (´)</th>
<th>Second (¨)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>60</td>
<td>3600</td>
</tr>
<tr>
<td>0.016666</td>
<td>1</td>
<td>60</td>
</tr>
<tr>
<td>0.277778 x10^-3</td>
<td>0.016667</td>
<td>1</td>
</tr>
</tbody>
</table>
Special Terms

Real roundness: Roundness: A representation of tolerance of roundness of cylinder, cone or sphere. For any section orthogonal to axis, its circumference is located within two concentric circles, and the tolerance of roundness is radial distance of the two concentric circles.

Image Processing

Relationship between Image Quality attributes and the corresponding components

<table>
<thead>
<tr>
<th>Major attributes of image quality</th>
<th>The related components</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution: the ability to regenerate image.</td>
<td>● lens ● screen ● camera</td>
</tr>
<tr>
<td></td>
<td>● image picking card</td>
</tr>
<tr>
<td>Contrast : the gray scale contrast between the object and the background</td>
<td>● lens ● lighting ● camera</td>
</tr>
<tr>
<td>Depth of Field (DOF) : difference between the farthest and shortest distance with the object an be clearly see, also called focus depth.</td>
<td>● aperture value</td>
</tr>
<tr>
<td>Distortion : it is the optical error caused when the object is enlarged by the lens.</td>
<td>● lens</td>
</tr>
<tr>
<td>Perspective Errors : is a kind of error occurring to the traditional lens. The telecentric lens is free from this kind of errors.</td>
<td>● lens</td>
</tr>
</tbody>
</table>
Introduction to Digital Image

In image processing circle, two kinds of image are distinguished: digital image and optical image. The two differs greatly on the method of processing the image data. Normally, optical images such as those produced by AUTOCAD, TURBOCAD, and ORCAD use vector to construct an image, i.e. it uses the coordinates of a few points to represent different point, line or surface. In this case, when the image is enlarged, no indentation will be caused. However, as big calculation is involved in the conversion of this kind of image, it requires larger computer memory and longer processing time. In contrast, digital image constructs an image in BITMAP method, namely, it uses value matrix to display the points of an image.

Some of the features of digital image include:

**High quality image:**

As the traditional electronic simulation circuit needs meticulous adjustment, this will result in the parts being apt to wear out. In addition, in writing or transmitting the image data, the simulation image signal is apt to be distorted or affected by noise. In contrast, digital image signal can be hardly affected by the above factors. As long as the design is errorless, a digital circuit will have better reliability and will produce higher image quality too.

**Multiple applications:**

Digital image processing have wider range of applications in terms of decoration, identification and image analysis by virtue of its multiple functions of Image Enhancement, Image Segmentation, Image Encoding, Image Transformation, Pattern Recognition etc. These techniques are widely used in industry, military, medical science, meteorology and commerce.

**Non-touch technique:**

The traditional way to measure surface smoothness has to use probe to touch the surface. While now, thanks to optical image picking technique, this touch is avoided.

**Term Explanation**

**Pixel** : A digital image is a image \( f(x,y) \) whose coordinates and brightness are both digitalized. You can regard a digital image as a matrix whose row and column decide the coordinates of the object. The value of an element in the
matrix then represents the brightness or gray level of a point. We call such element a pixel or pel (short form for picture element).

**Gray Level**: Image data is composed of numerous pixels. Each pixel has a fixed coordinates that correspond to a point of the object. The value of a pixel is called gray level, which is decided by the brightness of the object. The brighter the object is, the bigger the gray level. The value range is between 0 to 255 under 8-bit model.

**Binarization**: if the Gray Level of a pixel is smaller than a critical value, binarization will set it to 0 (black). If the Gray Level of a pixel is greater than or equal to a critical value, binarization will set it to 255 (white). The critical value is also called Threshold

\[
H(g_q) = \begin{cases} 
0 & g_q < t \\ 
255 & g_q \geq t
\end{cases}
\]

\(t\) is a Gray Level stands for Threshold; \(g_q\) stands for the Gray Level of a random point on an image; \(H\) stands for a Labeling Operation.

Original gray scale image
CCD: CCD is most important to a camera. The appearance of CCD is like an IC chip. On the chip there are many sensing components whose amount directly affects the image quality of a camera. These sensing components are also called “picture elements”

NTSC: National Television System Committee, established by USA.

**NTSC Specification:**

1. Vertical synchronous signal: 60 HZ
2. Horizontal synchronous signal: 15750 HZ
3. Field scans frequency: 60 per sec
4. Frame scans frequency: 30 per sec, a frame contain 2 fields
5. Field scans time: 1/60 per sec
6. Frame scans time: 1/30 per sec
7. Field resolution: 262.5
8. Frame resolution: 525
9. Horizontal scan speed per second: 525 X 30 =15750
10. Horizontal scan time of each unit: 1/15750 sec

PAL: Phase Alternation Line, established by Germany.

**PAL Specification:**

1. Vertical synchronous signal: 50 HZ
2. Horizontal synchronous signal: 15625 HZ
3. Field scans frequency: 50 per sec
4. Frame scans frequency: 25 per sec, a frame contain 2 fields
5. Field scans time: 1/50 per sec
6. Frame scans time: 1/25 per sec
7. Field resolution: 312.5
8. Frame resolution: 625
9. Horizontal scan speed per second: $625 \times 25 = 15625$
10. Horizontal scan time of each unit: $1/15625$ sec

**CCD Resolution:**

**Vertical Resolution:** Vertical Resolution is limited by the number of horizontal line. In case of NTSC the number is 525 lines, while PAL is 625 lines. If using KELL or wide exposure coefficient, the maximal resolution is only 3/4 of the designed lines, i.e. NTSC: $525 \times 0.75 = 393$; PAL: $625 \times 0.75 = 470$

**Horizontal Resolution:** theoretically speaking the horizontal resolution can be increased with no limit, but it is actually limited by the following two factors:

a. The current technique limits the amount of pixels a chip can process.
b. As the chip is smaller and smaller, if you increase the pixels a chip can process, the resolution is increased, but the sensitization will be reduced.

Typical Resolution of CCD:

a. Black and White CCD:
   - low resolution: 380~420 line
   - high resolution: 570 line

b. Color CCD:
   - low resolution: 330 line
   - high resolution: 470 line

**LENS**

The lens is mainly used to collect the light reflected by the object and cast the light on CCD. The image it projected on the CCD is an upside down picture, but the camera can reverse it. The imaging principle is quite similar to human’s eyes.

**A. Type of LENS:**
1. Fixed Focal lens
2. Zoom lens
3. Auto iris or manual iris

**B. Classification in terms of focus**
1. Standard lens
2. Wide-angle lens
3. Telescopic lens

**C. Classification in terms of iris:**
1. Fixed iris
2. Manual iris
3. Auto iris

EX : adjust according to image signal, highly sensitive.

EE : adjust according to photo sensor

**D. Zoom lens :**

Manner of zoom lens:
1. Motorized zoom lens
2. Manual zoom lens

Times of zoom : 6 times , 8 times , 10 times , 12 times, etc

**E. Lens related terms**
1. Iris
2. Focus
3. Zoom
4. F-stop
5. Focus length

**F. Meaning of F & f :**

F stands for the aperture diameter: F1.2, F1.4, F1.6, F1.8, F2.0. The smaller the value, the bigger the aperture can be opened and more light will be received.

F stands for focus range: f: 4mm; f: 6mm; f: 8mm etc; zoom lens f: 8-48; f: 8-80; f: 7.5-120 etc.

**G. Selection on lens and camera :**

Camera lens (standard lens) (zoom lens) (superzoom lens)

- 1/3" 6 mm 4.2 mm
- 1/2" 12 mm 6 mm 4.2 mm
- 2/3" 16 mm 8 mm 4.8 mm
- 1" 25 mm 12.5 mm 8 mm

**H. Factors affecting the lens performance :**

1. The number of lens used (multi lens can reduce color bias and improve focus, but will reduce transparency)

2. Lens transparency (lens with good transparency is also more expensive)

3. Plating and polishing (affects the performance of lens)

4. Mechanical devices (mechanical structure can influence the accuracy)

**Brief operating principle of lens:**

1. There are two kind of lens: concave lens and convex lens.

2. By arranging multiple lenses in specific order, you can form group lens of different focus.
3. Some lens in a group lens designed to be movable so as to achieve different needs.

4. The out image is picked by the lens group and projected on the CCD sensor of the camera.

**Fishbone graph of visual processing based checking technique**

**Introduction to SPC**

**Why use SPC?**

SPC (Statistical Process Control) is an effective method to improve management in enterprises. Based on mathematical statistics, and by examining and analyzing the collected data, SPC can effectively prevent in advance many incidences so that it conveniently controls the manufacture process and enhances quality.

SPC can correctly distinguish between normal and unusual state during the
manufacture process. It helps you to detect the unusual state and take measures against it. As a result, the quality cost can be reduced and quality of the product improved. It emphasizes on prevention and control over the whole process.

Firstly, SPC can tell you the changes during the manufacture process and let you decide whether you should adjust the manufacture process or not. As a globally accepted quality-improving tool, SPC can help you to achieve a quality level as high as 6 Sigma (or 3.4ppm), which is really a big benefit.

A stable quality can bring high satisfaction from the customer. Reducing variation can lower the ratio of inferior products and the loss of money or time they would cause. High quality is vital to promote the competition advantages of enterprises. Finally, it can assess the quality improving measure that you take, so that quality can be improved constantly.

**Origin of SPC**

In 1924, Dr. W. A. Shewhart drew the first picture of SPC. In 1931, he published a book called “Economic Control of Quality of Manufactured Products”. Since then, SPC started to be widely applied to improving various kinds of manufacture processes.

**Sources of Variation**

'Variation is a common phenomenon and a part of human life.' This statement, which is accepted as a simple fact nowadays, was actually not widely known until merely one hundred years ago. Variation exists in any process. Sometimes it may be big enough to be noticed; sometimes it could be very small as to be imperceptible to the eye.

If you randomly take out a few products from the manufacture line, and examine some specific characteristics of them, you are sure to find that the result will vary from each other as long as the measuring instrument is accurately enough. By the same token, when you count the surface flaws of a product or measure the thickness of a piece or measure the diameter of a screw cap or count the yield of a chemical course etc, you will definitely find variations in the result.

In Figure 1 and Figure 2, you can see the source variation and influence it causes on the product.
4. Process

One source of variation comes from the process, which includes tool wear, machine vibration, position of the holding machine, and the fluctuations of electricity or water supply. When these factors work together, it will cause some variations to the process within a certain degree. So even two machines are exactly the same, their ability still varies. So it is significant to bear this in mind when producing an important part.

5. Machine

After handling a lot of products, cutting tools usually lose some sharpness; the lubricating effect also changes with the change of temperature; the size of the products also changes with the different setting and position of the cutting tool. On the surface, the operation seem to be under the same condition, but in fact, there are a lot of variations happening in a way not noticeable, but influencing the quality of the products. Taking heat treatment as an example, the temperature of the electric stove varies with the constant change of the voltage. Different position in the stove, such as the stove mouth, stove top, stove wall or the stove heart also has different temperature. Consequently, the thing in the stove will have different
quality characteristic according to their different position.

6. **Material**

Since variation exists in the final product, it will also be found in the material because material is also another kind of final product of the supplier. Such characteristics as tensile strength, malleability, thickness, etc of the material are all likely to cause variation.

7. **Operator**

The operator can be the biggest source of variation. The operating procedure of the operator, the energy and mood of the operator, as well as the technique and physical feature of the operator (such as height, cleverness, left or right hand habit) are all sources of quality variation.

8. **Others**

Environmental factors like temperature, lighting, humidity, etc are also sources of variation. For example, if the temperature is high, then the water contained in paper material will change which may result in a bad effect on the final product. Poor measuring tool or wrong use of the standards are also possible sources of variation.

**The underlying principle of SPC**

SPC is a kind of scientific method used for analyzing data, and utilize the analysis result to solve real problem. So long as the problem can be numberized, you can use SPC to analyze. Generally speaking, whatever data you collect, variances are surely to occur. If you draw the data in picture, you will find that the data value changes within a certain range. What is the cause of the variance? The reason may come from raw materials, equipment, atmospheric pressure, operator's physiology, mental state, etc. The basic principle of SPC is as follows:

- The quality variations of the product measured are caused by some accidental factors.
- Some phenomena caused by certain accidental factors are unavoidable under any manufacture process or checking system.
Unable to find reasons for those consistent variations.
Variation caused under other state can be found and avoided.

It can be known that Dr. Shewhart distinguished two kinds of variations: the unavoidable variation and avoidable variation.

- The unavoidable variation can affect the product at any time.
- Avoidable variation will only influence the products under specific conditions.

If a process is only influenced by unavoidable variation, the process is called stable process, i.e. that variation can be predicted to be within a certain range. If a process is influenced by both unavoidable variation and avoidable variation, the process is unstable. The quality variation of the products under this situation can’t be predicted and calculated. SPC Chart is then such a statistic method to judge whether a process is stable or not and whether the variation is unavoidable or avoidable. Below is a standard SPC Chart, we can see that SPC is mainly used to examine or analyze the manufacture, product or part handling as well as the whole or partial process.

**Introduction to Control Charts**

**Basic principles of Control Charts**

According to the statistical theory, the population parameter can be estimated by samples randomly collected from it. The statistics foundation of SPC Chart lies in this theory. But SPC Chart cannot control a process. It only provides important information of the process, which serves as the foundation quality assessment and process adjustment. Ordinary SPC Charts can offer control lines of three processes: upper control limit (UCL), center line (CL) and Lower control limit (LCL). Different process has different data in control chart that can be classified into the following data types:

- Grouped data - to divide the quality of the products into 'good or bad', 'qualified or disqualified' etc.
- Count data – to count the number of happening times of a certain characteristic of a product, such as the error times, accident times, leading sales times, etc.
- Continuous data - value of a certain characteristic, such as the size, cost, time, etc.

The first two kinds of data are quantity data, the third is value data. When collecting data, quantitative data is usually preferred, because it involves less
comparative calculations, while offering more information.

**Basic Calculation**

Control chart can be demonstrated with a general formula. Suppose that $y$ is the sample statistics of the product quality, $\mu_y$ is the mean of $y$, the standard deviation is $\delta_y$, then

$$UCL = \mu_y + k\delta_y$$
$$CL = \mu_y$$
$$LCL = \mu_y - k\delta_y$$

In the above formula, $K\delta_y$ is the distance between control line and centre line. As this theory was firstly proposed by Dr. Waiter A. Shewhart, any control charts are established based on this theory is called Shewhart control chart.

**Range of application**

There are many ways in terms of the application of Control charts. In most cases, they are used to do online monitor of process. In other words, it collects sample data to set up the control chart based on the data. If the sample value falls within the range of control limit and has no systemic change, then the process is said to be under control limit. A control chart can also be used for evaluating the previous processes or predicting later processes. It also acts as a tool for estimation. Predictions on the value of some data, such as mean, standard deviation, disqualification rate, etc can be given by control chart as long as the process in under control. This ability plays an important role on the decision-making of the administrator, such as the decisions on purchasing or self-made, on improvement of process or not, and on the contract between the supplier and the customer.

**Implementing Procedure of Control Chart**

1. Choose a quality attribute.

2. Decide the type of control chart.
3. Determine the size of sample.

In designing a control chart, you must first decide the sample size and frequency of sampling. Generally speaking, the bigger the sample is the easier it is to detect minor changes in a process. Before deciding the sample size, you should first decide on the range of variance of the process. If the variance is big, you can use a small sample size. Otherwise, you should use a large sample size. In addition to determining the size of samples, the frequency of sampling should also be considered at the same time. It is ideal to collect big sample with high frequency. But economically speaking, this is not the best sampling method. A more feasible method is to collect big sample with long intervals or collect small sample with short intervals. Under the condition of mass production and multiple variations causes, it is more suitable to adopt the method of small sample and high frequency of sampling. With the development of the detecting device and automatic measuring technology, the present trend is to do 100% examination.

4. Sampling frequency and sampling method

The control chart utilizes the concept of rational sample group to collect the sample data. If this way of sampling can disclose the causes of variation factor, the possibility of between-group variation is the biggest, while the within group variation is the smallest.

When applying control chart to production, the production order is a logical rational sample group sampling method. There are two methods to do rational sample group sampling. The first method (see below picture (a)) is to collect within group sample under short interval. This sampling method can bring a maximal between group variation and minimal within group variation. It is the best method to estimate standard deviation of the process. The method is also called instant time method.

With the second method, the within group data comes from the representative products in the last sampling. Under this method, each sample can be regarded as a random sample within sampling interval (see picture below (b)). This sampling method is named distributed sampling method or period of time method. This method is usually used to decide whether the products from the previous sampling are acceptable.
5. Collect data

6. Calculate attributes of the control chart, generally including the centerline and upper and lower control limit.

7. Collect the data, and use control chart to monitor the process.

Reasons to Use Control Chart

1. It is an effective tool to improve productivity
   The effective application of control chart can reduce wasting and re-production, which is equal to mean productivity increasing, cost reduction and production improvement.

2. It is an effective tool to prevent disqualified products.
   As a preventative management tool, Control chart emphasizes on correct manufacture process rather than afterward inspection to promote the quality of product.

3. It can prevent unnecessary adjustment to the process
   Control chart can tell you the best time to adjust the process so as to avoid big variation that may cause by excessive adjustments.

4. Control chart can offer the information for diagnosis
   The nonrandom patterns on control chart can provide you with the information for diagnosis. A nonrandom pattern is usually caused by unusual reasons. With the nonrandom patterns of the control chart, you will be informed of the abnormal moments of the process so that the diagnosing time is shortened.

5. Control chart can offer information about the ability of a process
Control chart can provide information about the ability, stability and attributes, etc of a process, which are very helpful information to the product or process designer.

**Control chart of X (mean) R (range)**

1. Theoretic calculation

Suppose a quality attribute is in normal distribution. Suppose its mean is \( \mu \), variation is \( \sigma^2 \). The sample number is \( n \) (\( x_1, x_2, \ldots, x_n \)), and then the mean of this sample is:

\[
\bar{X} = \frac{x_1 + x_2 + \ldots + x_n}{n}
\]

among which \( \bar{X} \) is the normal distribution \( \cdot \) \( \mu \) is its mean

Standard Deviation is

\[
\sigma_x = \frac{\sigma}{\sqrt{n}}
\]

The possibility of any sample between

\[
\mu + z_{\alpha/2} \sigma_x = \mu + z_{\alpha/2} \frac{\sigma}{\sqrt{n}}
\]

and

\[
\mu - z_{\alpha/2} \sigma_x = \mu - z_{\alpha/2} \frac{\sigma}{\sqrt{n}}
\]

is \( 1 - \alpha \).

If \( \mu \) and \( \alpha \) is given, then the above formula can be regarded as the upper and lower control limits of the control chart of the sample mean (\( \bar{X} \)). Usually we use 3 to replace \( z_{\alpha/2} \). So it is also called 3 times standard deviation control chart.

\[
\text{UCL} = \mu + \frac{3\sigma}{\sqrt{n}}
\]

Center line = \( \bar{X} \)

\[
\text{LCL} = \mu - \frac{3\sigma}{\sqrt{n}}
\]
2. Practical Application

In calculating the above-mentioned control limits, we presume that quality attribute is in normal distribution. But even if it is not in normal distribution; the above calculation results can still be regarded as correct. The theory of middle extreme value explains the reason. Generally speaking \( \mu \) and \( \sigma \) are unknown, so they are estimated from the last sampling when the process is under control (usually need 20 to 25 group sample). Suppose that we have \( m \) group of sample (whose size is \( n \); \( n \) is usually 4, 5 or 6, because large sample will involve high measuring costs). Let \( \bar{x}_1, \bar{x}_2, \ldots, \bar{x}_m \) be the mean of each sample, then the best estimation of process mean \( \bar{\mu} \) is the population mean \( \bar{x} \), \( \bar{x} \) can calculated by the formula below:

\[
\bar{x} = \frac{\sum_{i=1}^{m} \bar{x}_i}{m}
\]

To get the control limit, you need to know the standard deviation \( \sigma \), which can be estimated from the standard deviation of \( m \) group of samples or the range. Next, we will introduce how to estimate standard deviation from range. The sample range \( R \), is the difference between the maximum and minimum value in the sample:

\[ R = x_{\text{max}} - x_{\text{min}} \]

Random variable \( W = \frac{R}{\sigma} \) is called relative range. The distribution parameter of \( W \) is the function of sample size. \( D_2 \) is the mean of \( W \) is \( d_2 \). As \( \bar{W} = \frac{R}{d_2} \), and the value \( d_2 \) can be checked from the table. So if \( n=5 \), then \( d_2 = 2.326 \).

If \( R_1, R_2, \ldots, R_m \), is the range of \( m \) group of sample, the mean range will be:
\[ \overline{R} = \frac{R_1 + R_2 + \ldots + R_m}{m} = \frac{\sum_{i=1}^{m} R_i}{m} \]

So estimated value of \( \sigma \hat{\sigma} = \overline{R} / d_2 \)

\( \overline{x} : \)

\[
\text{UCL} = \overline{x} + \left( \frac{3}{d_2 \sqrt{n}} \right) \overline{R} = \overline{x} + A_2 \overline{R}
\]

Center line = \( \overline{x} \)

\[
\text{LCL} = \overline{x} - \left( \frac{3}{d_2 \sqrt{n}} \right) \overline{R} = \overline{x} - A_2 \overline{R}
\]

\[
A_2 = \frac{3}{d_2 \sqrt{n}}
\]

If

\( \overline{R} \)

\( \text{UCL} = \overline{RD}_4 \)

Center line = \( \overline{R} \)

\( \text{LCL} = \overline{RD}_3 \)

\( A_2, D_3, D_4 \) can be checked from the table.

3. Steps of Implementation

The establishment of \( \overline{x} \)-R control chart contains the following steps:

1. Collect data according to the selected sampling method (including sample size, sample frequency, rational sample group, etc.)
2. Calculate the mean and range of the sample.
3. Calculate the control limits of \( \overline{x} \) and R control chart and draw the
graph of mean and range. And see if there is any point that is out of control limit. The commonly used judgment methods include one point beyond control limit method and other auxiliary method (block testing, sequence testing etc). If the process is within control according the control chart, do step 4, otherwise you need to diagnose the causes of the variation. If it is caused by identifiable factors, you should make adjustment and delete the bad sample data caused by that factor or factors, then recalculate the control limits. These adjustments and checking should always be done to ensure that \( \bar{x} \) and R control chart are always within control and the control limits are always calculated based on no avoidable factor data. Because \( \bar{x} \) control chart is affected by R, so you should start from R control chart in setting up the control chart.

4. If both the \( \bar{x} \) and R control charts are within control, you can use \( \bar{x} \)-R control chart to monitor the future process so that you can detect the identifiable factor of variation.

Its flow chart is as follows:

9. Practical example

For example: In the Coil manufacture process, \( \bar{x} \) and R control chart is used to monitor the coil resistance, the sample size being 5 and there are 25 groups of sample. The \( \bar{x} \) and R control chart is established based on the following data:
<table>
<thead>
<tr>
<th>Sample</th>
<th>Observed value</th>
<th>$\overline{x}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 3 0 3 2</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>9 7 1 1 1</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>5 0 0 7 0</td>
<td>2</td>
</tr>
<tr>
<td>4</td>
<td>0 1 2 1 1</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>9 4 3 0 2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>2 0 8 8 9</td>
<td>1</td>
</tr>
<tr>
<td>7</td>
<td>8 0 9 8 0</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>0 8 3 0 1</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>1 0 4 3 2</td>
<td>2</td>
</tr>
<tr>
<td>10</td>
<td>1 9 0 0 0</td>
<td>2</td>
</tr>
<tr>
<td>11</td>
<td>0 0 3 2 0</td>
<td>2</td>
</tr>
<tr>
<td>12</td>
<td>2 1 0 2 3</td>
<td>2</td>
</tr>
<tr>
<td>13</td>
<td>9 2 9 8 9</td>
<td>1</td>
</tr>
<tr>
<td>14</td>
<td>0 1 2 1 2</td>
<td>2</td>
</tr>
<tr>
<td>15</td>
<td>0 4 4 3 3</td>
<td>2</td>
</tr>
<tr>
<td>16</td>
<td>1 0 4 0 1</td>
<td>2</td>
</tr>
<tr>
<td>17</td>
<td>0 8 8 0 0</td>
<td>2</td>
</tr>
<tr>
<td>18</td>
<td>0 4 2 3 3</td>
<td>2</td>
</tr>
<tr>
<td>19</td>
<td>0 9 3 0 9</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>2 1 1 4 2</td>
<td>2</td>
</tr>
</tbody>
</table>
Solution:

Normally, you should start from R control chart in setting up $\bar{X}$ - R control chart. Because the control limit of $\bar{X}$ is determined by process variation. If the variation happens to be out of control limit, the $\bar{X}$ will be meaningless under that case.

Step 1:

$$\bar{R} = \frac{87}{25} = 3.48$$

You can see from the form that $D4 = 2.115$, $D3 = 0$

$$UCLR = \bar{R}D4 = 2.115 \times 3.48 = 7.360$$

Center line = $\bar{R} = 3.48$

$$LCLR = \bar{R}D3 = 0$$
Step 2:

Because the sample of the third group goes beyond the control limit, you should find out the reason for it, revise it and then recalculate $R$

$$\overline{R} = \frac{87 - 8}{25 - 1} = \frac{79}{24} = 3.29$$

$$UCLR = \overline{R} D_4 = 2.115 \times 3.29 = 6.958$$

$$LCLR = \overline{R} D_1 = 0$$
Step 3:
After revision, you can get

$$ \bar{X} = \frac{521 - 20.4}{25 - 1} = \frac{500.6}{24} = 20.858 $$

You will know by checking the table that $n = 5$, $A2 = 0.577$, the control limits are:

$$ \text{UCL} = \bar{X} + A2 \bar{R} = 20.858 + 0.577 \times 3.29 = 22.756 $$

$$ \text{LCL} = \bar{X} - A2 \bar{R} = 20.858 - 0.577 \times 3.29 = 18.960 $$

The $\bar{X}$ control chart is drawn based on the above data:
You will see from the chart that the sample data of group 15 22, 23 fall beyond the control limit. After finding out the reason, calculate again. You can draw the following final control chart.
Control Chart of X (mean) and S (standard deviation)

Though X-R control chart s widely used in the industry, sometimes it is more adequate to directly calculate the standard deviation of the process than indirectly estimate it from range. The control chart designed to consider this factor is called S control chart, among which S stands for the standard deviation of the sample (sometimes we will replace S with \( \sigma \), called \( \sigma \) control chart).

10. Situations suitable for X and S control chart

- When sample size is greater than 10 or 12.
- When sample size varies.

In this unit, we will introduce how to set up X-S control chart. At the same time we will state the treatments to deal with the changes of sample size and methods to replace X-S control chart.

6. Calculation of X and S control chart

If the distribution is unknown, the unbiased estimation of the variation \( \sigma^2 \) is:

\[
S^2 = \frac{\sum_{i=1}^{n} (x_i - \bar{x})^2}{n-1}
\]

However the sample standard deviation S is not the unbiased estimation of \( \sigma \).

If the data is in normal distribution, then S is actually \( c_4 \sigma \), \( c_4 \) being a constant whose size is decided by sample size (n). The standard deviation S is \( \sigma \sqrt{1-c_4^2} \). If the sample size is not equal, then \( \bar{x} \) and \( \bar{S} \) will be calculated as weighted average:
\[
\bar{x} = \frac{\sum_{i=1}^{n} n_i \bar{x}_i}{\sum_{i=1}^{n} n_i}
\]

\[
\bar{S} = \sqrt{\frac{\sum_{i=1}^{n} (n_i - 1) S_i^2}{\sum_{i=1}^{n} n_i - n}}
\]

a. S control chart of a probability distribution whose variation is already known

\[
\text{UCL} = c_4 \sigma + 3 \sigma \sqrt{1 - c_4^2} = B_6 \sigma
\]

Center line = \(c_4 \sigma\)

\[
\text{LCL} = c_4 \sigma - 3 \sigma \sqrt{1 - c_4^2} = B_5 \sigma
\]

In which \(B_5 = c_4 - 3 \sigma \sqrt{1 - c_4^2}\), \(B_6 = c_4 + 3 \sigma \sqrt{1 - c_4^2}\)

b. S control chart of a probability distribution whose variation is unknown

\[
\bar{S} + 3 \frac{\bar{S}}{c_4 \sqrt{1 - c_4^2}} = B_4 \sigma
\]

Center line = \(c_4 \sigma\)

\[
\bar{S} - 3 \frac{\bar{S}}{c_4 \sqrt{1 - c_4^2}} = B_3 \sigma
\]

Among which

\[
B_3 = 1 - 3 \frac{1}{c_4 \sqrt{1 - c_4^2}}, \quad B_4 = 1 + 3 \frac{1}{c_4 \sqrt{1 - c_4^2}}
\]

C. Control parameter of X

if use \(\bar{S}/c_4\) to estimate \(\sigma\), then the control attributes of \(\bar{x}\) are:

\[
\text{UCL} = \bar{x} + 3 \frac{\bar{S}}{c_4 \sqrt{n}} = \bar{x} + A_2 S
\]

Center line = \(\bar{x}\)
If let $A_3 = 3/(c_4 \sqrt{n})$

7. Practical instance

For instance: suppose the surface glass diameters of the wristwatch are as follows, try to calculate the limit of $X$ and $S$ control chart.

<table>
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<tr>
<th>Sample</th>
<th>Value</th>
<th>$\bar{X}_1$</th>
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</table>

Solution: process mean

\[
\bar{x} = \frac{1}{25} \sum_{i=1}^{25} x_i = \frac{1}{25} (100.029) = 4.0012
\]

\[
\bar{s} = \frac{1}{25} \sum_{i=1}^{25} s_i = \frac{1}{25} (0.215) = 0.0086
\]

So the attributes of \( X \) control chart are:

\[
\text{UCL} = \bar{x} + A_2 \bar{s} = 4.0012 + 1.427 \times 0.0086 = 4.0135
\]

Center line = \( \bar{x} \) = 4.0012

\[
\text{LCL} = \bar{x} - A_3 \bar{s} = 4.0012 - 1.427 \times 0.0086 = 3.9889
\]

So the attributes of \( S \) control chart are:

\[
\text{UCL} = B_4 \sigma = 2.089 \times 0.0086 = 0.018
\]

\[
\text{LCL} = B_3 \sigma = 0 \times 0.0086 = 0
\]

The control chart is drawn as follows: