



# Tutorial

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## **Pixform Pro User Guide & Tutorial**

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# 1. Pixform Pro Getting Started

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## System Requirements

See the page “[System Requirements](#)” in the chapter “[4. Basics](#).”

## Installing Pixform Pro software

See the page “[Installation and Licensing](#)” in the chapter “[4. Basics](#).”

## Starting Pixform Pro

Double-click the Pixform Pro icon on the desktop or click the **Start** button on the Windows taskbar and then click Pixform Pro in **Programs**.

## Using Pixform Pro’s example files

The example files are placed in the *installation directory*\**Sample** folder. The default *installation directory* is C:\Program Files\Roland Pixform Pro.

## Using tutorial sample files

The full manual and sample files are placed in the *installation directory*\**Tutorial** folder. All the sample files are located in the corresponding workbench directories.

1. Create a new folder on your system, and copy the sample files into the local folder.

---

**NOTE:** Since some of the sample files are used with more than one example, *do not* save changes to these files unless instructed to do so.

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2. Go through this manual from beginning to end, opening the proper sample for each function, or use the Table of Contents to locate topics of special interest to you.



## 2. Overview

---

Pixform Pro consists of four workbenches: **Scan, Polygon, Curve, Surface.**

### **Common (across all workbenches):**

- Customizable GUI (e.g. menu, toolbar, shortcut key, color map)
- Unlimited undo operation
- Program crash handling (backup file and bug report generation)
- Working view volume management
- Rotation center changing and view point saving
- Various selection tools
- Automatic symmetrical plane finding and mirror selection system
- Layer management
- Various reference geometries (e.g. point, vector, plane, circle, sphere, cylinder, cone, box, torus, coordinate)
- Dimension measuring
- Transformation (Translation, Rotation, Scaling)
- Landmark based automatic measuring
- Point cloud shading
- Complete texture information support
- 3D polygon data compression (ICF file format)
- Export color 3D content for Web-based applications
- Magellan/SpaceMouse® interface
- Open architecture: Windows® OLE automation-based API
- Comprehensive command interpreter

### **Scan Workbench :**

- Reduce scan noise caused by scanners
- Point cloud sampling (random, uniform or by curvature)
- Intelligent point cloud smoothing
- Automatic creation of polygonal models from point cloud data
- Align/register point/polygon data in two different coordinate frames
- Automatic registration for rotary table scans
- Merge multiple polygonal models with high accuracy
- Point cloud merging and polygon combining
- Texture based point dithering
- Volume based triangulation and merging operation

### **Polygon Workbench :**

- Automatic detection and cleaning of bad polygon meshes
- Quality enhancement smoothing and real-time smoothing
- Curvature-based decimation and large data decimation
- Automatic global re-meshing for dramatic polygon quality enhancement
- Intelligent subdivision
- Curvature-based hole filling
- Re-fitting polygon to original points, polygon or surfaces
- Automatic boundary edge shrinking (at variable depths)

- Sharp edge reconstruction using curves
- Re-fitting to primitive surfaces (Plane, Cylinder, Cone & Sphere)
- Virtual sculpting and freeform deformation
- Template based polygon refitting
- Medial axis transformation
- Polygon morphing
- Trim, weld, split, offset, divide, mirror, extend, swap, flip, etc.
- Verification tools (environment mapping, face angle plot, contour lines, etc.)
- Shelling and thickening polygon
- Boolean operations (union, intersection, difference)
- Align polygon models in user defined work volume
- Interference checking
- Overhang region searching
- Real-time collision detection and restriction
- Engrave & emboss any 2D image or text onto a 3D model
- Volume based hole filling and polygon offset

### **Curve Workbench :**

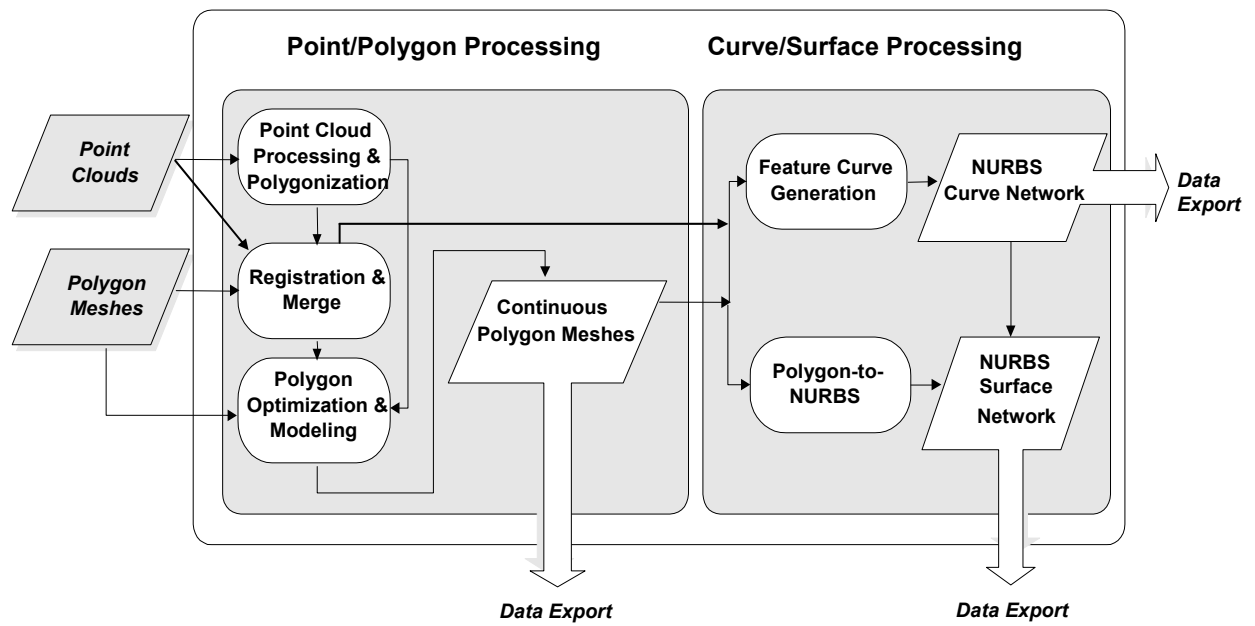
- Automatic feature recognition and curve creation
- Automatic global trimming
- Automatic loop finding
- Curve templates for similar objects
- Various curve generation tools (interpolate, poly-line, rectangle, circle, ellipse, grid, cross-section, etc.)
- Smooth boundary curve generation with rugged boundary edges
- Fitting curves to points
- Curve mirroring
- Automatic curve generation on sharp edges
- Various curve editing tools (trim, merge, smooth, offset, extend, rebuild, match, etc.)
- Curve to points conversion
- Curve deformation
- Deviation error checking and curvature/torsion plot
- Various curve viewing tools

### **Surface Workbench :**

- Automatic NURBS surface generation from polygon models
- High accuracy polygon-to-trimmed/untrimmed NURBS surface conversion
- Point cloud to surface conversion
- Surface mirroring by plane
- Extensive surface editing tools (trim, untrim, divide, smooth, rebuild, tessellation, sew, join)
- G0/G1/C1 continuity matching with multiple-adjacent surfaces
- Interactive accuracy and curvature verification
- Displacement map creation and export
- Seamless integration with other CAD systems

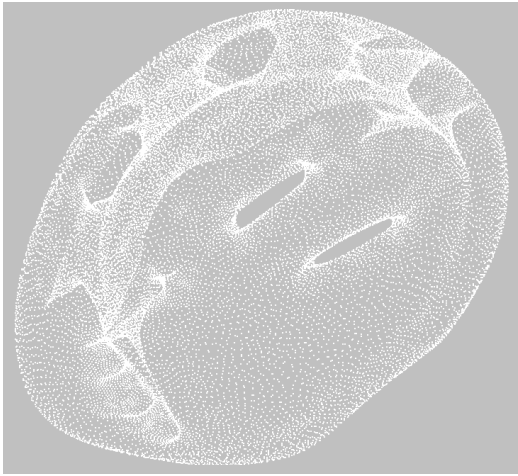
- Automatic IGES surface healing

# 3. Work Process

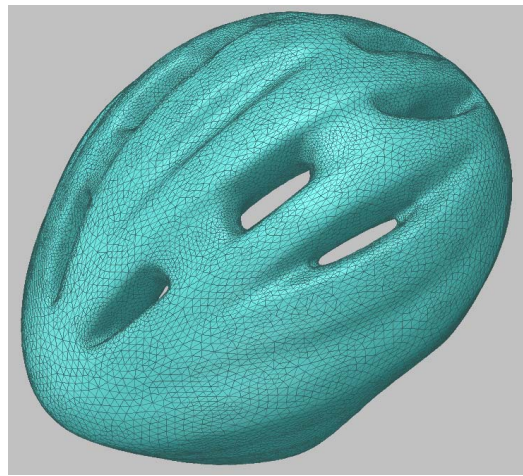


# Work Process: Surfacing

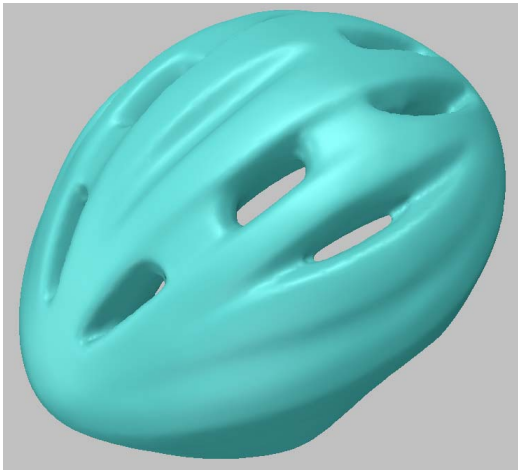
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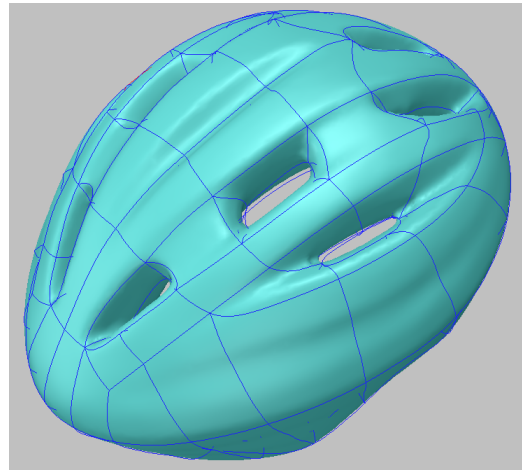
**Point Cloud**



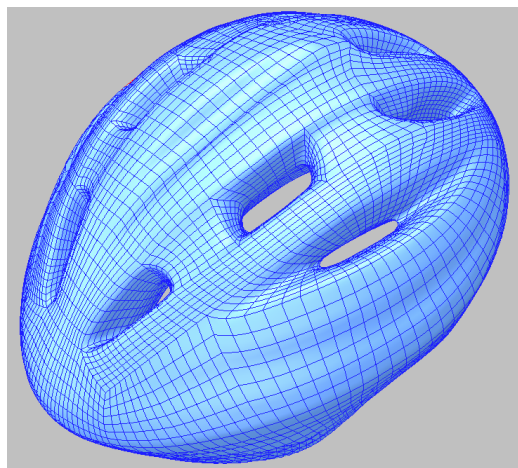
**Polygon Mesh**



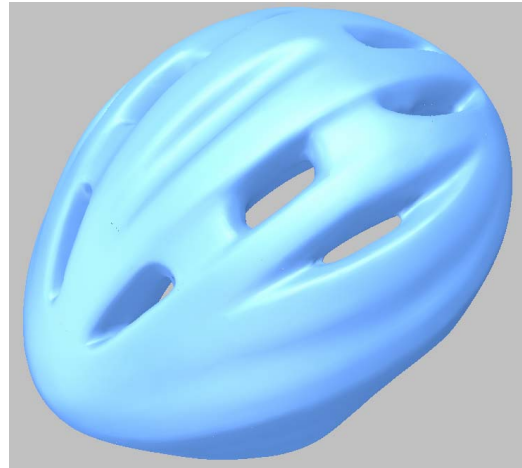
**Polygonal Surface**



**Curve Network**



**Surface Isoline**



**NURBS Surface**

## 4. Basics

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# System Requirements

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### Operating System:

- Any Pentium-based or AMD Athlon-based PC running Windows 2000, Me, XP or NT 4.0(SP6 or higher).

### Memory and Disk Space:

#### Memory:

- Minimum 512 MB is required (1GB or more is recommended)
- RAM requirements vary depending on the size of the model being worked on.
- A simple estimate is to occupy 1 MB for every 10,000 triangles in the model.
- In general, a physical memory for data handling needs two times of current occupied memory. (e.g.) Five million triangles need 500MB RAM for occupation and 1GB RAM for operation. Ten million points need 1GB RAM for loading and sampling.

#### Disk Space:

- 300 MB for program installation and more than 500MB free disk space is required for temporary file cache.
- An additional 400 MB for training sample files

### Graphics Card:

1280X1024 resolution, 32-bit color or above, OpenGL 1.2 or higher  
Recommended hardware OpenGL acceleration feature are listed below:

- NVIDIA Quadro/GeForce compatible chipsets
- 3DLabs Oxygen GVX Series
- ATI FireGL compatible chipsets
- 3DLabs Wildcat Series

**Note:** Pixform Pro may not work properly with an old graphic board. You need to download the latest graphic driver from the website acquainted by your provider.

# Installation and Licensing

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1. Connect a hard-lock (dongle) to a parallel port (printer port).
2. Insert the Pixform Pro software CD into the CD-ROM drive.
3. Within a few seconds, the installation program should appear automatically. If the autorun installation does not start automatically, browse the CD-ROM directory and then double-click on the autorun.exe file to start the installation program.
4. Follow the instructions provided by the installation program.
5. Run the application.

## File I/O Specifications

---

Extension	Application	Import	Export	Remark
mdl	Pixform Pro	(open)	(save)	Pixform Pro's own binary format
icf		X	O	INUS Compression Format
pix (ver.3)	Roland PICZA	O	X	point / polygon, inch
rdl	Pixform	O	X	point / polygon / surface
asc	ASCII points	X	O	point
wrl	VRML 1.0/97	X	O	point / polygon
dxf	AutoCAD	X	O	point / polygon
stl	Rapid Prototyping	X	O	point / polygon (ASCII or Binary)
igs / iges	IGES	X	O	curve / surface
3dm	Rhino 3.0	X	O	curve / surface

### NOTE:

- **MDL** format can also be opened and imported.
- ASCII points file with three numbers on a line are a set of XYZ coordinates.

### Importing Dr.PICZA Files

**PIX** format can be imported.

- Dr.PICZA versions 1 through 2

Not available.

- Dr.PICZA3 version 3

Use the [Save as...] command to save a file.

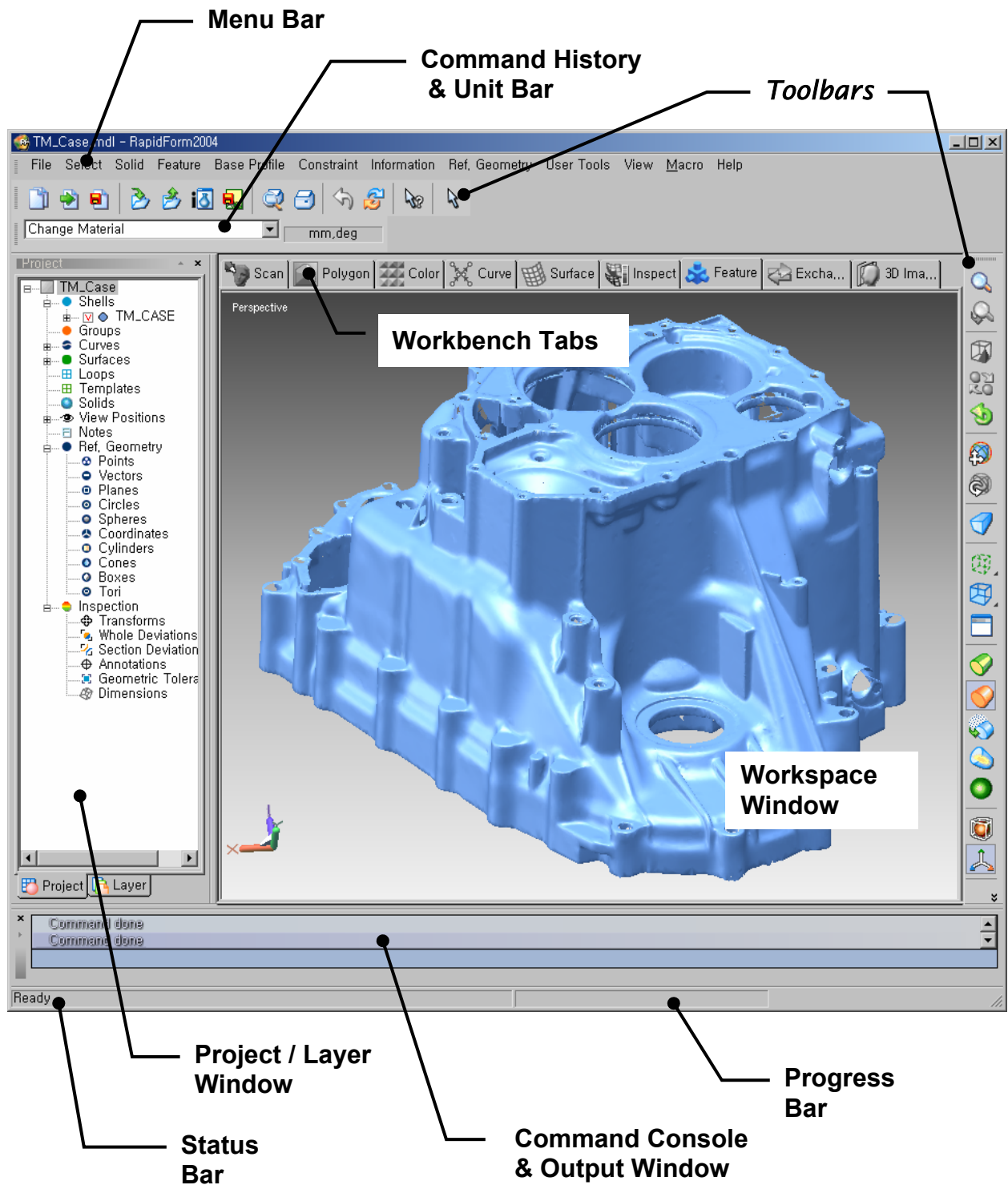
- Dr.PICZA3 version 4

Use the [Export] command to save a file.

The Dr.PICZA project format files (with the file extension .pjt) cannot be imported.

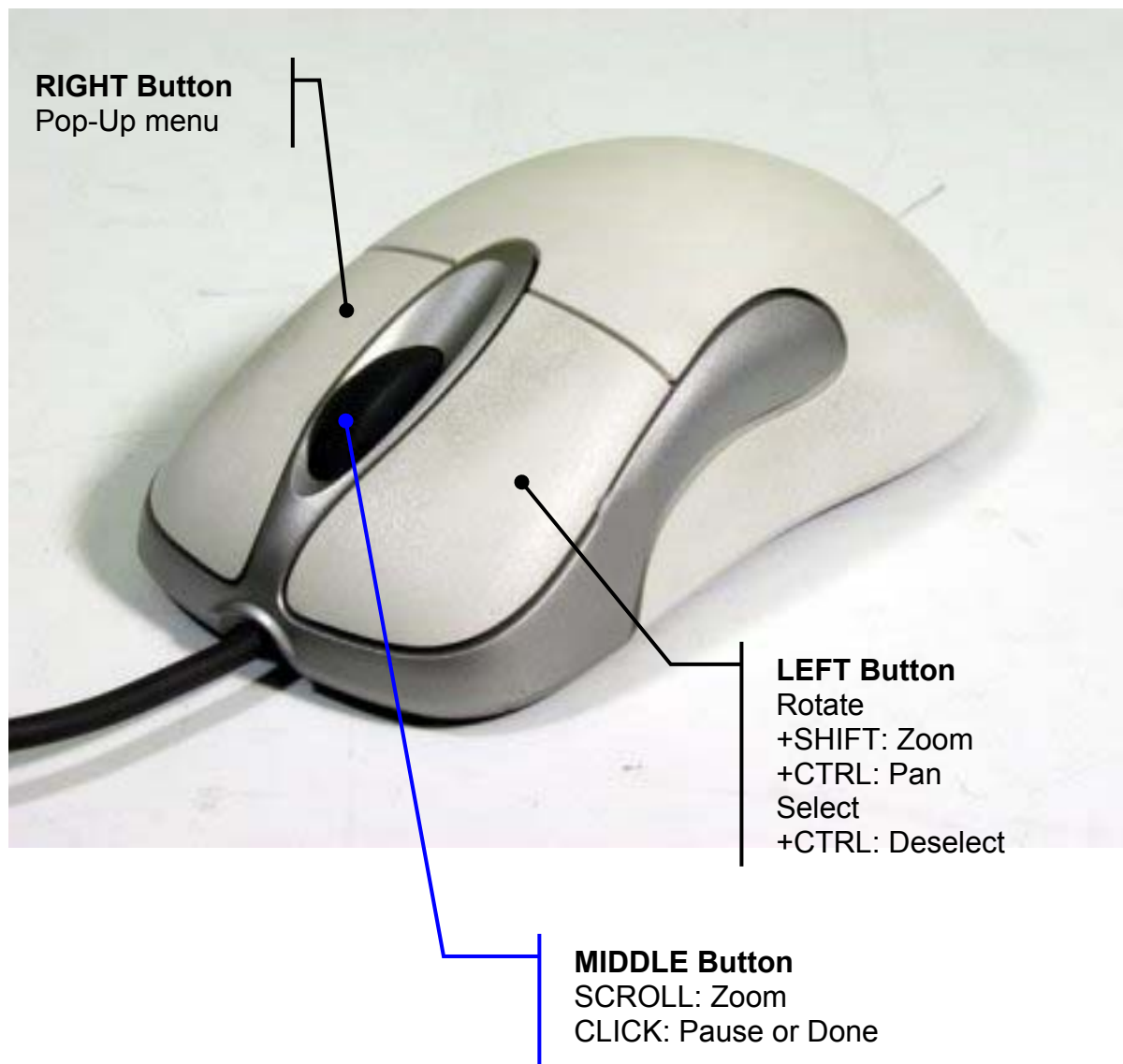


# GUI



# Mouse Control

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# Command Console

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The command console consists of the command prompt and a scrollable command output window. By default the command console is below the project tree and working window. A user can move the console window to other position.

Most Pixform Pro commands can be run by typing the name or its abbreviation into the command prompt. For the user convenience, if a user types buttons continuously without pause, the mouse cursor automatically moves to the command prompt.

A user can browse through a list of commands, and each command is accompanied by help information or balloon help.

While you are typing a command, **Esc** key clears the command prompt. If no command is active in the menu, you cannot run it in the command prompt either.

## Basic Command:

1. **help** - shows the usage of any command  
(command) help decimate .....show the usage of Decimate command
2. **list** - shows the list of commands  
(command) list sel\* .....show all commands beginning by "sel"  
(command) list /h sel\* .....show all command beginning by "sel" with help
3. **dump** - The text contents of command console are copied into the Windows Clipboard or notepad  
(command) dump /notepad .....copy all contents to a notepad
4. **clear** or **cls** – clear all the text contents of output window
5. **echo** – display comment in the output window  
(command) echo "Tips: decimate function reduces data size."

## Alias & Bind:

You can define your own command alias from the existing command. Command aliases are custom commands you can define to run Pixform Pro commands. You can type command aliases just like normal commands. You can use them to create abbreviations for often used commands.

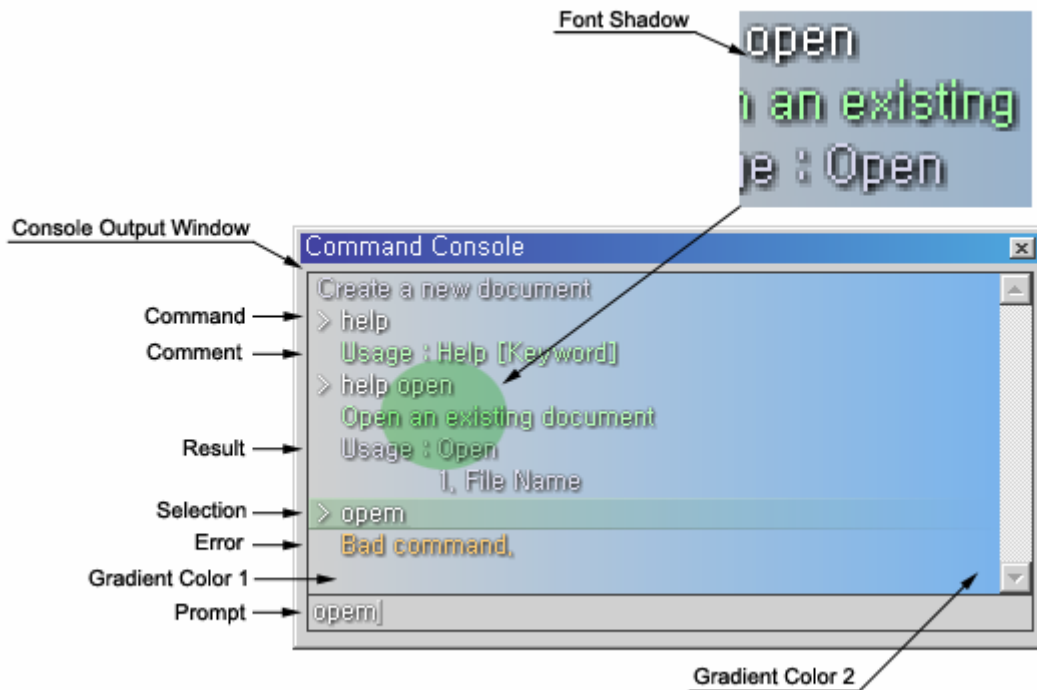
Also you can bind a series of commands to an alias. The aliases and bind commands are automatically saved to the **console.ini** file under the Pixform Pro home directory. When the application is launched, all the aliases and bind commands are automatically loaded from the file. To remove all user-defined commands, just delete the **console.ini** file from the directory.

Note that an alias must consist of two or more characters in order to distinguish shortcut keys.

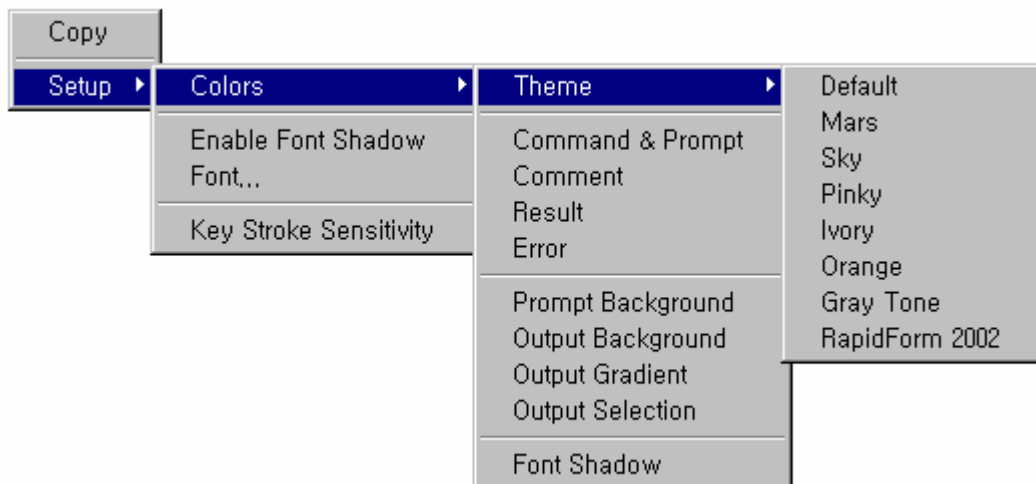
- (command) alias +remg RemeshGlobal .....add "remg" to alias table(console.ini)
- (command) remg .....run Remesh > Global command
- (command) alias -remg .....delete "remg" from alias table
- (command) bind +desm "selsh \*" "decimate 50%" "smooth 1 2"  
.....assign decimate and smooth commands to "desm"
- (command) desm .....select all shells and then decimate and smooth them
- (command) bind -desm .....delete "desm" from bind table (console.ini)

## Environment Setting:

It is possible to customize the environment of command prompt and console window as shown below.



You can easily change it with option menus by clicking the RMB on the console output window.



The **Copy** dumps the text contents of output window to the Windows Clipboard.

The **Key Stroke Sensitivity** sets an interval of key stroke so that the mouse cursor automatically moves to the command prompt. Set the parameter “**StrokeThreshold**” to an interger between 1 to 1000 (unit: msec). It is usually recommended 150 ~ 200 msec.

(command) set strobethreshold 200

The **Enable Font Shadow** sets the font shadow of text in the command prompt and output window to ON/OFF.

The **Font** sets the font style of text in the command prompt and output window.

(command) set consolefont /setup

You can also customize the color of command console with the **Colors** options or the “**set**” command following by the “**/setup**” parameter. Or, just select one of pre-defined color environments, **Theme**.

The **Command & Prompt** sets the color of commands in the command prompt and output window.

The **Comment** sets the color of comment text in the output window.

The **Result** sets the color of result message in the output window.

The **Error** sets the color of error message in the output window.

The **Prompt Background** sets the background color of command prompt.

The **Output Background** sets the background color of output window.

(command) set consolecoloroutput /setup

set consolecoloroutput 182 245 162 255(no gradient)

The **Output Gradient** sets the gradient color of output window. The first selected color is for the gradient of left side and the second one is for right side.

The **Output Selection** sets the color of selected line in the output window.

The **Font Shadow** sets the shadow color of text in the command prompt and output window.

The customized settings are saved to the **console.cfg** file under the Pixform Pro home directory. When the application is launched, all the option values are automatically loaded from the file. To remove all user-defined options, just delete the **console.cfg** file from the directory.

### Parameter Type:

All parameters in the dialog box of each function can be used in the command prompt. Each parameter is one of types with integer, real number, Boolean (true/false), string or special option. A command without any parameters might be executed by default values or the latest used ones.

(command) open test.mdl

(command) selsh scan1 scan2

(command) smooth 1 3 0.2 0.1 y n y n y

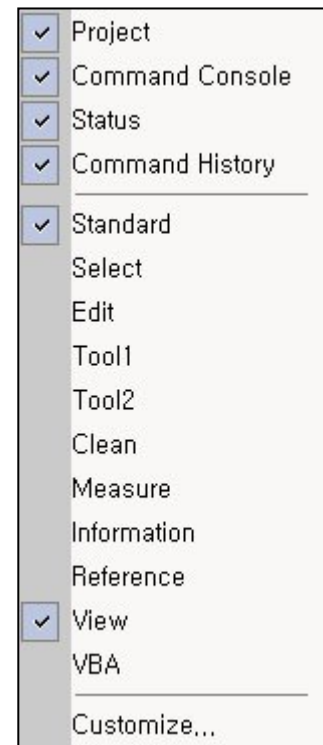
Please see the on-line help for all command list and detail parameters.

# Right Mouse Button Menu

In addition to the menu bar, there are menus that appear when you click the right mouse button (RMB).

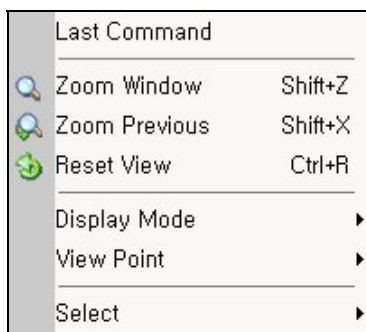
## On Toolbar:

You can show or hide toolbars as selecting them after clicking RMB on menu bar or toolbars (as shown right). Also, you can customize GUI and keyboard.



## On Workspace Window:

Last command can be repeated and also use display menu and selection menu frequently used by clicking RMB on workspace window (as shown below).



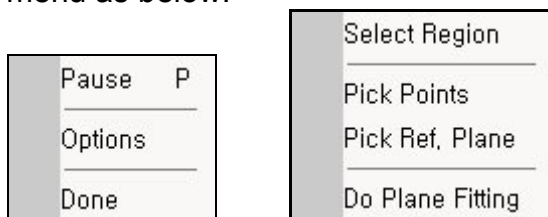
## On Project/Layer Window:

You can use quick menus for changing property of entities and exporting specific entities as clicking RMB on Project/Layer Window (as shown below).



## On running Operations:

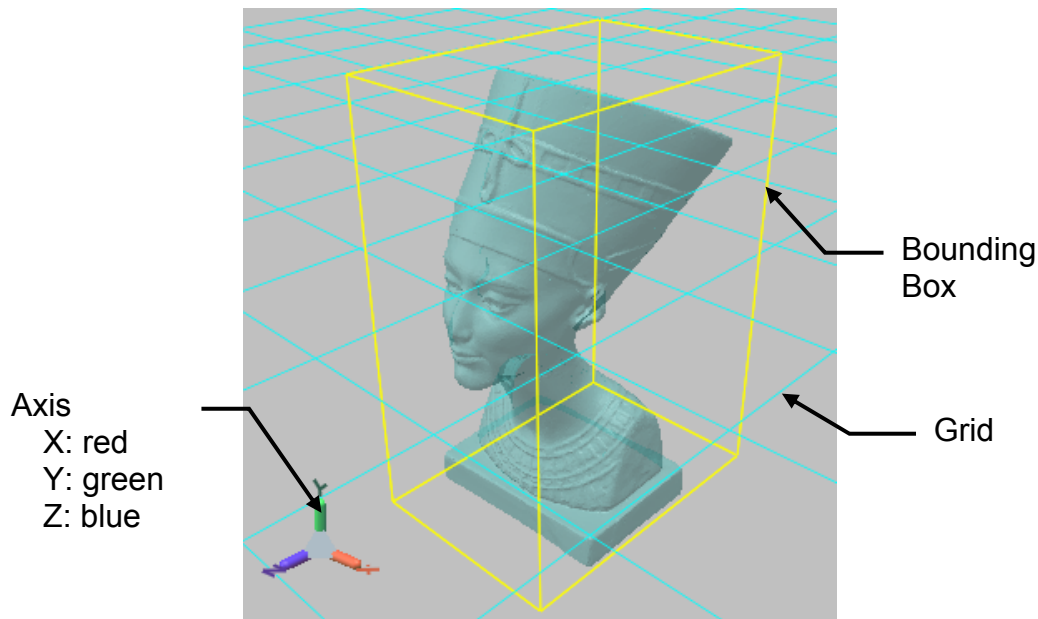
On running a specific operation, program usually waits your command input. At this time, you should click RMB on workspace window and select a specific menu as below.



# Viewing & Displaying

## Workspace Window:

- **Bounding Box** – a smallest rectilinear box that encloses a shell. When multiple shells exist, only one shell can be displayed in the desired color while others have a different color. This shell with a white bounding box is the *Active Shell*.
- **Axis** – helps you visualize the orientation of shells in the workspace window. This is not the origin.
- **Grid** – displays screen grid for visualization in workspace window



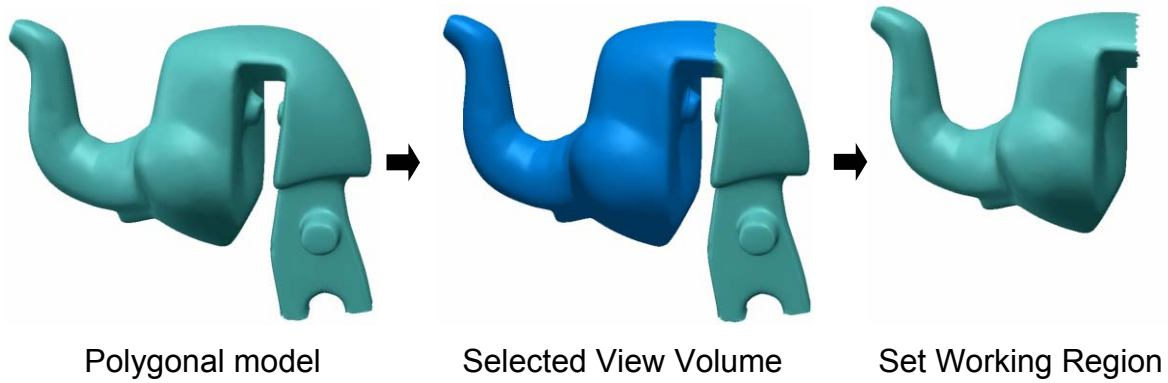
## Display Mode:

Mode	Icon	Hot Key	Explanation
Point Set		F1	Draw only vertices
Wireframe		F2	Draw edges of faces
Hidden Line		F3	Draw edges visible from the current viewpoint
Shaded		F4	Draw shaded faces
Shaded with Edges		F5	Draw shaded faces with edges
Transparent		F6	Draw shaded faces with transparency
Textured		F7	Draw texture mapped faces if the texture information is available

## Working view volume management :

This operation is for displaying only the user-defined regions on the workspace window.

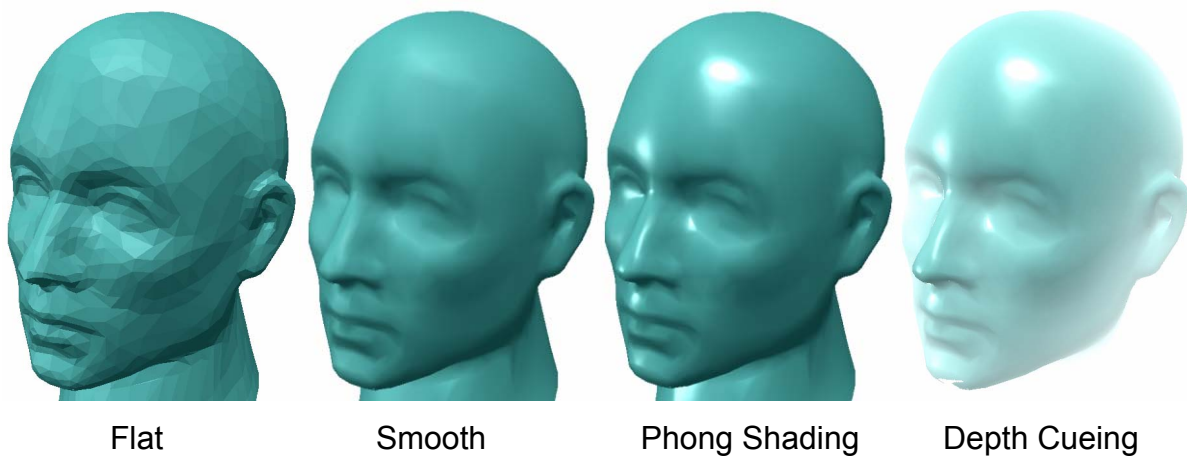
[Menu] View > Set Working Region



## View Point:


View point	Icon	Hot Key
Front		Alt+1
Back		Alt+2
Left		Alt+3
Right		Alt+4
Top		Alt+5
Bottom		Alt+6
Iso		Alt+7

## Shading Method:





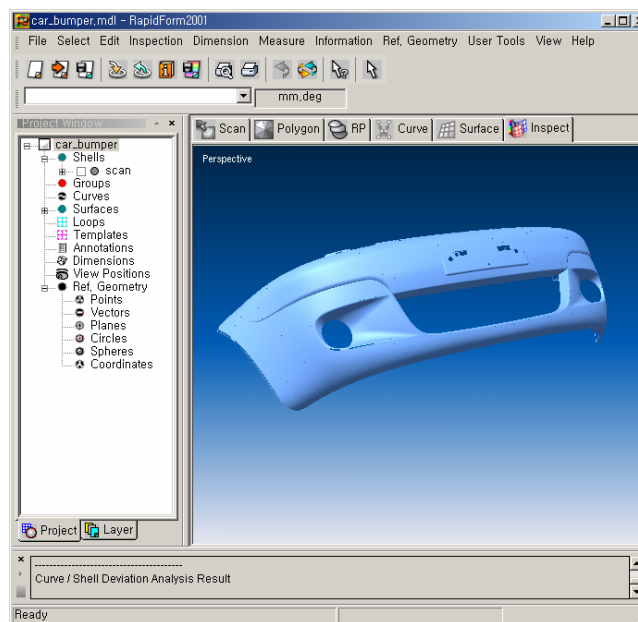
## Initialization of Perspective View

You can toggle off the *Perspective View* option when a new workspace window is opened. Go to the *Display Options* tab after performing *File > Preferences* menu, and turn off it, on as default, at the *Elements*. Also it can be directly toggled on/off by clicking the perspective icon (  ) on the view toolbar.

## Customizable System Color

The default shell color, surface rendering color, background, grid, dimension, bounding box and the colors of all entities can be changed.

[Menu] File > Preferences > Display Options > Color & Material



## Customizable Color Bar

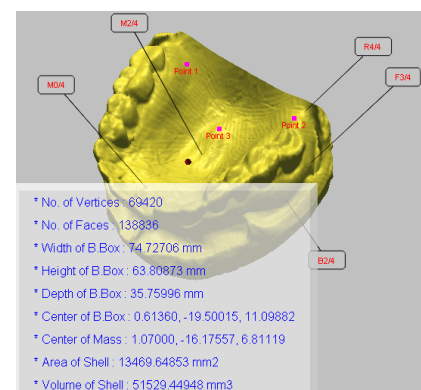
You can change the color arrangement of the color-coded map by these operations: *Shell/Shell Deviation*, *Curvature Plot*, or *Face Angle Plot* in the *Measure* menu, *Curve/Shell Deviation* in *Curve* menu, *Surface/Shell Deviation* or *Curvature Plot* in the *Surface* menu, *Whole Deviation* or *Sectional Deviation* in the *Inspection* menu. Also you can save your own color patterns and reload them for different visualizations.

[Menu] View > Customize Color Bar

## Customizable Text Font

You can change font, style, color and size of system text displayed on the viewing window by *Inspection > Annotation > Add Note* menu or *Information* menu.

[Menu] View > Customize Font > Small Text / Large Text

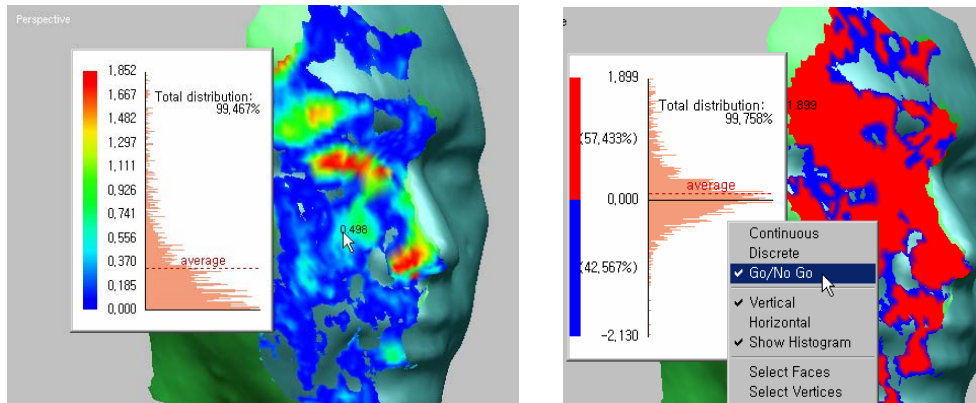


## Real-time Color Map Representation

If you move the mouse over the color map after performing operations for various deviation/curvature verifications, the values are represented on the color map in real-

time.

After you click the right mouse button on the color bar window, you can select sub menus, *Continuous*, *Discrete*, *Go/No Go* or *Show Histogram*.



## Point Shading

The point shading can be activated by Shading Method > Point on the View menu and points are resized by the Point Drawing Size of Preferences. This operation uses the scan direction of a scanner if it is included in a file. In case the normal of shaded is wrong partially in a point cloud shell, the Filter Noise operation may solve the problem.

## Histogram

The color bars of Shell/Shell Deviation, Surface/Shell Deviation and Whole/Section Deviation (With Polygon) have an option called Show Histogram on the popup menu. It spreads on the right side of color bar with a distribution chart of deviation. The color of histogram can be customized by the View > Customize Color Bar menu.

## Selection by color map

It is available to select faces or vertices by the min/max range of the deviation map. The color bars of Shell/Shell Deviation, Surface/Shell Deviation and Whole/Section Deviation (With Polygon) have sub menus called Select Faces and Select Vertices on the popup menu. It allows you to select faces or vertices within a specific range which values are default min/max deviations.

## User-defined View Positions

You can rotate a model to specific position and save the view. You can also rename the saved view and remove it from the *View Positions* node of *Project tree window*.

[Menu] View > Add Current View

## Environment Mapping

This operation executes the environment mapping to evaluate the face quality on the polygonal model. The map is better if you select the “High Quality Normal” option in *File > Preferences* and turn on “Smooth Shading Mode” icon in the “View” toolbar.

[Menu] Measure > Environment Mapping

## Face Angle Plot

This operation represents the angle between the face normal direction and a user-defined vector by the color map.

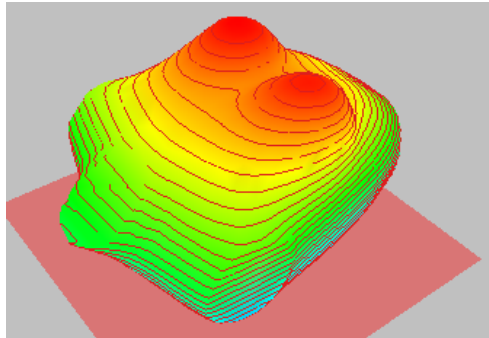
As drawing curves along the boundary of the color map, you can define the parting line for mold making.

[Menu] Measure > Face Angle Plot

## Contour Lines

This operation represents contour lines with color map on the model. This shows you positions that lie in same height from a reference plane.

[Menu] Measure > Contour Lines > Shell/Model



## Show/Hide Curve/Surface with Shell

You can set the display option to **On/Off** so that all the connected curves/surfaces are shown or hidden when a shell is shown or hidden.

[Menu] Curve(Surface) > Property > Show / Hide with Shell

## Ref. Geometry

1. **Show/Hide Name:** Using the RMB menu in the project tree window, you can show or hide the name of reference geometries in workspace.
2. **Render Ref. Geometry:** It determines to render reference plane, sphere, and cylinder. This option is in Display Options tab of Preferences.
3. **Depth-Test Ref. Geometry:** If the depth test is enabled, reference geometry is displayed while shells are hiding its part. This option is in Display Options tab of Preferences.

## Layer Management

1. When *Arrange Layers by Shell* is selected in layer tree window, curves/surfaces/loops are automatically re-arranged to user-defined layers classified by connected shells.
2. You create a new layer with curves(surfaces) selected by mouse drag after performing *Curve(Surface) > Tool > Create Layer Node* command. A new layer named "New Curve(Surface) Node" is registered on the bottom of the layer tree and the selected curves(surfaces) move to the new layer.

# Trackball & Transformation

## Virtual Trackball :

This operation is applied to the entire model, all shells on the workspace window.

But the model is not transformed but only view point is changed.

<b>Mouse Control or Keyboard</b>	Rotate	LMB(Left Mouse Button) or four arrow keys
	Zoom	SHIFT + LMB or Up/Down arrow keys, wheel mouse
	Pan	CTRL + LMB(Up/Down direction) or four arrow keys

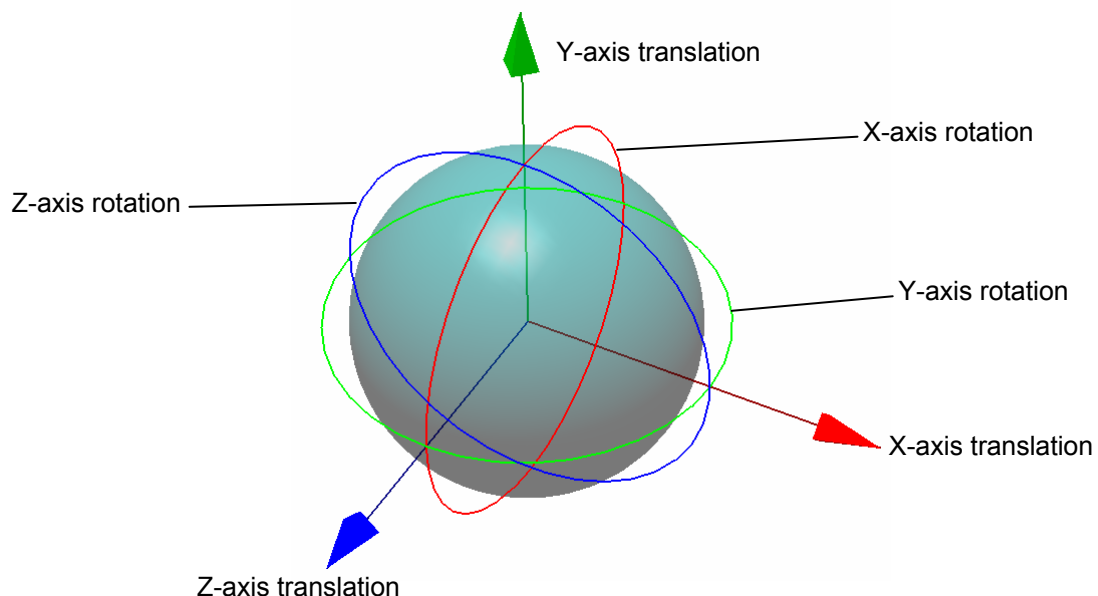
## Shell/Coordinate Trackball :

This operation is applied to a selected shell or coordinate system and its coordinate values are transformed.

[Menu] **Edit > Transform > Shell Trackball,**  
**Ref. Geometry > Transform > Coordinate > Coordinate Trackball**

<b>Mouse Control</b>	Rotate	LMB
	Pan	CTRL + LMB
	Depth Move	CTRL + SHIFT + LMB(Up/Down direction)

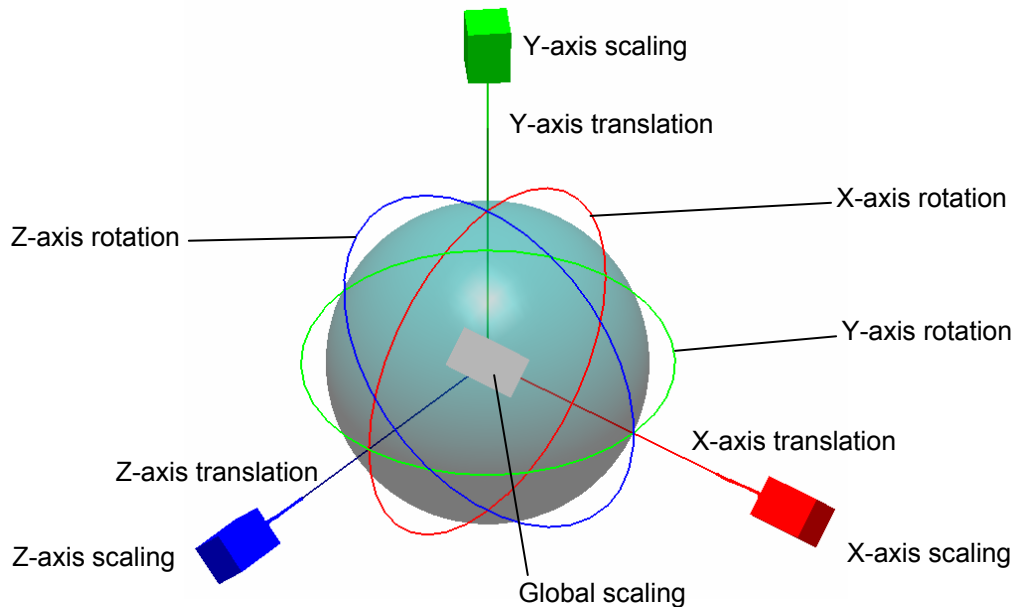
<b>Manipulator</b>	Translate	LMB + Left(-)/Right(+) direction on arrow
	Rotate	LMB + Left(-)/Right(+) direction on circle



## Curve Template Trackball :

[Menu] **Template > Tool > Transform**

Manipulator	Translate	LMB + Left(-)/Right(+) direction on arrow
	Rotate	LMB + Left(-)/Right(+) direction on circle
	Scale	LMB + Left(-)/Right(+) direction on box



## Changeable Trackball Center

You can change the trackball center to a user-defined position on the model. This viewing operation enables you to rotate an object discriminately while focusing on a part of it.

[Menu] View > Set / Reset Trackball Center

## Shell/Model Transformation :

[Menu] Edit > Transform > Shell / Model

- **Rotate** – rotate a shell/model as given angle around specific axis
- **Translate** – translate a shell/model as given distance in the x, y, or z direction
- **Scale** – increase or decrease the actual size of a shell/model

## Coordinate Transformation :

[Menu] Ref. Geometry > Transform > Coordinate > Transform Coordinate





- **Translation** – translate a coordinate as given distance in the x, y, or z direction of absolute coordinate or user-defined coordinate
- **Rotation** – rotate a coordinate as given angle around specific axis of absolute coordinate or user-defined coordinate

# Selecting & Deleting

## Commands:



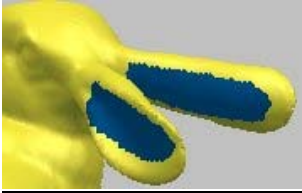
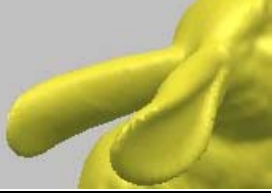



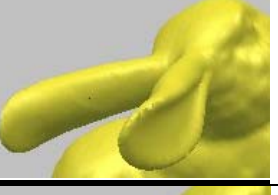


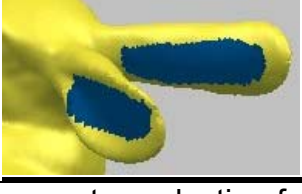
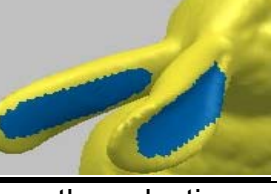
- **Select Entities** – Vertex, Face, Shell, Curve, Surface, Loop
- **Select All / None / Inverse** – Vertex, Face
- **Select Custom Region** – Face
- **Select Flood Fill** – Face
- **Select Boundary** – Vertex, Face
- **Select Around Curve/Surface** – Vertex, Face
- **Select Enlarge Depth/Feature region, Shrink One Depth** – Face
- **Select Visible / Through / Active Shell Only** – Vertex, Face
- **Select Mode** – Line, Rectangle, Circle, Polyline, Freehand, Paint Brush

## Selection Method:

- **Picking** – single selection, 
- **Freehand** – Vertex, Face, Control Point, Node, 
- **Paint Brush** – Vertex, Face, Control Point,   
(NOTE: By Paint Brush, visible vertices, faces, or surfaces only are selected, in case of polygonal or surface model)
- **Crossing** – Multiple Selection, Vertex, Face, Shell, Curve, Surface, Loop, 

**NOTE:** To selectively deselect entities, press the Ctrl key while selecting entities from the current highlighted selection.

## Selection Option:

Option	Menu	Selection Result	
No option	 Select Visible Only  Select Through		
Visible Only	 Select Visible Only  Select Through		
Through	 Select Visible Only  Select Through		

**Note:** If a shell is a point cloud without faces, vertex selection follows the selection options, **Select Visible Only** and **Select Through** in the point shading mode.

## Selecting Surface

The surface selection method provides you with a way to select only visible surfaces while they are in a rendered state. You can use the **Select Visible Only** and **Select Through** selection options to select surface in the same way you can select vertices and faces. When the surfaces are not rendered, the selection is accompanied by picking one of iso-curves on a surface as a single selection and by dragging mouse across iso-curves of surface as a multiple selection. All surfaces can be selected at a time using the rectangle selection mode. When surfaces are rendered, you can select using either the paint brush mode or the rectangle mode, and the Select Visible Only and Select Through options function in the same way as they do for vertices and polygons. Even in the paint brush mode, if the surfaces are not rendered, the surface selection is automatically accompanied by the rectangle mode.

## Deleting:

- **Single Entity** – (i) Vertex, Face, Shell: Edit > Delete or Delete key  
(ii) Curve, Loop, Template, Surface, Solid:  
[Menu] > Delete or Delete key
- **Multiple Entity** – Vertices, Faces, Curves, Loops or Surfaces can be deleted by directly performing each Delete command after selecting each entities

## Selecting & Deleting on Project Window:

- **Single Entity** – pick each node with LMB, and select Delete on RMB menu.
- **Multiple Entities** – pick an upper rank node with RMB and select Delete All on RMB menu or pick multiple nodes with LMB while holding Shift or Ctrl key and select Delete on RMB menu.
- **Shown Entity Deletion** – pick an upper rank node with RMB, and select Delete Shown *Entities* on RMB menu.

## Mark:

It marks specific edges or vertices so that they are not affected by editing operations such as smooth, subdivide, re-mesh and etc.

- **Edges** – edges on the shortest path passing selected vertices
- **Sharp Edges** – edges constructing less than or equal to a given angle between two adjacent triangles
- **Boundary Edges** – edges on a boundary
- **Vertices** – picked vertices

## Mirror system:

The mirror selection system allows a user to select the corresponding faces or vertices on the opposite side for a symmetrical object.

The **Apply Mirror Plane** command is an On/Off toggle menu for applying a symmetrical selection system. A user has to indicate a reference plane created by **Calculate Mirror Plane** or **Ref. Geometry > Create > Plane**. When a user selects faces or vertices, its corresponding are automatically selected.

- **Calculate Mirror Plane** – creates automatically a reference plane corresponding to the plane of symmetry of a complete object.
- **Apply Mirror Plane** – an On/Off toggle menu for applying a symmetrical selection system.

### **Picking Point:**

When select a point on an object using functions such as measuring, creating ref. geometries or creating interpolation curves, you can choose one of these point types: point(on face), vertex, ref. point, point on surface, or point on curve.

- **Point** – anywhere position on a face
- **Vertex** – an intersection point that edges meet each other
- **Ref. Point** – a user-defined point
- **Point on curve** – a point on a curve
- **Point on surface** – a point on a surface

Note that the “point on surface” option requires true color display and surface rendering information, therefore render a surface before select this option or the opened mdl file should have rendering information already.



# Reference Geometry

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Reference geometries are point, vector, plane, circle, sphere, cone, box, torus and coordinate which are introduced for various purposes such as dividing, making volume, slicing, section viewing, measuring, transformation, alignment, etc.

Reference geometries are listed on Project window, and can be managed through the corresponding object pop-up menu. You can edit the coordinate values on the Project window.

The colors of reference geometries can be specified by user at File > Preferences.

When you transform a reference coordinate, a shell, which is connected to the coordinate, is also transformed. Also other reference geometries bound to the shell are transformed.

Reference geometries are often used by the following operations:

## Point:

- Pick Point on every operation
- Build > Register > 2 Shells > Pick 3 Ref. Points
- Measure > Distance/Radius/Angle
- Measure > Auto Measure
- Curve > Create > Interpolate

## Vector:

- Build > Register > Rotary Table
- Edit > Add > Shell > Cylinder > From Ref. Vector
- Edit > Add > Shell > Cone > From Ref. Vector
- Tool > Fit Regions To > Cylinder
- Measure > Angle
- Curve > Create > Slice
- Curve > Create > From Ref. Geometry > Vector

## Plane:

- Select > Mirror System > Apply Mirror Plane
- Edit > Vertex > Pick On Plane
- Tool > Extend Region
- Tool > Divide/Mirror
- Tool > Make Volume > Extrude to Plane
- Tool > Fit Regions To > Plane
- Measure > Distance/Angle
- Measure > Cross Section > Shell/Model
- Curve > Create > Slice
- Curve > Create > Mirror
- Surface > Create > Mirror
- Surface > Create > From Ref. Geometry > Plane

## Circle:

- Edit > Add > Shell > Cylinder > From Ref. Circle
- Edit > Add > Shell > Cone > From Ref. Circle
- Curve > Create > From Ref. Geometry > Circle

## Sphere:

Tool > Fit Regions To > Sphere  
Surface > Create > From Ref. Geometry > Sphere

**Coordinate:**

Edit > Transform > Shell/Model  
Measure > Cross Section > Shell/Model  
Curve > Create > Slice

**Cylinder:**

Edit > Add > Shell > Cylinder > From Ref. Cylinder  
Tool > Fit Regions To > Cylinder  
Surface > Create > From Ref. Geometry > Cylinder

**Cone:**

Edit > Add > Shell > Cone > From Ref. Cone  
Tool > Fit Regions To > Cone

**Box:**

Surface > Create > From Ref. Geometry > Box

**Torus:**

Surface > Create > From Ref. Geometry > Torus

# Measure

---

You can measure the distance, radius and angle. Also, there are useful functions for three-dimensional quantitative measurements such as cross section viewing, curvature plot, etc. You can also get the model information such as the object size, area, volume, and numbers of entities.

## **Distance:**

- Point / Point along line
- Point / Point along surface
- Point / Vector
- Point / Plane
- Plane / Plane
- Perimeter with Point and Plane
- Perimeter with Points

## **Radius:**

- Circle
- Sphere
- Rounded Area Radius

## **Angle:**

- Plane / Plane
- Plane / Vector
- 3 Points
- 2 Vectors

## **Cross Section:**

- Perimeter
- Area
- Centroid
- Distance and displacement between points

## **Auto Measuring:**

- Landmark based, automatic dimension calculation

## **Deviation:**

- Shell/Shell, Curve/Shell, Curve/Curve, Surface/Shell, Point/Surface, Point/Polygon, Point/Curve

## **Curvature:**

- Mean, Gaussian, Maximum and Minimum

**NOTE:** *You can convert the deviation or curvature color maps to the vertex color of objects. For example, it is possible to draw feature curves on polygonal surface while viewing the curvature color map.*



# Undo

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You can use the Undo command to removes the effects of the last operation performed.

To perform the Undo command, a saving space called command stack is required. The Size of the command stack means the maximum number of recent commands undoable. There is no limit to the size of the command stack in Pixform Pro. You can record and undo commands as many times as the memory permits. But, the larger the size of the command stack, the weaker the performance. Therefore, setting a practically appropriate command stack size is important. To set the size of the command stack select **File > Preferences** menu, and change the value of **Undo depth** item in the **General Options** tab.

**Undo depth** configures the size of the command stack to return an object to the state it was in before the last action.

The Undo command, disabled by default, can be enabled or disabled alternately by clicking  icon in the standard toolbar or by clicking **Edit > Enable Undo** menu in toggle type. Only when **Undo** is enabled, recently executed operations are recorded. To undo an operation, click **Edit > Undo** in the menu bar or  icon in the standard toolbar or push the hot key, Ctrl+Z.

If you want to enable the Undo operation by default, check the **Enable Undo** option in the **General Options** tab of **File > Preferences** menu.

The Undo command is available for most operations except for the follows:

- Selection
- Viewing
- Measuring
- Inquiring Information

# Preferences

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You can change a variety of Pixform Pro's default settings to customize the application and accommodate your personal work style and needs. All of the options can be accessed by selecting **File > Preferences** menu.

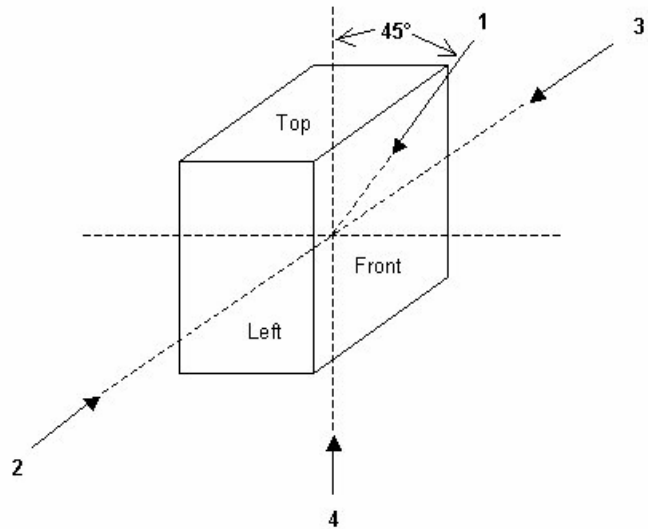
## General Options:

- **Enable Undo** – configures whether to enable or disable the Undo operation when Pixform Pro is launched or **File > New** menu is selected.
- **Undo depth** – configures the size of the command stack to return an object to the state it was in before the last action. For enabling or disabling this option, you should click **Edit > Enable Undo** menu in toggle type.
- **Auto save** – makes the current model save automatically at regular intervals in minute. This option can be enabled or disabled by checking or un-checking the small box in front of this item.
- **Default MDL file** – includes all the option settings of **Preferences** and material colors you defined. It originally locates in the Pixform Pro home directory as a default model file (rfDefaultModel.mdl) and a user can change it to his desired folder. When you launch Pixform Pro, the parameters of the default model file are automatically loaded. You can save your own default model file by **Save as Default MDL** of **File** menu to the desired directory of file. (Note: You can use this default model file when you do *New* and *Import* models, but if you do *Open* a model, you should use the parameters in the model.
- **Cache Directory** – is where the automatically saved file(MDLAutoSave1.mdl) and all the temporary files locate.
- **Number of recent MDL files** – is the number of recently worked file list shown beneath **File > Recent Files**.
- **Function of middle mouse button** – enables you to allocate **Pause** or **Done** function to the middle mouse button.
- **External Data Unit** – is the unit of external model imported through **File > Import** command, and used as the basic unit of numerical input while executing commands such as **Transform**, **Delete Spikes**, etc.
- **Internal Measure Unit** – is the unit used internally within Pixform Pro, and used as the basic unit for showing information while executing commands such as **Measure**, **Information**, etc.
- **Significant position of the decimal** – controls the decimal place, which affects all the numbers displayed in the working window, command console window, color map, deviation, dimension, and so on.

## Display Options:

- **Polygon draw** – **Offset factor** and **Offset unit** are parameters used when displaying shells with **Shaded with Edges** or **Hidden Line** rendering mode. In case edges do not look clearly, up or down the values of these parameters. The phenomenon arises from incompatible graphic driver.

- **Picking** – configures the size of the rectangle in the pixel unit, and it affects the accuracy of picking result. Turn on the Vertex snap option to pick a vertex when you pick a position close to it.
- **Show at launch** – decides whether or not to show the bounding box, axis, and grid on the screen and to apply perspective viewing to models when a new workspace window is opened.
- **Select** – is used to select only faces that are visible on the screen.
- **Light** – is the light source used when displaying shells with **Shaded** or **Transparent** rendering mode. The positions of each light source are shown as right
- **Dynamic Draw** – is used to increase the performance of virtual trackball
- **Gradient Background** – sets the default background color of Workspace window to gradient gray color.
- **2 Side Shading** – is used to render both sides of polygons
- **High Quality Normal** – enables objects to be shaded smoothly by considering the connection relationship among faces with original normal vectors of faces on polygonal model
- **Render Ref. Geometry**: It configures to render reference point, plane, sphere, and cylinder.
- **Depth-Test Ref. Geometry**: If the depth test is enabled, reference geometry is displayed while shells are hiding its part.
- **Point Drawing Size**: It configures the size of vertices when the point shading is active.
- **Color & Material** – is used to change the colors of a default shell color, a rendered surface, reference geometries, background, grid, dimension, bounding box, showing boundary and all entities.



### File I/O Options:

- **Shell Merge Options** – configures whether or not to preserve the original shell structure of the model.
- **IGES Import Options** – **Tolerance** configures the tolerance used when reading IGES format files. **Use Unit Information** determines whether use the unit of an IGES file imported. **Surface Healing** remedies the normals of surface patches and repairs small gaps and other flaws when an IGES file is opened. **Merge boundary curves** determines whether merge G1 tangent curves in a connected loop which is a boundary of a trimmed surface patch.
- **Import Material Information** – determines whether to include material information such as texture or vertex color when a file is imported.
- **Check Integrity Error** – configures whether or not to clean non-manifold faces, coincident vertices and zero area faces when a file is imported.

- **Executable File Formats by Double-Click** – determines to open a specific file format by double-clicking it on an explorer window. (Note: This setting is saved into the registry of Windows system, not to a default MDL file)

### **Curve/Surface Options:**

- **Tolerance** – configures the tolerances used for curve merging, surface intersection, surface area and all trim operations. If need more accuracy, the tolerance should be reduced.
- **Shell-Curve distance tolerance on creation** – sets tolerance between a shell and curves when curves are created.

# Hot Keys

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The hot keys provide quick access to the most commonly used commands. Keyboard shortcuts offer an alternative method of performing actions for users who prefer the keyboard to the mouse. Some of the commands in Pixform Pro are assigned hot keys by default.

You can also change the existing hot keys or create new hot keys for commands that do not have hot keys by default. For this purpose, use the Keyboard tab on the Customize dialog box after executing **View > Toolbars > Customize** menu. You can assign more than one shortcut key for any command and delete or change key assignments. You can also reset all shortcut keys to their default settings.

The following is the list of default hot keys in Pixform Pro.

## File menu

File Open	<b>Ctrl + O</b>
File Save	<b>Ctrl + S</b>

## Select menu

Select Vertex	<b>Shift + V</b>
Select Face	<b>Shift + F</b>
Select Shell	<b>Shift + S</b>
Select All	<b>Shift + A</b>
Select None	<b>Shift + N</b>
Select Inverse	<b>Shift + I</b>
Select Enlarge One Depth	<b>Shift + E</b>

## Edit menu

Undo	<b>Ctrl + Z</b>
Delete Vertex	<b>Alt + V</b>
Delete Face	<b>Alt + F</b>
Delete Shell	<b>Alt + S</b>
Copy	<b>Ctrl + C</b>
Paste	<b>Ctrl + V</b>
Shell Trackball	<b>Ctrl + T</b>
Edit Material	<b>Ctrl + M</b>

## Show/Hide Keys

Show/Hide All Shells	<b>1 / 2</b>
Show/Hide All Curves	<b>3 / 4</b>
Show/Hide All Surfaces	<b>5 / 6</b>
Show/Hide All Loops	<b>7 / 8</b>

## View menu

Zoom Window	<b>Shift + Z</b>
Zoom Previous	<b>Shift + X</b>
Reset View	<b>Ctrl + R</b>
Point Set Display	<b>F1</b>
Wireframe Display	<b>F2</b>
Hidden Line Display	<b>F3</b>
Shaded Display	<b>F4</b>
Shaded With Edges Display	<b>F5</b>
Transparent Display	<b>F6</b>
Textured Display	<b>F7</b>
Front View	<b>Alt + 1</b>
Back View	<b>Alt + 2</b>
Left View	<b>Alt + 3</b>
Right View	<b>Alt + 4</b>
Top View	<b>Alt + 5</b>
Bottom View	<b>Alt + 6</b>
ISO View	<b>Alt + 7</b>
Show / Hide Bounding Box	<b>B</b>
Show / Hide Axis	<b>A</b>
Show / Hide Grid	<b>G</b>

## ETC

Repeat Last Command	<b>Space</b>
Default	<b>Esc</b>
Pause	<b>P</b>
Show Boundaries	<b>E</b>
Render Surfaces	<b>R</b>




## Using On-line Help

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There are two ways you can access on-line help. You can open the Help window and search for information on a specific topic, or you can use context-sensitive help.

To access help for any commands, select **Help > Pixform Pro Help** menu or  icon on the Standard toolbar. Go to the **Menu description** to find the menu structure.

To access context-sensitive help for some commands, first select the desired menu.

When the dialog box is displayed for the command, press  button. The corresponding help page for the function will be displayed.

Pixform Pro provides an additional on-line help for Pixform Pro API. To access this, select **Help > Pixform Pro API Help** menu.

To open a PDF tutorial on-line, click **Help > Pixform Pro Tutorials** menu. It needs that a Acrobat Reader should be installed on your computer.

To check the version of your Pixform Pro, click **Help > About Pixform Pro...** menu or just type “about” in the command prompt.

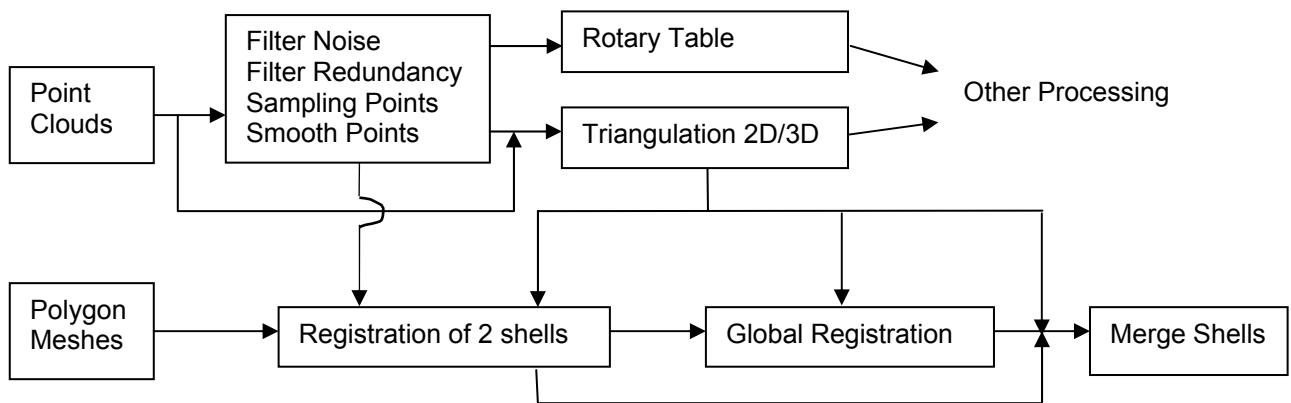
# 5. Scan Workbench

Scan workbench handles point-based processing. Pixform Pro accepts point clouds or polygon meshes from 3D scanners. There are many operations to improve the scanned data. Using them can quickly and conveniently clean up point clouds. Noisy data can be improved and intelligent filtering routines can be employed to reduce the count of the point set. Unnecessary or erroneous data captured during scanning can be eliminated. The smaller improved point set will polygonize more rapidly and result in a higher quality polygonal surface.

When the data includes polygon meshes, you may go to the registration process directly. If not, you should begin at the triangulation process. If use a scanning device with a global positioning sensor, you may skip the process of **Registration of 2 shells**.

Especially in case of large point data, you may skip the triangulation process and directly go to the registration and merging process.

### Work Process:



## Filter Noise

You can remove points placed in undesirable regions due to measurement errors. You can repeatedly use Build > Filter Noise menu.

**NOTE:** While noisy data will be gradually removed in every time it is used, too many repeat may remove the correct data as well.

### **Exercise:**

1. Open “noise.mdl” under “scan\_wb” folder.
2. Apply **Build > Filter Noise** a few times with default options.



Before filtering noise



After filtering noise

For point set that cannot be removed by this operation, you can remove them manually by Edit > Delete > Vertex menu.

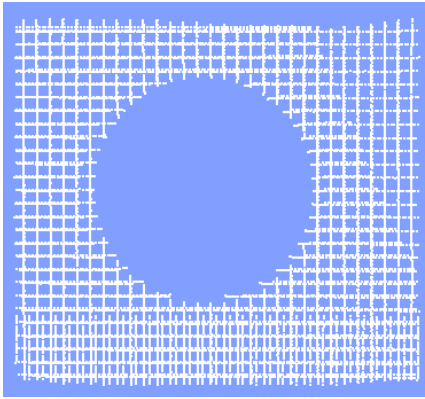
## Filter Redundancy

You can uniformly reduce the number of points in a point set which points are too close or overlapped each other. This operation, Build > Filter Redundancy, deletes only points which distance to adjacent points is smaller than mean distance between all points.

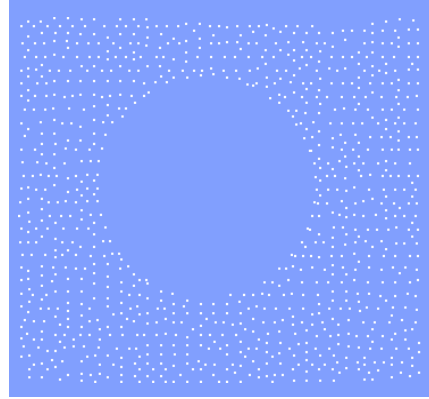
Filter Redundancy is very useful when you triangulate point set having overlapped points or scanned repeatedly.

### **Exercise:**

1. Open “filter.mdl” under “scan\_wb” folder.
2. Apply **Build > Filter Redundancy** twice with default value.



Point set before filtering



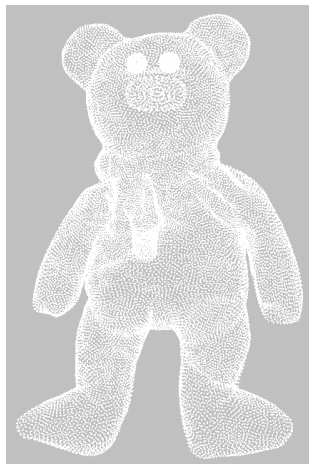
Point set after filtering

## Sample Points

The Uniform sampling operation performs a random sampling of point set. Before sampling, you can determine the percentage of total points you want reduced, and the application removes them automatically. The Line/Grid option is suitable for a line/grid type point cloud. The Curvature sampling operation reduces points based on the curvature. Points in a high curvature region are less deleted than low curvature region in order to maintain the accuracy of curvature line, but points in flat regions are much more likely to be deleted because those regions require less detail.

### Exercise 1:

1. Open “sampling.mdl” under “scan\_wb” folder.
2. Apply **Build > Sample Points > Uniform**.
3. Type in **40 %**, and click **OK** with **General** type.



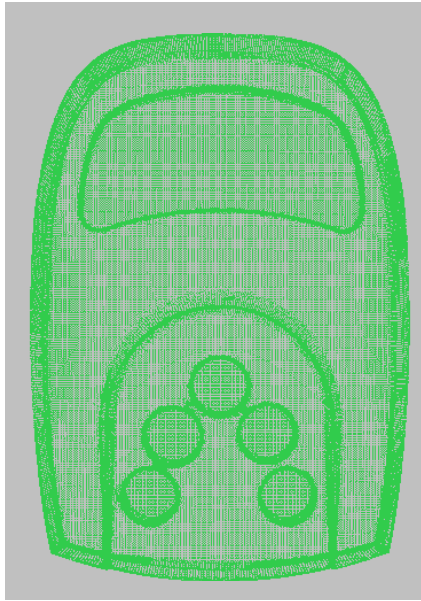
Before sampling points



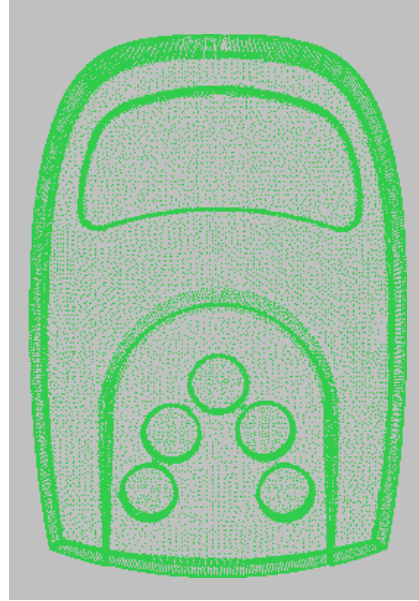
After sampling points

### Exercise 2:

1. Open “curvature\_sampling.mdl” under “scan\_wb” folder.
2. Apply **Build > Sample Points > Curvature**.
3. Type in **40 %**, and click **OK**.



Before sampling points



After sampling points

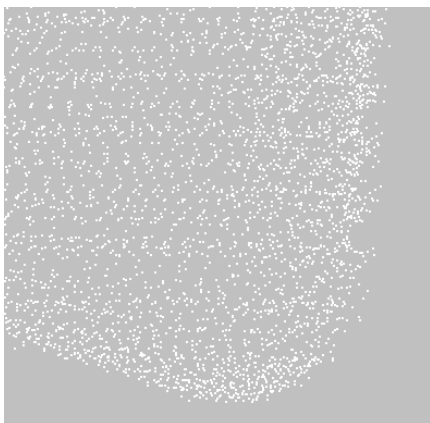
## Smooth Points

Smooth Point operation smooths point clouds for reducing roughness. This operation, **Build > Smooth Points**, removes noise from scanned data without reducing the count of points. You can use this tool to lessen sharp features or remove projecting points.

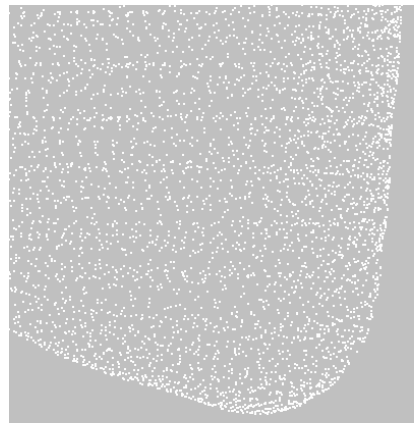
**NOTE:** *Too much smoothing can result in excessive loss of detail.*

### **Exercise:**

1. Open “smooth.mdl” under “scan\_wb” folder.
2. Apply **Build > Smooth Points**.
3. Type in **0.5** weight and **10** iterations, and select **OK**.



Before smoothing



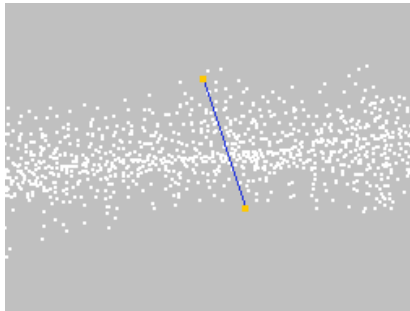
After smoothing

## Thin Points

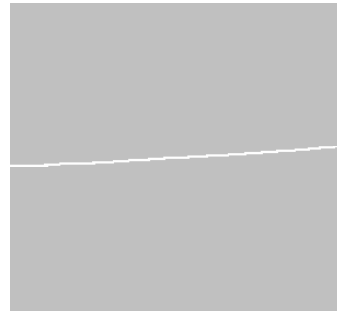
The Thin Points operation thins a selected point set and fits points to a curved line. The operation is useful for fitting a linear point set to a curve.

### Exercise:

1. Open “thin\_points.mdl” under “scan\_wb” folder.
2. Click **Measure > Point/Point Distance** menu. Click **Vertex** on RMB menu. Select two vertices as shown below left.  
(Distance will be referred as Search Radius in the step 4)
3. Click **Build > This Points** menu, and select the point cloud.
4. Type in **5** in **Search Radius for Near Vertices**.
5. Click **OK**.
6. Repeat this operation by typing in **3** **Search Radius**.



Original point cloud



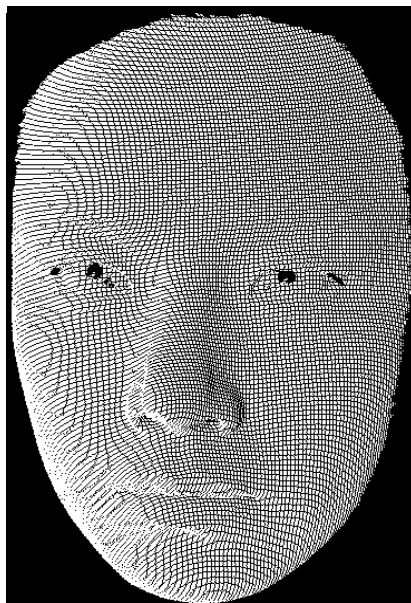
Thinning points

## Dither Points

This operation get a dithered point cloud from a texture polygon model by dithering its texture with the brightness and contrast. It results in denser point cloud over bright region and coarser point cloud over dark region.

### Exercise:

1. Open “dither.mdl” under “scan\_wb” folder.
2. Click **Build > Dither Points** and pick a shell.



Original point cloud

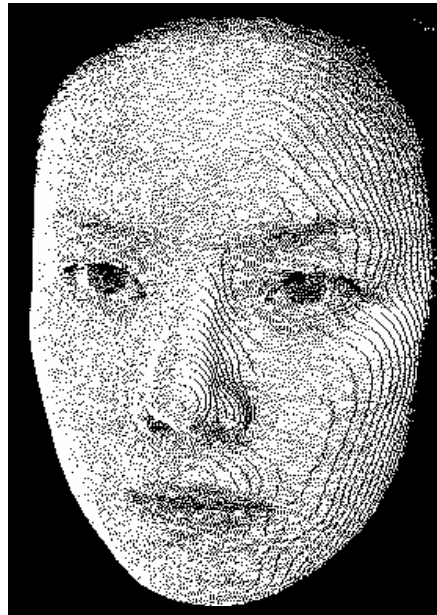


Original texture

3. Move slide bars as three steps for **Brightness** and **Contrast** to the right as below left picture. Then click **Dither Texture** button.
4. Finally, click **OK** button.



Modified brightness & contrast



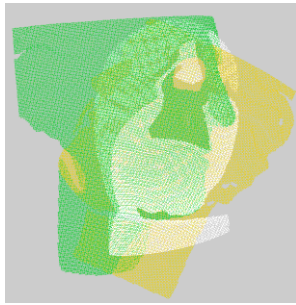
Dithered point cloud

## Point Cloud to Polygon (2D Triangulation)

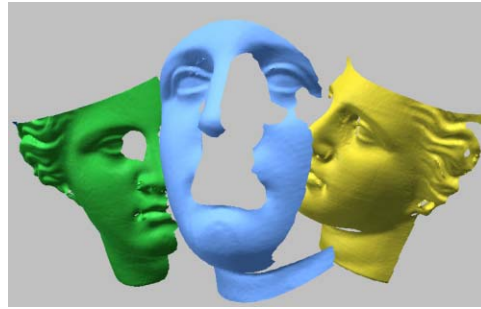
Polygonal model consists of open or closed surface containing triangles(faces), edges and vertices. You can get a polygonal shell as triangulating a point cloud scanned on a single view via Build > Triangulate > Surface > 2D. This operation projects points on three dimensional space onto two dimensional plane and then, apply *Delaunay Triangulation* process to projected points. Thus, for proper triangulation, all the points must be projected onto a plane without overlap. If a point cloud consists of 3D shape scanned by automatic aligning system such as CMM, go to the full 3D triangulation command.

### Exercise:

1. Open "venus\_point.mdl" under "scan\_wb" folder.
2. Show only "front" in project tree window.
3. After applying Zoom Window to a specific area, measure the diagonal distance between adjacent points by **Measure > Point / Point Distance**. It should be near **3.0**.
4. Show all shells by pushing **1** hot key.
5. Select **Build > Triangulate > Surface > 2D** menu, and select all shells by mouse drag.
6. Type in **4.0 Maximum edge length** option. Turn on **Facing angle** option, and select **OK**.
7. Push **F4** hot key, and select **View > Explode Shells** icon.
8. Apply **Change Material** to all shells using RMB menu on project tree window.
9. If necessary, push **E** hot key, and check polygon shells.



Before polygonizing



After polygonizing

## Registration of 2 Shells

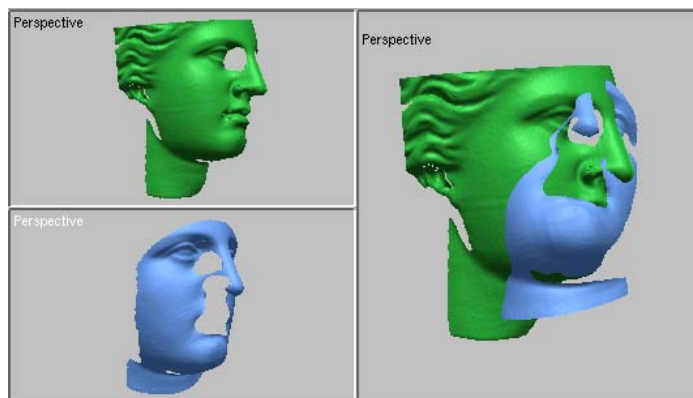
Registration allows you to register multiple point clouds or polygonal shells using overlapping regions. If multiple scans were taken to obtain various views of a 3D object, you need to properly align all of the scans within the viewport to construct the original object.

Registration is accomplished by identifying known features common to two datasets. This application calculates an approximate position of one shell with respect to another using common geometric features between two shells. When performing this operation, first selected shell is moved to second selected shell.

**NOTE:** *The application shows you a multiple window system to view individual shells and easily pick reference points during registration. If you don't want to separate the window, turn off the option **Show Each Shell Separately** in the **Build > Register > Options** menu. In this case, you have to manually separate each shell using *Shell Trackball*.*

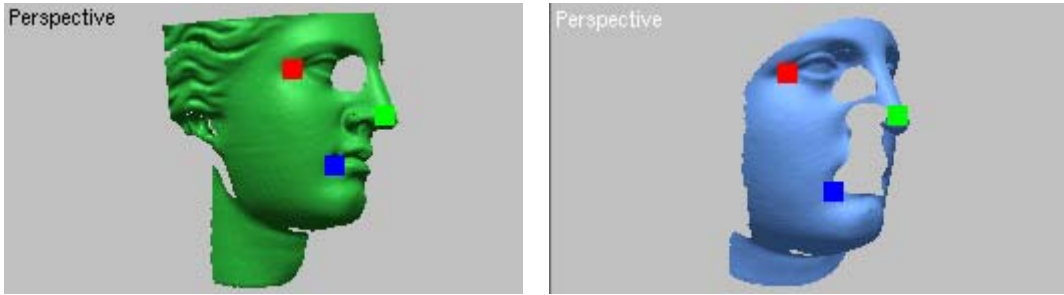
### Exercise:

1. Open "venus\_polygon.mdl" under "scan\_wb" folder if necessary.
2. Click **Build > Register > 2 Shells > Initial** menu and pick "right" and "front" in turn in project tree window.  
(NOTE: The "right" shell will be transformed to the "front" shell)
3. Rotate shells in each viewport in the same direction after clicking **Pause** on RMB menu as shown below.

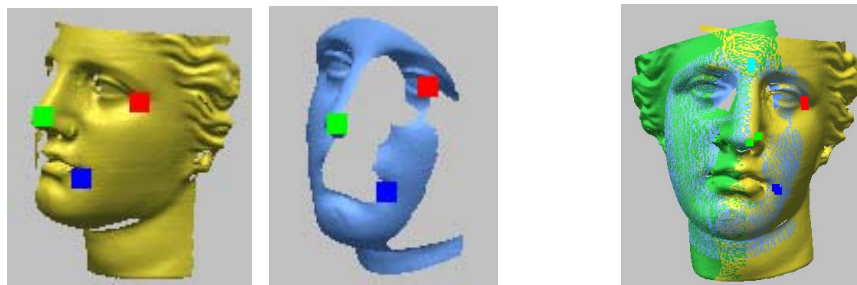


4. Pick more 3 pairs of corresponding points in each viewport as shown below.





5. Click **Done** on RMB menu. The “right” shell was transformed to the “front” shell.
6. Repeat the above process with “left” shell as a first selected shell and “front” shell as a second selected shell as below left. So, the “left” shell should be transformed to “front” shell.
7. As a result, three shells are registered each other as below right.



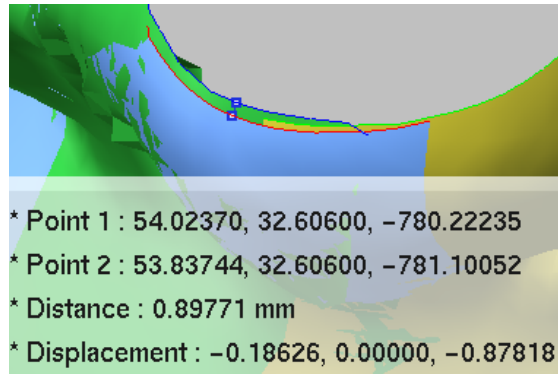
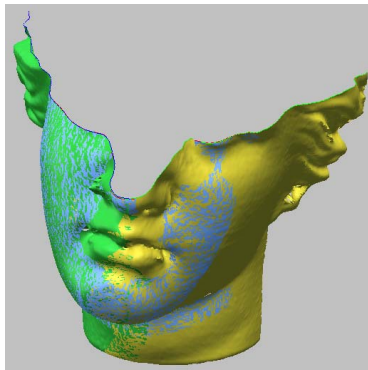
## Global Registration

Global Registration exactly matches the position of all the selected shells at the same time using the overlapped region, which is automatically found. When the overlapped region is too little or the two registered shells are located far from each other, the registration result may be poor.

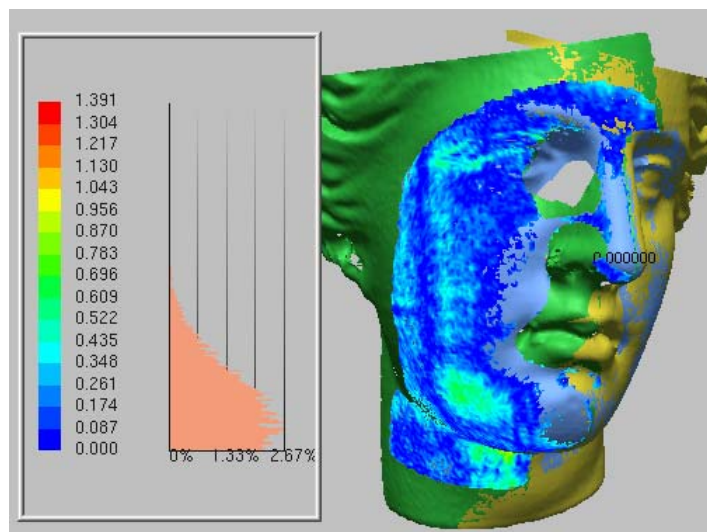
**NOTE:** To change the default parameters used in this operation, you can change the values of **Num. Of Max. Iteration** and **Max. Average Deviation** in the **Build > Options > Set Register Options** menu.

### **Exercise:**

1. Open “venus\_register\_initial.mdl” under “scan\_wb” folder if necessary.
2. Show all shells in project tree window.
3. Select **Build > Register > Fine** menu, and select **All** on RMB menu.  
(**NOTE:** All means all the shells shown in the workspace window. If you register globally only a few shells, hide other shells on project tree window before performing Global Registration operation)
4. Evaluate the registration result by **Measure > Cross Section > Model** menu. Move **Position** slide bar to the nose of model as shown below left, and turn on **Hide front** option in the dialog box. Zoom in the nose part, and measure the distance between two sections as below right after clicking **Dist.** button.



- To evaluate the registration by another tool, select **Measure > Shell/Shell Deviation** menu and then select two shells. Push RMB on color bar and select **Show Histogram**. You will see a distribution chart of deviation.

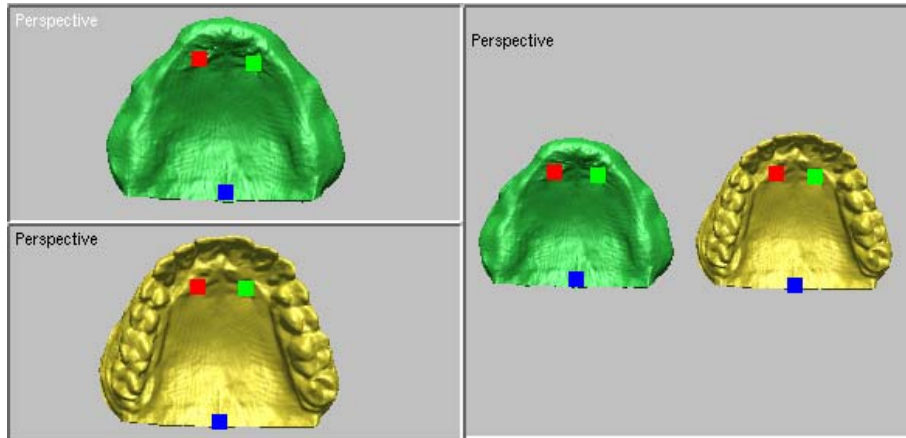


## Regional Registration

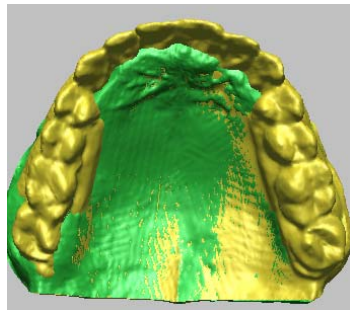
You can align exactly two shells which having common region partially. The advantage is to enable you to align two same objects though an old one is different from a new one partially because it is changed after a period of time goes by.

### **Exercise:**

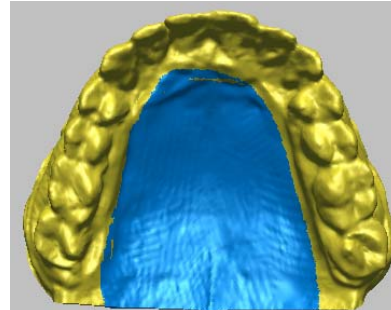
- Open “teeth\_region.mdl” under “scan\_wb” folder.
- Click **Build > Register > 2 Shells > Initial** menu and pick “base” and “teeth” in turn in project tree window.
- Pick more 3 pairs of corresponding points in each viewport as below and click **OK** on RMB menu.



- Click **Build > Register > 2 Shells > Regional** menu and pick “base” and “teeth” in turn in project tree window. And then select region on the shell “teeth” as below middle. Click **OK** on RMB menu.

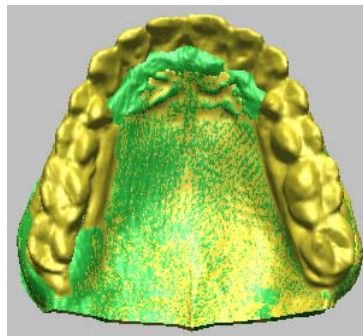


Initial aligning

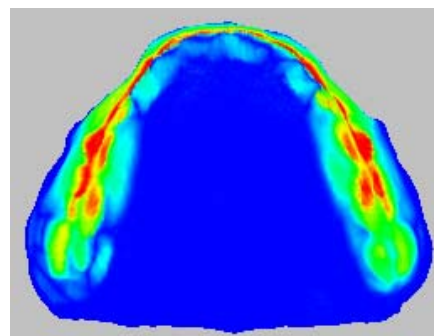


Selecting common region

- Click **Measure > Shell/Shell Deviation** menu and pick “base” and “teeth” in turn in project tree window. **Set Cal. Tolerance to 10**, click **Apply**, and hide all shells.




Regional aligning



Shell/Shell Deviation

## Surface Merging

This operation merges shells which have been aligned by registration process into one united shell. During the merging process, overlapped regions between shells are removed and neighboring boundaries are stitched together with newly added polygons. The result and accuracy of shells are still maintained after merging.

**NOTE:** Before executing this operation, click the Enable Undo Icon (  ) to make the rollback functionality possible.

### Exercise 1:

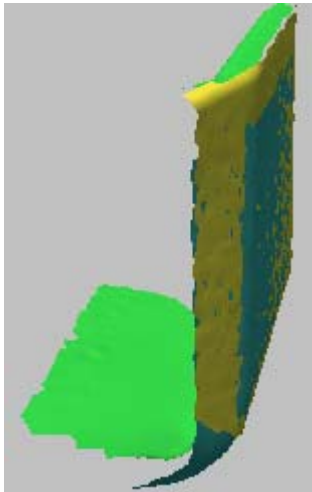
1. Open “venus\_register\_fine.mdl” under “scan\_wb” folder if necessary.
2. Show all shells in project tree window.
3. Select **Build > Merge > Meshes > Surface**, and select **All** on RMB menu.



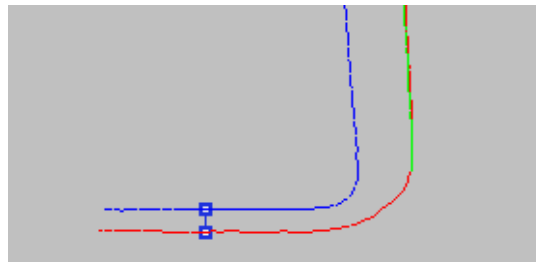
**NOTE:** The Merge Shells operation enables you to change a default parameter for merging shells in the **Build > Options > Set Merge Options** menu. A thin wall object is partially broken after merging process because the thickness is thin. You can control a decision criterion for whether two shells are merged or not, by entering the value ranging from **0.0** to **1.0**.

### Exercise 2:

1. Open “thin\_wall.mdl” under “scan\_wb” folder.
2. Click **Measure > Cross Section > Model** menu.
3. Select **X-axis** and **Sections only** option, and click **Dist.**
4. Click **Min. Distance** on RMB menu, and select two points as shown below right.
5. Click **Build > Merge > Meshes > Surface** and click **All** on RMB menu.
6. Press **E** key and rotate the merged shell to check the result.
7. Open “thin\_wall.mdl” again.
8. Click **Build > Options > Set Merge Options** menu.
9. Select **Manual Distance Criterion** option, type in **0.5**, and click **OK**.
10. Repeat the above step 5, and then compare the result of step 6.



Scans of thin object

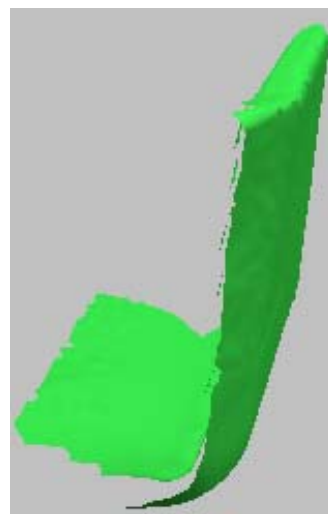


\* Point 1 : -46.62700, -27.89830, -51.61194  
 \* Point 2 : -46.62700, -28.60700, -51.78446  
 \* Distance : 0.72940 mm  
 \* Displacement : 0.00000, -0.70870, -0.17252

Check thickness of thin wall



Merging with default option



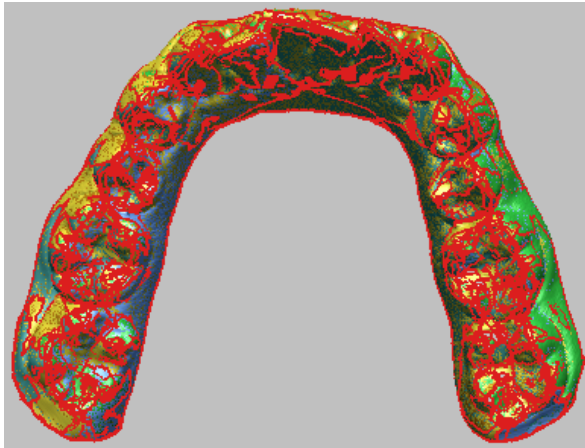
Merging with 0.5 parameter

## Volume Merging

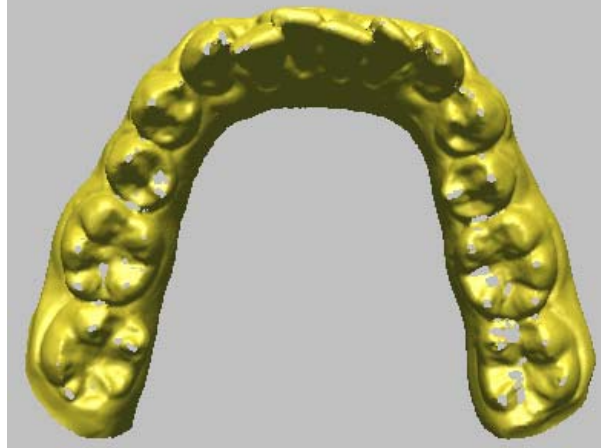
This operation merges multiple shells into a single one by allocating their geometry information to a reference voxel model with a volumetric method. Volume based merging is useful when surface based meshing creates poor merge results. This polygon merging tool helps you to merge scan data with many holes and messy boundary, or bad aligned data.

### Exercise 1:

1. Open "volume\_merge1.mdl" under "scan\_wb" folder.
2. Click **Build > Merge > Meshes > Volume**, and select **All** on RMB menu.
3. Set **Resolution** to 1 by default and check **Optimize Mesh** option.  
**Note:** Resolution is ratio to the average of vertex spacing. If the number is larger than 1, the edge length of merged shell will be larger than the average edge length of selected shell
4. Click **OK**.
5. Try to apply **Build > Merge > Meshes > Surface** to the same model and compare with each other.



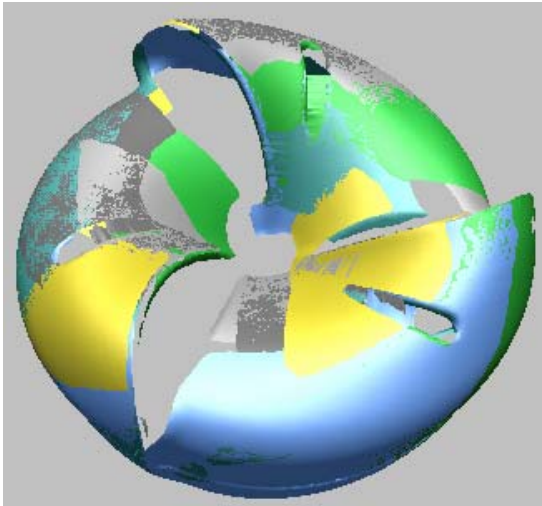
Before merging



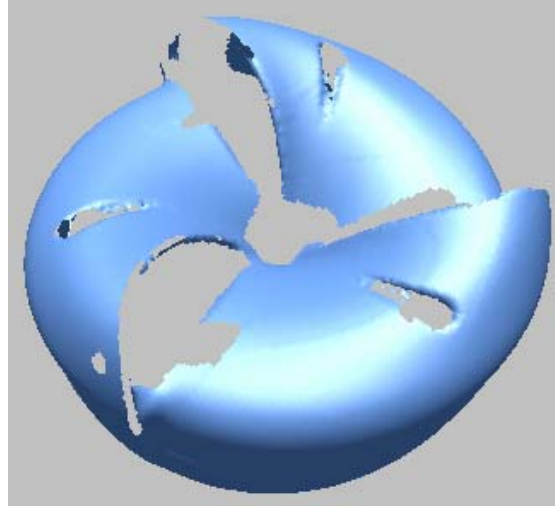
After merging

### Exercise 2:

1. Open "volume\_merge2.mdl" under "scan\_wb" folder.
2. Click **Build > Merge > Meshes > Volume**, and select **All** on RMB menu.
3. Set **Resolution** to 1 by default and check **Optimize Mesh** option.
4. Click **OK**.
5. Push **F5** key and check polygonal meshes.



Before merging



After merging

6. Compare with the result by **Build > Merge > Meshes > Surface**.

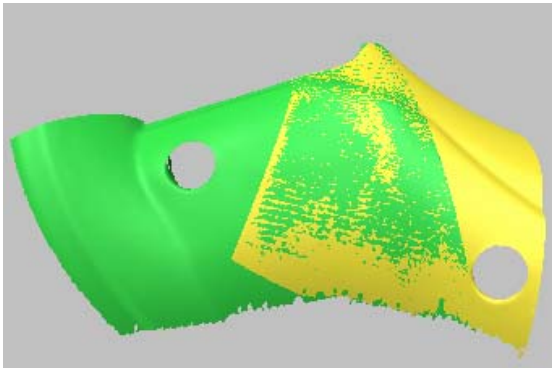
## Merge Point Clouds

The Merge Point Clouds operation merges selected shells and makes them into a point set. During the merging process, overlapped regions between shells are removed effectively.

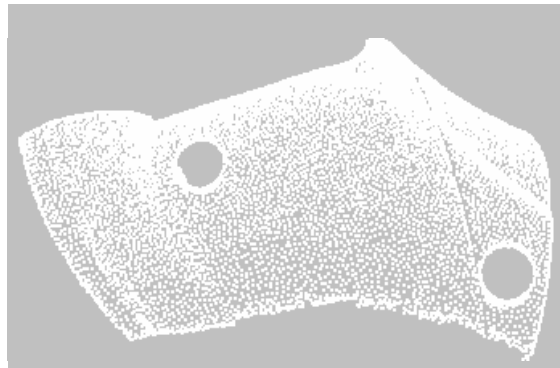
### Exercise:

1. Open "point\_merge.mdl" under "scan\_wb" folder.
2. Click **Build > Merge > Point Clouds** menu, and click **All** on RMB menu.
3. Click **OK** with **Merge Shells** option.
4. Click **File > Preferences**, and go to **Display Options** tab. Set **Point Drawing**

**Size to 3** and then click **OK**.



Overlapped two shells



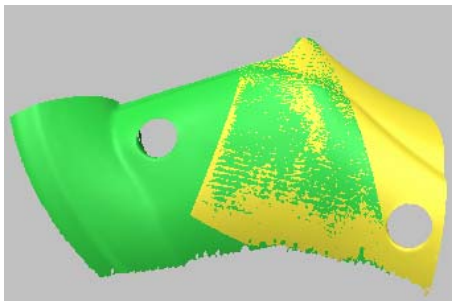
Merging points

## Combine Shells

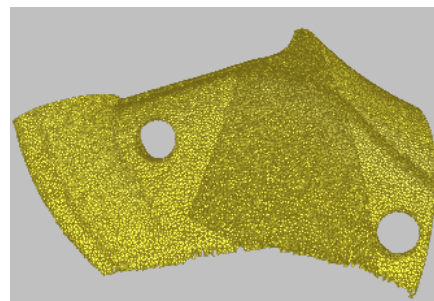
The Combine Shells operation combines shells simply into one united shell. By the combining process, overlapped regions between shells remains as it is. This command is useful for making simply a large model from many scan data for the purpose of inspection because it doesn't need much memory

### **Exercise:**

1. Open "point\_merge.mdl" under "scan\_wb" folder.
2. Click **Build > Combine Shells** menu, and click **All** on RMB menu.
3. Press **F5** key.



Overlapped two shells



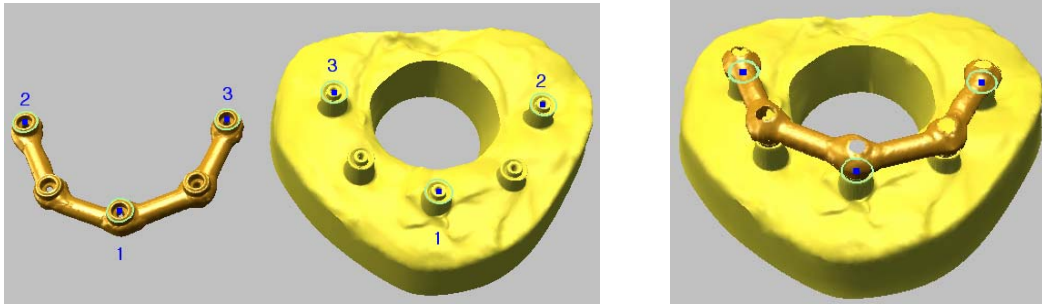
Combining shells

## Registration using Ref. Point

This operation registers two shells by user-defined reference points as another method of the Registration of 2 shells operation. The reference points can be defined by the features of object like circle or by scanning reference balls around object.

### **Exercise:**

1. Open "teeth\_frame.mdl" under "scan\_wb" folder.
2. Select **Build > Register > 2 Shells > Pick 3 Ref. Points** menu, and select "frame" and "base" shells in turn. And then, pick pre-defined 3 pairs of reference points in order of number with starting from "frame" shell as shown below left.
3. As a result, "frame" shell is transformed to "base" shell (as shown below right).



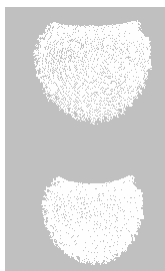
## Rotary Table

You can register and merge quickly multiple scans using a rotary stage. You should scan one shot of datum ball composing two spheres as shown below left before you scan a real object (as shown below right). The scan view of one shot is used to define the rotation axis of rotary table.

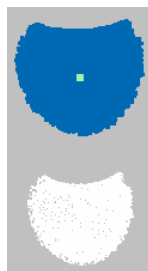


### Exercise:

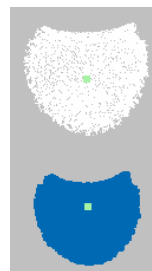
1. Open "rotary\_scan.mdl" under "scan\_wb" folder.
2. Show "datum\_ball" shell only on project tree window.
3. Select all vertices of upper sphere by Shift + V key, and find the center point of upper sphere by **Ref.Geometry > Create > Point > Fit Sphere**.
4. Unselect all selected faces by Shift + N key, and repeat above 3 step for lower sphere.
5. Push Shift + N key, and create a vector to be the rotation axis of rotary table. Select lower and upper reference point in turn after performing **Ref. Geometry > Create > Vector > Pick Points** and selecting **Ref. Point** on RMB menu.



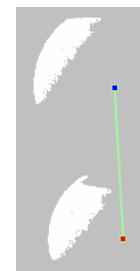
(1)



(2)



(3)

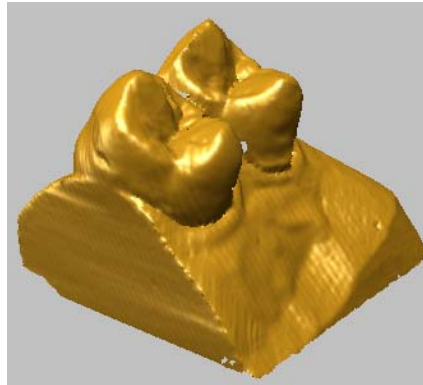
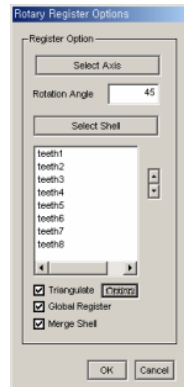


(4)

6. Show all shells, and select **Build > Register > Rotary Table**.
7. Click **Select Axis** button on the dialog box, and click the vector.
8. Set **Rotation Angle** into **45** degree (as shown below left).
9. Click **Select Shell** button, and select all shells in order of number except "datum\_ball" on project window.
10. Turn on **Triangulate** menu, and type in **0.5** in Maximum edge length after pushing Triangulate option button.



11. Turn on **Global Register** and **Merge Shell** menus, and click **OK**.
12. Apply **Change Material** to the merged shell as shown below right.

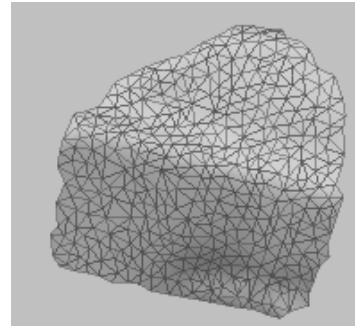
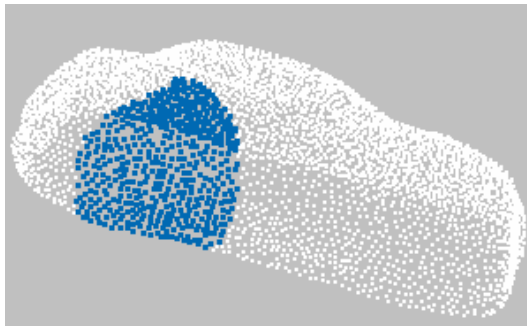


## 3D Surface Triangulation

This operation converts a merged point cloud of multiple scanning to a polygonal model. The model can consist of both closed surface encloses volume and triangles that do not bound volume. If point clouds have duplicate points or complex scanning patterns, you should reduce points by filtering operation like Filter Redundancy.

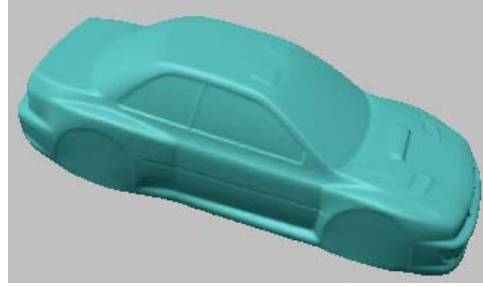
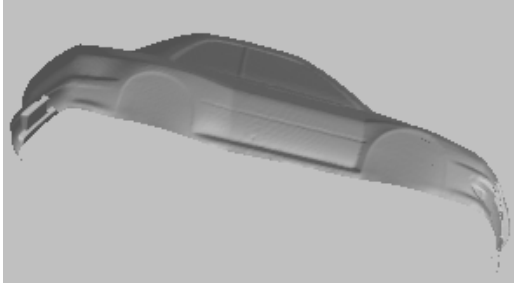
### Exercise:

1. Open “car.mdl” under “scan\_wb” folder.
2. Apply **Build > Triangulate > Surface > 3D** to the car model.
3. Check polygonal shape partially using **Select Vertices** on RMB menu and **Preview** button on the dialog box before applying to entire point cloud as shown below.



4. If triangles are not bad, click **OK** button.
5. Select **Yes** if the shaded image of polygonal surface looks correct.

**NOTE:** *Though you decided polygon’s normal direction is incorrect (as below left), you can invert its direction by **Edit > Reverse Normal > Shell** menu.*

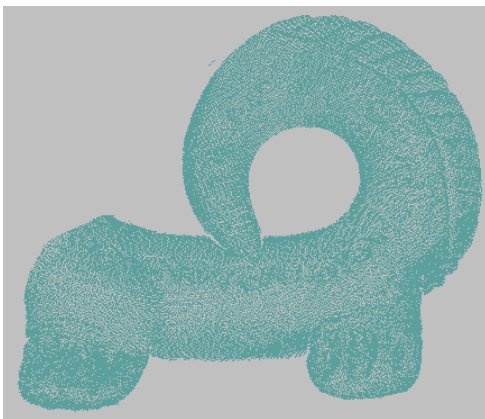


## 3D Volume Triangulation

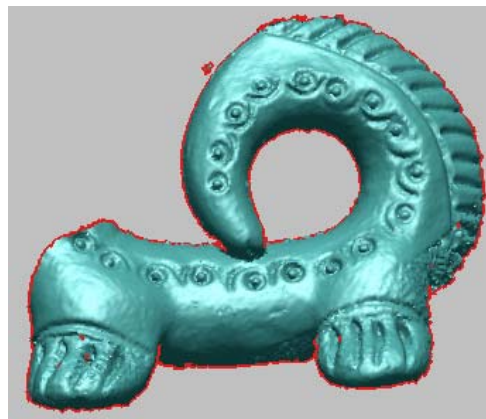
This operation creates a polygonal model from a point cloud by volumetric triangulation method that constructs polygon meshes by adding the topology information to a reference voxel model which possesses the geometry information of a point cloud. The volume triangulation allows you to get a clean polygon model from a messy point cloud even though vertices overlap each other. This operation creates a new polygonal shell while preserving a point cloud shell. Volume based triangulation is useful when surface based 3D triangulation results in poor mesh quality.

### Exercise:

1. Open "dragon.mdl" under "scan\_wb" folder.
2. Check the mean distance between vertices by **Build > Filter Redundancy**.
3. Click **Build > Triangulate > Volume** and select a shell.
4. Set **Edge Length** to **0.5** and check **Optimize Mesh** option, then click **OK**.
5. Press **F4** key and check boundary edges by pressing **E** key.



Point Cloud



After volume triangulation

6. Compare with the result by **Build > Triangulate > Surface > 3D**.

## 6. Polygon Workbench

The Polygon Workbench offers the most comprehensive set of functionalities available to manipulate and prepare polygon mesh models for a variety of applications. It includes virtually every tool needed to create high quality polygon meshes for rapid prototyping, 3D graphics, or downstream applications like NURBS surfacing. Pixform Pro's powerful hole filling algorithms intelligently fill in missing data, and several methods for surface smoothing can repair common errors in 3D scan data. A plethora of 3D measurements can be taken, including surface area, distance, volume and others.

Polygon workbench is specific to working with the polygonal model, such as cleaning abnormal polygon meshes, refining the surface by smoothing, re-meshing, or decimation and to prepare the polygonal model for rapid prototyping or NURBS surfacing. Polygon workbench includes the various polygonal mesh editing tools. You can refine the polygonal mesh to improve the quality of surfaces you will generate. However, the degree of accuracy of the surfaces is based on the quality of the original data.

Polygon workbench handles polygon-based volume model for RP(Rapid Prototyping) application. RP applications require a closed, watertight surface with a defined thickness. Pixform Pro provides many useful operations for rapid prototyping works like thickening, extrusion, aligning and Boolean operations, and so on.

Pixform Pro can write widely used rapid prototyping file formats, such as STL, DXF, CLI, SLI, and SLC so that you can interface directly slicing data file obtained from Pixform Pro with rapid prototyping systems. Using this process, you can quickly produce prototypes from scan data or surface geometry from other systems. This greatly shortens the production cycle between scanning physical prototypes, creating CAD models, and finally generating prototypes.

Typical abnormal faces defined in Pixform Pro are as follows:

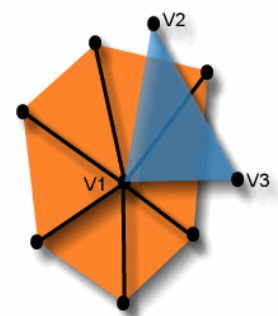
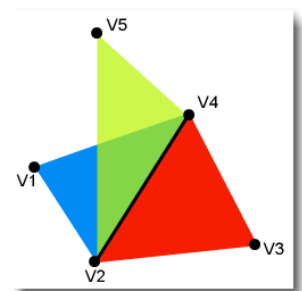
- . *Non-manifold face*: When faces share three or more edge, it is called non-manifold topology. In a pure mathematical term, only two faces can constitute an edge to be a manifold topology. However, an edge with only one face is classified as a boundary edge in Pixform Pro and considered to be normal.

The non-manifold faces may cause severe errors in various calculations, and even severe errors in other applications such as NC machining.

The right upper figure shows an example of the non-manifold topology, where faces (V1 V2 V4), (V2 V4 V3), and (V2 V4 V5) are sharing the edge (V2 V4).

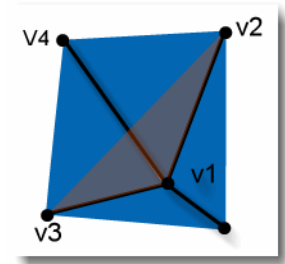
- . *Redundant face*: Other than boundary vertices, the number of faces and edges that share the same vertex must be identical. A face violating this rule is called a redundant face.

The right middle figure shows an example of a redundant face (V1 V2 V3).



- . *Crossing face*: When edges sharing a vertex intersecting with one another, they are geometrically incorrect and their faces are called crossing faces.

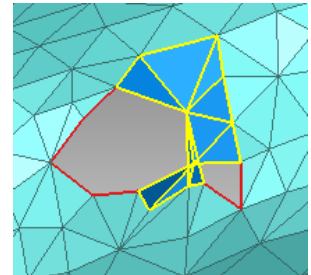
Explaining crossing face by an example, the edge (V2 V3) of face (V1 V2 V3) is crossed with the edge (V1 V4) in the right below figure.



Although crossing face is not a topological definition nor may

cause sever problems, they may cause errors in geometrical calculation and, therefore, must be corrected.

- . *Unstable face*: When faces consist of one side and one loop like Moebius Strip, their edges are recognized as boundary edges but their loop may not a hole and cannot be filled. Their faces are called unstable faces and can be easily found and deleted.



The typical work process is as follows:

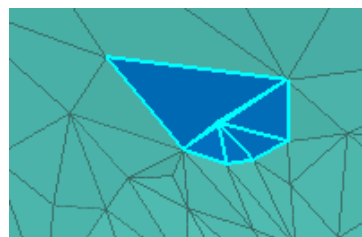
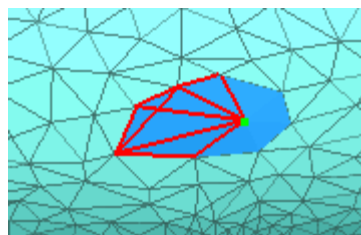
1. Clean Non-manifold faces, crossing faces and unstable faces
2. Fill holes in a model that may have been introduced during the scanning process
3. Edit or optimize polygonal surface using various tools like decimation, smoothing or remeshing for rapid prototyping, NURBS surfacing or downstream applications

## Clean

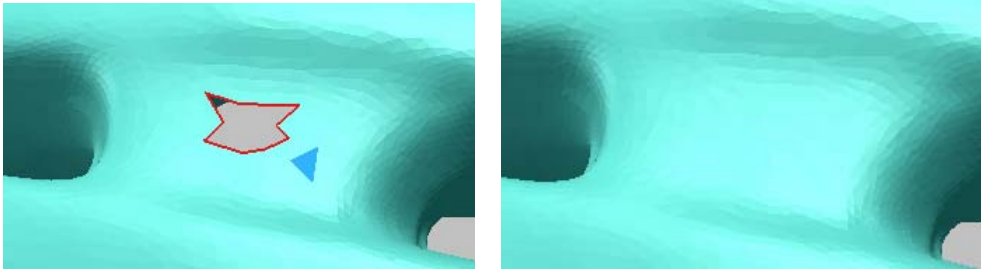
You can automatically delete non-manifold faces and cross faces using Clean menu. You can also delete spike faces that may have been introduced during the scanning process using Delete Spikes menu. Fix Bad Normals operation searches and corrects all the faces, which their normals are reversed, during 3D triangulation process. Delete Singularities operation deletes several kinds of unnecessary data in a single command.

### Exercise:

1. Open "helmet.mdl" under "polygon\_wb" folder.
2. Select **Clean > Find Abnormal Faces** menu. The below left shows non-manifold faces detected and the below right shows crossing faces detected.



3. Apply **Clean > Clean Non-manifold Faces** and **Clean > Clean Crossing Faces**.
4. Check again abnormal faces by **Clean > Find Abnormal Faces** menu.
5. Select **Clean > Fix Bad Normals** menu, and select a reference face whose normal is correct as below left. Then, select **OK** on dialog box. As a result, the shell is changed as below right.



## Fill Holes (Surface)

When the scan data is triangulated, holes or gaps can appear in the surface of the model. The Fill Holes operation fills holes in a model that may have been introduced during the scanning process. The operation constructs a polygonal structure to fill the hole, and both the hole and the surrounding region are remeshed so the polygonal layout is organized and continuous.

You can fill holes with: automatically filling all holes; manually filling holes; and the combination of both. You may automatically fill all small and simple holes, and then bridge the large, more complex, holes manually. Bridging results in smaller holes which can then be filled based on the polygon around them.

When the Fill Holes operation is activated, all boundary edges of holes are displayed with red color for easy identification, and you can choose to fill all of them or choose specific holes.

**NOTE:** *If there are holes which boundaries are not displayed as red color, they can be fixed by Clean > Fix Bad Normals function.*

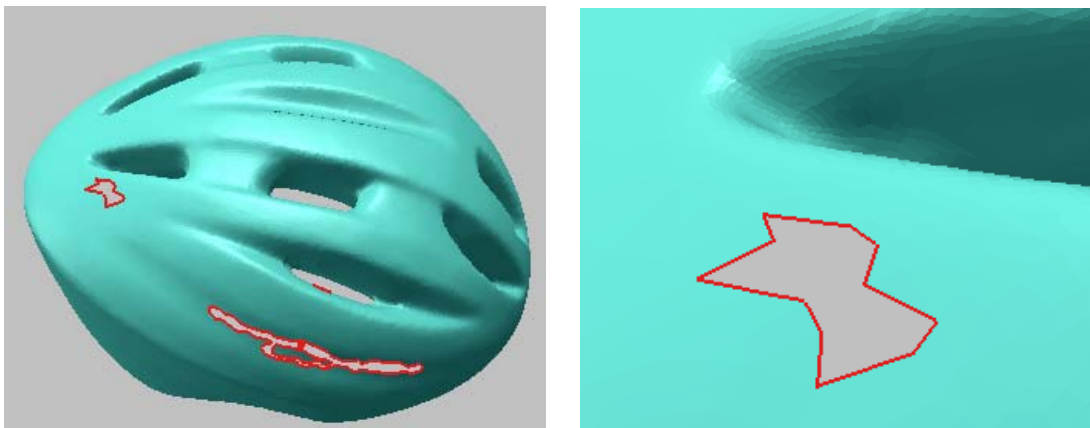
There is a curvature based filling option that ensures the polygonal structure used to fill holes in curved regions is curved to match the surrounding area.

**NOTE:** *The Fill Holes operation can be applied an entire shell or locally selected region.*

### **Exercise:**

*(Being continued)*

1. Apply **Tool > Fill Holes > Surface** to the shell, "helmet".
2. Pick a hole shown below right, and select **OK** with "Smooth" method.

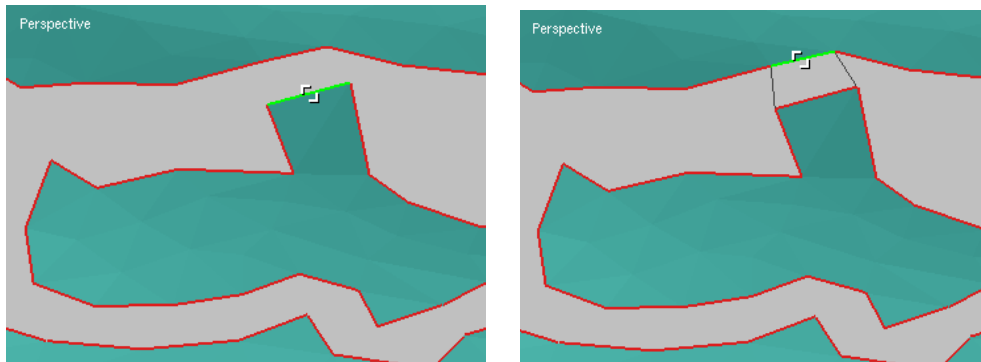


3. Change the viewpoint as shown below.

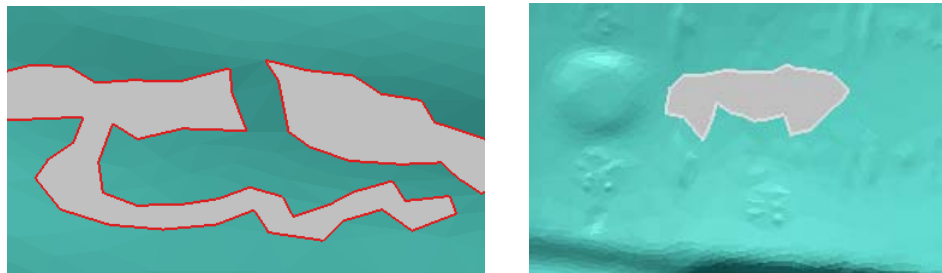


4. Select **Bridge Hole** on RMB menu, and select an edge on boundary of the hole as shown below left. Drag across a mouse pointer to another edge while holding down LMB (as shown below right). The other edge will become highlighted and a span of polygon should appear between the two edges.

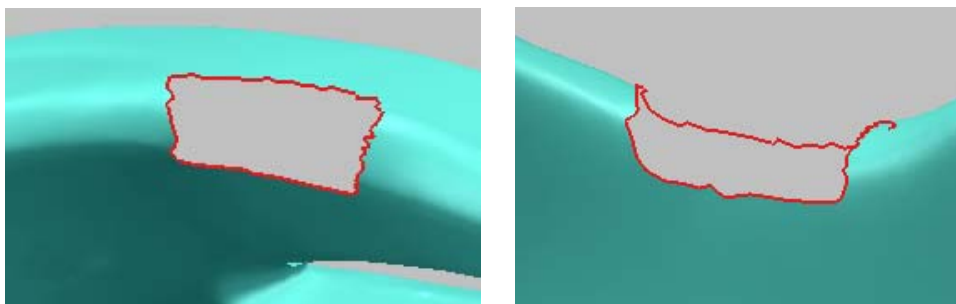
**NOTE:** *Bridge Hole option is very useful when a hole is too large or complex to fill.*



5. To accept a bridge, release the mouse. A bridge is created between the starting edge and the destination edge (as shown below left).
6. Select **Done** on RMB menu, and fill two holes of both sides with default option.
7. Click **Next** button in the **Hole Selection Options** dialog box to find easily another holes, and fill it.



8. Click **Next** button, and fill the hole with “Curvature” method.



9. Select **Quit** on RMB menu to exit the operation.

## Decimate

You can reduce the count of polygon meshes to reduce the amount of surface detail captured. In areas where you do not need as much surface detail, such as flat areas or unnecessarily rough areas, you may wish to decimate your model. This operation reduces the number of triangles while preserving original surface shape.

You can apply Decimate operation to multiple shells at the same time. In case of multiple shells, the *Number of faces* or *Reduction Ratio* is shared to all shells by same distribution ratio.

The operation provides three options: *Number of faces*; *Reduction ratio*; and *Error Bound*. You can simply type in the number of faces or reduction ratio, which you want to reduce to. Use *Error Bound* option instead of number or percentage for the limitation of point movement during decimation. For example, if you type in 0.05 Error Bound, maximum deviation error between original model and decimated one is lower than 0.05.

The *Don't move original vertices* option ensures to retain the positions of remaining vertices. The *Don't modify boundary edges* option ensures the boundary edges are not moved when the operation is applied. The *Try to preserve mesh quality* option lets program perform more rigorous calculation for making the modified faces as uniform as possible. The *Preserve Marked Edges/Vertices* option allows marked edges/vertices to be maintained as it is.

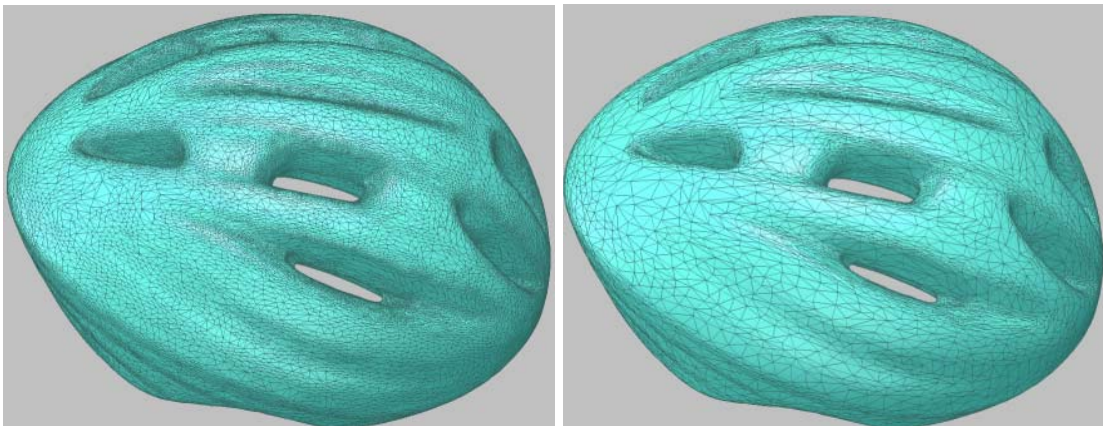
In case the model has several million of polygon meshes or more, you can reduce rapidly the count using the Large Data Decimation tool. The operation voxelizes a bounding box as a specific number of grid in the X, Y and Z direction, and reduces all points of each voxel to one point. The surface quality of polygon by the Large Data Decimation is not good compare to the High Quality Decimation, but the processing time is very short.

**NOTE:** *The Decimate operation can be applied an entire shell or locally selected region.*

### **Exercise:**

*(Being continued)*

1. Apply **Tool > Decimate > High Quality** to the shell "helmet".
2. Reduce to **30%**, and select **OK**.



Before decimation

After reducing to 30%

3. Check the number of triangles in project window and how shape is retained, despite a 70% reduction in polygon count.

## Smooth

Sometimes scan data may have too much detail, for example, it may include every bump and detail of surface roughness in the scanning process. You can reduce this roughness by smoothing the polygon model. Smoothing flattens any curved portion of the polygon where the surface changes direction, including corners. Take care when smoothing the polygon, however, because excessive smoothing can result in too much loss of detail.

The Smooth operation smoothes the surface of the polygonal model by changing the coordinates of the input vertices. The operation provides three methods: *Laplacian*, *Loop* and *Curvature*. The Laplacian method, selected by default, is a tool for enhance global smoothness while Loop method is a kind of local smoothing tool for keeping details of model. The Curvature method is used for curvature based smoothing.

The smooth process is iterative, and you can designate the number of iterations. You can also control the degree of smoothness with weight factor. The greater number of iterations and the stronger of weight factor, the smoother the model becomes. However, too many iterations and too much weight may significantly alter the original model data.

When applying the Smooth operation, you can deselect the *Move Boundary Vertices* option, selected by default, to ensure the boundary points are not moved. The *Preserve Sharp Edges* option allows sharp edges or feature lines to be maintained. The *Preserve Marked Edges/Vertices* option allows marked edges/vertices to be maintained as it is. If you check the *Constrained Smoothing* option, the shape quality of each face is enhanced but the speed is down. If you check the *Preserve Volume* option, the total volume of model will be preserved, thus prevent polygonal model shrinkage, during the smoothing process.

**NOTE:** *The Smooth operation can be applied an entire shell or locally selected region.*

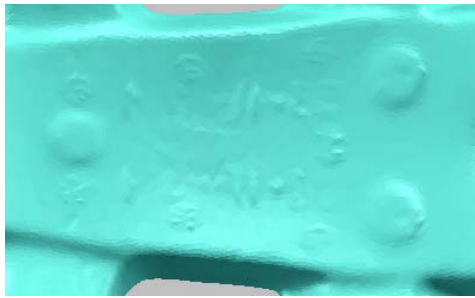
*Also you can use the paint tool to smooth locally in real time.*

### **Exercise:**

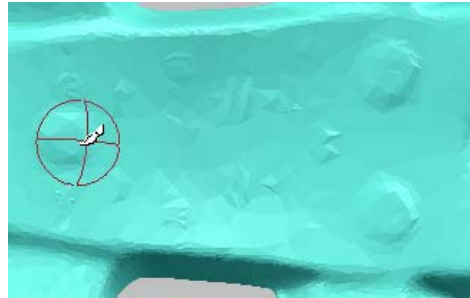
*(Being continued)*

1. Change the viewpoint to view the inside of “helmet” as shown below.
2. Select **Tool > Smooth > Paint** menu.
3. Drag the paint tool while holding LMB to smooth any rough region. You can resize the paint tool by dragging LMB to left/right direction by holding down Shift key.



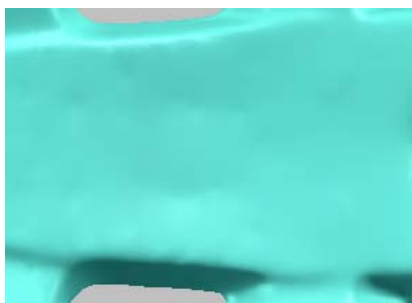


Before smoothing

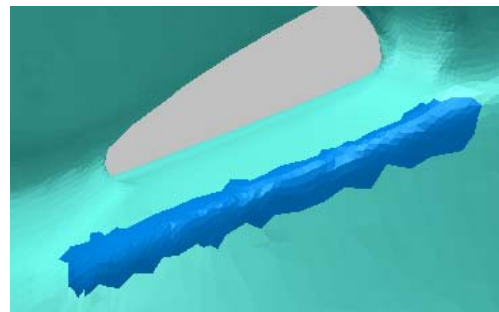


Paint tool

4. Push ESC key or select **Done** on RMB menu to complete this operation.
5. Select faces as below right, and apply **Tool > Smooth > Region** to the selected region.
6. Type in **3** iterations, and select **OK** with default options.



After paint smoothing



Selecting region

7. Deselect all selected faces by Shift+N key to apply the Smooth operation to the entire shell.
8. Select **Tool > Smooth > Shell** menu.
9. Type in **3** iterations, and click **OK** with other default options.

## Subdivide

The Subdivide operation improves the surface of the polygonal model by adding new vertices and adjusting the coordinates of existing vertices, resulting in a greater number of triangles in the selected area and a smoother surface.

The operation subdivides selected triangles, producing three or four triangles for every one original triangle. Each face is subdivided into three or four triangles by adding new vertices on each edge of the face. You can select **3x** if you want three new triangles to be produced and **4x** if you want four; not only are the new vertices to be added but the original vertex position is also recalculated, thus the continuity of the curvature is much improved.

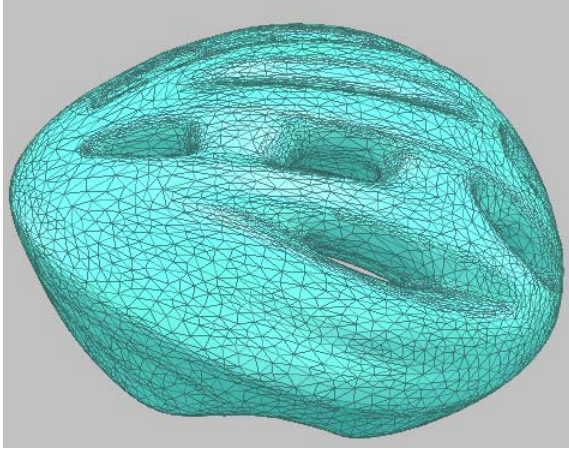
You can subdivide only the faces which edges are longer than the length you specify. You can select the *Preserve Sharp Edges* option to maintain sharp edges or feature lines. The *Preserve Marked Edges/Vertices* option allows marked edges/vertices to be maintained as it is. This operation also enables you to subdivide only high or low curvature region.

**NOTE:** *The Subdivide operation can be applied an entire shell or locally selected region.*

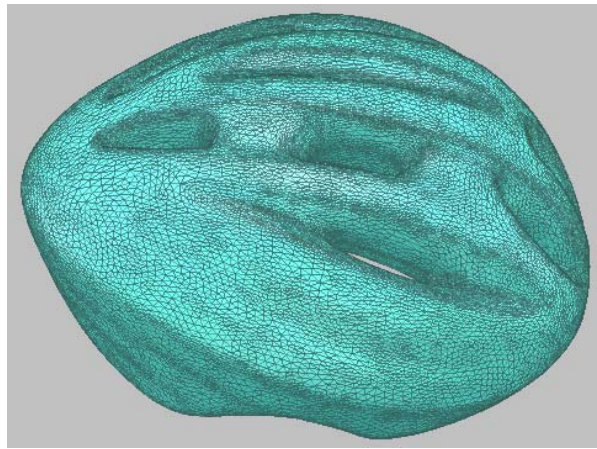
### **Exercise:**

*(Being continued)*

1. Select **Tool > Subdivide Shell** menu, and select “helmet”.
2. Click **OK** on dialog box with default option.



Before subdivision



After subdivision

## Defeature

The Defeature function removes selected region and to fill it using curvature-based method. The result is that you get a smooth polygonal surface on which features are eliminated.

### **Exercise:**

1. Open “defeature.mdl” under “polygon\_wb” folder.
2. Select faces by rectangle mode as below.



3. Click **Tool > Defeature** menu.



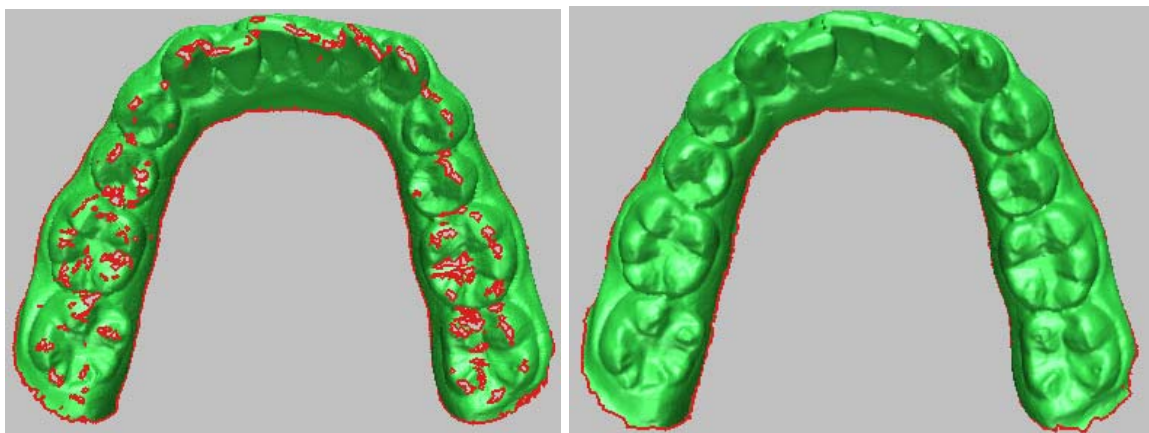
## Volume Hole Filling

This operation creates a new shell that its holes are filled by a volumetric hole filling method that constructs a reference voxel model having the geometry information of a shell and then fills its holes by extension of the boundary of holes. This new hole filling function allows you to fill holes which boundaries are messy and untidy. This operation creates a new polygonal shell while preserving an original shell.

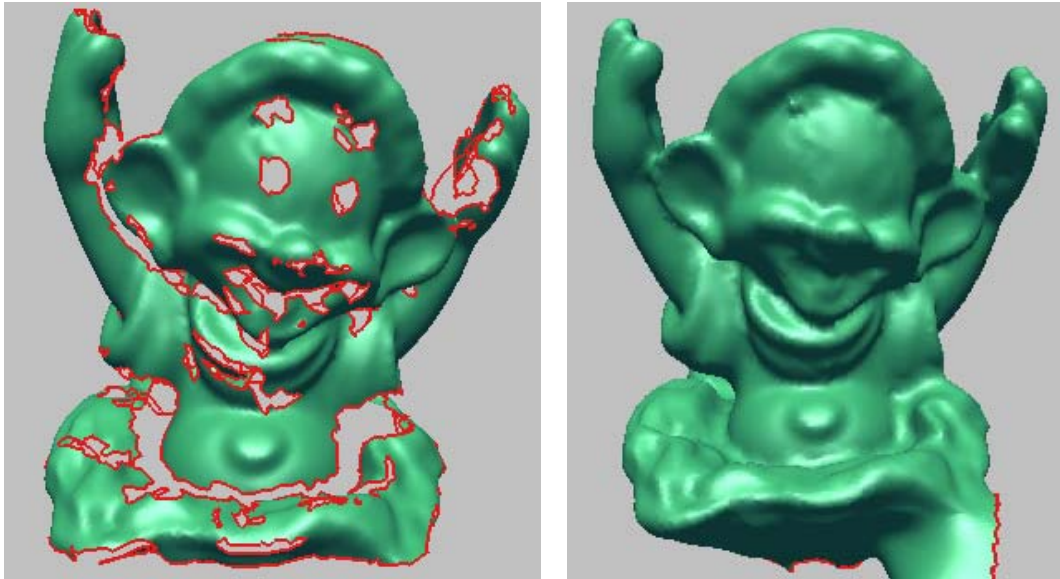
**NOTE:** You need to remove extra faces after applying the volume hole filling operation. The amount of extra faces depends on the number of iterations you select.

### **Exercise:**

1. Open “volume\_fillhole1.mdl” under “polygon\_wb” folder.
2. Check boundary edges by pressing **E** key.
3. Click **Tool > Fill Holes > Volume** and pick a shell.
4. Set **Number of iteration** to **30** and **Resolution** to **1**.  
**Note:** Resolution is ratio to the average of vertex spacing. If the number is larger than 1, the edge length of a new shell will be larger than the average edge length of selected shell
5. Check **Except the Biggest Hole** and **Optimize Mesh** options, then click **OK**.



6. Try to apply **Tool > Fill Holes > Surface** to the same model above.
7. Open “volume\_fillhole2.mdl” under “polygon\_wb” folder and repeat the above process.



## Remesh

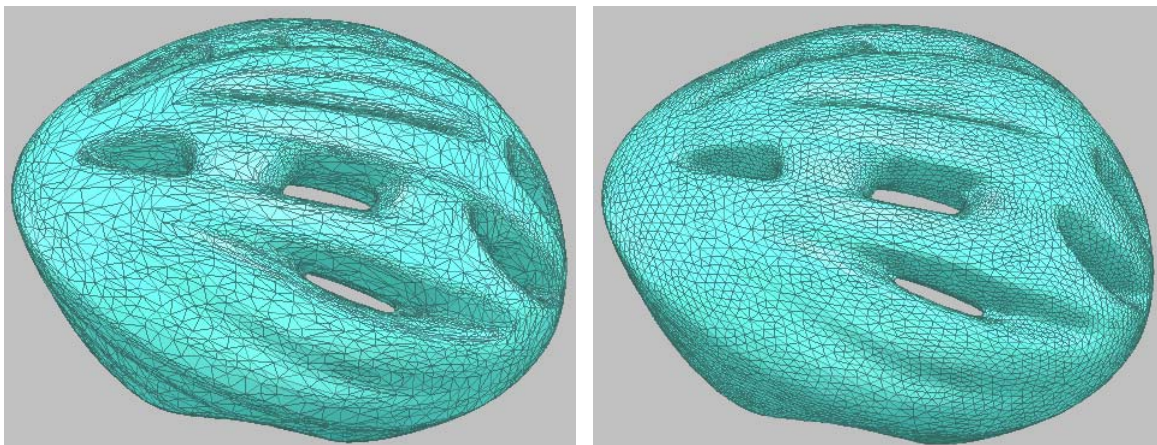
A face of good quality means that the face is close to an equilateral triangle. The Remesh operation improves the quality of the faces as re-triangulating the faces of the polygonal model.

This operation improves the surface of the polygonal model by changing the coordinates of existing vertices. Thus, the continuity of the curvature can be improved without adding new vertices, differently from the Subdivide operation. If there are marked edges or vertices, the preserve option window will pop up. Clicking Yes button allows the marked edges or vertices to be maintained as it is.

**NOTE:** *The Remesh operation can be applied on an entire shell or locally selected region.*

### **Exercise:**

1. Open "helmet\_decimated.mdl" under "polygon\_wb" folder.
2. Apply **Tool > Remesh > Global** to the shell.



Before remeshing

After remeshing

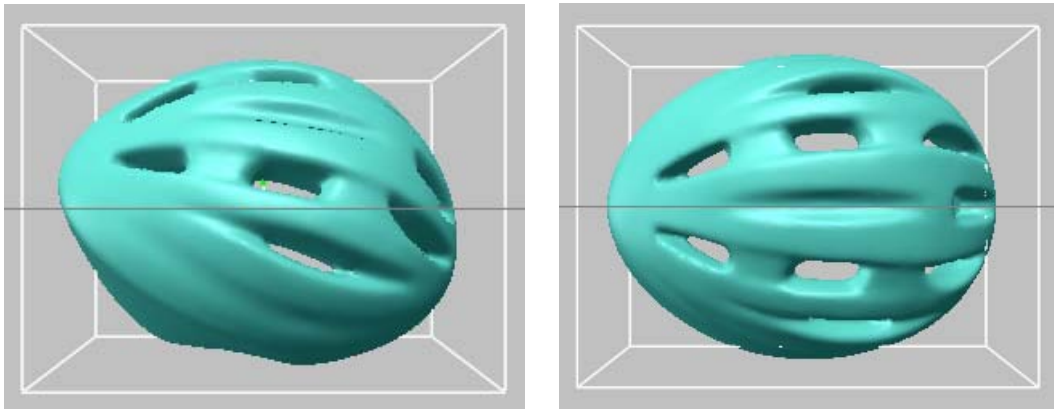
## Transform

Occasionally you will have data that is offset from the world origin or from the position you want it in. You may wish to reorient such data before working on it. You can rotate, translate or scale objects to reorient, reposition or resize them. You can also use *Calc Principal Axis Transform* option to ignore all the previous input and transform the object with respect to its principal axis. The object is so transformed that its centroid moves to the zero point and its bounding box has the minimum volume. The principal axis transform is useful to arrange the symmetric model.

### **Exercise:**

*(Being continued)*

1. Select **Edit > Transform > Model**, and click **Calc Principal Axis Transform** button. The amounts of rotation and translation are automatically generated.
2. Click **OK**.



## Divide / Mirror

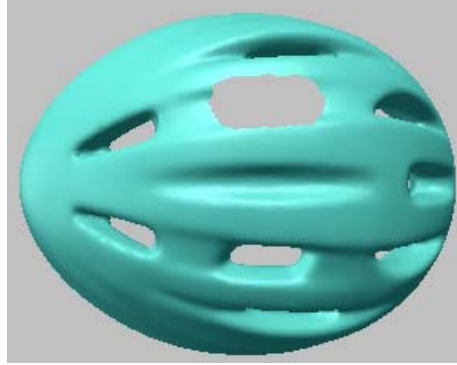
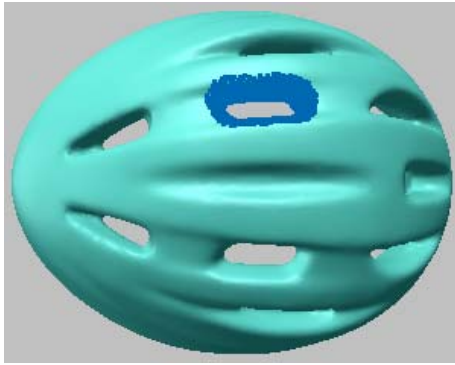
The Divide operation lets you slice a point cloud or a polygonal model using a reference plane. During dividing the model, you can select Mirror option. The Mirror creates a duplicate of a sliced model and flips and joins the copy at a reference plane so that it faces in the opposite direction of the original.

This is useful if you want to design or make changes to a symmetrical model. Thus, you can divide the model, make changes to one of the halves, then use the Mirror function to create and attach a reversed duplicate to the other side. The mirror option mirrors curves and surfaces attached to a polygon model when it is mirrored.

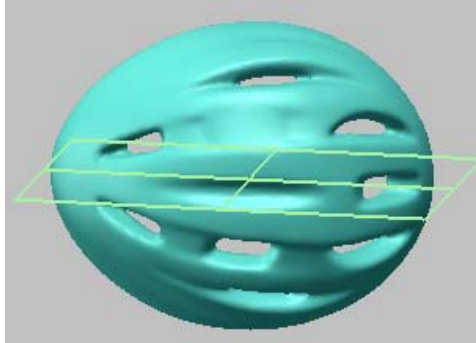
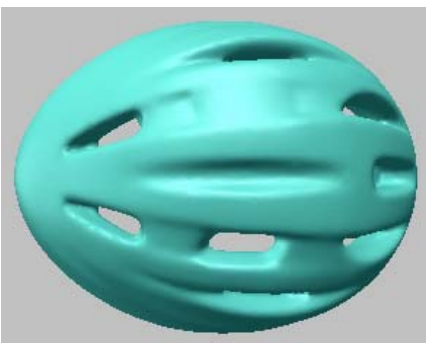
### **Exercise 1:**

*(Being continued)*

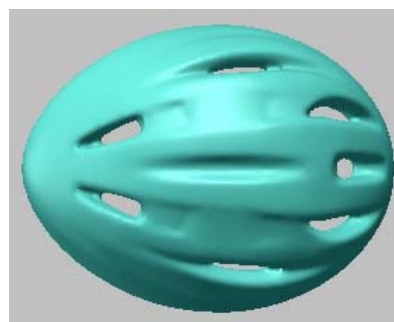
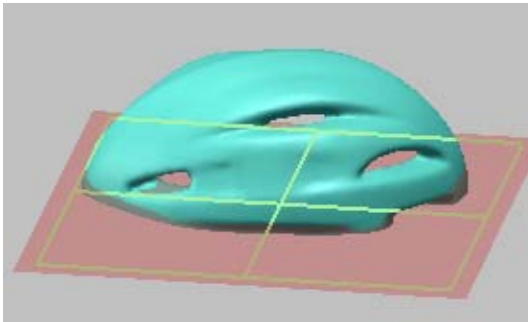
1. Select and delete vertices using Shift+V and Alt+V keys as shown below.



2. Fill two holes of inside and outside (as shown below left).
3. Select **Ref. Geometry > Create > Plane > Input Normal & Position** menu, and select **Add** with default values. Click **Close**.



4. Select **Tool > Divide/Mirror** menu, and pick the shell.
5. Select **Pick Ref. Plane** on RMB menu, and pick the reference plane.
6. Select **Done** on RMB menu.
7. Check **Mirror & merge upper shell** option and **Remove lower shell** on dialog box, and click **OK**.

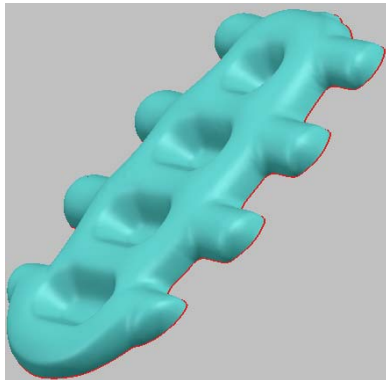


The Mirror operation enables you mirror polygonal shell without dividing. This operation provides a quick way of creating symmetrical object by requiring that only half of an object be perfected.

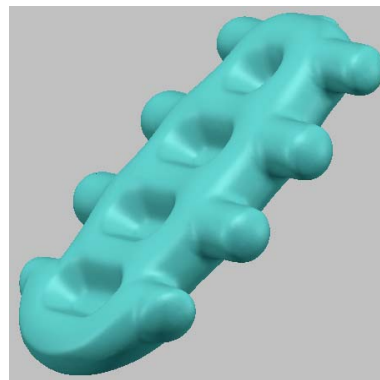
### Exercise 2:

1. Open “airbag.mdl” under “polygon\_wb” folder.
2. Click **Select > Boundary Vertices** menu.
3. Click **Ref. Geometry > Create > Plane > Fit Region** menu.
4. Click **Tool > Divide / Mirror** menu, and select a shell.
5. Click **Pick Ref. Plane** on RMB menu, and select the plane.
6. Click **Done** on RMB menu.

7. Select **Mirror Only** option, and click **OK**.
8. Click **Tool > Weld > Shells** menu.
9. Click **OK** with default tolerance.



Half of a symmetrical object



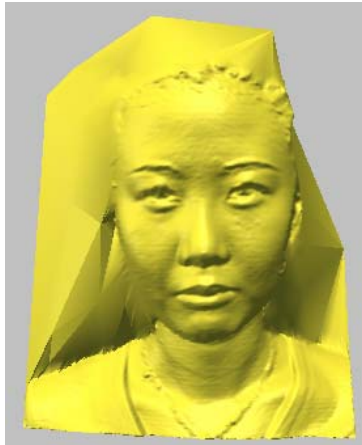
Perfect object by Mirror and Weld

## Shrink

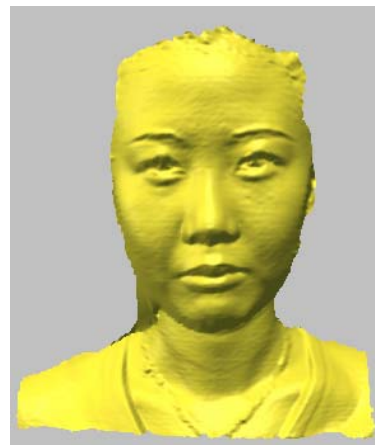
Generally, the region near the boundary of scanned data may contain more measurement errors. Therefore, it is a good idea to remove boundary portions before starting the registration or merging process. The Shrink operation removes faces on the selected boundary as a specific depth.

### Exercise:

1. Open “face.mdl” under the “polygon\_wb” folder.
2. Select **Tool > Shrink Shell**, and click the shell.
3. Select a boundary and type in **5** depth, and then click **OK**.



Before shrinking



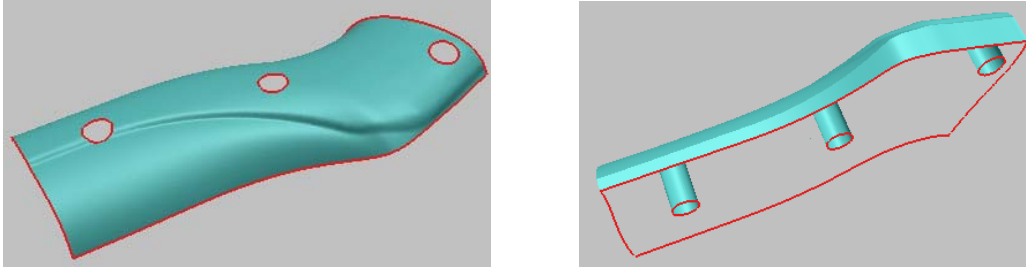
After shrinking

## Extend

The Extend Region command extends the boundaries of selected region onto the desired plane or in the normal direction of a default reference plane with a given distance.

### Exercise:

1. Open “joystick.mdl” under the “polygon\_wb” folder.
2. Click **Select > Boundary Faces** menu.
3. Click **Tool > Extend Region** menu, and uncheck **Tangent Extension** option on RMB menu. Select **Pick Ref. Plane** on RMB menu and pick a plane. Then click **Done** on RMB menu. Click **OK** with **to Plane** option.

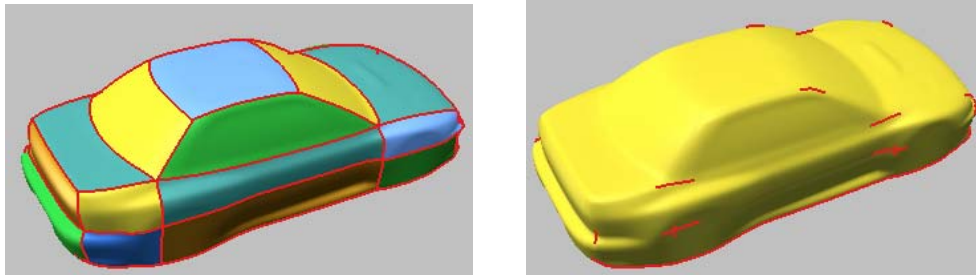


## Weld

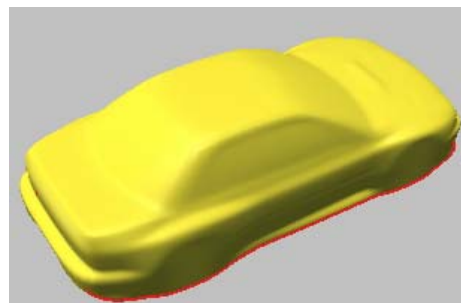
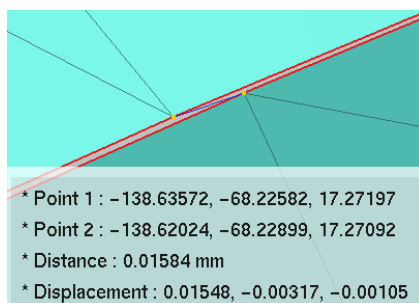
When you import the surface patches with foreign file format and tessellate them, you will need to stitch their boundaries to convert them into a combined shell. The Weld operation converts multiple shells to a combined shell, and also stitches the gaps between the boundaries of shells. You can also remove the small gaps between vertices on the combined shell in case that the gaps are smaller than a specific tolerance.

### Exercise:

1. Open “car.mdl” under the “polygon\_wb” folder.
2. Show boundaries by **Information > Show Boundaries** menu or hot key **E**.
3. Select **Tool > Weld > Shells** menu, and click **OK**. Show boundaries again as shown below right.



4. Zoom in a gap and measure the distance by **Measure > Distance > Point/Point > Along Line** menu as shown below left.
5. Select **Tool > Weld > One Shell** menu, and type in **0.1** tolerance. Click **OK**.



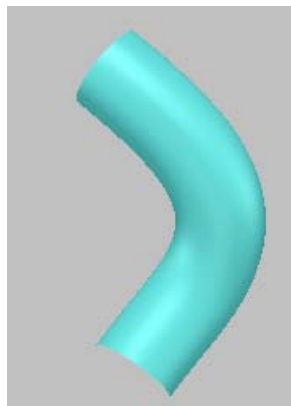


## Offset (Surface)

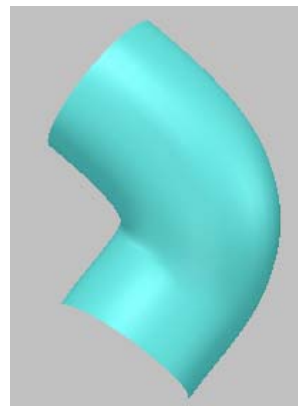
The Offset operation creates a new polygonal shell that is offset from the original. Although the operation appears to expand or contract the faces, it actually defines a new offset faces, which is a specific distance from the original shell.

### Exercise:

1. Open “offset.mdl” under “polygon\_wb” folder.
2. Click **Tool > Offset > Surface** menu, and select a shell.
3. Select **Forward** option as **Offset direction**, and click **Preview**.
4. Click **OK**.



Before offset



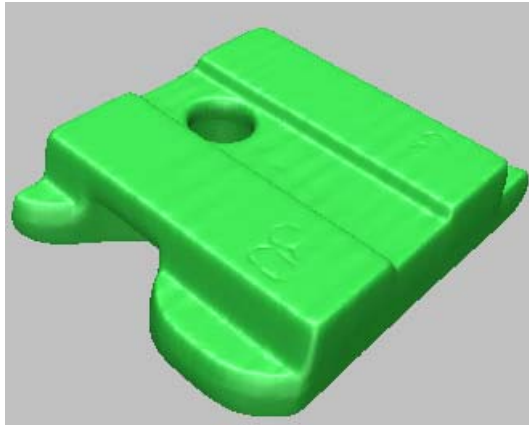
After offset

## Offset (Volume)

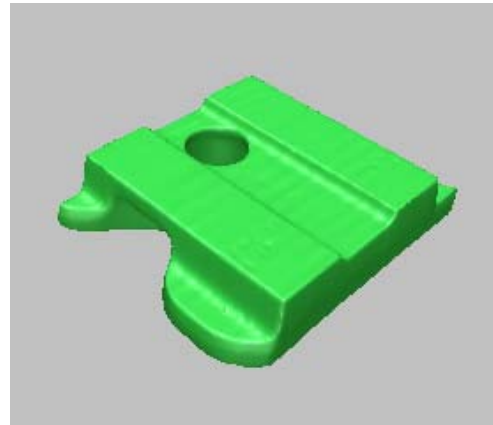
The **Volumetric Offset** operation constructs an offset polygonal shell by allocating its geometry information and the offset amount to a reference voxel model. This offset method can solve the problem that the meshes in offset region are entangled each other. This operation creates a new polygonal shell while preserving an original shell.

### Exercise:

1. Open “volume\_offset.mdl” under the “polygon\_wb” folder.
2. Click **Tool > Offset > Volume** and pick a shell.
3. Set **Offset Amount** to **0.5**, **Resolution** to **1** and **Offset Direction** to **Backward**,  
**Note:** Resolution is ratio to the average of vertex spacing. If the number is larger than 1, the edge length of a new shell will be larger than the average edge length of selected shell
4. Click **OK** with checking **Optimize Mesh** option.



Before offset



After offset

5. Compare with the result by **Tool > Offset > Surface**.

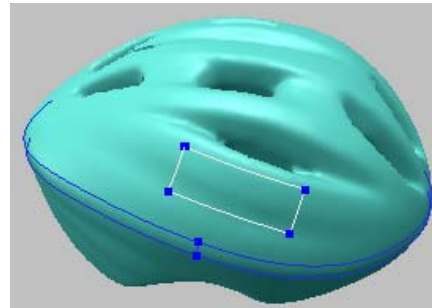
## Trim Region

You can freely cut the region of a shell by closed curves just as cutting a paper with a knife. If reference curves form a closed path, the inside region of the path is cut off and registered as a new shell. Otherwise, edges near the path are aligned along selected reference curves.

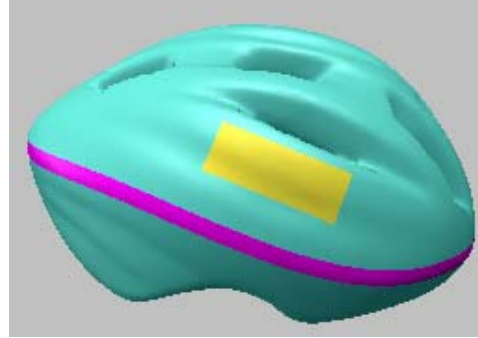
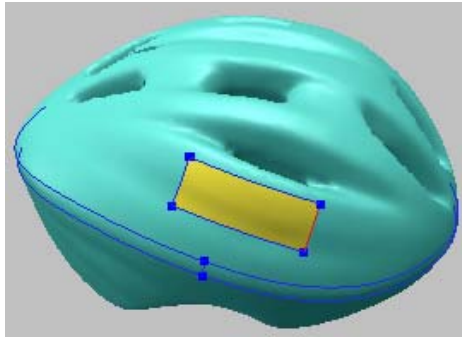
The Trim Region operation cuts off the region surrounded by given reference curves. You can define the reference curves in the Curve workbench.

### **Exercise:**

1. Open "helmet\_trim.mdl" under the "polygon\_wb" folder.
2. You are going to do texture mapping as shown below left. You have to divide regions before mapping images.
3. Click **Tool > Trim Region** menu, and select the shell.
4. Select four curves in a counterclockwise direction as shown below right.



5. Select **Done** on RMB menu.
6. Click **Yes** to cut the inside region off.
7. To change the color of a new shell, go to project window and select **Change Material** on RMB menu. Drag and drop yellow color on the new shell as shown below.
8. Apply above process to side part like band using pre-defined curves.



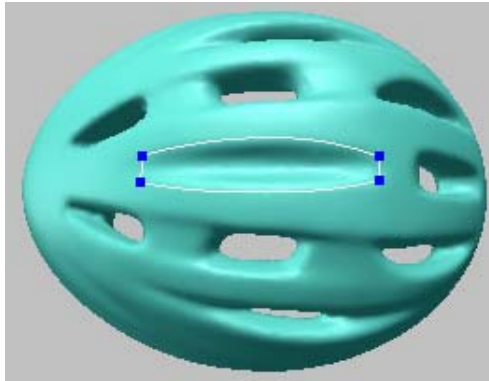
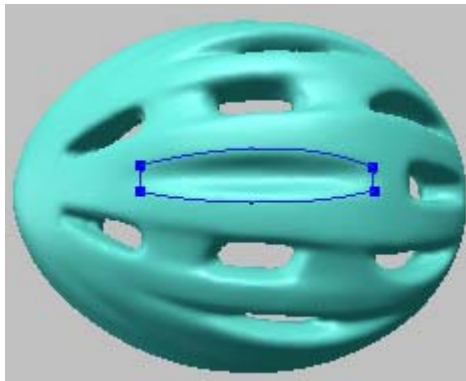
## Fit Edges To Curves

You can rearrange the meshes which reside near curves so that the boundary edges of meshes could be coincident with the curves. This operation can be used for repairing the boundary edges of polygonal model or for reconstructing sharp edges. It also may rearrange edges for dividing polygonal model by regions which you want.

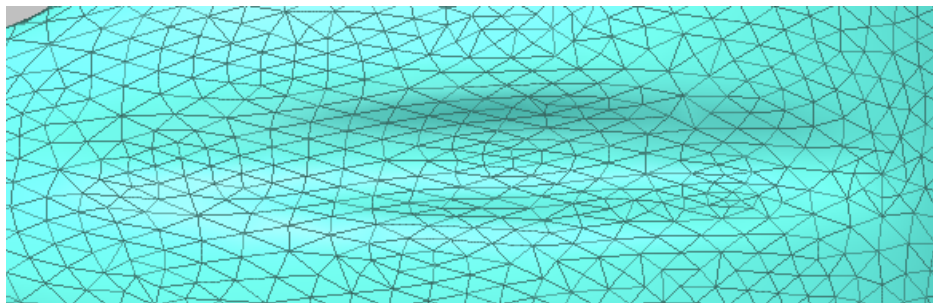
### Exercise:

*(Being continued)*

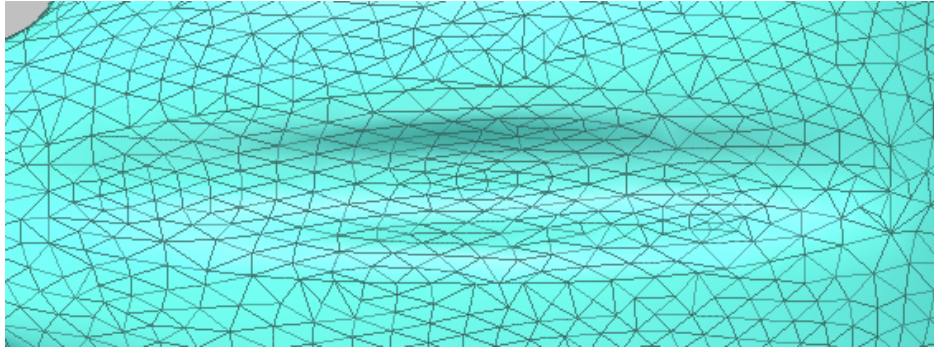
1. Click **Tool > Fit Edges To Curves** menu, and select the shell.
2. Select four curves as shown below right.



3. Select **Done** on RMB menu, and click **No** button to rearrange only faces crossing the selected curves.



Before rearranging edges



After rearranging edges

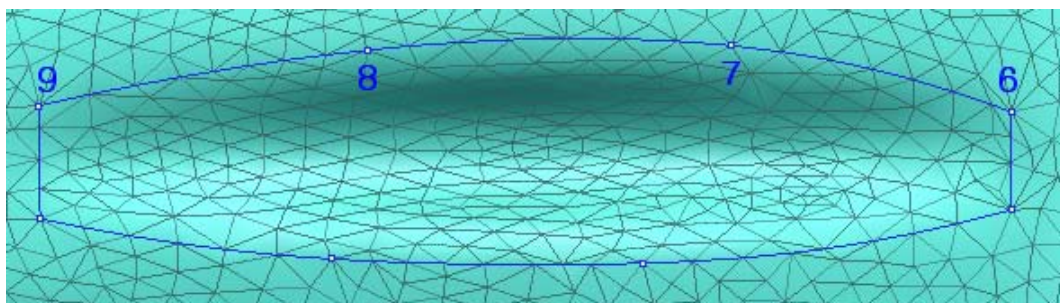
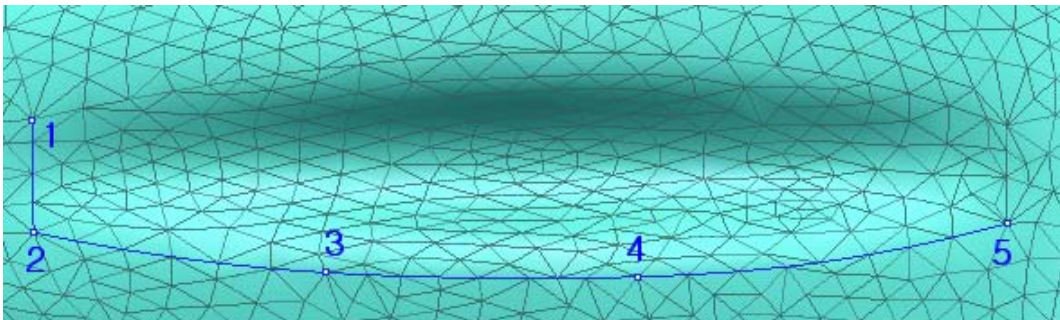
## Split Edges

The Split Edges operation splits faces to both sides along edges, which are connected to selected vertices. This operation automatically finds the edges consisting of a path by searching the shortest distances between the selected vertices. You have to select series of vertices so that they form a non-crossing path.

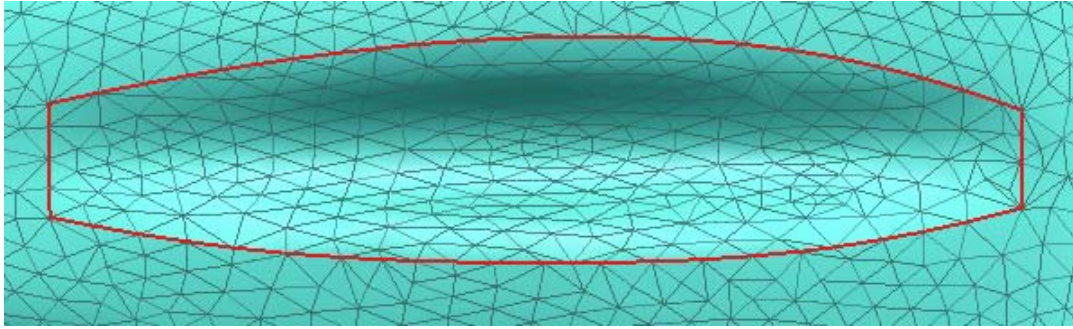
### Exercise:

*(Being continued)*

1. Click **Tool > Split Edges > By Custom Path** menu, and pick vertices in numerical order as below.



2. Select **Done** on RMB menu.
3. Push the hot key **E** to check the result.



4. Select **Select > Flood Fill** menu, and pick the inside of above closed path. Then the faces of the inside will be selected.
5. Open again “helmet\_trim.mdl” and try to apply **Tool > Split Edges > By Curves** operation.

## Twinking Polygon

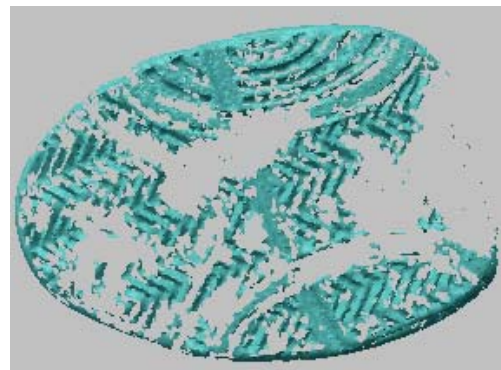
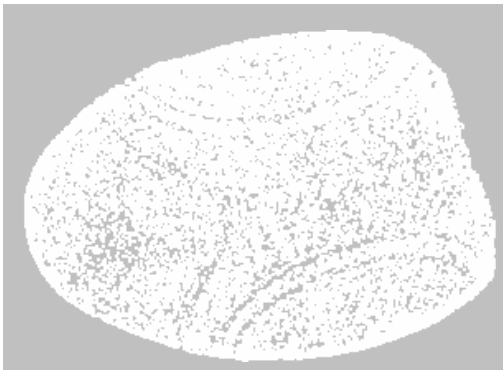
Sometimes point clouds from scanners are too complex to polygonize easily. To solve this problem, you firstly have to do point sampling. In this case, the polygonal model can distort the original point cloud. The Fit Shell To Point Cloud operation lets you have a triangulated model close to the original model by re-fitting the polygon shell to the original point cloud.

A polygonal model also can be distorted after editing polygonal meshes by smooth, decimation, and so on. The Fit Shell To Meshes operation lets you solve the problem by re-fitting the modified shell to the original polygon shell.

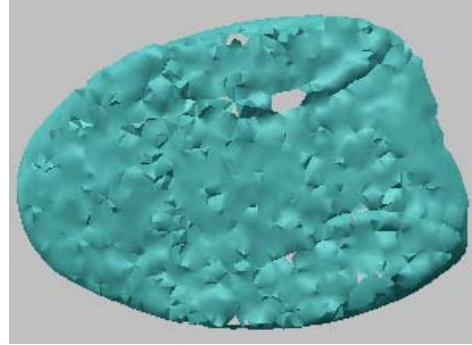
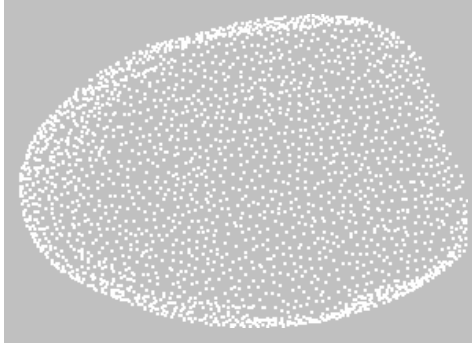
You will generate watertight, smooth surfaces on a polygonal surface in Surface workbench. You also can smooth or deform these surface patches. After then, you can regenerate a modified polygon model by re-fitting the original polygon shell to the generated surfaces using the Fit Shell To Surfaces operation. So you can get more smooth shell or completely deformed shell.

### **Exercise 1: Twinking Polygon To Point Cloud**

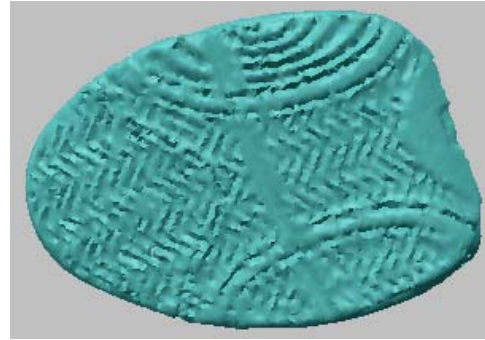
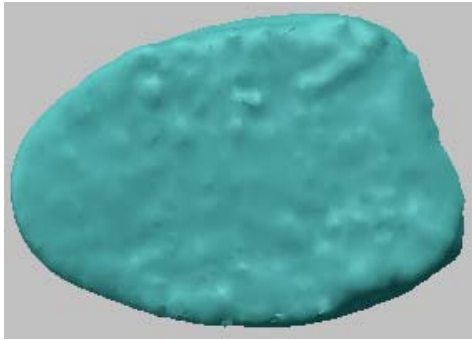
1. Open “sole.mdl” under the “polygon\_wb” folder.
2. Apply **Build > Triangulate > 3D** operation to the point cloud, and check the result.



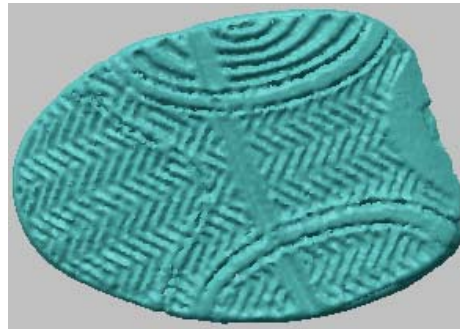
3. Open the file again. Copy the shell by pushing Ctrl+C and Ctrl+V keys in order.
4. Apply **Build > Filter Redundancy** operation to the copied shell three times.
5. Apply **Build > Triangulate > 3D** to the filtered shell.



6. Go to the Polygon workbench.
7. Apply **Tool > Smooth > Shell** to the triangulated shell without checking **Move Boundary Vertices** option.
8. Fill all holes using **Tool > Fill Holes > Surface** operation as below left.
9. Apply **Tool > Subdivide Shell** operation to the shell.
10. Select **Tool > Fit Shell To > Point Cloud** menu, and then pick the copied shell and the original point cloud in order. The result is shown as below right.



11. Repeat **Smooth**, **Subdivide** and **Fit Shell To Point Cloud** operations.



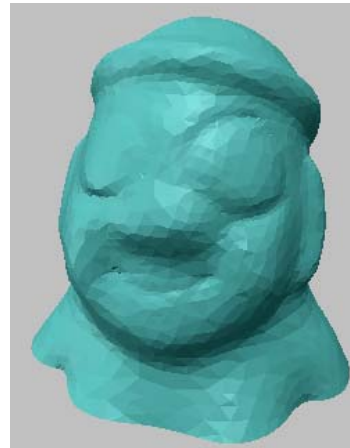
12. Apply **Tool > Subdivide Shell** operation to the shell.

## Exercise 2: Tweaking Polygon To Polygon

1. Open "harubang.mdl" under the "polygon\_wb" folder.
2. Copy the shell by pushing Ctrl+C and Ctrl+V keys in order.
3. Apply **Tool > Decimate > High Quality** to the copied shell. Reduce to **20%**.
4. Apply **Tool > Smooth > Shell** to the shell without checking **Move Boundary Vertices** option.

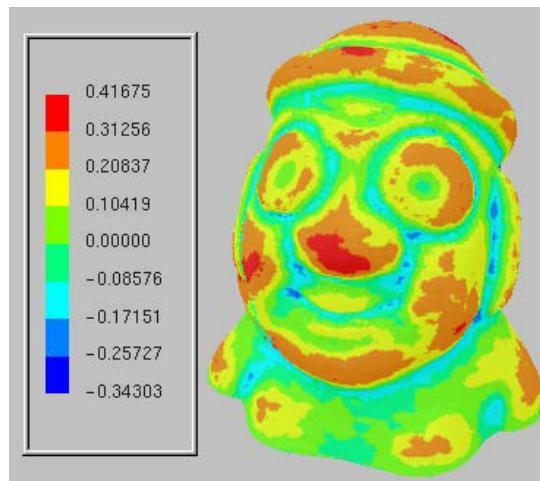


Original model

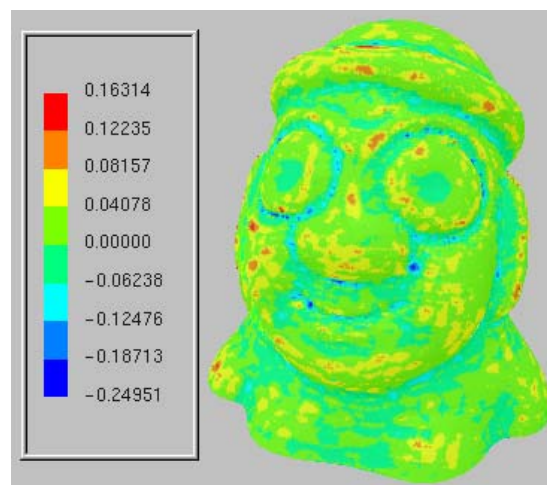


Modified model

5. Check deviation between two shells by **Measure > Shell/Shell Deviation** menu.

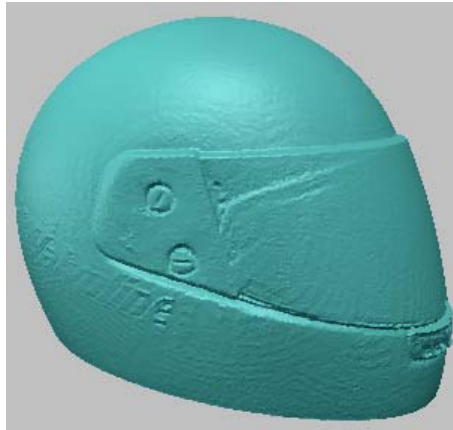


6. Apply **Tool > Fit Shell To Meshes** to the modified shell.
7. Check deviation again.

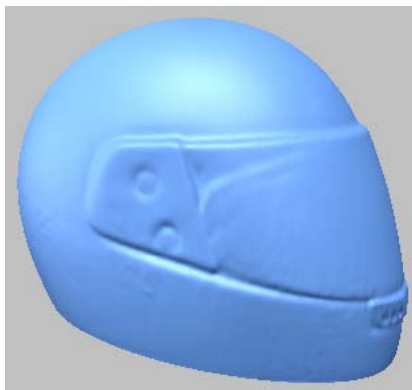


### Exercise 3: Tweaking Polygon To Surface

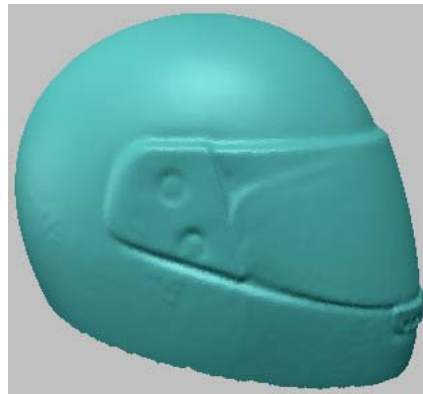
1. Open "helmet2.mdl" under the "polygon\_wb" folder.



2. Render the pre-defined NURBS surface by pushing the hot key **R**.
3. Click **Tool > Fit Shell To > Surfaces** menu.
4. Select the surface, and click **Done** on RMB menu.



Rendered surface



Re-fitted polygonal surface

## Fit Boundary To Curves

You can rearrange or clean the boundary meshes by curves. This operation can be used for repairing the boundary edges of a model that may have been introduced during the scanning process.

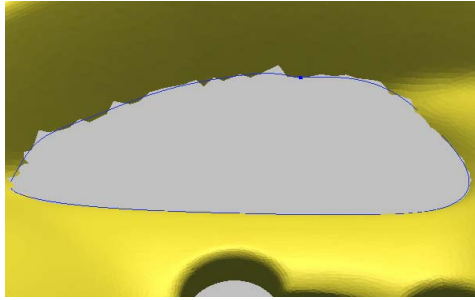
### **Exercise:**

1. Open “wheel.mdl” under the “polygon\_wb” folder.
2. Push the hot key **E** to display boundary edges.

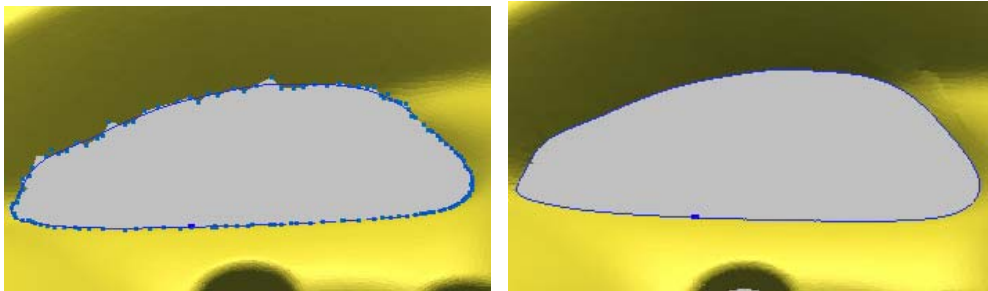


3. Go to the Curve workbench.
4. Click **Curve > Create > Fit Boundary** menu and select one of boundaries, and then click **Done** on RMB menu.
5. Move the slide bar to the left as two steps and click **OK**.





6. Go to the Polygon workbench.
7. Click **Select > Vertices Around > Curves** menu, and select the curve.
8. Click **Tool > Fit Boundary To Curves** menu and select the curve, and then click **Done** on RMB menu. Click **OK** with a default value.



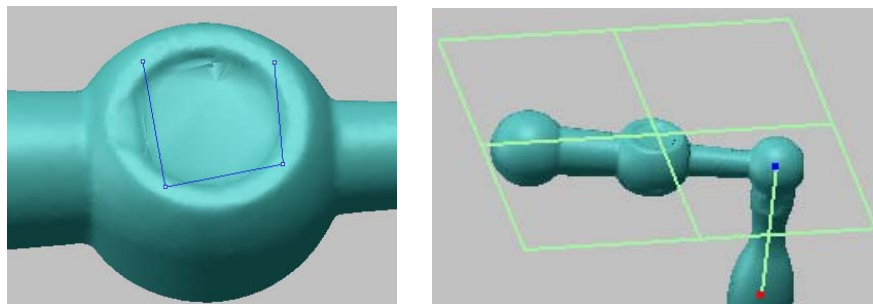
9. Apply Fit Boundary To Curves to other boundaries.

## Fit Regions To Plane/Cylinder/Sphere

You can fit polygons to a plane, cylinder or sphere, project them onto a primitive. Because the planes, cylinders and spheres created with these operations are mathematically perfect, this feature helps you create accurate mechanical shapes. This is very useful in cleaning up planar, cylindrical or spherical regions of a model containing noise or other imperfections. When you select a region of the model and apply the operation, the application assesses the selection, finds the best possible plane, cylinder or sphere within the selection and fits all the polygons to it. You can also define a reference plane or sphere, and the operation fits the selected polygons to that plane or sphere.

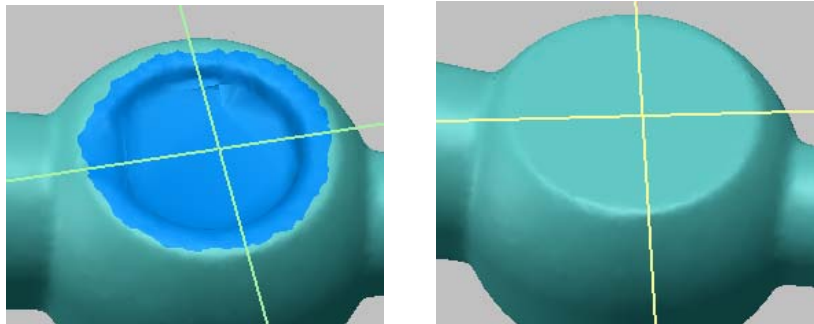
### **Exercise:**

1. Open “handle.mdl” under the “polygon\_wb” folder.
2. Select **Ref. Geometry > Create > Plane > Pick Points** menu, and pick three or more points as below left. Select **Done** on RMB menu.

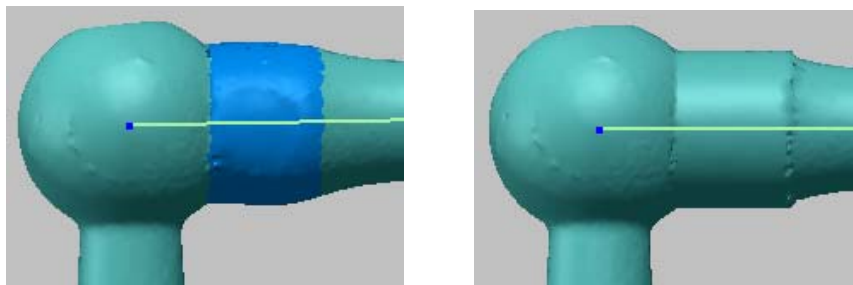


3. Push **Select Visible Faces Only** icon on the Select Toolbar.

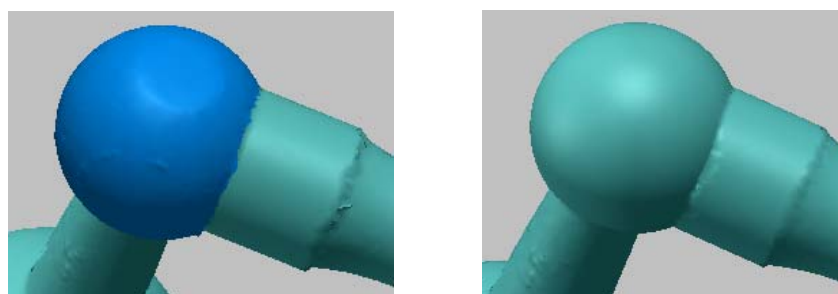
4. Select **Fit Regions To > Plane** menu. Click **Select Region** on RMB menu, and select faces as below left. Click **Done** on RMB menu.
5. Select **Pick Ref. Plane** on RMB menu, and pick the pre-defined plane.
6. Perform **Do Plane Fitting** on RMB menu, and push the hot key Shift+N.



7. Toggle off **Select Visible Faces Only** icon and on **Select Faces Through** on the Select Toolbar.
8. Select **Fit Regions To > Cylinder** menu. Click **Select Region** on RMB menu, and select faces as below left. Click **Done** on RMB menu.
9. Select **Pick Ref. Vector** on RMB menu, and pick the pre-defined vector.
10. Perform **Do Cylinder Fitting** on RMB menu, and push the hot key Shift+N.

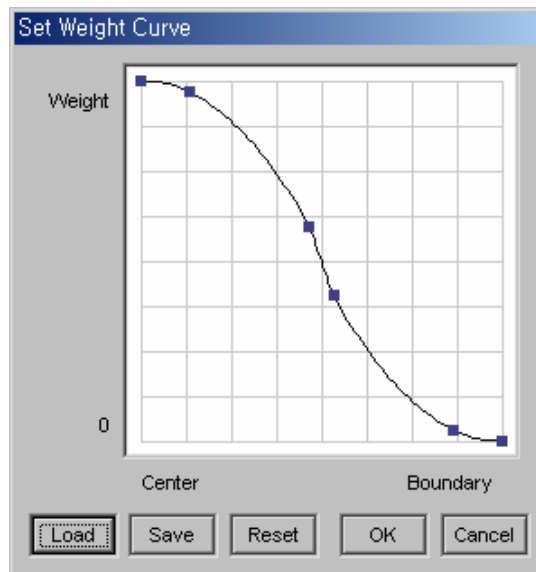


11. Select faces as below left.
12. Select **Fit Regions To > Sphere** menu.
13. Perform **Do Sphere Fitting** on RMB menu, and push the hot key Shift+N.



## Deform Polygon

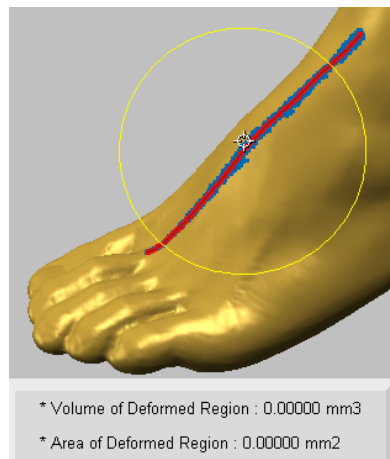
The Deform Polygon operation deforms the polygonal faces in real time by curve deformation, by free-form deformation or by painting. The **Deform By Paint** operation provides you an option, **Set Weight Curve**, which is a curve-based blending tool, enabling you to assign the weight factor to each position of the paintbrush.



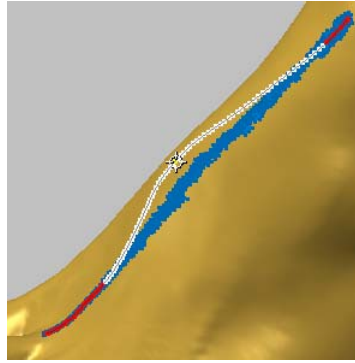
**NOTE:** On the dialog box, the horizontal axis of the graph represents the position from the center of paintbrush; the vertical axis represents the user-defined weight factor. You can assign the weight factor to each position of paintbrush elaborately.

### Exercise:

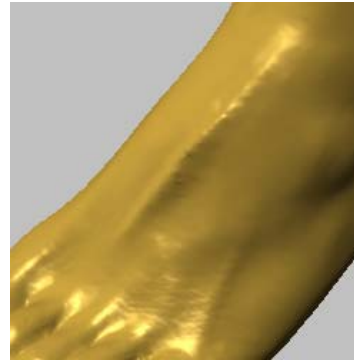
1. Open "foot.mdl" under the "polygon\_wb" folder.
2. Click **Select > Faces Around > Curves** menu, and click **Select > Enlarge > One Depth** menu.
3. Click **Tool > Deform By > Curve** menu, and select a curve.
4. Resize yellow circle by mouse drag while holding **Shift** key as below.



5. Deform curve by moving its control point as shown below left.
6. Click **Done** on RMB menu.

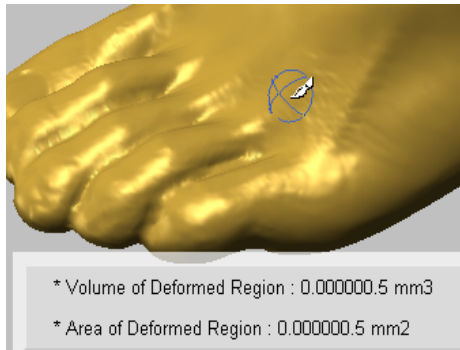


Deform curve

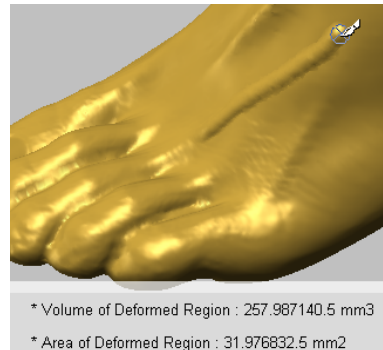


After deform by curve

7. Click **Tool > Deform By > Paint** menu.
8. Resize brush by mouse drag to the left or right while holding **Shift** key as below left.
9. Move brush on faces as painting, and then click **Done** on RMB menu.



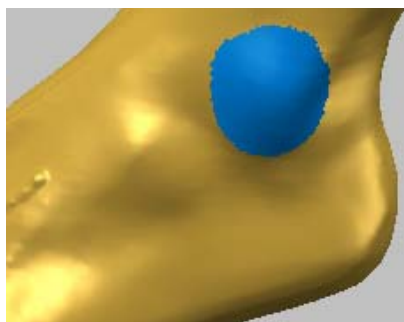
Resize brush



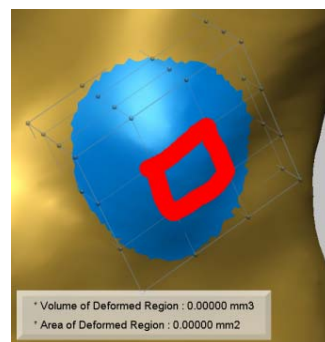
Deform by paint

(**Tip:** Move brush while pushing **Ctrl** key to impress the region down)

10. Select faces as below left.
11. Click **Tool > Deform By > FFD** menu, and select a shell.
12. Select four nodes to be moved by paint brush while holding **Shift** key as below right.

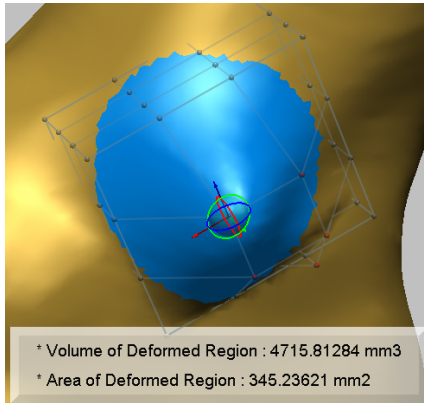


Selecting faces

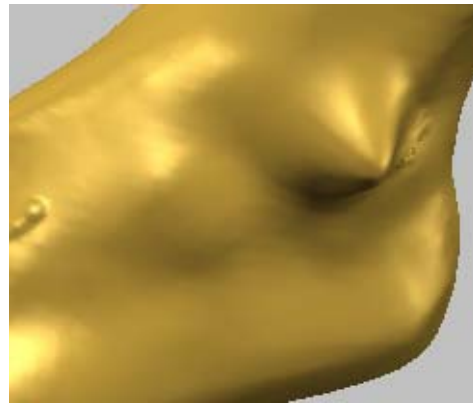


Selecting nodes

13. Click **Use Manipulator** on RMB menu, and pick one of the selected nodes.
14. Move mouse to the right while holding down LMB on the green arrow.



Using manipulator



Deform by FFD

15. Click **Save** button to reuse the table of control points.

## Engrave Text

The **Engrave Text** operation lets you engrave or emboss text on a polygonal object using most fonts on Windows systems including TrueType fonts. To engrave text on a polygonal surface a NURBS patch is needed, so a surface patch should be made before engraving. The initial orientation of the text will be parallel to the U-direction of the surface and vertical to the V-direction. The surface may be attached or be not attached to a polygonal object. In case of unattached surface, engraving generates a new shell in text shape. If the engraving height is a negative value, it impresses text on the polygon, while a positive value embosses the text.

**NOTE:** *To obtain a high quality engraving shape, the region should have a high density of polygon faces. To increase the number of faces in the region of the shell where the engraving will be, select the area and then use Tool > Subdivide Region before applying the engrave operation.*

*If English and other language are both engraved at the same time, only the English text is normally applied in the correct font.*

### **Exercise:**

1. Open "golfclub.mdl" under "polygon\_wb" folder.
2. Click **Tool > Engrave > Engrave Text** menu and select a surface.
3. Enter the desired text you want to engrave in the **Text** box.
4. Select a font type you want to use after pushing the **Font** button.
5. If necessary, use the **Rotate** or **Flip** button to adjust the text orientation, also move the slide bars of **U-Scale** and **V-Scale** items.



6. Set **Engraving Height** as 1.

**NOTE:** A negative value impresses text on the polygon, while a positive value embosses the text.

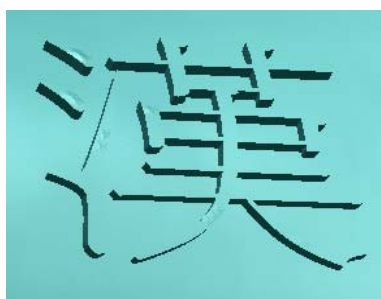
7. Turn on the **Trim the Selected Surface** option, and click **OK** button.



8. Hide the shell and the largest surface, and render the trimmed surfaces by pushing the hot key **R**.



9. The below is examples for Chinese and Korean characters.



## Engrave Image

The **Engrave Image** operation lets you engrave or emboss images on a polygonal

object using a 2D image. To engrave an image on a polygonal surface a NURBS patch is needed, so a surface patch should be made before engraving. The initial orientation of the 2D image will be parallel to the U-direction of the surface and vertical to the V-direction. The surface can be does not need to be attached (but it can be) to the polygon mesh. If the surface is not attached to the polygon mesh, a new shell will be created when engraving.

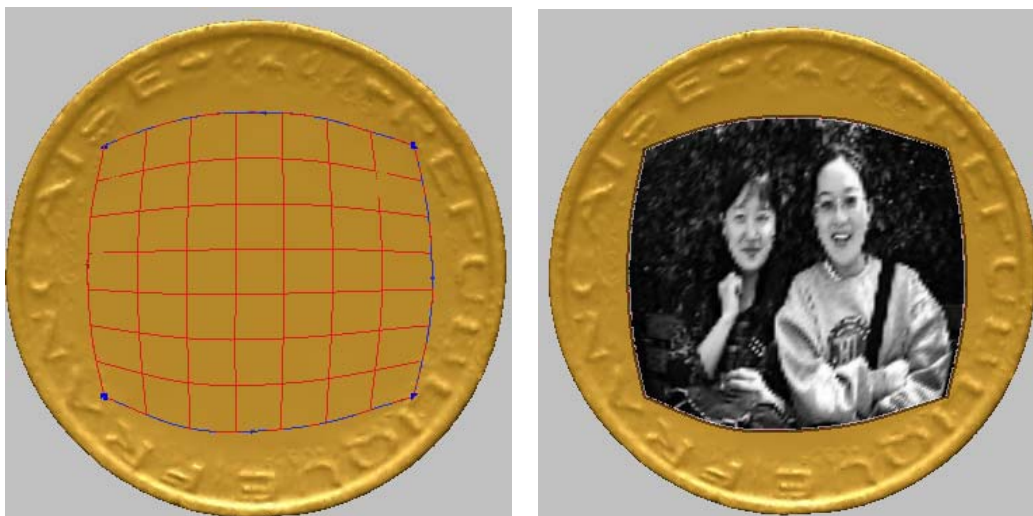
**NOTE:** *To obtain a high quality engraving shape, the region should have a high density of polygon faces. To increase the number of faces in the region of the shell where the engraving will be, select the area and then use Tool > Subdivide Region before applying the engrave operation.*

### Exercise:

1. Open “coin.mdl” under “polygon\_wb” folder.
2. Click **Tool > Engrave > Engrave Image** menu and select a surface on the coin.
3. Click the button in the right side of the **File Name** box and open “engrave.jpg” file from the “polygon\_wb” folder.

**NOTE:** *The image files which can be opened are **bmp, cgm, cmp, dwg, dxf, eps, jpg, pcx, png, psd, tga, tif, wmf, and xbm**. The selected image is displayed as a gray scale.*

4. Click twice the **Rotate** button to adjust the image orientation and move the slide bars of **U-Scale** and **V-Scale** items.

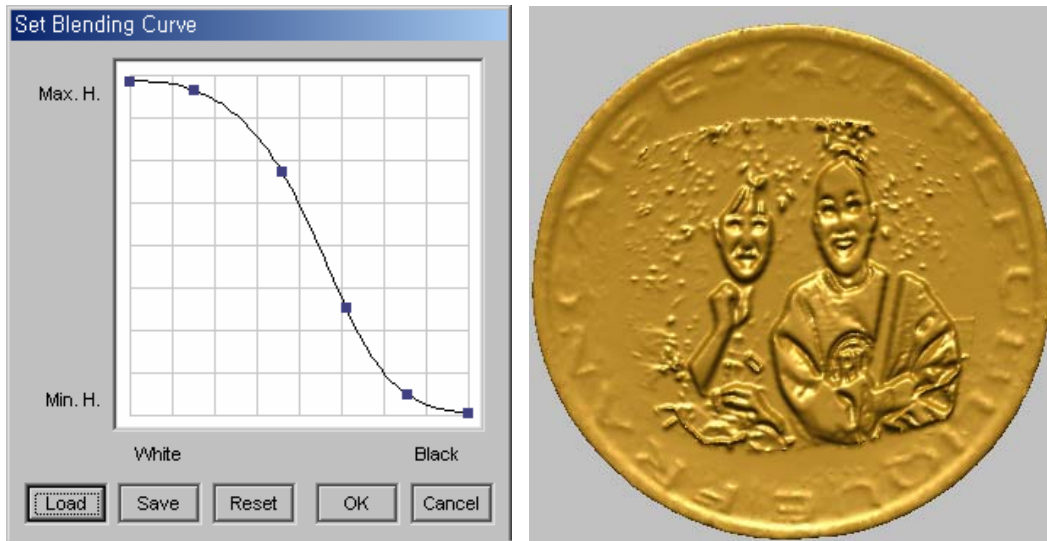


5. Set **Max. Height** as **0.5** and **Min. Height** as **0**, and then press the **Blending Curve** button. To adjust the height balance of the gray image, drag control points on a curve as shown below left or open “engrave.rbc” file from the “polygon\_wb” folder after pressing the **Load** button.

**NOTE:** *In this example, white color comes out from the surface with a max. height in its normal direction. But the default is that black color comes out and white color comes into the surface in the inverse direction of its normal. To back to the default state, click the **Reset** button.*

6. Push the **Preview** button and check the height of each pixel by rotating the object.

7. Turn on the **Smooth** option, and click **OK**.



## Polygon Template

The Polygon Template operation lets you reuse the polygon mesh structure as a template. Thus, you will be able to retrieve the polygon structure of one template model and apply it to a different model.

The operation automatically aligns the template model to another reference model and automatically generates anchor points. Auto Anchor automatically associates boundary vertices of a template with the closest points on the reference model.

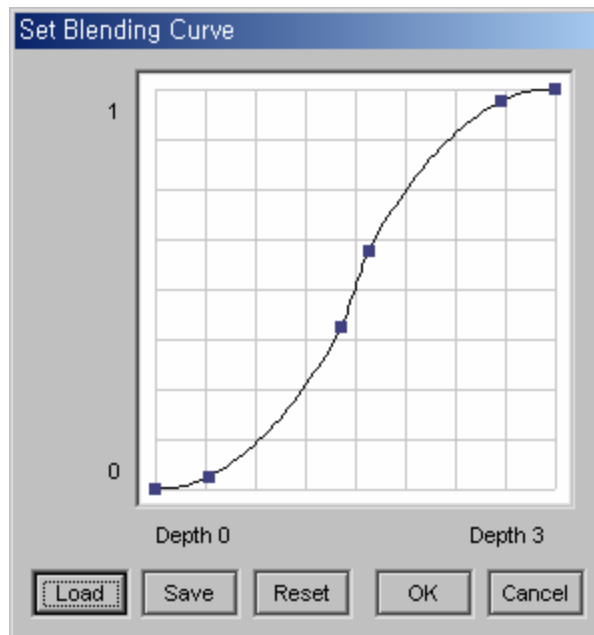
Although the associated points may be the closest points, they may not be where you want them. To remedy this, you can add and reposition anchor points.

You can move nodes of the template to the positions where you want on the reference model using deformation and translation rule of nodes. Finally, you can obtain a new template model for the reference model by relaxing template.

If you want to apply the polygon template operation to the part of shell, you have to select a region in the template shell in advance.

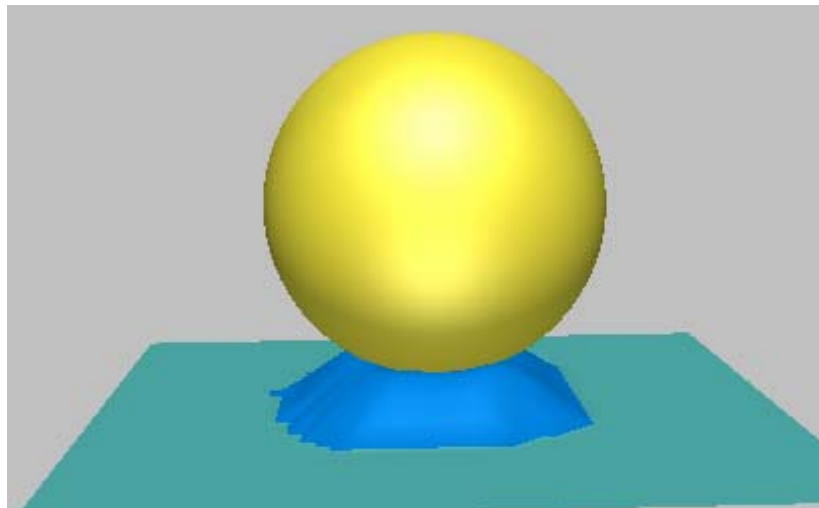
This operation can be applied to selected regions or the entire shell. By selecting a region, its boundary becomes fixed and its control points can be manipulated to match the reference shell. The number of control points that are moved along with the region boundary can be controlled using the **Blending Depth** option on the RMB menu. The operation provides you an option, **Set Blending Curve**, which is a curve-based blending tool, enabling you to adjust the position of vertices in the selected region of a template shell to a reference shell.





**NOTE:** On the dialog box, the horizontal axis of the graph represents the user-defined depth; the vertical axis represents the position of a template shell (0) and a reference shell (1). You can adjust the selected region in the template shell to the reference shell with the position of each depth. “Depth 0” means the boundary of the selected region.

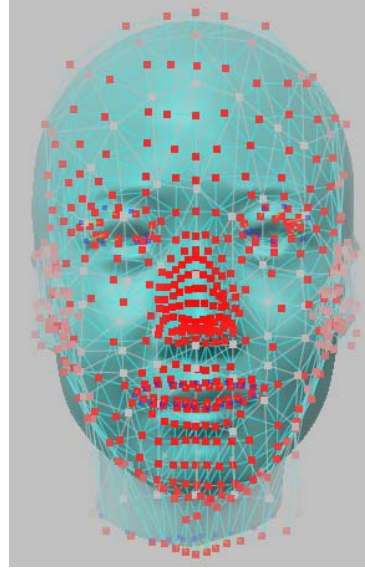
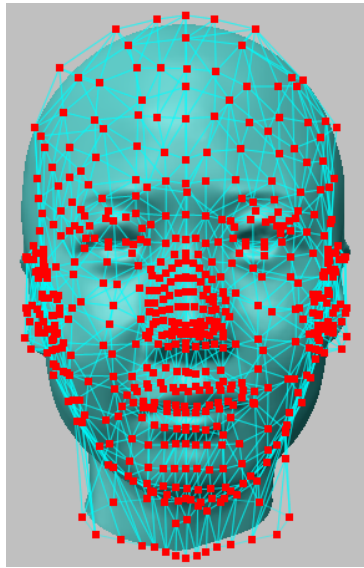
- The following is an example that the selected region of a plane is applied to a sphere.



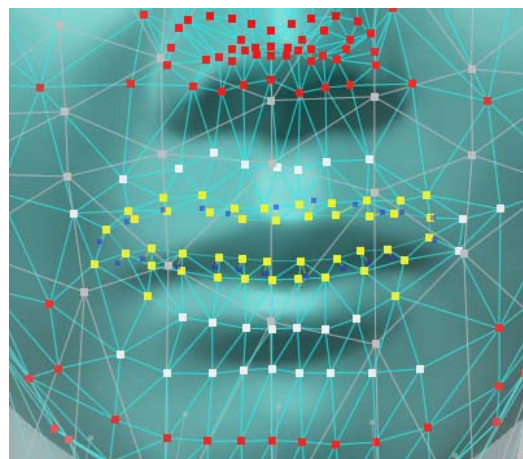
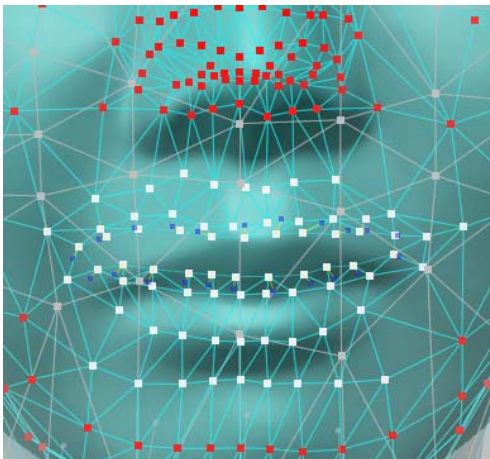
Plane (Template:0) & Sphere (Reference:1)

**Exercise:**

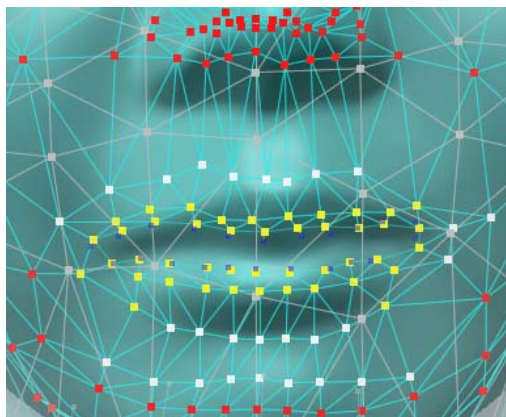
1. Open “template.mdl” under the “polygon\_wb” folder.
2. Select **Tool > Polygon Template** menu, and pick the “template” shell and the “reference” shells in order. Click **Yes** button to align two shells. If necessary, click **Depth Cueing** icon on the View toolbar to distinguish easily nodes in front from nodes at the back as shown below right.



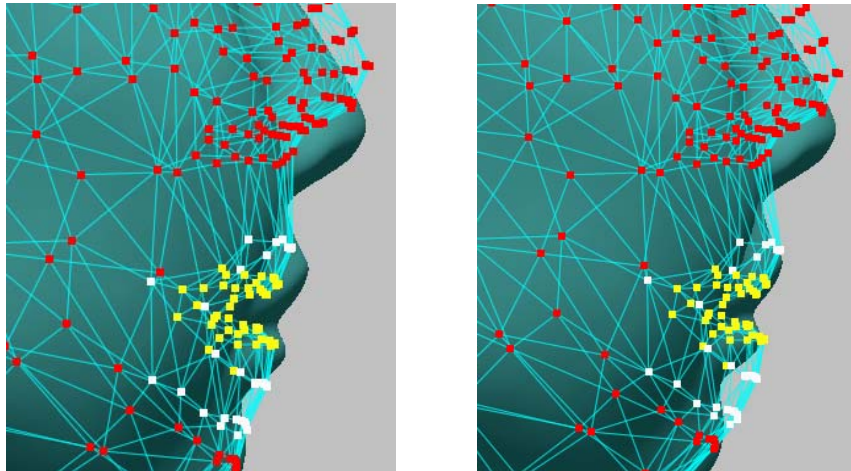
3. Zoom in mouth area, and uncheck **Pause** and click **Move Nodes** on RMB menu.
4. Select nodes around mouth to be deformed by dragging mouse with holding Shift+LMB as below left (white points). Continuously, select nodes to be translated by dragging mouse with Shift+RMB as below right (yellow points).



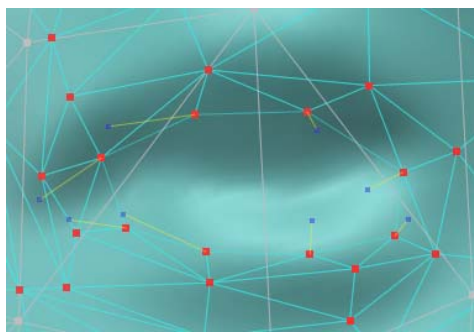
5. Deselect the selected nodes which you didn't intend by dragging LMB with holding Ctrl key.
6. Drag mouse pointer on an arbitrary node among selected ones with holding down LMB so that they position around mouth area of the reference shell.



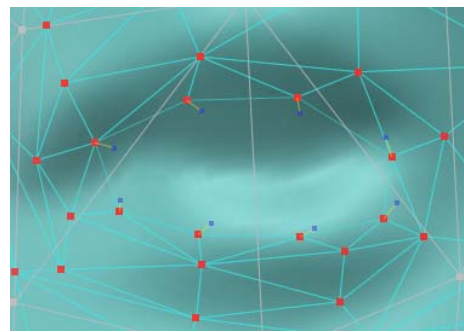
7. Change viewpoint as below left, and move nodes as below right.



8. Deselect all selected nodes by dragging LMB while holding down the Ctrl key.
9. Apply above process to nose and eyes area.
10. Click **Auto Anchor** on RMB menu, and click **Move Anchor** and then move the anchors to the position, which you want around eye as shown below. You can also add or delete anchors.

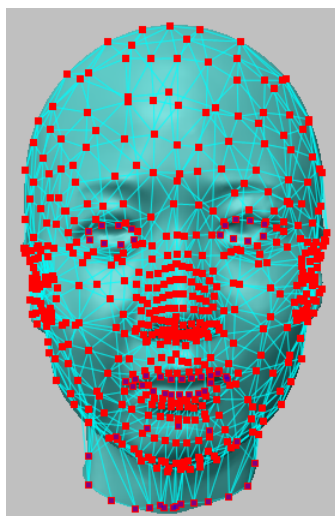


Before moving anchors

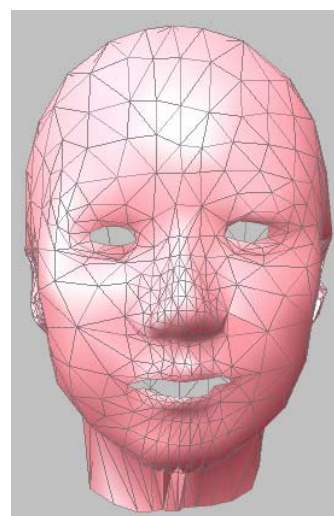


After moving anchors

11. Click **Relax Template** on RMB menu, and push Esc key. You will obtain a new template model (as shown below right).



After relaxing



New template model

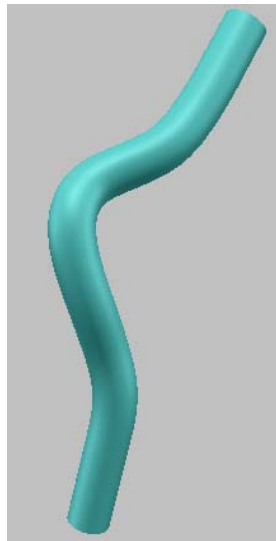
(**NOTE:** You may skip the above steps from 3 to 10 for similar shape models)

## Find Medial Axis Points

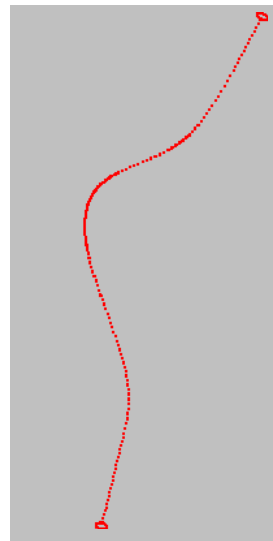
The Find Medial Axis Points operation creates a new point set by arranging vertices of polygonal shell around its medial axis. This operation moves all points on polygonal surface to a center axis or a midplane.

### Exercise:

1. Open “pipe.mdl” under “polygon\_wb” folder.
2. Click **Tool > Find Medial Axis Points** menu, and select a shell.
3. Hide “pipe” shell in the project tree window.



Pipe shape object



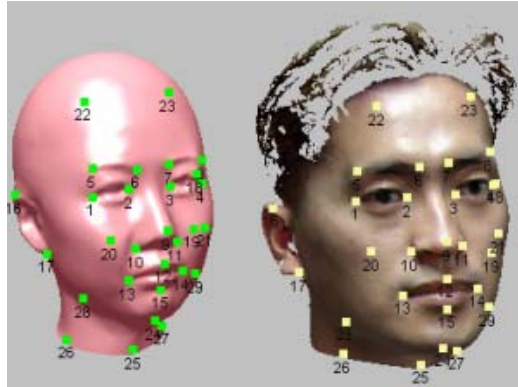
Medial Axis Transformation

## Polygon Morphing

The Polygon Morphing functionality enables you to transform a polygonal model to another polygonal model and to view and save interim morphs on the way to the transformation. Pixform Pro employs landmark based volume morphing, so you have to indicate some landmarks on each model. This operation supports the multiple window system for easy landmark selection.

### Exercise 1:

1. Open “face\_morphing.mdl” under “polygon\_wb” folder.  
(Reference points were predefined in each shell by Ref. Geometry > Create > Point > Pick Point menu and renamed in project window)
2. Push RMB on the string “Points” in project window and click **Show/Hide Name** on pupup menu.



(NOTE: The name of points at the same position in each shell should be same)

3. Click **Tool > Polygon Morphing** menu, and select “template” and then “reference”.
4. Click **Load** button in dialog box and open “landmark.txt” file.
5. Click **Scan Ref. Points** button, then IDs of two shells are automatically scanned.
6. Try to move the slide bar in **Interpolation Ratio** to the right. Click **Add Shell** button at ratio **0.3**. Move the slide bar at ratio **0.6** and move the slide bar of **Effective Intensity** to the left as one step.
7. Click **Add Shell**, and then click **Cancel** button to preserve the original template shell.



Template(0.0)    at (0.3)    at (0.6)    Reference(1.0)

## Exercise 2:

1. Open “dental.mdl” under “Pixform Pro/Sample” folder.
2. Create about 40 reference points on each shell, and rename them as a same name for a corresponding point.
3. Repeat the above exercise 1.

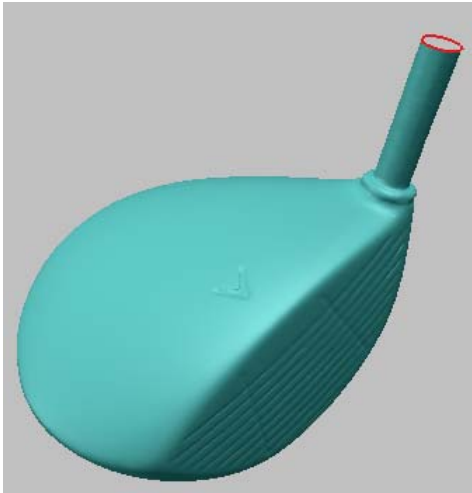
## Thicken

Pixform Pro’s thickening operation converts an open shell into a volume shell with a constant thickness, and also it converts a volume shell into a shell type model with a constant thickness. This operation allows you to control the direction in which the model’s surface is thickened.

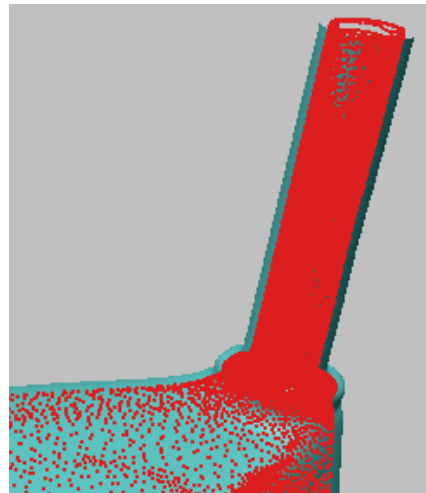
**NOTE:** *This operation may introduce self-intersections, which are undesirable in some cases.*

## Exercise:

1. Open "golf\_head.mdl" under "polygon\_wb" folder.
2. Apply **Tool > Make Volume > Thicken**.
3. Type in **1** thickness on the dialog box, and select **Preview** with **Backward** offset for inner direction as below right.



Golf head before thickening

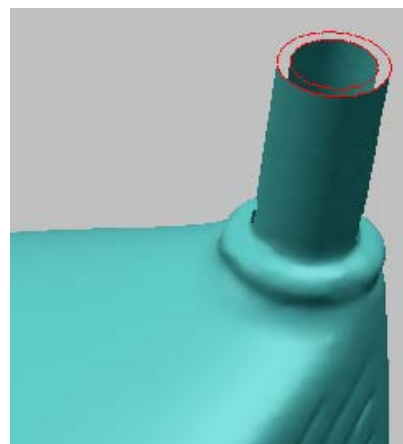


When preview

4. Select **OK**, and perform **Measure > Cross Section > Model** menu for checking the volume. Try to move position bar after checking **Z axis** and **Hide Front** option.

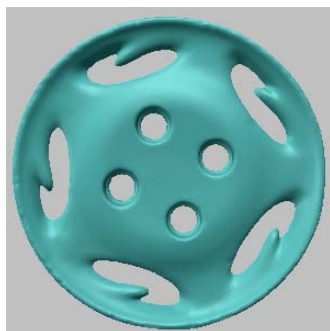


After thickening

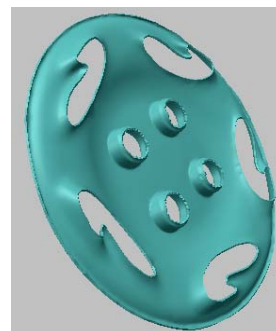


Cross section

5. Open "wheel\_cover.mdl", and repeat above process.



Wheel cover of car



After thickening

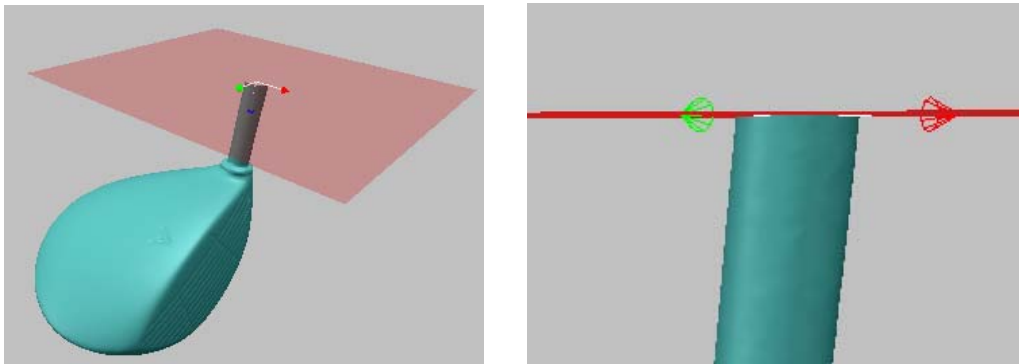
## Extrude to Plane

Similar to the thickening operation, extrusion operation also converts open shells that do not bound volume into closed solid models that do. The main differences between the two operations are the thickness of volume and the existence of open boundary. By this operation, volume shells don't have a constant thickness because boundary edges of open shell are extruded to a specific plane.

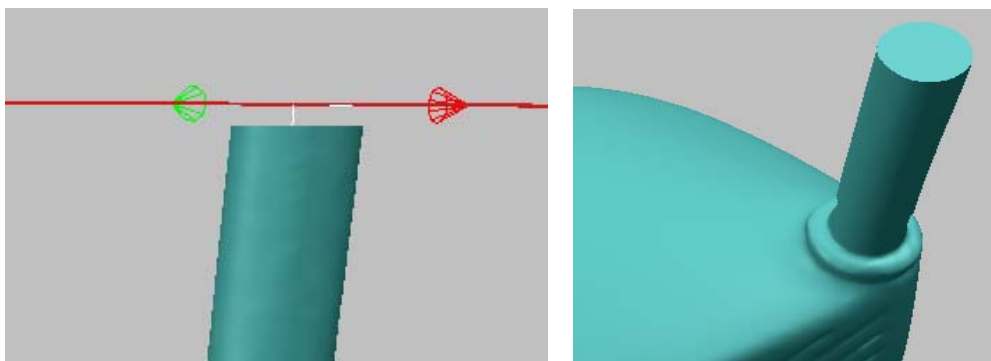
This operation allows two more holes or boundaries to extrude to the specific plane called the projection plane. It has a Tangent Extrusion option on the RMB menu, which extrudes the shell tangent to the boundary, in addition to the standard extrusion, which extracts directly to the plane.

### Exercise 1:

1. Open "golf\_head.mdl" again.
2. Apply **Tool > Make Volume > Extrude to Plane**.
3. Select **Pause** on RMB menu, and change view as below right.



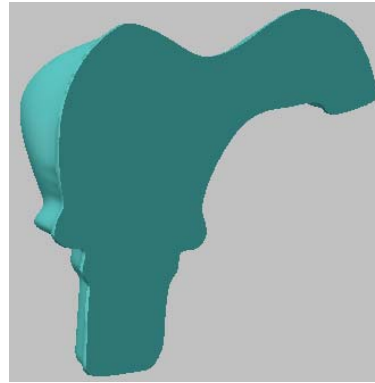
4. Separate the projection plane from object as small distance by CTRL+SHIFT+LMB(up/down direction) as below left, and then click **Done** on RMB menu.



5. Open "tap.mdl", and repeat above process.



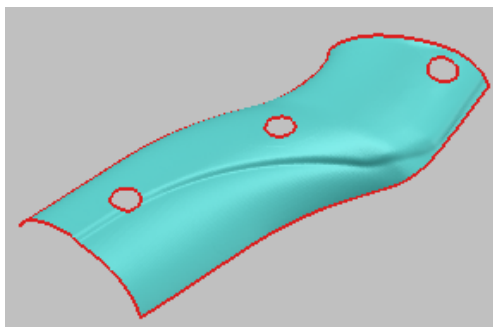
Tap before thickening



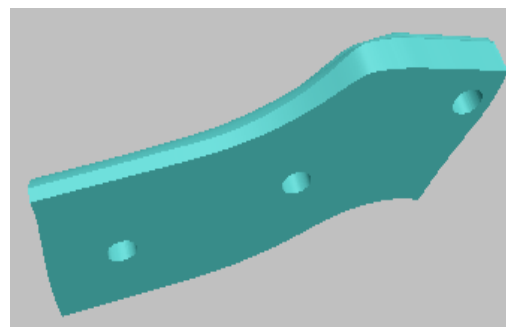
After thickening

## Exercise 2:

1. Open “joystick.mdl” under “polygon \_wb” folder.
2. Push **E** key to show boundaries.
3. Click **Tool > Make Volume > Extrude to Plane** menu, and select a shell.
4. Click **Pick Ref. Plane** on RMB menu, and select the plane.
5. Click **Done** on RMB menu.



Shell without thickness



Solid body by Extrude

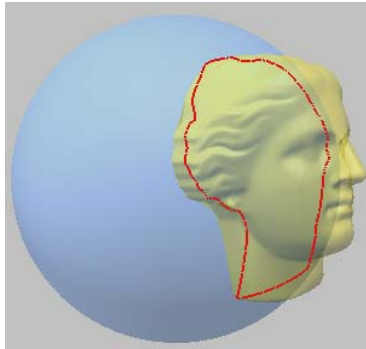
## Boolean Operations

Boolean operations let you add a solid to or subtract a solid from another solid. Pixform Pro provides you union, intersection, and difference as Boolean operation for polygon models.

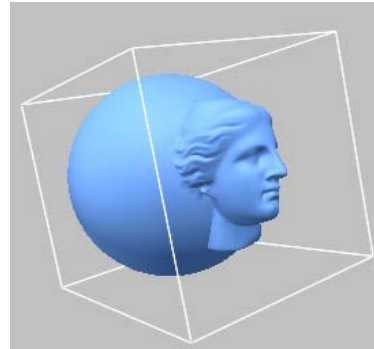
### Exercise:

1. Open “boolean.mdl” under “polygon \_wb” folder.
2. Apply **Information > Check Interference** to two shells for displaying the interference line as shown below left.
3. Select **Edit > Enable Undo** menu for activating undo command.
4. Apply **Tool > Boolean > Union**.



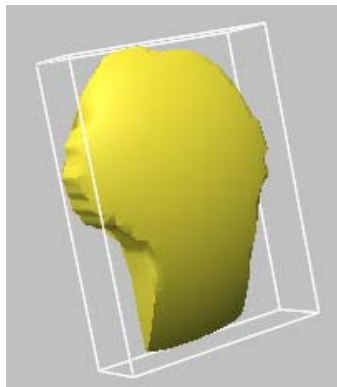


Check interference

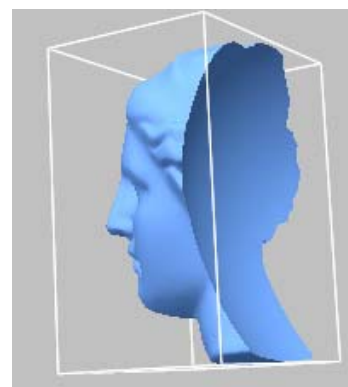


Union

5. Select **Edit > Undo** menu to return to the previous step.
6. Apply **Tool > Boolean > Intersection**.
7. Select **Edit > Undo** menu to return to the previous step.
8. Apply **Tool > Boolean > Difference**, and select “venus” and “sphere” in turn.



Intersection



Difference

## Work Volume

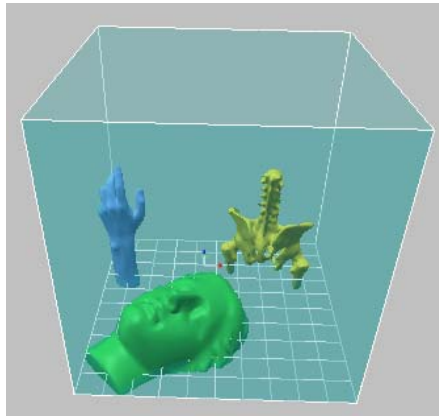
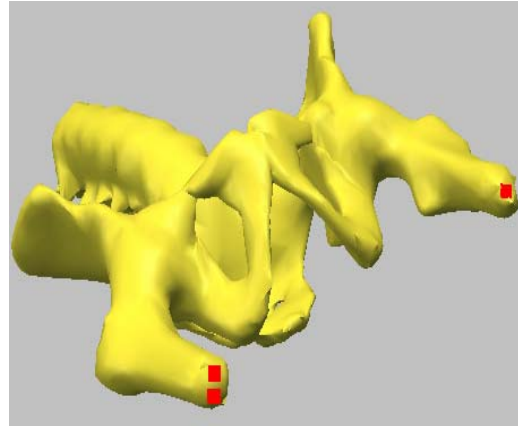
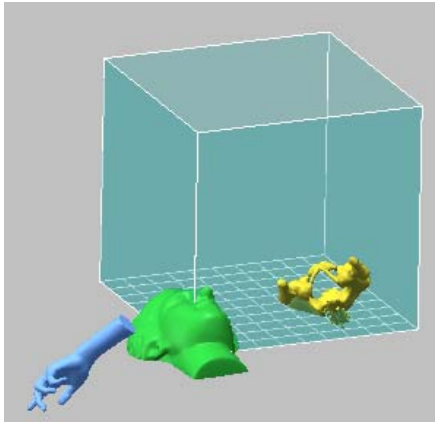
The accuracy and efficiency of rapid prototyping process depend on how the object is positioned in the work volume. The user's choice of part orientation in the building chamber will have an impact on build time, part resolution, and surface finish.

Obviously, minimizing the height of the geometry will reduce the number of layers required, thereby decreasing build time.

With RP workbench, you can define a work volume and align multiple objects onto it.

### **Exercise:**

1. Open “work\_volume.mdl” under “polygon\_wb” folder.
2. Apply **Tool > Work Volume > Create**, type in **500** each blank, and select **OK**. Turn off the perspective view icon on the View toolbar to disable it.
3. Apply **Tool > Work Volume > Align > Min Height** to “venus” shell.
4. Apply **Tool > Work Volume > Align > Face** to “hand” shell, and pick a face on the bottom of arm.
5. Apply **Tool > Work Volume > Align > 3 Points** to “pelvis” shell, and pick three points of leg bottom as below right.



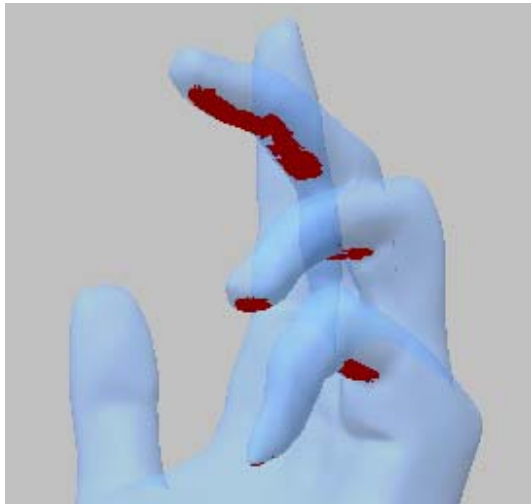
## Export Slices

Slicing will proceed along the slice axis, z-axis. The height of each step is the layer thickness used in that portion of the part. A support structure may be required, depending on the part's orientation. Finally, you may write the slicing data to several rapid prototyping file formats.

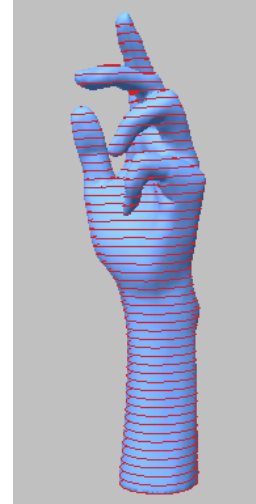
### **Exercise:**

*(Being continued)*

1. Apply **Tool > Find Overhang Region** to “hand” shell to find the area required the support structure.
2. Select “hand”, and click **Done** on RMB menu.
3. Type in **30** degree, and select **OK**.
4. Apply **Tool > Export Slices** to “hand” shell.
5. Type in **5 Layer Thickness**, and click **Preview**.
6. Click **Export** button, and save the slicing data to a specific data format.



Finding overhang region



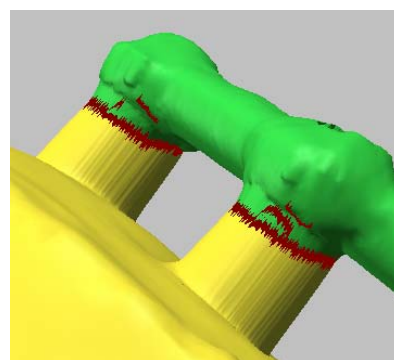
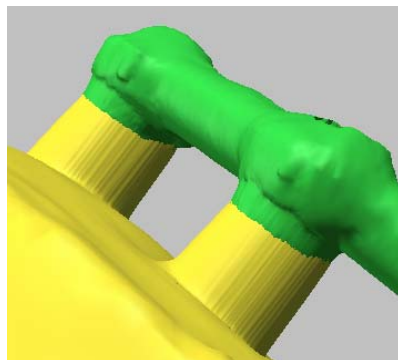
Slices

## Detect Collision

The Detect Collision operation is On/Off toggle menu for displaying the interference regions when a shell moves into another shells dynamically by *Edit > Transform > Shell Trackball*.

### Exercise:

1. Open "teeth\_frame.mdl" under "polygon\_wb" folder.
2. Click **Edit > Transform > Detect Collision** menu to toggle **ON**.
3. Push **Ctrl+T** key, and select a shell named "frame".
4. Try to move the shell in the **Z** (blue arrow) direction and check the detect region.
5. Push **ESC** key.



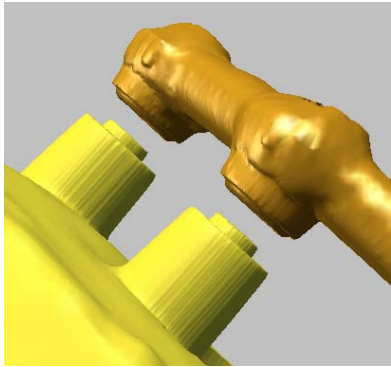
Before and After applying Detect Collision

## Restrict Collision

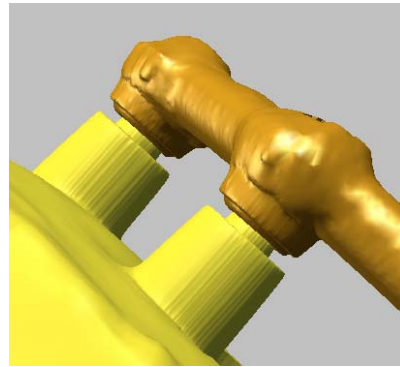
The Restrict Collision operation is On/Off toggle menu for restricting the penetration between shells when a shell moves to another shells dynamically by *Edit > Transform > Shell Trackball*.

### Exercise:

1. Open again “teeth\_frame.mdl” under “polygon\_wb” folder.
2. Click **Edit > Transform > Restrict Collision** menu to toggle **ON**.
3. Push **Ctrl+T** key, and select a shell named “frame”.
4. Try to move the shell in the **Z** (blue arrow) direction and check whether “frame” penetrates through “base”.
5. Push **ESC** key.



Before applying Shell Trackball



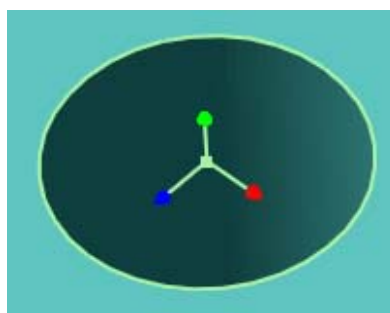
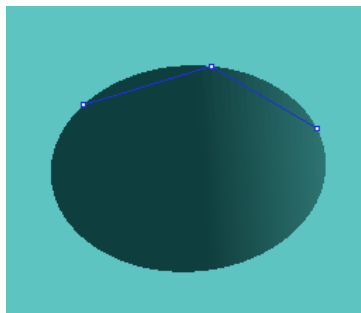
Effect of Restrict Collision

## Transformation by Ref. Geometry

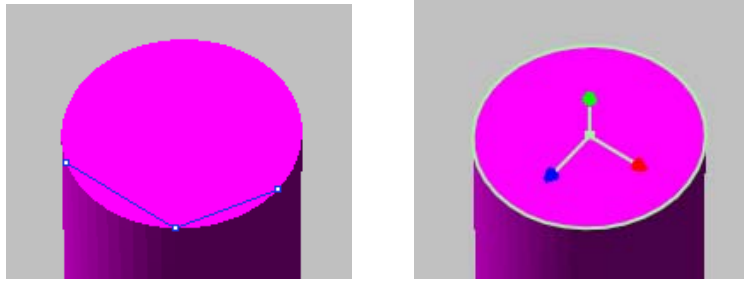
Reference geometries are point, vector, plane, circle, sphere, cylinder, cone, box, torus and coordinate which are introduced for various purposes such as dividing, making volume, slicing, section viewing, measuring, transformation, alignment, etc. Especially using these reference geometries, it is useful for aligning two different models which come from different coordinate system. Reference geometries are automatically attached to a shell if they are created by its entities. If necessary, you can break the connection with a shell.

### Exercise:

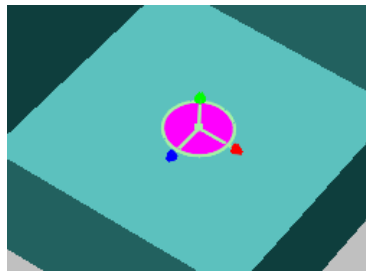
1. Open “ref\_geometry.mdl” under “polygon\_wb” folder.
2. Click **File > Preferences** menu and go to **Display Options** tab, and then select the **Vertex snap** check box in the **Picking** option.
3. Click **Ref. Geometry > Create > Circle > Pick Points** menu, and pick three points on the boundary of hole as below. And then click **Done** on RMB menu.
4. Click **Ref. Geometry > Create > Coordinate > Pick Origin & Input Rotation** menu, select **Ref. Point** on RMB menu, and pick the center point of the circle. And then click **OK** button in the dialog box.



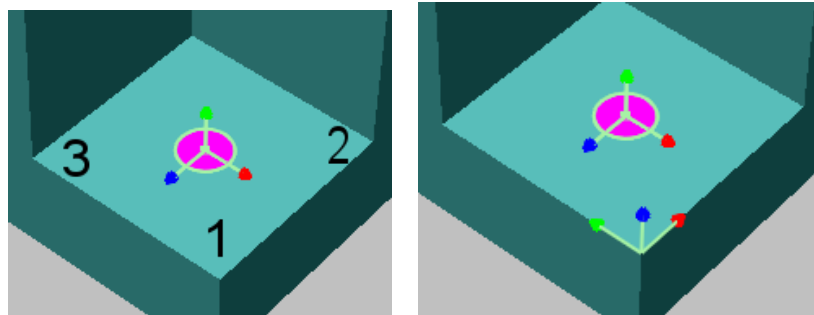
5. Apply a reference circle and a coordinate to a cylinder block.



- Click **Ref. Geometry > Transform > Coordinate > Align Coordinate** menu, and select the coordinate of cylindrical block and then the coordinate on the hole. Click **OK** in the dialog box.



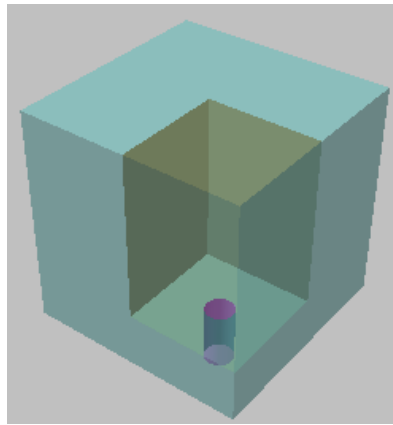
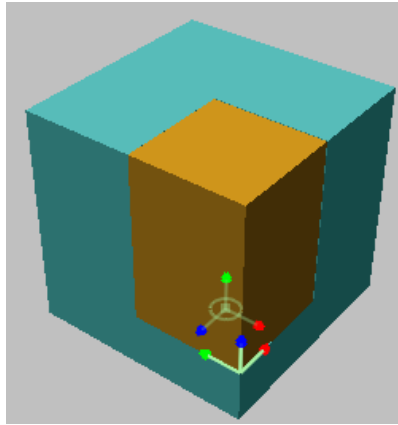
- Click **Ref. Geometry > Create > Coordinate > Pick Origin & X, Y Direction** menu, and pick corner points of a block1 in numerical order as below.



- Click **Ref. Geometry > Create > Coordinate > Pick Origin & X, Y Direction** menu, and pick corner points of a block2 in numerical order as below.



- Click **Ref. Geometry > Transform > Coordinate > Align Coordinate** menu, and select the coordinate of a block2 and then the coordinate of a block1. Click **OK** in the dialog box.
- Push **F6** key to check the assembly status.



## 7. Curve Workbench

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The surface creation process begins by laying down curves directly on the point cloud or the polygonal model to define the different surfaces to be created. You can define the layout of surfaces on your model by creating a network of curves that define the different surfaces. Each surface "patch" must be defined by two or more boundaries.

There are two kinds of curves in the workspace: One is "Shell curve" that is automatically connected to a shell when it is created and all editing operation can be applied. Another is "Space curve" that is not connected to any shell and several operations like deformation cannot be applied. They may be introduced by curve template.

There is another operation that can significantly speed up the surfacing process by eliminating many of the tasks involved in preparing a model for the NURBS surface. It is curve template. The Template operation allows you to save the curve network from one model and apply it to another model.

The typical work process is as follows:

1. Generate feature curves and boundary curves
2. Make curve network and optimize it using editing tools
3. Generate loops for surfacing
4. Create a template for a special purpose

**NOTE:** *If there are two or more shells in the workspace, you must activate a shell by selecting it in the project window before creating curves because most curve operations are applied to the active shell.*

**NOTE:** *In case both end points of a curve can be distorted, check out the vertex snap on the Display Options tab of File > Preferences.*

## Feature curve

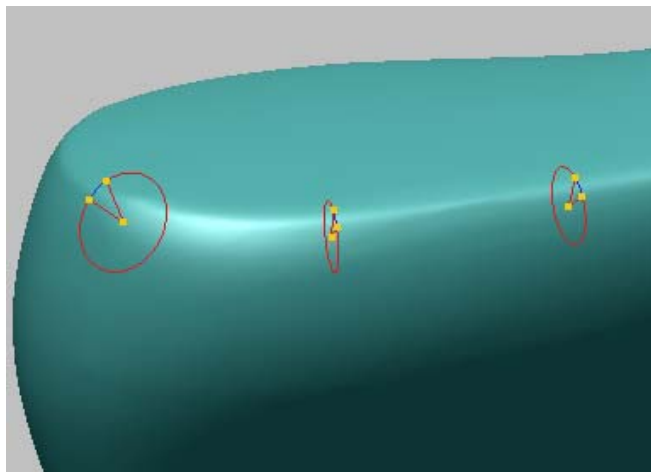
Feature curve speeds up the process of creating a curve network, a necessary step in surfacing. You can reduce the time it takes to construct a curve network for your model using the feature extraction and automated curve creation tool.

If an object has more 100,000 triangles, it will take long time to find feature curves. In this case, you have to duplicate it and reduce to less 50,000 triangles, and then find feature curves, attach the curves to original shell and delete the copied shell.

Additionally use an option, Quick Mode, a faster but less accurate curve generation method (useful for models with more obvious features). There is also an option on the RMB menu, Pick Radius Points, which allows you to capture the radius of a rounded region by picking points, and enters that information for feature curve generation automatically.

### **Exercise:**

1. Open “shoe\_last.mdl” under the “curve\_wb” folder.
2. Click **Curve > Create > Feature Curves** menu and pick the shell.
3. Click **Pick Radius Points** on RMB menu, and pick two points on each rounded region as below.



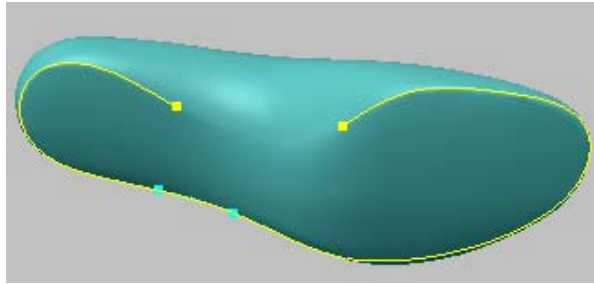
(**Tip:** A user can measure approximately the radius of rounding area by Measure > Radius > Rounded Area Radius)

4. Click **Done** on RMB menu. Then feature radius is automatically inserted into the dialog box.

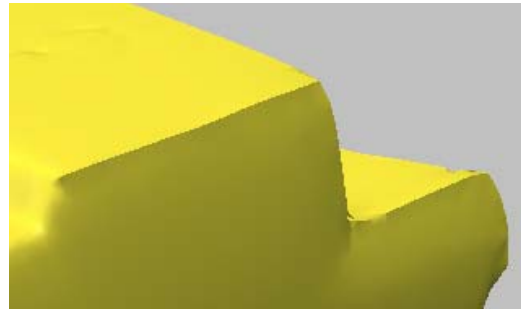
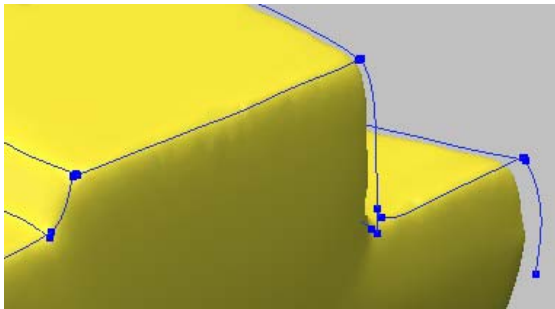
(**Tip:** A user can type in a specific radius manually by clicking New icon on the dialog box)

5. Check **Use Shell Curvature** option and click **Preview** button.
6. Select **Accept Curve** on RMB menu, and pick a curve as shown below.





7. Click **OK** and save the model as a different file name.
8. Open “cam.mdl”, and apply Feature curve operation to the shell.
9. Type in **10** radius, and use all options.
10. Construct sharp edges using **Tool > Fit Edges To Curves** operation in the Polygon workbench.

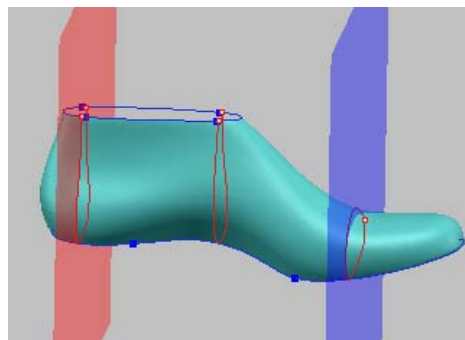


## Slice curve

The Slice curve operation allows you to have section curves of the polygonal model. You can indicate the number of slices or the width of slices to be created. You can also slice the shell by a reference coordinate you defined.

### **Exercise:**

1. Open the shoe model saved in the feature curve process above.
2. Select **Curve > Create > Slice** menu, and pick the shell.
3. Select **X-axis**, type in **3** number of slice, and position two reference planes as shown below. And then click **Preview**.



4. Click **Slice** button.

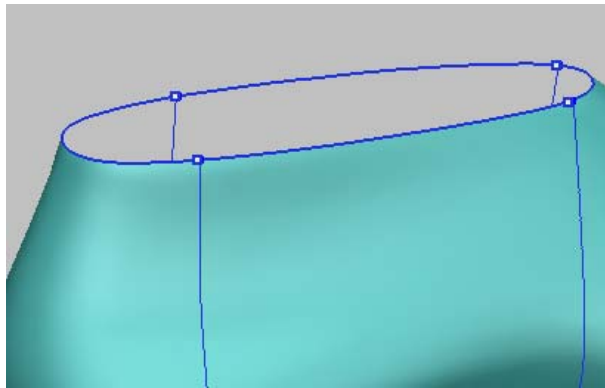
## Boundary curve

The Boundary curve is automatically generated on boundary edges of the polygonal model in case it is not closed volume shell. You can trim the boundary by picking trimming points during the creation of the boundary curves. In that case, you must pick points in the counterclockwise direction for outside boundary or in the clockwise direction for the inside hole.

### **Exercise:**

*(Being continued)*

1. Select **Curve > Create > Boundary Fit** menu, click **OK** with default Fitting Parameter.
2. Pick 4 trimming points around the slice curve in the clockwise direction as shown below, and click **OK** on RMB menu.



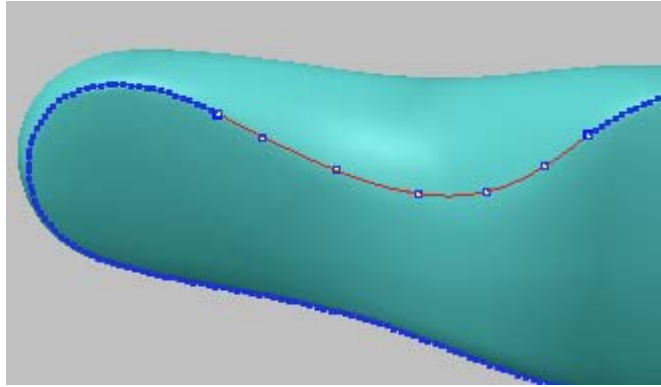
## Interpolation curve

The Interpolate curve is a freeform curve with a set of interpolation points. The Interpolate operation is the most general tool to create curves manually. By this operation, you can fit a curve on the polygonal surface or create a curve passing the interpolation points. You can change viewpoint during picking interpolation points.

### **Exercise:**

*(Being continued)*

1. Select **Curve > Create > Interpolate** menu, click **Start** on RMB menu.
2. Move mouse pointer closely to the end point of the pre-defined feature curve.
3. Pick the point when it becomes red color, and another points as show below.



4. Select **End > Generate Intermediate Points** on RMB menu.

## Projection curve

There are five kinds of projection curves, they are: Polyline; Rectangle; Circle; Ellipse; and Grid. You cannot change the viewpoint during the picking of projection points.

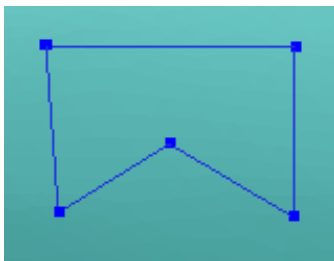
**Polyline:** multiple connected curves of line type

**Rectangle:** rectangular curves

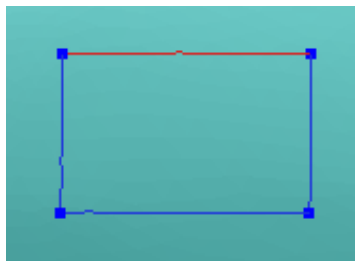
**Circle:** circular curves

**Ellipse:** elliptical curves

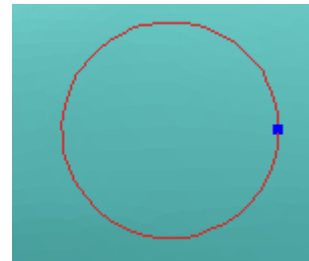
**Grid:** connected curves of grid type



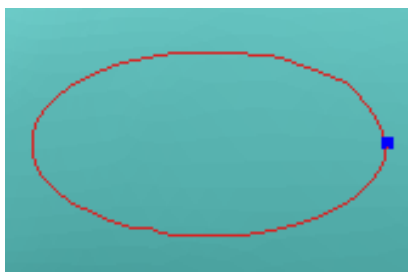
Polyline



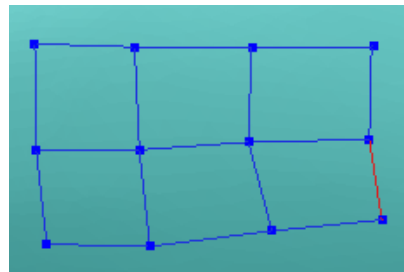
Rectangle



Circle



Ellipse



Grid

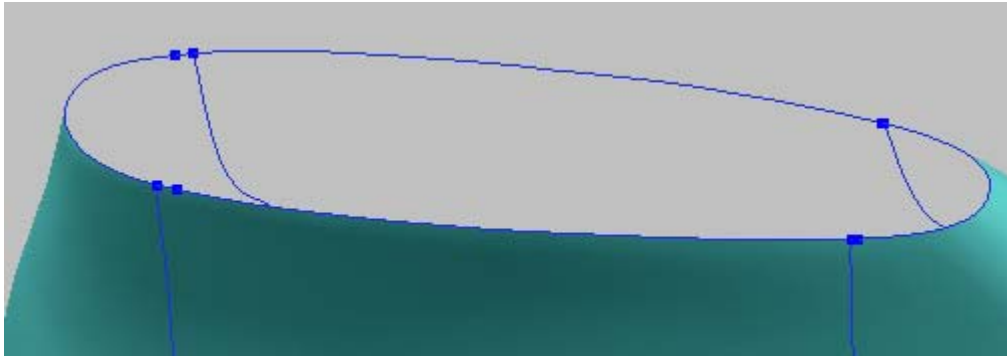
## Match

The Match operation matches two curves so that their end points should be coincident or tangent to each other. The first selected curve is matched to the second selected curve.

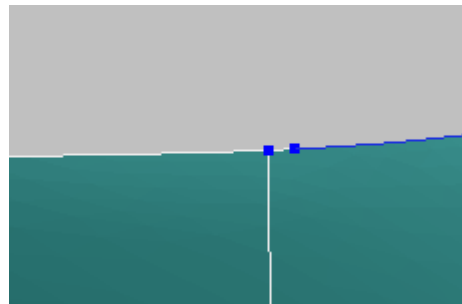
### Exercise:

*(Being continued)*

1. Select **Curve > Tool > Match** menu.



2. Pick two curves in turn.



3. Check **Position** Continuity, and click OK. If fail, increase **Matching Tolerance**.
4. Repeat for other curve that its end points are positioned closely.

## Deform

The Curve Deform operation deforms the geometry of a curve by translation of its control points. Curves can be smoothened by this operation.

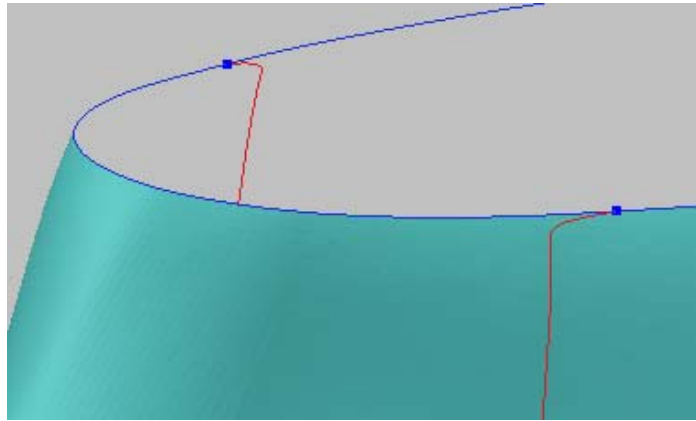
You can deform curves not only on the polygonal surface but also by space. If curves are disconnected from a polygon shell, “*Move on Polygon*” option is automatically turned off and curves are deformed without relation to the shell. So if you want to deform curves on polygon, firstly connect curves to the shell using *Attach to Shell* functionality.

You can deform curves continuously without quitting the operation.

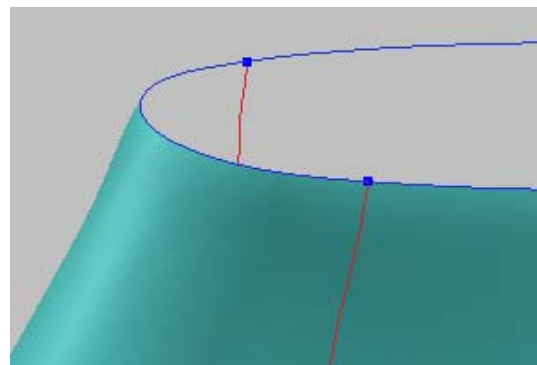
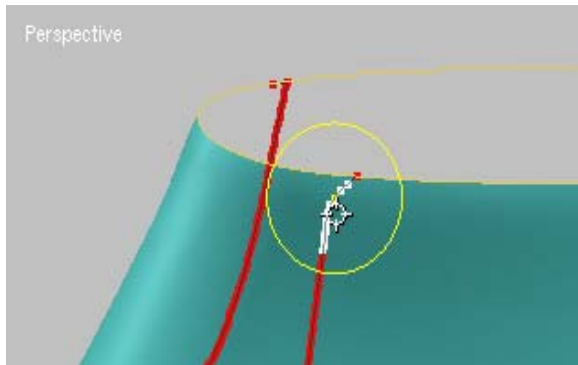
### Exercise:

*(Being continued)*

1. Select **Curve > Edit > Deform** menu, and pick a curve below.



2. Define the region of control points to be deformed with a yellow circle by mouse drag to the left or right direction while holding down LMB and Shift key.
3. Drag mouse pointer on an arbitrary control point among selected ones while holding down LMB.



## Trim

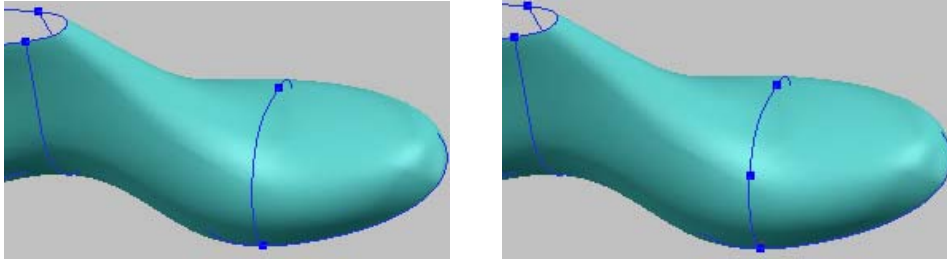
The Trim operation trims curves into more than two curves.

The Curve/Curve operation breaks two overlapping curves into four separate curves that share a break at the intersection. The Curve/Surface operation breaks a curve at its intersection points with a surface patch. The Pick Point operation creates a break in a curve at a selected point. This is useful for making T-joints. The N-division operation breaks a curve into  $N$  curves such that all the trimmed curves have same length with each other. The Global operation breaks selected curves globally at their intersections.

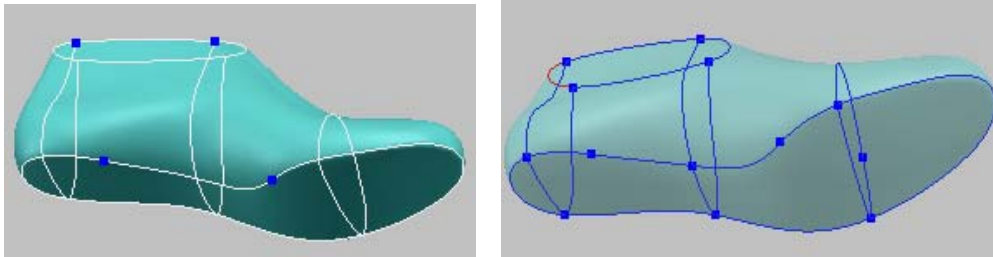
### **Exercise:**

*(Being continued)*

1. Select **Curve > Trim > Pick Point** menu, and select a curve and a point as below.



2. Select **Curve > Trim > Global** menu, and select all curves by mouse drag. Then click **Done** on RMB menu.



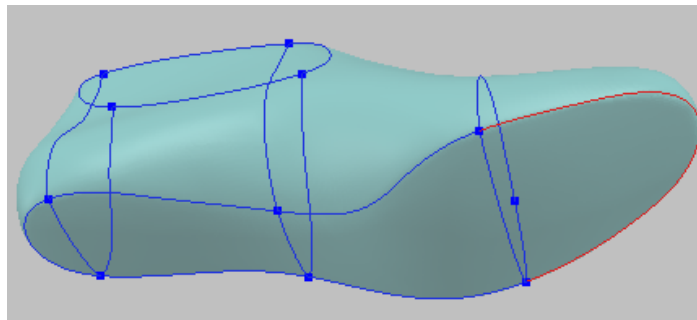
## Merge

The Merge operation connects two curves that share a common end point. These two curves should be matched at the end point.

### Exercise:

*(Being continued)*

1. Apply **Curve > Tool > Merge** operation to four divided curves.

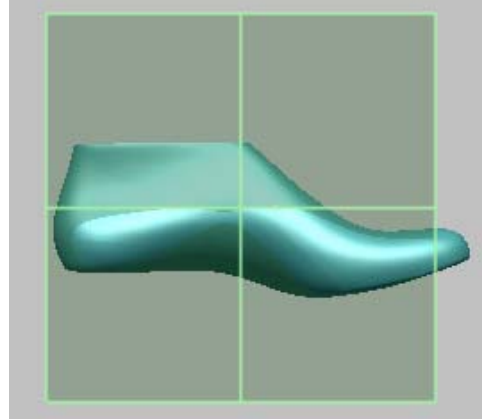
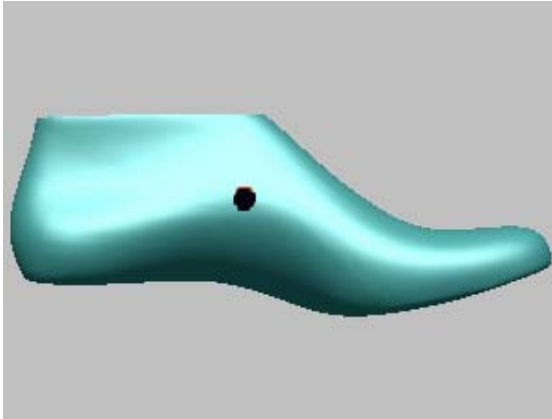


## Silhouette Curve

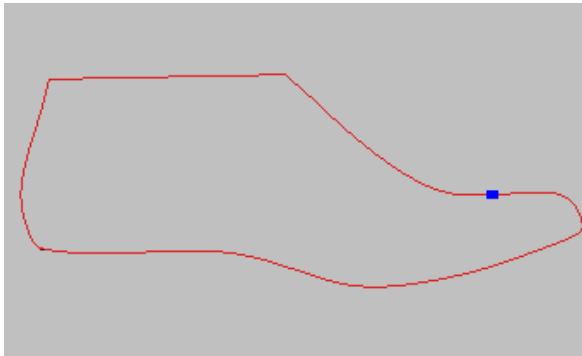
The silhouette curve is a set of visual edges where the model stops and the background begins on the current view. This command provides you two kinds of silhouette curves, visible silhouette and projected silhouette. Like mold's parting line, they are used to cut the model in two along the silhouette.

### Exercise:

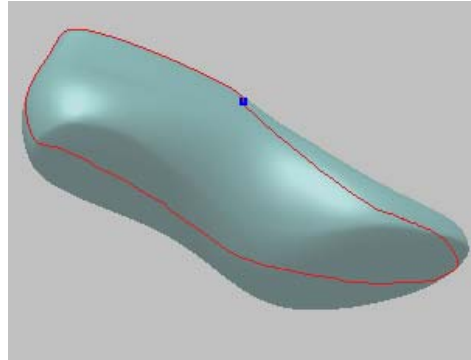
1. Open "shoe\_last.mdl" under "curve\_wb" folder.
2. Set the viewpoint as below by pressing **Alt+6** key.
3. Click **Ref. Geometry > Create > Plane > Pick Point with Viewing Direction** and pick a point at the center of shoe.



4. Click **Curve > Create > Silhouette > From Shell** and pick a shell then select a ref. plane.
5. Click **OK** with **Generated Projected Silhouette Curves** option.
6. Repeat the above process with **Generate Visible Silhouette Curves** option.



Projected Silhouette Curve



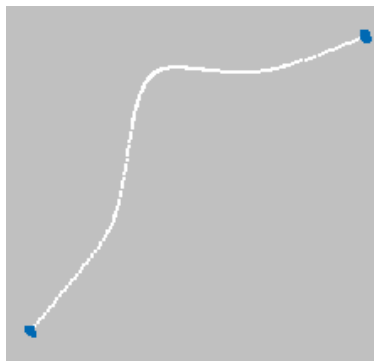
Visible Silhouette Curve

## Fit Points

The Fit Points operation creates a curve fit to the path of curve typed point cloud.

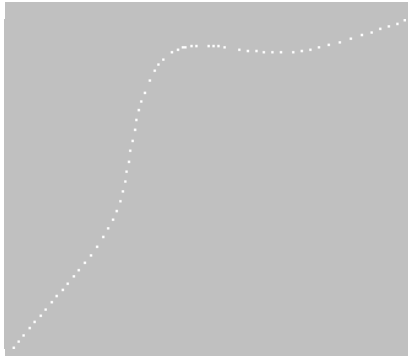
### Exercise:

1. Open "pipe.mdl" under "polygon\_wb" folder.
2. Click **Tool > Find Medial Axis Points** menu, and select "pipe."
3. Hide "pipe" and select "Medial Axis Shell" in the project tree window.
4. Select vertices in both ends as below, and push **Alt+V** key to delete them.

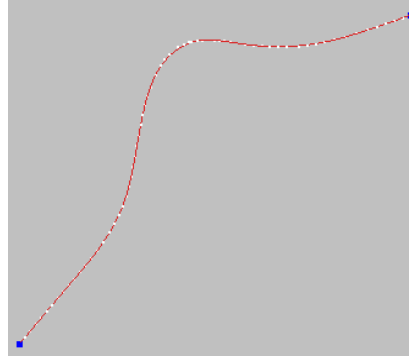


5. Go to Scan workbench.

6. Click **Build > Filter Redundancy** menu, and select “Medial Axis Shell”.
7. Click **OK** with default value.
8. Repeat once more the above step 6 and 7.
9. Go to Curve workbench.
10. Click **Curve > Create > Fit Points** menu, and select “Medial Axis Shell”.
11. Click **OK** with default value.



Curved point cloud



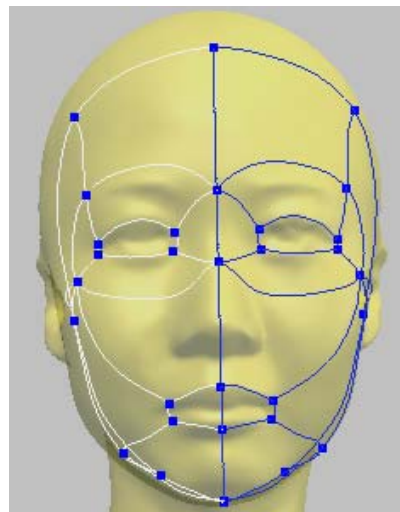
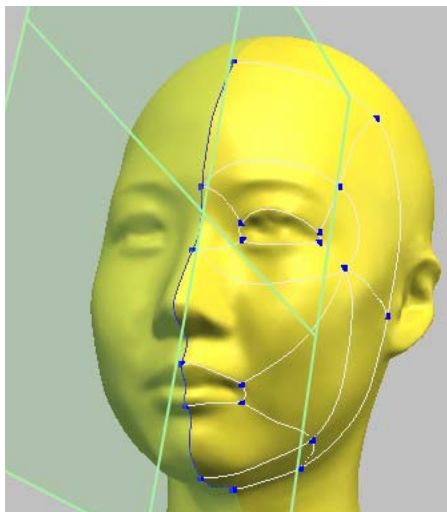
Curve fit to points

## Mirror

The Curve Mirror operation allows you to mirror curves against a center plane. The mirrored curves are space curves and are not attached to the shell. This operation enables you to save the modeling time and effort to generate a curve network for a symmetrical object.

### Exercise:

1. Open “mirror.mdl” under “curve\_wb” folder.
2. Click **Curve > Create > Mirror** and select all curves except ones on the center plane as below left. And then click **Done** on RMB menu.
3. Select a center plane. Push **F6** key for transparent viewing.
4. Click **Curve > Tool > Attach to Shell** and select all mirrored curves as below right, and then select the shell.
5. Click **Curve > Tool > Rebuild** and select all mirrored curves, and click **Done** on RMB menu. Check **Use existing point numbers** option and click **OK**.



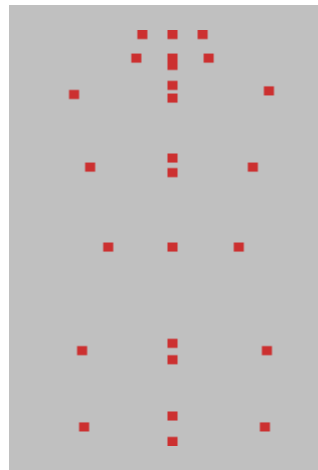
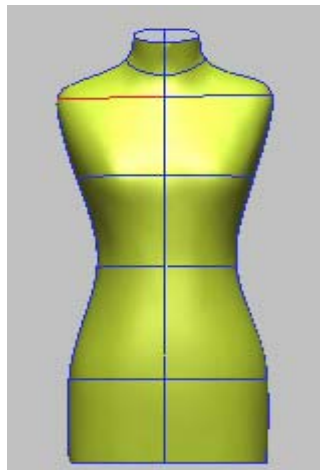


## Convert To Shell

The Convert To Shell operation converts the selected curves into a point cloud through the tessellation process. The new shell may consist of uniform or non-uniform point clouds, or it can be constructed with only the end points of the curves.

### Exercise:

1. Open “torso.mdl” under “curve\_wb” folder.
2. Click **Curve > Tool > Convert To Shell** and select all curves, and click **Done** on RMB menu.
3. Check **Use Curve Node Point Only** option on the dialog box and click **OK**.
4. Hide the shell “torso” in project window and push **4** key to hide all curves.
5. Click **File > Preferences** and select **Display Options** tab, and set **Point Drawing Size** to **5** and click **OK**.



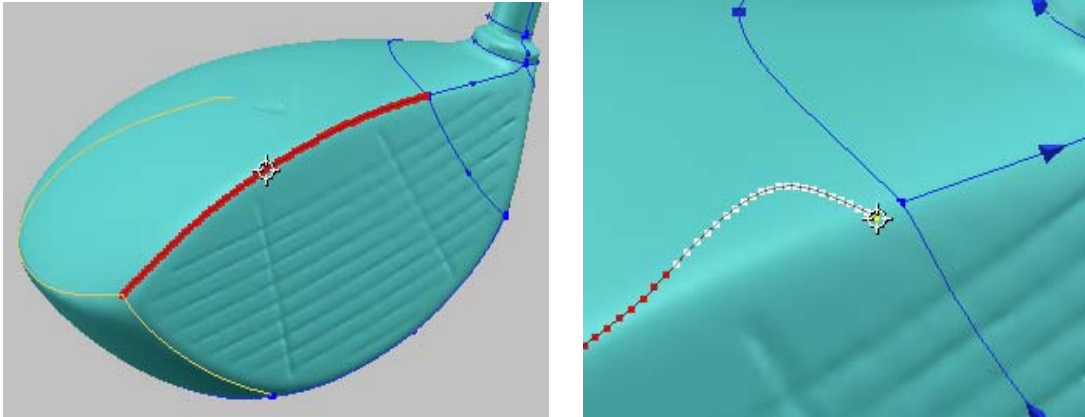
## Merge Node

The Merge Node operation enables all nodes of curves to connect each other and matches all curves so that their end point should be coincident. The advantage is to reduce the drawing errors within tolerance when you create curves manually.

### Exercise:

1. Open “merge\_node.mdl” under “curve\_wb” folder.
2. Click **Edit > Enable Undo** to activate the undo function.
3. Click **Curve > Edit > Deform** menu, and select a curve as shown below left.
4. Try to move the end point of curve as shown below right.

**NOTE:** *Two yellow ones are coincident at the end of the selected curve, but three blue ones are disconnected to it.*



5. Push **ESC** key and click **Edit > Undo** to return to the previous state.
6. Click **Curve > Tool > Merge Nodes** menu.
7. Type in **0.1** as tolerance, and click **OK**.
8. Click **Curve > Edit > Deform** menu, and select the curve again.
9. Repeat the above step 4.



Effect of curve deformation after merging nodes

## Template

The Curve Template operation can significantly speed up the surfacing process by eliminating many of the tasks involved in preparing a model for the NURBS surface. The Template operation allows you to save the curve network from one model and apply it to another model. That is, if you have the Templates functionality and an existing set of curves for a similar model, you may apply those same curves to your model.

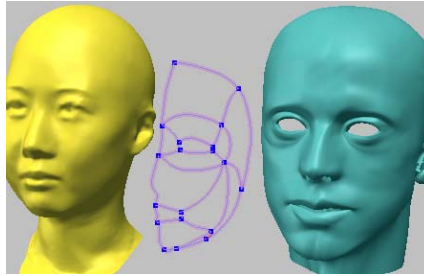
**NOTE:** *If you create a template with loops, you can't delete the loops until the template is deleted.*

### **Exercise:**

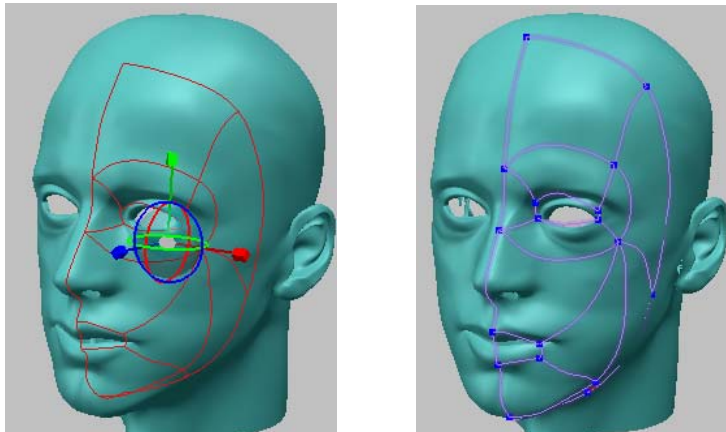
1. Open "template.mdl" under the "curve\_wb" folder.
2. Select **Template > Create** menu, and select all curves.



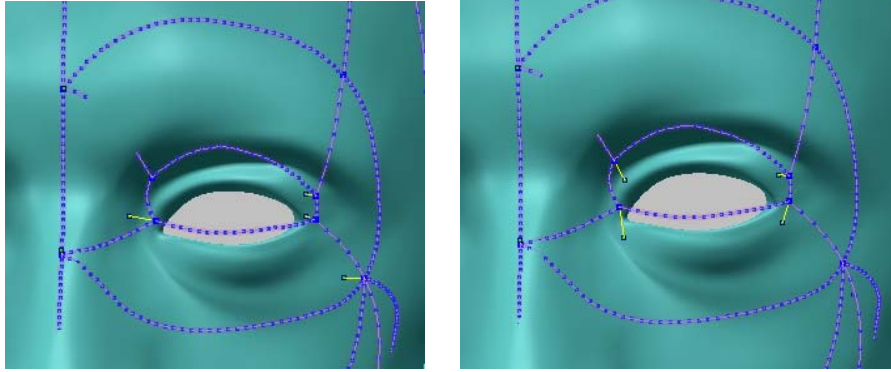
3. Select **Template > Tool > Detach** from shell menu, and pick the template.



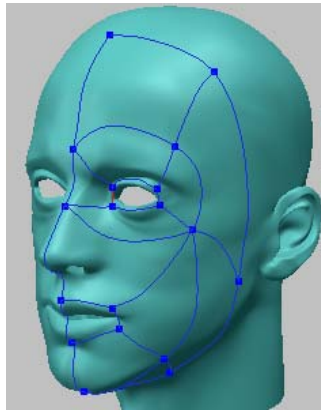
4. Select **Template > Tool > Attach** to shell menu, and pick the template, then “man\_face” shell.
5. Select **Template > Tool > Transform** menu, and pick the template.
6. Approximately transform the template to the similar position of the man using manipulator.



7. Select **Template > Projector > Auto Generation** menu, and pick the template.
8. Zoom in around eye.
9. Select **Template > Projector > Add/Edit** menu, and pick the template.
10. Click **Edit Projector** on RMB menu, and move nodes to the proper position.



11. Click **Done** on RMB menu.
12. Select **Template > Apply** menu, and pick the template.



## 8. Surface Workbench

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When you have created and edited the curve network or loops, you are then ready to generate NURBS surfaces. Pixform Pro allows you to generate a watertight, smooth surface.

There are two methods to create NURBS surface: Automatic and Manual. Automatic surface generation doesn't need tedious curve drawing, so helps you speed up your surfacing work. Manual surface generation can completely maintain the flow line of the original polygon surface though it takes much time than auto surfacing. Manual surfacing branches to work by curves or by loops. Manual surfacing by loops is closer to the auto surfacing to some extent. Also manual surfacing allows you to create trimmed NURBS surface.

Surfacing work using loop is faster than the same work using only curves. Loop is a set of curves that form a closed loop topology. If a surface is created with a loop, the loop contains the connection with the surface, the number of control points of it, and surface type.

Pixform Pro provides various generic surface creation tools such as n-boundary, blend, loft, sweep, extrude, revolution, offset, planar, spherical and cylindrical. Once the NURBS surface is generated, you can edit it by deforming, trimming, smoothing, or editing control points, and improving surface continuity. You can evaluate the surface by plotting deviation between surface and original polygon, curvature plotting and environment mapping. You can also generate displacement maps of the deviation between the original polygonal surface and the NURBS surface.

There are two types of surface: Untrimmed surface and Trimmed surface. The former is for a patch having 4 boundary curves and the latter is for patches having 2, 3, or more than 5 boundary curves. You can control the shape of the surface by using the number of control points in the U and V directions. In the Untrimmed surface, the U direction is defined by a curve that is first picked. In the Trimmed surface, the U direction is automatically determined by algorithm. You can assign the number of total control points instead of U and V control points.

In the workspace, there are two kinds of surfaces: One is "Shell surface" that is automatically connected to a shell when it is created and all surface operations are available. Another is "Space surface" that is not connected to any shell and operations related to a shell are not available.

The typical work process is as follows:

1. Fit NURBS surface to polygonal model
2. Edit NURBS surface patches
3. Analyze the surface
4. Improve the continuity and smoothness
5. Export to the downstream application

## Loop

Loop is a set of curves that form a closed loop topology. If a surface is created with a loop, the loop contains the connection with the surface, the number of control points of it, and surface type.

For creating a loop, pick more than two curves of the closed loop, which will become the boundaries of a surface in the clockwise (CW) or counterclockwise (CCW) direction. But the direction of a seed loop, which is used to automatically find loops, must be CCW. The direction of a loop is same as the direction of the first selected curve.

The Synchronize operation automatically synchronizes the direction and start curve of loops to match the number of control point in U, V directions.

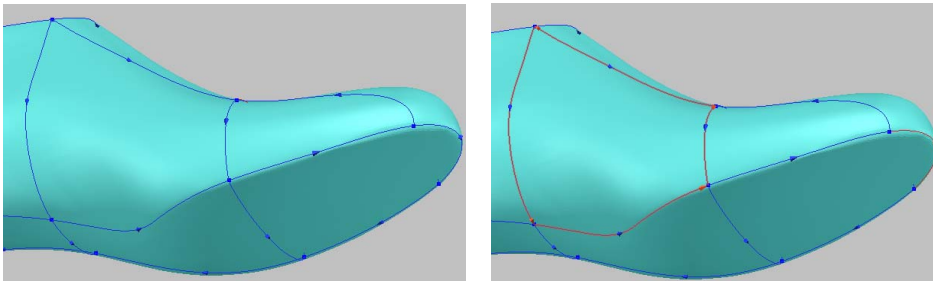
**NOTE:** *If you create loops with curves, you can't delete the curves until the loops are deleted.*

### **Exercise:**

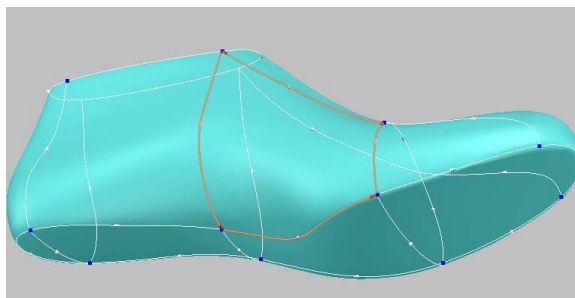
1. Open "shoe\_loop.mdl" under the "surface\_wb" folder.
2. Make sure to show direction of curves by **Curve > Options > Show Direction** as shown below left.
3. Select **Loop > Create** menu, pick four curves in CW or CCW direction as shown below right.

**NOTE:** The direction of a first selected curve determines the direction of loop which should be CCW.

4. Click **Quit** on RMB menu.



5. Select **Loop > Find Loops** menu, and select all curves. Click **Done** on RMB menu.



6. Select a seed loop made in the above step 3.
7. Check **Use outer loop** option, and click **OK**. Click **Loop > Delete** and select a loop around the hole as below. Click **OK**.



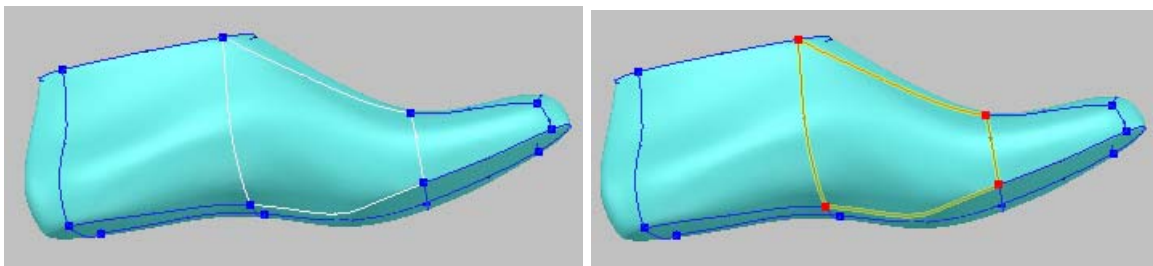
8. Synchronize loops by **Loop > Synchronize** operation.

## Polygon Fit

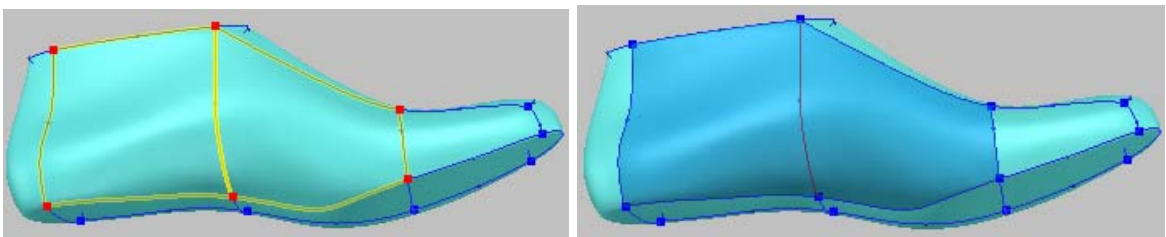
The Polygon Fit operation fits the surface to polygon with the curves or loops, which were drawn on the polygon model. You can create more than two surfaces at once by applying the same parameters to all surfaces.

### Exercise 1: By Curves

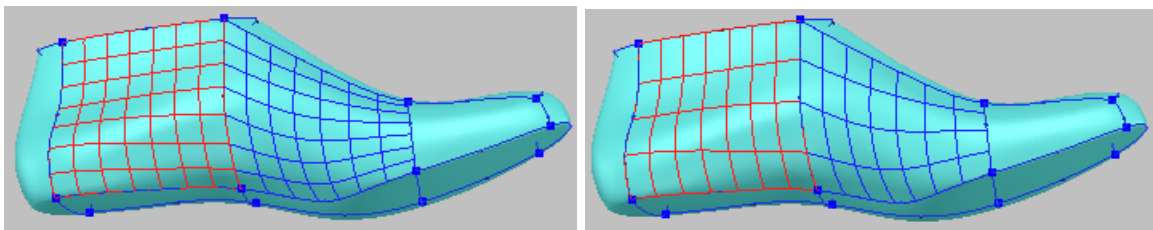
1. Open “shoe\_curve.mdl” under the “surface\_wb” folder.
2. Select **Surface > Create > Polygon Fit > By Curves** menu, and pick four curves as shown below in the counterclockwise direction. Click **Add Loop** on RMB menu.



3. Select another four curves, and click **Add Loop** on RMB menu. Click **Done** on RMB menu.



4. Click **Preview** button with default values.
5. Change **No. of U Control Points** to **7**, and click **Preview** again.

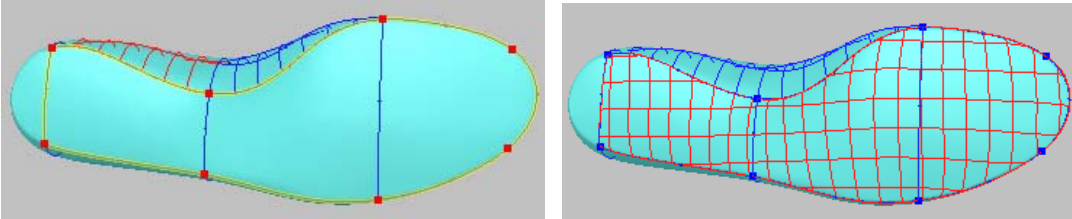


(U, V)=(10 X 10) C.P.

(U, V)=(7 X 10) C.P.

6. Click **OK**.

- Now, select curves on the bottom as shown below, click **Add Loop** and **Done** on RMB menu. Set **No. of Total Control Points** to **300** and change **Surface Type** to **Trimmed**, and click **Preview**.

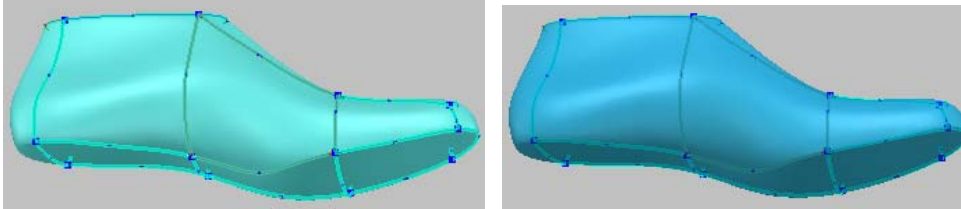


- Click **OK**.

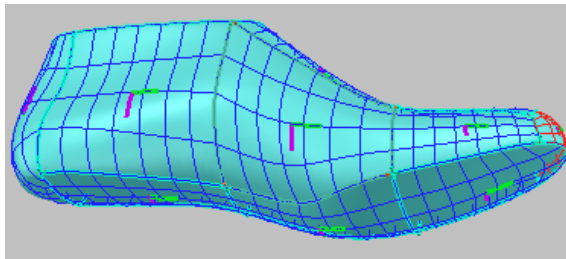
## Exercise 2: By Loops

*(Being continued)*

- Hide all curves and show all loops in project window.
- Select **Surface > Create > Polygon Fit > By Loops** menu, and select all loops with mouse drag. Click **Done** on RMB menu.

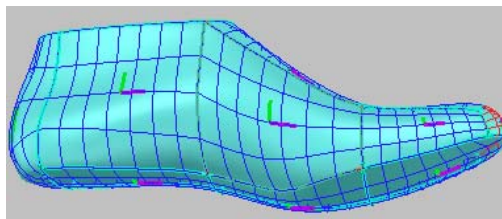


- Set **No. of U and V Control Points** to **7** and **10** each, click **Preview**.



(Violet axis: **U** direction, Green axis: **V** direction)

- Click **OK**.
- Delete all surfaces in project window.
- Repeat the above step2.
- Check **Swap UV axis** and **Use Loop Data** of **Loop Options**, and click **Preview**.



- Click **OK**.

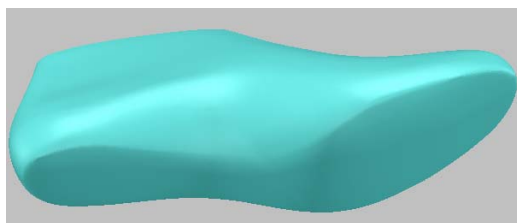


## Auto Surfacing

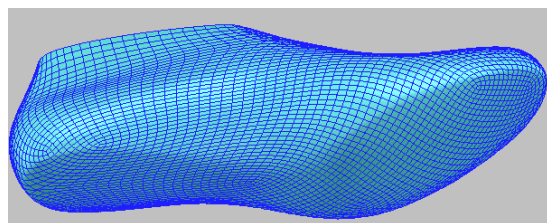
The Auto Surfacing operation automatically makes all patch boundaries and generates a watertight, smooth surface. You can determine patch count, boundary matching, and the amount of detail you want. If you select **Modify Patch Network** option, the application shows you quadrangular patch network based on a target patch count. A patch boundary is defined by four polylines traced on the polygonal surface. Pixform Pro provides several tools for editing a boundary layout and determining where the boundaries should be placed on the model. During editing a boundary layout, you can relax the patch network repeatedly until the boundaries are relaxed to the desired positions.

### **Exercise 1: No Reference Shell, Without Editing Patch Network**

1. Open “shoe\_auto\_input.mdl” under the “surface\_wb” folder.
2. Select **Surface > Create > Auto Surfacing** menu, pick the shell and itself as a reference shell.
3. Set **No. of Surfaces** and **No. of Control Points** to **100** and **10** each, and click **OK**.



Before auto surfacing

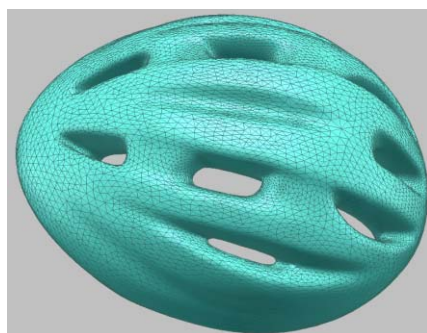


After auto surfacing

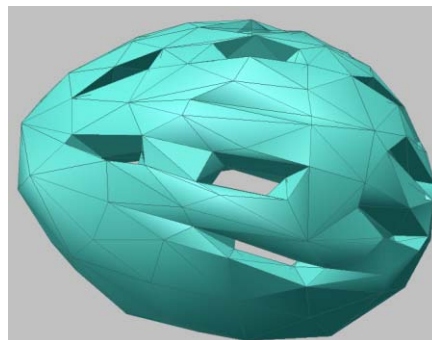
### **Exercise 2: Use Reference Shell, Without Editing Patch Network**

1. Open “helmet\_auto\_input.mdl” under the “surface\_wb” folder.
2. Duplicate the shell by pushing **Ctrl+C** and **Ctrl+V** keys.
3. Apply **Tool > Decimate > High Quality** to duplicate.
4. Reduce to **500** faces.

**NOTE:** *About 1000 patches of surface, double the number of polygon mesh, will be created.*



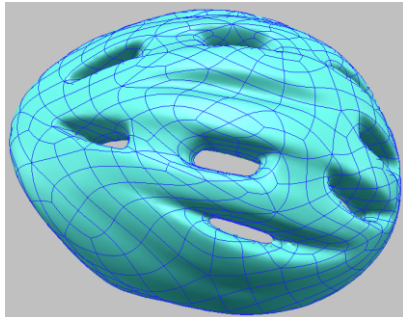
Original shell



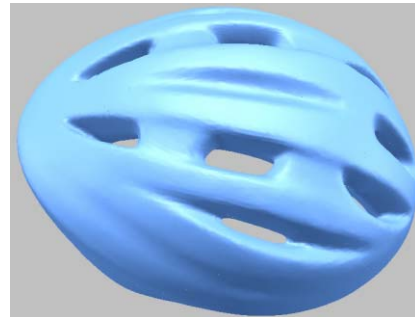
Duplicate decimated

5. Go to the Surface workbench.

6. Select **Surface > Create > Auto Surfacing** menu, pick the original shell and the duplicate as reference shell.
7. Click **OK** with default values.
8. Select **Surface > Options > Drawing Quality > Boundary Only** menu.
9. Render the surface by the hot key **R**, and hide all entities by pushing the hot keys **2, 4** and **6**.



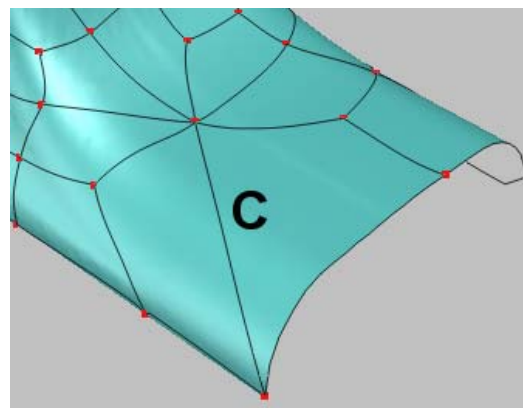
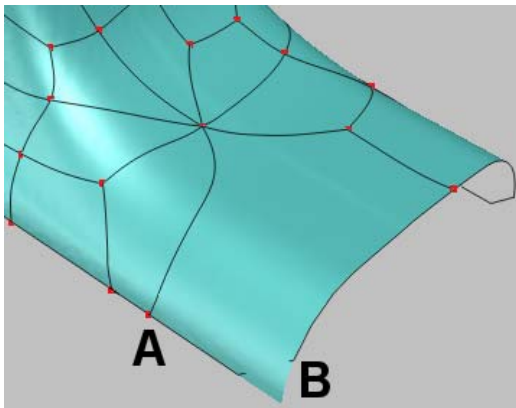
Surface boundaries



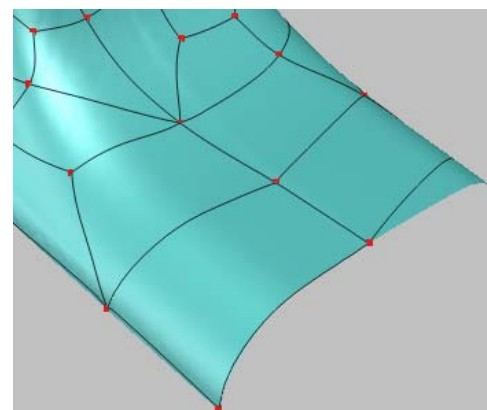
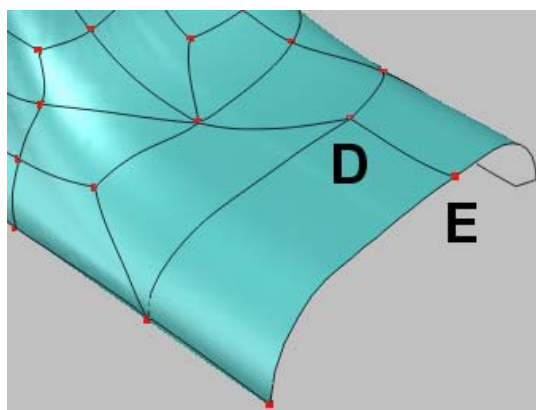
Rendering surface

### Exercise 3: No Reference Shell, With Editing Patch Network

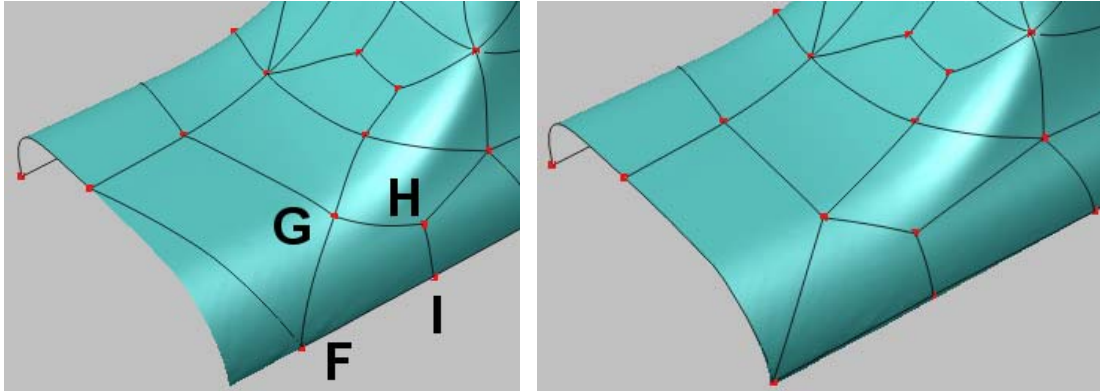
1. Open “duct\_auto.mdl” under the “surface\_wb” folder.
2. Click **Surface > Create > Auto Surfacing** menu and pick twice a shell.
3. Set **No. of Surfaces** and **No. of Control Points** to **300** and **10**, uncheck **Match Surfaces Globally**, check **Modify Patch Network**, and then click **OK**.
4. Select **Move Vertex** option in the dialog box and move a vertex “A” to “B” as below.



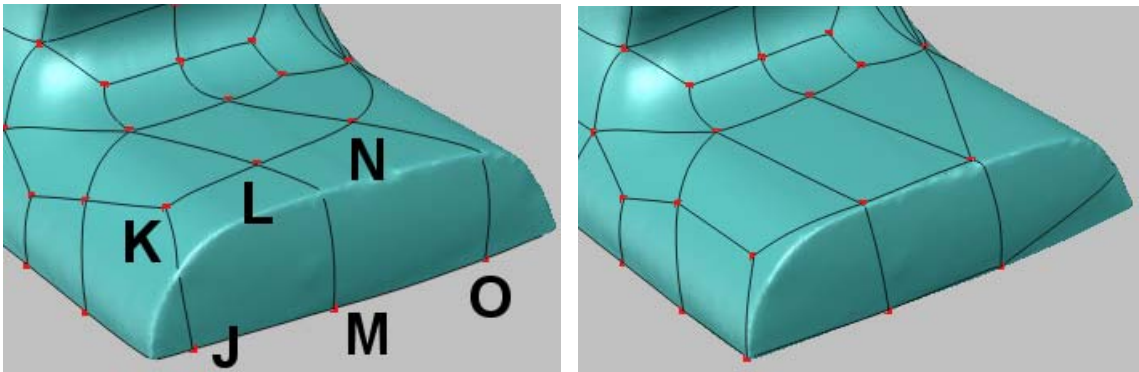
5. Select **Rotate Edge** option and pick two end points of an edge “C” twice. Select **Move Vertex** option and move two vertices “D” and “E” as below.



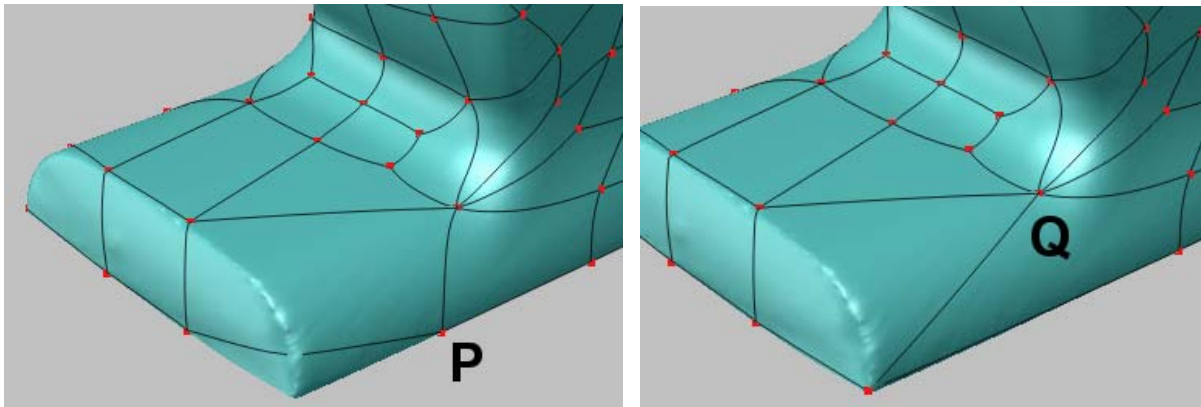
6. Change the viewpoint as below left and then select **Move Vertex** option and move four vertices “F”, “G”, “H” and “I” in order as below right.



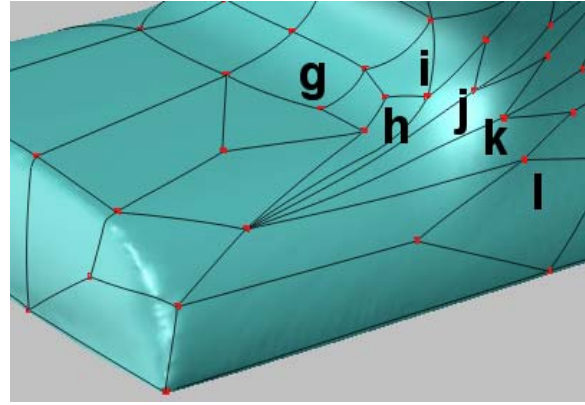
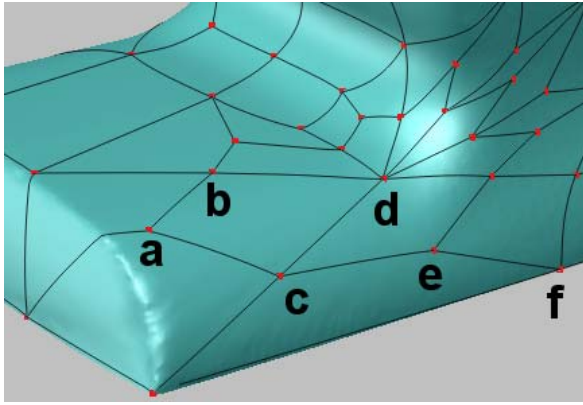
7. Change the viewpoint as below left and then select **Move Vertex** option and move a few vertices from “J” to “O” in order as below right.



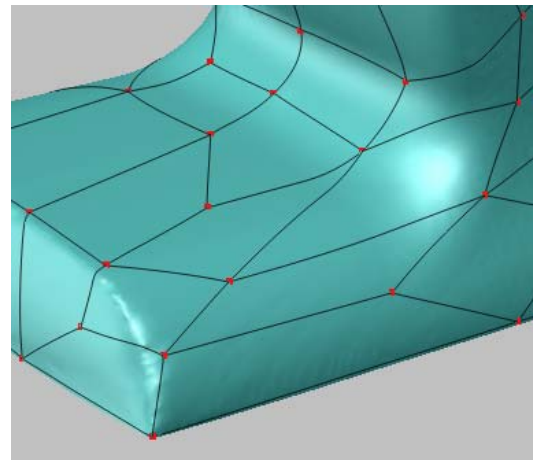
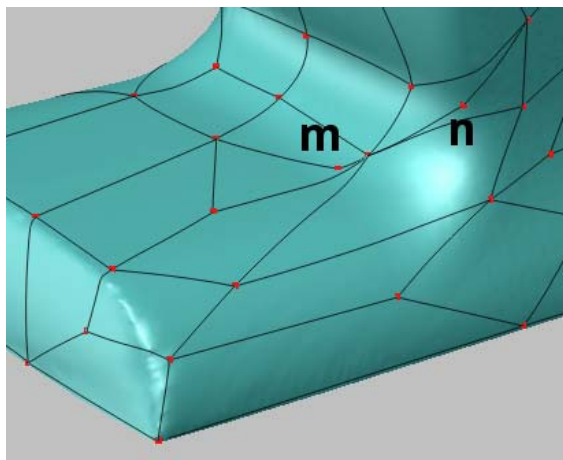
8. Change the viewpoint as below left and select **Move Vertex** option then move a vertex “P” as below right.



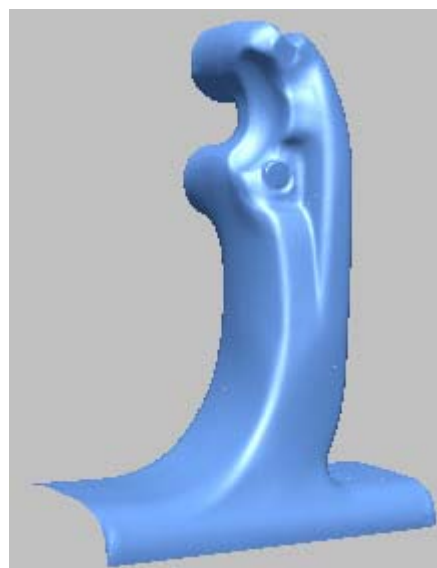
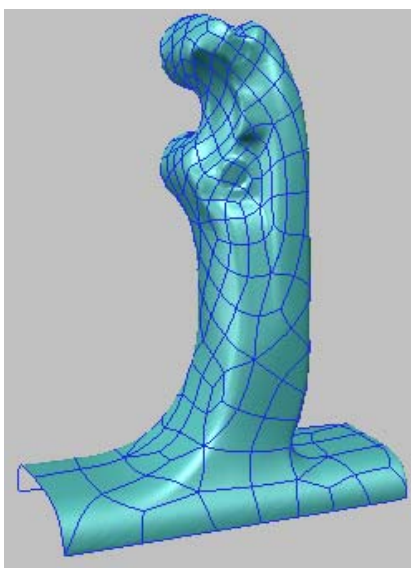
9. Select **Subdivide Vertex Star** option and pick a vertex “Q.” Select **Move Vertex** option and move a few vertices from “a” to “f” in order.



10. Select **Merge Vertex** option and pick some pairs of vertices “g” and “h”, “i” and “j”, and “k” and “l”. Select **Remove Vertex** option and pick two vertices “m” and “n.”



11. Press the RMB and click **Relax Patch Boundary** on it.
12. Click **OK** in the dialog box to finish this operation.
13. Click **Surface > Options > Drawing Quality > Boundary Only** menu.
14. Click **Surface > Options > Rendering Quality > High** menu, and push R key to render surface.

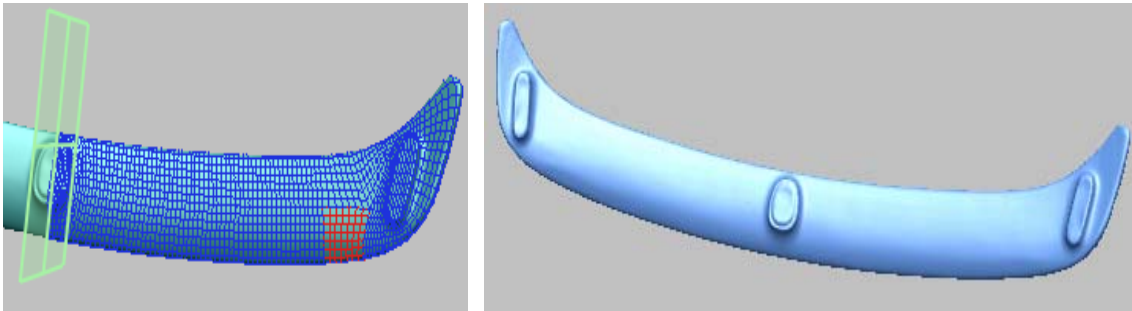


## Mirror

The Surface Mirror operation mirrors surfaces against a reference plane. This reduces the time and resources needed to surface a symmetrical object. The mirrored surfaces are space surfaces and are not attached to the shell.

### Exercise:

1. Open “mirror.mdl” under the “surface\_wb” folder.
2. Click **Surface > Create > Mirror** menu, and select all surfaces.
3. Click **Done** on RMB menu, and then select a center plane.
4. Render surface and hide all entities in the project window.

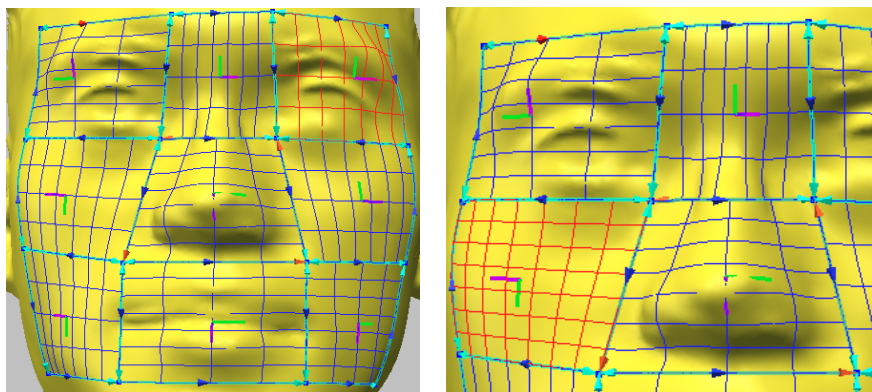


## Change UV & Propagate Isocurves

The Change UV operation changes or propagates UV axis directions of untrimmed patches. The Propagate Isocurves operation matches the isocurve number of two patches neighboring each other.

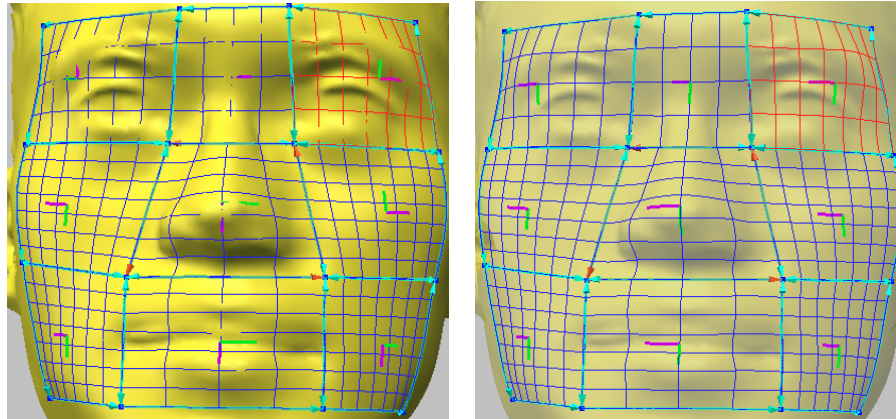
### Exercise:

1. Open “face\_loop.mdl” under the “surface\_wb” folder.
2. Select **Surface > Create > Polygon Fit > By Loops** menu, and select all loops by mouse drag. Click **Done** on RMB menu.
3. Set **No. of U and V Control Points** to **10** and **7** each, and click **OK**.
4. Select **Surface > Property > Show UV Axes** menu.
5. Select **Surface > Edit > Propagate Isocurves** menu, and pick first a patch in center and then pick a patch in its left.

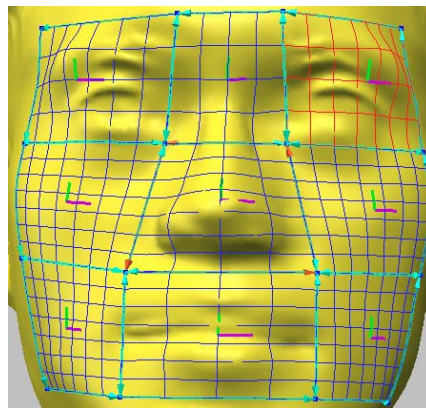


6. Repeat **Propagate Isocurves** operation for all surface patches.

7. Select **Surface > Edit > Change UV** menu, and select all patches by mouse drag.
8. Check in **Set All** option, and click **Change**.
9. Click **Change** again to propagate the direction of UV axes.
10. Click **OK** button.



11. Delete all surfaces in project window.
12. Select **Surface > Create > Polygon Fit > By Loops** menu, and select all loops.
13. Check in **Use Loop Data** option, and click **OK**.



**NOTE:** *Though surfaces of loops were deleted, you can recreate the previous structure of patches with Use Loop Data option.*

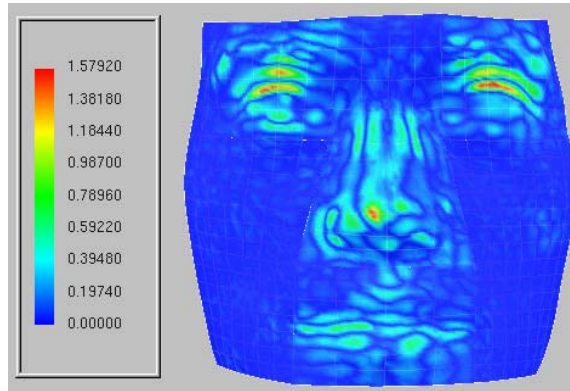
## Rebuild

The Surface Rebuild operation rebuilds the surface with the reassigned number of control points. This operation can be effectively used to minimize the gap distance between the surface and the polygon model as well as to make it easy to modify the surface.

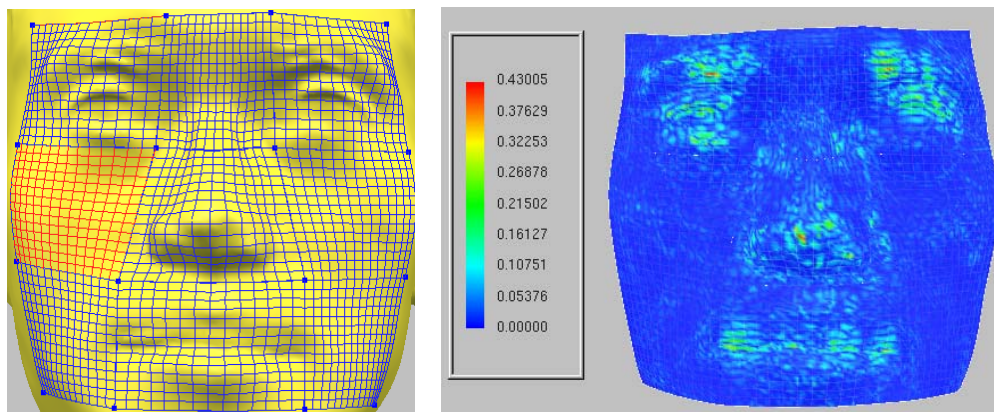
### **Exercise:**

*(Being continued)*

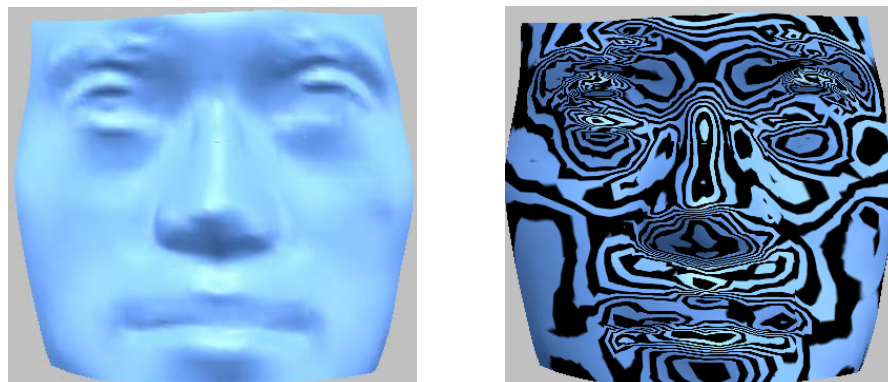
1. Evaluate the surface fitting accuracy by **Surface > Analysis > Surface/Shell Deviation**. Select all surfaces by mouse drag and click **Done** on RMB menu.



2. Select **Surface > Tool > Rebuild** menu, and select all surface patches by mouse drag. Click **Done** on RMB menu.
3. Set both of **No. of U and V Control Points** to **15**, check in **Preserve Continuity** option, and click **OK**.
4. Toggle off UV axes and hide all loops. Analysis the error deviation again.



5. Render surfaces, and hide all entities.
6. Show all surfaces by the hot key **5** and apply **Surface > Analyze > Environment Mapping**.



## Continuity & Match

Typically, you need two surface patches to have matching (or continuous) values of some sort where they meet. If the patches touch, there is positional continuity between them. If they slope in the same direction, there is tangent continuity. Tangent continuity depends on positional continuity. If two patches don't touch, they won't have tangent continuity with each other.

Continuity between patches may be interpreted geometrically or parametrically. In addition to specifying a geometric relationship, the parametric interpretation is more rigorous, requiring that the parameter values between the two patches be proportional. Parametric continuity is generally trivial to achieve once geometric continuity is established, since the parameter values of patches may be adjusted to any arbitrary range.

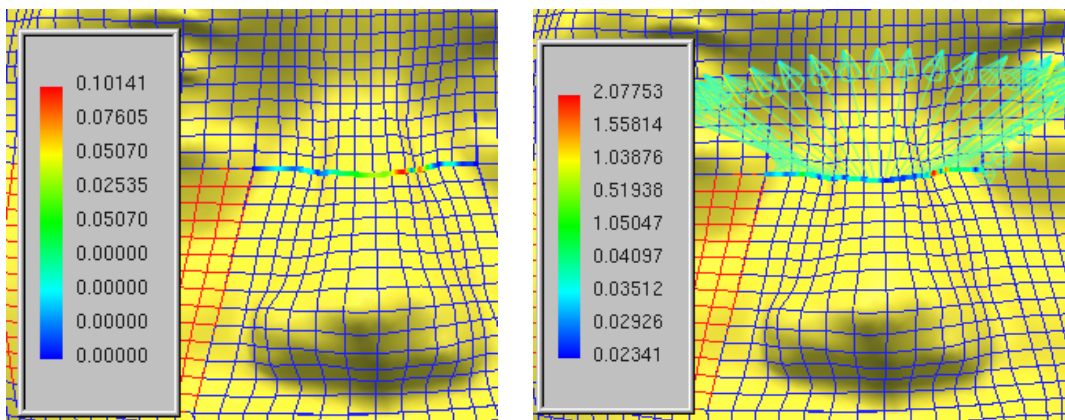
Specific abbreviations are used to describe continuity relationships depending on the desired continuity. Positional continuity (also known as zero-order continuity) is called G0 (Geometric) or C0 (Parametric). Tangent continuity (first-order) is called G1 or C1. Again, since cases of geometric continuity may normally be reparameterized to achieve parametric continuity, they are virtually equivalent.

The Surface Match operation supports two types of continuity, C0 and C1. C0 creates a watertight seam between surfaces by matching the control points along the seam, both in number and position. C1 creates a watertight seam that is also smooth by matching the control points along the seam and making the points on the surfaces tangent.

## Exercise:

*(Being continued)*

1. Select **Surface > Analysis > Check Continuity > Position** menu, and pick twice the boundary between two patches as shown below left.
2. Select **Surface > Analysis > Check Continuity > Tangency** menu, and pick twice the boundary between two patches as shown below right.



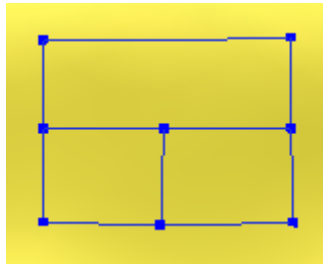
3. Select **Surface > Tool > Match** menu, and select all surfaces by mouse drag.
4. Click **Done** on RMB menu.
5. Click **OK** with **Tangency(C1)** option.
6. Analyze again the continuity.

## T-Junction Match

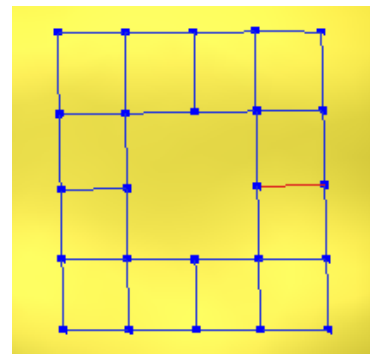
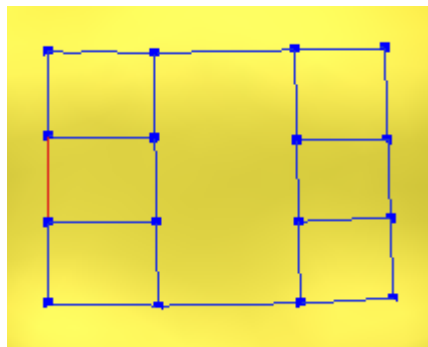
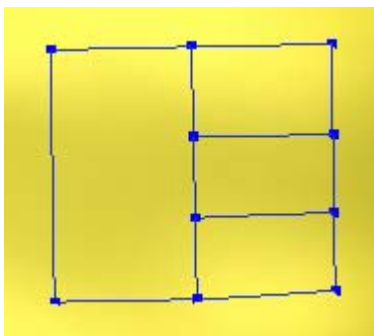
T-junctions occur when two or more patches are connected to one boundary of a surface patch. The T-Junction Match function gives you an ability to match untrimmed surfaces with T-junctions and to fit G1 or C1 continuous NURBS surfaces through these junctions. With T-junction capabilities, users are able to create the same curve network topology that they would create in their CAD system, preventing



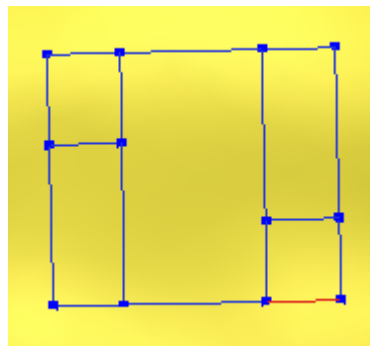
the creation of unnecessary curve segments that are produced by systems that only support networks of untrimmed patches.  
The simplest case of T-junction is below.



The T-Junction Match operation supports all kinds of T-junctions that an untrimmed patch has a corresponding patch on the opposite side for a T-junction patch. Some examples are below.



The below is the only unsupported case in which a T-junction patch doesn't meet at the corresponding position with another T-junction patch on the other side.



## Smooth

The Surface Smooth operation stretches surface to make a smooth shape. The boundary of the surface resulting from this operation can be disjointed from the adjacent surfaces. Thus, the disjointed surfaces can be matched again with the Match operation.

### **Exercise:**

*(Being continued)*

1. Select **Surface > Tool > Smooth** menu, and select all surfaces by mouse drag.
2. Set **Number of iterations** to **3** and turn off the check box of **Move Boundary Vertices**, and click **OK**.

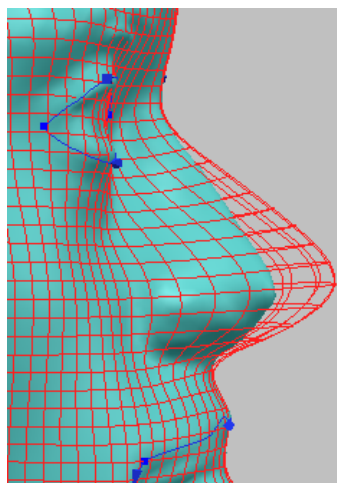
3. Compare the smoothness with the step 6 of the Rebuild operation above by **Surface > Analyze > Environment Mapping**.

## Apply To Shell

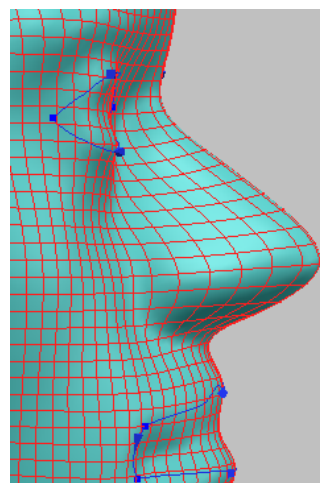
The Apply To Shell operation converts the surfaces into a polygonal shell through the tessellation process, and then combines the new polygon shell to the original shell. As a result, the original polygon surface has more smoothness.

### **Exercise:**

1. Open “face\_curve.mdl” under the “surface\_wb” folder.
2. Select **Surface > Tool > Apply To Shell** menu, and pick the deformed patch.
3. Click **OK** with default option.



Before applying to shell



After applying to shell

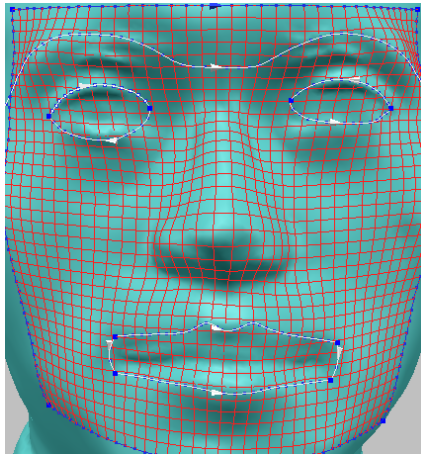
## Trim

The Surface Trim operations trims a surface by a closed curve loop or divides a selected untrimmed surface to two trimmed surfaces with a given curve. The Surface Untrim operation removes the trimmed boundaries of a trimmed surface. So you can reconstruct an untrimmed surface of a trimmed one.

### **Exercise:**

*(Being continued)*

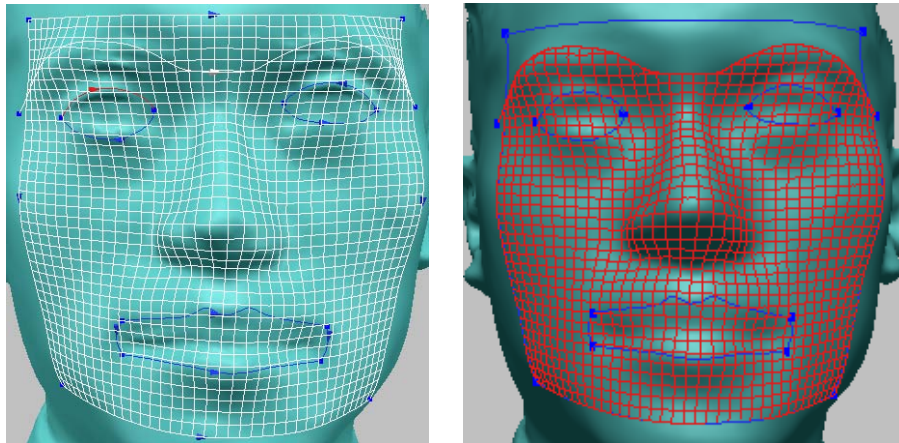
1. Show all curves by pushing the hot key **3**.
2. Go to the Curve workbench.
3. Select **Curve > Tool > Rebuild** menu, and select curves by mouse drag as shown below.



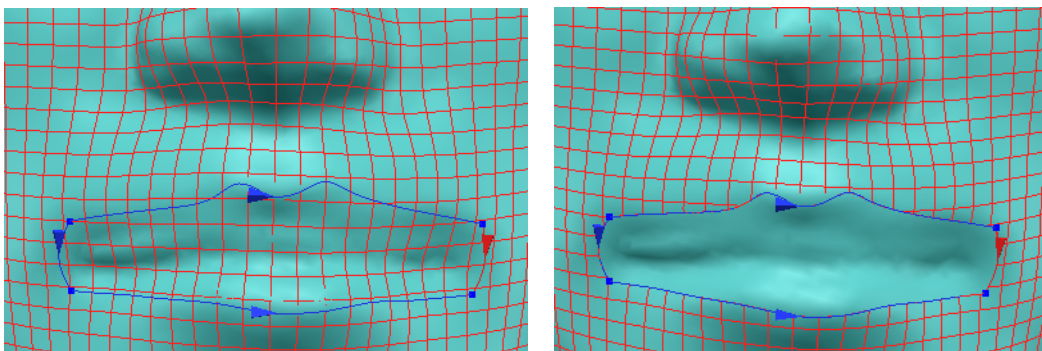
4. Click **Done** on RMB menu.
5. Check **Use existing interpolation points** option, and click **OK**.

**NOTE:** *You must refit all curves on polygonal surface before applying the surface trim operations because the polygon is refitted on the surface patch by Apply To Shell operation.*

6. Select **Surface > Trim > Divide** menu, and select a surface and a curve as below. At this time, the picked side of surface against the curve is remained.

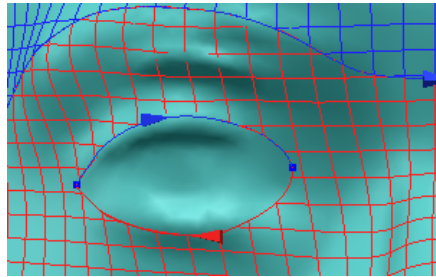


7. Select **Surface > Trim > Add Loop** menu, and pick a surface.
8. Pick closed curves with starting from an upper long curve as below.
9. Click **Done** on RMB menu.

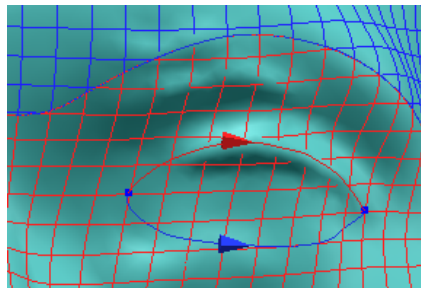


**NOTE:** *The isocurves in the left side of first selected curve are left after trimming. Selected curves should be closed but the selection order is not important.*

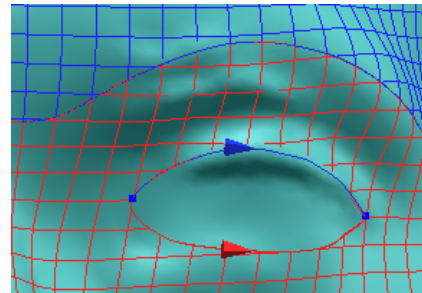
10. Apply **Surface > Trim > Add Loop** to the closed curves of left eye.



11. Apply same operation to the right eye, but inverse the direction of one of two curves to trim the inside of eye out.



Inversing of curve direction



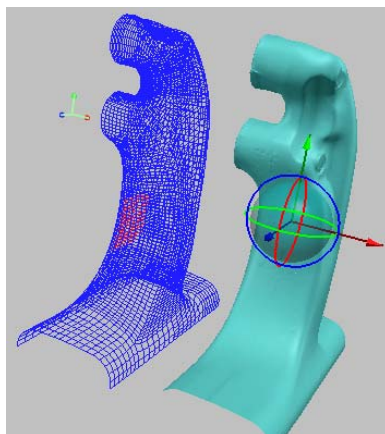
Trimming surface

## Detach Surface

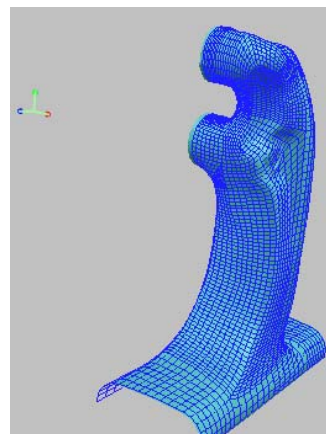
The Detach Surface operation disconnects surfaces from the shell that they connected. Then you can control surfaces independent of the shell.

### Exercise:

1. Open "duct.mdl" under "surface\_wb" folder.
2. Push **Ctrl+T** key, select "duct", and move it as shown below left.
3. Click **Done** on RMB menu.

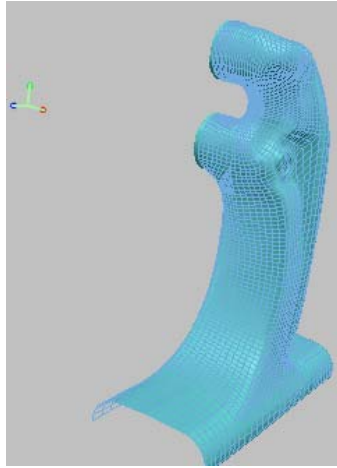


Shell Trackball

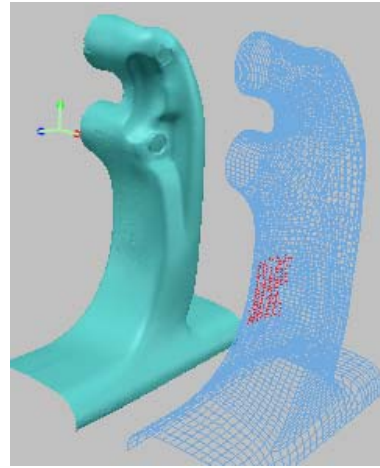


Transformed with surface

4. Click **Surface > Tool > Detach From Shell** menu, and select all surfaces.
5. Click **Done** on RMB menu. Apply **Shell Trackball** to the shell.



Detached surface



Transformed shell only

## 9. API

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The Pixform Pro API(Application Programming Interface) is an OLE (Object Linking and Embedding) programming interface to Pixform Pro. The API contains hundreds of functions that you can call from Visual Basic, VBA (Excel, Access, etc.), C++, Java, or Pixform Pro macro files. These functions provide direct access to Pixform Pro functionality. **Note that Pixform Pro API is compatible to RapidForm API.**

### Automation

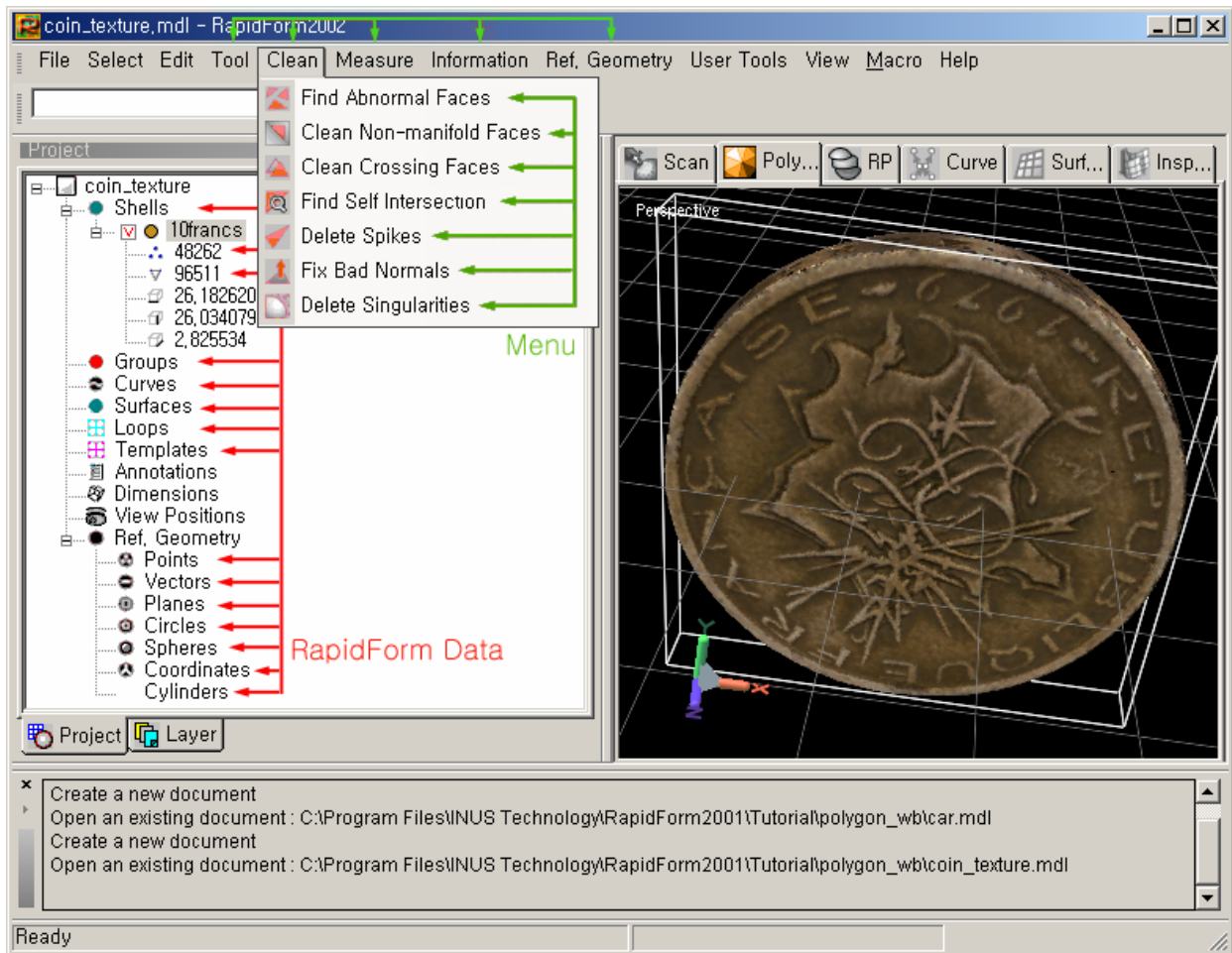
Automation (formerly called OLE Automation) is a technology that allows software packages to expose their unique features to scripting tools and other applications. Automation allows applications to communicate, exchange data, and control one another. It allows a client application to create and control an object, using the exposed object's interface. An Automation object is an object that is exposed to other applications or programming tools through Automation interfaces. Automation uses the Component Object Model (COM), but may be implemented independently from other OLE features, such as in-place activation.

Using Automation,

- \* Create applications and programming tools that expose objects.
- \* Create and manipulate objects exposed in one application from another application.
- \* Create tools that access and manipulate objects. These tools can include embedded.

### Automation in Pixform Pro

Pixform Pro APIs are designed based on Automation. This means that user can access Pixform Pro objects and reuse Pixform Pro codes to develop their own functions and applications. This is a great benefit to Pixform Pro users to customize Pixform Pro according to their purpose. Most of fundamental Pixform Pro Objects like shell, vertex, face, curve, and surface are accessible through automation. In addition to it, Pixform Pro made a lot of powerful functions as OLE objects, which are grouped as curve tools, surface tools, mesh tools, point tools, select tools, reference geometry tools, and draw tools. Pixform Pro have integrated Visual Basic for Application, so you don't need to use a separate development environment to write your programs. However, you can write programs that control the Pixform Pro engine in any language that supports Automation. For example, you can create and edit simple macros that can replace series of menu clicking and even insert powerful functions that are not in menus in Visual Basic editor. If you are familiar with MS office automation, you can understand the power of automation. You can create independent executable application that can use Pixform Pro data structure and functions combined with other applications objects instead of writing a code from a scratch.



Pixform Pro API supports all of Pixform Pro core data structure and most of menu as Automation objects.

## Solutions Using Pixform Pro APIs

### **(1) Simplification of work process**

If you have a series of tasks that you perform over and over again in Pixform Pro, you can automate these tasks in Pixform Pro by using macros. A macro is a set of computer instructions that you can record and associate with a shortcut key combination or a macro name. Then, when you press the shortcut key combination or click the macro name, your computer program carries out the instructions of the macro. This saves you time by replacing an often-used, sometimes lengthy series of actions with a shorter action. For example, instead of clicking several menus and buttons to manipulate your models in Pixform Pro, you can record those steps in a macro and then just click the macro to change the model as you intend in one step. Pixform Pro lets you automate not only keystrokes, but also most of the actions you can perform in Pixform Pro.

### **(2) Creation of new functions**

Pixform Pro support OLE automated APIs, with which you can write your own codes that does special functions for you. You can record or write macros to make Pixform Pro perform a series of related actions that are available on menus or toolbars. In addition to it, you can write code by hand to make Pixform Pro perform actions that aren't available on menus or toolbars. Pixform Pro supports about 800 APIs. Some

of the APIs does the same functions as those in menu, but many of the APIs support creating basic entities like vertices, triangles and nurbs, and also support high-end functions like triangulation and decimation. For example, you can make a new function of importing a special file format. You can parse the file with your algorithm and add vertices and triangles to Pixform Pro.

### **(3) Development of independent applications**

OLE automated APIs enable you to create stand-alone applications that use Pixform Pro functions. Solutions built with Pixform Pro are developed and deployed more quickly than those built from scratch. Developers can reuse the power and functionality of the host application and develop solutions with any computer languages that support OLE automated API.

## **Macro Menu**

Macro menu provides commands for managing addins and creating, editing and managing macros.

If you have a series of tasks that you perform over and over again in Pixform Pro, you can automate these tasks in Pixform Pro by using macros. A macro is a set of computer instructions that you can record and associate with a shortcut key combination or a macro name. Pixform Pro contains Visual Basic for Application module (VBA). Using this VBA, user can create and edit macros.

### **Addin Manager...**

Macro > Addin Manager... command displays the Add-in manager dialog. If a user has installed any add-ins, this dialog provides all available addins. For each addin, user can set Loaded/Unloaded, Load on Startup and Command Line options.

## **Addins**

Macro > Addins show all the loaded addins. A user can execute any loaded addins by selecting it on this menu.

Pixform Pro API supports about 800 functions, which are designed based on OLE automation. Using these APIs, user can develop custom functions and register it as addins.

## **Macros**

Macro > Macros command displays the Pixform Pro macro dialog. A user can run, edit and even debug existing macros and create new macros.

## **Record**

Macro > Record command provides commands to record macros. In Pixform Pro, this command is supported only for the following operations:

*Triangulate 2D, Register Fine, Merge Shells, Smooth Shell/Region, Decimate Shell/Region/LargeShell, Subdivide Shell/Region, Remesh Global/Local, Shrink Shell/Region, Divide/Mirror, Offset, Separate Clusters, Thicken Shell, Fit Shell To PointCloud/Meshes*



- Macro > Record > Start command starts recording a macro. This macro is saved in 'ThisDocument' in the current project.
- Macro > Record > Pause command pauses recording the macro for a while.
- Macro > Record > Resume command continues recording the macro.
- Macro > Record > Stop command finishes recording the macro.
- Macro > Record > Run command runs the recorded macro.

### **Visual Basic Editor**

Macro > Visual Basic Editor command displays Visual Basic for Application editor integrated into Pixform Pro. Pixform Pro provides an integrated development environment for convenient development of VBA projects.

Most of Pixform Pro data can be access as objects in Visual Basic. Therefore, a user can combine power and functionality of VBA with Pixform Pro.

User can make form based macros in addition to simple macros.

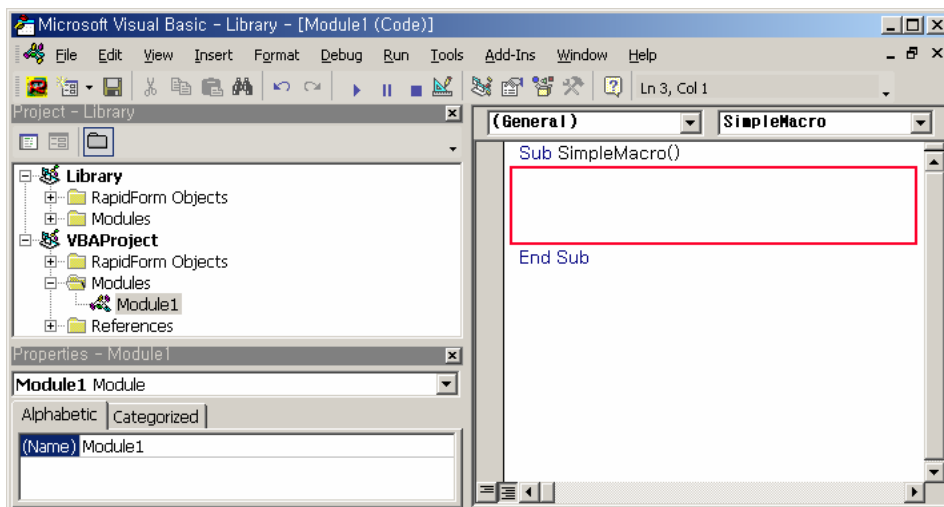
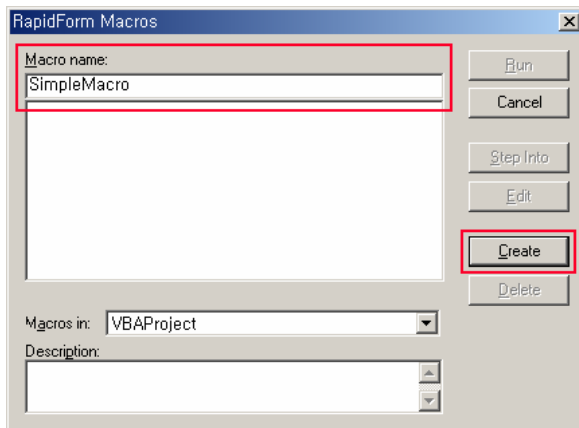
## **Simple Macro Creation**

If you have a series of tasks that you perform over and over again in Pixform Pro, you can automate these tasks in Pixform Pro by using macros. A macro is a set of computer instructions that you can record and associate with a shortcut key combination or a macro name. Then, when you press the shortcut key combination or click the macro name, your computer program carries out the instructions of the macro.

Let's make a simple macro. For this example, let's say that you want to make a complete model from a few scan data of point clouds taken from different viewpoints. First, you have to import all scan data to Pixform Pro and convert the point clouds to polygon surfaces as a pre-process for registration. Converting point clouds to polygon surfaces requires a series of Pixform Pro functions. You can make it as a single command by creating a macro.

### **Exercise:**

1. Open 'venus\_point.mdl' under 'scan\_wb' folder.
2. On the Macro menu in Pixform Pro, click **Macros...** This displays the **Pixform Pro Macros** dialog box.
3. Input the name of a new macro in **Macro name** box and click **Create**. Here, type 'SimpleMacro' for the new macro name. This displays the **Visual Basic editor**.
4. Write your code between *Sub SimpleMacro()* and *End Sub*. This macro will be located in VBAProject->Module1 as SimpleMacro.



5. Write the following codes to convert point clouds to polygon surfaces.  
(This codes are included to the "SimpleMacro.bas" file in the "Tutorial/API" directory)

```

01 Dim err As RFErroRCode
02 Dim sh As RapidForm.RFShell
03 Dim shID() As RFEntityID

04 Set sh = RapidForm.Application.Shell
05 nSh = Document.GetShellCount
06 ReDim shID(nSh)
07 dummy = model.EnumShells(shID(0))

08 For i = 0 To nSh - 1
' Scan Mode: Build -> Filter Noise
09   err = PointTools.FilterNoisePoints(shID(i), True, 0, 100)
10   If err <> RF_SUCCESS Then
11     MsgBox "Error while running Filtering Noise. Code Number is:" & err
12     Exit Sub
13   End If
14   Document.RegenShell shID(i)

' Scan Mode: Build -> Triangulate -> 2D
15   err = PointTools.Triangulate2D(shID(i), RF_TRIANGULATE_DIRECTION_MINUS_Z, 13, 0, 0, 0)
16   If err <> RF_SUCCESS Then
17     MsgBox "Error while running Triangulating Points. Code Number is:" & err
18     Exit Sub
19   End If
20   Document.RegenShell shID(i)

21 Next

```

01: Every Pixform Pro APIs return an error code as a type of RFErroRCode.

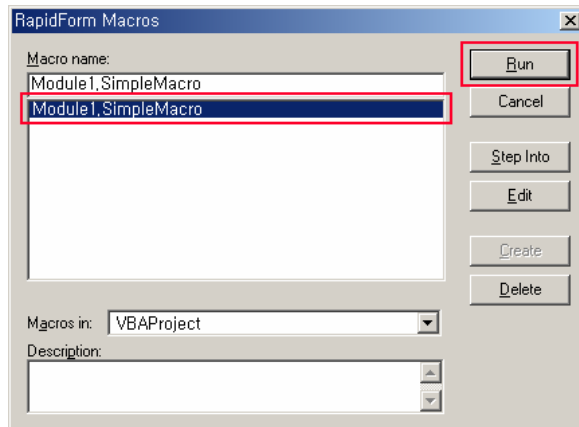
04: Pixform Pro shell objects can be accessed only through the shell instance in Application.

07: All the entities in Pixform Pro have unique ID. All the shell IDs in current model can be obtained by passing the first element of RFSHELL array.

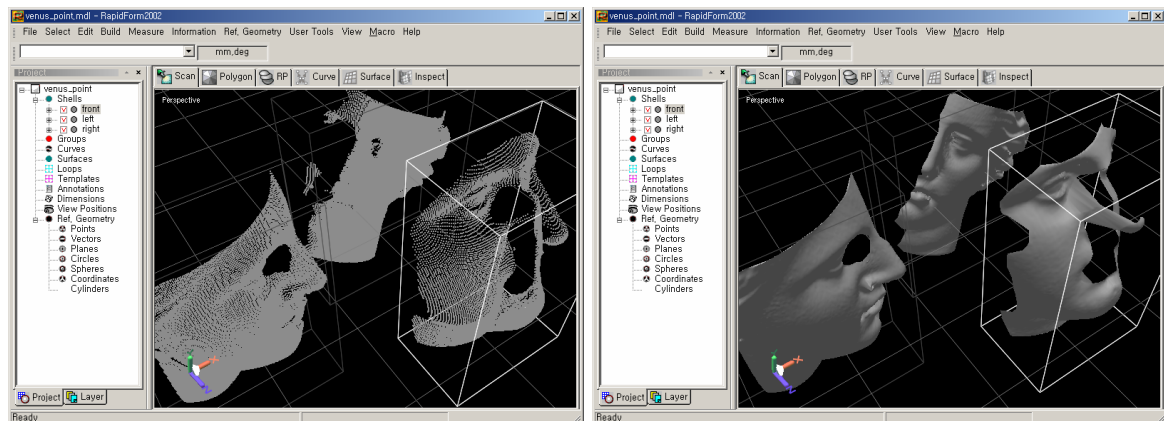
10: If Pixform Pro API is completed successfully, it returns RF\_SUCCESS constant.

14: When a core data has been modified, all shells must be regenerated. This operation updates not only Pixform Pro core data but also the project tree.

6. To run this macro, select **Module1.SimpleMacro** in **Pixform Pro Macros** dialog box. Click **Run** to execute this macro for the current model.



7. To display shaded images, push F4 key.

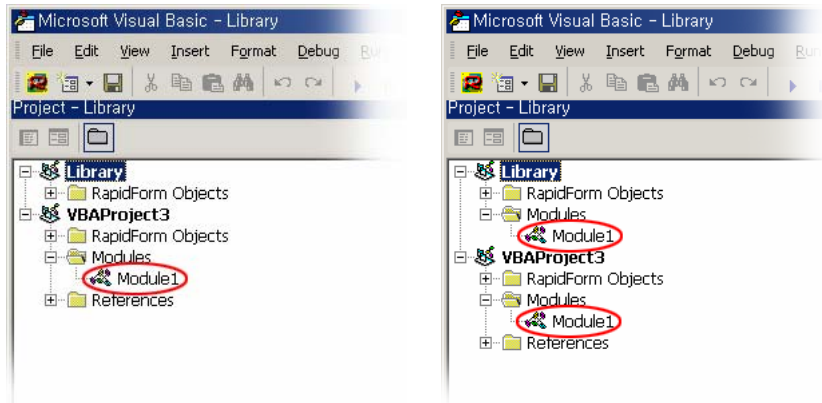


## [Global Macro Creation in Pixform Pro](#)

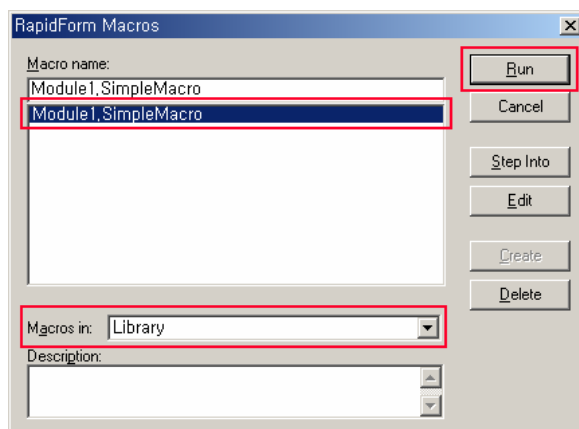
The SimpleMacro macro of the previous example is attached to the model file. Therefore, it cannot be used in other models. To solve this problem, Pixform Pro supports a global macro library. You can find global macros in the **Library project** in Project pane of Visual Basic editor. The macros in the **Library project** can be called regardless of model files and is stored in a separate file named '**RFDefaultMacro.mcr**' under Pixform Pro root directory. In this example, we make the SimpleMacro macro in 'venus\_point.mdl' file as a global macro.

### **Exercise:**

1. Open 'venus\_point.mdl' under 'scan\_wb' folder. (Previous exercise should be done first)
2. On the **Macro** menu in Pixform Pro, click **Visual Basic Editor**.
3. You can see SimpleMacro in **VBAProject** project in the Project pane. Use drag and drop to copy the SimpleMacro to **Library project**.



4. To run this global macro, change **Macros in** as **Library** and select **Module1.SimpleMacro** in **Pixform Pro Macros** dialog box. Click **Run** to execute this macro for the current model.



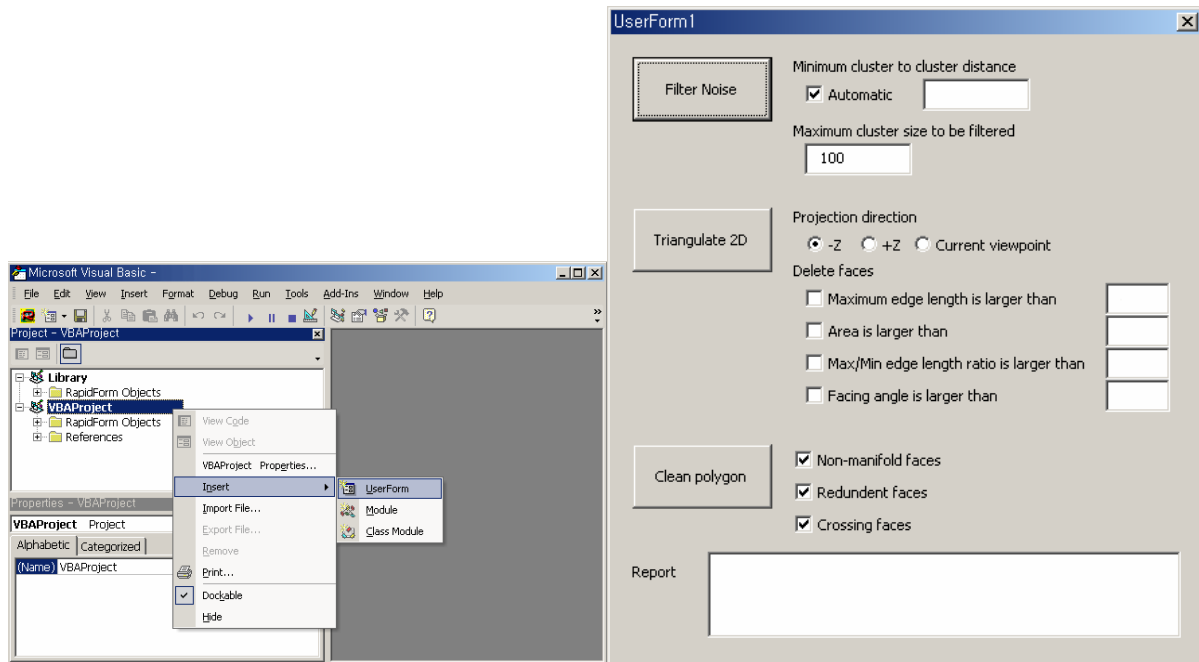
## Form-Based Macro Creation

Pixform Pro has integrated Visual Basic for Application (VBA) to create and edit macros in Pixform Pro edition. This environment enables user to combine the power and functionality of VBA with Pixform Pro functions to customize Pixform Pro. User can make a form like in Visual Basic and use objects all the time—controls such as command buttons, user forms, databases, and fields. In this example, we will make the previous example as a form-based macro and add a clean polygon function.

### **Exercise:**

1. Open 'venus\_point.mdl' under 'scan\_wb' folder.
2. On the **Macro** menu in Pixform Pro, click **Macros...** This displays the **Pixform Pro Macros** dialog box.
3. Input the name of a new macro in **Macro name** box and click **Create**. Here, type 'FormMacro' for the new macro name. This displays the Visual Basic editor.

4. Insert a **UserForm** in **VBAProject** and create layout buttons. Each control's type and property setting is shown in the table below.



Control Type	Property	
CommandButton	Name	btnFilterNoise
	Caption	Filter noise
CommandButton	Name	btnTriangulate2D
	Caption	Triangulate 2D
CommandButton	Name	btnCleanPolygon
	Caption	Clean Polygon
Label	Name	lblFilterNoise01
	Caption	Minimum cluster to cluster distance
Label	Name	lblFilterNoise02
	Caption	Maximum cluster size to be filtered
Label	Name	lblTriangulate2D01
	Caption	Projection direction
Label	Name	lblTriangulate2D02
	Caption	Delete faces
Label	Name	lblReport
	Caption	Report
CheckBox	Name	checkboxFNAutomatic
	Caption	Automatic
	Value	True
CheckBox	Name	checkboxT2DMaxEdgeLen
	Caption	Maximum edge length is larger than
CheckBox	Name	checkboxT2DArea
	Caption	Area is larger than
CheckBox	Name	checkboxT2DEdgeLenRatio
	Caption	Max/Min edge length ratio is larger than
CheckBox	Name	checkboxT2DFaceAngle
	Caption	Facing angle is larger than
CheckBox	Name	checkboxCPNonManifold
	Caption	Non-manifold faces
	Value	True
CheckBox	Name	checkboxCPRed
	Caption	Redundent faces

	Value	True
CheckBox	Name	chkboxCPCross
	Caption	Crossing faces
	Value	True
OptionButton	Name	optbtnT2DMZ
	Caption	-Z
	Value	True
OptionButton	Name	optbtnT2DPZ
	Caption	+Z
OptionButton	Name	optbunT2DCV
	Caption	Current Viewpoint
TextBox	Name	txtboxFNDist
TextBox	Name	txtboxFNMaxSize
	Value	100
TextBox	Name	txtboxT2DmaxEdgeLen
TextBox	Name	txtboxT2DArea
TextBox	Name	txtboxT2DEdgeLenRatio
TextBox	Name	txtboxT2DFaceAngle
TextBox	Name	txtboxReport
	Multiline	True

5. On the **View** menu in **Visual Basic editor**, click **Code** to insert the following codes in the **UserForm** created in the previous step. (The following codes are included to the "UserForm1.frm" file in the "Tutorial/API" directory)

```

Dim err As RFErroRCode

Private Sub btnFilterNoise_Click()
    Dim curShell As RFEntityID
    err = SelectTools.GetCurrentShell(curShell)
    If chkboxFNAutomatic.Value = True Then
        err = PointTools.FilterNoisePoints(curShell, True, 0, txtboxFNMaxSize.Value)
    Else
        err = PointTools.FilterNoisePoints(curShell, False, txtboxFNDist.Value, txtboxFNMaxSize.Value)
    End If

    If err <> RF_SUCCESS Then
        txtboxReport.Value = txtboxReport.Value & Chr(13) & Chr(10) & _
            "Error while running Filter Noise. Code Number is:" & err
        Exit Sub
    Else
        txtboxReport.Value = txtboxReport.Value & Chr(13) & Chr(10) & _
            "FilterNoise is applied successfully."
    End If

    Document.RegenShell curShell
End Sub

Private Sub btnTriangulate2D_Click()
    Dim curShell As RFEntityID
    Dim direction As RFTriangulateDirection
    Dim length As Double, area As Double, ratio As Double, angle As Double

    err = SelectTools.GetCurrentShell(curShell)
    If optbtnT2DMZ.Value = True Then
        direction = RF_TRIANGULATE_DIRECTION_MINUS_Z
    ElseIf optbtnT2DPZ.Value = True Then
        direction = RF_TRIANGULATE_DIRECTION_PLUS_Z
    Else
        direction = RF_TRIANGULATE_DIRECTION_CURRENT_VIEW
    End If

    If chkboxT2DMaxEdgeLen.Value = True Then
        length = txtboxT2DMaxEdgeLen.Value
    Else
        length = 0
    End If

```

```

End If

If chkboxT2DArea.Value = True Then
    area = txtboxT2DArea.Value
Else
    area = 0
End If

If chkboxT2DEdgeLenRatio.Value = True Then
    ratio = txtboxT2DEdgeLenRatio.Value
Else
    ratio = 0
End If

If chkboxT2DFaceAngle.Value = True Then
    angle = txtboxT2DFaceAngle.Value
Else
    angle = 0
End If

err = PointTools.Triangulate2D(curShell, direction, length, area, ratio, angle)

If err <> RF_SUCCESS Then
    txtboxReport.Value = txtboxReport.Value & Chr(13) & Chr(10) & _
        "Error while running Triangulating Points. Code Number is:" & err
    Exit Sub
Else
    txtboxReport.Value = txtboxReport.Value & Chr(13) & Chr(10) & _
        "Triangulate2D is applied successfully."
End If

Document.RegenShell curShell
CheckPolygon
End Sub

Function CheckPolygon()
    Dim curShell As RFEEntityID
    Dim countNon As Long, countRed As Long, countCross As Long
    err = SelectTools.GetCurrentShell(curShell)

    err = MeshTools.FindAbnormalFaces(curShell, True, True, True, countNon, countRed, countCross)
    If err <> RF_SUCCESS Then
        txtboxReport.Value = txtboxReport.Value & Chr(13) & Chr(10) & _
            "Error while running abnormal face search. Code Number is:" & err
        Exit Function
    Else
        txtboxReport.Value = txtboxReport.Value & Chr(13) & Chr(10) & _
            "----- Abnormal faces in current shell -----" & Chr(13) & Chr(10) & _
            "- Non-manifold faces : " & countNon & Chr(13) & Chr(10) & _
            "- Redundent faces : " & countRed & Chr(13) & Chr(10) & _
            "- Crossing faces : " & countCross
    End If

    Document.RegenShell curShell
End Function

Private Sub btnCleanPolygon_Click()
    Dim curShell As RFEEntityID
    Dim countNon As Long, countRed As Long, countCross As Long
    err = SelectTools.GetCurrentShell(curShell)

    err = MeshTools.FindAbnormalFaces(curShell, True, True, True, countNon, countRed, countCross)
    err = MeshTools.CleanAbnormalFaces(curShell, chkboxCPNonManifold.Value, _
        chkboxCPRed.Value, chkboxCPCross.Value)

    If err <> RF_SUCCESS Then
        txtboxReport.Value = txtboxReport.Value & Chr(13) & Chr(10) & _
            "Error while running Clean Polygon. Code Number is:" & err
        Exit Sub
    Else
        txtboxReport.Value = txtboxReport.Value & Chr(13) & Chr(10) & _
            "Clean Polygon is applied successfully."
    End If

    Document.RegenShell curShell

```

```
CheckPolygon  
End Sub
```

6. To make **FormMacro** macro to display the **UserForm**, type the following codes in **FormMacro** function.

(This codes are included to the “Module1.bas” file in the “Tutorial/API” directory)

```
Dim myForm As UserForm1  
Set myForm = New UserForm1  
Load myForm  
myForm.Show
```

7. To run this macro, select **Module1.FormMacro** in **Pixform Pro Macros** dialog box. Click **Run** to execute this macro for the current model.



# 10. Hardware

---

Pixform Pro supports external hardware devices that can help in the modeling process: the Magellan/SpaceMouse®.

## Space Mouse

The Magellan/SpaceMouse® is a device similar to a joystick in purpose, but it also provides movement control with 6 degrees of freedom. Pull up or push down to move your model, eye point up or down. Push left or right to move your model left or right. Pull towards you or push away to move your model nearer or farther away. Orient your model on the screen by simply twisting in any direction to rotate it around the X, Y or Z axis (pitch, roll, yaw). With this 3D motion controller, you can intuitively zoom, pan and rotate models, exploring and navigating your designs as naturally as if they were objects in the real world.



Pixform Pro allows you to control eight (1~8) programmable buttons of the 3D motion controller. It can be performed by the **Customize Magellan** command of the **View** menu. To map a function to any buttons, just click that function in the menu toolbar after selecting the corresponding button.

# 11. Appendix

This appendix lists all the commands available in the basic platform without any license key.

## Basis Command List

The following is the table of commands available in Pixform Pro Basis (Basic platform). You can execute the following commands, though you don't have any license for Pixform Pro.

Menu	Command	
<b>File</b>	New Open Save Save As Save As Default MDL Import Publish ICF Page Setup Print Preview Print Preferences Summary Info Recent Files Exit	
<b>Select</b>	Entities  Custom Region Flood Fill All None Inverse Boundary Vertices Boundary Faces Vertices Around Faces Around Enlarge  Shrink One Depth From Selected Vertices From Selected Faces Mode  Option	Vertex/Face/Shell Curve/Surface/Loop Line on Section Deviation   Curves/Surfaces Curves/Surfaces One Depth Feature region > Face Normal/Face Curvedness  Line Rectangle Circle Polyline Freehand Paint Brush Select Visible Only

		Select Through Active Shell Only Set Brush Size
<b>Edit</b>	Delete  Transform Material	Vertex/Face/Shell Section Deviation Note/Annotation/GT/Dimension Shell Trackball
<b>Information</b>	Vertex Face Region Shell Model Curve Loop Template Surface Ref. Geometry Show Boundaries Shown Whole Deviation Section Deviation Loop in Section Deviation Annotation Geometric Tolerance Dimension Check Interference Note  Report Information	Add Edit Move Delete Show All Hide All Slant Line Plumb Line Add Note
<b>Measure</b>	Distance  Radius  Angle  Cross Section Shell/Shell Deviation Curvature Plot Environment Mapping	Point/Point > Along Line/Along Surface Point/Ref. Vector Point/Ref. Plane Ref. Plane/Ref. Plane Perimeter > Point & Plane/Points Circle (3 Points) Sphere (4 Points) Rounded Area Radius Ref. Plane/Ref. Plane Ref. Plane/Ref. Vector 3 Points 2 Vectors Shell/Model

	Auto Measuring Face Angle Plot Contour Lines	Shell/Model
<b>Ref. Geometry</b>	Delete	
<b>View</b>	Zoom Window Zoom Previous Zoom to Fit Set Working Region Explode Shells Reset Set Trackball Center Reset Trackball Center Shading Method Display Mode  View Point Add Current View Bounding Box Axis Grid Skins  Customize Color Bar Customize Font	Flat/Smooth/Point/Depth Cueing/Phong Shading Point Set/ Wireframe Hidden Line/ Shaded Shaded With Edges/ Transparent Textured Front/Back/Left/Right/Top/Bottom/Iso  Window Default/ Office XP Mac/ Funny/ User Image  Small Text/Large Text
<b>Help</b>	Pixform Pro Help Pixform Pro API Help Pixform Pro Tutorials OpenGL Information Request License About Pixform Pro	
<b>Curve</b>	Delete Property	Show All/Hide/Hide All Show Control Points Show/Hide with Shell Show Direction Show Node
<b>Loop</b>	Delete Property Options	Show All/Hide/Hide All Show Direction
<b>Surface</b>	Delete Property  Options	Render Show All/Hide/Hide All Show Control Points Show Edges Show UV Axes Show/Hide with Shell Rendering Quality > High/Mid/Low Drawing Quality > High/Mid/Low/Boundary Only

		Quick Rendering
<b>Template</b>	Delete Property Options	Show All/Hide/Hide All
<b>Inspection</b>	Whole Deviation	Hide All Delete All Delete Shown
	Section Deviation	Show All Hide All Delete All Delete Shown
	Annotation	Large Annotation Small Annotation Show Name Slant Line Plumb Line
	Geometric Tolerance	Show/Hide With Deviation Show All Hide All Slant Line Plumb Line Show Graphical Display Show Name
	Dimension	Show/Hide With Deviation Show All Hide All Show Name Show/Hide With Deviation
<b>Solid</b>	Property	Show All Hide Hide All
	Delete	Show/Hide With Shell

## 12. Glossary

---

The following sections define many of the basic terms and concepts you should know in order to use Pixform Pro effectively.

### A

#### **ACIS**

A component software that provides a solid modeling "engine" (also called "kernel") used by many commercial and research organizations as the core of CAD/CAM/CAE applications. Creates models in the SAT format. (Note: ACIS is not an acronym). (Spatial Technology Corp.)

#### **Anti-aliasing**

Anti-aliasing is sub pixel interpolation, a technique that makes edges appear to have better resolution.

#### **API**

API (Application Programming Interface) is a series of functions that programs can use to make the operating system do their dirty work. It serves as a software interface to be used by other programs.

#### **Aspect Ratio**

Ratio of width to height

### B

#### **Bezier Curve(Surface)**

A smooth curve controlled by three or more control points. The Bezier curve always intersects the first and last control point, but is usually only influenced by the others. The Bezier surface is an extension of the Bezier curve. Named after its inventor, Pierre Bézier, a CAD system designer in France.

#### **Bitmap**

A Bitmap is a pixel by pixel image.

#### **Boundary**

Borders of a model

#### **Boundary Edge**

Edge of a polygon that is not shared with another polygon

#### **Boundary Representation (B-rep)**

A solid modeling database structure that defines and stores a solid as a topological set of explicitly defined vertices, edges, and faces.

#### **Box**

A closed box composed of three pairs of rectangular faces placed opposite each other and joined at right angles to each other, also known as a rectangular parallelepiped.

## C

### **C0 or G0 Continuity**

Positional continuity. Two surfaces that share a set of boundaries are C0 or G0 continuous when the adjoining edges of the surfaces match up exactly with respect to surface position.

### **C1 or G1 Continuity**

Tangential continuity. Two surfaces that share a set of boundaries are C1 or G1 continuous when the normals at the boundaries of those surfaces are exactly aligned in direction and are the same in magnitude.

### **C2 or G2 Continuity**

Curvature continuity. Two surfaces that share a set of boundaries are C2 or G2 continuous when they have the same curvature values where they meet.

## **CAD**

Computer Aided Design

## **Centroid**

The centroid (sometimes called a center of gravity) is the center point or middle point of the area. Traditionally, this point is found by cutting the area out of cardboard and balancing it on a pin. The balance point location is the centroid.

## **CMM**

Coordinate Measuring Machine

## **Control Points**

A set of points that parameterize and control the shape of a NURBS curve or surface

## **CT**

CT (Computed Tomography) scans measure photon linear attenuation of a tissue relative to water. These scans produce high-resolution anatomic images because the contrast between soft tissue and skeletal structures such as calcifications and bone are easily seen with this modality and has a spatial resolution of about 1 mm.

## **Curvature**

This is a mathematically-defined term which refers to the amount of roundness located at a point on a curve or surface. If a curve is flat, then its curvature is zero. As the curve becomes more rounded, the radius of curvature goes down and the curvature goes up. Curvature 'k' = 1 / rho, where rho is defined as the radius of curvature. These two values ('k' and 'rho') are inversely related.

## **Curve**

A curve is a mathematical function that describes the path of a point moving through space. In Pixform Pro, curves are displayed by sampling the mathematical description of the curve at specified intervals, then drawing line segments between these sample points. Pixform Pro uses NURBS to represent the curve geometry.

## **D**

### **Decimation**

An operation that reduces the count of entities. This operation usually attempts to preserve the object's overall shape and sharp features.

### **Depth Cueing**

Depth cueing is the lowering of intensity as objects move away from the viewpoint.

### **DICOM**

The Digital Imaging and Communications in Medicine (DICOM) standard was created by the National Electrical Manufacturers Association (NEMA) to aid the distribution and viewing of medical images, such as CT scans, MRIs, and ultrasound.

### **Displacement map**

A function defined on NURBS surfaces that depicts the deviations between a NURBS surface and the original polygonal mesh.

### **Draft Angle**

The amount of angle required to permit release of the part from the tool, measured from the die removal angle.

## **E**

### **Edge**

Line between two connected vertices on a polygon

## **E**

### **Face**

A face is a triangle composed of three vertices, and it is defined as three edges connected with each other.

### **Feature**

In Pixform Pro, the base feature can be an analytic shape such as planes(including box), a sphere, cylinder, or cone. And the advanced feature can be one of a hole, cut, fillet, chamfer, or an extrusion, a revolution, or a free-form shape such as a sweep or loft.

### **Feature Curve**

Curve that maintain characteristics in the feature topology of a model



## **Feature-based modeling**

Modeling technique in which you design the part by applying features that are similar to how the part is manufactured (e.g., holes, ribs, fillets, cuts, and bosses)

## **Flat Shading**

The flat shading method is also called constant shading. For rendering, it assigns a uniform color throughout an entire polygon. This shading results in the lowest quality, an object surface with a faceted appearance and a visible underlying geometry that looks 'blocky'.

## **G**

### **Gaussian Curvature**

The double curvature of a point on a surface. If a surface is developable (flat in one direction), then the Gaussian curvature is zero. As the surface becomes more curved in two directions (twisted), the Gaussian curvature increases (positively or negatively). Mathematically, the Gaussian curvature is the product of the two principal curvatures.

### **Geometric Dimensioning and Tolerancing (GD&T)**

Geometric dimensioning and tolerancing (GD&T) is a language used on mechanical engineering drawings composed of symbols that are used to efficiently and accurately communicate geometry requirements for associated features on components and assemblies.

### **Geometric Tolerance (GT)**

A geometric tolerance describes the degree to which a nominal design feature can vary while satisfying functional requirements. It also describes the variation that is allowed when fabricating parts from a design. Manufacturing processes have particular and repeatable ranges of variation. The tolerance associated with a process depends on expected process variation and the techniques used for measurement. In Pixform Pro, flatness, straightness, circularity and etc are defined as GT.

### **Gouraud Shading**

Gouraud shading, one of the most popular smooth shading algorithms, is named after its French originator, Henri Gouraud. Gouraud shading, or color interpolation, is a process by which color information is interpolated across the face of the polygon to determine the colors at each pixel. It assigns color to every pixel within each polygon based on linear interpolation from the polygon's vertices.

### **Grid**

A tessellation of congruent squares sometimes used to measure distance

### **GUI**

Graphic User Interface

## **H**

### **Hidden lines**

Broken lines used to signify lines that normally wouldn't be seen in a drawing

### **Healing**

A series of functions whose purpose is to correct geometric abnormalities contained within a surface or solid model. Common functions may include surface simplification (mapping spline surfaces to analytic shapes such as planes, cylinders, cones, etc.), face stitching, and edge gap repair. More advanced functions may include the ability to merge coincident vertices, repair self-intersections, and reduce and/or redeploy curve and surface control nodes. Programs typically perform healing on geometry that you import through neutral formats such as IGES, STEP, and SAT with problems caused by conditions ranging from imprecise geometric definitions to poor entity mapping to poorly written translator code. A CAD system may perform healing externally (on the neutral file), as it imports the neutral file, or internally after the neutral file is imported.

### **Hybrid**

Solid modeling system that employs two or more distinct database structures (e.g., CSG and B-Rep) to store and define a solid. Hybrid systems are known for their ability to mix advanced surfacing and solid functions within the same database. Hybrid systems may also let you explode a solid, perform surface and solid functions on open volumes, and then sew the faces back into a solid.

## **I**

### **IGES**

Initial Graphics Exchange Specification, the standard for exchanging geometric information

### **Interpolation**

The process of defining a curve (or surface) that passes through a set of points.

### **Isocurve(Iso-parameter curve)**

A set of curves on the surface that occur in the UV direction and define the surface shape. A parametric surface is typically crossed with flow lines that are constant U or V parameter curves on the surface, which are referred to either as isocurves.

## **L**

### **LMB**

Left Mouse Button

### **Loop**

A set of curves with ends that meet

## M

### **Manipulator**

An interactive control device, which is usually used to transform an object

### **Model**

A model is a logical set of several shells. Only one model can exist on the workspace window.

### **Mouse Drag**

Moving the mouse while pressing and holding the mouse button.

### **MRI**

MRI (Magnetic Resonance Imaging) scans acquire highly detailed anatomic information. Magnetic pulse sequences highlight the different amounts of water (hydrogen protons) contained in anatomical structures and fluids.

## N

### **Noise**

Erroneous data resulting from the scanning process. Usually represented as unnecessary points in a point cloud.

### **Normal**

A vector perpendicular to a polygonal mesh

### **NURBS**

Non-Uniform Rational B-Spline. This is a type of spline where the curve passes close to but not through the control points or knots and used in spline-based modeling.

## O

### **OLE**

OLE (Object Linking and Embedding) allows users to integrate data from different applications. Object linking allows users to share a single source of data for a particular object.

## P

### **Parameter**

For B-splines, this refers to the independent value or parameter that is used to define the curve or surface. For curves, the parameter is called 'u' and its value changes from 0.0 at one end of the curve to 1.0 at the other end. Rectangular-like B-spline surfaces have two parameters: constant 'u' for the row direction and constant 'v' for the column direction. Their values also range from 0.0 to 1.0, so that every combination of 'u' and 'v' values between 0.0 and 1.0 define the entire surface.

## **Parasolid**

A solid modeling engine used by many commercial and research organizations as the core of CAD/CAM/CAE applications. (Unigraphics Solutions Inc.)

## **Parameterization**

The flow of the curves defining a parametric surface

## **Patch**

A portion of a surface defined by a set of control points. The program allows you to deal with the surface on a patch-by-patch basis.

## **Perspective view**

A view in which perspective can be observed. Perspective views are used to give a 3D appearance.

## **Phong Shading**

Phong shading is a sophisticated smooth shading method, originated by Phong Bui-tuong. The Phong shading algorithm is best known for its ability to render precise, realistic specular highlights. During rendering, Phong shading achieves excellent realism by calculating the amount of light on the object at tiny points across the entire surface instead of at the vertices of the polygons. Each pixel representing the image is given its own color based on the lighting model applied at that point. Phong shading requires much more computation for the hardware than Gouraud shading.

## **Point Cloud (or Point Set)**

A point cloud is defined as a set of points in 3D space. A point cloud may consist of a single point or several million points. In Pixform Pro, the number of points in a point cloud is limited only by the memory limitations of the host computer.

## **Polyline**

A collection of  $n$  lines defined by the  $n + 1$  points that define the endpoints of each line segment

## **Polygonal model**

A model composed of polygon faces.

## **Primitives**

Pre-defined objects, either 2D or 3D, i.e., circle, square, arc, plane or sphere, cube, cylinder, cone, torus, and various polyhedrons.

## **Profile**

A 2D sketch drawing on a reference plane.

## **Propagate**

The process of creating equal numbers of isocurves across the boundary of two or more adjacent surface patches along the boundary's perpendicular direction

## **R**

### **Region**

A region is a user-selected set of vertex or face, which is just a temporary set in the job process. A region is released after the corresponding job is finished.

### **Rendering**

The process of creating life-like images on a screen using mathematical models and formulas to add shading, color, and lamination to a 2D or 3D wireframe

### **Reverse Engineering**

In general, the processing of understanding the design and functionality of a product using a sample of the product itself. For CAD, the term refers more narrowly to the process of scanning or digitizing the shape of an object and turning that data into a model which can then be treated as a normal CAD model, ultimately to re-manufacture the part or product.

### **RMB**

Right Mouse Button

### **RP (Rapid Prototyping)**

A various manufacturing processes as well as a burgeoning industry. RP processes involve devices--ranging from office modelers to four-ton machines--that accept 3D CAD files, slice the data into cross-sections, and construct layers from the bottom up, bonding one on top of the other, to produce physical prototypes for applications such as engineering form, fit, and function; soft tooling for prototypes; and patterns for hard tooling. The RP industry consists of RP systems, materials, and after-market products as well as a services sector.

## **S**

### **SAT**

A file format for 3D solid geometry, created by systems that use the ACIS solid modeling engine. (Spatial Technology Corp.)

### **Shell**

A shell is a logical set of several faces. Faces are usually connected with each other, but not always. Normally, polygon meshes obtained through triangulation process of a point cloud measured on one view are managed as a shell.

### **Shell curve**

Curves that are automatically connected to a shell when they are created

### **Shell surface**

Surfaces that are automatically connected to a shell when they are created

### **Sketch**

2D geometry, such as lines, arcs, circles, and curves, used to drive geometric features. The sketch environment contains a constraint manager that lets you place dimensional and relational constraints on geometry.

## **SLA**

The 3D file format used by Stereolithography Apparatus (SLA) rapid prototyping machines. Can also be used as a general 3D file format for viewing. (3D Systems Inc.)

## **Space curve**

Curves that are not connected to any shell. Space curves can be usually generated by importing foreign data formats such as IGES, STEP or VDAFS.

## **Space surface**

Surfaces that are not connected to any shell and operations related to shell are not available. Space surfaces can be usually generated by importing foreign data formats such as IGES, STEP or VDAFS. They may be introduced by generic surface creation tools such as blend, loft, sweep, and N-boundary filling.

## **STL(Stereolithography)**

Stereo Lithography file format. A rapid prototyping (RP) process, introduced in 1987 by 3D Systems Inc. launched the RP industry. A Stereolithography Apparatus (SLA) machine builds physical models in this manner: it focuses an ultraviolet (UV) light onto the surface of a vat filled with liquid photopolymer. The light beam, moving under computer control, draws each layer of an object onto the surface of the liquid. Wherever the beam strikes the surface, liquid changes to solid. 3D parts are built from the bottom up, one layer at a time; when the part is finished, it is exposed to UV light for curing. (3D Systems Inc.)

## **STEP**

The Standard for the Exchange of Product Model Data is a comprehensive ISO standard (ISO 10303) that describes how to represent and exchange digital product information.

## **Surface (Patch)**

A surface is defined as a mathematical function that describes the geometry fit to polygonal meshes. A surface(called patch) is bounded by iso-parameter curves(called flow line), controlled by a selected set of control points in the bi-direction, U-direction and V-direction. The surface is divided into 2 types, untrimmed and trimmed surface. The untrimmed surface has 4 boundary curves, while the trimmed surface has 2, 3, or more than 4 boundary curves. The trimmed surface is a special type of surface that is trimmed by its boundary curves after a basic surface, that is, an untrimmed surface is generated. Pixform Pro uses NURBS to represent the surface geometry.

## **I**

## **Template**

A function that copy, save, and reuse layouts. Thus, you can copy and use them on other parts of the same model.

## **Tessellation**

Tessellation is the process of subdividing a surface into smaller shapes. To describe object surface patterns, tessellation breaks down the surface of an object into manageable polygons. Triangles or quadrilaterals are two usually used polygons in drawing graphical objects because computer hardware can easily manipulate and calculate these two simple polygons.

## **Texture Mapping**

Texture mapping is based on a stored bitmap consisting of texture pixels, or texels. It consists of wrapping a texture image onto an object to create a realistic representation of the object in 3D space.

## **Toggle**

To switch from one setting to another. The term toggle implies that there are only two possible settings and that you are switching from the current setting to the other setting.

## **Toolbar**

Movable palette of tools that perform operations

## **Topology**

Data that tells the software how to connect the entities

## **Torsion**

A twisting deformation of a body about an axis in which straight lines that are initially parallel to the axis become helices. In mathematics, it is defined by the magnitude of the derivative of the normal to the plane of curvature with respect to distance on the curve.

## **Torus**

A torus is a surface having a single hole. The usual torus embedded in three-dimensional space is shaped like a donut, but the concept of the torus is extremely useful in higher dimensional space as well. In general, tori can also have multiple holes.

## **Transformation**

Change of coordinates; a series of mathematical operations that act on output primitives and geometric attributes to convert them from modeling coordinates to device coordinates.

## **U**

## **Undercut**

A face that is oriented opposite to the direction in which the mold will be pulled.

## **UV Direction**

Each surface patch has two directions, U and V. Isocurves within a patch run in U or V direction.

## **V**

### **VDAFS**

Vereinigung Deutsche Automobilindustrie Flächen Schnittstelle is a German neutral file format for the exchange of surface geometry. It was developed to exchange free form surfaces and it became a DIN standard in 1986. VDAFS supports elementary curve and surface geometry entities and some topology to define more complex models.

### **Vertex**

A single point defined by its Cartesian coordinates(X, Y and Z)

### **Voxel**

A voxel is an element in a 3D volume. A voxel is the 3D equivalent of a picture element, or pixel. It is also defined as the smallest discrete spatial component of a digital volume.

### **VRML(Virtual Reality Modeling Language)**

A language that lets Web browsers view and interact with 3D models; requires a special viewer.

## **W**

### **Wireframe**

A geometric model that describes 3D geometry by outlining its edges.

### **World Coordinates**

In 3D space, a coordinate system that enables the software and the artist to establish an exact location for objects, lights, or cameras. The origin of the world coordinate system is (0, 0, 0).



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