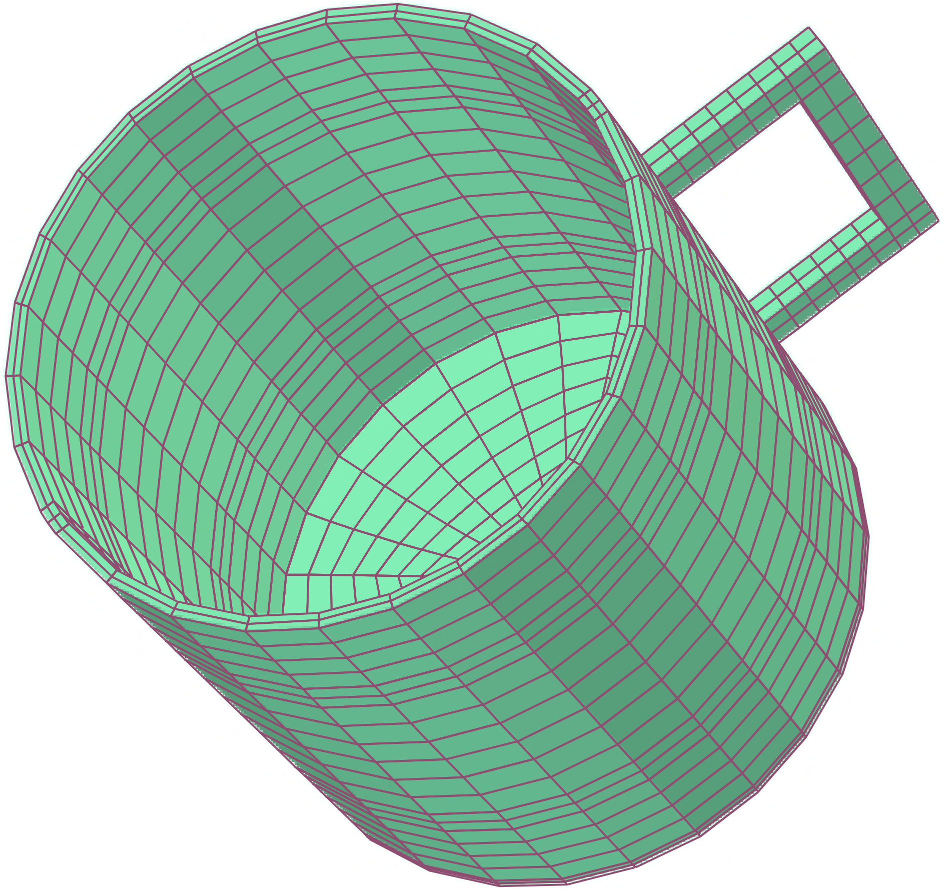
True*Grid*® Training Manual

block 1 3 5 7 9 11 13 15;
1 3 5 7 9 11 13 15;
1 3 5 7 9 11 13;
-2.1 -2 -.6 -.1 .1 .6 2 2.1
-2.1 -2 -.6 .6 2 2.1 3.1 3.4
0 .1 1 1.3 3.1 3.4 4.3
dei 1 3 0 6 8; 1 3 0 4 6;;
dei 2 7; 2 5; 2 7;
dei 1 4 0 5 8; 6 8;;
dei 4 5;6 8; 1 3 0 6 7;
dei 4 5; 6 7; 4 5;
sd 1 cy 0 0 0 0 0 1 2
sd 2 cy 0 0 0 0 0 1 2.1
sfi -1 -8; -1 -6;;sd 2
sfi -2 -7; -2 -5;;sd 1
sd 3 plan 0 0 0 1 1 0
sfi 1 2; -4; 1 7;sd 3
sfi -3; 5 6; 1 7;sd 3
pb 7 4 1 8 4 7 xy 2 2
pb 6 5 1 6 6 7 xy 2 2
curd 1 lp3 2 -2 0 2 -2 5 ;;
curs 6 1 1 6 1 7 1
curs 6 2 1 6 2 7 1



curs 8 3 1 8 3 7 1
curs 7 3 1 7 3 7 1
tri 1 2; -3; 1 7;
v 0.204784e-01
-0.527519e-01 -2.15000
tf rt -0.204784e-01
0.527519e-01 2.15000
rt 0.846535 0.551037
2.15000
rt -0.518763 0.919765
2.15000;
pb 3 2 1 3 2 7 xy
-1.370804e+00
-1.456330e+00
pb 3 1 1 3 1 7 xy
-1.459775e+00
-1.509655e+00
mseq i 0 5 1 0 1 5 0
mseq j 0 5 5 5 0 4 0
mseq k 0 2 0 4 0 2
endpart
merge
stp .001

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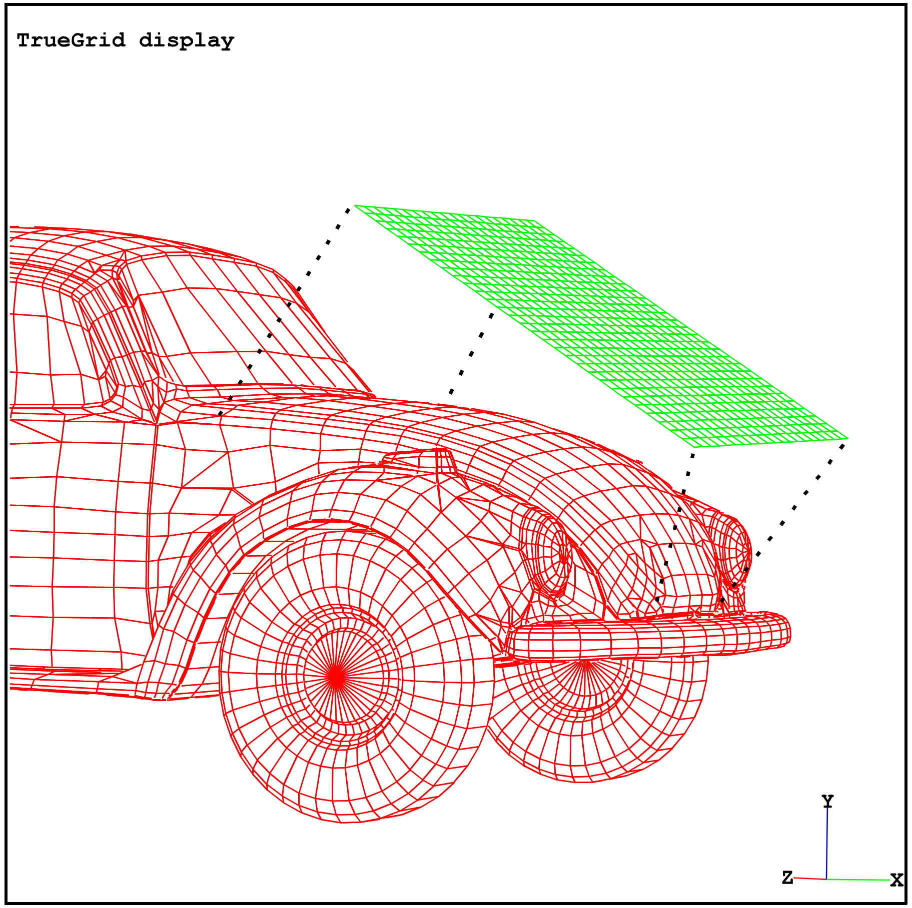
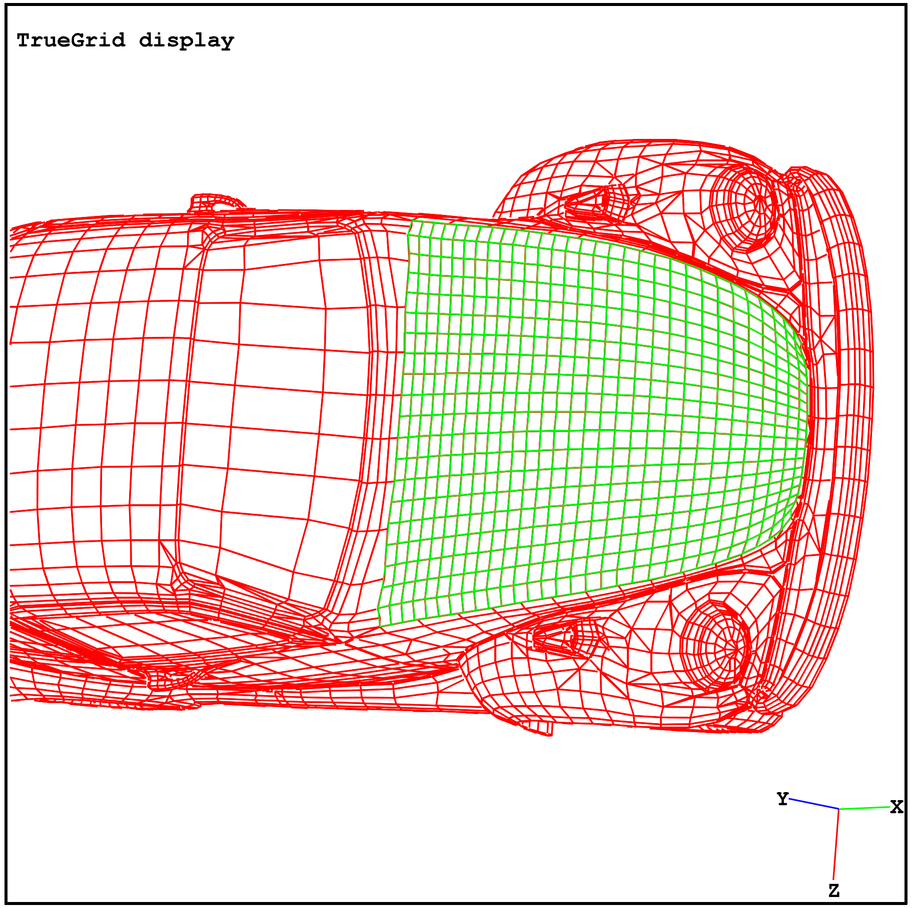
True*Grid*® implements the powerful projection method.

Before projection



After projection



TrueGrid can be executed by switching between the interactive or batch modes.

Interactive mode

- Execute the selected or typed commands on the screen interactively.
- TG records commands and parameters in the tsave file.

Batch mode

- TG records commands and parameters in the tsave file.
- Execute the command file.

The tsave file can be renamed, edited, and run as a command file.

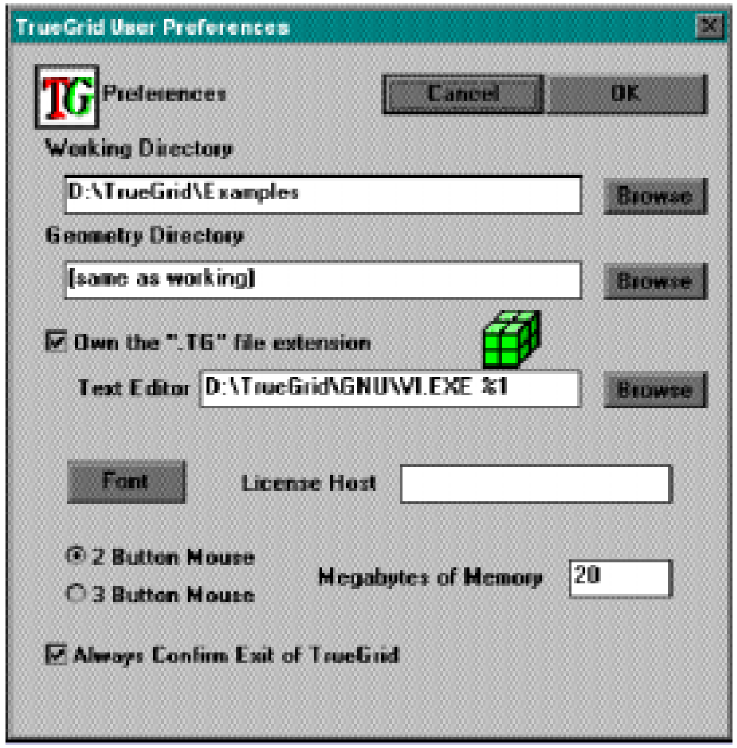
Interactive → **Resume** → **Batch**

Batch → **Interrupt** → **Interactive**

Type the execution line under the UNIX & LINUX OS.

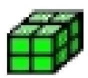
TG i = comd s = csave o = model len = size -font name -display hostname:0.0

i = comd	Initial command file name
s = csave	Session file name which defaults to tsave. Recommend renaming the tsave file after TrueGrid stops.
o = model	Output file name
len = size	Memory size in Megabytes which defaults to 20 MB.
-font name	Font selection for X windows only.
-display hostname:0.0	Remote execution for X windows.



Execution under WINDOWS

After **True*Grid*®** is installed, run the controls program from the program menu or double click on the icon and make the required selections (see the window on the right). Run **True*Grid*®** by double clicking on the icon or using the program menu. Every command file ending with .tg will have the icon which is shown on the right. Double click on the icon to run **True*Grid*®** with the command input file.



impeller.tg

A mesh may be generated interactively following this recipe.

1. Execute **True*Grid*®**

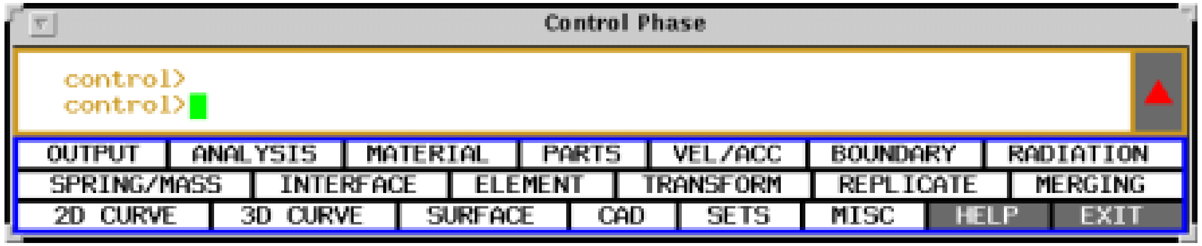
2. Enter Control Phase
   - Input title (a brief description of the structure or fluid)
   - Select output format in terms of the analytical codes
   - Select material type and properties (keep consistent units)
   - Select properties of sliding interfaces and symmetry planes
   - Define cross sectional properties
   - Import geometry (if needed)

3. Enter Part Phase as many times as needed
   - Build a part from a single block or multiple blocks - bricks, shells, and beams
   - Select number of nodes and nodal distribution
   - Generate geometry where needed
   - Identify parts of the mesh to be formed to the geometry
   - Check the quality of the mesh
   - Select boundary conditions

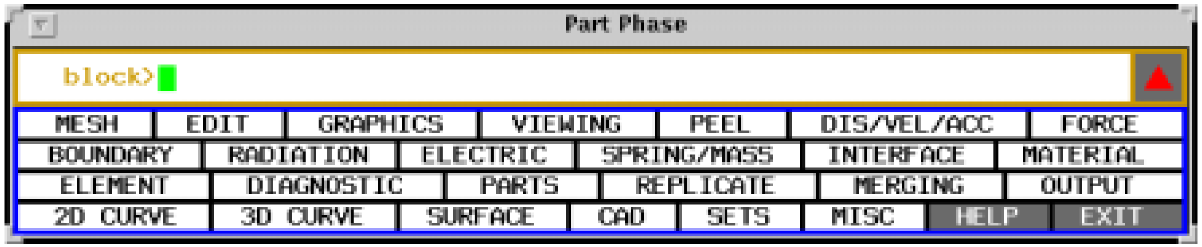
4. Enter Merge Phase
   - Merge parts into one integrated structure
   - Check the quality of the mesh
   - Generate beam and special elements
   - Write output file

Many options are provided in the main menu in each phase.

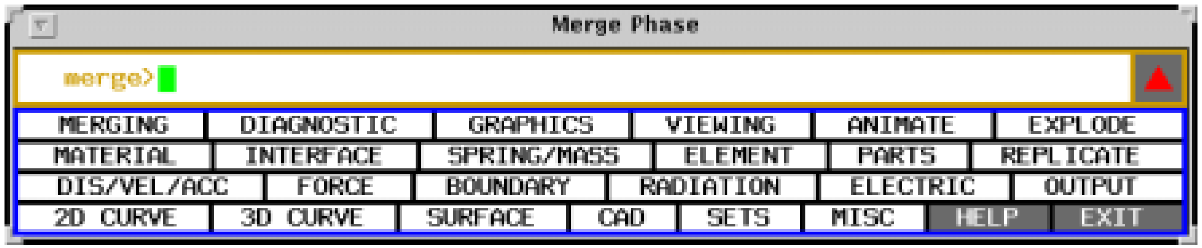
Control Phase



Part Phase



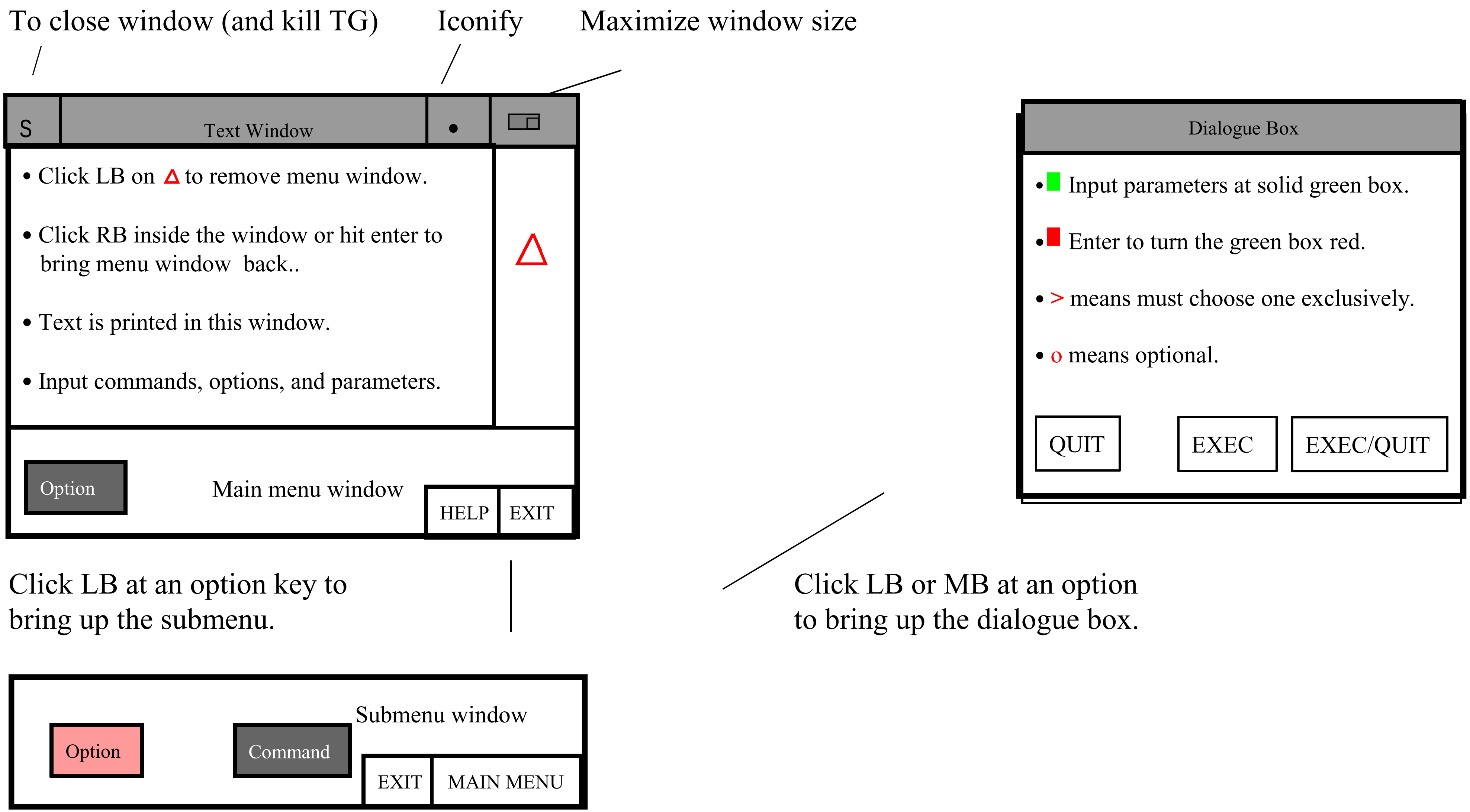
Merge Phase



Meshes can be generated in the Part Phase only.

Geometry can be generated in all three phases.

The text window is for typing in commands and parameters.



Dialogue box prompts you with the required parameters.

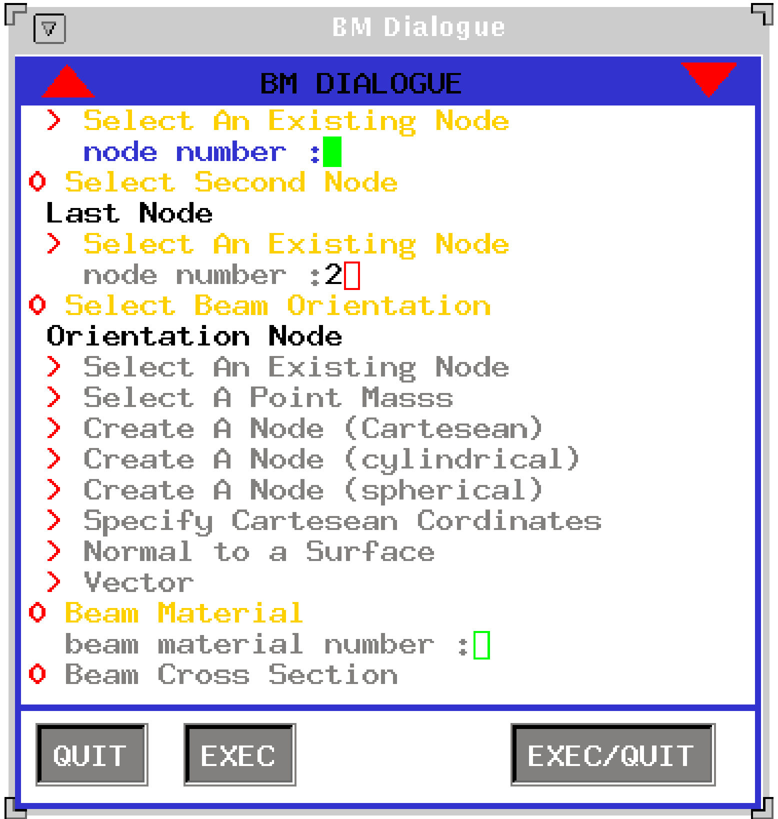
The option turns yellow when it is clicked. One more click turns it off.

If execution is issued before entering all parameters, the first incomplete line is highlighted in blue.

Click **MB** on **EXEC/QUIT** or **EXEC** to execute right away and force a redraw.

Click **LB** on **EXEC/QUIT** or **EXEC** to enter the command for execution but with no redraw event.

When the **MB** is left inside the **EXEC** after execution, then the **EXEC** turns red to flag against duplicate execution. Just move the mouse off of the button and it will return to its original color.



The comprehensive help package is available in all three phases.

To access the help window:

In any menu, click on the **HELP** to activate the help window.

Then click on an **option** for the pop up help window.

Alternatively, type the help command.

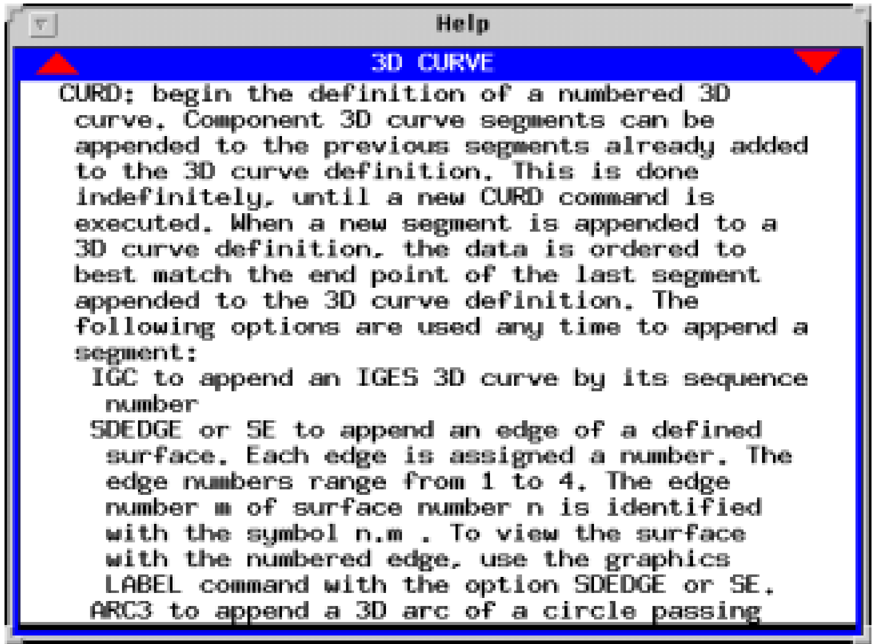
Scrolling in the help window:

Click **LB** or page key to scroll by page.

Click **MB** or arrow key to scroll by line.

Click **LB** on **HELP** to close the help window, or

click **LB** on the **-** in the border of the help window.



Mouse buttons and special keys

LB	To select options and to enter parameters (text in the text window).
MB	To move 3D objects in the picture and execute commands (paste text in the text window).
RB	To create additional windows and write Postscript (physical window only).
CT+r	Same as remove in the display list panel.
CT+s	Same as show only in the display list panel.
CT+u	Erase the text string (text window only).
CT+v	To display the hidden command option names (dialogues only).
CT+z	Recreate a dialogue box from highlighted text (text window only).
F1	To enter selected mesh into the dialogue box.
F2	To clear mesh selection.
F3	To display command history in the text window.
F4	To freeze the current window configuration.
F5	To select beginning vertex of a mesh.
F6	To select the ending vertex of a mesh.
F7	To extract coordinates for a selected vertex.
F8	To type the selection label into the text window or dialogue.

Commands Syntax

Stack the input commands and parameters on any number of 256 character lines of input.

Begin a Single-line comment with a " c " or { ... } for multiple lines.

Prompt for each argument of a command.

Click the Esc key to abort any input sequence in the text window.

List values and terminate with a semicolon. `ld 1 lp2 1 1 1.2 3 1.4 3 1.6 2;`

Use Fortran expressions in square brackets. `sd 1 sp 0 0 0 [%len*sqrt(2)]`

Define parameters and refer to them. `para a 1.3 b 2.5 d [%a/sqrt(%b)];`

FORTRAN like IF... ELSEIF ... ELSE ... ENDIF statements.

```
if(%len.le.0.0.and.sqrt(sin(%r)/%s).gt.0.1)then
        ...
elseif(%len.lt.1.1)then
        ...
else
        ...
endif
```

Text window may be use to acquire information.

WHILE statement to repeat a block of commands until a condition is met. The ENDWHILE terminates the block of commands. While statements can be embedded 20 deep. The BREAK command jumps out of a WHILE block of commands.

Include commands from files

The DEF command defines a function. `def ds(a,b,c,d)=sqrt((a-c)^2+(b-d)^2)`

Cut and paste with the mouse into the text and dialogue windows.

Commands from dialogues are shown in the text window.

Extract coordinates of the selected vertices and compute the distance between these vertices using the DISTANCE command.

Calculate an angle from 3 points in the picture. `subang 1 1 0 0 0 0 1 1 1`

Calculate cross products and inner (dot) products of vectors. `crprod  1 1 0 1 1 1`

Can be used for calculation like a desk top calculator. `dc 12.5 + 1.3 * 5.4/3`

Many commands with the info suffix. `painfo`

Transform a point. `trapt x y z type id`

Create a mesh starting in the Control or Merge phase.

Method 1:
Type the following command into the text window.

```
Block  1 11; 1 11; 1 11;  -1 1;  -1 1; -1 1;
```

Method 2:
Select the dialogue box by clicking the **LB** on **PARTS** > **BLOCK** .
Then fill in the parameters.

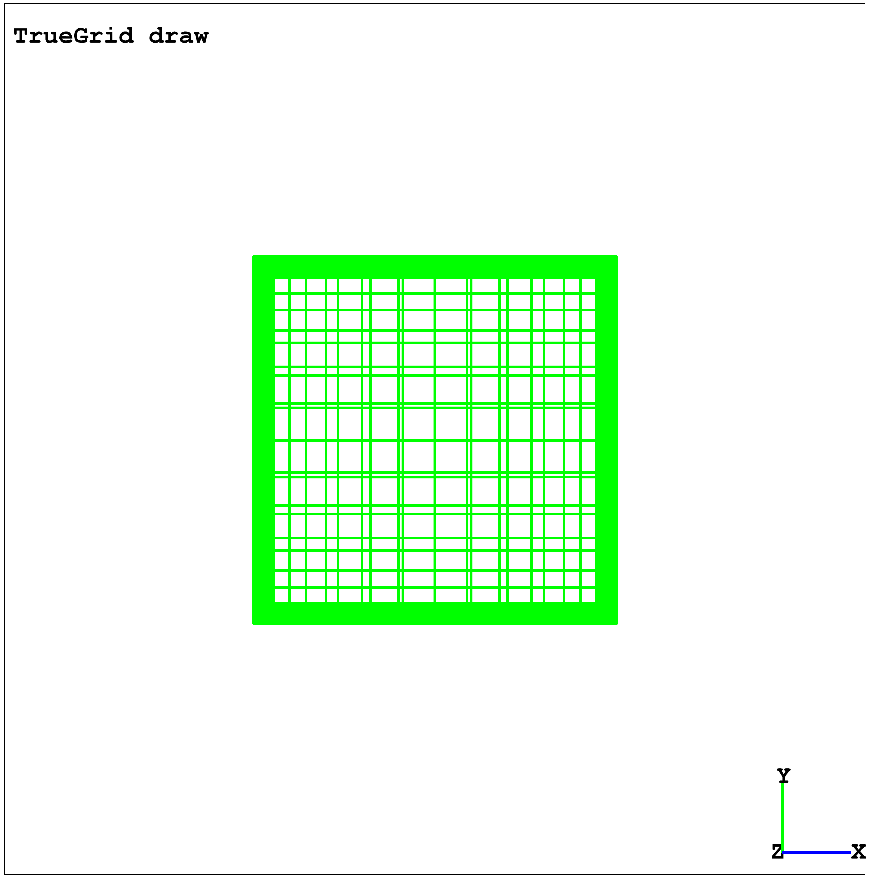
BLOCK DIALOGUE

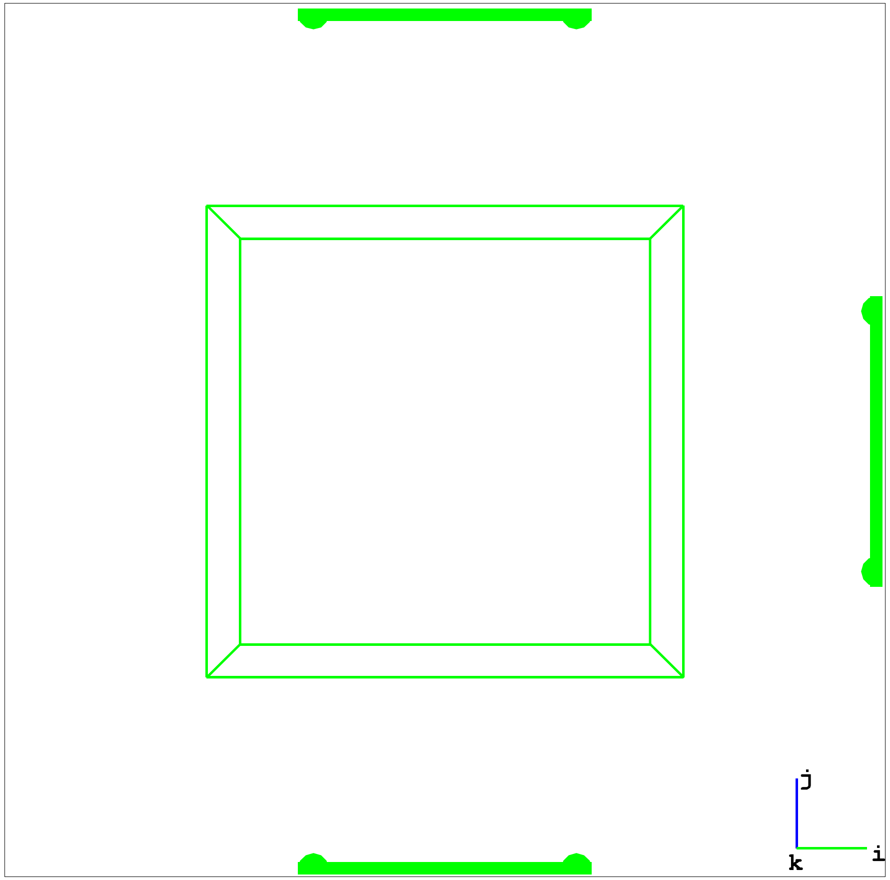
Specify An Index Progression
i-list : 1 11
j-list : 1 11
k-list : 1 11
List the x,y,z Coordinates
x-list : -1 1
y-list : -1 1
z-list : -1 1

QUIT EXEC EXEC/QUIT

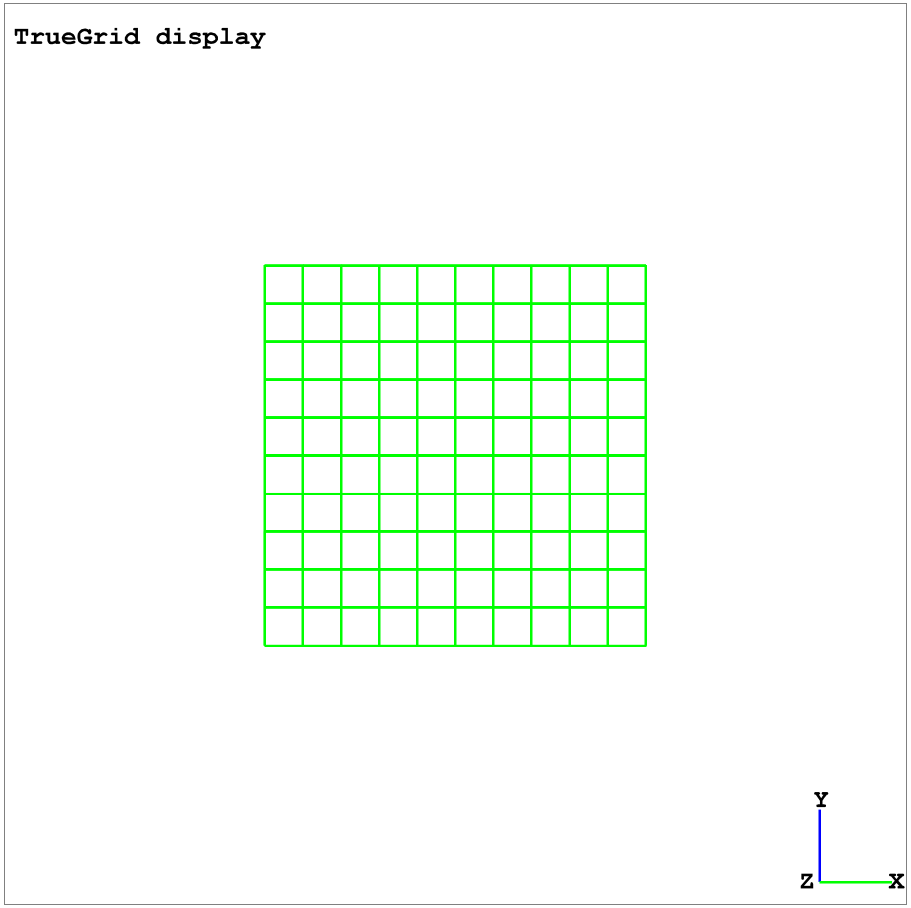
Mesh in the Physical and Computational windows.

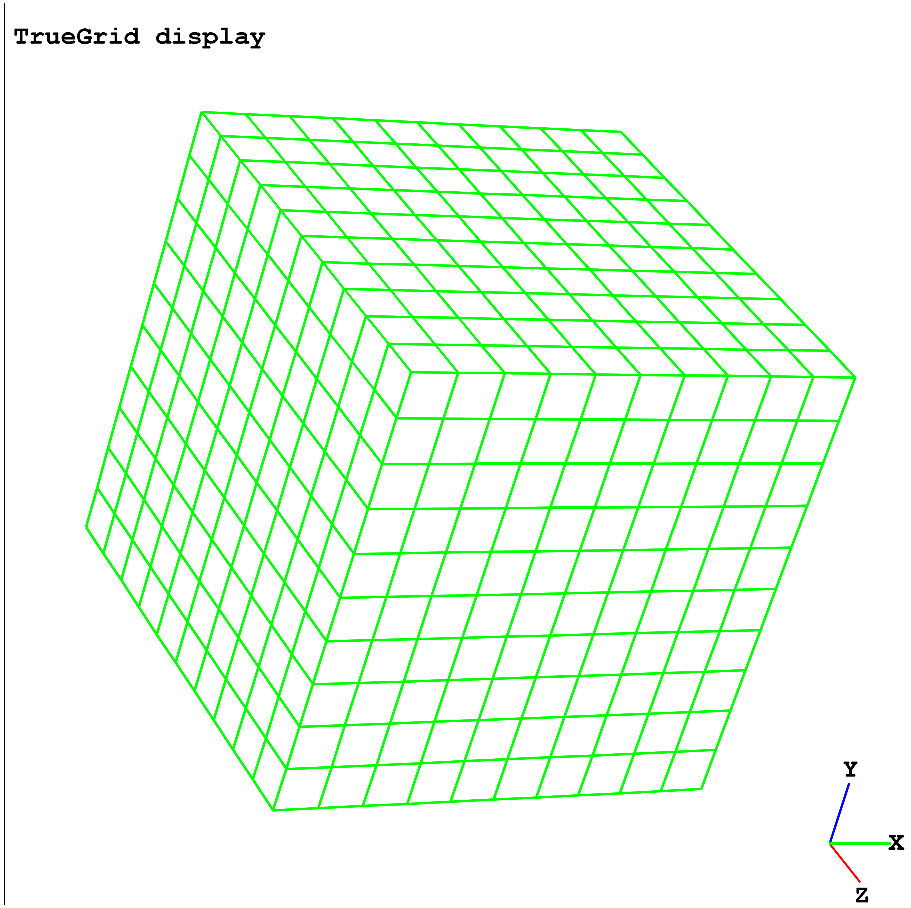
Perspective is on by default. The front face appears to be larger than the back face for both the physical mesh on the left and the computational mesh on the right.





Cent and Rest fit the entire mesh in the screen.





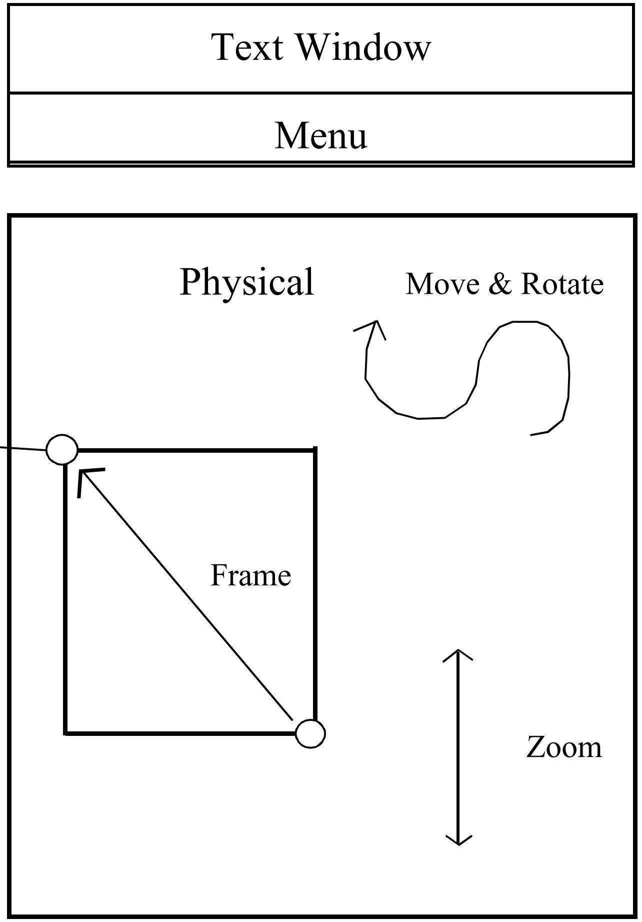
To activate the grid,
Click on **GRAPHICS** > **GRID**
Select on or off in the Dialogue.

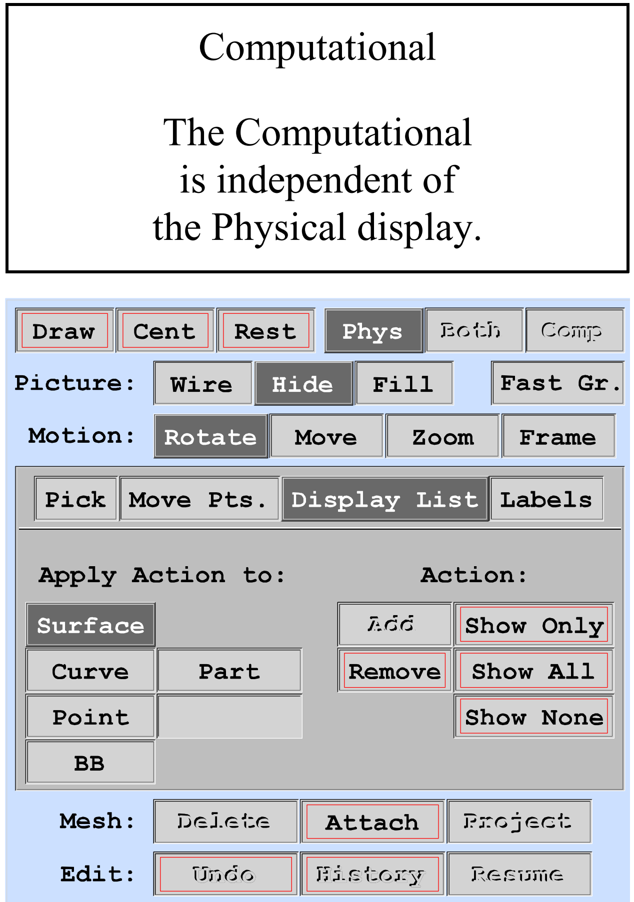
Rest Displays the geometry and block lining up the global coordinates (geometry with the screen coordinates.)

Environment window has display screen control.

Use SHIFT + **MB** to rotate large angles when zoomed in.

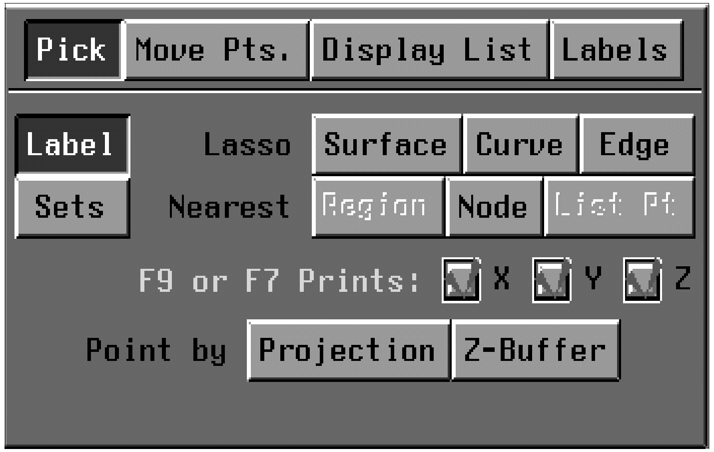
Drag the mouse out of the window to kill the Frame action.

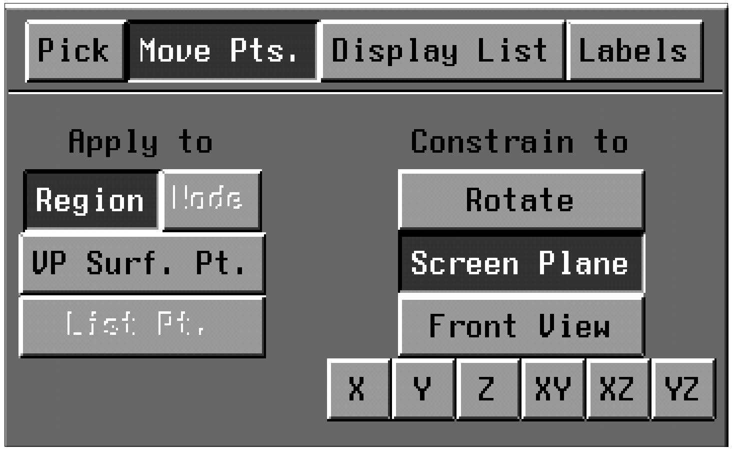


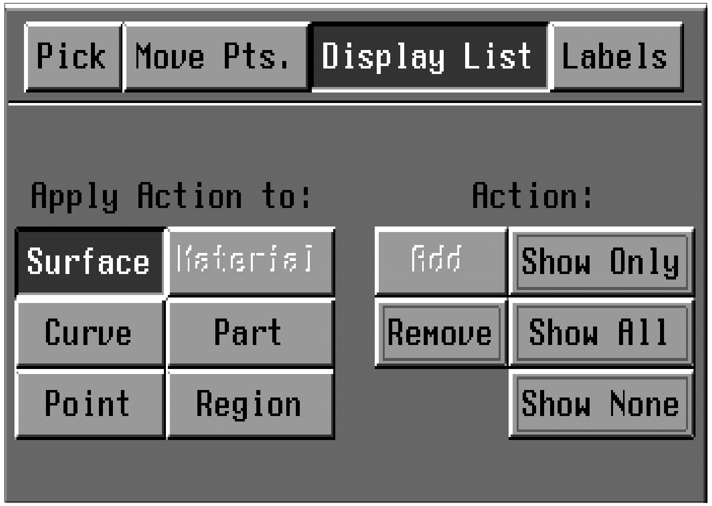


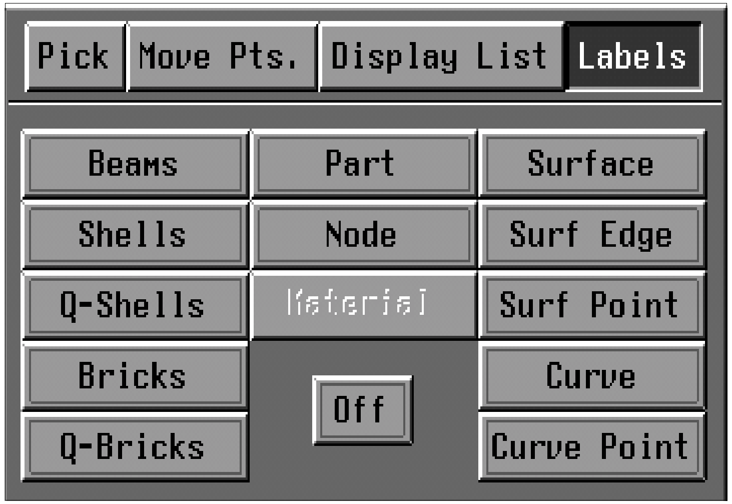
Select the type of motion control from the Environment window with the **LB**. Move the mouse into the Physical or Computational window. Then click and drag the **MB** to change the picture. Release the **MB** for a full redraw of the picture. If you select fast graphics (Fast Gr.), many functions will be unavailable.

Environment provides multiple-layer-panel for display, edit, and label features.









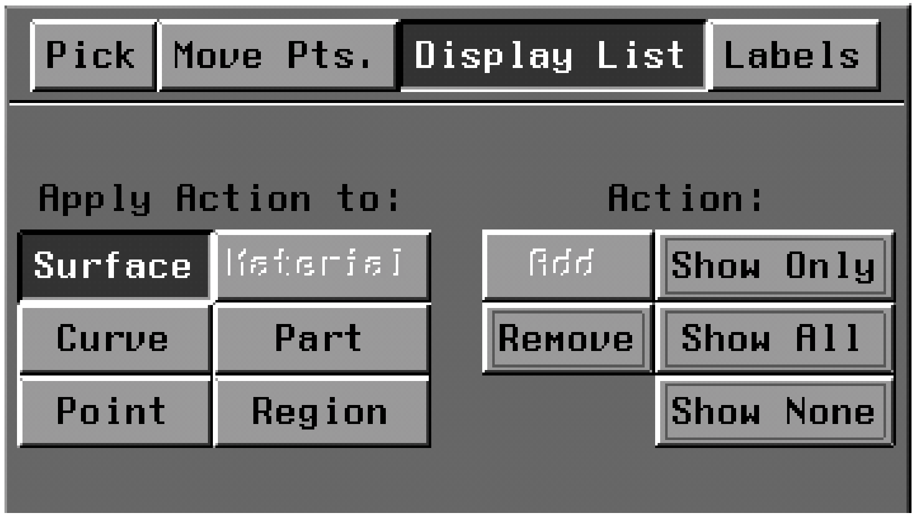
Display List Control Commands

Menu	Surface	3D Curve	Parts	Material	Interface	Cad	Cad
Type	**Surfaces (sd)**	**3Dcurves (cd)**	**Parts (p)**	**Materials (m)**	**Boundaries (bb)**	**Groups (grp)**	**Levels (lv)**
Display 1 (d*)	dsd #	dcd #	dp #	dm #	dbb #	dgrp #	dlv #
Add 1 (a*)	asd #	acd #	ap #	am #	abb #	agrp #	alv #
Remove1 (r*)	rsd #	rcd #	rp #	rm #	rbb #	rgrp #	dlv #
Display Many (d*s)	dsds list ;	dcds list ;	dps list ;	dms list ;	dbbs list ;	dgrps list ;	dlvs list ;
Add Many (a*s)	asds list ;	acds list ;	aps list ;	ams list ;	abbs list ;	---	---
Remove Many (r*s)	rsds list ;	rcds list ;	rps list ;	rms list ;	rbbs list ;	---	---
Display All (da*)	dasd	dacd	dap	dam	dabb	---	---
Remove All (ra*)	rasd	racd	rap	ram	rabb	---	---

A list can include a sequence where only the first and last numbers of the sequence are give and separated by a " : ". For example:

dsds 2 14 19:29 32 97 63:69;

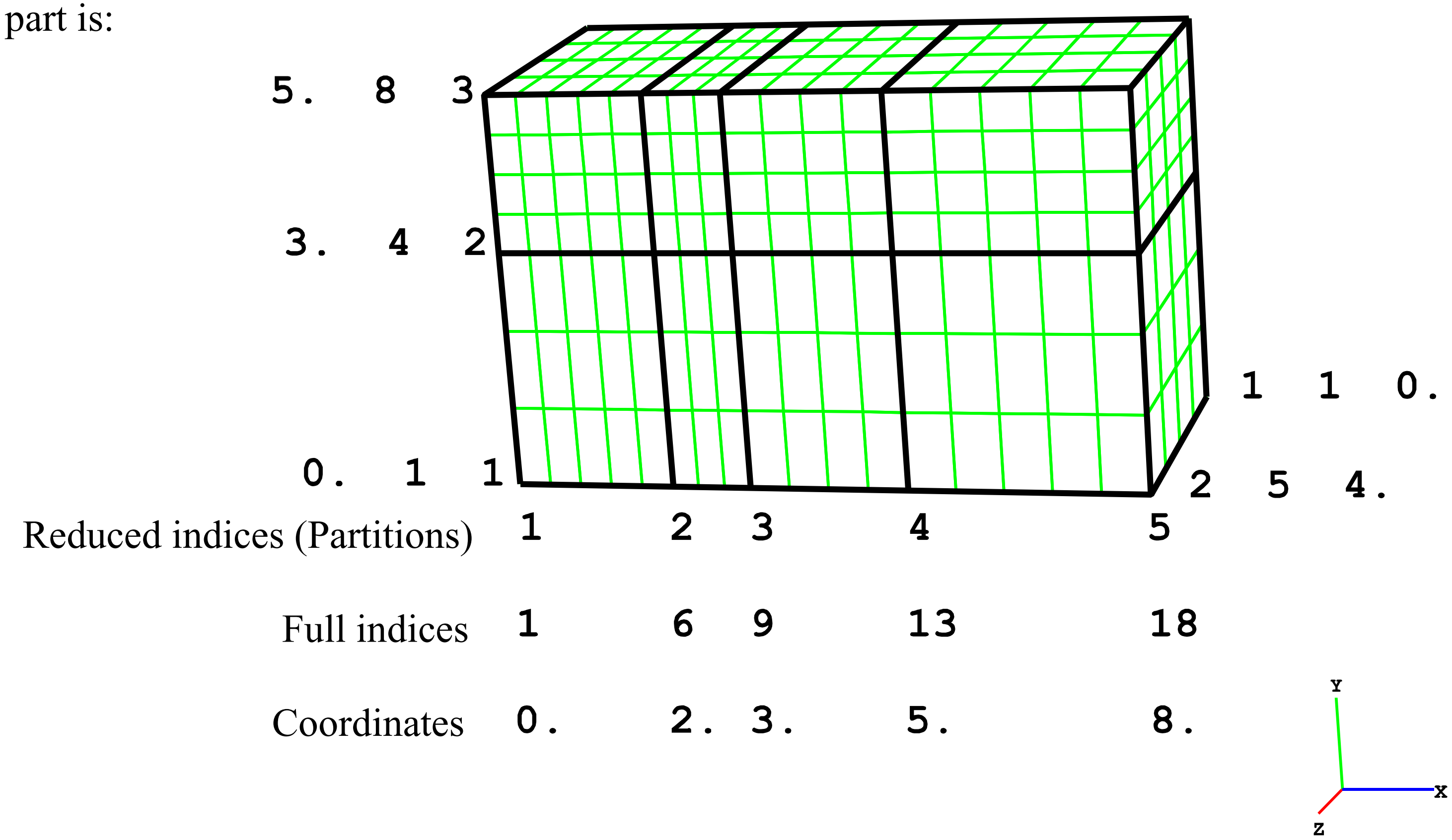
The display list panel in the environment window has buttons for some of the commands in the picture to the right.



Physical Window Showing Indices and Coordinates

The command that created this part is:

```
block   1   6   9   13   18;
        1   4   8;
        1   5;
        0.  2.  3.   5.   8.
        0.  3.  5.
        0.  4.
```



The Computational window shows the topology of the multi-block part.

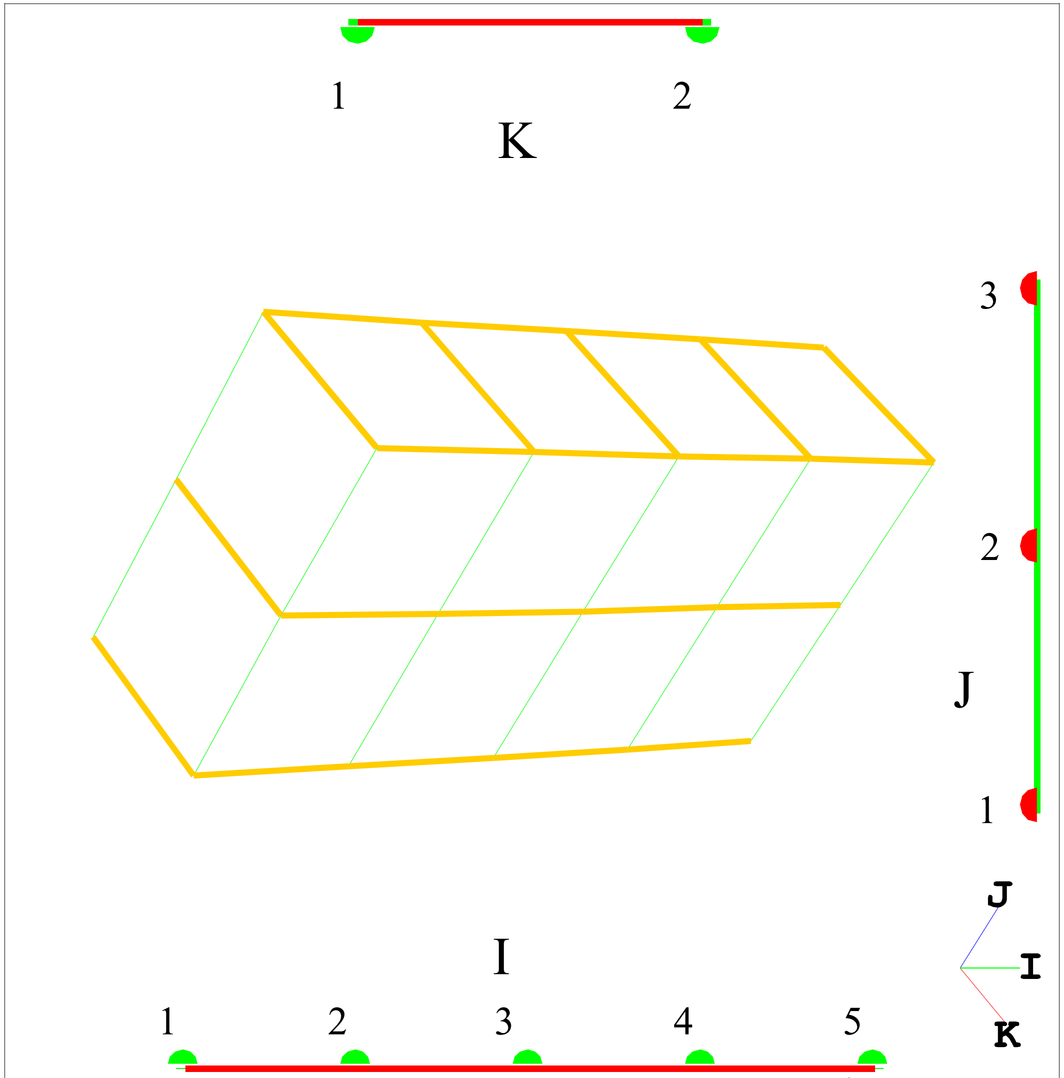
The buttons on the I, J, and K index bars are tied to the corners of the Physical and Computational meshes.

The primary use of the buttons along the index bars is as an easy and unambiguous method of selecting parts of the mesh. There are many ways to select parts of the mesh to attach, project, and assign properties.

Click on a button to toggle it on and off.

When a solid region between two buttons is selected, the solid bar between the buttons turns red. A click and drag mouse action from one button to the other toggles the selection.

Corners, edges, faces, and solids of the mesh can be selected with this technique. Each type of object is color coded.



4 Ways of Selecting mesh objects

PURPOSE: Select regions of the mesh easily and accurately.

Commands are driven by the regions selected.

METHODS: Index bars - dots and segments

Click-and-drag in the computational window

F5 and **F6** in the physical window

Pick by Region in the environmental window and the click-and-drag in the physical window.

NOTES: Click **F2** to clear all mesh selection.

Red means a vertex.

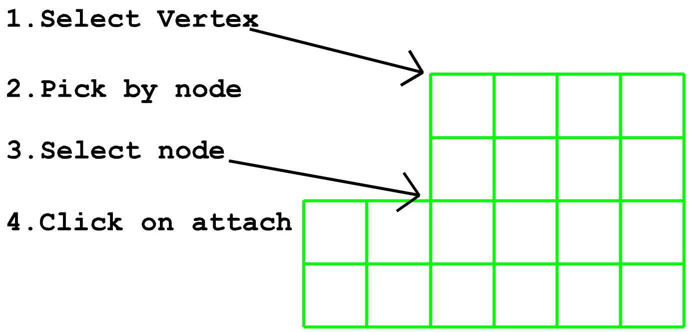
Blue means an edge.

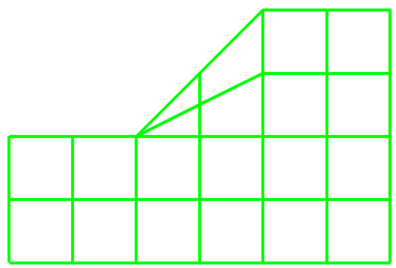
Yellow means a face

Magenta means a block.

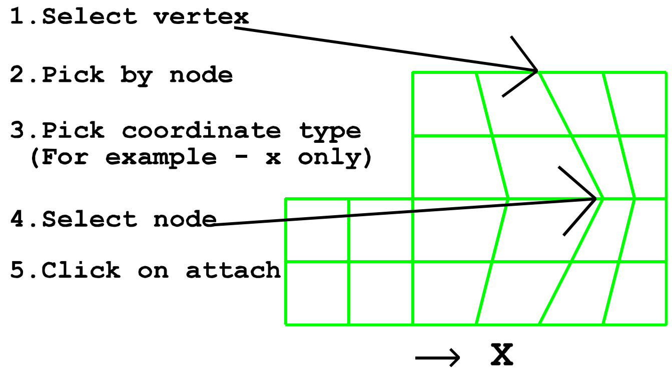
Coincident Coordinates

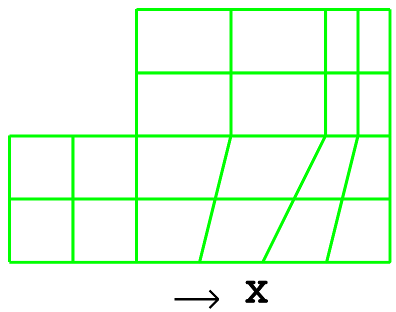
Move a vertex to another vertex.





Aligning a vertex with another vertex.



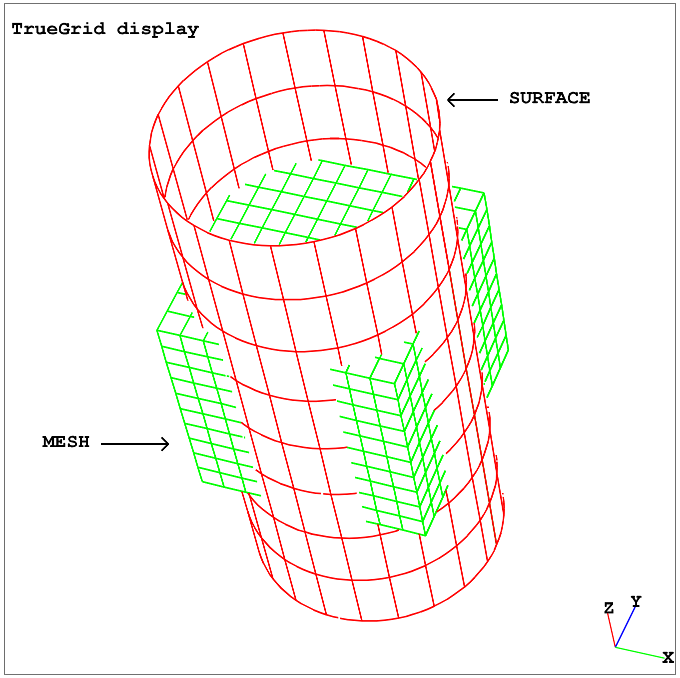


The projection function constrains the mesh to the geometry.

Simple block mesh projected on a cylindrical surface.

Block 1 11; 1 11; 1 11; -2 2 -2 2 -2 2
Sfi -1 -2;-1 -2;;sd 1

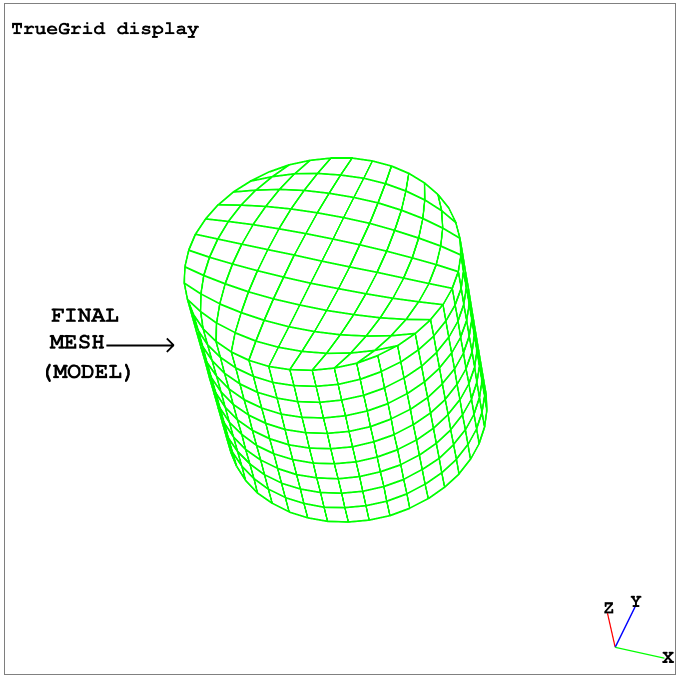
Before projection



STEPS

1. Select mesh region
2. Select surface
3. Project

After projection



Use the **sf** or the **sfi** command under the mesh menu to constrain parts of the mesh to a surface. Alternatively, use the **project** button in the environment window. There are several ways to make selections.

Selecting the target surface for projection.

Method 1:

Click **LB** on **Labels** > **Surface** in the Environment window.

Click **LB** on **Pick** > **Label** in the Environment window.

Click **LB** on **Project** the surface number in the Physical window.

Click **LB** on in the Environment window.

Method 2:

Click **LB** on **Pick** > **Surface** in the Environment window.

Click-and-drag **LB** forming a box containing part of the surface.

Click **LB** on **Project** in the Environment window

. **Method 3**:

Click **LB** on **Label** > **Surface** to show the surface labels.

Then click **LB** on **Pick** > **Surface**.

Type the surface number next to the **Show** button.

Click **LB** on **Project** to execute projection.

Selecting the target surface for projection (cont`d).

Method 4:

Type **sfi** in the Text window, press the **F1** key, and type the surface number as shown.

sfi -2; -2; -1 -2; sd 1;

Method 5

Select the dialogue box **MESH** > **SFI**

Press the **F1** key and select **Existing Surface** and type the surface number.

Click **LB** on **EXEC/QUIT** in the Dialogue box.

Method 6

Click **LB** on **Pick** > **Surface** in the Environment window.

Click **LB** on surface number in the Physical window.

Place the mouse button in the Text/Dialogue window.

Press **F8** to print the surface label into the window and execute the command.

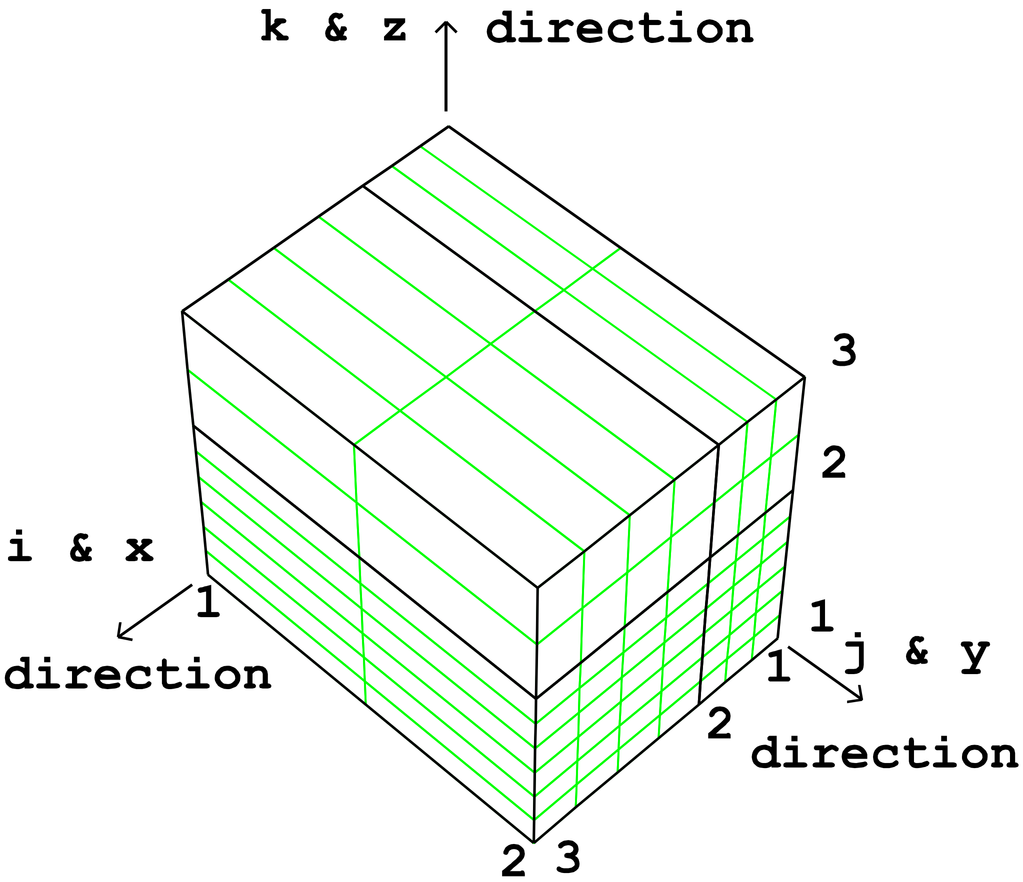
Block Command Explanation

Command syntax:

Block	**i-list ;**
	j-list ;
	k-list ;
	x-list
	y-list
	z-list

For Example:

Block	**1 4 8 ;**
	1 3 ;
	1 7 9 ;
	0 .5 1.5
	-1 1
	.3 1.3 2



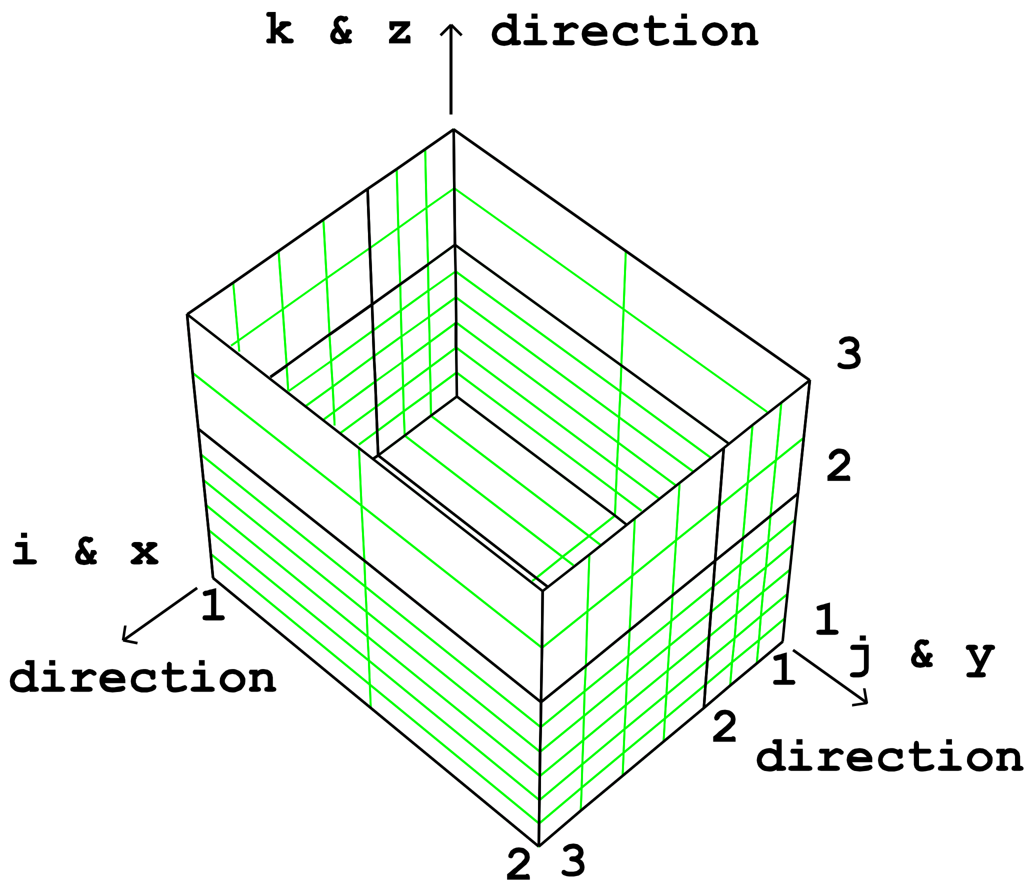
The **i-list** contains the node numbers of the block in the i-direction. In the example, there are 2 blocks in the i-direction. The nodes starting at 1 and ending at 4 (i.e. 3 elements thick) forms the first block. Nodes 4 to 8 (i.e. 4 elements) form the second block. The **x-list** assign the x-coordinates to the faces (or partitions) in the block in the i-direction. There must be as many x-coordinates in the **x-list** as there are i-indices in the **i-list** so that each i-partition has an x-coordinate. There is a similar interpretation for the **j-list** and the **y-list**, and the **k-list** and the **z-list**. The **partmode** selects a simpler version of the block command, if no shells are needed.

Block Command Explanation (cont.)

When negative integers are used in the **i** , **j** , or **k-lists** , then the faces of the blocks corresponding to the negative numbers become shells.

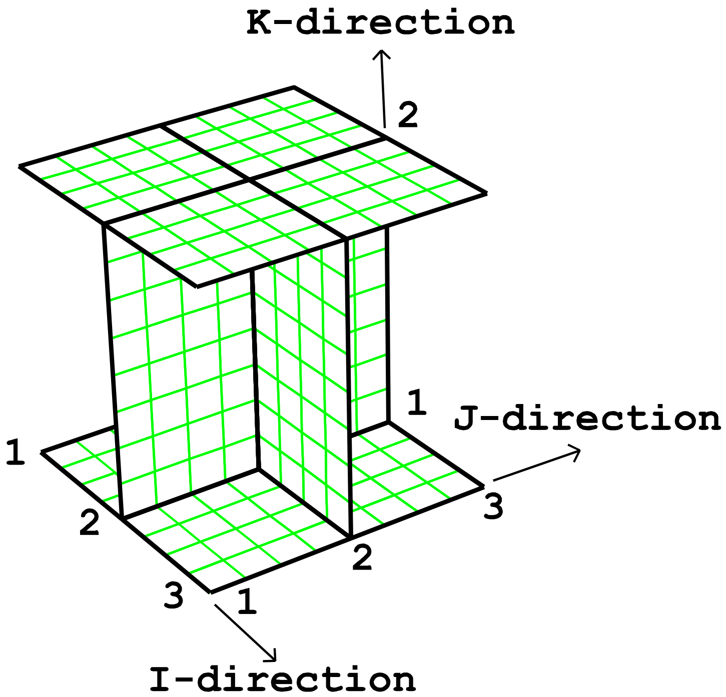
For example:

Block **-1 4 -8 ;**
-1 -3 ;
-1 7 9 ;
0 .5 1.5
-1 1
.3 1.3 2

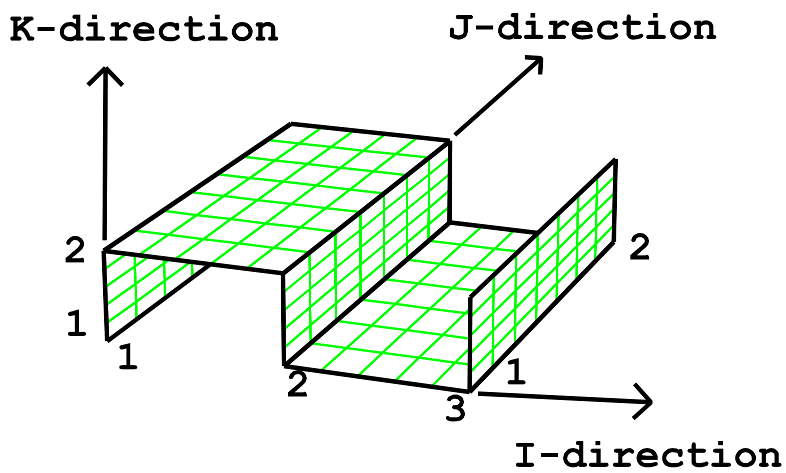


This example produces two shells faces in the i-direction , 2 shells faces in the j-direction , and 1 shell face in the k-direction to form a five-sided box with a bottom. There is a face corresponding to each negative number in the index **i**, **j**, and **k-lists**.

Block Command Exercises

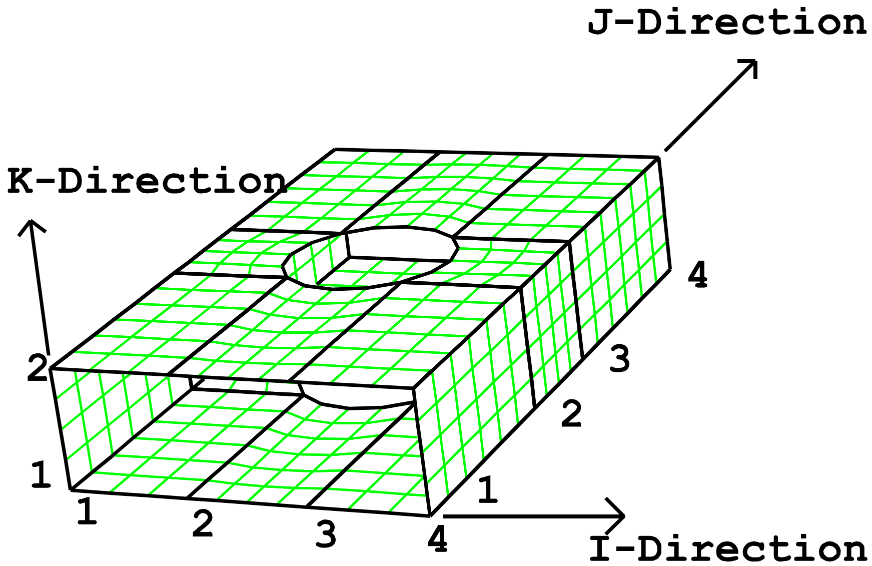


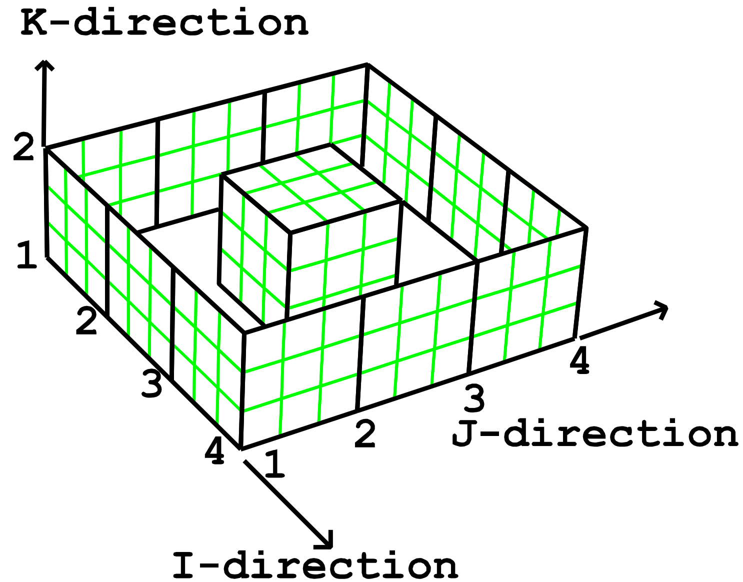
Block
1 -5 9; 1 -5 9; -1 -9;
1 2 3; 1 2 3; 1 3;
endpart



Block
-1 -6 -11; 1 8; -1 -6;
0 2 4; 0 5; 0 1;
dei 1 2 ; ; -1;
dei 2 3 ; ; -2;
endpart

Block Commands Exercises (cont)

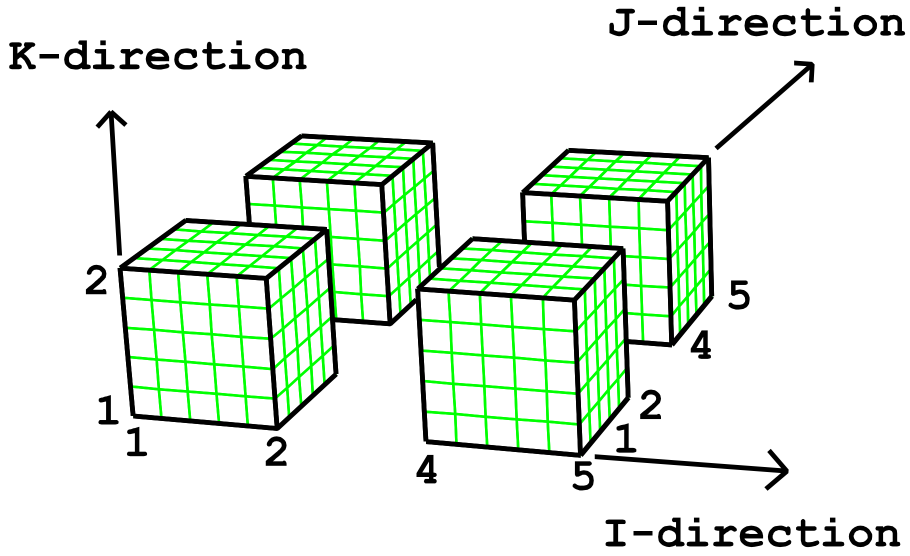




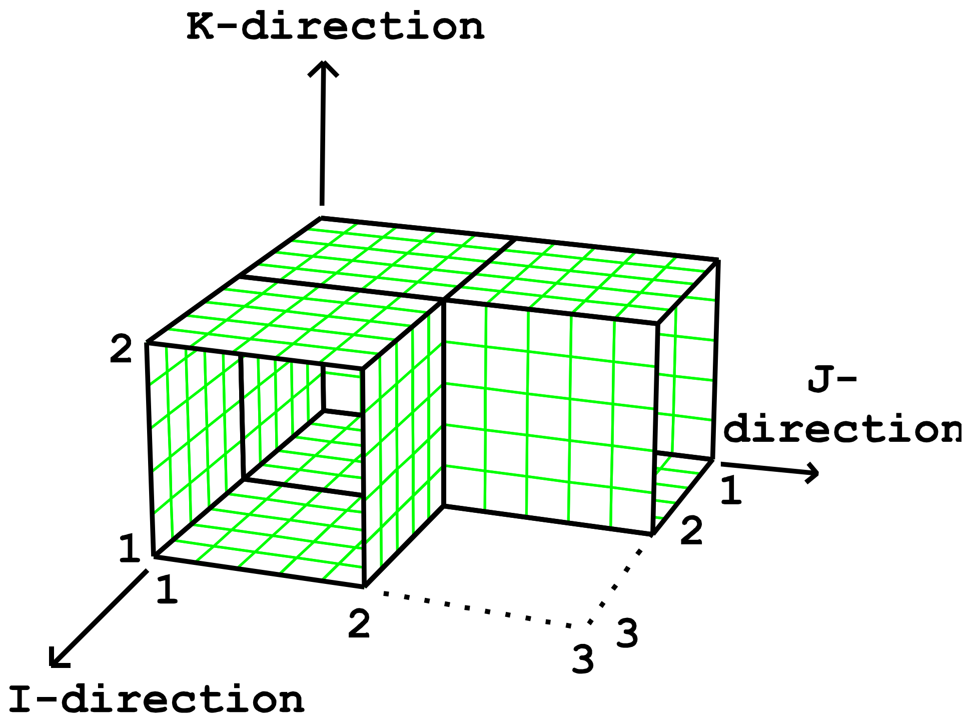
Block
-1 4 8 -11; 1 7 11 17; -1 -5;
0 1 2 3; 0 2 3 5; 0 1;
sd 1 cy 1.5 2.5 0 0 0 1 .7
dei 2 3; 2 3; ;
sfi -2 -3; -2 -3; 1 2; sd 1
endpart

Block
-1 4 7 -10; -1 4 7 -10; 1 4;
1 2 3 4; 1 2 3 4; 1 2;
endpart

Block Commands Exercises (cont)



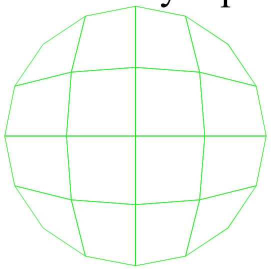
Block
1 6 0 7 12; 1 6 0 7 12; 1 6;
1 2 0 3 4; 1 2 0 3 4; 1 2 ;
endpart



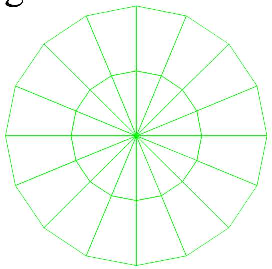
Block
-1 -6 11; -1 -6 11; -1 -6;
0 1 2; 0 1 2; 0 1;
dei 2 3; 2 3; -1 0 -2;
dei -2; 1 2; 1 2;
dei 1 2; -2 ; 1 2;
endpart

Butterfly Technique

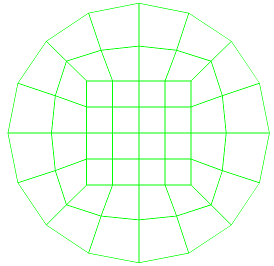
The butterfly topology is used to create a good mesh of a curved object using quad or hex elements.



Simple Block Topology



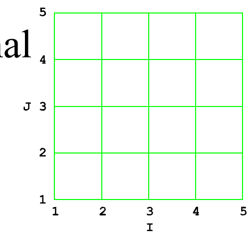
Simple Wedge Topology



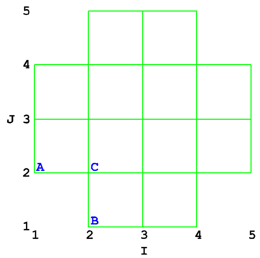
Butterfly Topology

Computational Mesh

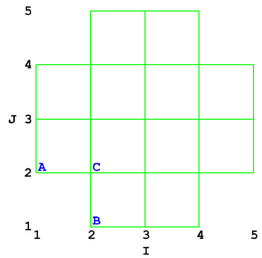
Step 1



Step 2



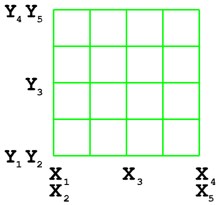
Step 3



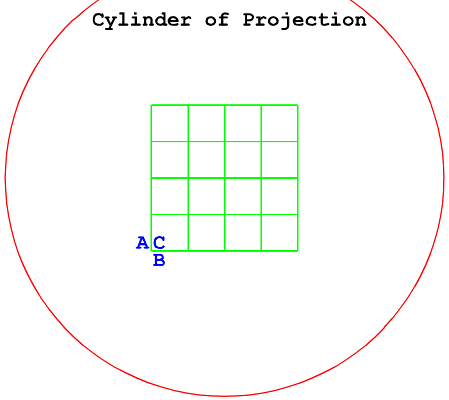
Physical Mesh

Initial Part

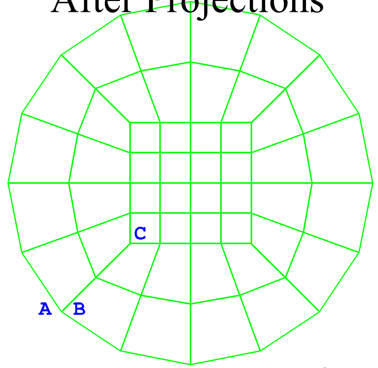
$X_1=X_2,\ X_4=X_5,\ Y_1=Y_2,\ Y_4=Y_5$



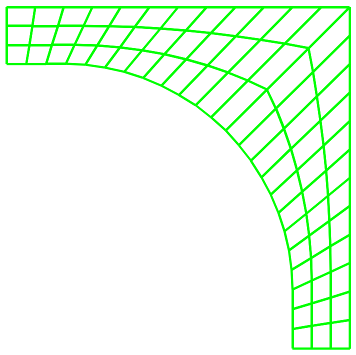
Delete Corner Blocks

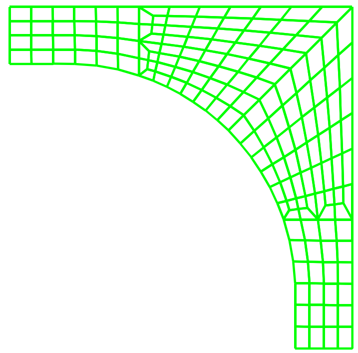


After Projections

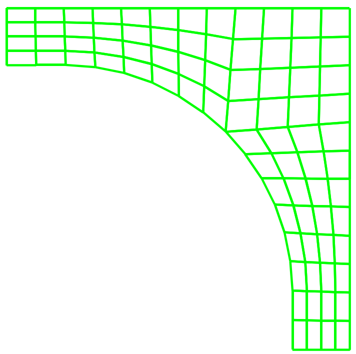


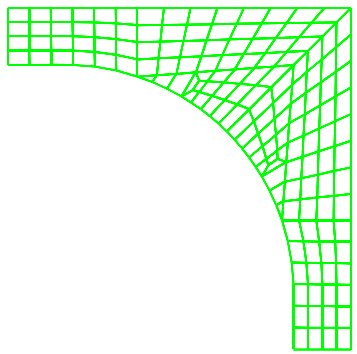
Choices In Block Topology



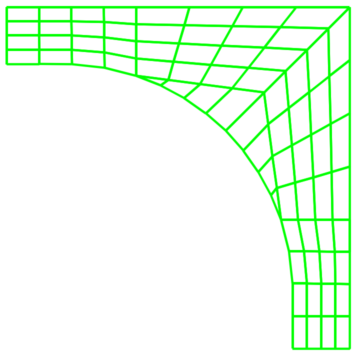


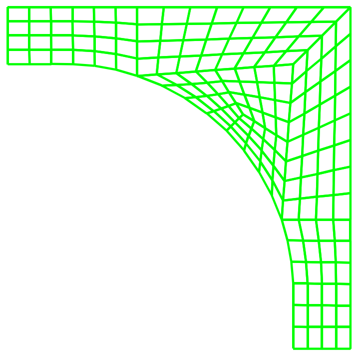
There are many topological choices to consider when designing a mesh. The mesh quality and density are the main issues. Complexity is usually a secondary issue. This simple fillet example shows 8 variations in the topology.

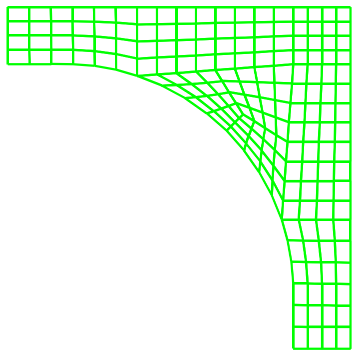


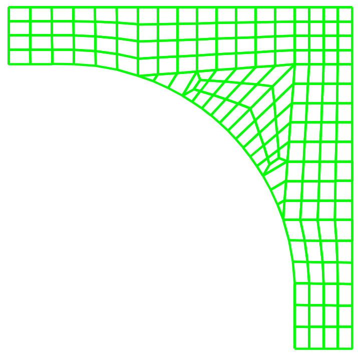


Construct the block commands used to generate these examples. Many of these examples use more than one part. The triangular elements are created by collapsing an edge of a region. The transitional regions are automatically generated between 2 parts using the bb and trbb commands, respectively.



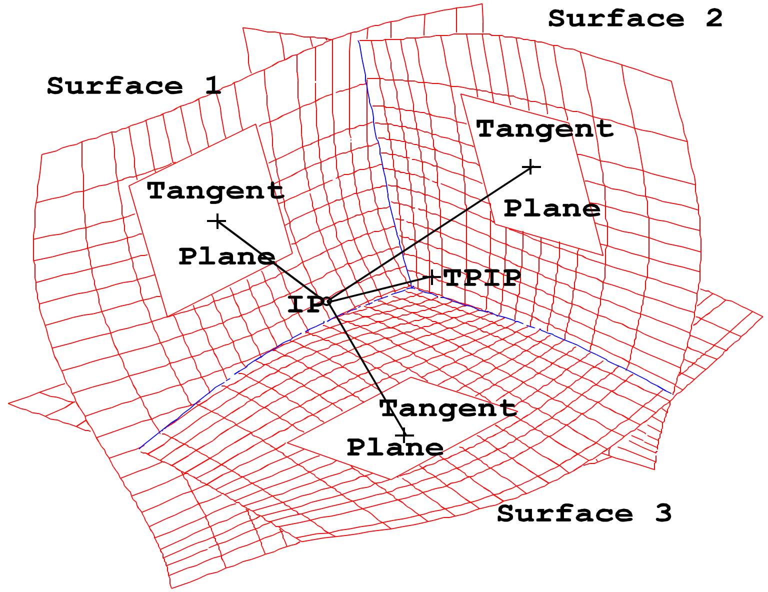






Projection to 3 Intersecting Surfaces

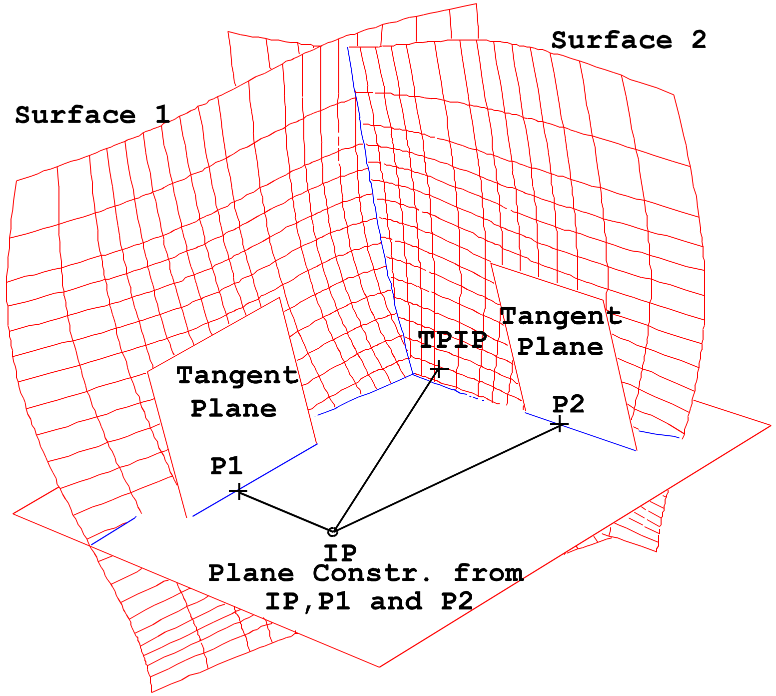
Project onto the intersection of 3 **Surfaces** uses the projection onto 1 surface for each of the 3 surfaces. The resulting **Tangent Planes** are intersected. The node at **IP** is moved to this intersection point **TPIP** and the process is repeated. Convergence to the desired point of intersection occurs if the initial point **IP** is closed. This is a relative issue based on the curvature of the surfaces. When the surfaces are flat, the initial point **IP** can be almost anything. Many features in **True*Grid*®** make it easy to move control points of the mesh so that they are close to the desired points of intersection of the 3 surfaces.



IP - Initial Point
TPIP - Tangent Plane Intersection Point

Projection to 2 Surfaces

The two **Tangent Planes** from the projection to two **Surfaces** are intersected with the plane which passes through the two points of projection **P1** and **P2** and the Initial Point **IP**. The node is moved to this point of intersection **TPIP** and the process is repeated. This is commonly the case with edge nodes that are required to be on two surfaces.



IP - Initial Point
TPIP - Tangent Plane Intersection Point

Projection onto Multiple Surfaces

It is easy to form a composite surface. The first step is to determine which surfaces are to be combine. If you can isolate the surfaces by showing only the surfaces you want to combine, then use the **lasd** command to list all of the surfaces in the picture.

Issue a command like the following:

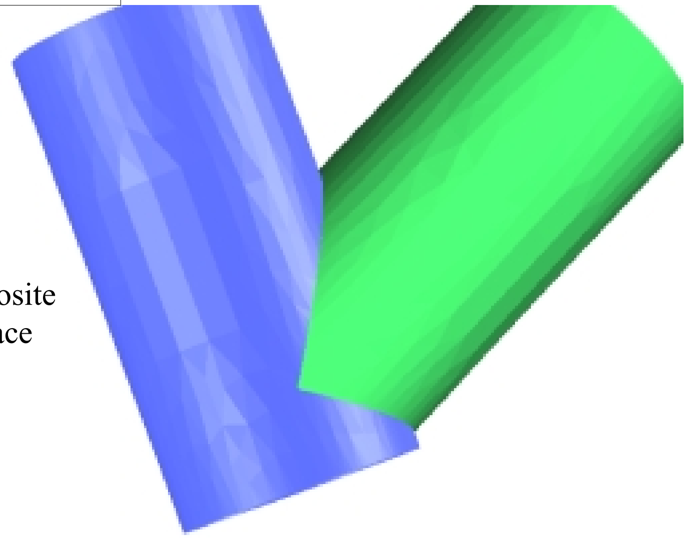
sd 25 sds 3 6;

This creates a new surface number 25 consisting of surfaces 3 and 6. Then project.

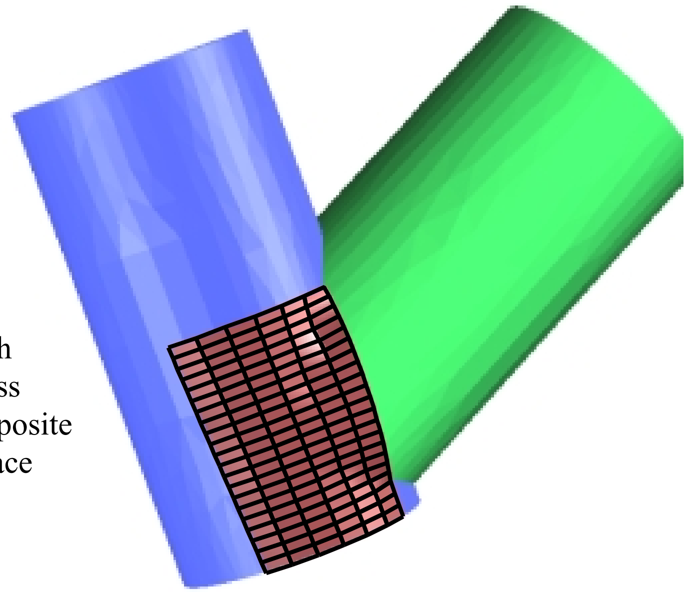
sfi ;;-1;sd 25

CAD models typically have thousands of surfaces. This feature helps organize the geometry. Then one can build the mesh with out regard to the boundaries of the component surfaces. Without this feature, one would be forced to use a mesh topology based on the boundaries of the surfaces instead of the right topology.

Composite surface

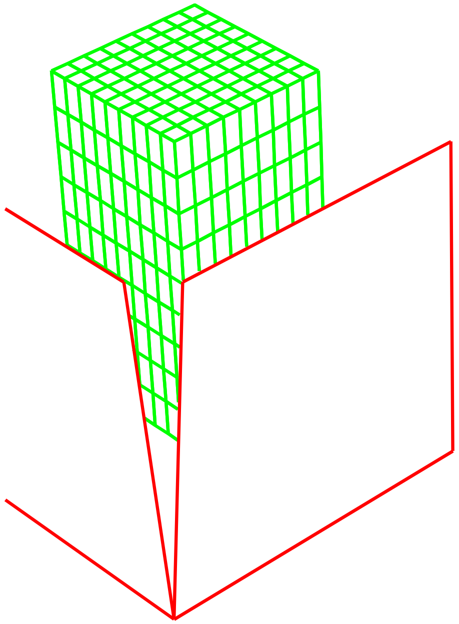


Mesh across composite surface

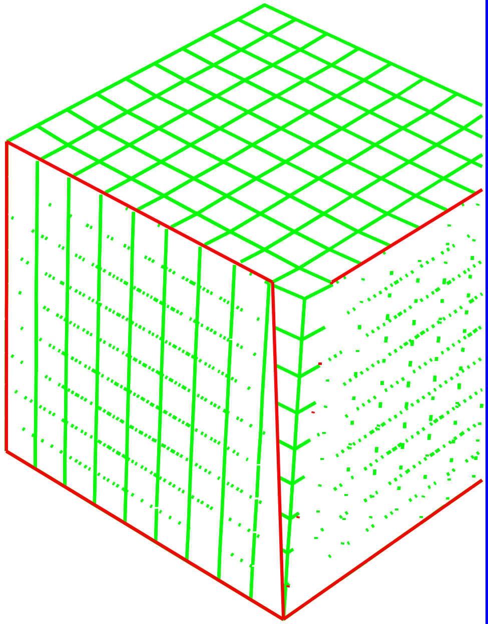


Intersecting Surfaces With Gaps

Before



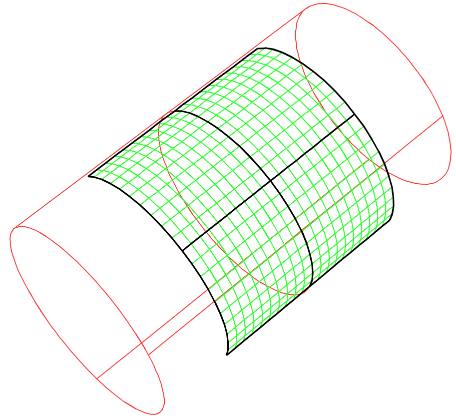
After



Geometry can be used directly from most CAD systems without clean-up. It is typical that surfaces do not meet perfectly. The intersection of surfaces automatically compensates for surfaces that do not quite intersect. This is because the algorithm intersects the tangent planes of closest points instead of intersecting the actual surfaces.

In the example to the right, the before view shows the initial position of the mesh before projections. The left face is projected to the left surface and the right face is projected to the right surface. No special care is needed as long as the gap between the two intersecting surfaces is smaller than a element.

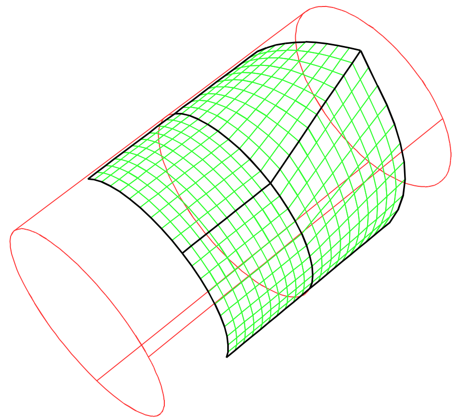
Exercise



PURPOSE: experiment with interpolations

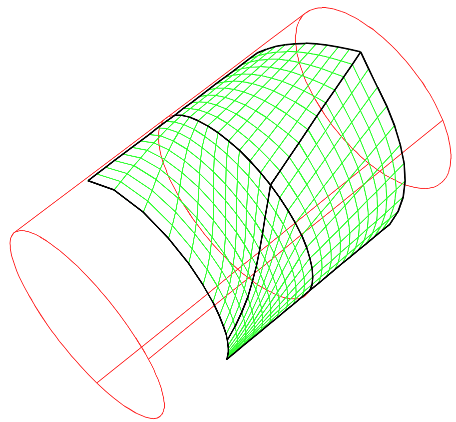
Create a 4 block shell part like the one on the right with commands like:

block 1 11 21; 1 11 21; -1; -4 0 4; -4 0 4; 1;
sd 1 cy 0 0 0 1 0 0 4
sfi ; ; -1; sd 1



Select the pick panel in the Environment window. Be sure no objects have been selected in the computational window by clearing the selection with the F2 key. Then use the left mouse with a click and drag movement in the physical window to move some of the control points around. This changes the initial coordinates of the selected vertex.

Use some of the nodal distribution functions to change the way the nodes are clustered along the edges of the blocks.



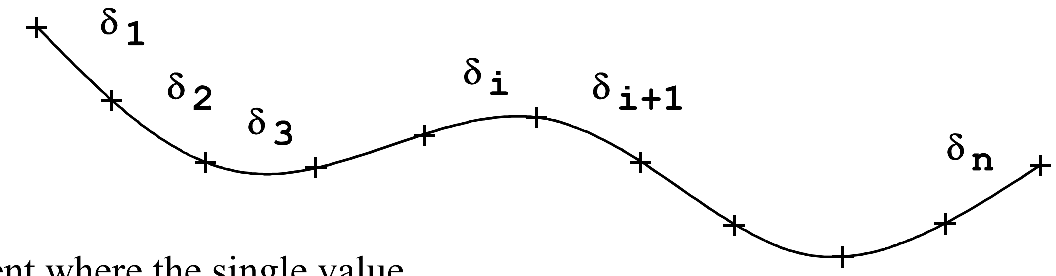
Now use some of the facial interpolation functions (**lin, tf, relax, tme**) to change the way the interior face nodes are distributed. These interpolations are based on the way the nodes are distributed on the boundaries. Note that the nodes remain on the cylinder.

Nodal Distributions Along Edges Only

There are 5 ways to control the distribution along an edge of the mesh.

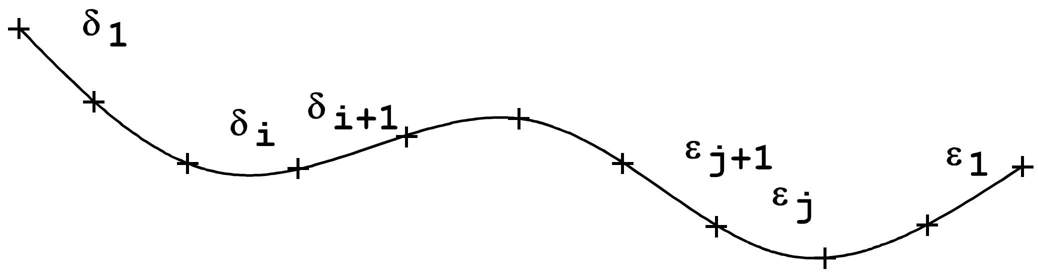
res - relative spacing by a ratio

$$\frac{\delta_{i+1}}{\delta_i} = \rho \text{ for all } i$$



as - absolute spacing by the size of the first or last element where the single value

$\rho = \frac{\delta_{i+1}}{\delta_i}$ is determined and true for all i (i.e. only δ_1 or δ_n is specified)



drs - double relative spacing by two ratios

$$\frac{\delta_{i+1}}{\delta_i} = \rho \text{ and } \frac{\varepsilon_{j+1}}{\varepsilon_j} = \sigma \text{ for all } i \text{ and all } j$$

das - double absolute spacing by the size of the first and last element where the two values

$\rho = \frac{\delta_{i+1}}{\delta_i}$ and $\sigma = \frac{\varepsilon_{j+1}}{\varepsilon_j}$ are determined and true for all i and all j (i.e. only δ_1 and ε_1 are specified)

nds - generalized density function for nodal spacing (Use the **ndd** and **dndd** commands first)

Interpolation

1. The default interpolation of edges, faces, and regions is linear because it is fast. This is equivalent to using the **lin** command. The default interpolation can be changed to **tfi** by using the **intyp** command.

2. Interpolation commands are used for two reasons. A partition in the mesh goes all of the way through the part. In some portions of the mesh, a partition may get in the way. If this partition is within the interior of a selected interpolation, it is as if that partition was not there.

3. The second reason to interpolate is to get a better quality mesh. Experimentation is usually needed to determine the best method for a problem.

4. Edges are the boundaries of a face and faces are the boundary of a solid. All interpolations treat the boundary of the selected region as fixed and only interpolate the interior. Sometimes the boundaries will require interpolation as well.

5. Some interpolations require a single block (**lin, tfi, tme**) with no holes. The **relax** command allows for holes. **Relax**, **esm**, and **unifm** allow for multiple blocks with coincident faces or edges glued together with the **bb** command.

6. **Esm** was an experiment, it is difficult to use, and other methods can be just as effective in most cases. **Esmp** is used to set the nodal distribution biases for **esm**.

7. **Tfi** is not iterative (algebraic), is more expensive than **lin**, and almost as good as **tme** for orthogonality. It is more sensitive to boundary curvature.

8. Most iterative methods (**relax**, **tme**, and **esm**) are expensive. **Unifm** is very expensive. There usually is no need to do many iterations.

9. These iterative methods can be combine in sequence, with the results supper imposed on the previous.

10. Relax is good for structural problems where equal sized elements are desired.

11. **Tme** is good for CFD calculations where an orthogonal boundary layer is desired.

12. **Esm** is good when specific control of the mesh near singularities are desired.

13. **Unifm** is great. The Dirichlet boundary condition is the default. The Neumann boundary condition (**Neu**) is available.

14. **Tfi**, **relax**, **tme**, and **unifm** work on faces and solids. **Lin** works on edges, faces, and solids. **Esm** works for faces.

15. Never select the step size in an iterative method to be greater than 1. It will be unstable. This step size is intended to be made smaller than 1.0 when one wants to spread the smoothing over a large area (which will require a larger number of iterations), but dampen its effect.

16. The iterative methods re-attach and re-project interior regions each iteration.

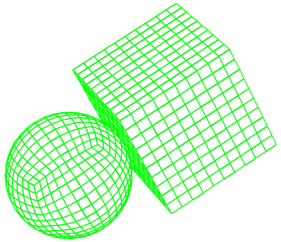
17. All methods work on non-smooth surfaces and surfaces with holes.

18. All interpolations cause the mesh to sag. **Unifm** is the exception. If the problem is two severe, split the region into two, control the nodal distribution along the new partition, and interpolate each separately.

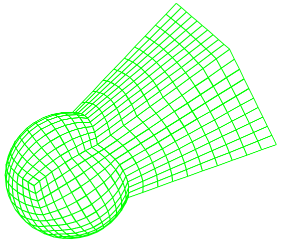
19. **Esm** handles the meeting of 3, 4, and 5 blocks at a node. **Unifm** handles any number of blocks joined at a node.

Block Boundaries and Transitions

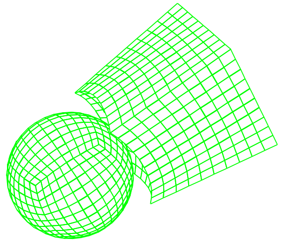
The **bb** (block boundary) command has many uses. Care must be taken to initialize the slave side so that the mapping of the slave to the master is obvious.

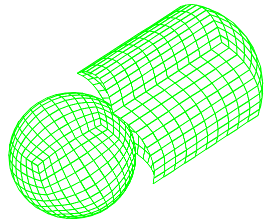


Before BB



After BB

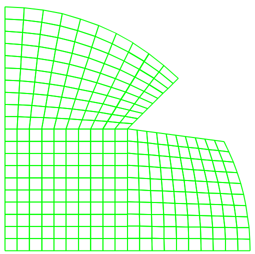




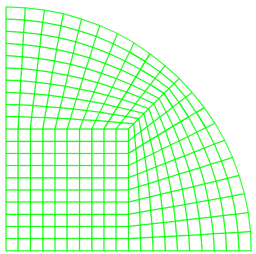
Glue 2 parts together

Normal offset gap between 2 parts

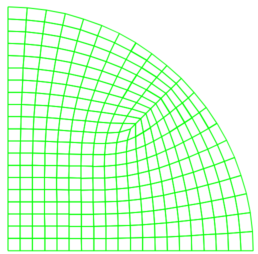
Periodicity in the mesh



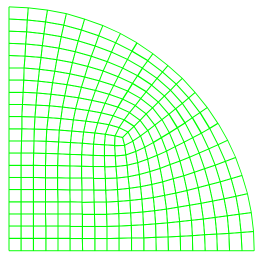
Before BB



After BB



Before BB

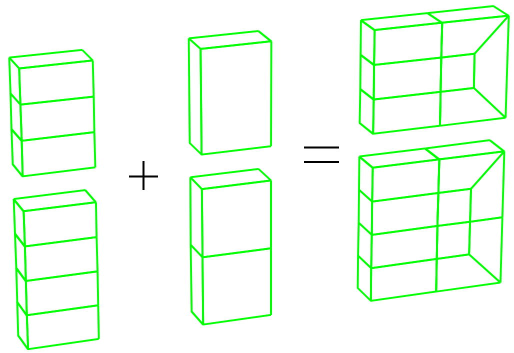


After BB

Keep disjoint regions of a part together

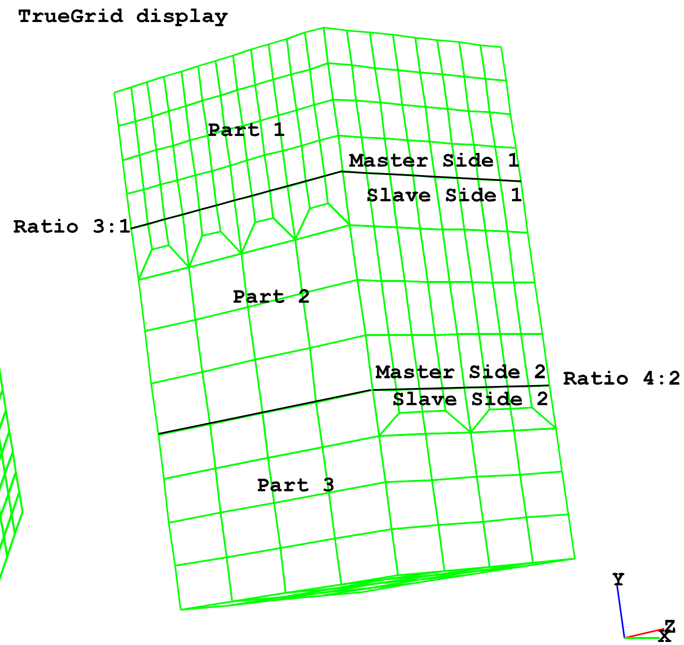
Smooth the mesh within a part across disjoint regions

The **trbb** (transition block boundary) command is an alternative to the bb command used to select a slave side to a block boundary interface. This is valid only between parts.



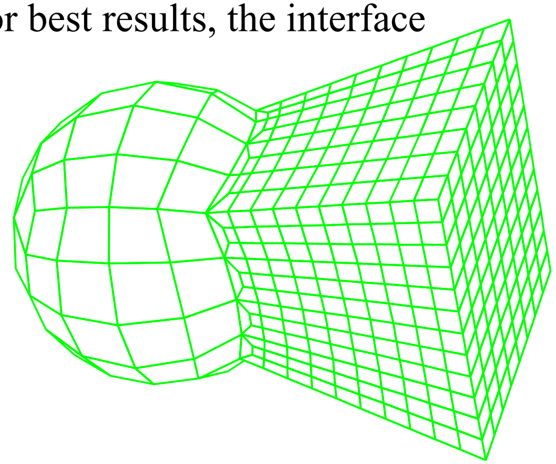
The ration of elements at the interface must be selected carefully so that in one direction, the slave to master ratio is either 2:4, 4:2, 1:3, or 3:1. Anything else will cause an error. The 2:4 and 4:2 ratio means that both sides must have an even number of elements.

A transition in 2 directions can be done with an intermediate part with transitions at both interfaces. Alternatively, a 2-way transition is accomplished by an appropriate ratio in both directions.



The transition row of elements are not generated until the part is ended. The only way to see them is to go to the merge phase.

This feature is very useful in transitioning from a coarse to a fine mesh. Care must be taken to create a good quality mesh. For best results, the interface region should be nearly planer and orthogonal.



Block Boundary Exercise

Create three files with the following commands as text:

File 1 (bb1.tg)
```
block
9;9;12;
0 10 0 10 -2 6
bb 2 1 1 2 2 2 1;
mate 1
endpart
```

File 2 (bb2.tg)
```
block
9;9;12;
20 25 10 25 5 10
mate 2
```

File 3 (bb3.tg)
```
block
6 6;3;6;
30 35 40 12 22 7 12
inttr .5
mate 3
```

Run tg without an input file

Type `partmode i`

Type `include bb1.tg`

Type `merge`

Type `rabb`

Type `include bb2.tg`

Glue part 2 to part 1 by attaching to bb 1

Define master bb 2 on opposite face

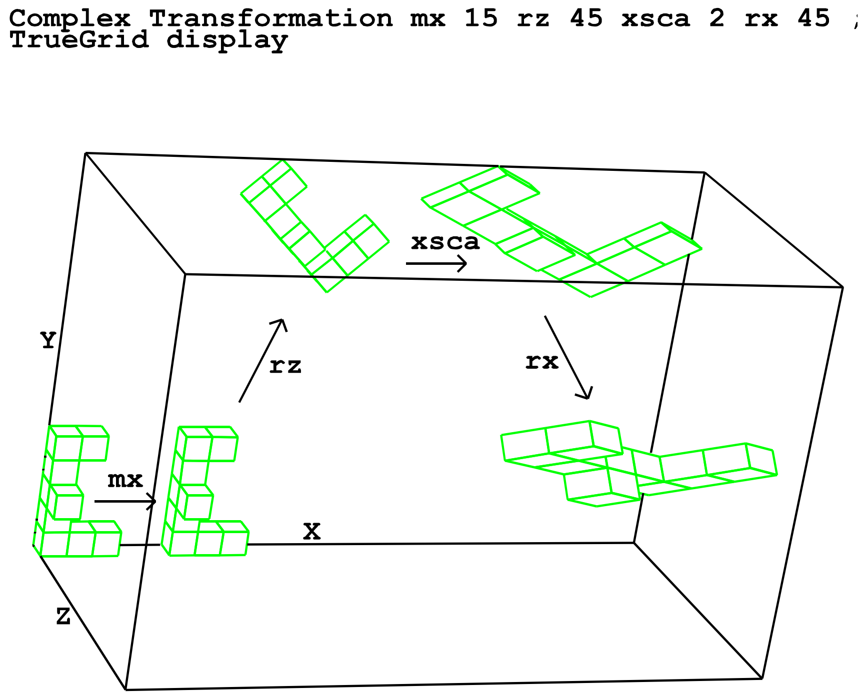
Type `include bb3.tg`

Use trbb to glue part 3 to part 2

Transformation

Transformations are used to position, scale, and reflect geometric entities such as surfaces and 3D-curves and to duplicate a mesh part. Simple operators are listed in order to from complex transformations. The simple operators are:

x-transformation	mx δ_x
y-transformation	my δ_y
z-transformation	mz δ_z
translation	v δ_x δ_y δ_z
x-rotation	rx θ_x
y-rotation	ry θ_y
z-rotation	rz θ_z
axis of rotation	ρ x_0 y_0 z_0 x_n y_n z_n
x-scale	xsca σ_x
y-scale	ysca σ_y
z-scale	zsca σ_z
scale	scal σ
xy-reflection	rxy
yz-reflection	ryz
zx-reflection	rzx
reference frame	tf X_1 X_2 X_3
frame to frame	ftf X_1 X_2 X_3 Y_1 Y_2 Y_3

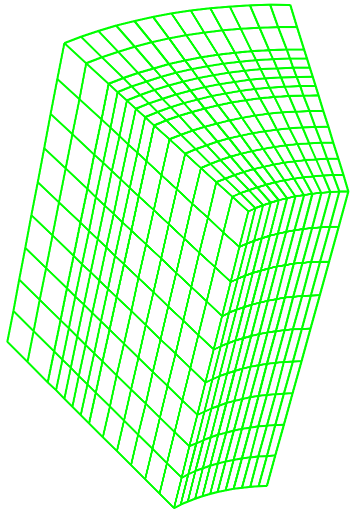


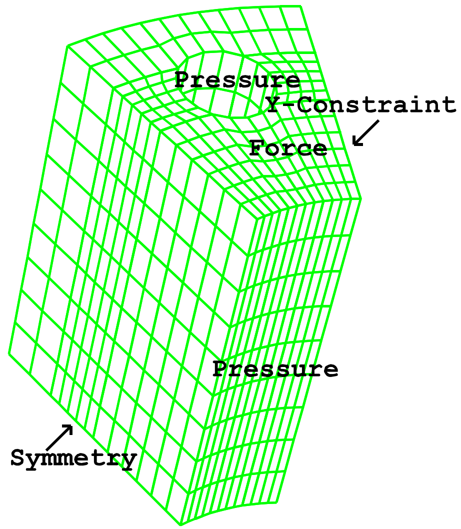
Sample transformation: mx 15 rz 45 xsca 2 rz 45

Flange with Bolt Circle

Part replication is performed with the transformation and replication commands. The transformation command lct/gct defines a table of transformations which are activated with the lrep/grep replication command.

```
cylinder 1 7 12 14;1 5 9 13;1 10;
         3 5 6 7 0 10 20 30 0 6
sd 1 cy 5.3 1.4 0 0 0 1 .7
dei 2 3; 2 3;;
sfi -2 -3; -2 -3;;sd 1
lct 11 rz 30;rz 60;rz 90;rz 120;rz 150;
rz 180;rz 210;rz 240;rz 270;rz 300;rz 330;
lrep 0 1 2 3 4 5 6 7 8 9 10 11;
```





The shorter version of the transformations and replications is:

```
lct 11 rz 30;repe 11; lrep 0:11;
```

The gct and grep commands work together in the same way and could have been used here instead of lct and lrep. When the two pairs of commands are used together, the result is the product of their individual transformations. The following accomplishes the same thing:

```
lct 2 rz 30;rz 60; lrep 0:2; gct 3 rz 90;rz 180;rz 270; grep 0:3;
```

Levels (lev, pslv, and pplv commands) are used in a similar fashion with the benefit of replicating any number of sequential parts. These are like FORTRAN do loops which can be nested 20 deep.

COMMAND HIERARCHY

RULE 1: Vertices, edges, faces, and volumes are automatically calculated in that order.

RULE 2: Commands are executed in the order according to the command type.

RULE 3: Commands of the same type are executed in the order they are issued.

These rules are expanded in the table below so that dependencies can be understood. This table is known as the command hierarchy. It will be necessary to understand this ordering and dependencies to build a complex model.

Position vertices - initialize/project

1. Initialization. There are three types of initialization.
   i) **BLOCK** and **CYLINDER** commands can contain initial coordinates of the vertices.
   ii) **BB** and **TRBB** initializes and freezes block interface nodes.
   iii) **PB**, **MB**, and **TR** commands initialize vertices.
2. Specified interpolation of edges along 3D curves and faces along patches.
   (**CUR**, **CURE**, **CURF**, **CURS**, **EDGE**)
3. Project vertices to specified surfaces, (**SF**)

Position Edges - interpolate or attach/project

4. Specified edge linear interpolations. (**LIN**)
5. Default edge linear interpolations.
6. Project edges to specified surfaces. (**SF**)

COMMAND HIERARCHY (cont)

Position Face - interpolate/project

7. Specified bi-linear interpolations of faces. (**LIN**)
8. Default interpolation of faces.
9. Project faces to specified surfaces. (**SF**)
10. Transfinite interpolation of specified faces. (**TF**)
11. Equipotential relaxation of specified faces. (**RELAX**)
12. Thomas-Middlecoff elliptic relaxation of specified faces.(**TME**, **ESM**, **UNIFM**)
13. Re-interpolate and project edges and faces affected by 10, 11, and 12.

Interpolate interiors - interpolation and smoothing only

14. Specified tri-linearly interpolation of solid regions. (**LIN**)
15. Default interpolation of solid regions.
16. Transfinite interpolation of solid regions. (**TF**)
17. Equipotential relaxation of specified solid regions. (**RELAX**)
18. Thomas-Middlecoff elliptic relaxation of specified solid regions. (**TME**, **ESM**, **UNIFM**)

Expressions - algebraic modification by coordinates and indices

19. expressions (**X**, **Y**, **X**, **T1**, **T2**, **T3**)

History Window

To activate the History window, click on the History button in the Environment window. This is available only in the Part Phase.

The history window allows you to inspect the commands affecting a selected region of the mesh.

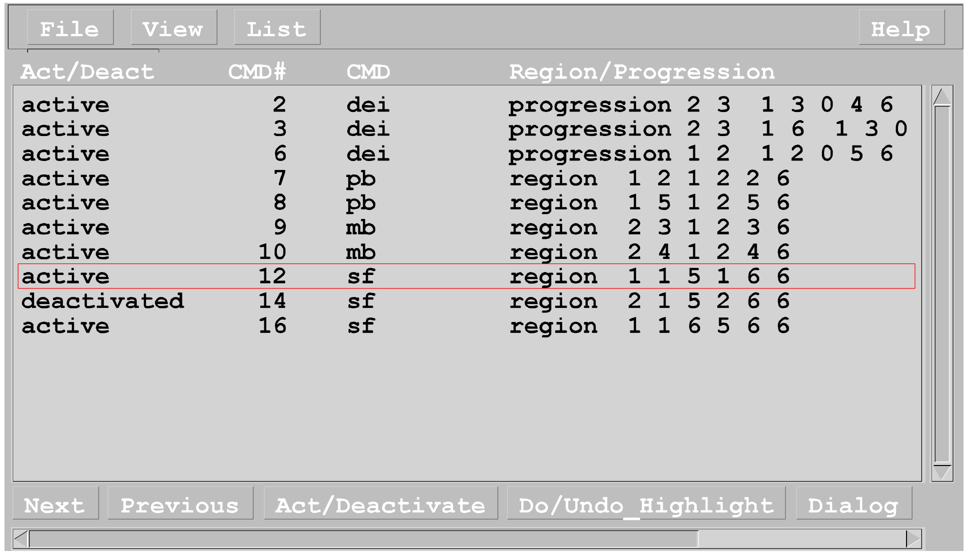
Commands can be deactivated or re-activated.

The dialogue box for a command can be retrieved so that the arguments can be modified and the command reissued.

Regions of a command can be highlighted with one click of the mouse.

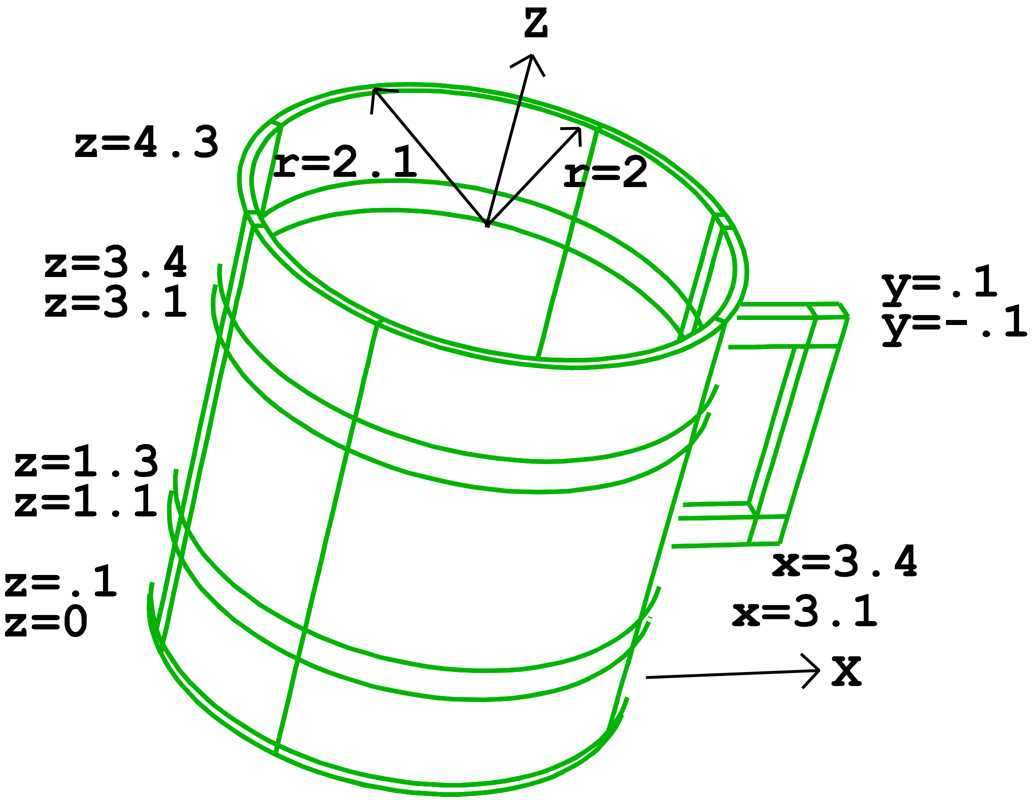
The commands can be ordered by sequence or by the command hierarchy.

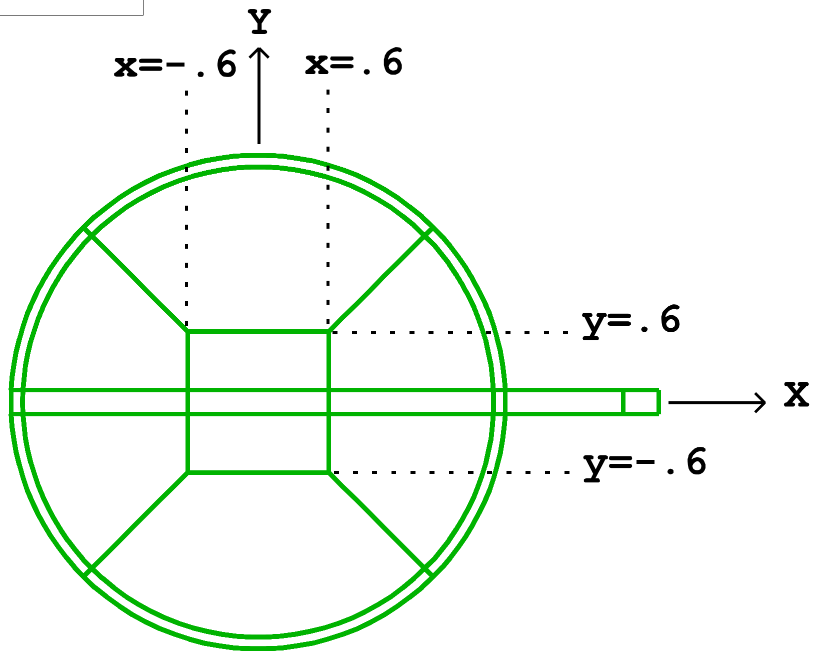
Geometry references can be listed.



These features can be very useful when debugging a mesh.
They are also useful in understanding the technique used to generate the part.

Cup with Handle Diagram





Block Command with Regions to Delete

Block 1 3 5 7 9 11 13 15;

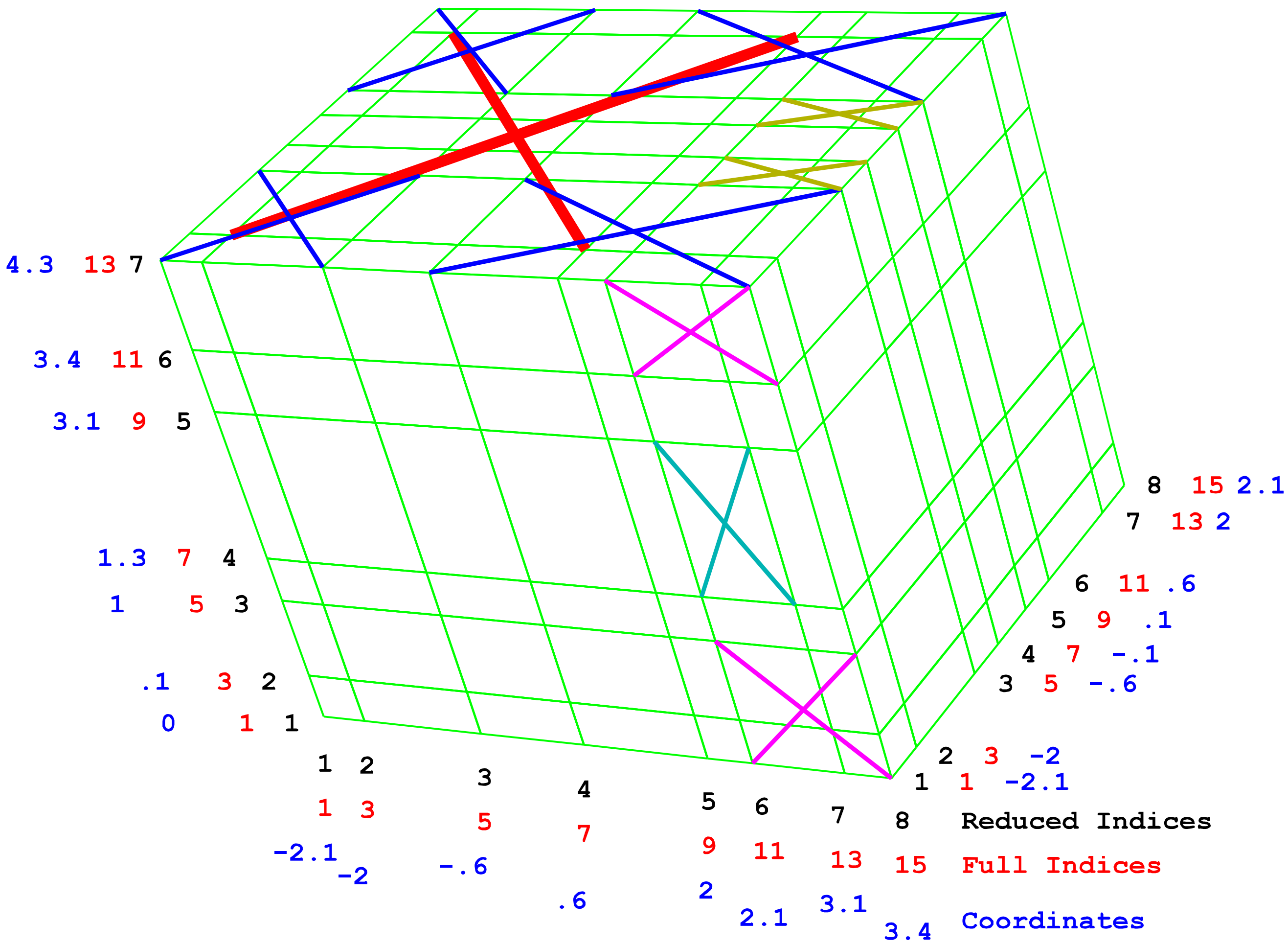
1 3 5 7 9 11 13 15;

1 3 5 7 9 11 13;

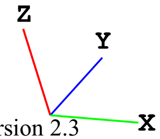
-2.1 -2 -.6 .6 2 2.1 3.1 3.4;

-2.1 -2 -.6 -.1 .1 .6 2 2.1;

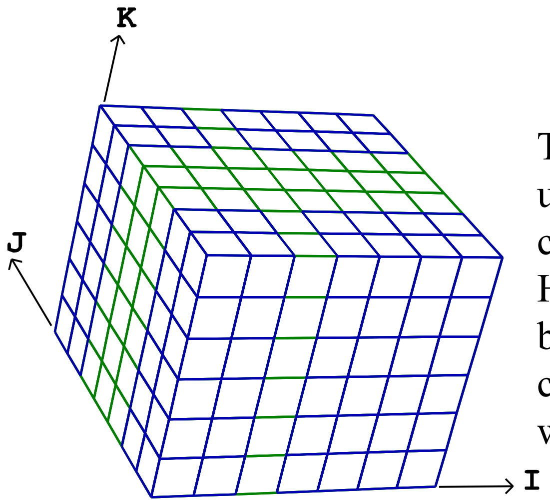
0 .1 1.1 1.3 3.1 3.4 4.3;



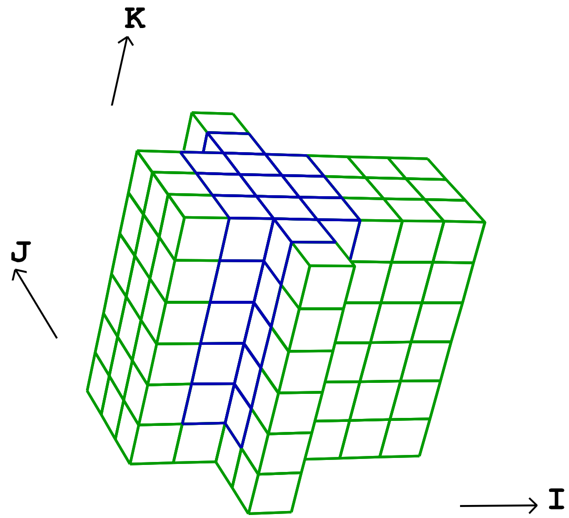
DELETE: Corners
Cavity
Sides of Handle
Above and Below Handle
Handle Hole

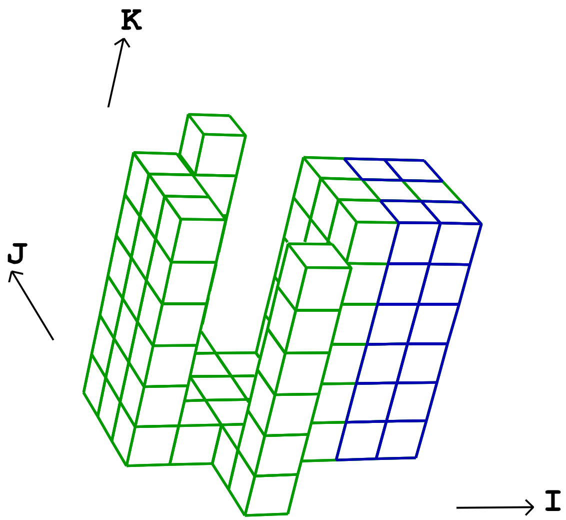


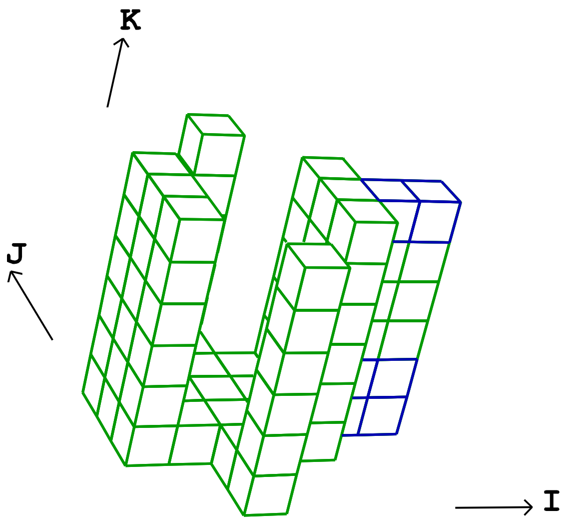
Regions to be Deleted

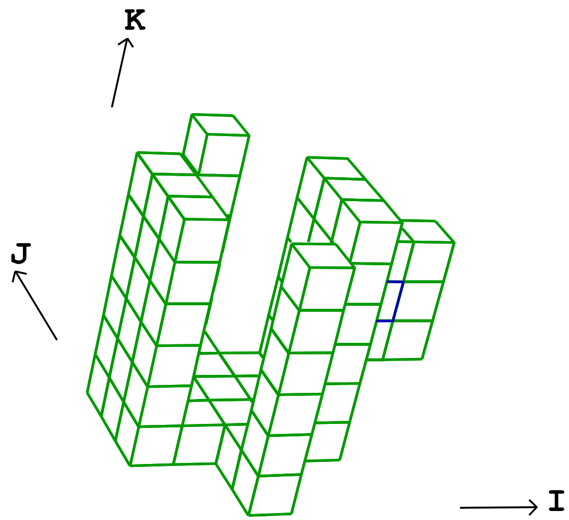


The blue regions in these pictures are the unneeded regions to be deleted. See if you can delete these regions using only 5 deletions. Highlight the regions using the index bars in the computational window. Then click on the Delete button in the Environment window.

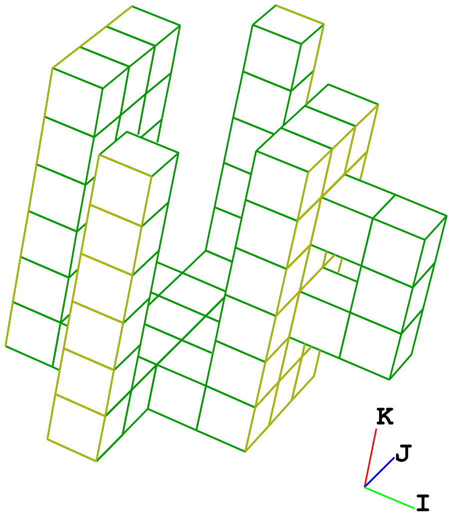


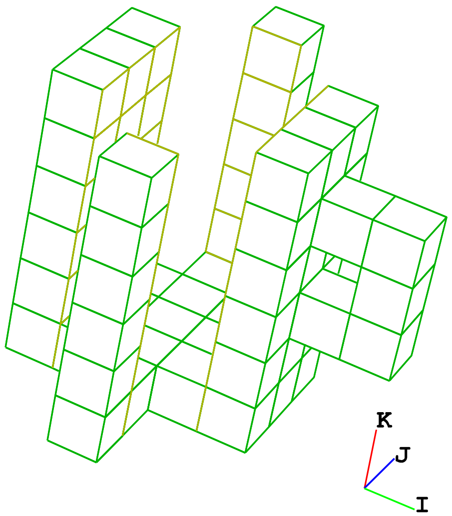


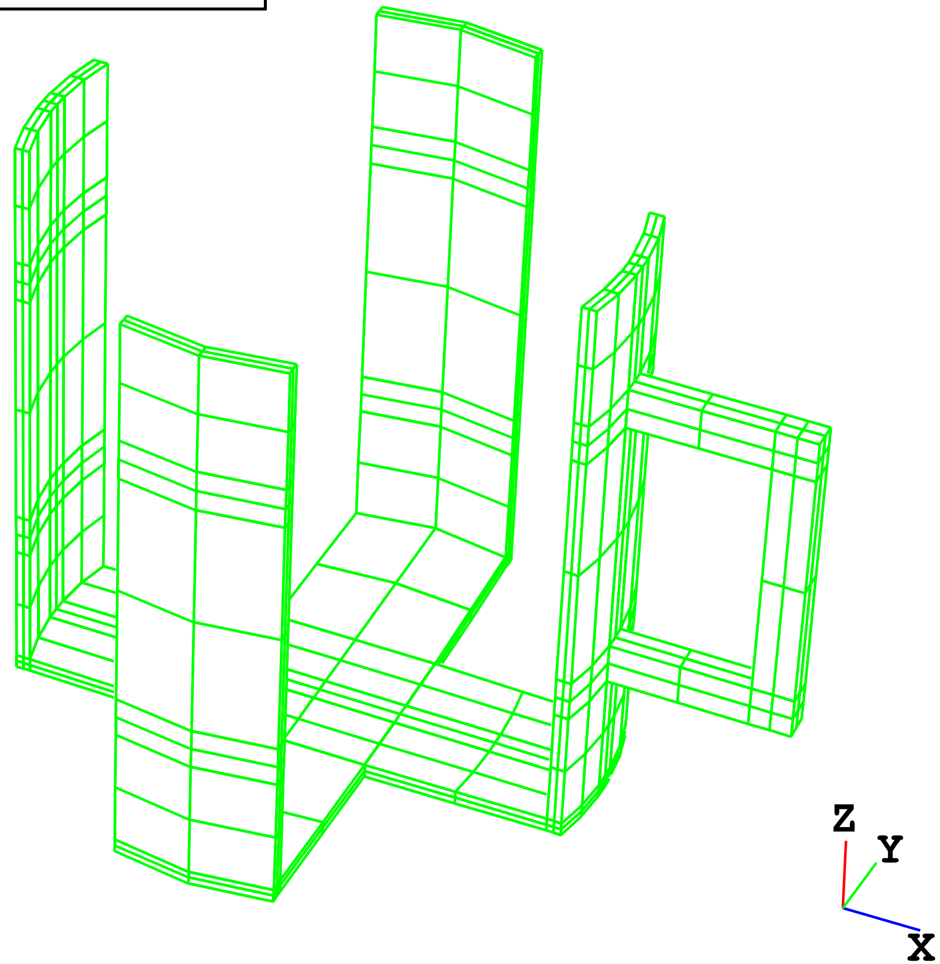




Project to the Cylinders

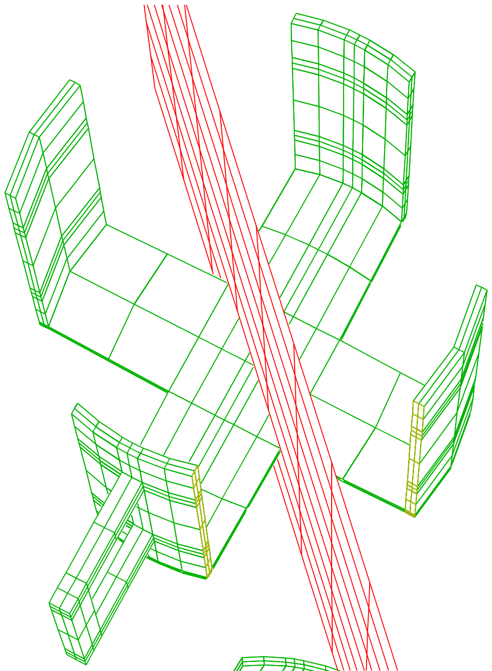


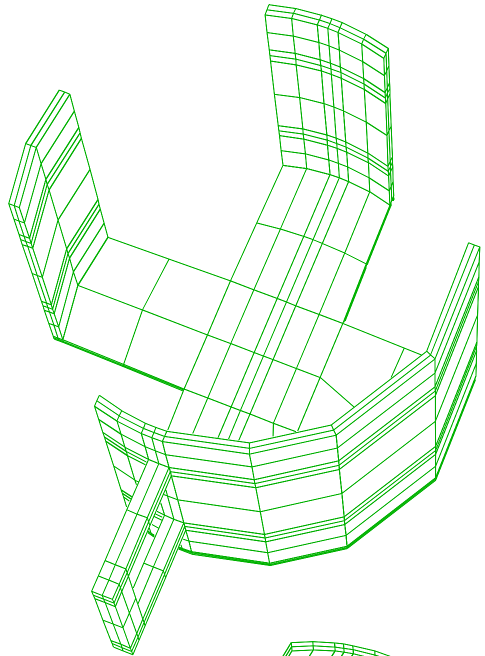




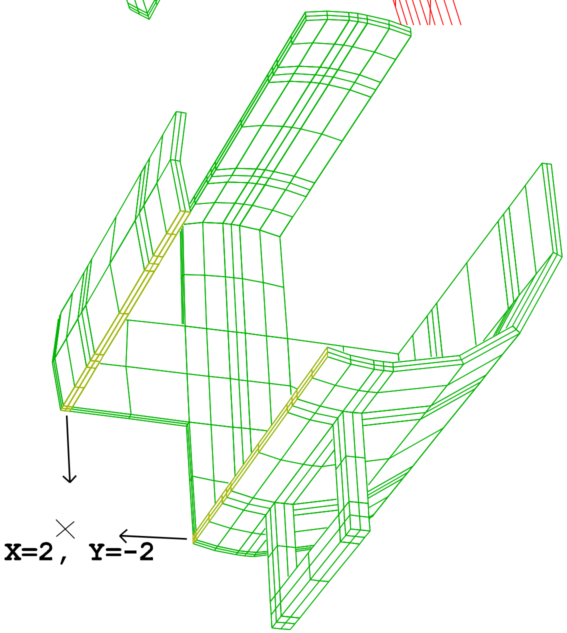
The inner an outer faces are projected onto the inner and outer cylinders with two commands.

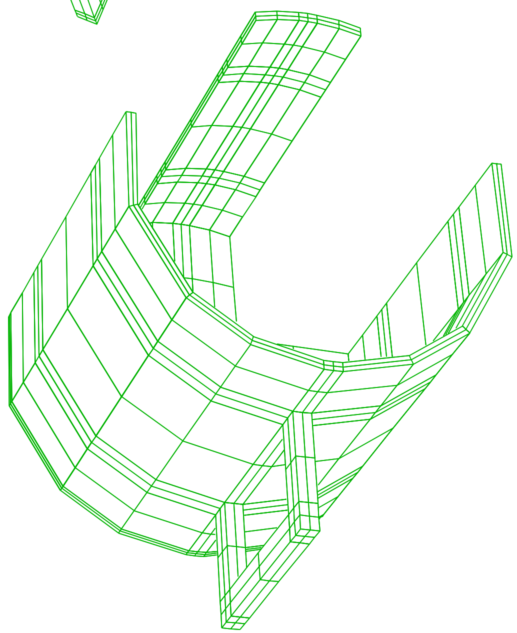
Four ways to Close the Gaps



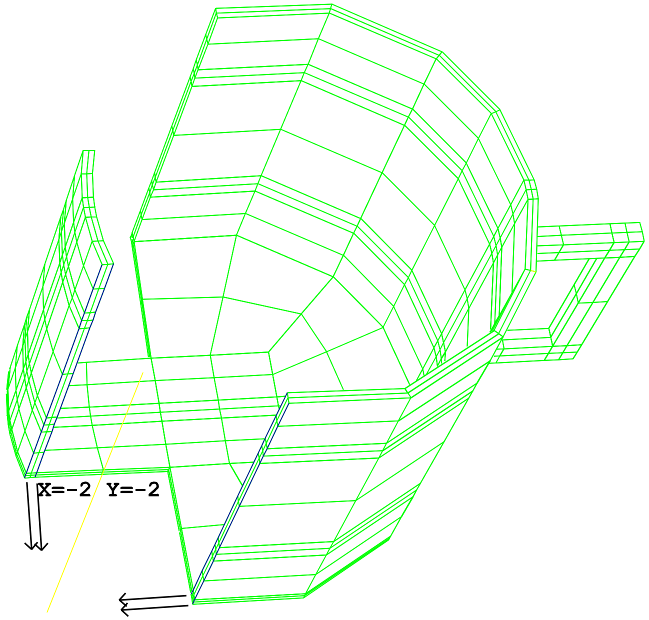


Construct a diagonal plane and project two opposing faces to that surface.

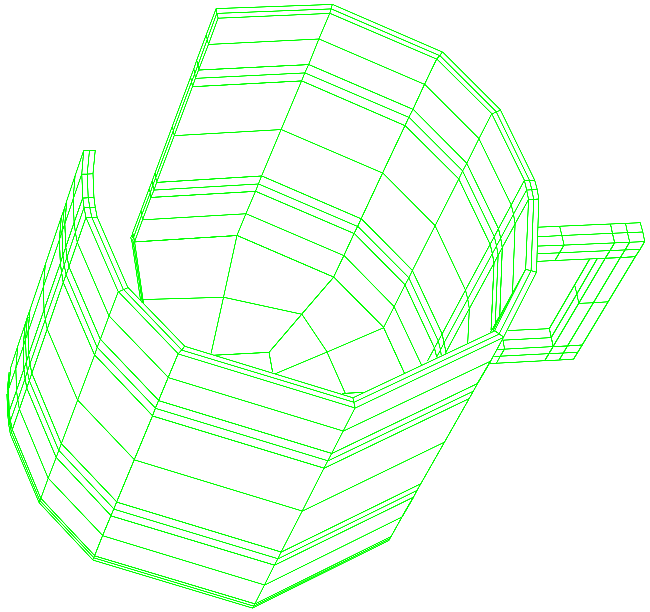


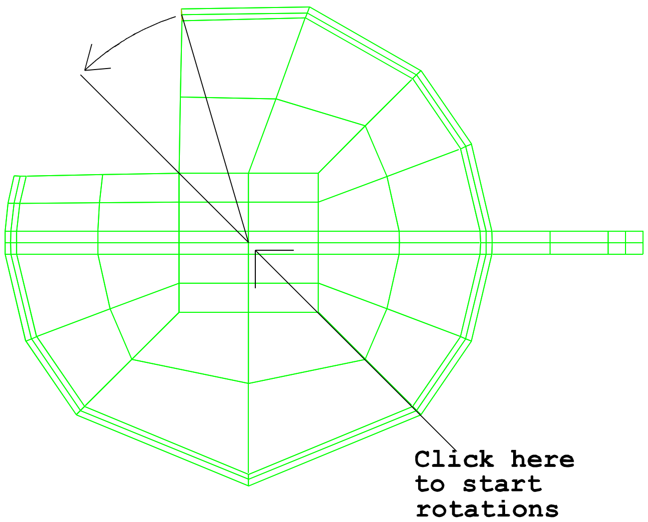


Change the initial x and y-coordinates of two opposing faces so that both faces are on the diagonal before the project to the cylinders occurs. If they both start out the same, they both end up in the same place. Use the **PB** command for this.

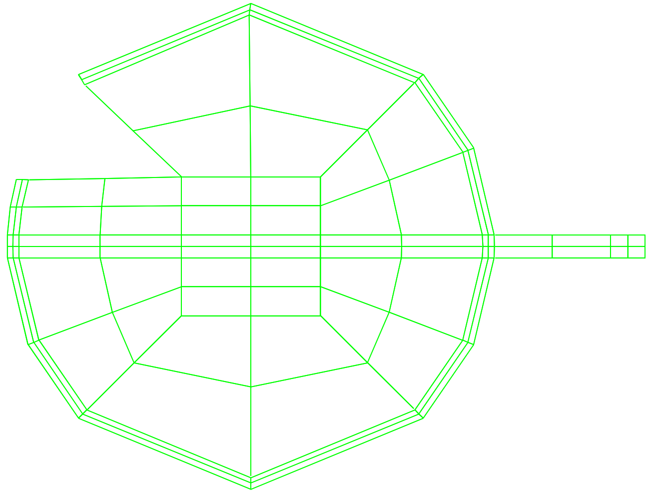


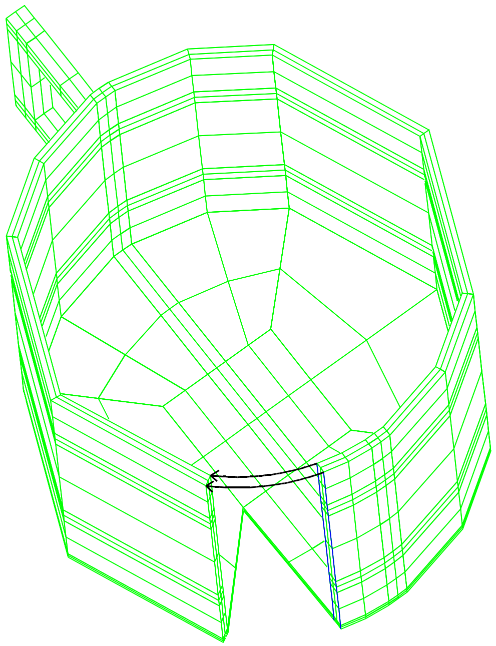
Construct a vertical line 3D curve at one of the diagonal positions using the **CURD** command. Then attach the vertical edges of the two opposing faces to this curve This also changes the initial position of the faces before they are projected to the cylinders. Treat both opposing faces equally.



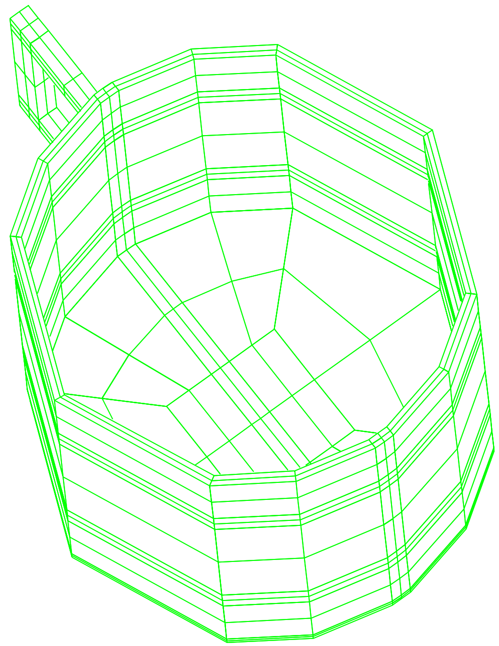


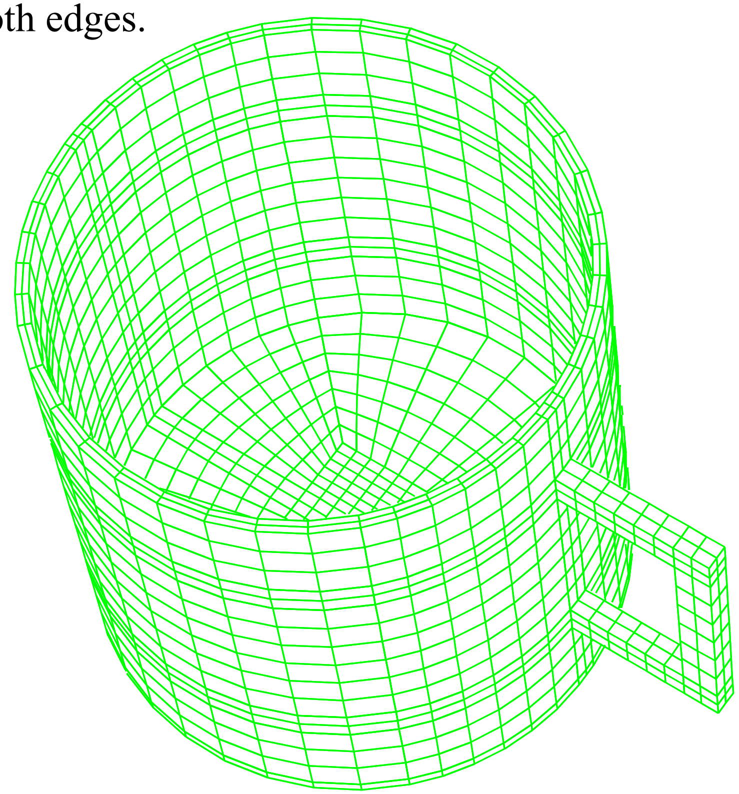
Change the initial coordinates of a face by rotation. Select the face, select rotation in the environment window, set the angle of perspective to 0, restore the picture so that you get the view you see here, and then rotate. This is done by starting the mouse at the center and then click and drag to get the desired rotation.





Move the remaining two edges to the same position as the opposing edges. This is done by selecting pick by node in the pick panel and deselecting the z-coordinate. Highlight one of the edges, pick a node of the opposing edge, and attach. Only the initial x and y-coordinates are changed. Do this for both edges.





The last step is to use the **MSEQ** command to add more elements to round out the model. Take care to add matching number of elements in the regions that were folded together.

8 Basic Functions in Part Phase

It is most important to understand the commands in the Mesh menu, which can be simplified by grouping the commands by basic functions.

1. **Mesh Density** - mseq
2. **Block Deletion -** de ,dei
3. **Intialization -** pb, mb, mbi, tr, tri
4. **Edge Shaping -** cur, curs, cure, curf, edge
5. **Interpolation** - lin, lini, tf, tfi, relax, relaxi, tme, tmei, unifm, unifmi
6. **Projection -** sf, sfi
7. **Nodal Distributions -** res, drs, as, das
8. **Block Boundary interfaces** - bb, trbb

Commands with the i suffix use index procession, but otherwise are equivalent to the same command without the i suffix.

RECIPE FOR SUCCESS

Steps below can be arranged in almost any order. If the **INSPRT** command is used, then order is important since the commands after insertion of a partition will cause the numbers referencing the partition to change. Steps performed in the **CONTROL**, **PART**, and **MERGE** phase are color coded.

1. Draw a block diagram of the topology with partitions along features
2. Break problem into parts and draw topology diagrams for each part
3. Start **True*Grid*** ® and select an output option (DYNA3D, ANSYS, MARC, AUTODYN,...)
4. Import IGES geometry and/or create geometry (IGES, IGESFILE, SD, CURD, LD)
5. Create one part at a time (BLOCK, CYLINDER)
6. Delete regions that are not needed (DE)
7. Move vertices to key positions (PB, MB, TR)
8. Select faces to be attached to previously generated parts (BB, TRBB)

RECIPE FOR SUCCESS (cont)

9. Attach edges to curves or surface edges (CURS, CUR, CURF, EDGE)
10. Select faces and project to desired surfaces (SF)
11. Add elements (MSEQ)
12. Select nodal distributions along edges (RES, DRS, AS, DAS)
13. Choose special interpolations or smoothings for problem faces (LIN, TF, RELAX, TME, UNIFM)
14. Choose special interpolations or smoothings for problem interiors (LIN, TF, RELAX, TME, UNIFM)
15. Assign loads/materials/ boundary conditions (PR, B, FL,...)
16. Start the next part (go back to step 5)
17. Assign material properties and select analysis options (CONTROL, *MATS and *OPTS)
18. Merge parts together and inspect them (MERGE, STP, BPTOL, PTOL, BNSTOL, LABELS, CO, MEASURE)
19. Write the output file (WRITE)

CAD

IGES file format - Initial Graphics Exchange Specification (NIST)

Viewpoint and STL data

IGES and IGESFILE commands

Numbering of surfaces and curves and multiple IGES files

USEIGES and SAVEIGES commands

IGES levels and associativity groups

Tolerances

Tangent surfaces, trimmed surfaces, and composite surfaces

How to deal with gaps and overlaps at mesh intersections

Viewpoint Data Format

Two files with data similar to Finite Element meshes: nodal element files. Each element is associated with a surface which is named in the first field on the element definition.

Nodal coordinate file has the following format:

```
1, -3.383404, -0.583990 , 2.585073
2, -3.187954, -0.598938 , 2.572747
3, -3.186691, -0.594553 , 2.575749
4, -3.383906, -0.579564 , 2.587889
5,  4.597703, -0.602771 , 2.579074
...
```

Element connectivity file has the following format:

```
hood  7306  7302 7249 7244
body  7121  7125 7129 7116
body  7124  7307 7247 7130
hood  7301  7298 7253 7250
hood  7297  7294 7257 7254
 ...
```

IGES Data Format

Each file contains String, Global, Directory, Parameter, and Terminator data. Pairs of directory records identify a geometric entities by the first number. The second number is a pointer into the parameter data. For example, type 128 is a NURBS surface. All geometric entities are algebraic.

```
Text messages or comments                                            S      1
1H,,1H;,, 8Hpack.igs,                                                G      1
5HANSYS,21HREV 5.0      UP 90292,,,,,,,,,,,,13H9210 5. 6 224,,,,,,;     G      2
     128       1       0       0       0       0       0       000000001D      1
     128       0       0      12       0       0       0 SURFACE       0D      2
     126      13       0       0       0       0       0       000000001D      3
     126       0       0       6       0       0      0B-SPLINE       0D      4
...
128,       1,       1,       1,       1,       0,       0,            1P      1
           1,       0,       0,                                       1P      2
  0.000000000000E+00,  0.000000000000E+00,   1.00000000000    ,       1P      3
   1.00000000000    ,  0.000000000000E+00,  0.000000000000E+00,       1P      4
   1.00000000000    ,   1.00000000000    ,   1.00000000000    ,       1P      5
   1.00000000000    ,   1.00000000000    ,   1.00000000000    ,       1P      6
  -2.27778406141    ,  -1.31507924098    ,   3.13843157742    ,       1P      7
   12.5598045656    ,   7.25140654689    ,  -6.74905435536    ,       1P      8
   7.52332454819    ,   4.34359345309    ,   22.7490543554    ,       1P      9
   22.3609131752    ,   12.9100792410    ,   12.8615684226    ,       1P     10
  0.000000000000E+00,   1.00000000000    ,  0.000000000000E+00,       1P     11
   1.00000000000    ;                                                 1P     12
126,       1,       1,       0,       0,       1,       0,            3P     13
...
186,     737,       1,       0,       0,       0,       0;          739P   2642
S      1G      2D    740P   2642                                     T      1
```

3D Curves

Purpose: 3D curves are used primarily to force a mesh edge on a geometry feature defined by a curve.

Usage: Only mesh edges and vertices can be attached to 3D curves (know as initialization)

Types of 3D Curves

- IGES curve
- Edge of a surface
- Surface contour
- B-spline
- NURBS spline
- 2D to 3D conversion
- Interpolate between two curves
- Surface or curve point selection
- Parameterized function curve
- Project a 3D curve to a surface
- Project a 3D curve to a surface and smooth
- Arc of a circle (3 points)
- Section of a 3D curve
- Copy and transform a 3D curve
- Combine a set of 3D curves and transform

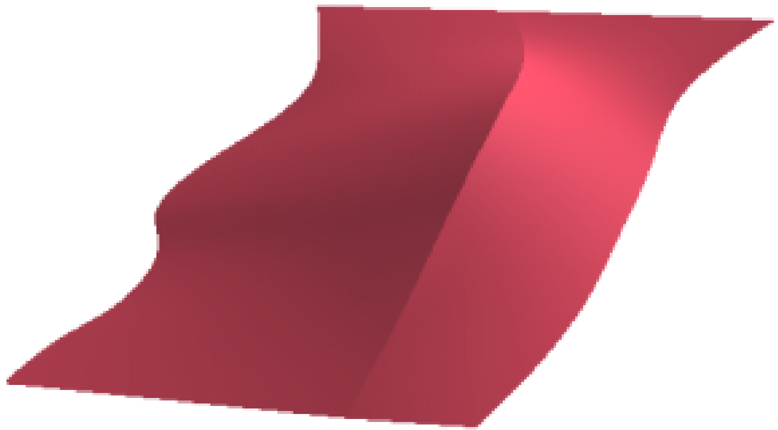
Interactive 3D Curve Creation

LP3 - Piecewise linear curve of interactively selected points

SPLINE - Cubic spline between interactively selected points

TWSURF - Curve automatically created at the intersection of two surfaces; 4 - 10 points, interactively selected, are needed to initialize this curve

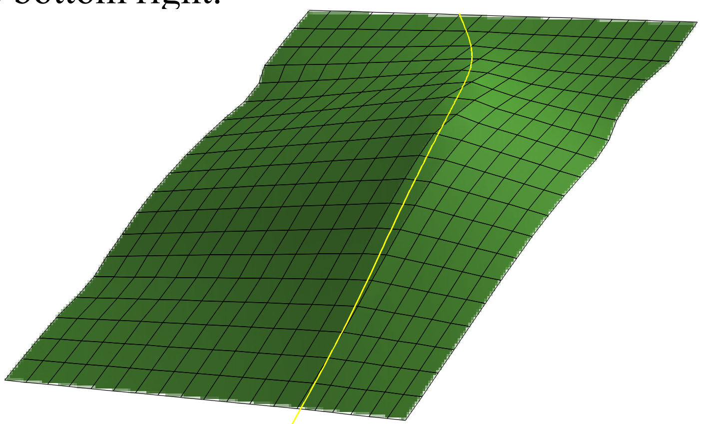
COEDG - Create curves from surface edges

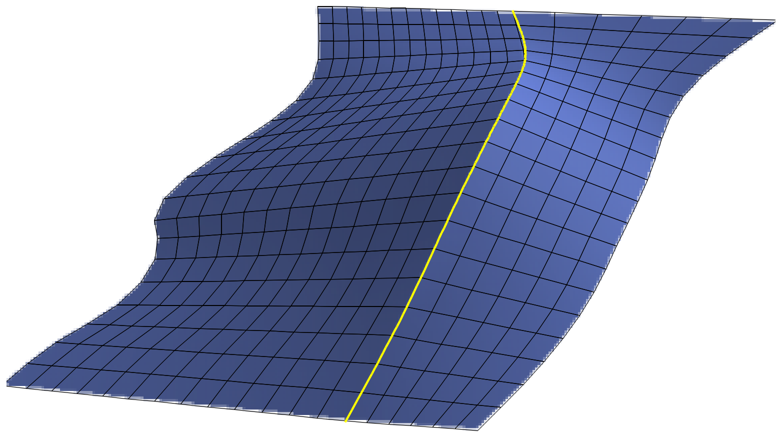


The surface on the right has a non-concave boundary and an interior feature.

The mesh on the bottom left, which was projected to this surface, does not have an interior mesh line which follows the interior feature highlighted in yellow. Also, the boundaries of the mesh do not include the convex portions of the boundaries of the surface.

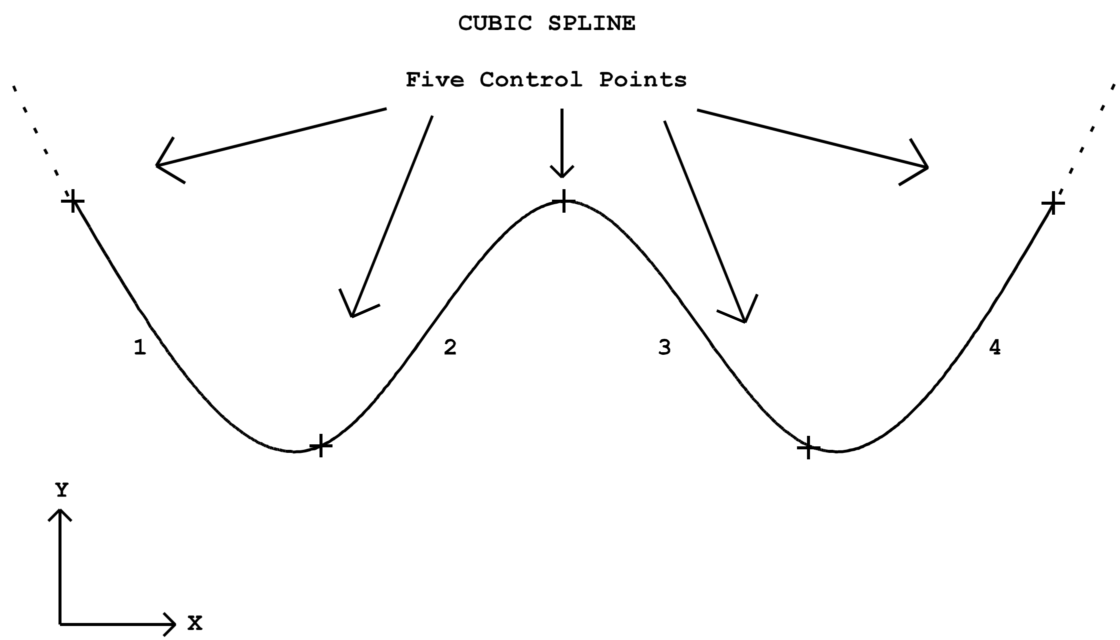
By attaching the boundary of the mesh to the edges of the surface and by attaching an interior line of the mesh to the 3D curve that follows the interior feature, one gets a mesh that more accurately represents the surface, as shown on the bottom right.





Cubic Spline w/Natural Derivatives - 2nd Derivatives are 0 at the Endpoints

Every segment of a cubic spline is a parametric cubic polynomial. This spline passes through each of the control points. There are several options based on the properties of cubic spline. The subscript i below denotes the ith segment:



$$X(t) = a_i t^3 + b_i^2 + c_i t + d_i$$

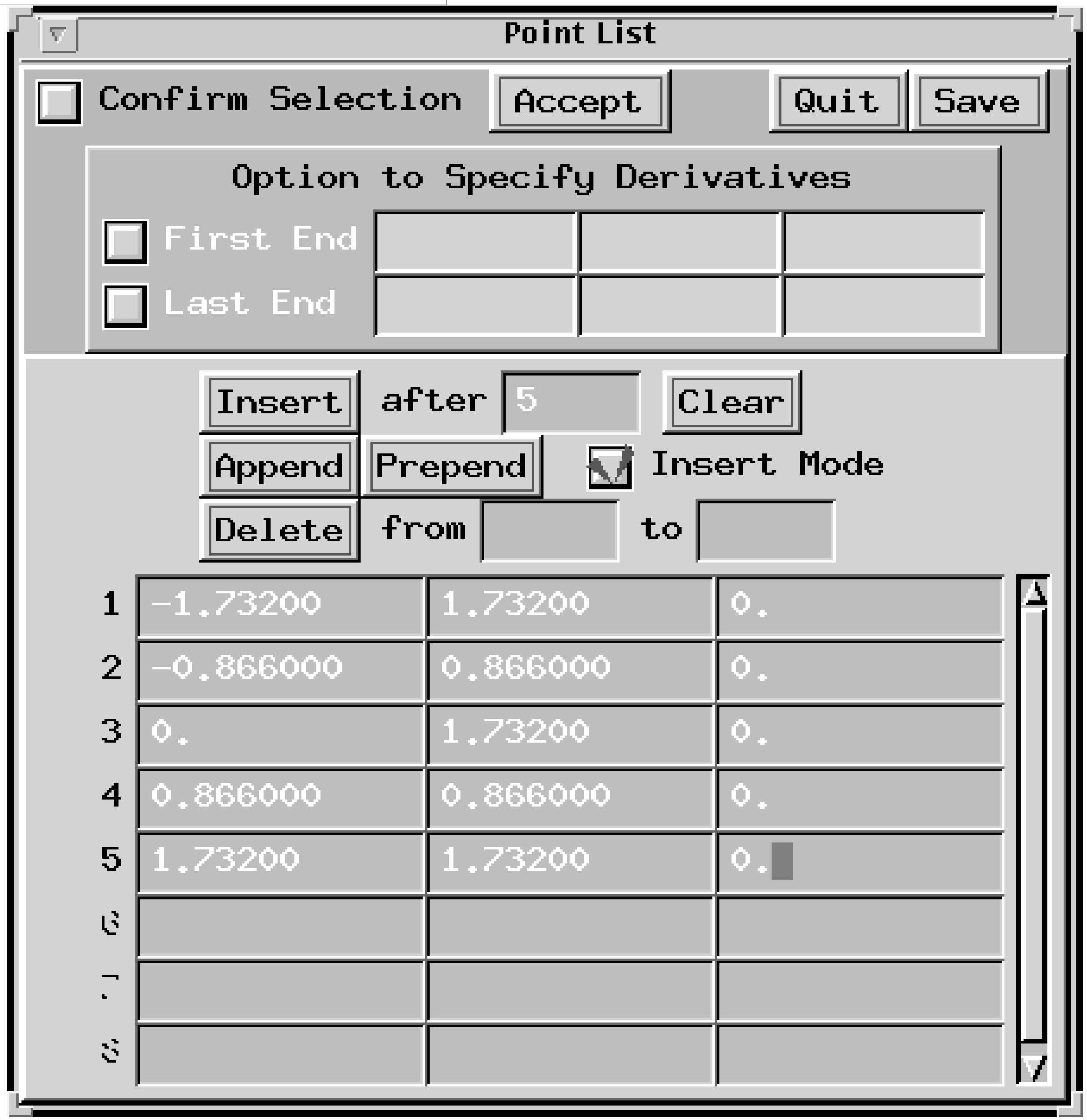
$$Y(t) = e_i t^3 + f_i t^2 + g_i t + h_i$$

$$Z(t) = j_i t^3 + k_i t^2 + l_i t + m_i$$

where the independent variable t is allowed to range over a short interval Suppose there are n segments in the cubic spline. This produces 12n unknowns. There are 6n constraints since the endpoints of each section passes through the control points. There are 6n-6 additional constraints imposed so that the curves has two derivatives at the interior control points. You can choose the derivative at the end points to impose the remaining 6 constraints.

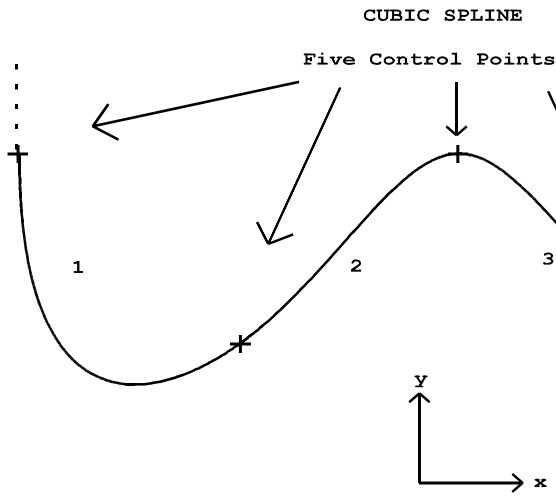
Creating a Cubic Spline

To create a spline, choose **SPLINE** from the 3DCURVES menu. You must be in either the Merge or Part Phase for this feature. Select points to be entered into the table that appears.

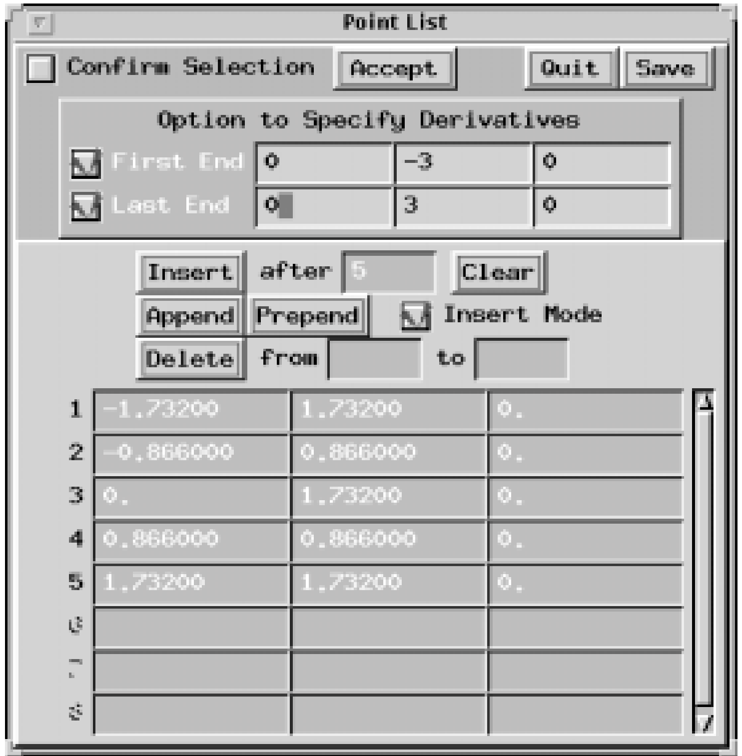


To save the curve, click on the **SAVE** button with the left mouse button and type a curve number. Then select the **QUIT** button with the left mouse.

Control the End Derivatives of a Cubic Spline

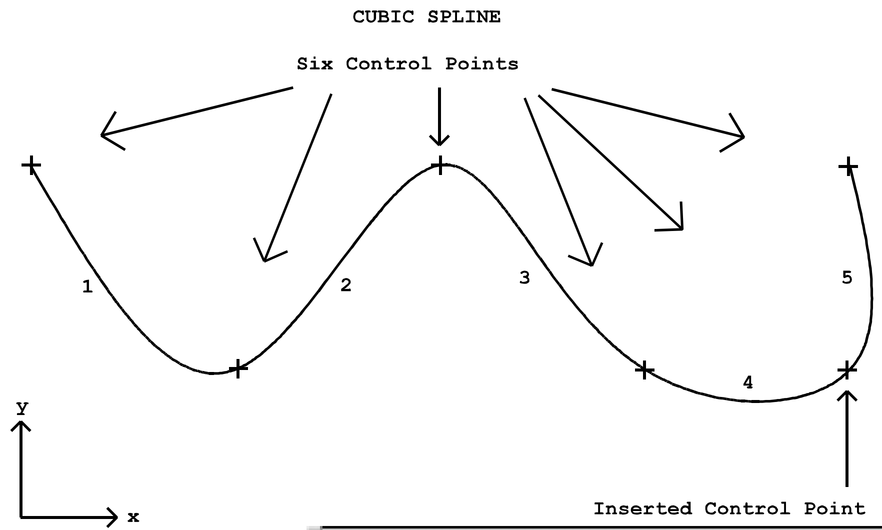


Click on the box next to First End in the Point List window and enter the three vector components of the derivative for the first end point. To specify the derivative at the other end point, fist select the box next to Last End in the Point List window then enter the vector components of the derivative.



Inserting a Cubic Spline Control Point

Before a new control point can be selected, its position in the sequence of control points must be selected. Insertion is done after the selected control point. There are three ways to select the point of insertion.



Method 1 - Scroll through the control points with the keyboard arrow keys. The mouse must be in the Point List window. As you scroll, you will see a small box in the picture move from one control point to anther.

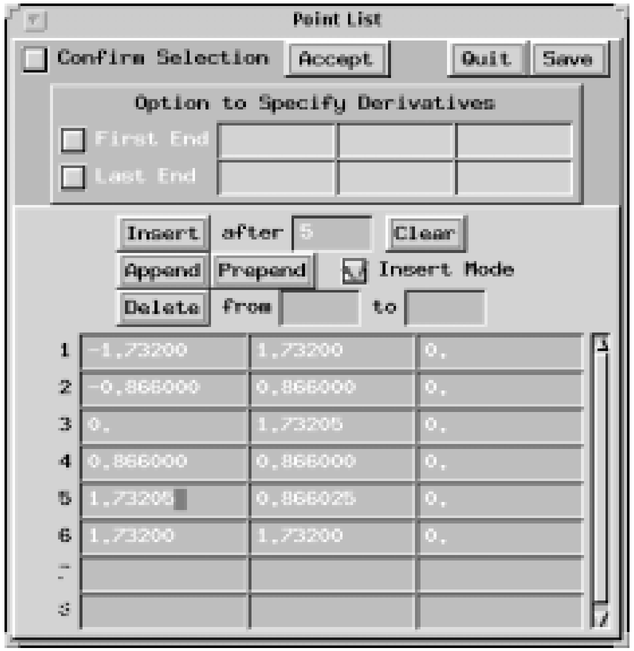
Method 2 - Click on the row of the desired control point with the left mouse button.

Method 3 - Move the mouse close to the control point in the picture and push the F5 function key.

Method 4 - Enter the control point sequence after the Insert button. Either type the return key or click on the **Insert** button.

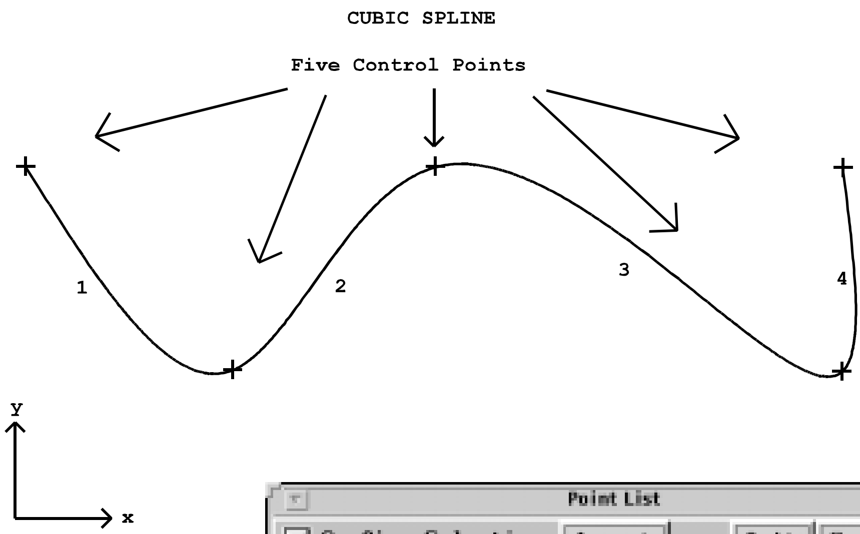
Now select a point in the picture to add a new control point.

In this example, the fourth control point was selected and a new control point was inserted after the fourth. Any additional after this new one until a new insertion point is selected.



Deleting a Cubic Spline Control Point

Before a control point can be deleted, its position in the sequence of control points must be selected. There are four methods to deleting control points.



Method 1- Scroll through the control points with the keyboard arrow keys. The mouse must be in the Point List window. As you scroll, you will see a small box in the picture move from one control point to another.

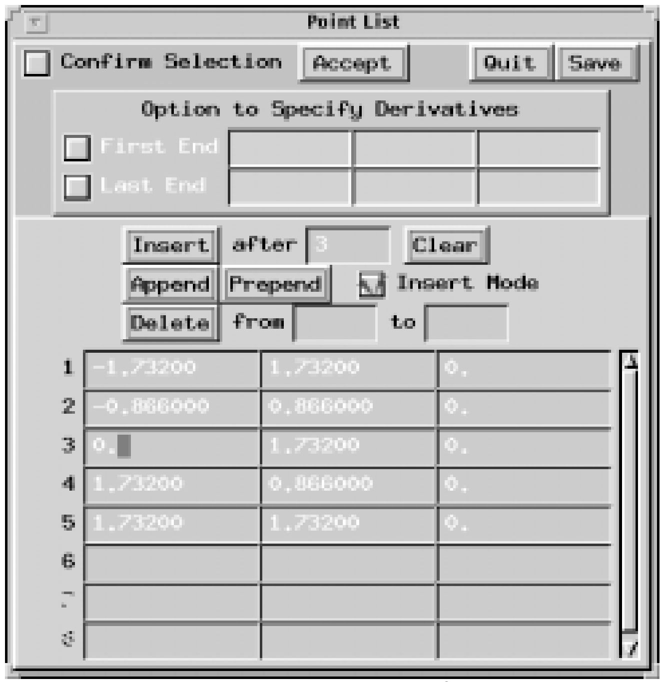
Method 2- Click on the row of desired control point with the left mouse button.

Method 3- Move the mouse close to the control point in the picture and push **F5** function key.

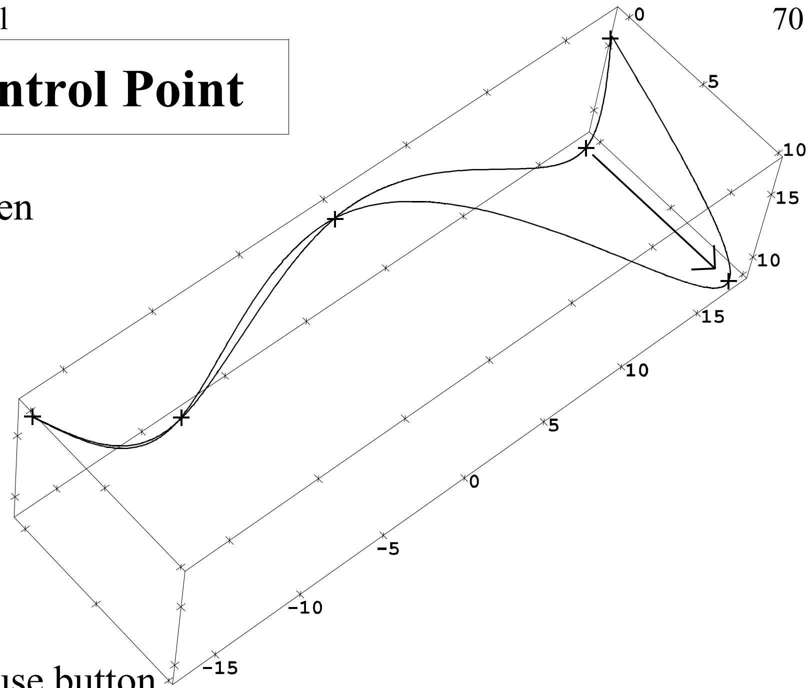
Method 4- Enter the sequence numbers of the control points into the **from** and **to** boxes next to the Delete button.

Click on the Delete button.

In this example, the fourth control point was selected and deleted from the Point List.



Moving a Cubic Spline Control Point



Before a control point can be deleted, the Point List window must be taken out of the insert mode and the control point must be selected. To get out of the insert mode, click the left mouse button on the box next to **Insert Mode** so that the check is no longer in the box. There are three ways to select the control point to be moved.

Method 1- Scroll through the control points with the keyboard arrow keys. The mouse must be in the Point List window. As you scroll, you will see small box in the picture move from one control point to another.

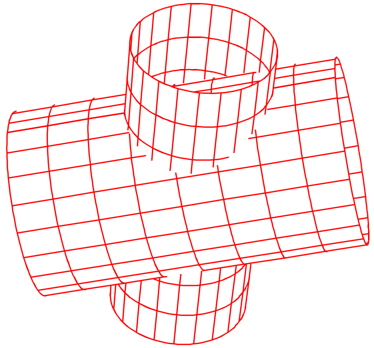
Method 2- Click on the row of the desired control point with the left mouse button.

Method 3- Move the mouse close to the control point in the picture and push the F5 function key.

Select the [Move Pts.] panel. Then select [List Pt.] Then select one of the methods under the label **Constrain to.**

With the left mouse, click and drag in the physical picture to move the control point to a new location. In this example, the fourth control point was selected and moved in the z-direction. Alternatively, use the [Pick] panel options [projection] or [Z-buffer] .

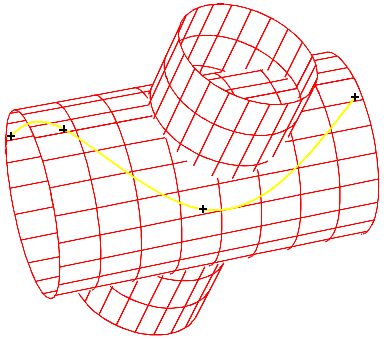
3D Curves Exercise



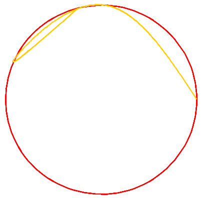
Create 2 intersecting cylinders.

sd 1 cy 0 0 0 1 0 0 2 sd 2 cy 0 0 0 .3 1 0 1.5

Create a spline curve with points from a cylinder.

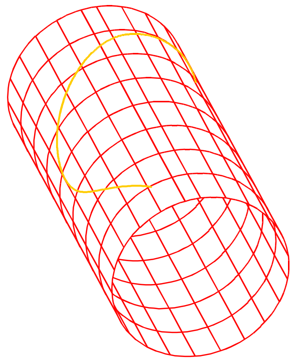


1. Hide mode graphics with sdint on for interior contour lines on
2. 3D Curve > SPLINE
3. PICK > Z-BUFFER
4. Select points with the left mouse button



Notice that the entire spline is not on the cylinder.

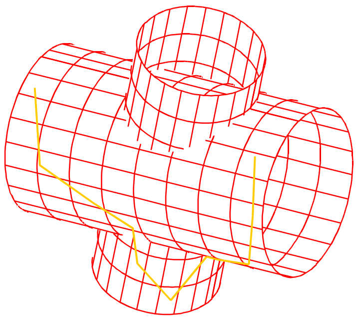
```
angle 0 dsd 1 rest ry -90
```



Project this curve onto the cylinder.

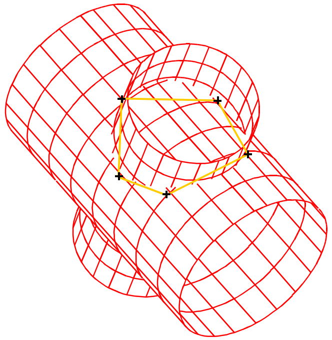
```
curd 2 projcur 1 1 ;
```

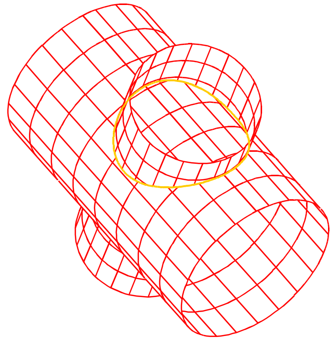
Build a polygonal curve from surface points.



1. `racd dasd rest`
2. 3D Curve > lp3
3. Click the clear button
4. Select points with the left mouse button

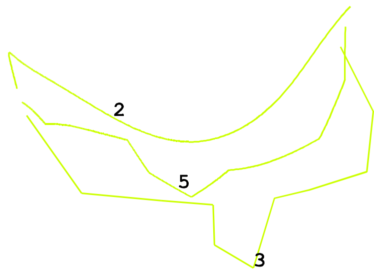
Form the curve at the intersection of the two cylinders.





1. **`racd`** `rest`
2. 3D Curve > **twsurf**
3. Click the clear button
4. Select points forming a crude approximation
5. Close the loop using Prepend and Accept
6. Type the two surface numbers into the window

Interpolate a curve from two other curves

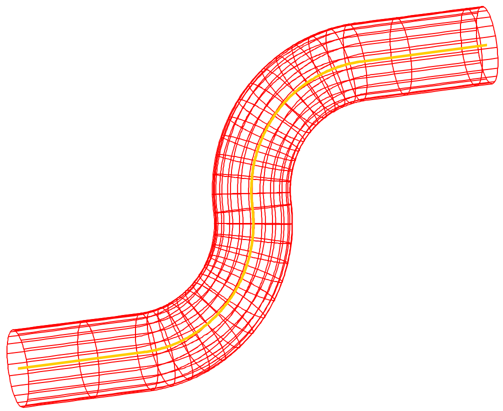



```
curd 5 intcur 2 3 .5 ;
```

Create a composite curve with arcs.

```
curd 6  lp3 0 0 0; ;
        arc3 seqnc rt 1 0 0 rt [1+1/sqrt(2)] [1-1/sqrt(2)] 0 rt 2 1 0 ;
        arc3 seqnc rt 2 1 0 rt [3-1/sqrt(2)] [1+1/sqrt(2)] 0 rt 3 2 0 ;
        lp3 4 2 0; ;
```

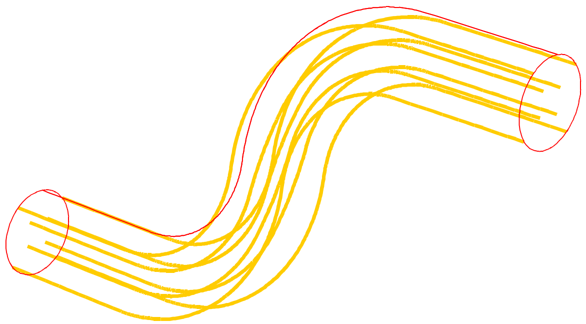
Create a pipe surface about this curve.



```
sd 3 pipe 6 .3 0 .3 1;;
```

Select contours from the surface.

```
curd  7 contour 3.1.14 3.0.14;;
curd  8 contour 3.1.41 3.0.41;;
curd  9 contour 3.1.68 3.0.68;;
curd 10 contour 3.1.95 3.0.95;;
```

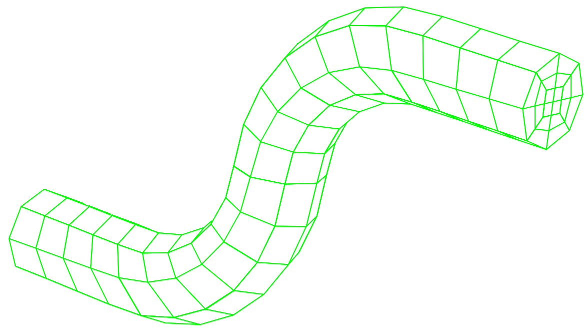


Create interpolated curves for the interior.

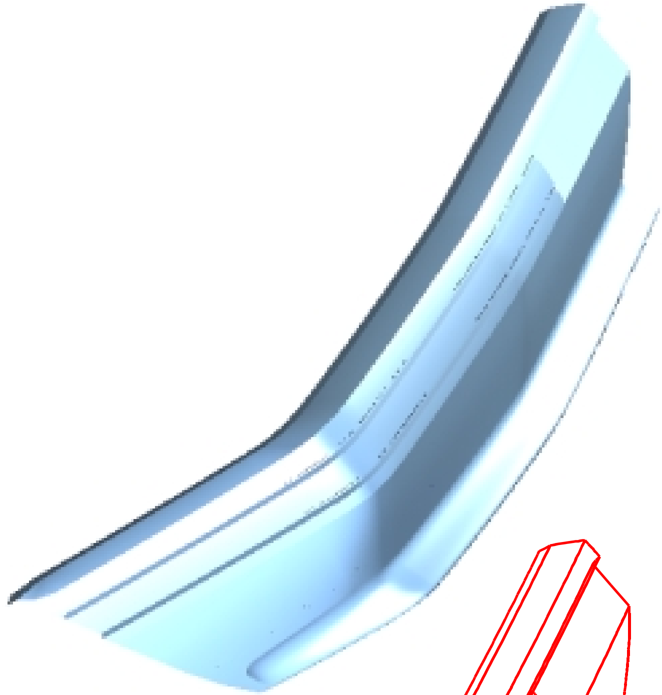
```
curd 11 intcur 7  9 .3 ;
curd 12 intcur 7  9 .7 ;
curd 13 intcur 8 10 .3 ;
curd 14 intcur 8 10 .7 ;
```

These curves can be used to create a butterfly part by attaching the edges to the curves and projecting to the pipe surface.

```
block 1 21;1 3 5 7;1 3 5 7;0 4 -.3 -.1 .1 .3 -.3 -.1 .1 .3
dei ; 1 2 0 3 4; 1 2 0 3 4;
curs 1 4 2 2 4 2  7 curs 1 3 1 2 3 1  7
curs 1 2 1 2 2 1  8 curs 1 1 2 2 1 2  8
curs 1 4 3 2 4 3 10 curs 1 3 4 2 3 4 10
curs 1 2 4 2 2 4  9 curs 1 1 3 2 1 3  9
curs 1 3 2 2 3 2 11
curs 1 2 2 2 2 2 13
curs 1 2 3 2 2 3 12
curs 1 3 3 2 3 3 14
sfi ; -1 -4; -1 -4;sd 3
```

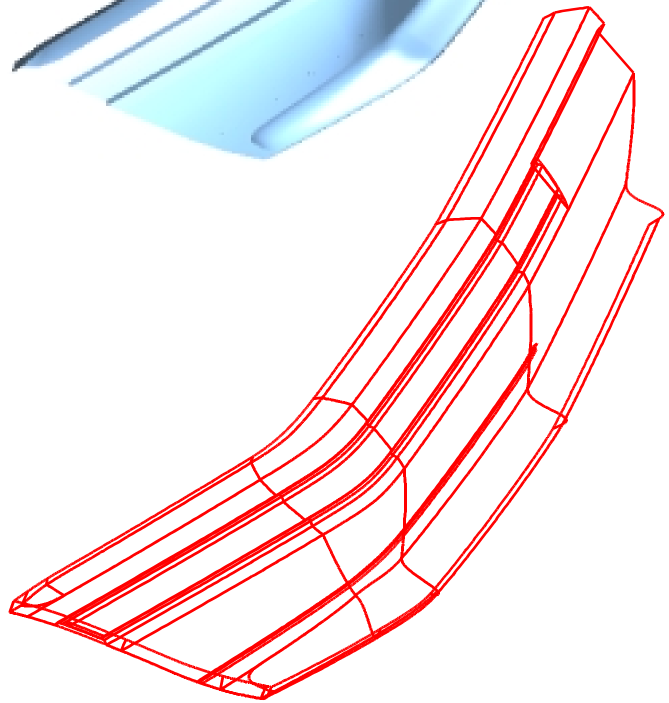


IGES Example



The following example is a typical session using IGES geometry.

1. an IGES model is read
2. extra surfaces are removed from the display
3. all remaining surfaces are combine
4. many of the surfaces are removed
5. the few remaining surfaces are combine
6. surface edges are labeled
7. coedge is used to form a boundary curve
8. edge points are labeled
9. lp3 is used to create a line segment curve
10. curd and the contour option extracts a curve
11. a block command is issued to create a shell part
12. the coordinates for the block part are selected from the surfaces
13. vertices of the mesh are attached to points on the curves
14. edges are attached to curves
15. mesh is projected to the composite surface



```
merge
iges bumper.igs 1 1;

lasd
sd 100 sds 1:84; sd 101 sds 43 40 37;

curd 1 se 37.1 se 40.1 se 43.1 se 43.2 se 43.3 se 40.3 se 37.3 se 37.4
curd 2 lp3 -7.4805054e+02 -7.1426914e-12 5.4925686e+01
           -7.3228943e+02 3.9822571e+02 5.4640636e+01 ;;;
curd 3 contour 40.16.1 40.16.0;

block -1;1 21;1 7 15 31; -767.5 ; 1.8 396.6 ;49.9 53.1 107 240.8 ;

pb 1 1 4 1 1 4 xyz -8.606400e+02 -1.517009e-12 2.422500e+02
pb 1 2 4 1 2 4 xyz -8.441700e+02 4.121500e+02 2.422500e+02
pb 1 1 3 1 1 3 xyz -7.309481e+02 -6.398427e-12 1.060805e+02
pb 1 1 2 1 1 2 xyz -7.482186e+02 -7.297460e-12 5.532226e+01
pb 1 1 1 1 1 1 xyz -7.196600e+02 -2.913225e-13 5.023000e+01
pb 1 2 3 1 2 3 xyz -7.156154e+02 3.961476e+02 1.065876e+02
pb 1 2 2 1 2 2 xyz -7.324869e+02 3.982503e+02 5.503202e+01
pb 1 2 1 1 2 1 xyz -7.042600e+02 3.947600e+02 5.023000e+01

curs 1 2 1 1 2 4 1 curs 1 1 1 1 1 4 1 curs 1 1 4 1 2 4 1
curs 1 1 1 1 2 1 1 curs 1 1 3 1 2 3 3 curs 1 1 2 1 2 2 2

sfi -1; -1; -4;sd 101
```

Loads and Sets

LOAD OPTIONS

Assigned within the parts phase - parametric

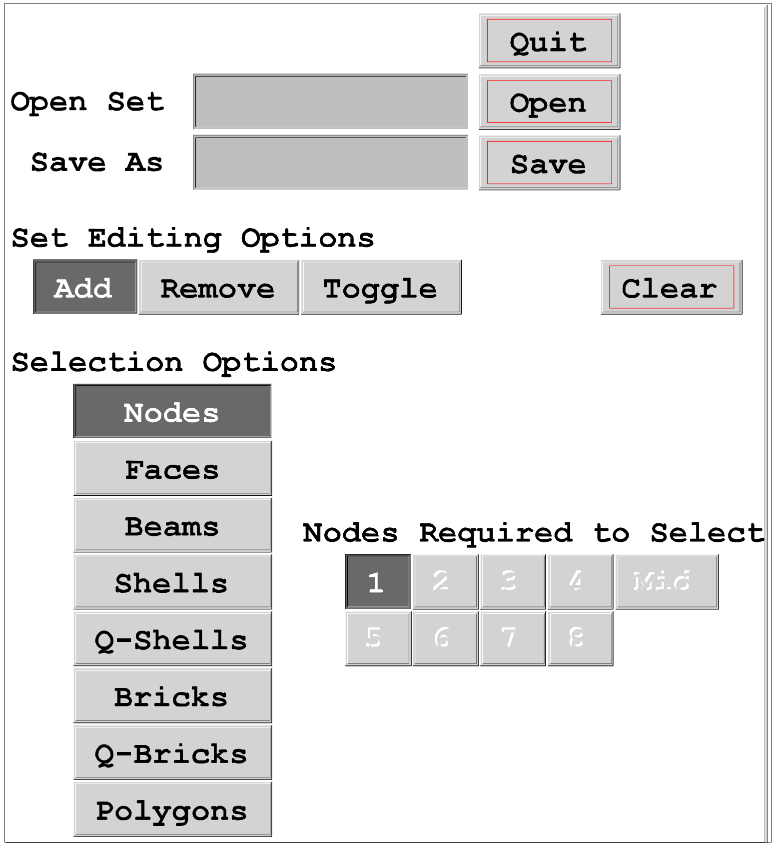
Assigned in the merge phase by creating sets

SET CREATION OPTIONS

Create sets in the part phase - parametric

Create sets with the mouse in merge phase - graphical

Create sets with geometry in merge phase - global parametric



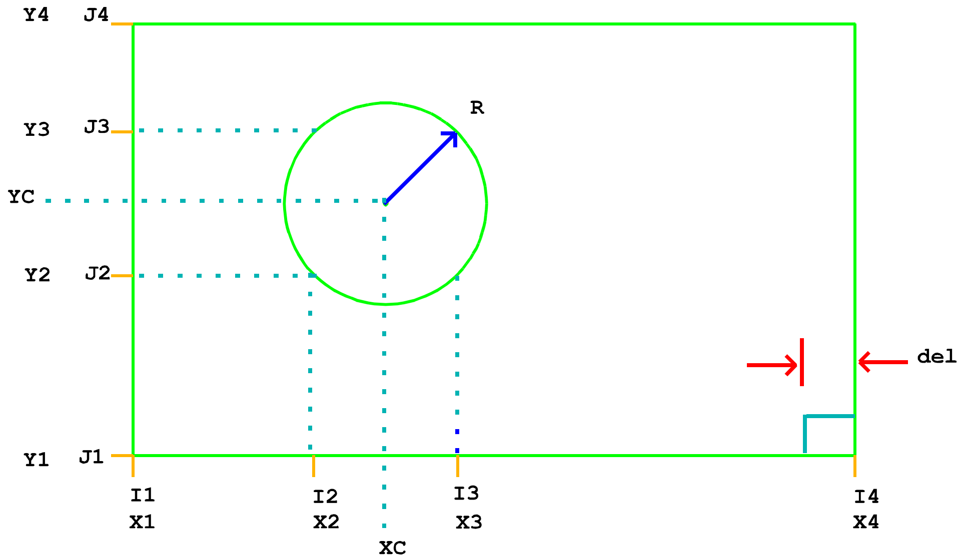
NOTE: To get the Set Editing window, click on the pick and the sets buttons in the environment window.

Shells and Orientation

In the following example, 2 shells are created from one part. Then shell thicknesses are assigned along with material properties. Then a contact surface is defined between the two shells. Boundary conditions are applied and the orientation of the shells are set. Note that the contact surfaces defined between the shells have an orientation which does not match the orientation of the shells. All of these properties are checked in the merge phase.

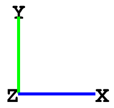
```
cylinder -1 -3;1 21 31;1 5 10;2 2.2 0 60 90 0 1 2
sid 1 sv ; c set the properties of the sliding interface
dei -1; 2 3;;
orpt + 0 0 0 c set the shell orientation to point toward the origin
n 1 0 0 1 0 0
n 2 0 0 2 0 0
orpt - 0 0 0 c set the master side to point towards the slave side
sii -1;;;1 m ;
orpt + 0 0 0 c set the slave side to point towards the master
sii -2;;;1 s ;
bi ;;-1;dx 1 dy 1 rx 1 ry 1 rz 1; c set the boundary constraints
thick .02 c set the default thickness
thi -1;;; .01 c set the thickness of the first shell to differ from the default
mate 1 c set the default material
mti -2;1 2;1 2;2 c set the material of a region to differ from the default
merge
co si 1 s co si 1 m co dx co dy co rx co ry co rz co thic co n
```

PARAMETER USAGE EXAMPLES



Example conditions:

- Place a hole with radius R at coordinates XC, YC.
- Produce a uniform mesh with elements size **del**.



Parameter Example Input File

```
c para
para
 del .5     c  element size
 r   3      c  hole radius
 xc  12     c  x coordinate of hole center
 yc  7.     c  y coordinate of hole center
c
 x1 0
 x2 [%xc-%r*.707]
 x3 [%xc+%r*.707]
 x4 20
 y1 0
 y2 [%yc-%r*.707]
 y3 [%yc+%r*.707]
 y4 10
;
c hole beyond top
 if ((%yc+%r+%del).gt.%y4) then
  para
   r [%y4-%yc-%del]
   x2 [%xc-%r*.707]
   x3 [%xc+%r*.707]
   y2 [%yc-%r*.707]
   y3 [%yc+%r*.707];
c hole beyond bottm
  elseif ((%yc-%del-%r).lt.%y1) then
   para
    r [%yc-%y1-%del]
    x2 [%xc-%r*.707]
    x3 [%xc+%r*.707]
y2 [%yc-%r*.707]
y3 [%yc+%r*.707];
endif
para
 i1 1
 i2 [nint(%i1+(%x2-%x1)/%del)]
 i3 [nint(%i2+(%x3-%x2)/%del)]
 i4 [nint(%i3+(%x4-%x3)/%del)]
 j1 1
 j2 [nint(%j1+(%y2-%y1)/%del)]
 j3 [nint(%j2+(%y3-%y2)/%del)]
 j4 [nint(%j3+(%y4-%y3)/%del)]
c
sd 1 cy %xc %yc 0 0 0 1 %r
c
block
%i1 %i2 %i3 %i4;
%j1 %j2 %j3 %j4;
-1;
%x1 %x2 %x3 %x4
%y1 %y2 %y3 %y4
0
dei 2 3; 2 3; -1;
sfi -2 -3; -2 -3; -1; sd 1
res 1 1 1 1 4 1 j 1
res 4 1 1 4 4 1 j 1
relaxi 1 4; 1 4; -1; 10 0 1
mate 1
endpart
```

Labels (la)

More commonly used label commands:

la nodes	label all nodes
la 3d	label all 3D elements
la 2d	label all 2D elements
la 1d	label all 1D elements
la locnd #	show node #
la loc3d #	show 3D element #
la loc2d #	show 2D element #
la loc1d #	show 1D element #
la nodeset #	node set #
la faceset #	face set #
la size 3	set token size
la tol p1 p2	show merged part1 and part2
la off	turn labels off

c merging operations

la cracks 1	find all cracks less then 1 deg
la tol 2 3	show merged nodes between parts 2 and 3
bptol 2 3 0	do not merge nodes between parts 2 and 3
bptol 2 3 .001	merge tolarance between parts 2 and 3 overide stp
stp .01	merge all parts within .01 tolerance

integer number

Condition (CO)

More commonly used condition commands:

co dx	x constraint
co dy	y constraint
co dz	z constraint
co rx	rx constraint
co ry	ry constraint
co rz	rz constraint
co pr #	pressure / curve #
co ve	initial velocity
co si # b	slide surface
co fv #	velocity
co fc #	point load
co fd #	nodal displacement
co acc #	acceleration

\#   integer number

Using IGES

USING IGES SURFACES

1. Set "getol 30" (getol can have a range from 1-300).
2. Read iges file.
3. Save a binary database file (file.bin) of the surfaces created by TrueGrid.

EXAMPLE:

```
getol 30
iges file.igs 1 1 "transformations";
saveiges file.bin
end
```

4. The input file to TrueGrid should now have the following lines inserted at the beginning of the file. Since the binary database file (file.bin) ofthe surfaces has already been created it does not have to be recreated. It only needs to be read in.

EXAMPLE:

```
getol 30
useiges file.bin
iges file.igs 1 1 "transformations";
```

Important VI Commands

x - delete current character

dd - delete current line

6dd - delete next 6 lines

:1,$ - delete all lines in file

o - add a line of text after current line <esc> to end additions

a - add text after current character

i - add text before current character

r - replace character at cursor with one character

R - replace next characters with text - <esc> to end addition

s - substitute current character with text - <esc> to end text

yy - yank current line

p - put yanked or deleted line after new current line (move to new line first)

/<pattern> - search forward for <pattern>

?<pattern> - search backward for <pattern>

n - search for next <pattern>

N - search backward for next <pattern>

:1 - go to line 1

:$ - go to last line

up arrow - move up one line

down arrow - move down one line

right arrow - move righ one character

left arrow - move left one character

u - undo last command

ZZ - end vi

:w - save all changes

:q! - quit vi - disregard all changes

. - repeat last command

<BACKSPACE> - backspace during text addition or replacement

:set nu - precede each line with line number

:set nonu - turn nu off

:,$g/^c /d -delete all lines with c<space> in column 1

copy lines from current location to end of current file to another file "master"

:,$ya a - put lines in buffer “a”

:w - save current file

:e master - go to file “master”

<move cursor to desired location>

:pu a - put lines from buffer “a” here.