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GridTool: A Surface Modeling and Grid Generation Tool

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GridTool is an interactive program for grid/geometry applications . Most grid generation programs represent geometry by a set of structured points which is not consistent with the Computer Aided Design (CAD) representation. The purpose of GridTool is to bridge the gap between the CAD and the grid generation systems.

Introduction

GridTool is designed around the concept that the surface grids are generated on a set of bi-linear patches. This type of grid generation is quite easy to implement, and it avoids the problems associated with complex CAD surface representations and associated surface parameterizations. However, the resulting surface grids are close to but not on the original CAD surfaces. This problem can be alleviated by projecting the resulting surface grids onto the original CAD surfaces. GridTool is designed primary for unstructured grid generation systems. Currently, GridTool supports VGRID [1] and FELISA [2] systems, and it can be easily extended to support other unstructured grid generation systems.

The data in GridTool is stored parametrically so that once the problem is set up, one can modify the surfaces and the entire set of points, curves and patches will be updated automatically. This is very useful in a multidisciplinary design and optimization process.

GridTool is written entirely in ANSI "C", the interface is based on the FORMS library [3], and the graphics is based on the GL library. The code has been tested successfully on IRIS workstations running IRIX4.0 and above. The memory is allocated dynamically, therefore, memory size will depend on the complexity of geometry/grid.

GridTool data structure is based on a link-list structure which allows the required memory to expand and contract dynamically according to the user's data size and action. Data structure contains several types of objects such as points, curves, patches, sources and surfaces. At any given time, there is always an active object which is drawn in magenta, or in their highlighted colors as defined by the resource file which will be discussed later.

Surface Representation and Grid Projection

References [4]-[6] contain detailed descriptions of Surface Representation and Grid Projection. For completeness sake, a short summary will be provided here. In CAD systems, curves and surfaces are represented typically by NonUniform Rational B-Splines (NURBS) which is the most general mathematical representation for curves and surfaces. Most parametric curves and surfaces can be converted to an equivalent NURBS [7]-[8] representation without any loss of accuracy.

The surface-grid can be generated either in a parameter space or on approximated/simplified NURBS surfaces. Grids generated in a parameter space have two serious restrictions. The first restriction is that the choice of surface parameterization affects the CFD surface-grid. As shown in Refs. Ref. 6 and Ref. 9, a poor parameterization may cause the CFD surface-grid to be highly skewed. The second limitation is that a CFD surface-grid can not be generated over several overlapping NURBS surfaces which is the most serious restriction.

In the second method , the NURBS surfaces are approximated by a few bi-linear patches, then, the surface grids are generated based on these bi-linear patches. The resulting surface grids are close but they are not on the original NURBS surfaces. This problem can be alleviated by projecting the resulting grid points onto the original NURBS surfaces. This method is easy to implement, and it avoids the problems associated with surface parameterization. This method of grid generation will require a very robust and fast grid point projection.

Advancing Front Applications (VGRID System)

In this section, using GridTool for VGRID system is described. VGRID system is a robust and fast unstructured grid generator developed by VIGYAN Inc. for NASA Langley Research Center. The VGRID code is fully functional and supported and can be obtained from NASA Langley Research Center (contact: Dr. Neal Frink, N.T.FRINK@LaRC.NASA.GOV). The VGRID system is based on an advancing front technique, and readers are referred to an excellent and detailed report by Parikh, Pirzadeh and Löhner VGRID[1]. A short description of advancing front technique will be given here for the sake of completeness.

The advancing front method is an unstructured grid generation method similar to parabolic and hyperbolic methods for structured grid generation. Grids are generated by marching from boundaries (front) towards the interior. First, the domain of interest is subdivided into a set of patches which cover the entire domain. Next, these patches are triangulated to form the "initial front". Finally, tetrahedral elements are generated based on the initial front. As tetrahedral elements are generated, the "initial front" is updated until the entire domain is covered with tetrahedral elements, and the front is emptied. The above process can be summarized in the following steps:

1. subdivide the domain of interest using GridTool,
2. specify grid spacings using GridTool,
3. generate the "initial front" using VGRID,
4. update the GridTool restart file to reflect the changes from VGRID using GridTool,
5. project the front onto the CAD surfaces using GridTool,
6. generate the volume grid using VGRID,
7. post-process the volume grid using VGRID.

The first step is to define the boundaries for the domain of interest. These boundaries are then subdivided into smaller patches using GridTool. In this paper, a patch is synonymous with a three-dimensional polygon. In the VGRID system, three types of patches are allowed: triangular Barnhill-Gregory-Nielson patches (three arbitrary sides), bilinear transfinite Coon's patch (four arbitrary sides), and planar patches (defined by an arbitrary number of sides, all lying in one plane). Each patch consists of several sides, and each side consists of several curves. In step 2, the grid spacing is defined by nodal and linear sources. An excellent description of these sources can be found in Ref. [10]. In step 3, all patches are triangulated to form the "initial front" using the VGRID system. In this step, VGRID may change the patch orientation. If so, in step 4, the GridTool restart file must be updated to reflect the changes. In step 5, the "initial front" is projected back onto the original surfaces using GridTool. In step 6, the volume grid is generated in one run or several restart runs using VGRID. In step 7, the volume grid can be post-processed to enhance grid quality. The details for steps 3, 5 and 6 can be found in Ref. 1.

GridTool Interface

The interface consists of a main panel and several sub-panels. The panels consist of a set of buttons, input-fields, sliders, dials, positioners, browsers and message boxes. This section describes the user interaction with the GridTool interface. The user interacts with GridTool program by pointing/clicking the mouse buttons and the keyboard while the cursor is over a panel or the display window. Panels can be activated by pressing their buttons from the main window. They can be stowed away either from the panel itself by pressing the "*Stow*" button or by pressing the panel's button in the main panel. Whenever a panel is activated, the color of its button in the main panel will be changed from blue to green. Here is a list of actions and how they can be accomplished in the panels.

- To press a button, place the the cursor over the button and click with any of the three mouse buttons.
- To change the value in an input-field, place the the cursor over the input-field, click with any of the three mouse buttons, enter the value in the input-field, and complete the input by entering the "Return" key. The "ESC" key can be used to delete the entire field, or the "BackSpace" key can be used to delete a portion of it.
- To change the position of a slider, dial or a positioner, hold and drag the right mouse while the cursor is over the object.
- To select an object from a browse, place the the cursor over the object in the browser and click the right mouse. The background color of the selected object in the browser will change from black to green when they are selected.

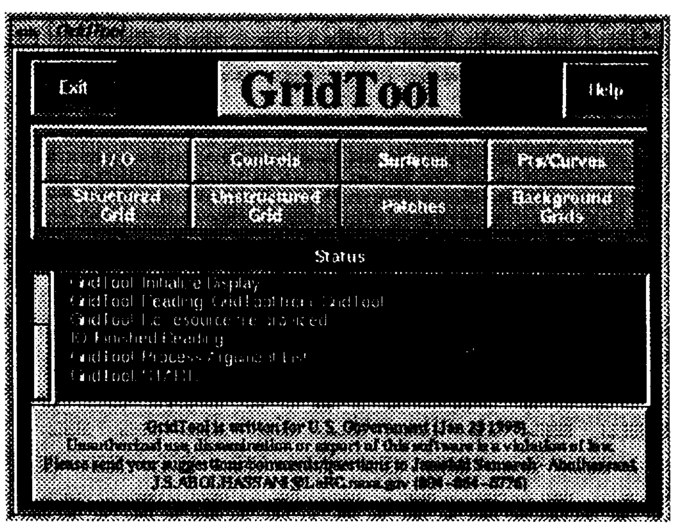

Fig. 1 Main Panel

Hot Keys

A series of hot keys are available in the display window which allow the user to accomplish some tasks without use of the panels. These keys can be activated by placing the cursor over the display window and clicking the hot key. The hot keys can be used to translate/rotate/zoom the object, to pick or to create an object.

List of Hot Keys

Keys	Action
Left Mouse	Translate (gridgen mode), rotate x, and y (PLOT3D mode)
Middle Mouse	Zoom, rotate z (PLOT3D)
Right Mouse	Translate (PLOT3D)
SHIFT + Mouse	Sparse Mode
b	Make a source active
c	Make a curve active
C	Move center of rotation to center of the active curve
f	Make a patch active
F	Move center of rotation to center of the active patch
g	Save the orientation
G	Restore the orientation
m	Move the active point to an existing point on a curve
n	Move the active source to an existing source and copy spacing
p	Make a point active
P	Move center of rotation to active point
r	Reset the image
s	Make a surface active
S	Move center of rotation to center of the active surface
t	Move the active point to an existing point on the active surface
w	Turn the active surface on/off
x	Turn axes on/off
F1	The same as "*Next Curve*" button
F2	The same as "*Next Point*" button
F5	The same as "*Next Patch*" button
F6	The same as "*Next Edge*" button
F7	The same as "*Find Edge*" button
F8	The same as "*Reverse the Active Patch*" button
F12	Turn Surfaces on/off

GridTool Executions

GridTool can be executed by typing "GridTool" or "GridTool options filename", and here is a list of command line argument.

Command Line Arguments

Arguments		Action
-h		help
-f	restart_filename	read a restart file
-gf	gridgen_filename	read a gridgen formatted file
-g	gridgen_filename	read a gridgen binary file
-pf	plot3d_filename	read a plot3d formatted file
-p	plot3d_filename	read a plot3d binary file
-IGES	IGES_filename	read an IGES file
-felisa		run GridTool in FELISA Mode

When GridTool starts, it looks for the resource file, ".GridTool". This file could be at either the user's root, the current directory or defined by "setenv" unix command as "setenv GridTool_resources my_resource_filename". Users may change the resource file by customizing it to their needs. If the resource file does not exist, GridTool will use the defaults values which are listed in the Appendix A. The resource file may contain the preferred colors for displaying objects and the boundary conditions. A comment line can start either with a space or "#" in the first column. The default boundary conditions are based on the USM3D [11] code developed by Neal Frink at NASA/Langley Research Center. In the following sections, the application of GridTool for setting up data files for an advancing front technique (VGRID system) is described. One important feature of GridTool is that each operation is accomplished in one step only. Therefore users can create and manipulate objects randomly.

There is some limited on-line help which can be activated by pressing the "*Help*" button in the main panel which in turn will open a browser. As the user moves the cursor over any object in the panels, a description of that button will be given in the browser.

I/O

GridTool is capable of reading geometry/grid definitions in ASCII or C-Binary formats.

File input/output formats

File Type	Options
IGES [12]	read
RESTART	read/write
GRIDGEN [13]	read/write (Binary as well)
PLOT3D [14]	read/write (Binary as well)
CURVES	read/write
LaWGS [15]	read/write
VGRID-NET [1]	read/write
VGRID-FRONT [1]	read/write
VGRID-FRONT (Update) [1]	read/write
VGRID-d3m [1]	read/write
VGRID-d3m (Update) [1]	read/write
FELISA system [2]	read/write

The IGES (Initial Graphics Exchange Standard) files are based on the industry standard as described in IGES manual [12]. GridTool is only capable of accepting the following entities: copious data (entity 106), lines (entity 110), parametric splines (entity 112), parametric surface spline (entity 114), NURBS curves (entity 126) and NURBS surfaces (entity 128). Surfaces defined by points can be read/written in GRIDGEN [13], PLOT3D [14], LaWGS [15] or VGRID-NET [1] formats.

The surface triangulation, "the initial front", can be read/written in a front format defined by the VGRID system [1] or FELISA system [2]. The necessary information for advancing front methods can be read/written either in a "d3m" input-file format for VGRID system [1] or in a "dat" input-file format FELISA system [2]. An ASCII "restart" file can be read/written at any time, which contains all created/modified/read objects. It is possible to combine several restart files to form one. This allows several people to work on the same configuration and combine all pieces at a later time. Before reading/writing a "d3m", "front" or a "dat" file, a "project name" must be selected. This name is used as the file name suffix for all necessary files (e.g. project.front). Once the file is read/written, the "*Files*" browser will be updated. To update the list displayed in "*Files*" browser, press the "*Update*" button.

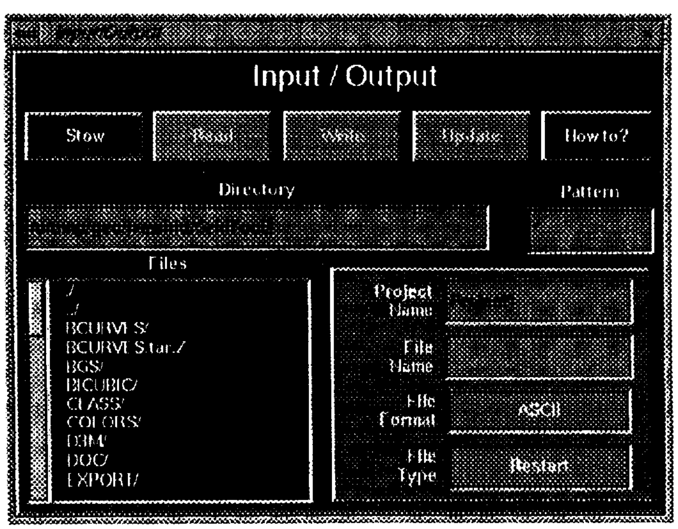

Fig. 2 I/O Panel

Display and Viewing Controls

The display can be controlled either from the display window using the mouse and the keyboard, or from the "*Viewing Controls*" panel. The mouse can be used either in a default mode or in a PLOT3D [14] mode. The mode can be changed by pressing the "*PLOT3D*" button which is located in the "*Viewing Controls*" panel. The default mouse mode is similar to the GRIDGEN system [13]. In the default mode, while pressing the left mouse button, left, right, up, and down mouse movements will cause the object to translate in the corresponding directions. By holding the middle mouse down, up and down mouse movements will cause the object to zoom out and in. The object can be rotated using the numeric keypad, and this will be explained later. In the PLOT3D mode, by holding the left mouse down, left/right and up/down mouse movements will cause the object to rotate about the x and y screen coordinates, respectively. By holding the middle mouse down, left/right mouse movements will cause the object to rotate about the z screen coordinate, up/down mouse movements will cause the object to zoom out and in, respectively. By holding the right mouse down, left, right, up, and down mouse movements will cause the object to translate in the corresponding directions.

Mouse Movements

Mode	Movements	LM (down)	MM (down)	RM (down)
Default,	Right	Translate Right		N/A
Default,	Left	Translate Left		N/A
Default,	Up	Translate Up	Zoom out	N/A
Default,	Down	Translate Down	Zoom in	N/A
PLOT3D,	Right	Rotate Screen y	Rotate Screen z	Translate Right
PLOT3D,	Left	Rotate Screen -y	Rotate Screen -z	Translate Left
PLOT3D,	Up	Rotate Screen x	Zoom out	Translate Up
PLOT3D,	Down	Rotate Screen -x	Zoom in	Translate Down

In either modes, the object can be rotated using the numeric keypad. The object can be rotated about two sets of axes: screen coordinates and body coordinates (world). The top row of the numeric keypad, the "Num Lock", "/" and "*" keys control the rotation about the x, y and z world coordinates, respectively. The second row, the "7", "8" and "9" keys control the rotation about the x, y and z screen coordinates, respectively. The rotation continues as long as the keys are pressed down. The object can be rotated ninety degrees by holding the "PageUp" or "PageDown" key while pressing the appropriate key on the numeric keypad. The object can be rotated in the reverse direction by holding down the "–" key from numeric keypad and the appropriate rotation keys. The object orientation can be reinitialized by pressing the "r" key which is the hot keys for resetting the object. All object manipulations can be accomplished from the "*Viewing Controls*" panel as well.

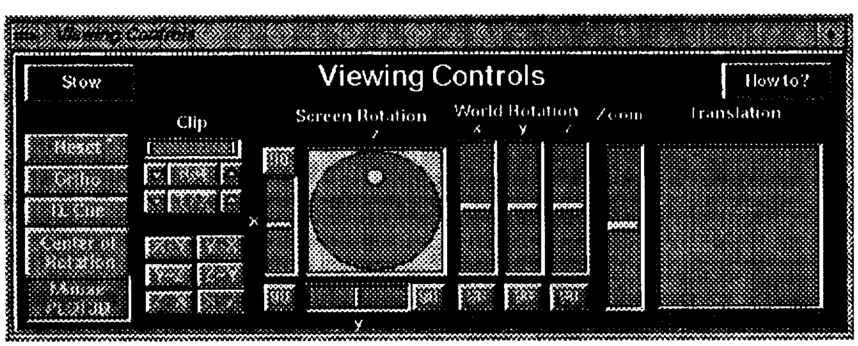

Fig. 3 Viewing Controls Panel

Center of Rotation

This panel is designed to allow the user to move the center of rotation to an arbitrary point in space. The center of rotation can be moved to: an exiting point by using the three sliders, "*x*", " *y*", "*z*" to centers of the active surface/curve/patch/point by pressing the appropriate buttons. The center of rotation can be reset by pressing the "*Reset CR*" button. The hot keys, P, C, F, S can be used in the display window to move the center of rotation to the active point, active curve, active patch and active surface.

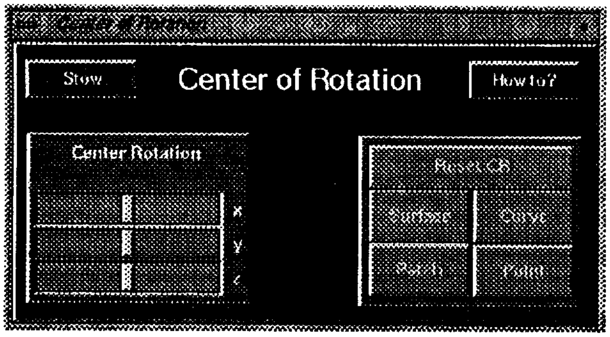

Fig. 4 Center of Rotation Panel

Surface Attributes

This panel is designed to allow the user to manipulate the surface properties. In order to change the background color of the display window, the "*Background*" button in the "*Attributes*" panel should be pressed. Then, the color can be changed by moving three sliders for the colors or by inputing the RGB color number (Red, Green, Blue) in the input-fields.

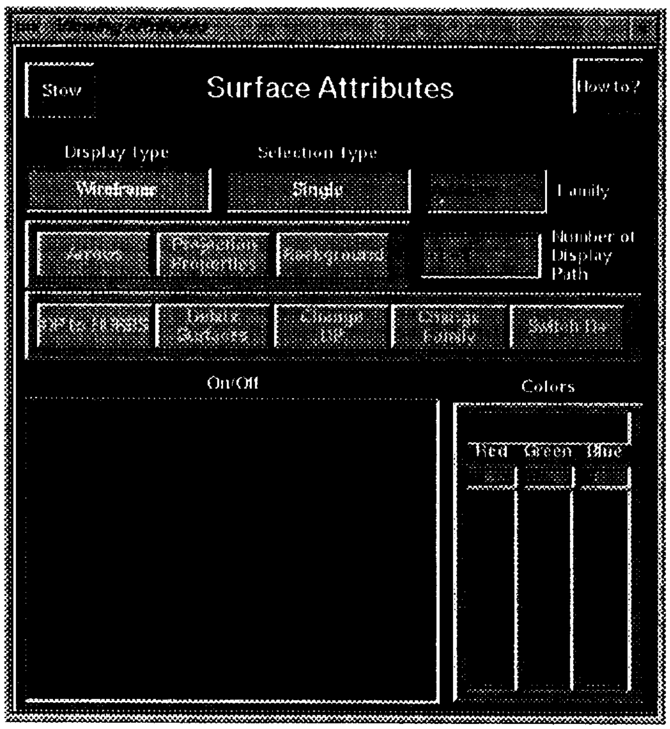

Fig. 5 Surface Attributes Panel

The surface properties such as color, direction and number of display paths can be changed in this panel. First, the "*Surfaces*" button in this panel should be pressed, and then "*On/Off*" browser will appear. In order to change the properties of some of the surfaces, first they must be turned on. This can be done either from the display window or from the "*On/Off*" browser by placing the cursor over the surface number and clicking with the left mouse. In order to turn a surface on/off from the display window, first the surface must become an active surface by placing the cursor over the surface and hitting the hot key "s". Then, the active surface can be turned on/off by hitting the hot key "w". Once the appropriate surfaces are turned on, then the properties can be changed. Surface colors can be changed by using the three sliders for colors or by inputing the RGB color number in the input-fields. The direction of surfaces can be changed by pressing the "*Directions*" button. The number of display paths can be changed by inputing the desired numbers of display paths in u and v coordinates in the input-field for "*number of display path*" and then pressing "*Change DP*" button.

Projection Properties

This panel is designed for modifying the projection parameters, and it displays the projection parameters for the active surface. For detail description of these properties, readers are referred to Refs. [4]-[6]. In this panel, it is also possible to change the parameters such that part of a surface is displayed and projected to. This can be done by changing the limits of the surface parameters, us (minimum u), ue (maximum u), vs (minimum v), and ve (maximum v). The "*Itmax*" is the number of iteration for the projection to converge. The "*EPS*" is the residual limit for the projection to converge. The "*du*" and "*dv*" are the step size in u and v directions, respectively. The "*magn*" are parameters used to pull grid points to boundaries, and their values range from 0–1.

1. "*mag1*" for minimum v
2. "*mag2*" for maximum u
3. "*mag3*" for maximum v
4. "*mag4*" for minimum u

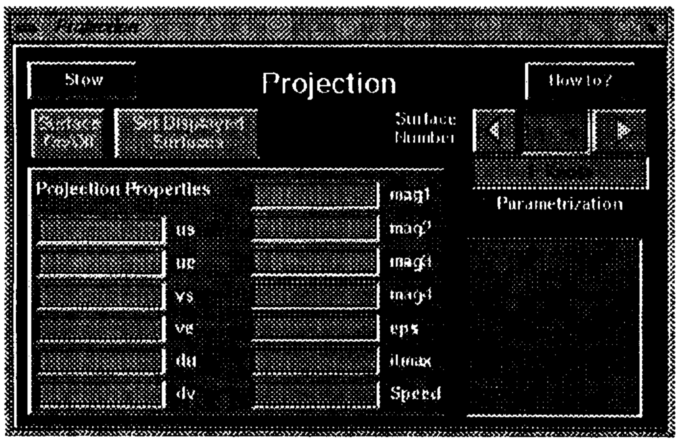

Fig. 6 Projection Properties Panel

Points/Curves

This panel contains several buttons, input–fields and a positioner, and they are used to create/modify/delete points and curves. In GridTool, a curve is represented by a link–list of points. These points are either on a surface (surface points) or somewhere in space (XYZ points). For surface points, in addition to the x, y, z, the surface number and its parametric coordinates, u and v are stored in the data base. Curves can be created together as a family. For example, all curves associated with a wing could be created together as a "wing" family. The family name for curves is selected from the " *Patches*" panel which will be discussed later. To start a new curve, press the "*Next Curve*" button. To create a new point for a curve, the "*Next Point*" button should be pressed, and this newly created point becomes the active point. Since every operation is done in one step, the new point will be placed where the last point was, and then the user can move the new point, (the active point), to any location. The active point can be moved to an existing point on a curve by placing the cursor over the desired curve point and hitting the hot key "m". Similarly, the active point can be moved to an existing point on the active surface by placing the cursor over the surface point and hitting the hot key "t". Also, the active point can be moved to any location on the active surface by either: (1) typing the parametric coordinates in the "*U & V*" input box, (2) moving the "*U & V*" positioner, (3) moving the "*U & V*" sliders. In order to move the active point in space, first the point should be converted to an "XYZ" point by pressing "*On Surface*" button. Once the active point is an XYZ point, the "*x*", "*y*", and "*z*" sliders can be used to move the point to anywhere in the space. It is also possible to change the coordinate by typing the values in the input field boxes. A point can be inserted ahead of the active point on a curve by pressing the "*Insert Point*" button. The new point becomes the active, and if the two neighboring points are on the same surface, then the inserted point will also be on the same surface. The point or the active curve can be deleted by pressing the "*Delete Point*" or the "*Delete Curve*" buttons, respectively. A point or a curve can become active by placing the cursor over it and hitting the hot key "p" or "c", respectively.

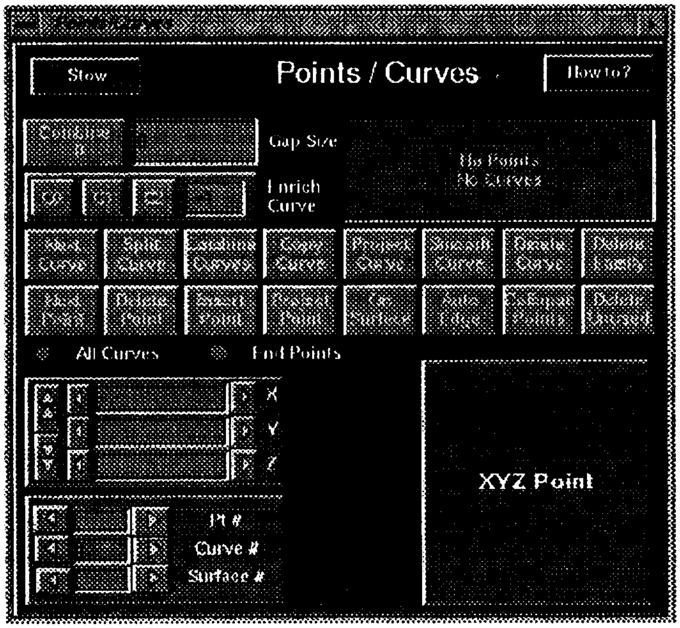

Fig. 7 Points/Curves Panel

Patches

A patch is a closed three–dimensional polygon which is defined by a set of curves. Nonplanar patches should be 3– or 4–sided, and planar patches could be n–sided. Each side of a patch could consist of several curves. Each patch is stored as a link–list of curves. To create a patch, the "*Next Patch*" button should be pressed. Then, the first curve for the patch must be activated by the user, and then it can be accepted as the first curve by pressing "*Accept Edge*" button. The subsequent curves can be added by letting GridTool find them. This can be done by pressing "*Find Edge*" button until the correct curve is found. GridTool will find the next curve within the tolerance define in the " *tol*" input–field box. Once the correct curve is found, it should be accepted by pressing the "*Accept Edge*" button. Once a patch is created, its direction can be reversed by pressing the "*Reverse Patch*" button.

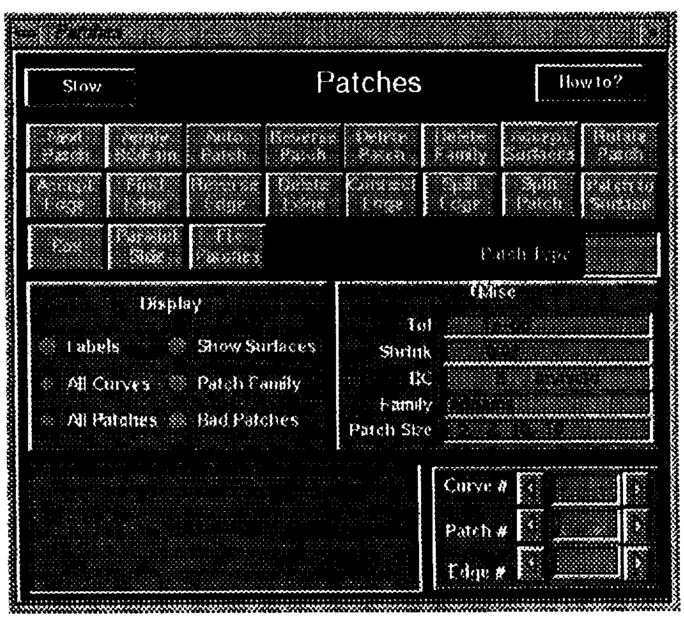

Fig. 9 Patches Panel

BOX

This panel is designed to allow the user to create/delete a box. To create a box, press "*Create Box*" button which will create a box bounded by minmax in x, y, z coordinates defined in the six input–fields in the panel. The resulting curves and patches are grouped together as the "Box" family. To delete the box, press the "*Delete Box*" button which will delete all patches and curves in the "Box" family.

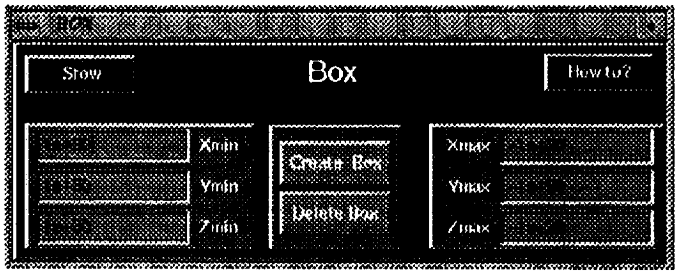

Fig. 10 BOX Panel

Bg Grid

This panel contains several buttons and input–fields, and they are used to create/modify/delete nodal and linear sources. In order to define grid spacing, nodal and linear sources must be created and placed in the right locations. In order to create a source, the "*Bg Grid*" and "*Points/Curves*" panels must be activated. To create a source, press the "*Next Source*" button. This will create a source similar to the last source. If this is the first source, it will create a nodal source and place it in the middle of the domain. The location of a source can be moved by using the same techniques as described for moving points. The value spacings, "S1" and "S2", are the sizes of ideal tetrahedrals for the source locations. An excellent description of parameters "a_n, b_n, alpha" can be found in Ref. 10.

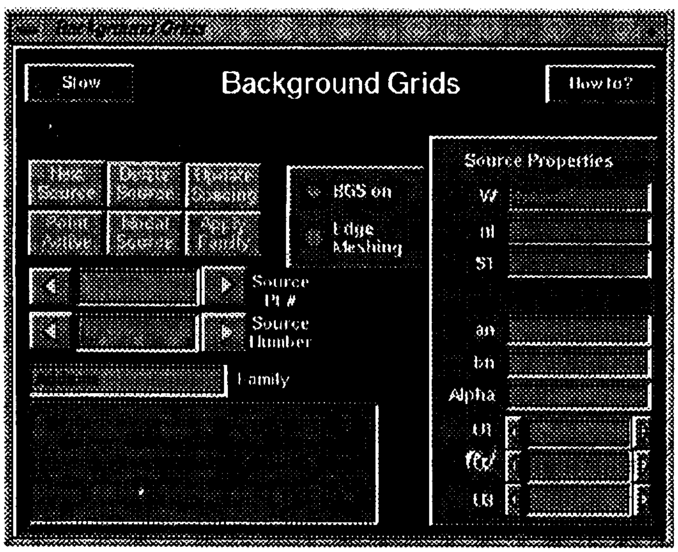

Fig. 11 Background Grid Panel

Unstructured Grid

This panel is designed to manipulate the unstructured surface grid. The "*Front*" button is used to activate the "*Front*" from which a surface triangulation can be projected onto a set of surfaces.

Front

This panel is used to project the surface triangulation (front) onto a set of surfaces, and this process can be divided into five steps: (1) read the front using the "*IO*" panel, (2) turn the appropriate patches on, (3) turn associated surfaces on, (4) project the front onto the surfaces, and (5) check for the validity of the new triangulation. In order to have a successful projection, users are required to insure that: (1) the surface triangulation is close enough to the associated surfaces, and (2) the associated surfaces have sufficient display paths.

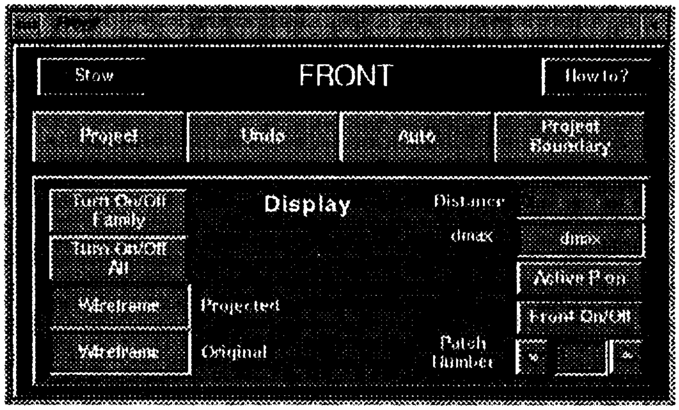

Fig. 12 Unstructured Grid Panel

Structured Grid

This panel is used to project the entire or portion of a structured surface grid onto a set of surfaces, and this process can be divided into five steps: (1) read the surface definition and the surface grid using the "*IO*" panel, (2) turn on associated surfaces, (3) make the surface to be projected active, (4) project the surface grid onto the surfaces, and (5) check for the validity of the new surface grid. In order to have a successful projection, users are required to insure that: (1) the surface grid is close enough to the associated surfaces, and (2) the associated surfaces have sufficient display paths. User may undo the projection or reinterpolate a protion of the surface grid.

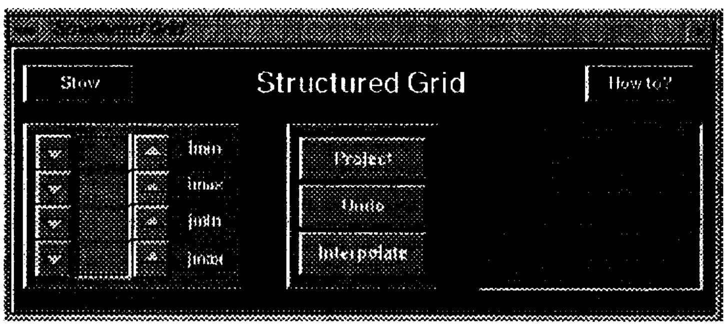

Fig. 13 Structured Grid Panel

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Appendix A: Sample Resource File

```
#
# This is a comment line
  This is also a comment line

# plot3d mouse movement
plot3d

#color  item                R      G      B

#       Background Color for the Display
color   background          0      0      0      black

#       Color for the Active Surface
color   active_surface      199    21     133    medium violet red

#       Colors for the Points
color   xyz_pt              67     110    238    royal blue
color   active_pt           255    0      0      red
color   surface_pt          34     139    34     forest green

#       Color for the Curves
color   xyz_curve           100    149    237    cornflower blue
color   active_curve        255    0      0      red
color   surface_curve       34     139    34     forest green

#       Color for the Patches
color   normal_patch        219    112    147    Pale violet red
color   active_edge         199    21     133    medium violet red
color   active_patch        199    21     133    medium violet red

#       Colors for the Background Grid
color   normal_bgs          255    255    0      yellow
color   active_bgs          255    0      0      red
color   active_bgs_pt       199    21     133    medium violet red
#
# BOUNDARY CONDITIONS Based on USM3D
#
bc      freestream          0
bc      reflection plane    1
bc      extrapolation       2
bc      inflow/outflow      3
bc      viscous             4
bc      inviscid            5
bc      nacelle inlet       101
bc      nacelle exit        102
bc      inlet mass          110
bc      inlet pressure      111
bc      inlet mach          112
bc      inlet velocity      113
bc      special bc1         1001
bc      special bc2         1002
bc      special bc3         1003
bc      special bc4         1004
bc      special bc5         1005
```