MESHBASE TM- An Interactive Graphic Processor for 3-D Finite Element Models (Meshes)

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Abstract

Information on a finite element analysis is associated with a node or an element of the underlying finite element mesh. Quick identification of node and element numbers is vital to efficient manipulations of nodal and elemental information. An interactive graphic-interfaced processor, MESHBASE^{TM}, has been developed on the Macintosh II for quick identification of node and element numbers on visible surfaces. MESHBASE^{TM} allows a user to prepare, update and document nodal and elemental information such as nodal restraints, material properties, etc. by pointing directly at the hidden-line removed perspective plots of the mesh. Working in conjunction with spread sheet windows, information including numerical data, text data, graphics and images can be easily stored, retrieved and updated.

MESHBASE^{TM} is comprised of 1) a 3-D graphics display/retrieving system that enables the user to identify nodes, elements, curves and surfaces of particular interest in real time by directly pointing at a 3-D meshplot, 2) a graphics file management system and, 3) a spread sheet data base management system. These systems are well integrated with the Macintosh window and system, a fast hidden line removal algorithm, and many unique mesh manipulation utilities for easy and intuitive mesh information processing.

MESHBASE^{TM} employs an object-oriented approach and the Macintosh "cut and paste" capability for text, graphics and image manipulations. It is a powerful tool for preparing and documenting finite element model and output. It is also an information base for storing and retrieving other information such as experiment results and pictures, design drawings, remarks, assumptions, analysis results and graphics. MESHBASE^{TM} is a very useful tool for engineering data organization and presentation.

INTRODUCTION

Finite element modeling and analysis requires the definition, modification and retrieval of the properties for nodes and elements. Given a list of node or element numbers, manipulations of nodal or elemental information are straight forward. However, to find a list of nodes or elements of interest is not straight forward and very often can be quite frustrating. In the past it is common practice for an engineer to carefully lay out numbering schemes in the mesh generation process so that nodes and elements of interest can be identified and defined with relative ease. Many 'automatic' mesh generation systems even require the nodal and elemental properties be defined in the mesh preparation process to avoid the difficulties in node and element identification. Since the modification of nodal and elemental properties and the identifications of node and elements for input/ouput are inevitable after a model has been created, automatic mesh generation without an 'automatic' node and element identifier simply creates a bigger gap in man-model interaction. Many CAD geometric modeling systems provide fairly good capabilities in preparing model geometry. However, they do not provide an easy way for the preparation of a complete finite element model. To eliminate the aforementioned deficiencies of existing modeling systems in

identifying nodes and elements and to provide the user easy and thorough control over models and their associated information, MESHBASE^{TM} is developed.

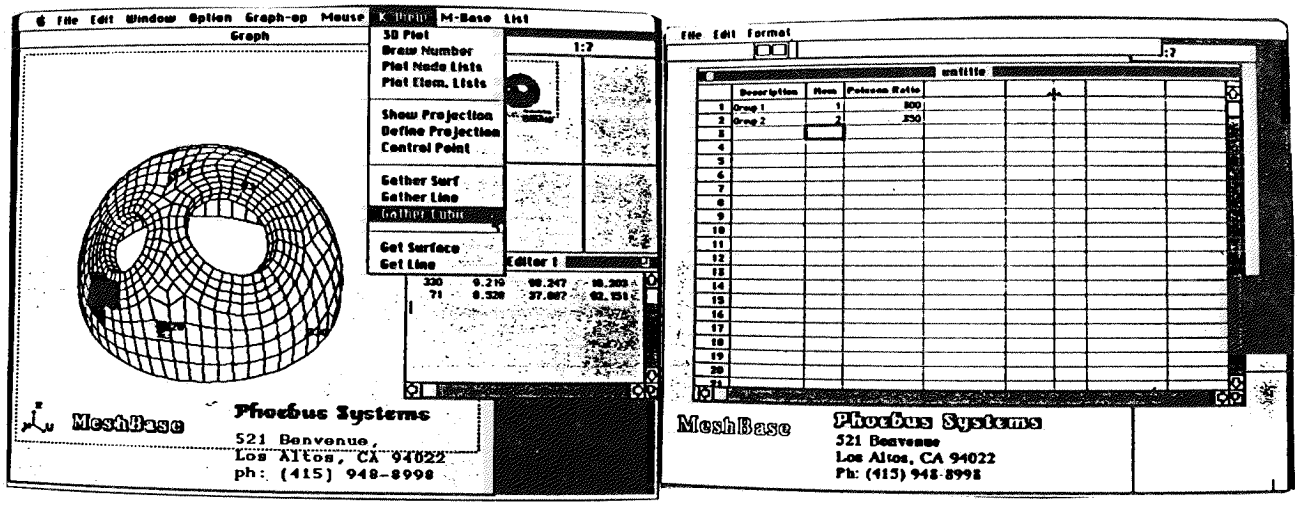
Human and computer perceive information quite differently. Node and element numbers are best received by the computer for accessing stored information but poorly received by the human in performing the same task. On the other hand, the human vision system can immediately identify locations of particular interest. In order for the computer to access stored information, nodes or elements corresponding to those locations must be identified. For 2-D objects, an interactive system that responds to the human vision system and produces a list of nodes or elements can be easily developed. The reason is that that there is a one-to-one correspondence between a model object and a 2-D display/input device, and 2-D graphics processing is generally fast enough to satisfy interactive usage. For 3-D objects and 2-D display/input systems, a one-to-one correspondence generally does not exist. Hidden line (surface) removals are required. In an interactive environment, the hidden line (surface) removal algorithm used must be very fast and support reverse processing; e.g. given a mouse location, find the corresponding node or element on the visible surface.

Even for a system which can interactively identify the nodes and elements of interest in real time, it is still quite cumbersome for the user to pick out all the nodes (elements) on a curve (surface). Intelligent retrieval of nodes between a sequence of control nodes and retrieval of elements or nodes bounded by a curve (loop) are highly desirable. A practical hidden line algorithm which supports interactive processing and intelligent node/element retrievals are fundamental to an efficient 3-D mesh information processing. The design of algorithms and data structures that can well accommodate these two simple requirements is the central theme of the MESHBASE^{TM} development.

Since the intent of this development is to bridge the gap between the user and computer (model), a user friendly environment is very important. The Apple® Macintosh^{TM} computer provides one of the best user environments and is selected as the platform for this development. FaceIt© of Faceware is used for quick setup of user menus and dialogs. For easy input of engineering data, special spread sheet windows are developed. The spread sheet windows are designed specifically for engineering environments in which the user can specify the title, data type, and format of each field (column) in a spreadsheet. The window is resizable, scrollable, and the width of each field is adjustable. With the MESHBASE^{TM} system, the user has real control over finite element models with simple clicks of a mouse.

MESHBASE USER ENVIRONMENTS

Text editors, spread sheet window, and graphics window environments are essential tools for a user to efficiently perform various engineering information processing and management. MESHBASE^{TM} is designed so that these environments are optimally integrated. MESHBASE^{TM} window environment is illustrated in the following figures.



A good "TALK" environment for the user to communicate with editors, spread sheets, and graphics windows is a must. In other words, the screen(window) is not only a display device but also an input device. The user should be able to identify on the screen the data to be operated on by simply pointing at them. Therefore, all algorithms and data structures for MESHBASE^{TM} are developed with "TALK" capabilities and neural architectures so that transfer of data is bi-directional.

FAST HIDDEN-LINE REMOVAL

A new and fast hidden line removal scheme which supports interactive mesh operations is developed so that meaningful 'TALK' environment can be provided. For the finite element model (1926 nodes and 1174 eight-node cubic elements) shown in Fig. 1, the removal of hidden lines takes less than 15 seconds (include CPU, disk I/O for compacted meta file generation) on a MACII. The hidden line removal scheme can plot dashed hidden lines (Fig.2) and make silhouette plots(Fig. 3). It will also plot the intersecting lines produced by intersecting elements (Fig. 4).

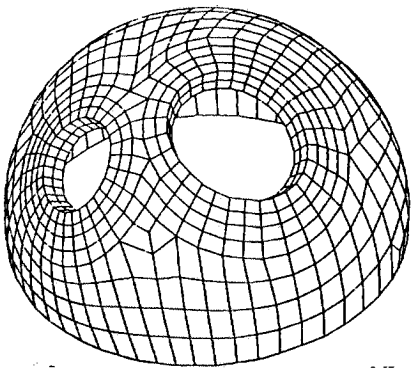


Fig. 1

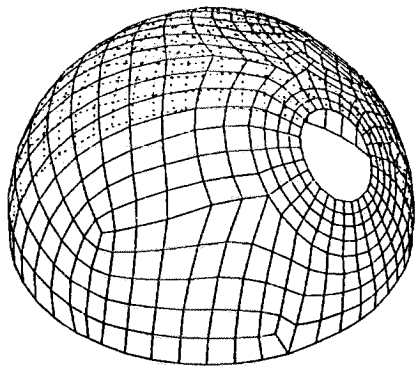


Fig. 2

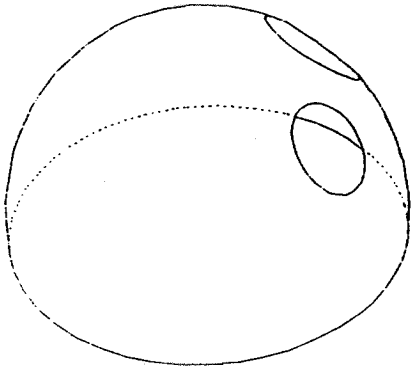


Fig. 3

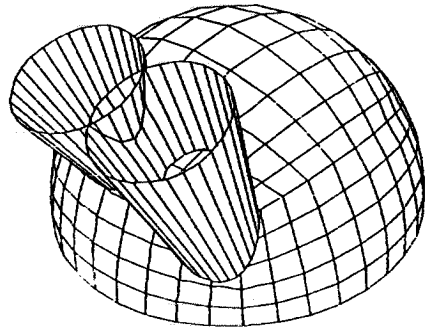


Fig. 4

In addition, after a hidden-line removed meshplot is displayed on the screen, the user can perform the following mousable operations with real time response.

1. Retrieve information on mouse-pointed nodes and elements.
2. Draw any or all node element numbers on visible surfaces.
3. Intelligently define and retrieve any curve and surface from the meshplots with a mouse.

These unique capabilities are achieved through new data structures and algorithms that efficiently support both graphics and mesh manipulation requirements.

GEOMETRIC REPRESENTATION

The current version of MESHBASE^{TM} does not provide geometric modeling and mesh generation capability. The geometric model (node coordinates and element connectivities) is assumed to be generated by other CAD systems or stand alone pre-processors. A companion

product of MESHBASE^{TM}, KMESH3D^{TM} is available to produce large scale and sophisticated models. KMESH3D^{TM} supports variable, register, symbolic processing, macro, DO loop, block IF etc. with which adjustable meshes can be generated.

The MESHBASE^{TM} system is designed to accept a mix of 1) lines, 2) arbitrary-sided polygonal surfaces (convex or concave), 3) hexahedrons and their degenerates as the basic model primitives. The system can handle 3-D finite element models involving beam, shell, and cubic elements. In a typical finite element application, the model geometry in MESHBASE^{TM} is represented by 1) nodes and their coordinates, and 2) element connectivities.

NODE AND ELEMENT LISTS

A finite element geometric model can be described directly and completely in terms of node and element described above. Very often information for a group of nodes or elements may be processed identically . For quicker operation and easier reference, lists of nodes and elements with user defined symbolic names can be created with ease for this purpose.

A node list corresponds physically to a line or a curve while a shell element list corresponds to a surface. MESHBASE^{TM} allows the user to define node or element lists by 1) typing in a list description through a dialog window, 2) selecting nodes or elements from 3-D meshplot using a mouse, and 3) intelligent extractions of lines or surface by selecting a few control nodes from a 3-D meshplot with the mouse.

MESHBASE^{TM} lets the user define a symbolic name of up to eight characters for a list. A node list and an element list may have the same name. A list can be defined and stored in a compact form. For example: { 5, 10,15,25,30,35,45,50} can be abbreviated as {5 to 50 by 5} or { 5 -50 by 5}. Whenever lists are anticipated in a command operation, a dialog window will automatically pop up to allow the user select lists of interest from a scrollable list that contains all the names of the lists which have been created. The user can rename, delete, and concatenate lists.

MESH INFORMATION

For CAE applications, information is associated with a node or an element. Since many nodes and many elements may share identical information, information should be grouped. Information needs only be defined once for each group and group numbers are tagged to nodes and elements. In other words, mesh information can be manipulated by 1) defining and modifying detailed information for each group without worrying about node or element numbers and 2) tagging group numbers to nodes and elements.

A spread sheet environment is ideal for defining and modifying information. One spread sheet is used for one piece of information such as material property with each row corresponding to a group number and each column to an information item such as Young's modulus or poisson ratio. A node or an element may be tagged with different group numbers for different information items. MESHBASE^{TM} currently lets the user define up to 30 different information items.

Since MESHBASE^{TM} allows the user to easily extract lists of nodes and elements, tagging group numbers to lists of nodes or elements is a trivial task.

COMMANDS AND FUNCTIONS in MESHBASE^{TM}:

MESHBASE^{TM} is comprised of two major systems; K-VIEW and SPREAD SHEET systems.

A. K-VIEW SYSTEM

The K-VIEW system is different from existing 3-D graphics display systems in three ways: 1) It is both menu and graphics data driven , i.e. it has 'TALK' capability, 2) It is superfast and renders a pleasant 'touch and feel' and great savings on valuable engineer hours, 3) It is innovative and targeted for a mesh processing environment.

The K-VIEW system consists of several menus, each of which has several options. In addition to four basic menus by FaceIt© for desk assessory (APPLE), file operations (FILE), text and graphics editings (EDIT) and window controls (WINDOW), K-VIEW provides the menus and options described below. Upon selecting a command option, adequate dialog windows are popped up for inputting, selecting, or checking of proper control and operating parameters.

1. K-VIEW : For retrieving model geometries and 3-D perspective plots.

3-D PLOT -- 3-D perspective plots with/without hidden line removed. Silhouette plots and dashed hidden lines are supported.
DRAW NUMBER -- Draw node and/or element numbers on the meshplot. If hidden line option is on, the node/element numbers are drawn only on visible surfaces(in real time).
PLOT NODE LISTS -- Plot selected node lists on the meshplot.
PLOT ELEM. LISTS -- Plot selected element lists on the meshplot.

SHOW PROJECTION -- Show all defined projections (triads).
DEFINE PROJECTION -- Define desirable viewing projections.
CONTROL POINTS -- Define control points of projection plans.

GATHER SURFACE -- Select surfaces from data base for plotting.
GATHER LINE -- Select lines from data base for plotting.
GATHER CUBIC -- Select cubic parts from data base for plotting.

GET SURFACE -- Get surfaces from data base for plotting.
GET LINE -- Get lines from data base for plotting.

2. MOUSE : For selecting and retrieving nodes, elements, curves and surfaces in real time by pointing directly at meshplots.

SHOW NODE -- Show node number coordinates for the pointed node.
SHOW ELEMENT -- Show element number for the pointed element.
DISTANCE -- Show the coordinates and distance between two pointed nodes.

PICK A NODE LIST -- Obtain a node list by pointing.
PICK AN ELEMENT LIST -- Obtain a element list by pointing.

EXTRACT A CURVE -- Intelligently retrieve any curve on a mesh by pointing at few nodes controlling the trajectory of a curve.

EXTRACT A SURFACE (NODE) -- Intelligently retrieve all the nodes in a arbitrary surface.
EXTRACT A SURFACE (ELEMENT) --Intelligently retrieve all the elements in an arbitrary surface.

3. M-BASE : For defining nodal or elemental information and assigning property group to each nodal or elemental information.

NEW INFORMATION -- Initialize a new nodal or elemental property.
SELECT INFORMATION -- Select a working nodal or elemental property.
DEFINE GROUP # FOR LISTS -- Define property group number.
SHOW GROUP # FOR LISTS -- Plot property group number.

GO TO SPREAD SHEET -- Open spread sheet associated with the working property.

4. LIST : For node/element list operation and management.

NEW -- Define a node or element list by typing.
OPEN -- Write selected node or element lists to text editor.
READ FROM EDITOR -- Read a node or element list from text editor.
DELETE -- Delete a node or element list.
RENAME -- Rename a node or element list.
CONCATENATE -- Concatenate several lists into one list
FORMAT PRINT -- Print mesh information to the editor in an order and format specified by the user.

5. GRAPH-OP : For graphics meta file management. Each plot displayed to the graphics window is captured as a picture segment. One or more segments can form a picture. A meshplot meta file can be retrieved for display and associated "MOUSE" operations.

PLOT SEGMENT -- Plot selected picture segments to the graphics window.
PLOT PICTURE -- Plot selected pictures to the graphics window.

DELETE SEGMENT -- Delete selected picture segments from meta file.
DELETE PICTURE -- Delete selected pictures from meta file.

RENAME SEGMENT -- Rename selected picture segments.
RENAME PICTURE -- Rename selected pictures.

ADD SEG. TO PIC. -- Add picture segments to a picture.
DEL SEG. FROM PIC. -- Delete segments from a picture.

NEW SEGMENT -- Create a new picture segment.
NEW PICTURE -- Create a new picture.

CLOSE SEGMENT -- Close a picture segment.
MERGE SEGMENT -- Merge several picture segments into one segment.

KVIEW-COPY -- Copy the memory that is necessary to support 'MOUSE' operations to the meta file system so that the user can mouse on the graphics retrieved from the meta file.
KVIEW-PASTE -- Paste the memory necessary to support 'MOUSE' operations.

6. OPTION : For file import, color, font and numbering controls

SELECT META FILE -- Select another meta file to process.
IMPORT -- Import mesh generated by other programs such as AutoCAD®, VersaCAD®,etc. (will be implemented in a near future)

GRAPH-COLOR-FONT -- Select desirable color, font, etc.
NODE/ELEM NUMBERING -- Select control parameters for node/element numbering.

B. SPREAD SHEET SYSTEM

The spread sheet system is developed to provide an easy and organized user interface for input and modification of engineer data. It is designed for CAE applications in which each field in the spread sheet may define its own data type and format. To jump to the spread sheet system the user selects 'GO TO SPREAD SHEET WINDOW' from KVIEW system.

The spread sheet window works very similar to other commercial grade spread sheet except it is tuned to satisfy many engineering requirements. Details on the spread sheet system will be presented later on a separate paper due to space limitations

CONCLUSION

MESHBASE™ represents a new way to process mesh information. The meshplots obtained are not only graphics images, but also intelligent information-bases; every node or element is a sensor ready to receive the user's commands and respond with mesh information in real time. MESHBASE™ also provides a new way to document and transfer information. Instead of documenting various mesh information in details, the user can simply retrieve MESHBASE™ graphics meta file and then mouse in and out all the desired information.