CR-189391

EXPERIMENTER'S LABORATORY FOR VISUALIZED INTERACTIVE SCIENCE

FINAL REPORT

SECTION I

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COMMUNICATING WITH "ELVIS"

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Introduction

The role of visualization in space science is expanding, encompassing exploratory data evaluation and emerging as a valuable tool in interdisciplinary communication. Visualization technologies permit scientists to communicate the informational content of large, complex data sets in a simple, intuitive format readily understood by both scientists and nonscientists in a range of disciplines.

The ability to communicate the essence of a scientific data set through visualization has additional applications in education where the interpretation of the data needs to be conveyed from instructor to student. This is especially true in undergraduate and interdisciplinary education where, for example, a scientist may wish to present global climate change information to pre-college students, political science students, computer science students, or journalism students. The Experimenter's Laboratory for Visualized Interactive Science or "ELVIS" is an interactive scientific visualization tool capable of promoting such interdisciplinary communication, education, and scientific exploration.

ELVIS Overview

ELVIS is an interactive visualization environment that enables scientists, students, and educators to visualize and analyze large, complex and diverse sets of scientific data. It accomplishes this by presenting the data sets as 2-D, 3-D, color, stereo, and graphic images with movable and multiple light sources combined with displays of solid-surface, contours, wire-frame, and transparency. By simultaneously rendering diverse data sets acquired from multiple sources, formats, and resolutions and by interacting with the data through an intuitive, direct-manipulation interface, ELVIS provides an interactive and responsive environment for exploratory data analysis.

ELVIS is an integrated set of software tools, developed for use on a range of popular and affordable computer workstations, and currently hosted on Sun and Silicon

Graphics Workstations. These integrated tools include a Graphical User Interface based on GSFC's Transportable Applications Environment (TAE Plus). The internal architecture is based on a reusable C++ object library which includes objects for 2-D and 3-D graphics, a data object, a geometric object, a light object, and color objects. The 3-D rendering package is an extension of the popular NCAR "Polypaint" package and the data access software is based on concepts from the Network Common Data Format (NetCDF), an access library developed by the NSSDC.

ELVIS is designed to support the needs of scientists, students, and educators from a range of Earth and space science disciplines. ELVIS prototypes have been evaluated by representatives of the space science community throughout the program, and the design refined to meet the evolving recommendations of these users.

ELVIS enables its users to work on scientific or educational problems (and not on computer science details) by employing an intuitive and responsive user interface. It provides the user with the flexibility to present specialized displays while supporting common capabilities with simple instructions.

Graphical User Interface

ELVIS' Graphical User Interface (or GUI) is simple to access, understand, and operate. The GUI is key to providing efficient data exploration and communication technology to the scientific and educational communities. The graphical user interface in ELVIS supports these user needs by promoting functionality and maintaining simplicity. ELVIS' pulldown menus are designed to be accessible while minimizing interference with the visualization windows (Figure 1). The pulldown menus each have several pop-up submenus which permit more advanced data and graphical manipulations. The features of the ELVIS GUI are included in a set of editors and tutorials:

The ***Color Editor*** allows the user to intuitively choose colors for coding data. The colors are identified by sight rather than by number as is common in many visualization packages. The distinction between true color and indexed color hardware is hidden. The direct manipulation color editor allows the user to visually select a single color or build a complex color ramp without knowledge of the hardware or the underlying software.

The ***View Editor***, manipulated in 3-D within a fixed coordinate system, enables the perspective of the "user's eye" to be adjusted by moving the eye in one plane at a time or in all planes simultaneously. Before rendering, the user can check the orientation of the

3-D object using a low resolution panel. The view angle can also be changed by directly manipulating a diagram representing the actual visualization.

The ***Light Editor*** allows the user to add and delete light sources and shadows with the ability to change their color, properties, and location.

The ***Visualization Editor*** displays a selected data set using default attributes. Displays of the default attributes may then be modified by the user to tailor the visualization to their own needs. The meta-data are also stored in the data object allowing the visualization editor to make intelligent decisions regarding the defaults.

Tutorials which provide new users with a demonstration on how to utilize ELVIS are also available as part of the GUI. Context sensitive help is available for any menu window by first selecting the help button and then clicking on the item or object for which information is desired. By integrating comprehensive help and tutorial information into ELVIS, the time and effort required to learn the package is reduced.

Data Visualization Techniques

ELVIS, with its Polypaint+ rendering package developed by NCAR, provides procedures for displaying complex structures in 3-D data fields using color shaded surfaces and provides the ability to control lighting, viewing, and shading. Data volumes can be sliced and the cross-sections displayed using 2-D graphics options. ELVIS provides a number of visualization methods including:

- 3-D topographic surfaces where data fields and topographic surfaces may have different resolutions.
- 3-D volumetric or density visualizations
- 3-D isosurface and transparent isosurface shells
- 2-D graphics which can be interacted with via the mouse. The value and location of the data are displayed when a graphic object (contour line, map outline, vector, or raster image) is selected.
- 2-D contour plots featuring contour lines and color-fill contour regions as display options.
- 2-D vector plots which enable the user to visualize vectors based on magnitude and direction. It differs from straight vectors because an interpolation scheme is used to calculate the magnitude and direction at small time intervals, thus showing any small curvature that the vector may have.

- 2-D raster images (see Figure 2).

- 2-D map outlines using the World Data Bank II. Map features can be added or deleted interactively to provide more or less detail (see Figure 2).

- Projection and 2-D window capability allow correct placement of data in a 2-D window according to either the meta-data or user specified world coordinates. Data can be projected in Cartesian, Mercator or Lambertian coordinates.

Features for the Scientific User

The value of ELVIS to the scientific community is based on its simplicity, durability, large data capacity, and its easily understood function menus. Beyond its base structure, ELVIS incorporates several features which are particularly useful to scientists.

- True color surface shading allows the user to visually identify small anomalies in the data. The use of true color surface shading permits visual recognition of features not discernible through traditional indexed shading or simple numerical evaluation of the data.

- The ability to insert a discrete color into a color ramp using the color editor menu permits the user to highlight features in the data. It complements the contour mapping features. For example, this feature is being employed to insert narrow bands of bright red into a gray scale ramp in order to visually isolate and roughly quantify small fluctuations in global total ozone measurements.

- Visualization of large data sets provides the user with an information rich assessment of the data in a fraction of the time necessary to prepare and perform numerical evaluations and comparisons. With visualization, the interpretation is simple and rapid, with resultant decreases in the time necessary to interpret more detailed numerical evaluations.

- Manipulation of the data visualizations created in ELVIS is convenient and straightforward, in comparison with many data display packages in which image manipulation is often confusing and tedious.

- With the selection of appropriate surface overlays and shading, the scientific information contained in a data set may be intuitively understood by non-scientists. For example, by displaying global ozone data overlaid on a map of the Earth's surface, the resulting visualization is that of "ozone clouds" over the globe. From this type of visualization, an understanding of how ozone varies from location to location and with the seasons is readily available to all. An understanding of how "ozone clouds" block ultraviolet radiation may be intuitively gained through analogy to outdoor brightness on a clear day as compared to a cloudy day. These features makes ELVIS a valuable communication tool for education.

Hardware and Data Formats Supported

ELVIS has been tested on the Silicon Graphics and Sun 4 workstations. Data conversion from a variety of binary formats to NetCDF, so they may be read and visualized, is achieved via a window menu integrated into ELVIS.

Visualization Applications

The ELVIS tool has been used to visualize planetary data (Figure 3), meteorological data (Figure 4), and atmospheric constituents (Figure 2) from the perspectives of scientists, new (not a programmer) users, students, and educators. The visualizations of Earth and space science data are being used at the Colorado Space Grant College (Figure 5) to educate students and to encourage high school students to pursue their interests in space based research.

The use of ELVIS as an educational communication facilitator has been promising in its early applications. Students are able to grasp more complex scientific phenomena with less effort and time. We plan to use visualizations from ELVIS in portions of the University of Colorado's "Introduction to Space Experimentation" course in the Spring of 1995 to provide engineering undergraduates with an overview of Earth Science as observed from space. It is anticipated that interdisciplinary applications such as this will benefit from the enhanced communication afforded by scientific visualization.

The ELVIS Mosaic homepage contains many sample graphics. It also describes the software and workstation requirements. The URL is http://polypaint.colorado.edu:4444/home.html. ELVIS is available at no cost to those who sign a license agreement. Anyone interested in obtaining ELVIS should contact Marjorie Klemp at margi@aries.colorado.edu to receive a license agreement form.

Aeknowledgments

This research was inspired by Jeff Star of the University of California at Santa Barbara who helped develop the initial ELVIS concept and who served as a representative of the educational and Earth Science community. His contributions, vigor, and friendship are remembered.

The authors also gratefully acknowledge the participation by a core development team made up of talented and dedicated scientists, engineers, and students from the University of Colorado's Space Grant College (Anthony Colaprete, Allison Kipple, Mike Porkert, Jennifer Ray, and Kevin Stephens) and Laboratory for Atmospheric and Space

Physics (Eric Hillis and Ed Loehr), from the National Center for Atmospheric Research (Bill Boyd and Scott Davis), from Goddard Space Flight Center, and from the University of California at Santa Barbara. This core team was assisted by a group of talented and supportive scientists who helped evaluate the prototypes and guide the design, made up of Joe Klemp, Steve Lee, O.R. White. Gary Rottman, Gary Heckman and others.

The work was supported by a contract from the Information Systems Division of NASA's Office of Space Science and Applications, and by students earning research and design credit at the University of Colorado.

Figure Captions

Figure 1: ELVIS' Graphical User Interface (or GUI) is key to effectively providing graphical data exploration and communication technology to the scientific community.

Figure 2: A 2-D raster plot of global ozone illustrating Antarctic ozone depletion. The World Data Bank II map features are overlaid for geographic perspective. The Meteor-3 Total Ozone Mapping Spectrometer data used in this plot was obtained by anonymous ftp from Goddard Space Flight Center.

Figure 3: A 3-D visualization of Mars elevation data overlaid with red filter albedo data from the Hubble Space Telescope. The surface features are exaggerated by a factor of 50.

Figure 4: A 3-D isosurface of a cloud with a rain field rendered transparently. The baseplane and bounding box provide the relative orientation of the cloud model data.

Figure 5: Visualizations of Earth and space science data are being used at the University of Colorado Space Grant College to educate students and to encourage high school students to pursue their interests in space science and technology fields.

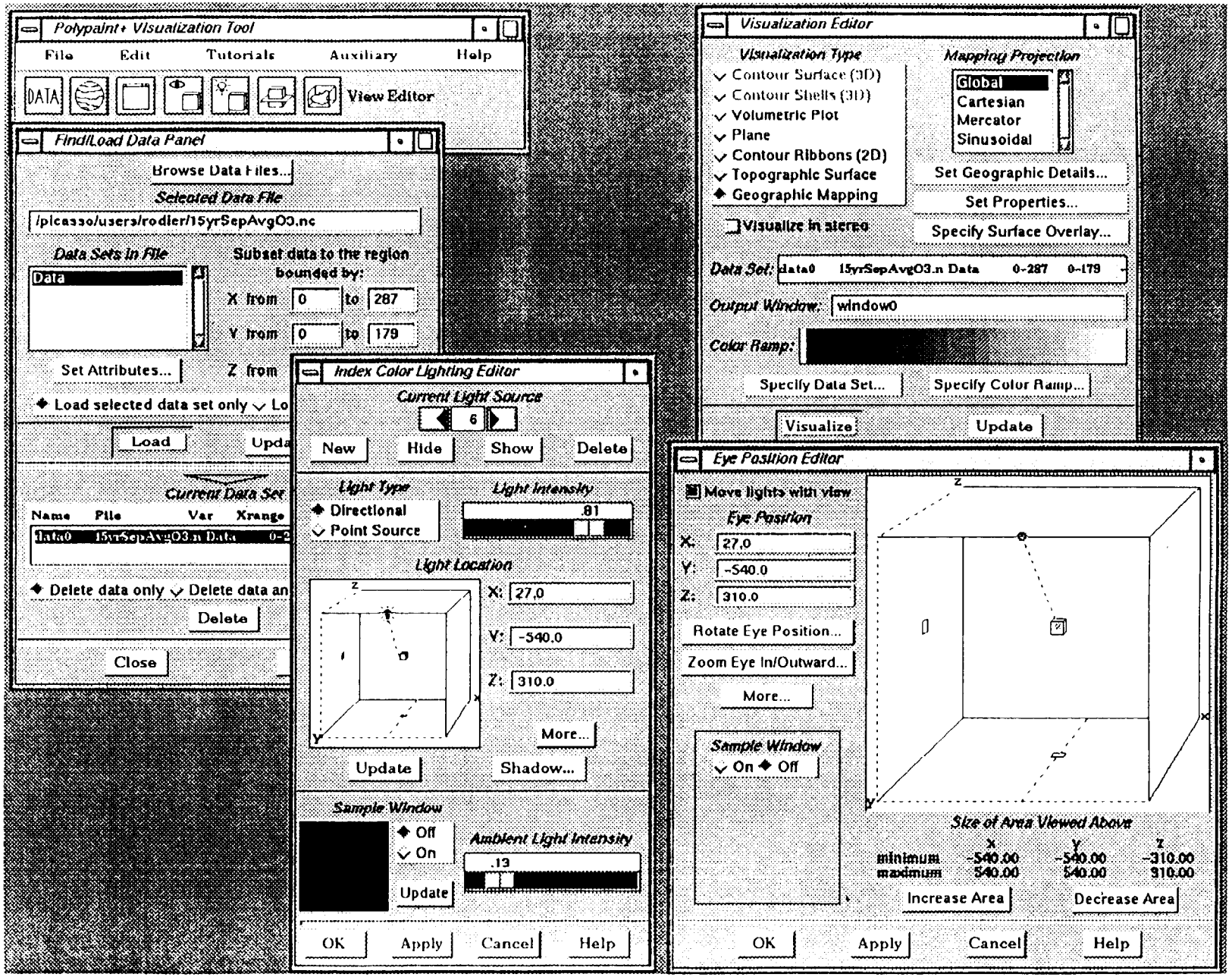

Polypaint+ Visualization Tool
File
Edit
Tutorials
Auxiliary
Help
DATA
View Editor
Find/Load Data Panel
Browse Data Files...
Selected Data File
/picasso/users/rodler/15yrSepAvgO3.nc
Data Sets in File
Data
Subset data to the region bounded by:
X from 0 to 287
Y from 0 to 179
Z from
Set Attributes...
Load selected data set only
Load
Current Data Set
Name File Var Xrange
Delete data only
Delete
Close
Index Color Lighting Editor
Current Light Source
6
New
Hide
Show
Delete
Light Type
Directional
Point Source
Light Intensity
.81
Light Location
X: 27.0
Y: -540.0
Z: 310.0
More...
Update
Shadow...
Sample Window
Off
On
Update
Ambient Light Intensity
.13
OK
Apply
Cancel
Help
Visualization Editor
Visualization Type
Contour Surface (3D)
Contour Shells (3D)
Volumetric Plot
Plane
Contour Ribbons (2D)
Topographic Surface
Geographic Mapping
Mapping Projection
Global
Cartesian
Mercator
Sinusoidal
Set Geographic Details...
Set Properties...
Visualize in stereo
Specify Surface Overlay...
Data Set: data0 15yrSepAvgO3.n Data 0-287 0-179
Output Window: window0
Color Ramp:
Specify Data Set...
Specify Color Ramp...
Visualize
Update
Eye Position Editor
Move lights with view
Eye Position
X: 27.0
Y: -540.0
Z: 310.0
Rotate Eye Position...
Zoom Eye In/Outward...
More...
Sample Window
On Off
Size of Area Viewed Above
x y z
minimum -540.00 -540.00 -310.00
maximum 540.00 540.00 310.00
Increase Area
Decrease Area
OK
Apply
Cancel
Help

Figure 1

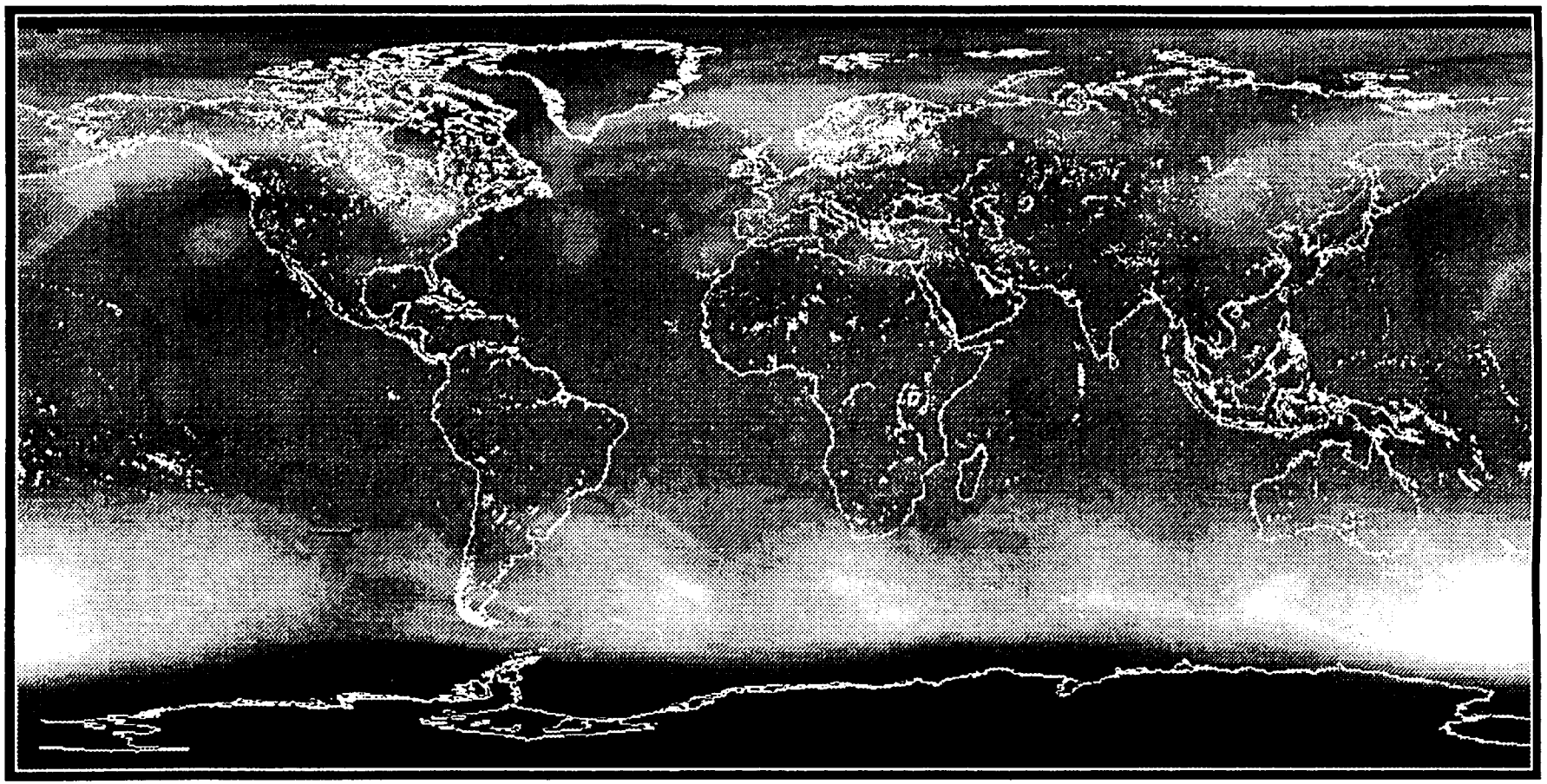


Figure 2

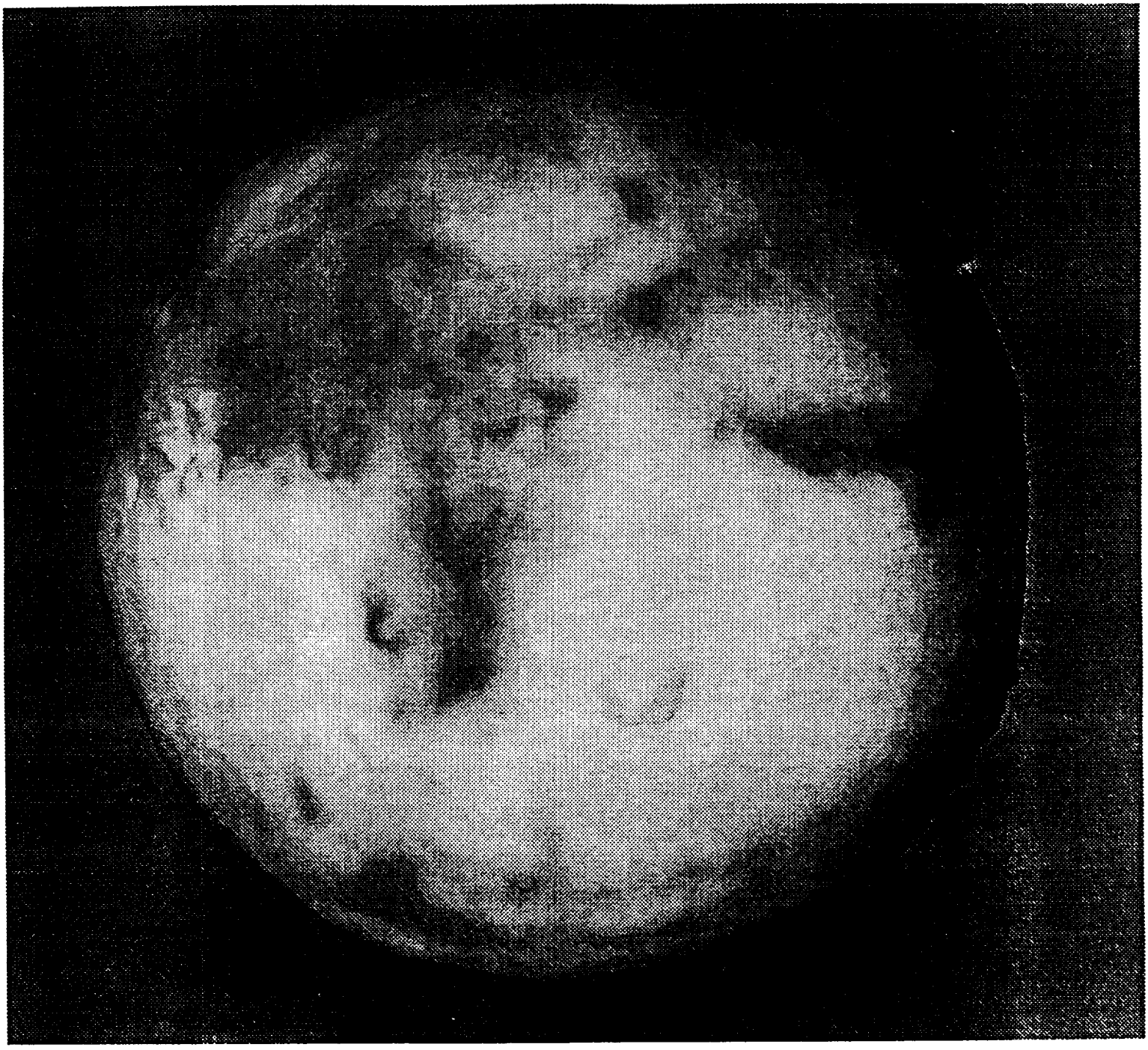


Figure 3

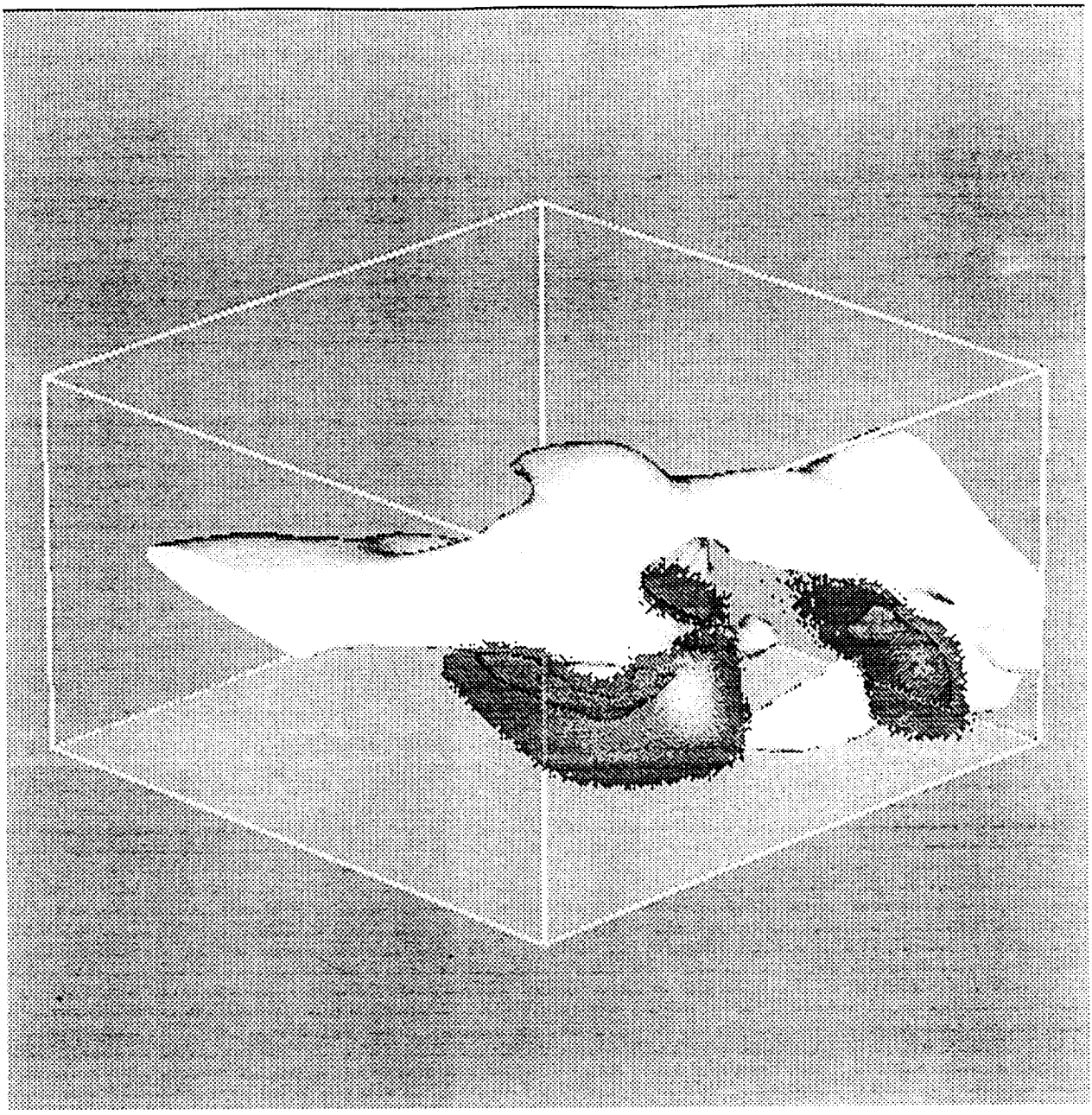


Figure 4

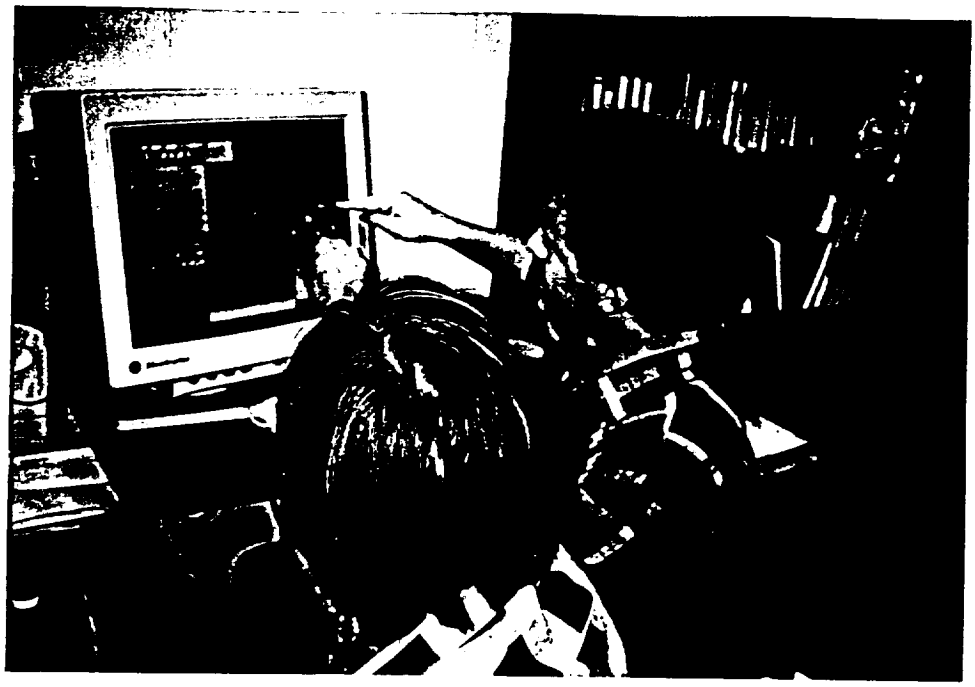


Figure 5

EXPERIMENTER'S LABORATORY FOR VISUALIZED INTERACTIVE SCIENCE

FINAL REPORT
SECTION II

MAJOR ACCOMPLISHMENTS:

A beta version of ELVIS, an interactive scientific visualization tool, has been completed. It has been tested on the SGI IRIX 4.0.5MM, IRIX 5.2 SunOS 4.1.3, and Solaris 5.3 environments and is currently available through NASA's Software Support Laboratory at no cost.

ELVIS is an interactive scientific visualization tool that utilizes an NCAR rendering package, called Polypaint+, to display complex structures within three-dimensional data fields. It provides color shaded-surface displays and simple volumetric rendering in either index or true color. For shaded surface rendering, the ELVIS routines first compute the polygon set that describes a desired surface within the 3D data volume. These polygons are then rendered as continuously shaded surfaces. ELVIS contains a wide variety of options that control lighting, viewing, and shading. Objects rendered volumetrically may be viewed along with shaded surfaces. Additional data sets may be overlaid on shaded surfaces by color coding the data according to a specified color ramp. 3D visualizations can be viewed in stereo for added depth perspective.

Currently supported 3D visualizations include:

- Shaded isosurfaces
- Transparent contour shells or isosurfaces at varying levels
- Volumetric or density plots
- Planes
- Contour ribbons
- Topographic surface from 2D geographic data sets
- 3D Geographic Mapping which may be overlaid with additional data

3D data volumes may be sliced in the X, Y, or Z plane using an interactive cutting plane. A cross-section of the data volume can be viewed

in a 2D window as a 2D contour plot with contour line or color-filled contour areas; a vector plot with straight or curved vectors; a raster image; or a combination of these options superimposed. Map outlines can be used as a background for 2D cross-section plots of geographic data. All data are projected according to the area defined for the cross-section window. Any combination of these visualization types can be overlaid in the cross-section window and the data will be projected. The cross-section can be easily visualized using a user-interface panel which specifies the coordinates desired in data units or geographic coordinates.

The user interface provides direct manipulation tools for specifying the eye position, center of view, light sources, and color ramps. Subsetting of data can be done easily through selecting the data by index or geographic coordinate. On-line contextual help provides easy access to detailed information about the software. Tutorials which range from very simple visualizations to complex combinations of data sets provide the user with a quick learning tool.

Currently, ELVIS accepts only data which is in the NetCDF file format. There is a data conversion utility which is a part of the application which converts unformatted binary data files to NetCDF. For instance, a file created by IDL using the WRITEU procedure can be read by this utility and converted to NetCDF. This utility is also provided as a stand alone program which provides the same file conversion function. Other ways of creating NetCDF files include using IDL's NetCDF interface procedures, using NetCDF utilities, or writing a program using the NetCDF library.

The following tasks were completed for this beta version of ELVIS:

USER INTERFACE:

User interviews throughout design and implementation phases helped the development team understand the type of tasks a scientist would likely perform.

The user interface was prototyped, tested, and refined several times before the alpha release was released. The alpha release was distributed to a limited number of test sites. Feedback from these sites was integrated into the beta release.

The following user interface tools were designed and implemented:

Color editor

The primary focus of the design wass to allow the user to choose colors for color coding data intuitively. Other objectives were to have the colors identified by sight rather than by number as is the common method used in visualization packages, and to hide the distinction between true color and indexed color hardware. The result is a direct manipulation color editor which allows the user to select a single color or build a multi sequential color ramp visually. No hardware knowledge is required. Colors are associated directly with data values.

View editor

Selecting an eye position for viewing a 3D data set is often difficult. If the display itself is manipulated, the user looses their perspective of the data set and becomes disoriented. It also is very expensive to continuously render the data as the eye position is changed. This is particularly true on a workstation that has no built-in graphics hardware. To solve these concerns, the ELVIS view editor manipulates the eye in a 3D, fixed coordinate system. User testing led to modifications of the 3D manipulation and the addition of methods for moving the eye in one plane at a time. A second panel was added which allows the user to verify the orientation of the 3D object before actually rendering the complete visualization. The editor permits rapid 3D object reorientation in an intuitive manner.

Light editor

The same viewer used for modifying the eye position is used for changing the position of the light source. The light editor allows the user to add and delete light sources and to change their color and properties. It also allows access to the shadow control menu.

Visualization editor

In order to make visualizing science data as simple as possible, we have defaults so that once the data are selected, they can be visualized immediately. The visualization editor displays all the default attributes that have been set. These attributes can be modified easily to refine the visualization. Since the meta-data are stored in the data object, the visualization editor can use them to make intelligent decisions about

appropriate defaults. Additional tools will be added to make these decisions more accurate.

ON-LINE CONTEXT SENSITIVE HELP:

Tutorials

Tutorials are included to teach the user how to apply ELVIS to the visualization of science data. They describe step-by-step procedures for utilizing the software and hardware tools available for understanding scientific data.

NetCDF file

The NetCDF file conversion utility is available to read unformatted binary data files and convert them to NetCDF.

KEY FEATURES FOR THE SCIENTIFIC USER:

The value of ELVIS to the scientific community is based on its simplicity, durability, large data capacity, and its easily understood function menus. Beyond its base structure, ELVIS incorporates several features which are particularly useful to scientists.

- True color surface shading permits the user to visually identify small anomalies in the data. During the evaluation of ELVIS, the use of true color surface shading led to the visual recognition of an error in certain global ozone measurements. The error, presumably caused by incorrectly accounting for variations in the reflectivity of the Earth's surface, is not discernible through traditional indexed shading or numerical evaluation of the data.

- The ability to insert a discrete color into a color ramp using the color editor menu permits the user to highlight features in the data. For example, this feature is being employed to insert very narrow bands of bright red into a gray scale ramp in order to visually isolate and roughly quantitate the error in global ozone measurements mentioned above.

- The ability to insert a discrete color into a color ramp also allows the user to create color-coded contour maps of the data.

- Visualization of large data sets provides the user with an information rich assessment of the data in a fraction of the time necessary to perform numerical evaluations and comparisons. With visualization of the data the interpretation is simple and rapid, with resultant decreases in the total time necessary to interpret numerical evaluations.

- Manipulation of the data visualizations created in ELVIS is convenient and straightforward, in comparison with other data display packages in which image manipulation tends to be confusing and tedious for many scientists.

- With the selection of appropriate surface overlays and shading, the scientific information contained in a data set may be intuitively understood by non-scientists. For example, by displaying global ozone data overlaid on a map of the Earth's surface, the resulting visualization is that of "ozone clouds" over the globe. From this type of visualization, an understanding of how ozone varies from location to location and with the seasons is readily available to non-scientists. An understanding of how "ozone clouds" block ultraviolet radiation may be intuitively gained through analogy to outdoor brightness on a clear day as compared to a cloudy day. This feature makes ELVIS a valuable educational tool.

Through the course of evaluation, several features were identified for inclusion into future versions of ELVIS. The ability to blend the shading of multiple data overlays would permit the visualization of the differential value of the data sets with respect to time or varying conditions. This would be particularly useful in detecting and observing time-dependent changes in Earth science measurements expected as a result of global change, i.e. atmospheric components, global vegetation indices, global temperatures, and etc. The inclusion of the option to save the visualization format (type of overlay, data range - lat/lon range, etc.) in future versions will make it easier to compare visualizations that were created over the course of several weeks or months and will reduce the visualization set-up time. Also, the ability to print a visualization while inside ELVIS would save time and be more convenient than saving the image as a postscript file, opening another window, and printing as is presently required.

SOFTWARE DESIGN AND IMPLEMENTATION:

A complete object design was developed to facilitate an interactive and flexible interface for implementation in a follow-on effort. The design is based on base classes called IV_OBJECT which handle propagation of attribute changes in a spreadsheet-like fashion. This capability will allow the user to build interfaces and new visualizations on-the-fly without the complexity of a programming language.

C++ classes are implemented. The following classes have been completed.

Object hierarchy:

```
IV_OBJECT                 -- Superclass
    DATA,                 -- DataObject
    GEOMETRIC,            -- Geometric
    IMAGE,                -- Image (superclass)
    SURFACE,              -- Surface
    VOLUMETRIC,           -- Volumetric
     WIRE,                -- Wire
     RAMP_IMAGE,          -- RampImage

    IV_WINDOW,            -- IV_Window

    XCOLOR_MAPPER,        -- XColorMapper (superclass)
      COLOR_TABLE,        -- ColorTable
      TRUE_COLOR,         -- IV_TrueColor


    VISUALIZATION,        -- Visualization
    LIGHT,                -- Light
    NETCDF,               -- NetCDF
    COLOR_OBJECT,         -- ColorObject  (superclass)
     COLOR_RAMP,          -- ColorRamp
     SINGLE_COLOR,        -- SingleColor
     COLOR_CHUNK,         -- ColorChunk

    PREFERENCES,          -- Preferences
    CURRENT_STATE,        -- CurrentState
    TWODVIS,              -- twodvis
    PROJECTION,           -- Projection
```

```
IV_GRAPHIC,          -- IV_Graphic   (superclass)
  IV_PICTURE,        -- IV_Picture   (superclass)
    IV_MAP,          -- IV_Map
    IV_CONTOUR,      -- IV_Contour
    IV_VECTOR,       -- IV_Vector
  IV_POLYLINE,       -- IV_PolyLine  (superclass)
    IV_VECTORLINE,   -- IV_VectorLine
  IV_MAPFEATURE,     -- IV_MapFeature
  IV_CONTOURLEVEL,   -- IV_ContourLevel
  IV_2DRASTER,       -- IV_2DRaster

IV_2DWINDOW,         -- IV_2DWindow
IV_OBJECT_VIEW,      -- IV_ObjectView
```

The geometric and image classes are actually C++ wrappers which call subroutines in the National Center for Atmospheric Research (NCAR) PolyPaint library. It was necessary to modify the PolyPaint library quite extensively to accommodate this object-oriented design. The IV_graphic class is used for all 2D graphics. The underlying graphics primitives are from Stanford's InterViews. The algorithms used for contour plots, vector plots, and geographic maps were written in C++ using an object-oriented design. This will make it possible to identify sub-objects such as contour intervals and to interactively change their attributes. The other objects are coded in C++.

New ways of visualizing data

The NCAR PolyPaint graphics library provides procedures for displaying complex structures in 3D data fields by using color shaded surfaces with the ability to control lighting, viewing and shading. Volumetric or density visualizations in 3D are also included.

As part of the ELVIS project the following visualization methods were implemented:

- Mapping data fields to 3D topographic surfaces. Data fields are not required to have the same resolution as the data used to generate the topographic surface.

- Object-based 2D contour plots will allow the user to click on a contour object and either change it's attributes or display the data.

- Object-based 2D vector plots to enable the user to click on a vector and either change it's attributes or display the data. A new type of vector plot was implemented called curved vectors visualize vectors based on magnitude and direction. It differs from straight vectors because an interpolation scheme is used to calculate the magnitude and direction of a vector at small time intervals, thus showing any small curvature that the vector may have. The vector lengths may be adjusted by the user.

- 2D raster image

- A 2D map outline using the World Data Bank II. Map features can be added or deleted interactively to provide more or less detail.

- A projection class and a 2D window class allow placement of data in a 2D window according to either the meta-data provided in the data object or user specified world coordinates. Data can be projected in Cartesion, Mercator or Lambertian coordinates.

An object editor prototype

With the object editor, the user would be able to select an object either by using the mouse to click on that object on the screen or through an object browser. An options menu includes the option of displaying an object editor. This editor would be used to view and modify any attribute of the object such as color, visibility, or line style. The object editor also provides an interface to the spreadsheet object which propagates changes between objects related by formulas.

The object editor and spreadsheet object were not completed due to cuts in funding for the project. We hope to include these capabilities in a future version of ELVIS.

Other enhancements to ELVIS will be implemented with other funding sources at NCAR. They include:

- Design and implementation of a 3D data transformation pipeline. This is essential to having scientific data properly registered and displayed. Design work has begun to create a pipeline to align regularly gridded data fields and to handle a variety of irregularly gridded data.

- Design and implementation of 3D drawing capabilities including integration of drawing 2D visualizations into 3D visualizations.
- Default color ramps tailored to specific visualization types.
- Refined 24 to 8 bit color dithering scheme to improve the quality of rendering complex visualizations on low-end workstations.
- Include the ability to read HDF-NetCDF data formats.

TEST PROCEDURES:

Cognitive walk throughs were used by the designers to understand what would be involved in carrying out a task. These were used with scenarios of user activities to explore his/her data.

Usability tests were performed throughout the development of the interface. Results were used to modify and refine the interface. A technique called "talking aloud" was effectively used to determine how the user was reacting to the interface.

Software tests were done by various members of the design and implementation team. The tutorials provide good tests for the basic capabilities of the software.

Alpha testing with users provided additional insight into the needs of space scientists from a variety disciplines including planetary and Earth sciences. Some new areas in which ELVIS will be used in the future include:

- The NCAR Graphics Group is investigating integrating ELVIS into the NCAR Graphics Package. They would use the programming interface provided by a C++ library of objects which is the basis for the ELVIS application.
- NCAR and Ohio State Supercomputing are investigating the feasibility of developing a collaborative visualization tool which would be shared interactively over a network by scientists working at different sites.

- Educational use of ELVIS at several universities is being investigated. The tutorial functionality of ELVIS along with appropriate data sets can be used to help students visualize and learn about scientific phenomena.

RECENT ACCOMPLISHMENTS:

- The color-filled 2D contour visualization object was completed and integrated.

- The 2D graphics objects were integrated into the ELVIS package.

- On-line context sensitive help was written for every item in the interface.

- The following tutorials were designed and implemented:

  Simple starter
  in stereo
  as a wireframe
  with haze
  Many transparent objects
  All visualization types
  Geographic data
  with an overlay
  Make a complex color ramp
  Change the view
  Change the lighting
  Slice through a window
  Convert data to NetCDF

- ELVIS was ported to SunOS 4.1.3. Modifications were made to run on an Indigo2 because there were differences in the C++ compiler on the Indigo2 versus the Indigo. ELVIS was compiled and tested on IRIX 5.2. Some changes were necessary due to reorganization of SGI libraries and other systems software.

- A software distribution was set up including appropriate README and INSTALL files. Sample procedures were developed for

converting data to NetCDF via utilities in the NetCDF distribution and using IDL. A stand-alone data conversion program was written. Its functionality was included in the ELVIS application. Licensing issues were investigated by consulting with NCAR and University of Colorado (CU) lawyers. A license agreement was developed which must be signed by any user who wishes to install ELVIS on their computer. There will be no charge for the software.

- A Mosaic homepage was created which is accessible from the Software Support Laboratory (SSL) homepage. It uses the recommended format for the SSL and includes example visualizations and user interface panels.

- Several demonstrations of the software were given to visitors.

- Potential science users at the Colorado Space Grant College and the Laboratory for Atmospheric and Space Physics (LASP) were given in-depth demonstrations. They provided feedback on features which they would like in future versions.

- ELVIS was installed on alpha user's computers. In general the software was easy enough to use that no training was required. However, time was spent with users to demonstrate effective ways of visualizing data. This provided additional feedback to the ELVIS team for modifications and new features.

- A spreadsheet object was designed and implementation was started. This object will allow changes to propagate through any number of objects created by ELVIS, much as a spreadsheet does, by specifying relationships between the attributes of the objects with formulas. These formulas could be used to relate screen objects as well as data, color ramps or any other object created by the application. It will be an effective way of creating new interface components such as animations without programming.

- An object editor was prototyped. The object editor panel is displayed when a user selects a screen object with the mouse or any object with an object browser. It provides a method for viewing all attributes of an object and for changing any attribute. It also is the interface for specifying formulas which relate objects and establish the propagation of values for the spreadsheet engine. This

editor is highly dependent on the spreadsheet object and could not be tested without the complete implementation of the spreadsheet object. The object browser was prototyped. Several approaches were considered and tests were run to make sure performance was adequate. It also depends on the spreadsheet object's completion.

- The C++ library of objects was completed, documentation was written, and sample programs were created to demonstrate its use for other applications.

- Extensive regression testing was conducted to assure a stable version of the software.

- User testing was again performed on the alpha release by letting selected users try the package without any training or support from the ELVIS team. This demonstrated the ease of learning of the package. We found that after about four hours, using tutorials and exploring the interface, a user was familiar enough with the interface to visualize his/her data. There were only occasional questions which were generally problems with terminology in the tutorials.

EXPERIMENTER'S LABORATORY FOR VISUALIZED INTERACTIVE SCIENCE

FINAL REPORT

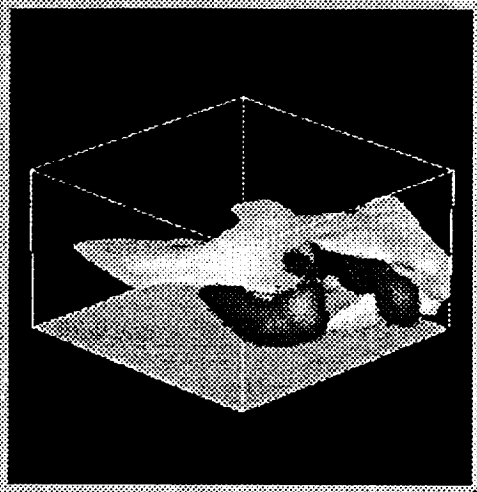
SECTION III

NCSA Mosaic: Document View

File Navigate Options Annotate Help

Document Title: PolyPaint+, 3D visualization software

Document URL: http://polypaint.colorado.edu:4444/home.html



PolyPaint+, 3D visualization software

This page provides information about the PolyPaint+ software package, a joint effort of the University of Colorado and NCAR (National Center for Atmospheric Research) funded by the NASA AISRP program.

Table of Contents

- General Description...
- Developer Information...
- Software System Requirements...
- Hardware System Requirements...
- File Formats...
- Documentation...
- Software Support...
- Distribution...
- Costs and Licensing...
- Current Status...
- Design...
- Examples...

http://polypaint.colorado.edu:4444/cloud.gif

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NCSA Mosaic: Document View

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Document Title: PolyPaint+ Description

Document URL: http://polypaint.colorado.edu:4444/ppaint_body.ht#

PolyPaint+ Software Details

This page contains information about PolyPaint+ software as well as pointers to other helpful information.

1 General Description:

What is PolyPaint+ Software all about?

PolyPaint+ is an interactive scientific visualization tool that displays complex structures within three-dimensional data fields. It provides both color shaded-surface display and simple volumetric rendering in either index or true color. For shaded surface rendering, the PolyPaint+ routines first compute the polygon set that describes a desired surface within the 3D data volume. These polygons are then rendered as continuously shaded surfaces. PolyPaint+ contains a wide variety of options that control lighting, viewing, and shading. Objects rendered volumetrically may be viewed along with shaded surfaces. Additional data sets can be overlaid on shaded surfaces by color coding the data according to a specified color ramp. 3D visualizations can be viewed in stereo for added depth perspective.

Currently supported 3D visualizations are the following:

- ☐ Shaded isosurface
- ☐ Transparent contour shells or isosurfaces at varying levels
- ☐ Volumetric or density plot
- ☐ Planes
- ☐ Contour ribbons
- ☐ Topographic surface from 2D geographic data sets

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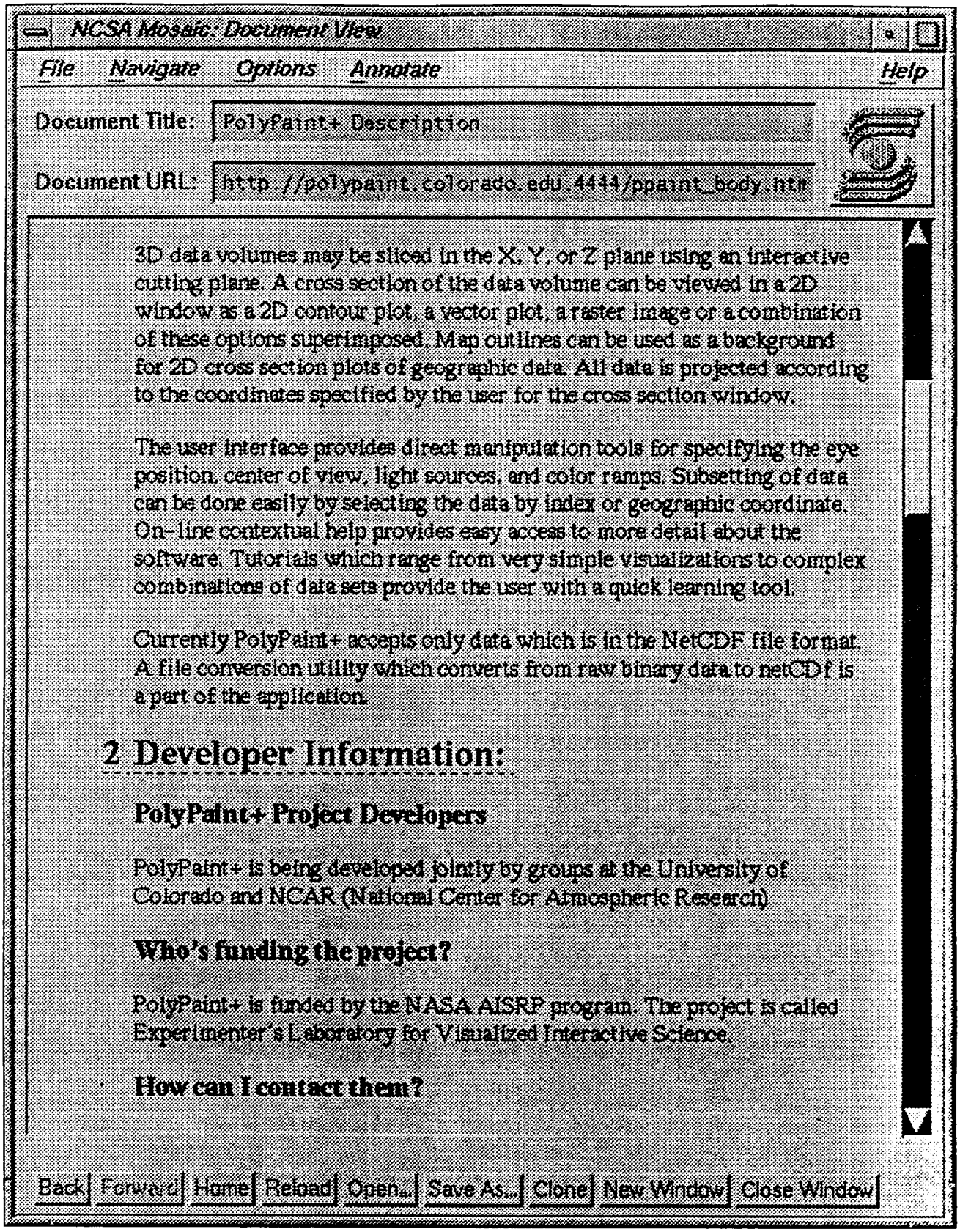

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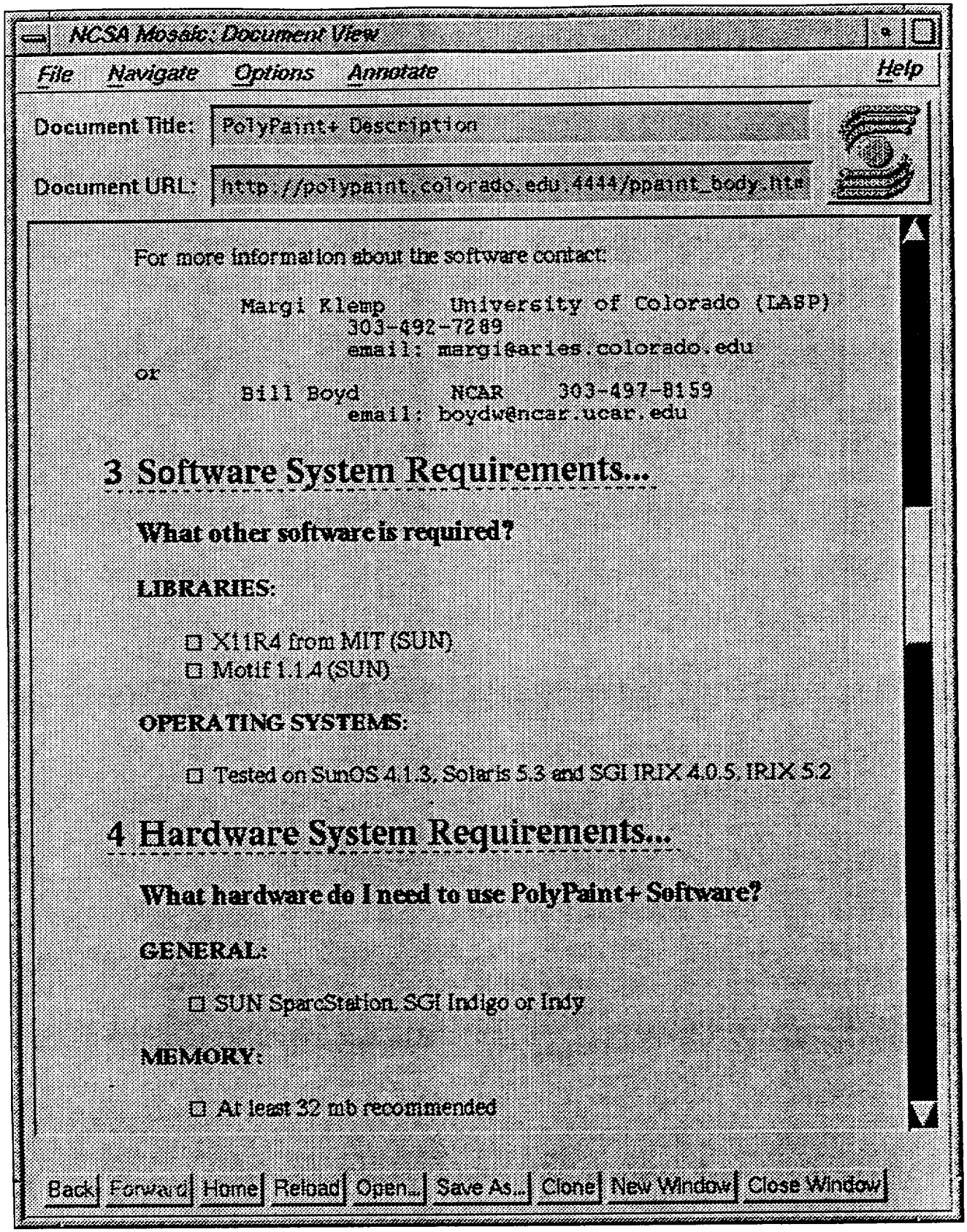

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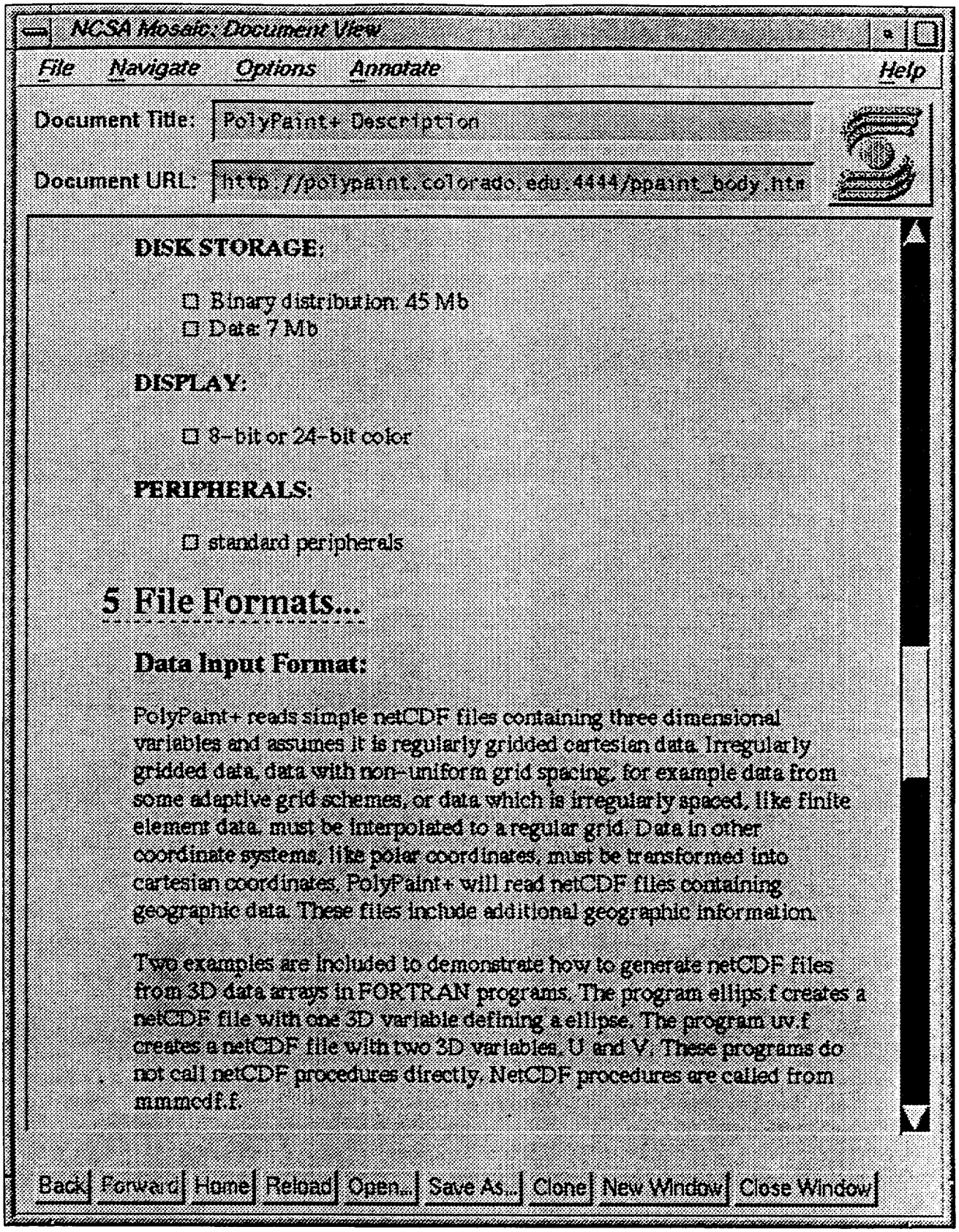

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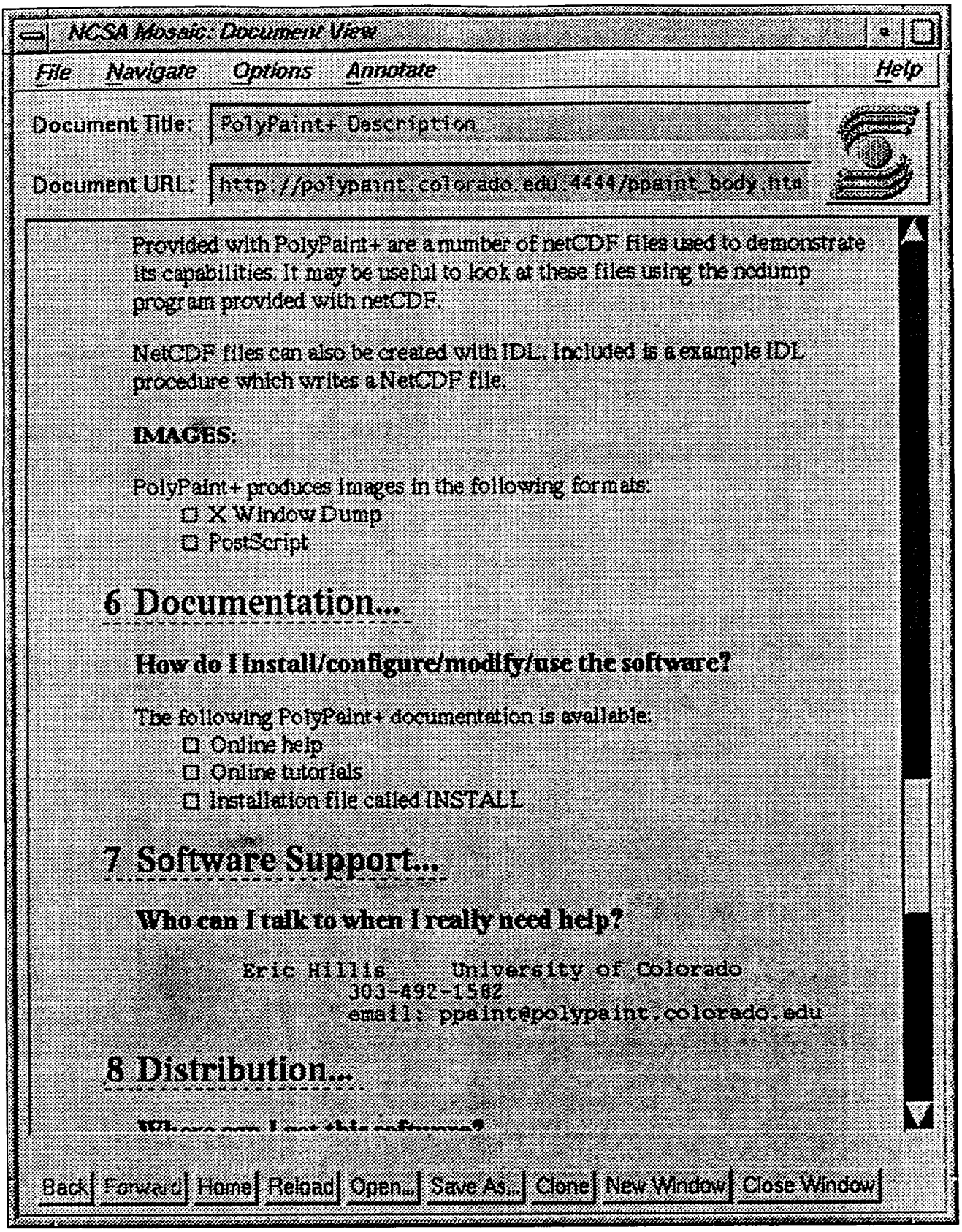

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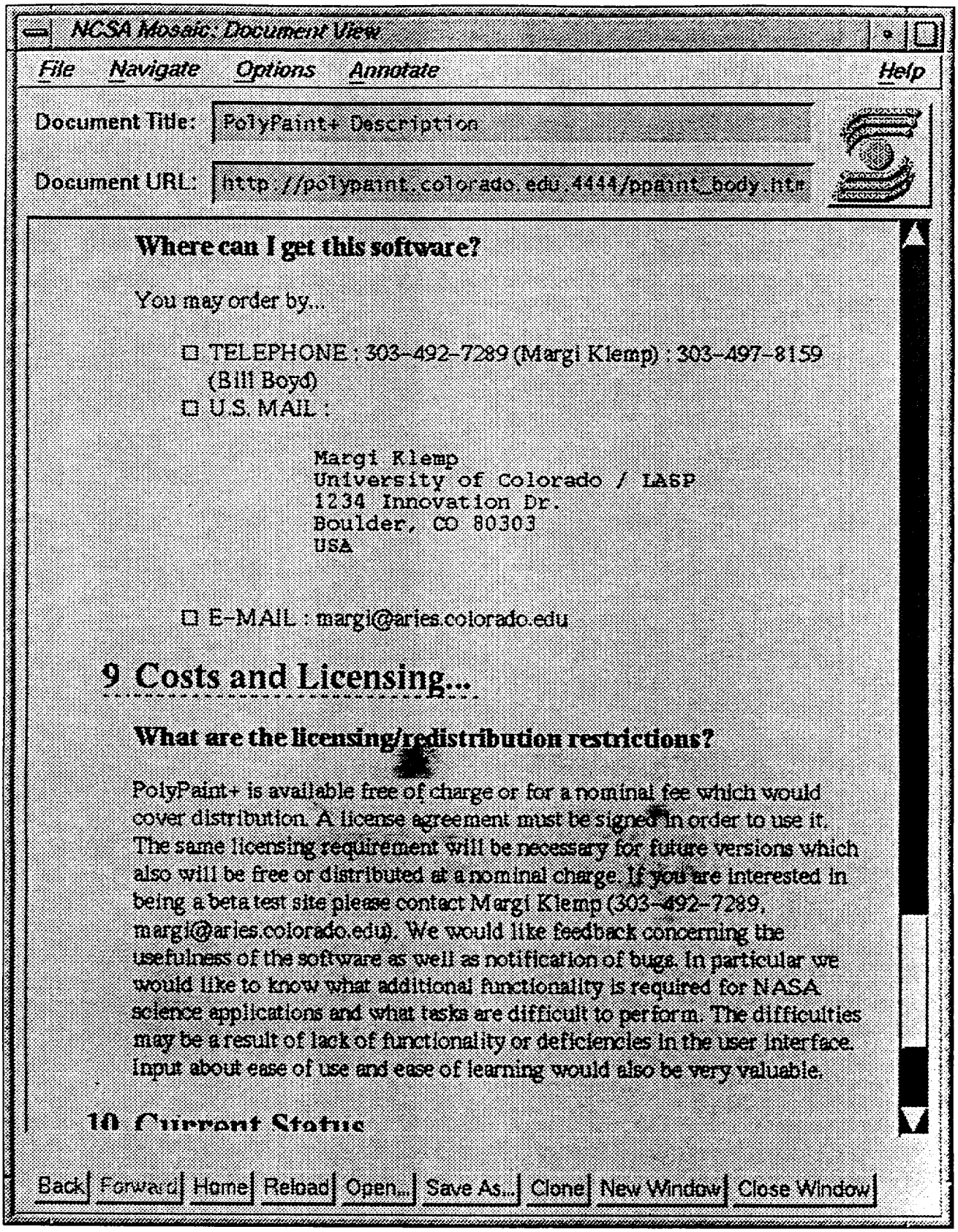

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NCSA Mosaic: Document View

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Document Title: PolyPaint+ Description

Document URL: http://polypaint.colorado.edu:4444/ppaint_body.ht#

E-MAIL : margi@aries.colorado.edu

9 Costs and Licensing...

What are the licensing/redistribution restrictions?

PolyPaint+ is available free of charge or for a nominal fee which would cover distribution. A license agreement must be signed in order to use it. The same licensing requirement will be necessary for future versions which also will be free or distributed at a nominal charge. If you are interested in being a beta test site please contact Margi Klemp (303-492-7289, margi@aries.colorado.edu). We would like feedback concerning the usefulness of the software as well as notification of bugs. In particular we would like to know what additional functionality is required for NASA science applications and what tasks are difficult to perform. The difficulties may be a result of lack of functionality or deficiencies in the user interface. Input about ease of use and ease of learning would also be very valuable.

10 Current Status...

What's the current state of affairs?

A beta version of PolyPaint+ is currently available.

11 Design, Research, Publications

PolyPaint+ is an object-oriented application written in C++. It uses the NCAR PolyPaint subroutine package and the Stanford Interviews software for it's graphics functions. The NASA/GSFC user interface builder, TAE+, was used for prototyping and creating the interface panels.

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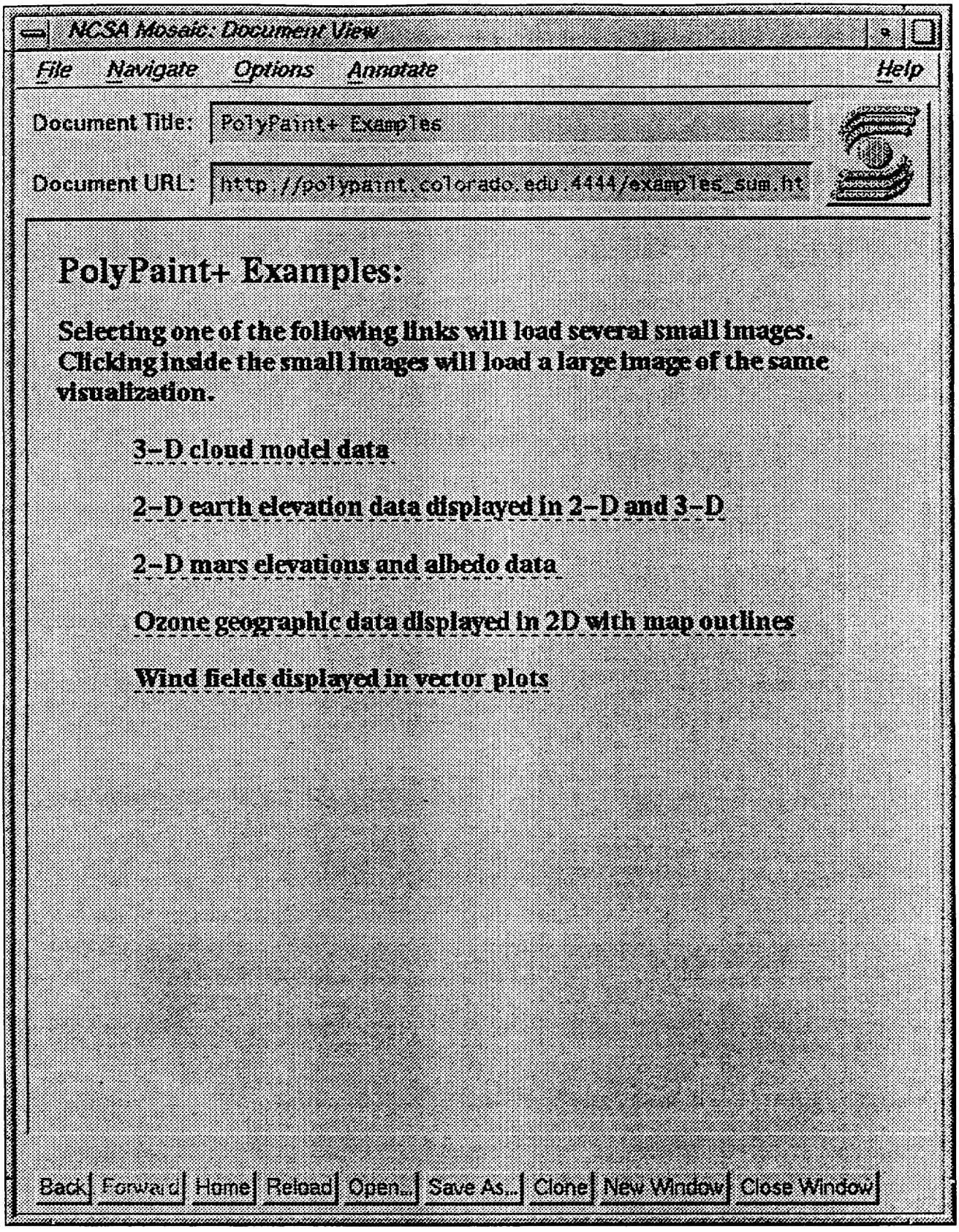

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NCSA Mosaic: Document View

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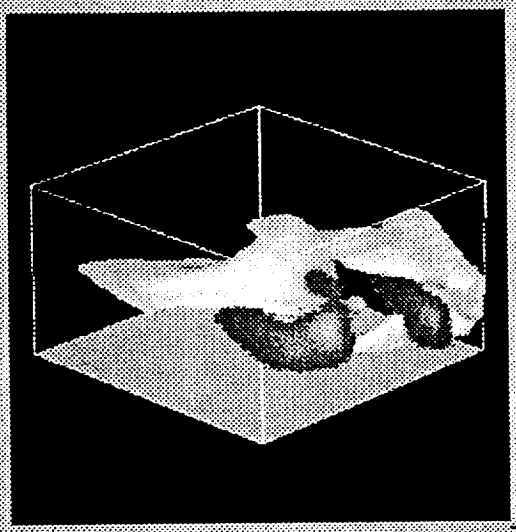
Document Title: Cloud Examples

Document URL: http://polypaint.colorado.edu:4444/cloud_exam.html

3-D visualizations of modeled cloud data from NCAR



A 3-D isosurface of a cloud with a rain field rendered transparently using a magenta to white color ramp. A baseplane and bounding box provide orientation information.

A 3-D volumetric or density plot of the cloud data used in the previous isosurface visualization. The most dense areas have the most reflected light and appear the brightest.

NCSA Mosaic: Document View

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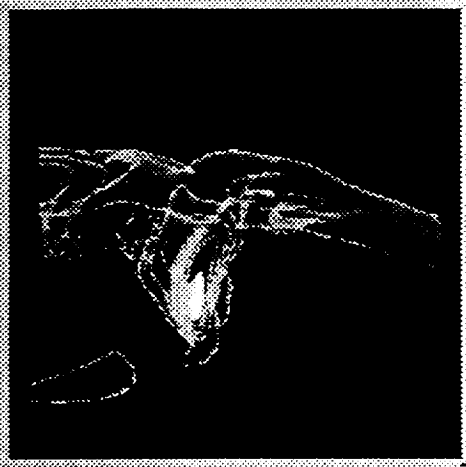
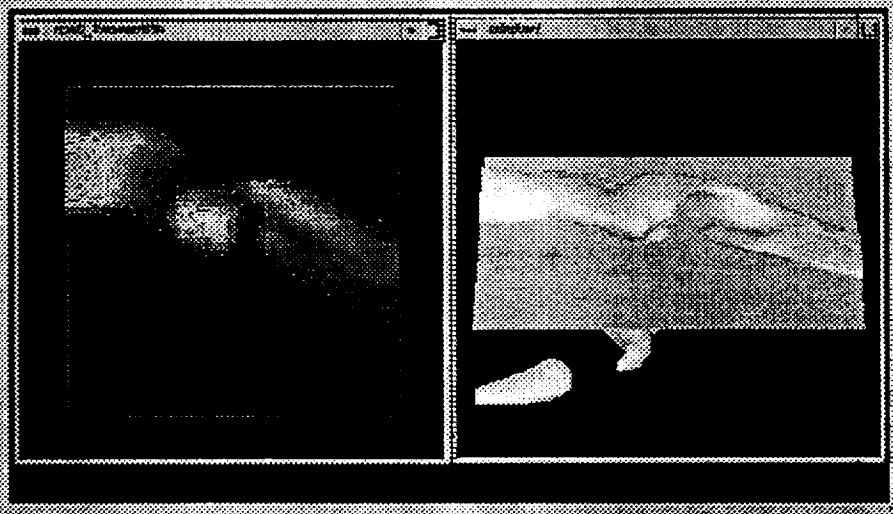
Document Title: Cloud Examples

Document URL: http://polypaint.colorado.edu:4444/cloud_exam.html



A set of isosurfaces at a specified range of contour values are displayed transparently so that they are all visible. The inner most isosurface has been displayed as an opaque surface. The same cloud data set was used for this visualization.



On the right is a 3-D visualization of a cutting plane intersecting the cloud isosurface visualization. On the left is a 2-D visualization of the cross section where the cutting plane intersects the 3-D data. A pseudo-color raster image overlayed with a contour plot of the slice are visualized in the left window.

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NCSA Mosaic: Document View

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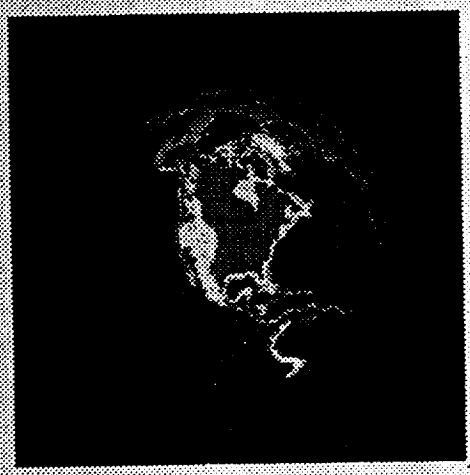
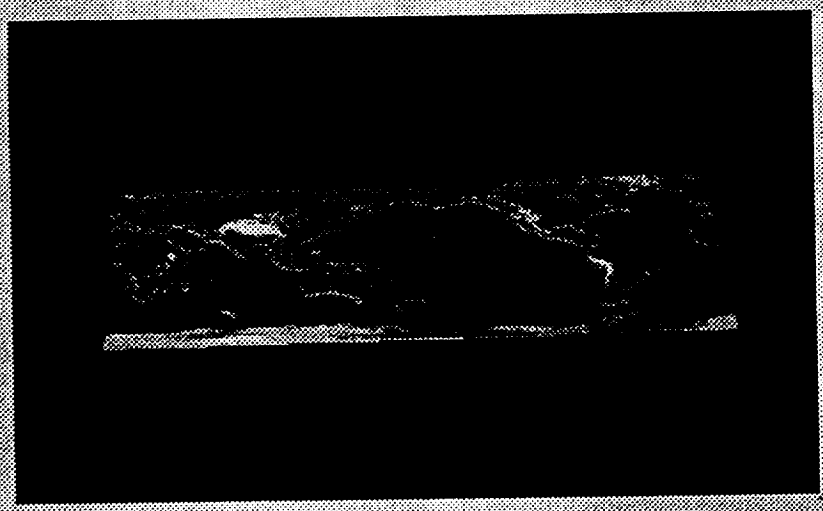
Document Title: Earth Examples

Document URL: http://polypaint.colorado.edu:4444/earth_exam.html

3-D visualizations of earth elevation data



An earth elevation data set is visualized here using a global mapping transformation. A color coded overlay of the data shows the elevation using a multi-color color ramp designed to give a realist representation of the earth.



The earth elevation data set is visualized using a cartesian mapping transformation. The eye position can be changed with a direct manipulation view editor.

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Document Title: Earth Examples

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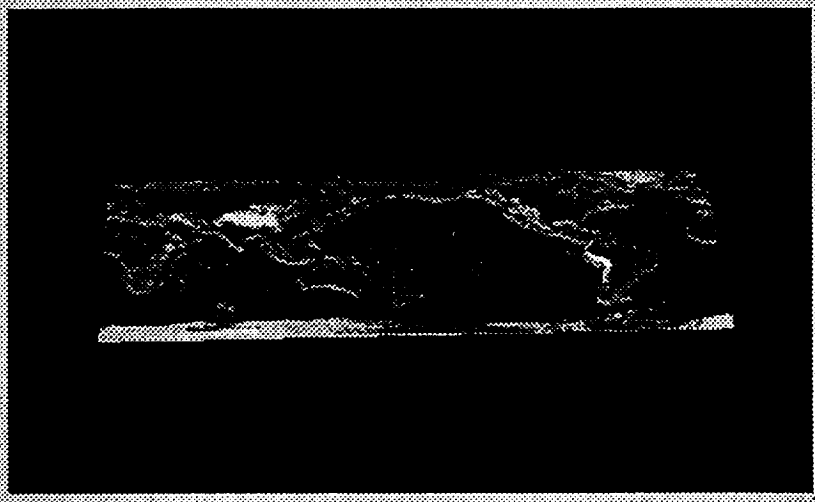
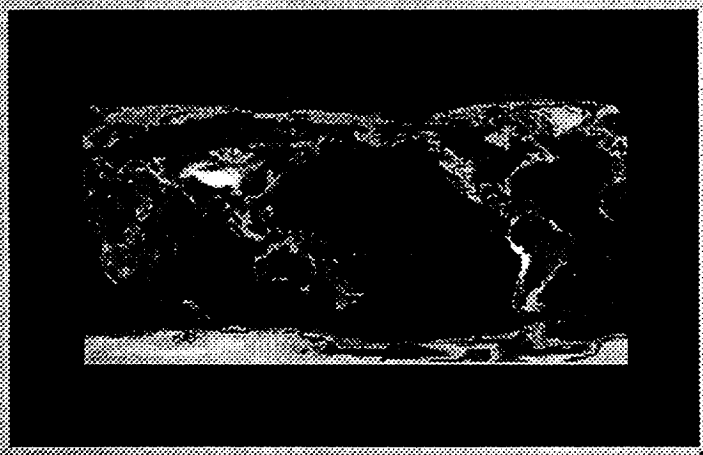
An earth elevation data set is visualized here using a global mapping transformation. A color coded overlay of the data shows the elevation using a multi-color color ramp designed to give a realist representation of the earth.



The earth elevation data set is visualized using a cartesian mapping transformation. The eye position can be changed with a direct manipulation view editor.



A 2-D raster image of the earth data set is displayed using the same color ramp as above.

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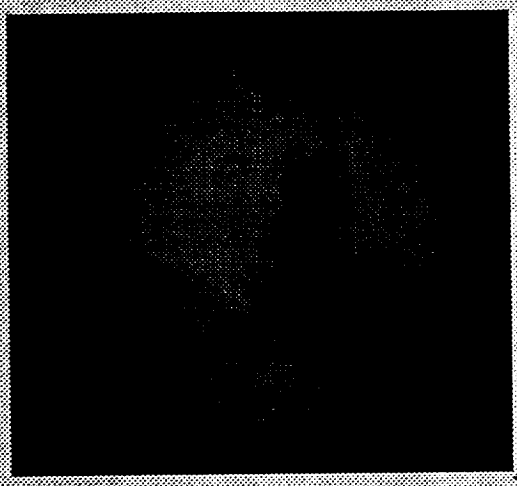
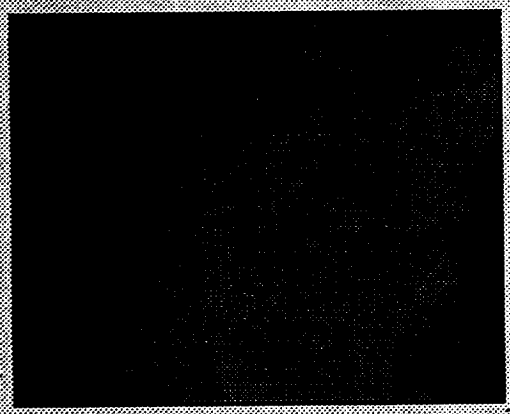
Document Title: Mars Examples

Document URL: http://polypaint.colorado.edu:4444/mars_exam.html

3-D visualizations of mars elevation data overlaid with red-filter albedo data from the Hubble Space Telescope



A mars elevation data set is projected with a global mapping transformation. Albedo data taken with a red filter is overlaid on the surface. The elevation data is exaggerated by a factor of 50 to make the features more prominent.



A close up view of a portion of the mars image obtained by modifying the view angle and eye position with the view editor.

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NCSA Mosaic: Document View

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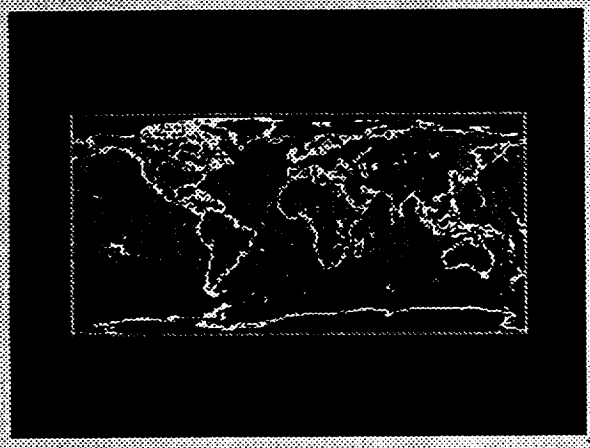
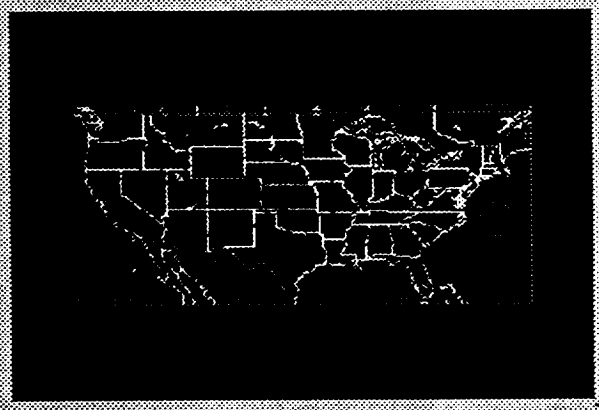
Document Title: Ozone Examples

Document URL: http://polypaint.colorado.edu:4444/ozone_exam.html

2-D visualizations of TOMS ozone data



A 2-D ozone geographic data set is displayed using color-filled contours, overlaid with contour lines and map features from the World Database II.



The ozone data set can be easily subsetted by using sliders to choose the longitude, latitude region of interest. This visualization shows a subset which includes the USA.

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Document Title: Ozone Examples

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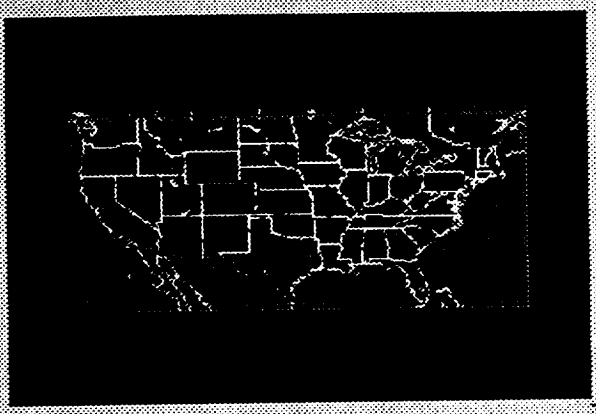
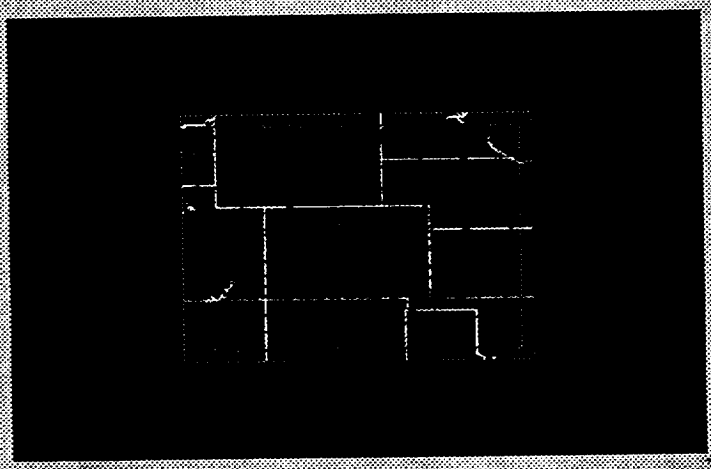


The ozone data set can be easily subsetted by using sliders to choose the longitude, latitude region of interest. This visualization shows a subset which includes the USA.



The map features in the colorado area are shown in this subsetted region of the ozone data. They retain their high resolution due to the resolution of of the map database.

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NCSA Mosaic: Document View

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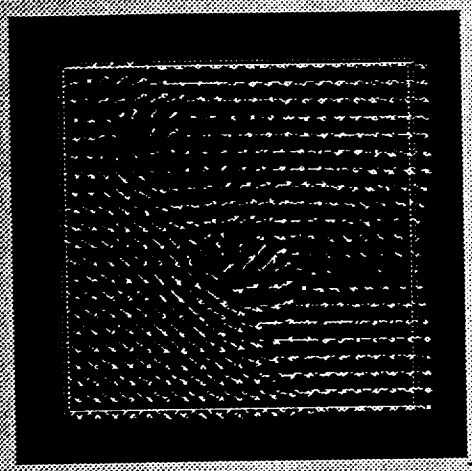
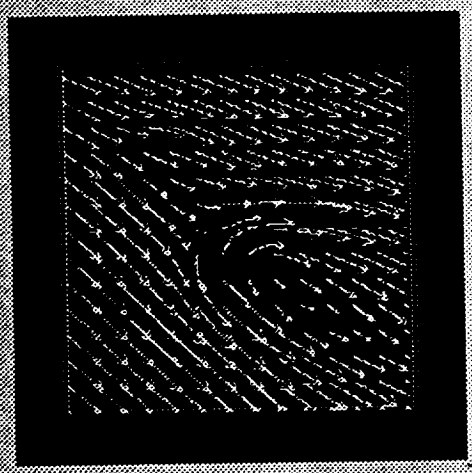
Document Title: Vector Examples

Document URL: http://polypaint.colorado.edu:4444/vectors_exam.ht

2-D vector visualizations of modeled meterological data from NCAR



A vector plot displays a modeled meterological data set using straight vectors at every other point in the x and y directions. The vector length is set to 3 times the normal magnitude. The density and length of vectors can be adjusted easily.



A curved vector plot displays the instantaneous magnitude and direction of the data. Vectors are displayed at every third data point.

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13. ABSTRACT *(Maximum 200 words)*
ELVIS (Experimenter's Laboratory for Visualized Interactive Science) is an interactive visualization environment that enables scientists, students, and educators to visualize and analyze large, complex, and diverse sets of scientific data. It accomplishes this by presenting the data sets as 2-D, 3-D, color, stereo, and graphic images with movable and multiple light sources combined with displays of solid-surface, contours, wire-frame, and transparency. By simultaneously rendering diverse data sets acquired from multiple sources, formats, and resolutions and by interacting with the data through an intuitive, direct-manipulation interface, ELVIS provides an interactive and responsive environment for exploratory data analysis.

14. SUBJECT TERMS
visualization, graphical user interface

15. NUMBER OF PAGES
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16. PRICE CODE

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