Introduction to OpenDX

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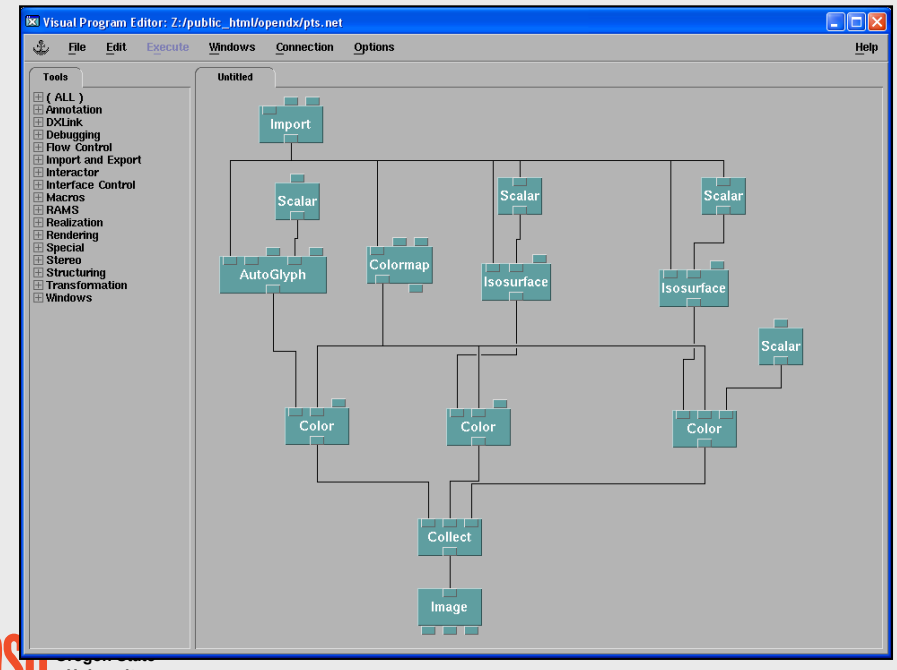
OpenDX

- Started out life as *IBM Visualization Data Explorer*
- When the product was cancelled, IBM put it into Open Source and renamed it *OpenDX*
- Basic premise is a series of interconnected modules, living together in an environment called the Visual Program Editor (VPE)
- There are lots of provided modules
- You can also write your own

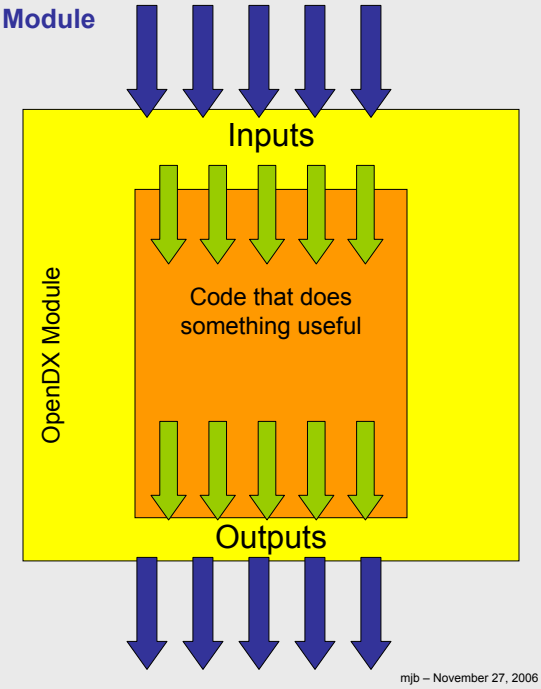
`http://www.opendx.org`

`http://www.vizsolutions.com`

`http://eecs.oregonstate.edu/~mjb/opendx`



The Structure of an OpenDX Module



Steps in Creating a Visualization

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Seven Steps to Creating a Visualization

1. Get the data
2. Formulate a scientific strategy. What do you want to show? How do you want to show it?
3. Import the data
4. Create a *simple* OpenDX network
5. Incrementally embellish the network. Save it often!
6. Choose what quantities you want to interact with. Change the Interactor styles to match the quantities being modified.
7. Create the output.

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Starting OpenDX in OSU's Computer Graphics Education Lab

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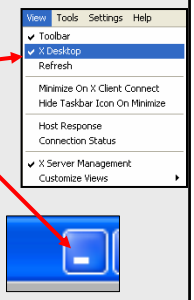
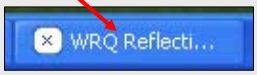
Starting OpenDX on the OSU CGEL Systems

1. Start → All Programs → WRQ Reflection → Reflection X
2. In the *View* menu, click off *X Desktop*
3. Minimize the Reflection X window (the _ in the upper right corner)
4. Start → All Programs → OpenDX → DX



Quitting OpenDX on the OSU CGEL Systems

1. Select *Quit* from the OpenDX Main Menu
2. Maximize the Reflection X window by clicking here in the Task Bar
3. In the *File* menu, select *Exit*



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The OpenDX Main Menu and Categories of Modules

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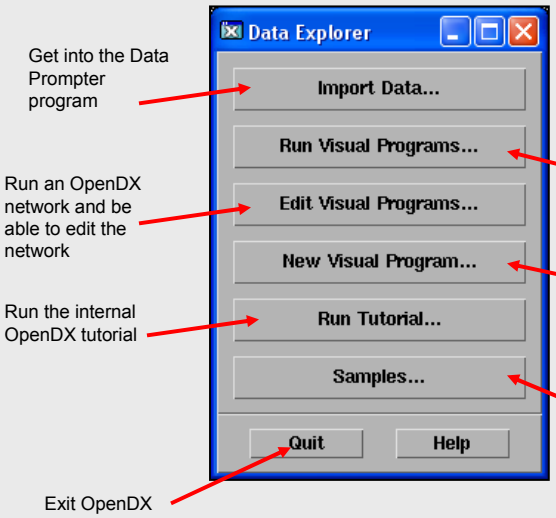
The OpenDX Main Menu



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Nine Categories of OpenDX Modules

Annotation	Interactor	Special
Debugging	Realization	Structuring
Import & Export	Rendering	Transformation

Annotation OpenDX Modules

- AutoAxes – creates an axis box for whatever data you are plotting
- AutoGlyph – designs and produces glyphs for the data based on the data values
- Caption – creates caption text for an image
- ColorBar -- creates a colorbar to be displayed
- Format – creates a string from a number (used to create file names)
- Glyph – produces an identical glyph for every point in the data
- Legend – produces a legend to be displayed
- Plot – creates a 2D plot
- Ribbon – creates a flow field ribbon
- Text – displays text in 3D space
- Tube – creates a flowfield tube

Debugging OpenDX Modules

- Describe – describes an object
- Print – prints information about a field to the Message Window

Import & Export OpenDX Modules

- Export – writes data from OpenDX into a file
- Import – reads data into OpenDX from a file
- ImportSpreadsheet – reads data into OpenDX from a tabular file
- Include – includes or excludes points in a field based on their data values
- ReadImage – reads an image into OpenDX from a file
- Reduce – filters and resamples a field into a lower resolution
- Refine – interpolates a field into a higher resolution
- Slab – takes a positional subset of the data
- Slice – takes a positional slice through the data
- WriteImage – writes an image from OpenDX into a file

Interactor OpenDX Modules

- FileSelector – presents a dialog box to let you select a file
- Integer – allows the user to input an integer number
- Scalar – allows the user to input a floating point number
- Selector – allows the user to select one of a number of options
- String – allows the user to input a string
- Toggle – allows the user to select one of two options
- Vector – allows the user to input a vector

Realization OpenDX Modules

- AutoGrid – maps a set of scattered points onto a grid
- Band – divides a field into bands
- Connect – creates triangle connections for scattered data points in a field
- IsoSurface – creates surfaces or lines of constant data value
- MapToPlane – projects a data field onto an arbitrary plane
- RubberSheet – deforms a surface field by the amount of the data value at each point
- ShowBox – creates a bounding box for display
- ShowConnections – displays the outline of connectivity elements in a field
- ShowPositions – displays the positions in a field
- Streakline – computes an advection path through a changing flow field
- Streamline – computes a path through a non-changing flow field

Rendering OpenDX Modules

- AmbientLight – specifies the ambient light
- Arrange – creates a single side-by-side image from a collection of images
- AutoCamera – selects a good camera view of the data
- Camera – specifies a camera view
- Display – a more elaborate image-rendering system than Image
- Image – renders and displays field data
- Light – specifies a distant (parallel) light source
- Normals – compute point or face normals for shading a surface
- Render – renders a field and creates an image
- Rotate – rotates field data
- Scale – scales field data
- Shade – specifies object-shading parameters
- Transform – performs a general matrix transform of an object
- Translate – translates field data

Special OpenDX Modules

Colormap – presents an interactive tool for specifiying color vs. data value

Receiver – receives the output of a Transmitter

Sequencer – creates an animation “VCR” display

Transmitter – “wirelessly” connects a network to a receiver

Structuring OpenDX Modules

- Collect – collects objects into a group
- Inquire – returns information about a field
- Mark – marks a new field component as “data” (e.g., for Compute)
- Remove – removes a specified component from a field
- Rename – renames a specified component in a field
- Unmark – undoes the effects of Mark

Transformation OpenDX Modules

- AutoColor – automatically color a data field (blue→green →red)
- Color – assign a color by name of by RGB values
- Compute – perform point-by-point arithmetic on a field’s “data” component
- DivCurl – computes the divergence and curl of a flow field
- Equalize – apply histogram equalization to a field
- Gradient – computes the gradient of a scalar field
- Histogram – creates a histogram that can be rendered with Plot
- Map – projects one field’s data onto another field’s geometry
- Measure – calculates surface area and volume of a geometry (e.g., isosurface)
- SimplifySurface – reduces the size of the triangular mesh
- Statistics – computes the mean, standard deviation, variance, minimum, and maximum of a field’s data

Adding and Connecting Modules

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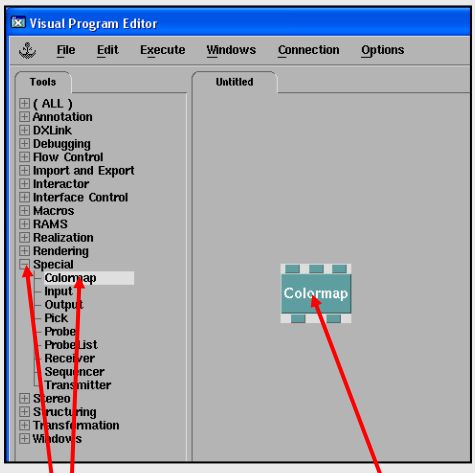
Adding a Module into the Visual Editing Area



It's not drag-and-drop, it's click-and-click

1. Left-click on the module category to list its modules.
2. Left-click on the module you want to add
3. Move the cursor into the Editing Area and left-click

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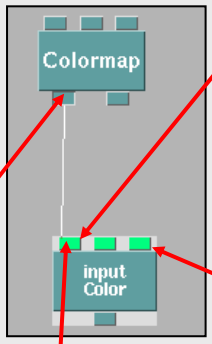
Connecting Modules in the Visual Editing Area



If an input tab is in the "up" position, you are allowed to try to connect to it.

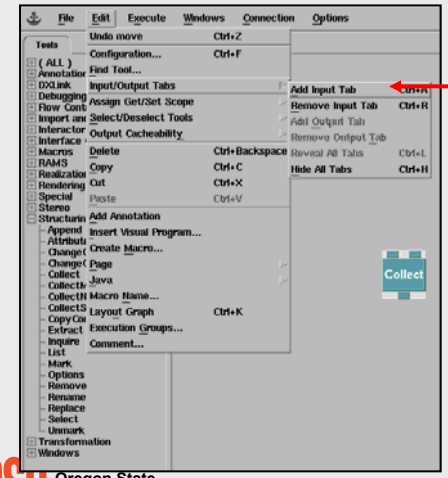
If an input tab is "down", then it has already been set to a constant within the module itself, and cannot take an external connection until that constant has been un-set.

Just because an input tab is up, however, doesn't mean that this input is data-compatible with the output you are trying to connect to it. Data-compatability is indicated by the input tab(s) turning bright green.

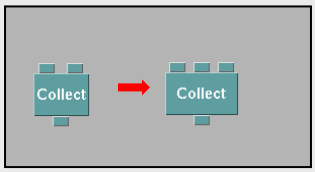
This, however, still doesn't imply that the connection makes logical sense. ☺

1. Left-click on the output tab of the module you are connecting from
2. Keeping the left button down, drag to the input tab of the module you are connecting to
3. When you get close, the tabs to which a connection make sense will highlight in green
4. Move the cursor on top of the tab you want to connect to, and release the left mouse button
5. To disconnect, reverse the process. Click on the input tab and drag back to the output tab.

Some Modules Can Have Variable Numbers of Tabs



Edit→Input/Output Tabs→Add Input Tab



Collect and *Compute* are two common modules that work this way

Terrain Visualization

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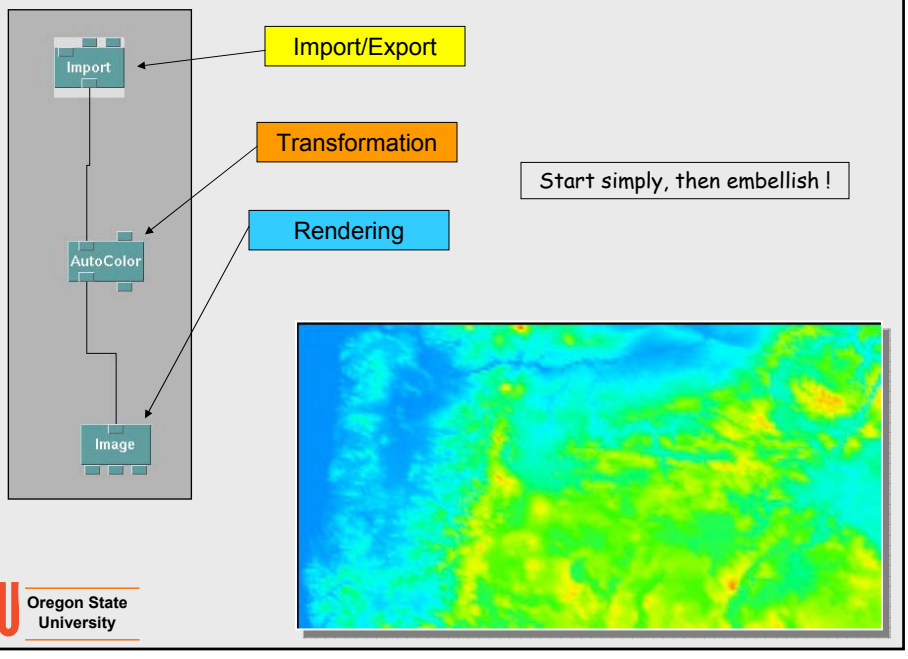
Terrain Visualization



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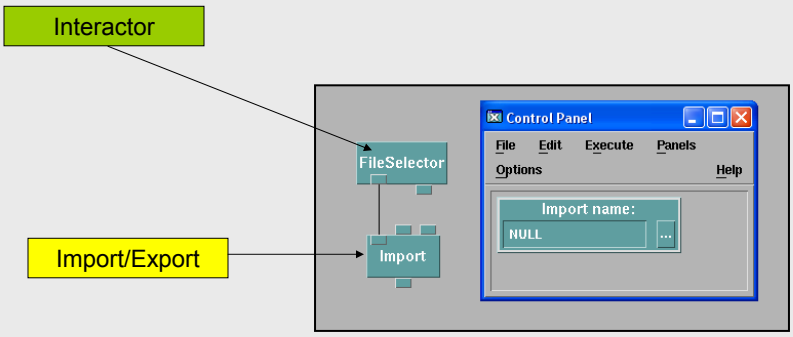
The Import and FileSelector Modules



You can type a filename into the Import module, but hooking in a FileSelector module makes it way easier and friendlier

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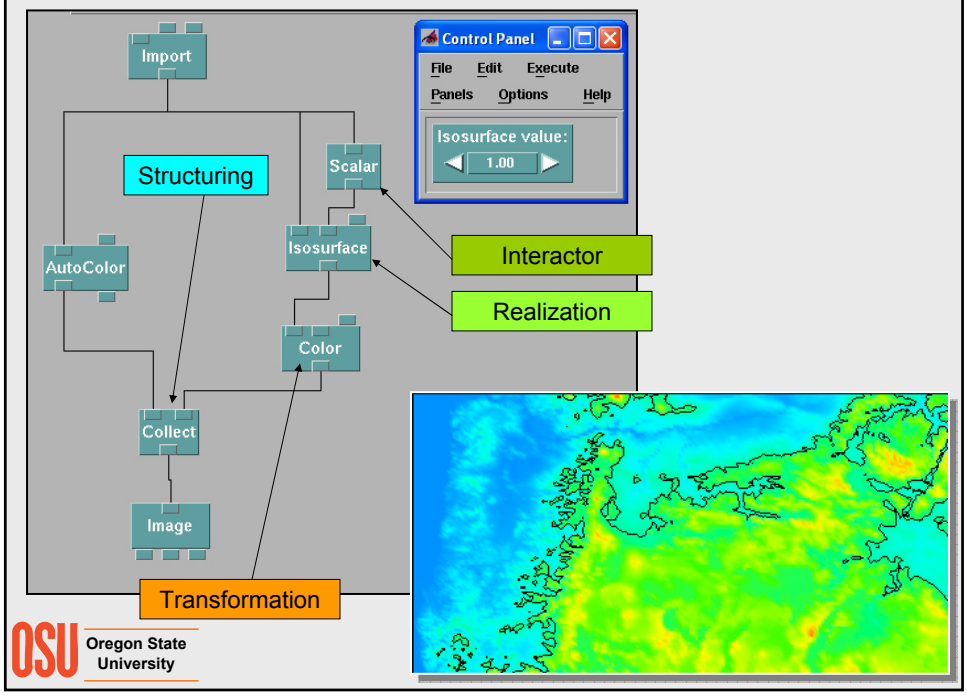

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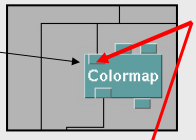
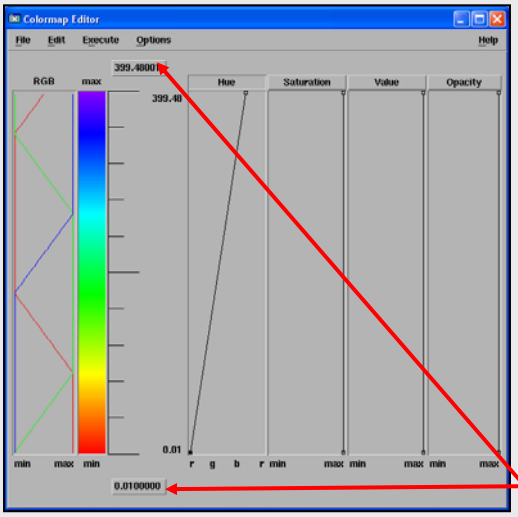
The Colormap Editor Module

Special





- The first input "tab" is the field input.
- Click on the Hue, Saturation, Value, or Opacity labels to edit that curve.
- Double-click on a line to add a control point there.
- Click on a control point to select it.
- Sweep a box over several control points to select them all.
- Hold down the left mouse button on a control point to move it. If several are currently selected, all will move together,
- Edit → Delete to remove selected control point(s).

The data value range over which the colors apply is determined by scanning the data itself.

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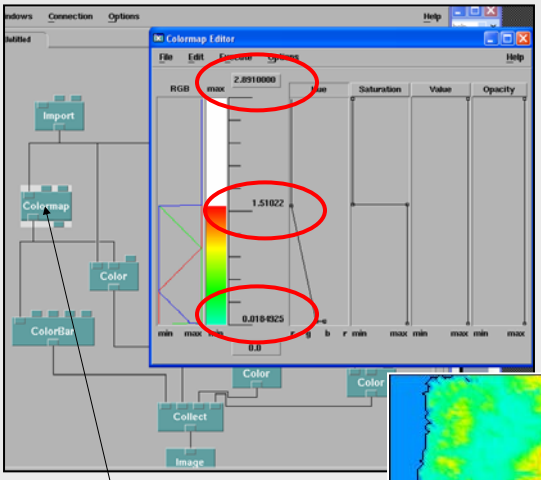
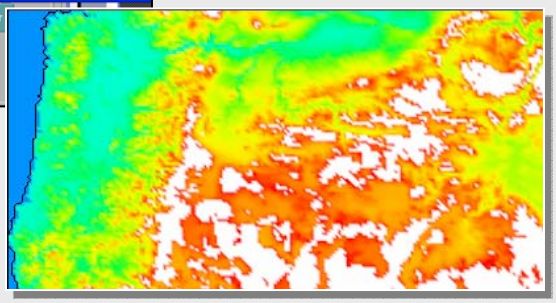
The Colormap Editor in Action





Special

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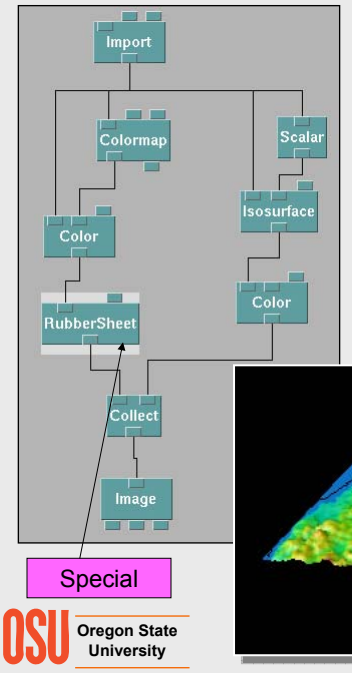
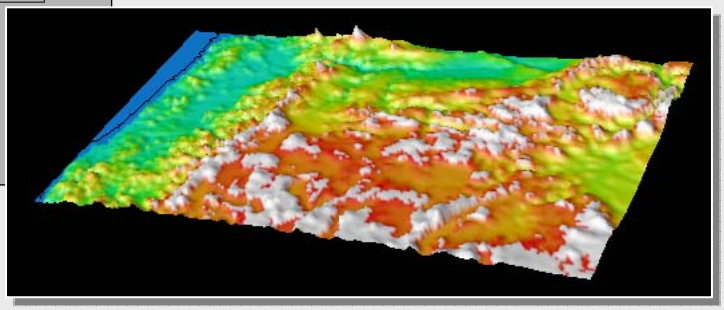
Rubbersheeting the Terrain Surface





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The Image Window

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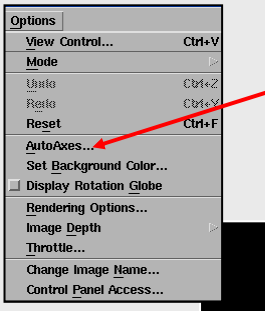
Image Window Options



The *AutoAxes* option has many ways to embellish the visualization with axes, labels, grids, etc.

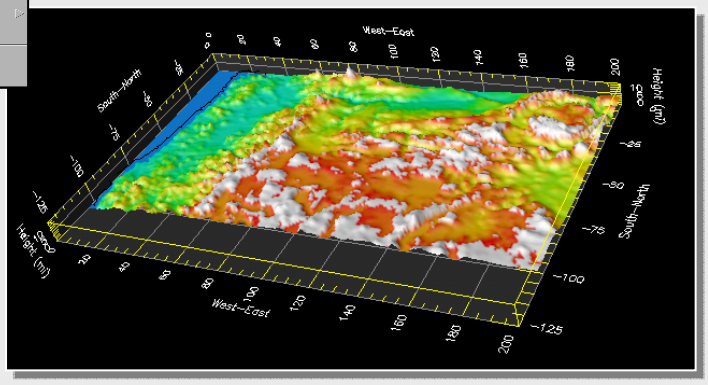


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Image Window Options

The *Mode* option lets you set what scene transformation the mouse will perform.

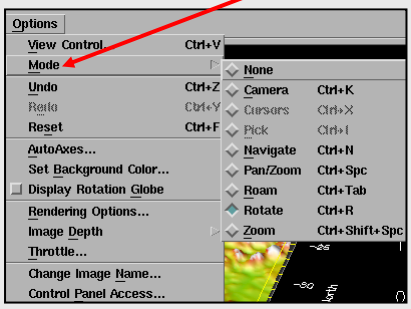

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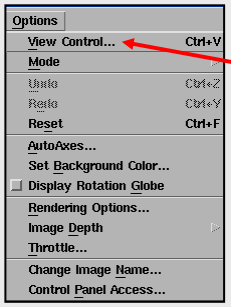
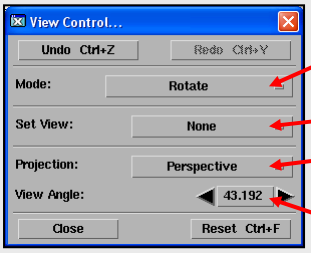
Image Window Options



The *View Control* option lets you set various aspects of how the scene will appear.



Same as the *Mode* option

Set a pre-defined view

Specify Perspective or Orthographic 3D projection

If using Perspective, this specifies the field-of-view angle. The larger this number, the more severe the perspective will be.

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Debugging

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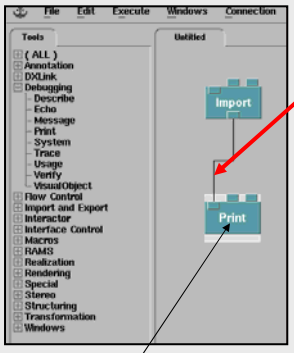
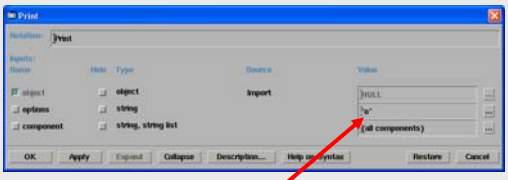
The Print Module



First argument is the field to print



Second argument is a string with one or more characters:

- **r** recursively traverse the object
- **o** print only the top level of the object
- **d** print first and last 25 items in arrays, as well as headers
- **D** print all the items in arrays as well as headers
- **n** print object to **n** levels.

Debugging

"rD" works well

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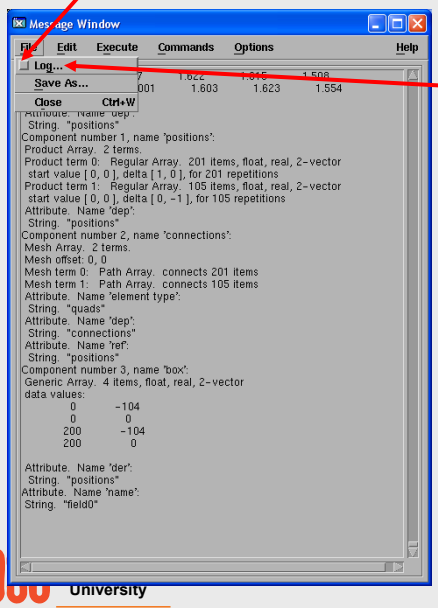
Printing to a File ("logging")

Checkbox to turn logging on/off

Specify the file to write to



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Scalar Visualization

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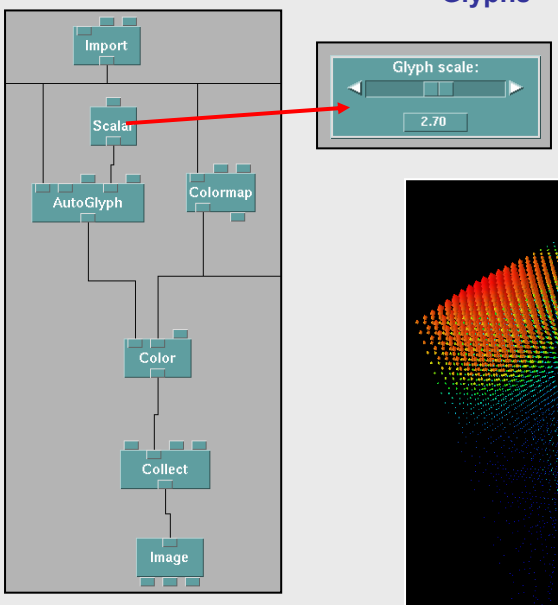
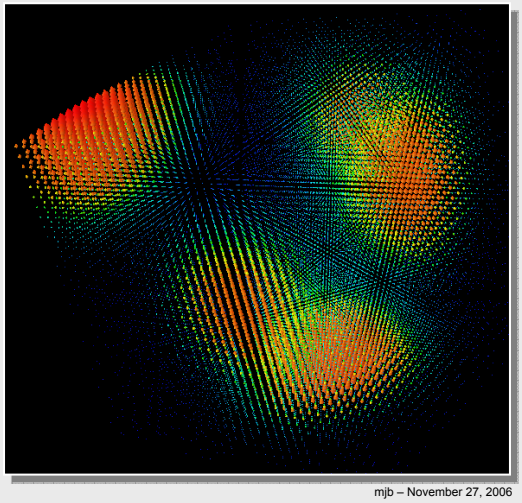
Glyphs





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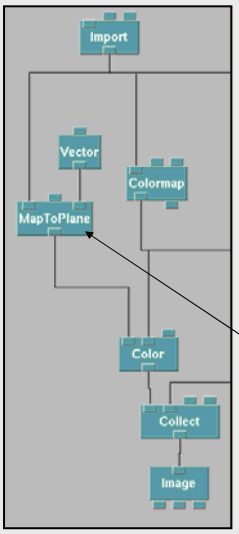
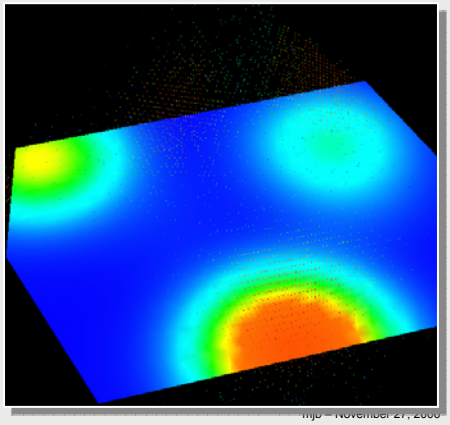
3D Cutting Plane – Interpolated Colors



MapToPlane interpolates the 3D field onto the given plane. The first argument is the field, the second is a 3D point on the plane, and the third argument is a 3D normal to the plane.

Realization



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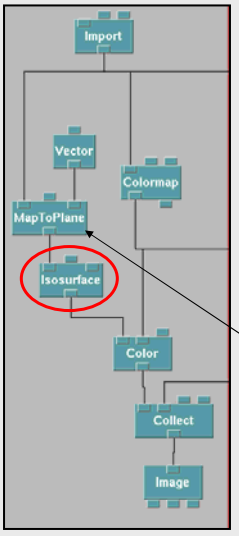
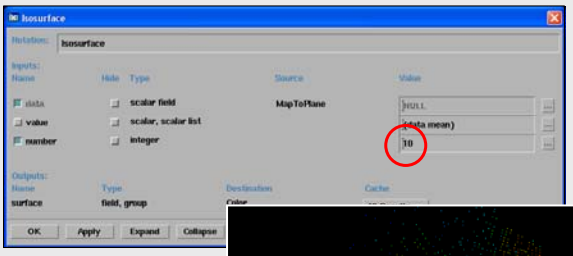
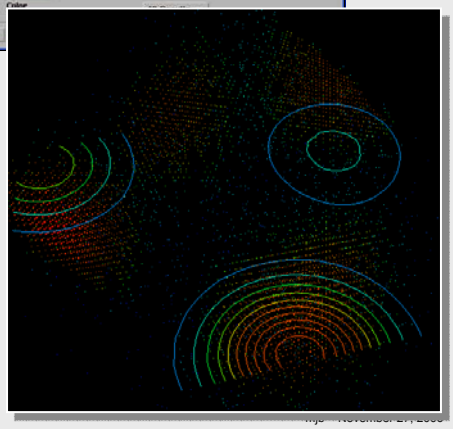
3D Cutting Plane – Contours





Realization



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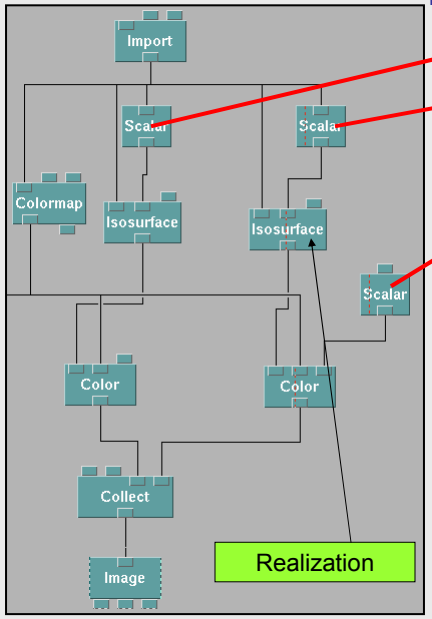
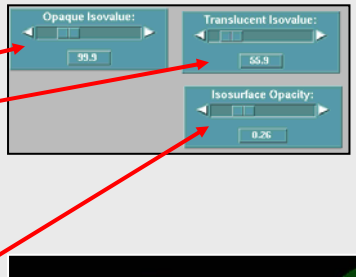
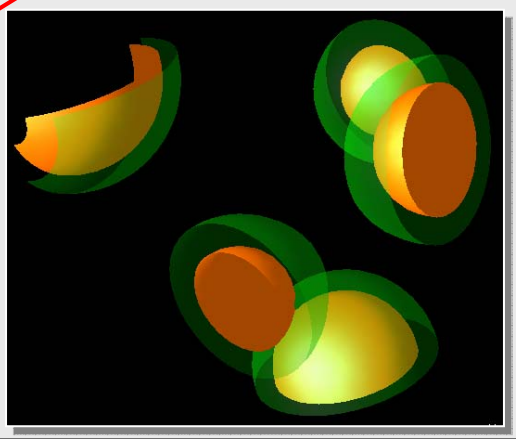
Isosurfaces







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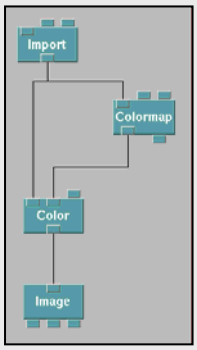
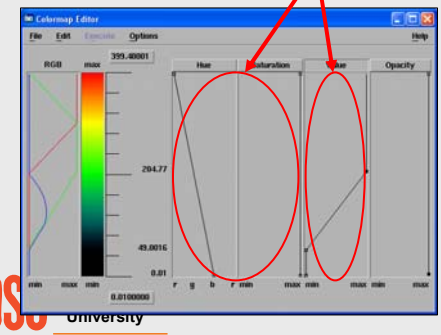
Direct Volume Rendering

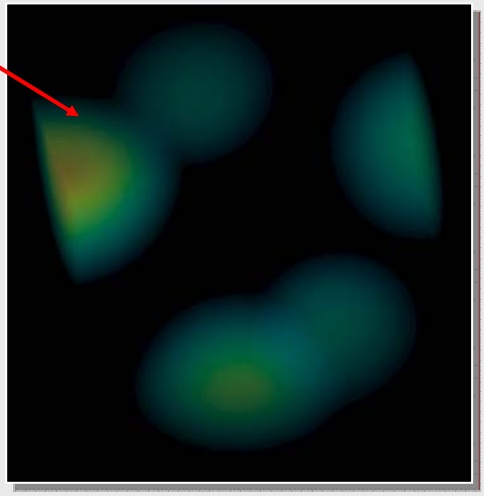


A Volume Rendering "Transfer Function" relates data scalar value to its corresponding color and opacity. For volume rendering, OpenDX uses the color *Value* as the opacity, not the color Opacity.

The direct volume rendering part of the Image module will only work in Orthographic projection.

These are the "Transfer Function"





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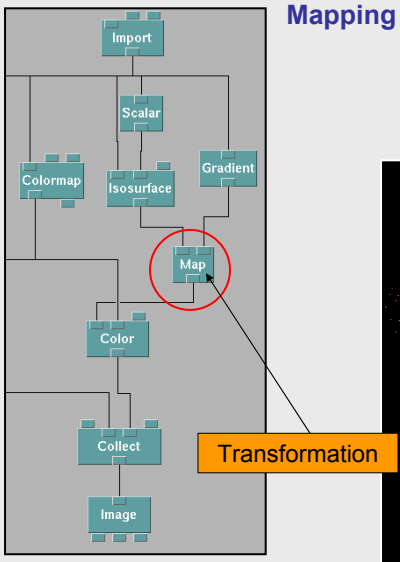
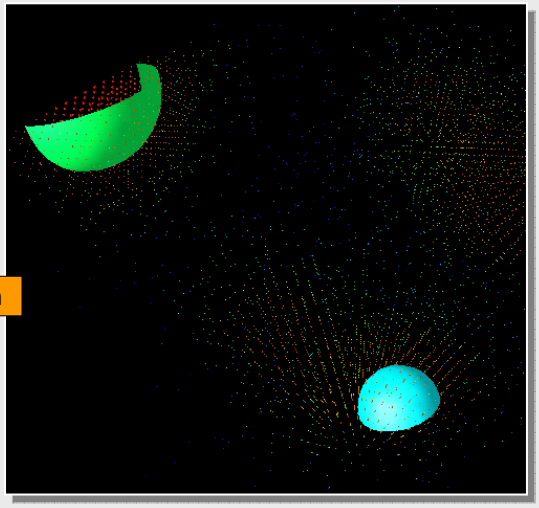
Mapping Another Data Field onto Isosurfaces

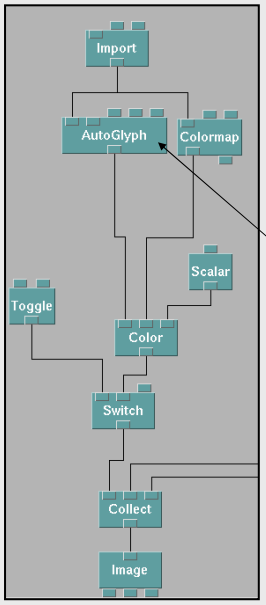


Transformation

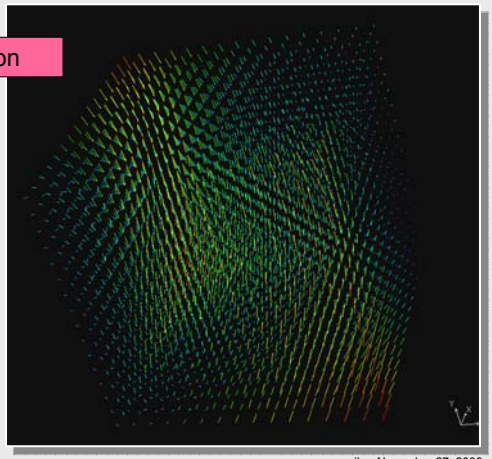


Vector Visualization

Vector Cloud



Annotation



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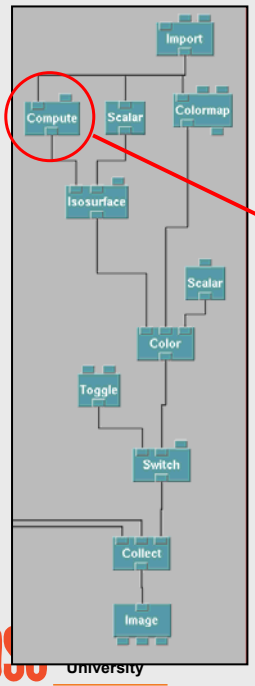
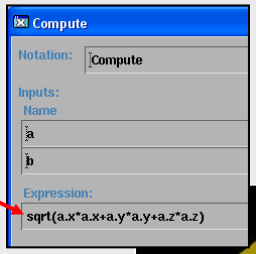
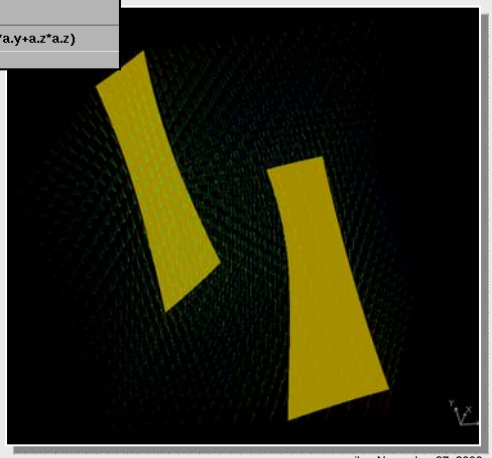
Speed Isosurfaces







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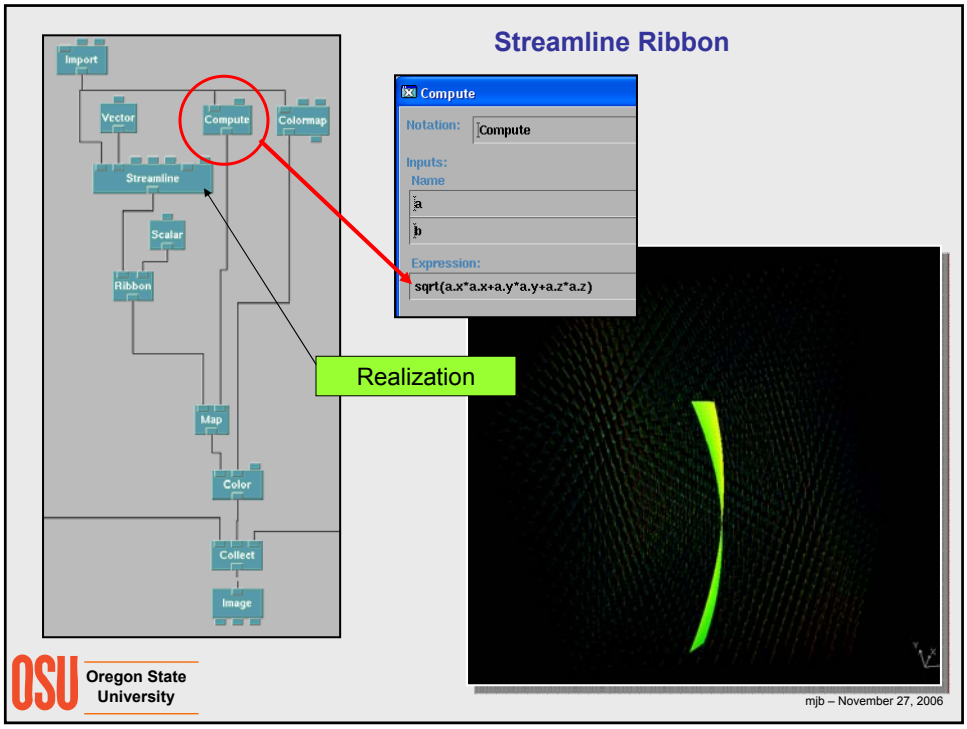
Streamline Ribbon
Import
Vector
Compute
Colormap
Streamline
Scalar
Ribbon
Map
Color
Collect
Image
Compute
Notation:
Compute
Inputs:
Name
a
b
Expression:
sqrt(a.x*a.x+a.y*a.y+a.z*a.z)
Realization
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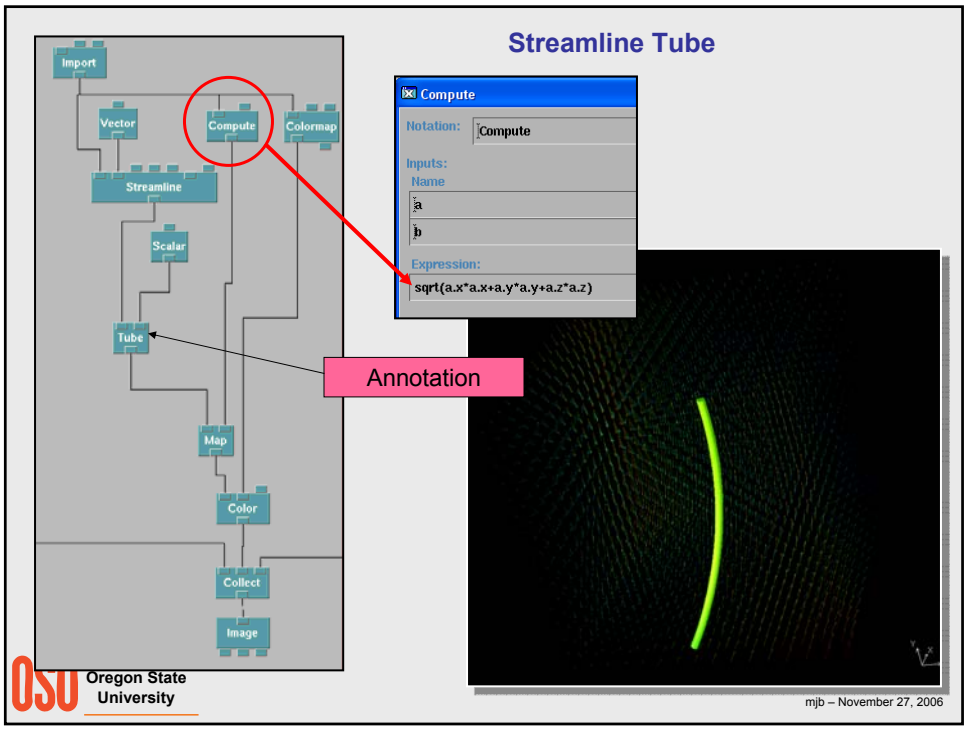
Streamline Tube
Import
Vector
Compute
Colormap
Streamline
Scalar
Tube
Map
Color
Collect
Image
Compute
Notation:
Compute
Inputs:
Name
a
b
Expression:
sqrt(a.x*a.x+a.y*a.y+a.z*a.z)
Annotation
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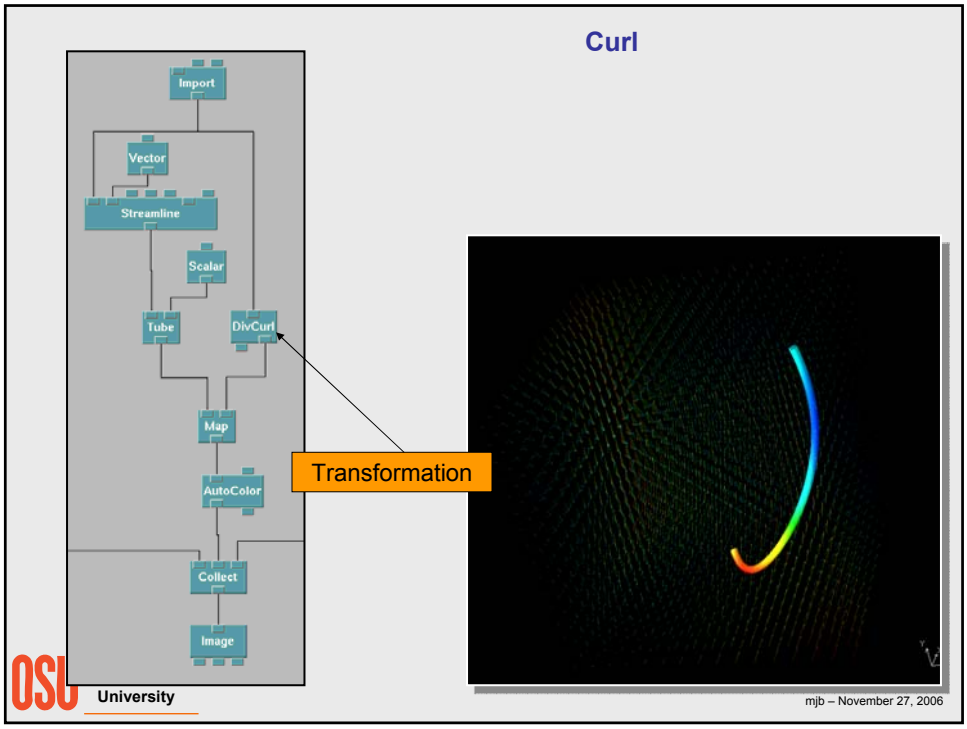
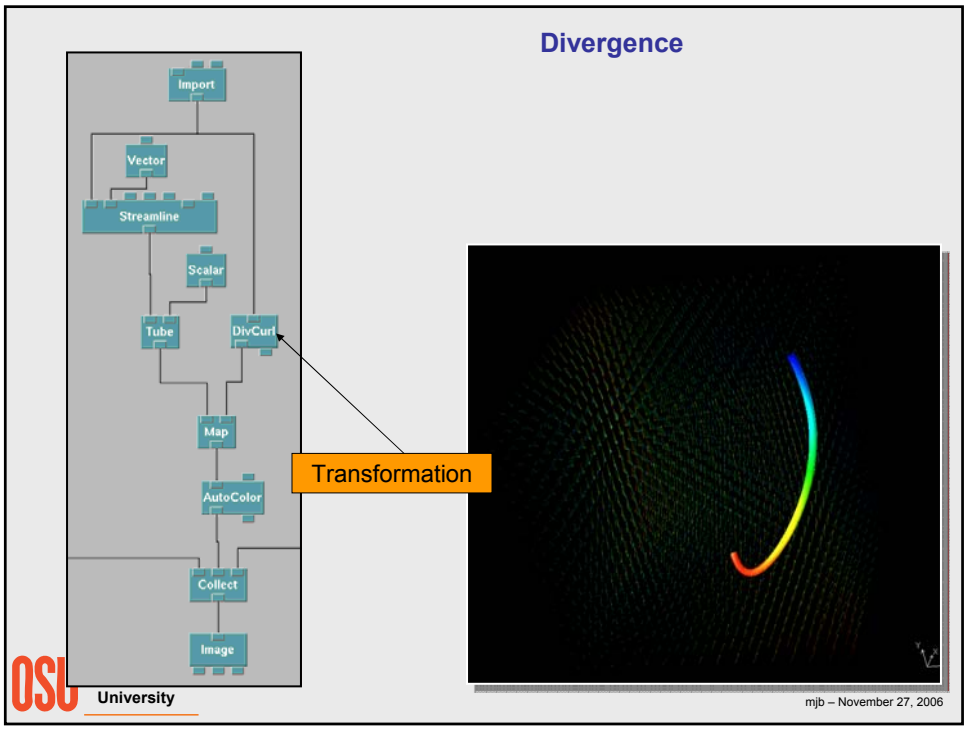

Curl
Import
Vector
Streamline
Scalar
Tube
DivCurl
Map
AutoColor
Collect
Image
Transformation
OSU
University
mjb – November 27, 2006


Divergence
Import
Vector
Streamline
Scalar
Tube
DivCurl
Map
AutoColor
Collect
Image
Transformation
OSU
University
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Animation

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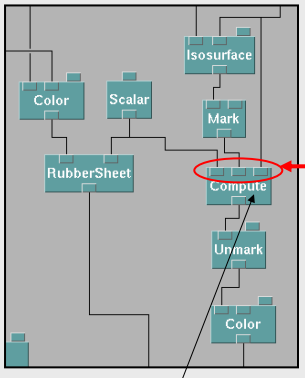
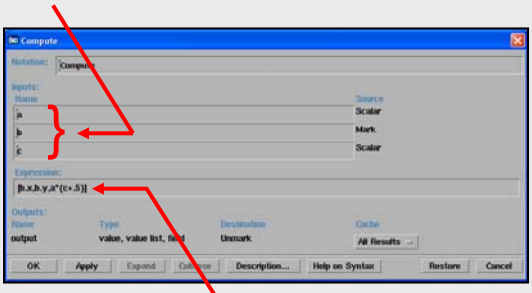
The Compute Module



Does arithmetic on the point-by-point Data component of a field, and outputs the modified field

The 3 (in this case) inputs



Transformation

The output expression, in this case, a 3-vector with a newly-created Z value

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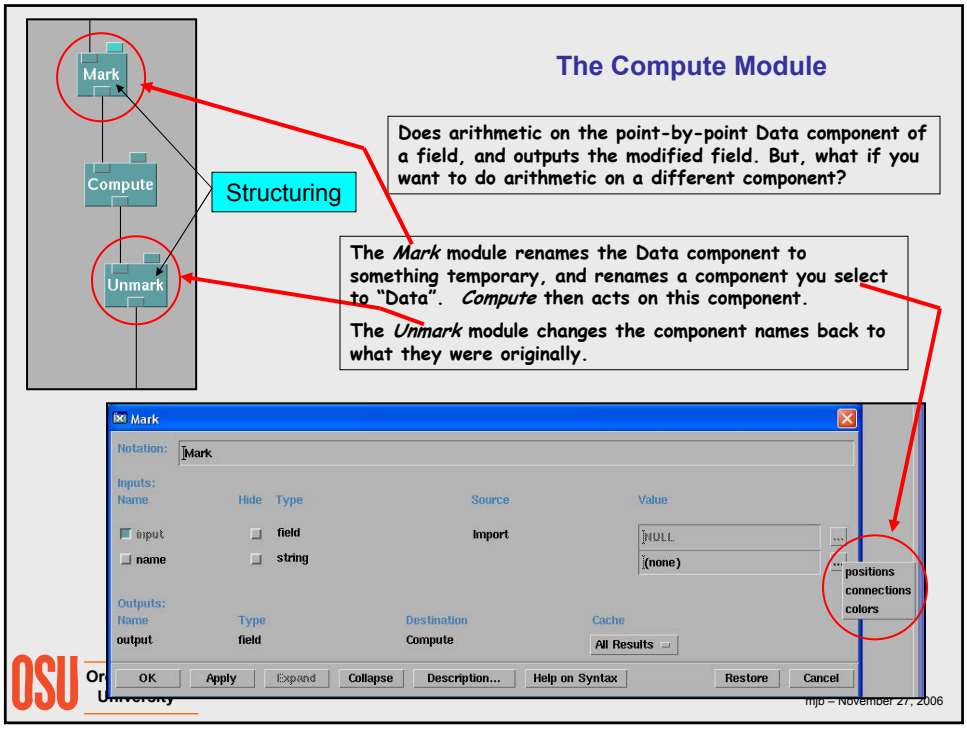
The Compute Module
Mark
Compute
Unmark
Structuring
Does arithmetic on the point-by-point Data component of a field, and outputs the modified field. But, what if you want to do arithmetic on a different component?
The Mark module renames the Data component to something temporary, and renames a component you select to "Data". Compute then acts on this component.
The Unmark module changes the component names back to what they were originally.
Mark
Notation:
Mark
Inputs:
Name
Hide
Type
Source
Value
input
field
Import
NULL
name
string
(none)
positions
connections
colors
Outputs:
Name
Type
Destination
Cache
output
field
Compute
All Results
OK
Apply
Expand
Collapse
Description...
Help on Syntax
Restore
Cancel
OSU
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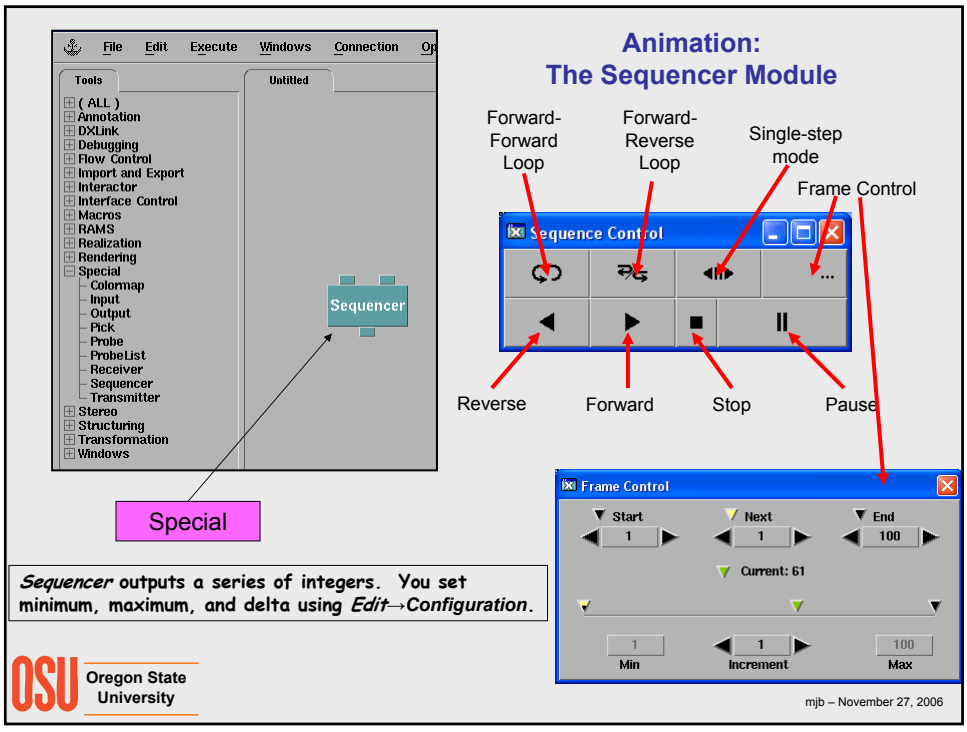
Animation:
The Sequencer Module
File
Edit
Execute
Windows
Connection
Tools
Untitled
(ALL)
Annotation
DXLink
Debugging
Flow Control
Import and Export
Interactor
Interface Control
Macros
RAMS
Realization
Rendering
Special
Colormap
Input
Output
Pick
Probe
ProbeList
Receiver
Sequencer
Transmitter
Stereo
Structuring
Transformation
Windows
Sequencer
Special
Forward-Forward Loop
Forward-Reverse Loop
Single-step mode
Frame Control
Sequence Control
Reverse
Forward
Stop
Pause
Frame Control
Start
Next
End
1
1
100
Current: 61
1
Min
1
Increment
100
Max
Sequencer outputs a series of integers. You set minimum, maximum, and delta using Edit→Configuration.
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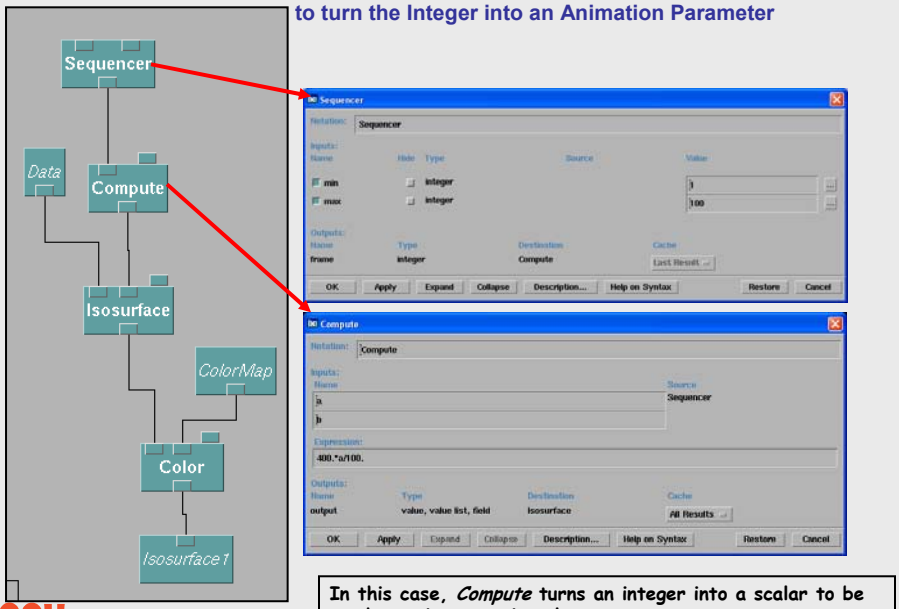
The Sequencer Module: Usually Used with the Compute Module to turn the Integer into an Animation Parameter



In this case, *Compute* turns an integer into a scalar to be used to animate an isovalue

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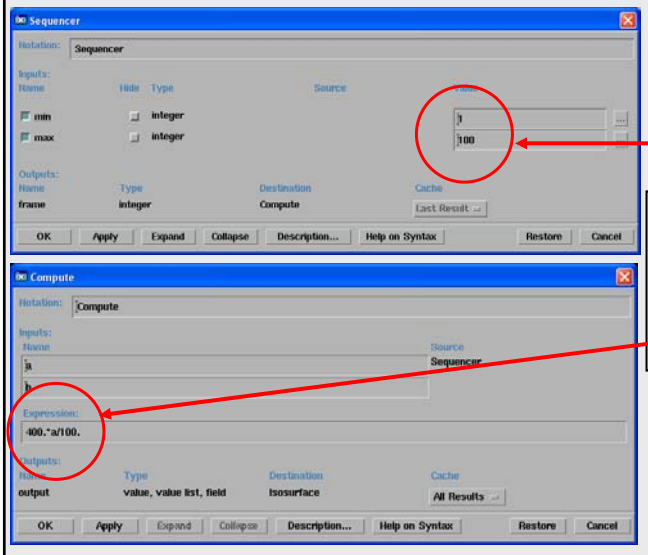
The Sequencer Module: "Percent Units Strategy"



A good Sequencer Strategy: Run the sequence from 1-100 (or 0-100).

Then, base the *Compute* quantity on these "Percent Units".

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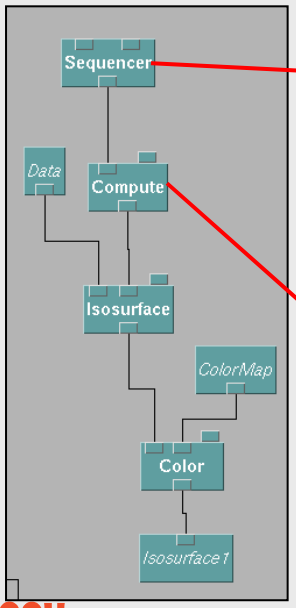
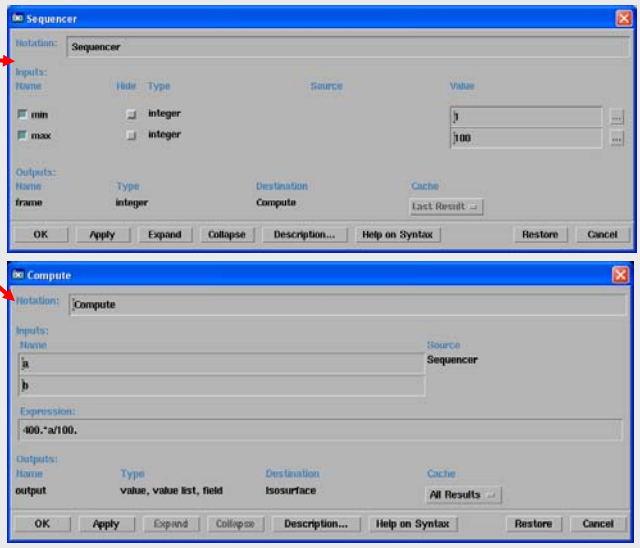
The Sequencer Module: Setting a Scalar Isovalue





In this case, *Compute* turns an integer into a scalar to be used to animate the isovalue

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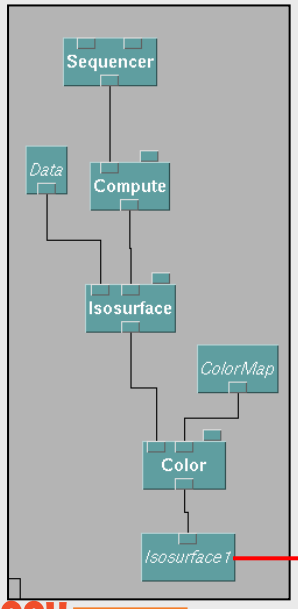
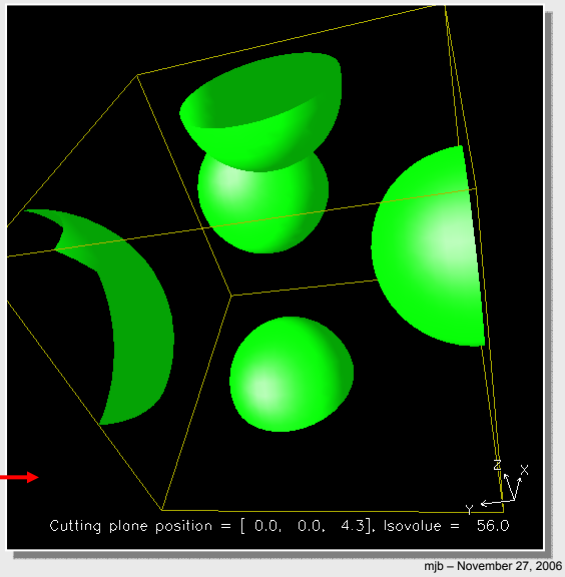
The Sequencer Module: Setting a Scalar Isovalue





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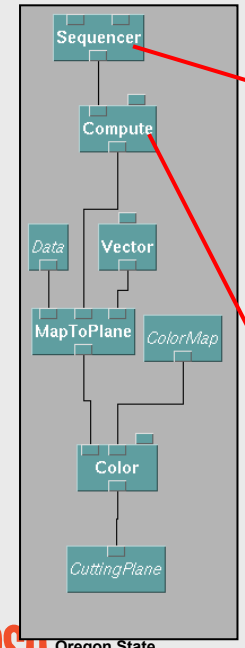
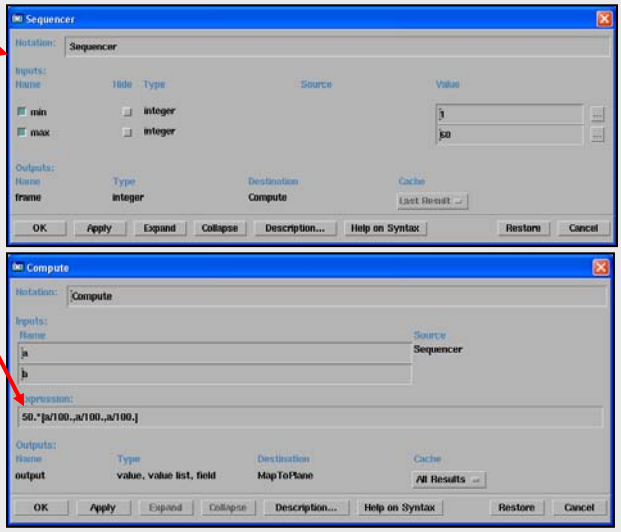
The Sequencer Module: Setting a Vector to act as a Plane Location





In this case, *Compute* turns an integer into a 3-element vector to be used to animate the position of the cutting plane

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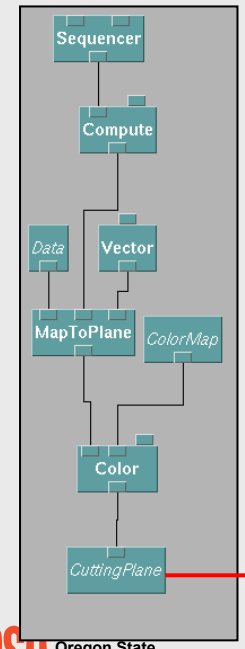
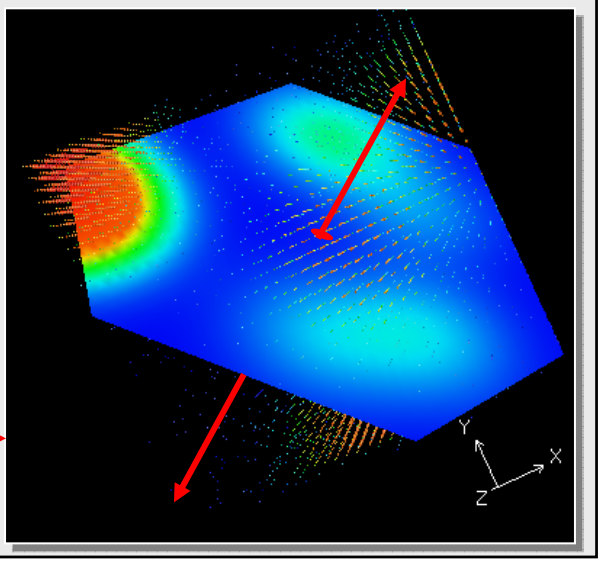
The Sequencer Module: Setting a Vector to act as a Plane Location





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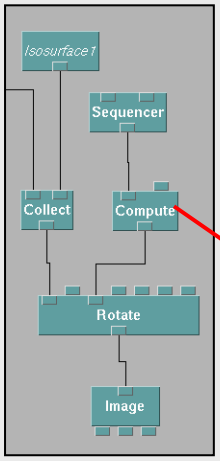
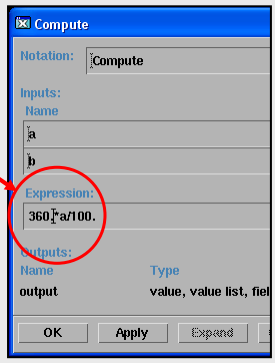
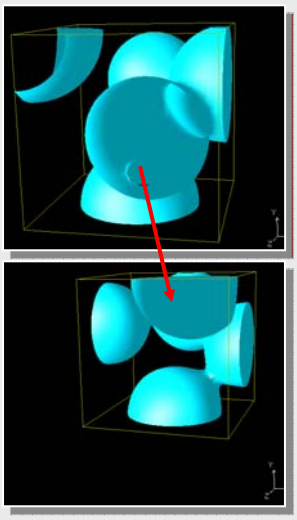
The Sequencer Module: Setting a Transformation







In this case, *Compute* turns an integer into a rotation angle in *degrees*.

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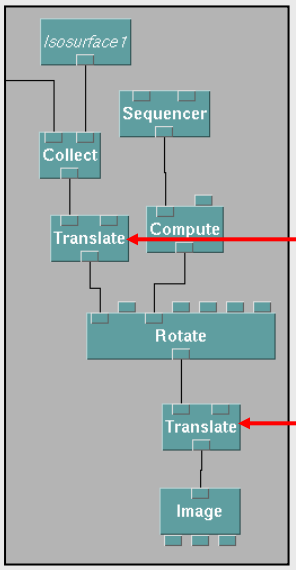
Why Does the Rotation Occur around the Edge of the Cube, not about its Center?



Rotation and Scaling *always occur about the origin*. To change this to the center of the volume, translate the volume to the origin, perform the rotation or scale, and then translate it back.

Translate by [-15,-15,-15]

Translate by [15,15,15]

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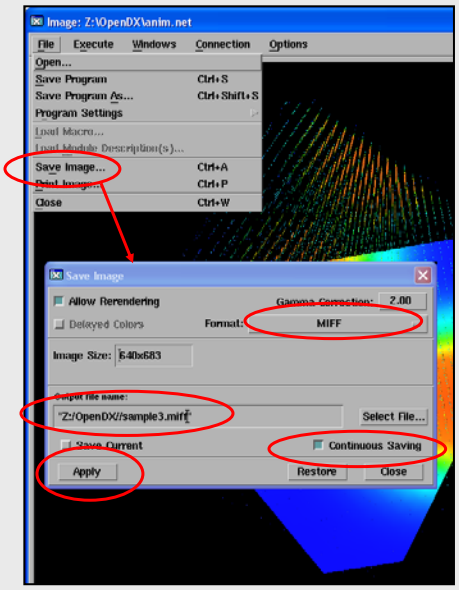
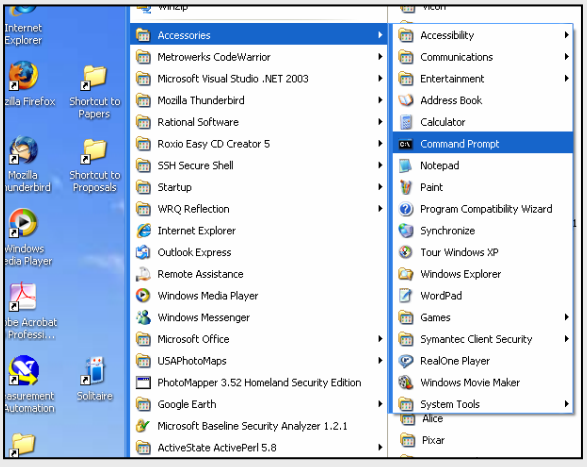
Writing Out a MIFF Animation File



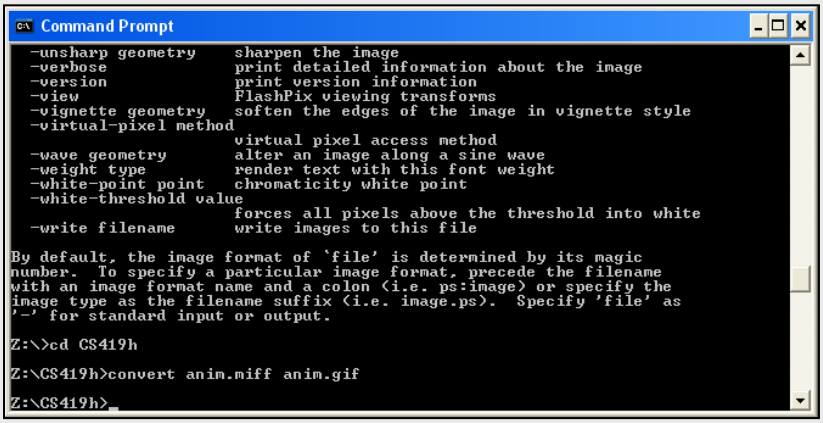
Converting a MIFF Animation File into an Animated GIF File using the ImageMagick Package



Click on: **Start→All Programs →Accessories →Command Prompt**

Converting a MIFF Animation File into an Animated GIF File using the ImageMagick Package

Type: **convert anim.miff anim.gif**
(where anim is the name of your MIFF animation file written from the *Image* module)



http://www.imagemagick.org

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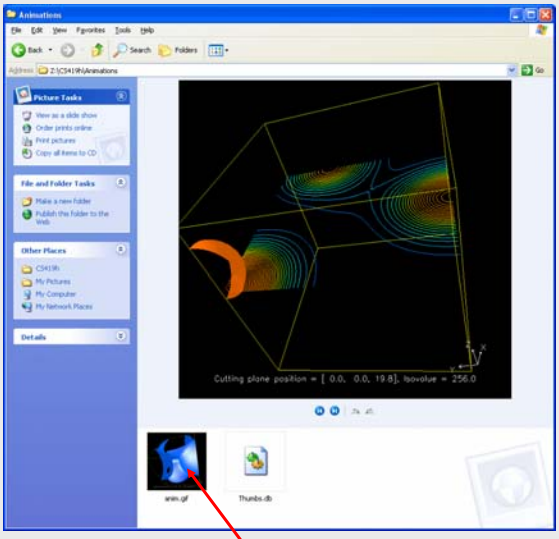
Animated GIF Files work in Windows Explorer



Double-click on the animated GIF file

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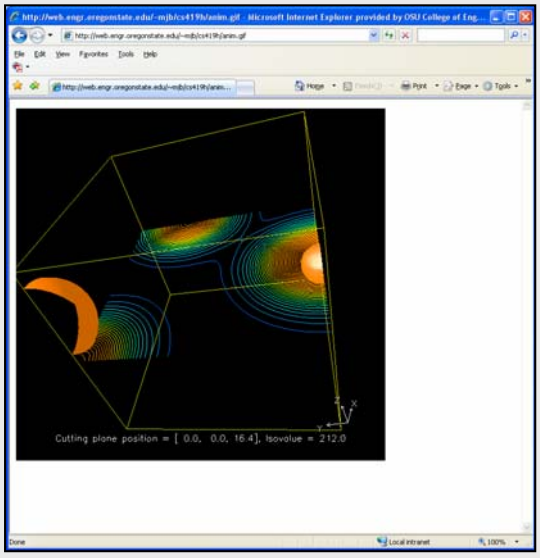
Animated GIF Files work in Web Pages



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<img src="anim.gif">

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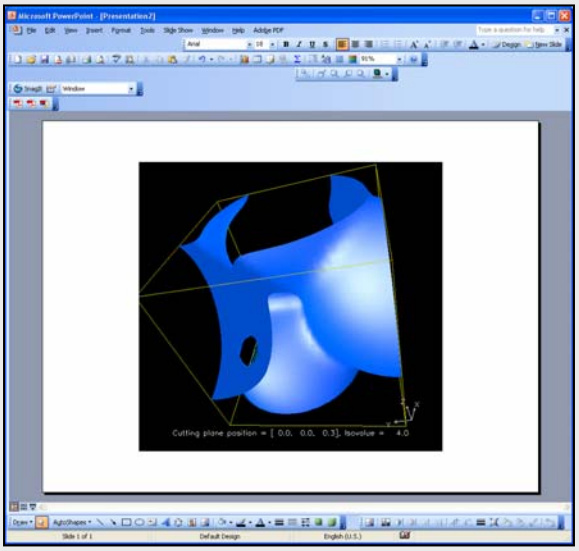
Animated GIF Files work in PowerPoint



Insert→Picture →From File…

In a presentation, the image will start animating when this slide becomes active

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Interactors

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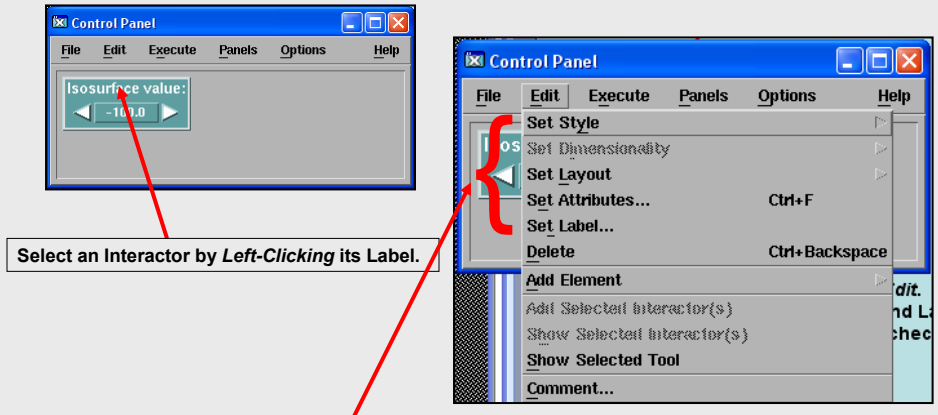
Editing Interactor Attributes



Select an Interactor by *Left-Clicking* its Label.

Then, click *Edit*. You can change the Interactor's Style, Layout, Attributes, and Label. Under *Set Attributes*, clicking on the *Continuous* checkbox is usually a good thing.

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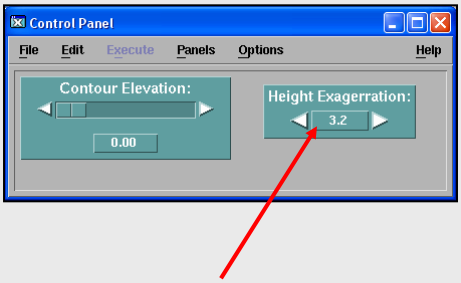
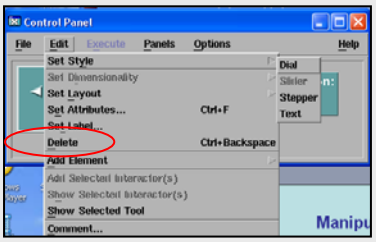
Ganging Interactors



You can place all Interactors in a single window by using the **middle mouse button** to drag them over. This copies them, not moves them. Then select the original Interactor in its original window and *Edit-Delete* it.



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Transmitters and Receivers

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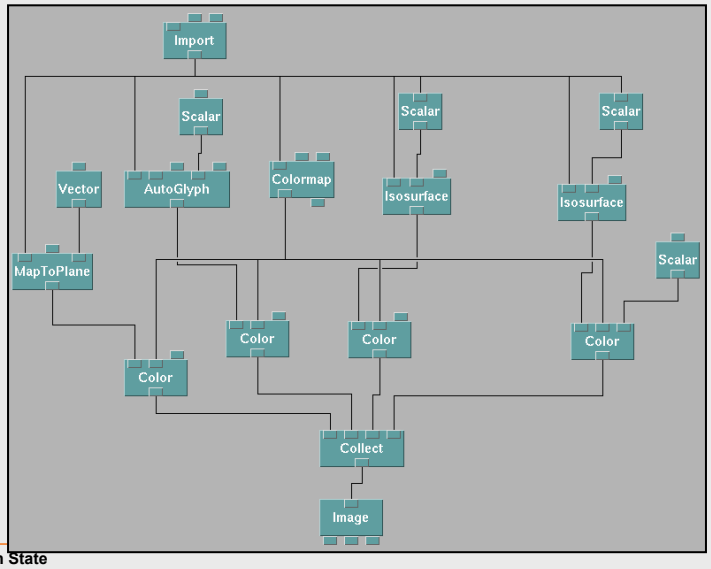
It's Easy to Get Cluttered, Especially Around *Import* and *ColorMap*!



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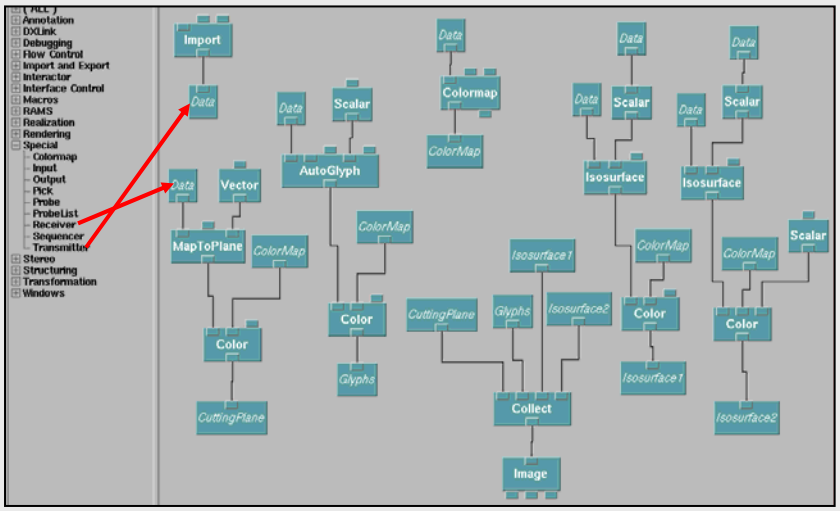
It's Also Easy to Get Un-cluttered with *Transmitter* and *Receiver*



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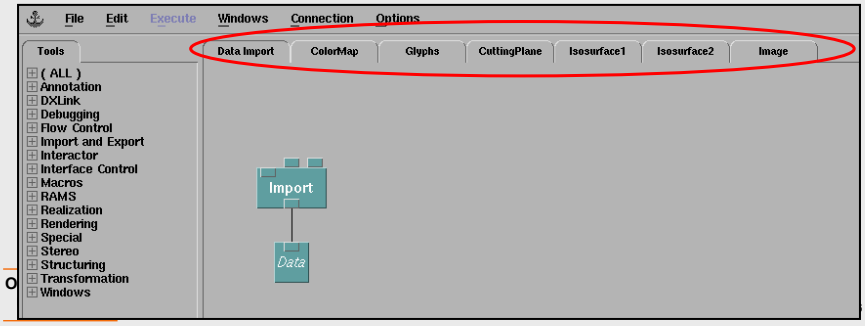
Notice how this lets you create separate "regions" for different functions. Wouldn't it be nice if you could put each region on its own page?

Using *Transmitter* and *Receiver*, You Can Also Spread the Network Out on Multiple "Pages"

Click *Edit→Page→Create Empty Page* to make a new page

Double-click on the page's tab, type in the page's name, and hit Enter

You can create from scratch in the other pages, or cut-and-paste from where you started



Switching, Selecting, and Toggling

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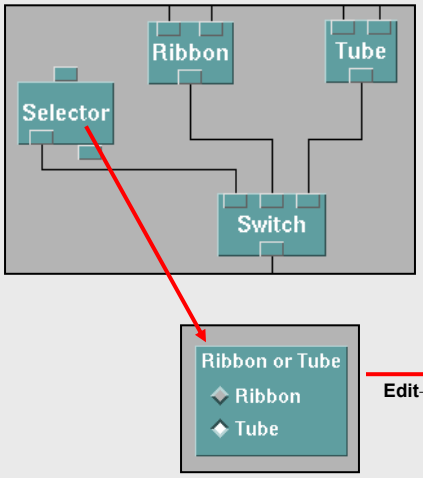
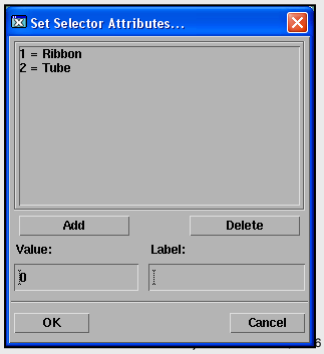
Selecting from Multiple Objects: *Selector* and *Switch*



The Switch module sends nothing through when its first input is 0. It sends the second input through when the first input is 1. It sends the third input through when the first input is 2, etc.

Edit→Set Attributes



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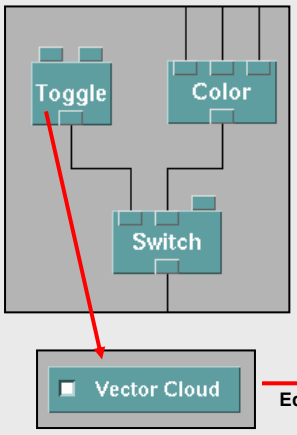
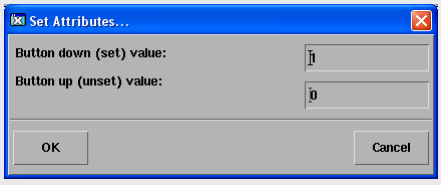
Toggling Objects On and Off : *Toggle* and *Switch*



The Switch module sends nothing through when its first input is 0. It sends the second input through when the first input is 1. It sends the third input through when the first input is 2, etc.

Edit→Set Attributes



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Captions

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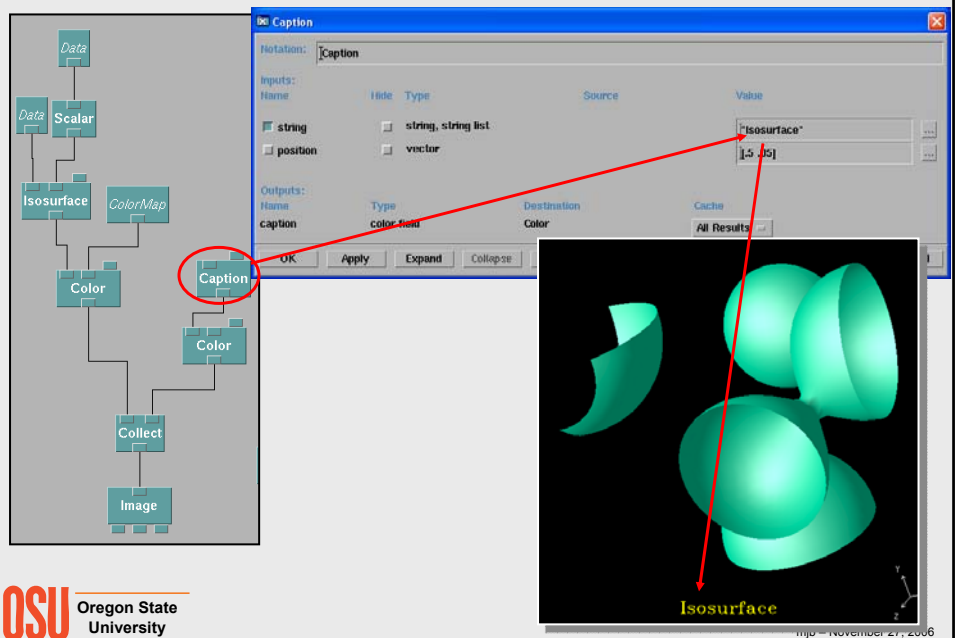
Placing a Caption on a Visualization



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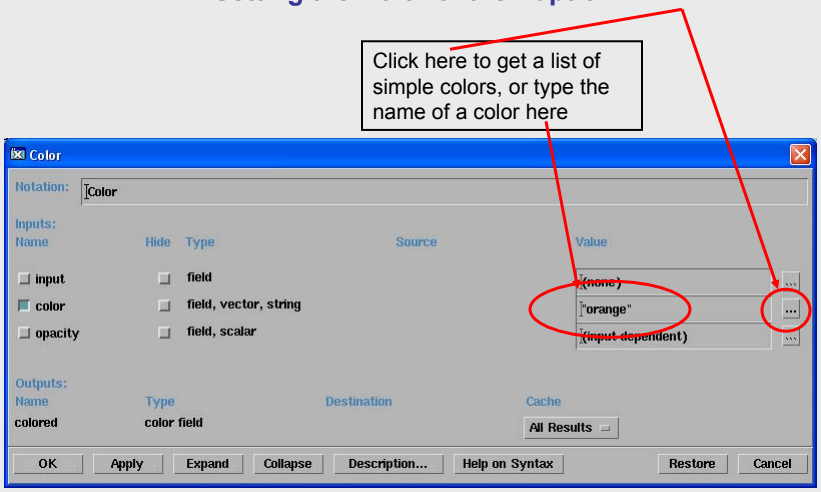
Setting the Color of the Caption



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Color Names you can use in the Color Module

aquamarine	darkturquoise	lightgrey	midnightblue	springgreen
black	dimgray	lightsteelblue	navy	steelblue
blue	dimgrey	limegreen	navyblue	tan
blueviolet	firebrick	magenta	orange	thistle
brown	forestgreen	maroon	orangered	turquoise
cadetblue	gold	mediumaquamarine	orchid	violet
coral	goldenrod	mediumblue	palegreen	violetred
cornflowerblue	gray	mediumforestgreen	pink	wheat
cyan	green	mediumgoldenrod	plum	white
darkgreen	greenyellow	mediumorchid	red	yellow
darkoliveggreen	grey	mediumseagreen	salmon	yellowgreen
darkorchid	indianred	mediumslateblue	seagreen	
darkslateblue	khaki	mediumspringgreen	sienna	
darkslategray	lightblue	mediumturquoise	skyblue	
darkslategrey	lightgray	mediumvioletred	slateblue	

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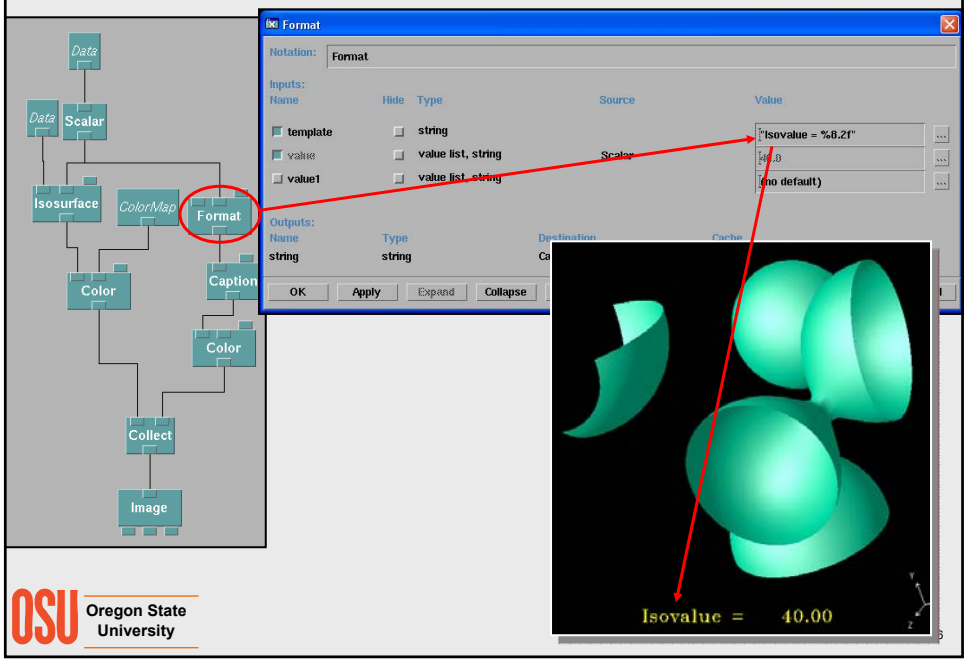
Placing a Data-formatted Caption on a Visualization



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Importing Your Own Data

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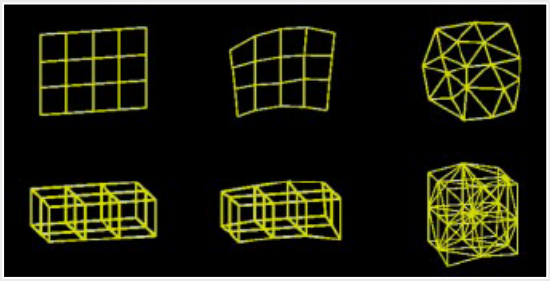
OpenDX Data Grid Types

Surfaces

Volumes



Regular:	**Deformed Regular:**	**Irregular:**
R positions, R connections	IR positions, R connections	IR positions, IR connections

R = “regular”
IR = “irregular”

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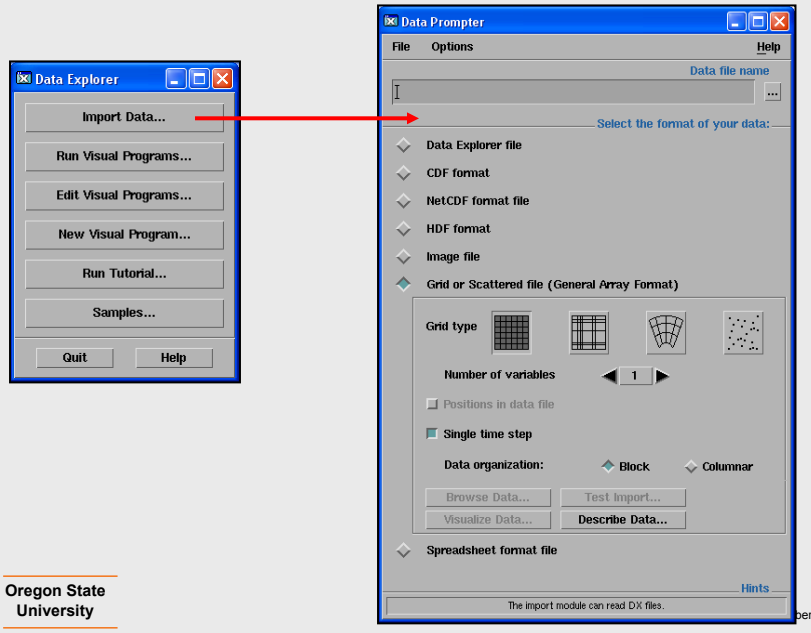
Creating an OpenDX Data Descriptor File using the Data Prompter



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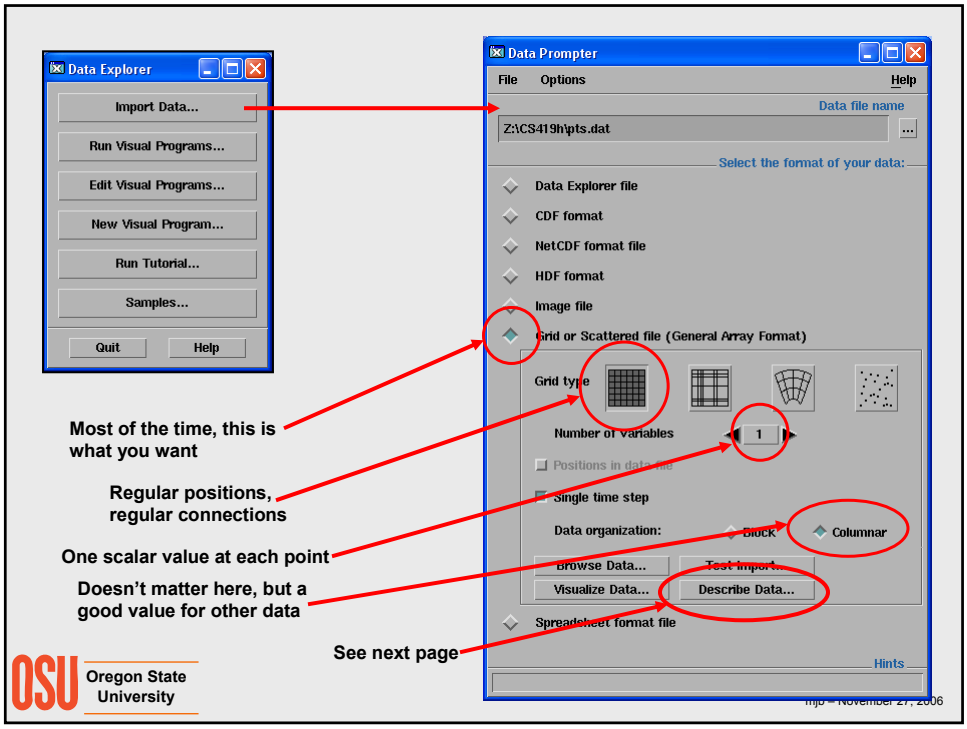
Data Explorer
Import Data...
Run Visual Programs...
Edit Visual Programs...
New Visual Program...
Run Tutorial...
Samples...
Quit
Help
Data Prompter
File
Options
Help
Data file name
Z:\CS419h\pts.dat
Select the format of your data:
Data Explorer file
CDF format
NetCDF format file
HDF format
Image file
Grid or Scattered file (General Array Format)
Grid type
Number of variables
1
Positions in data file
Single time step
Data organization:
Block
Columnar
Browse Data...
Visualize Data...
Describe Data...
Spreadsheet format file
Hints
Most of the time, this is what you want
Regular positions, regular connections
One scalar value at each point
Doesn't matter here, but a good value for other data
See next page
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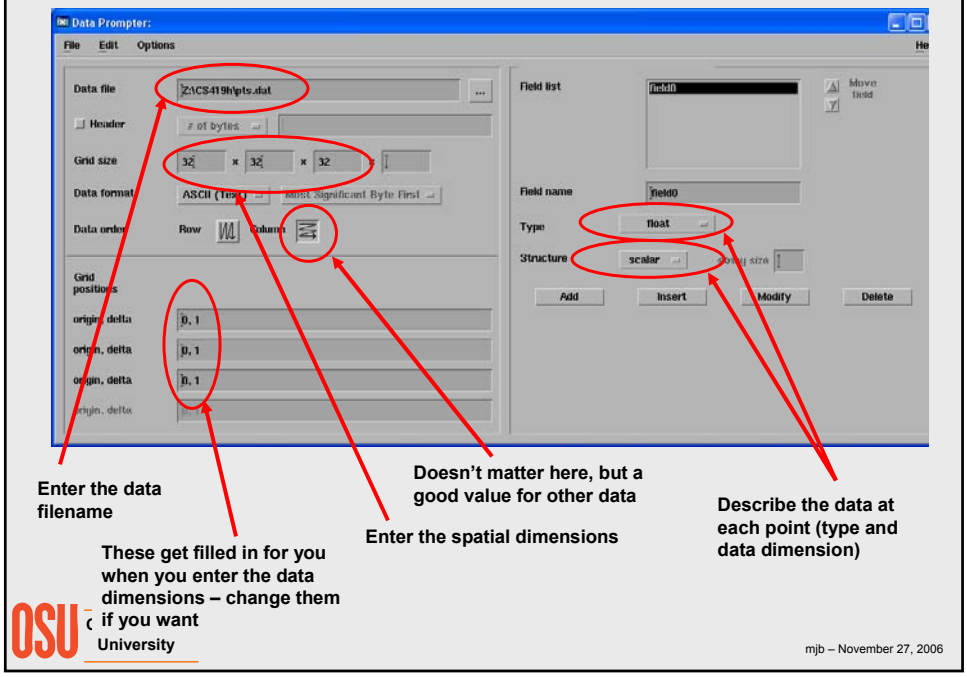
Data Prompter:
File
Edit
Options
Data file
Z:\CS419h\pts.dat
Header
# of bytes
Grid size
32
32
32
Data format
ASCII (Text)
Most Significant Byte First
Data order
Row
Column
Grid positions
origin, delta
0, 1
origin, delta
0, 1
origin, delta
0, 1
Field list
field0
Field name
field0
Type
float
Structure
scalar
Add
Insert
Modify
Delete
Enter the data filename
These get filled in for you when you enter the data dimensions – change them if you want
Enter the spatial dimensions
Doesn't matter here, but a good value for other data
Describe the data at each point (type and data dimension)
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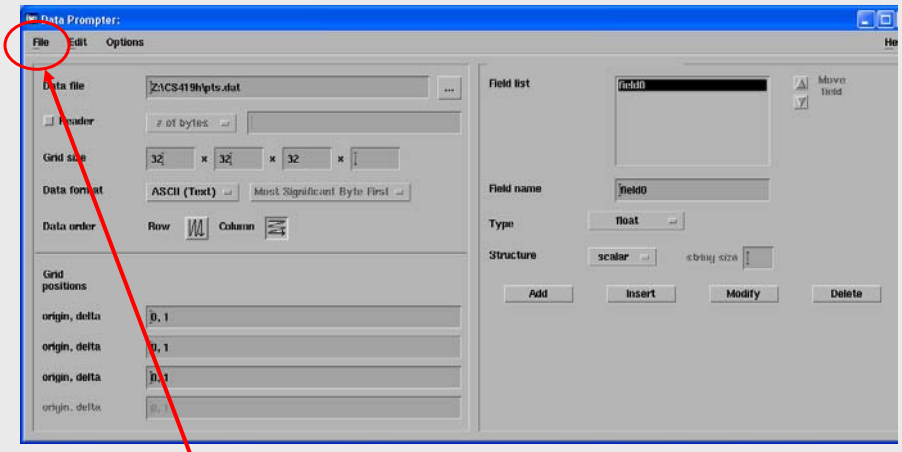

File → Save As ...

This saves the .general file, which will eventually tell OpenDX where to find the data and how to handle it.

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The OpenDX .general File for a 3D Scalar Dataset

```
file = Z:\CS419h\pts.dat
grid = 32 x 32 x 32
format = ascii
interleaving = field
majority = row
field = field0
structure = scalar
type = float
dependency = positions
positions = regular, regular, regular, 0, 1, 0, 1, 0, 1
end
```

3D

Scalar

Regular positions

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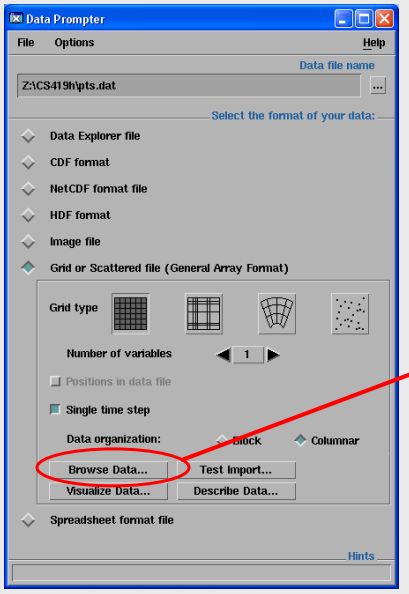
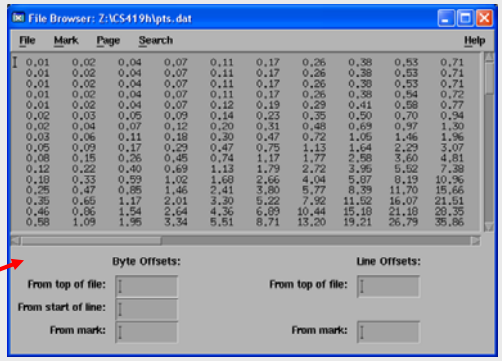
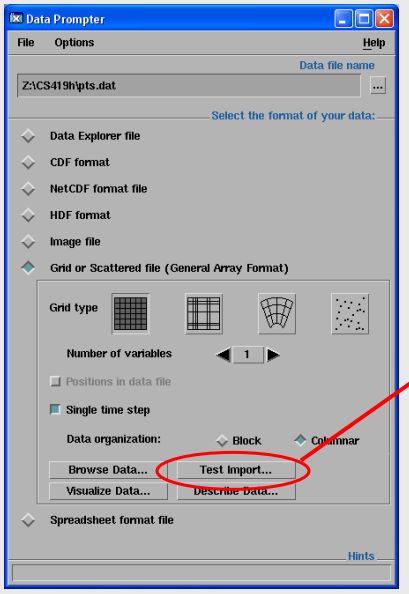
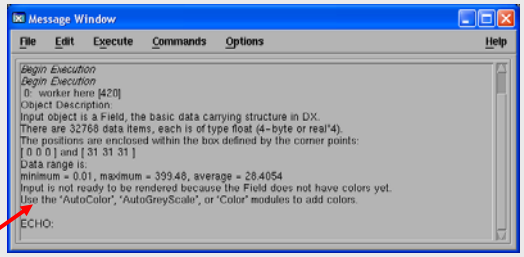
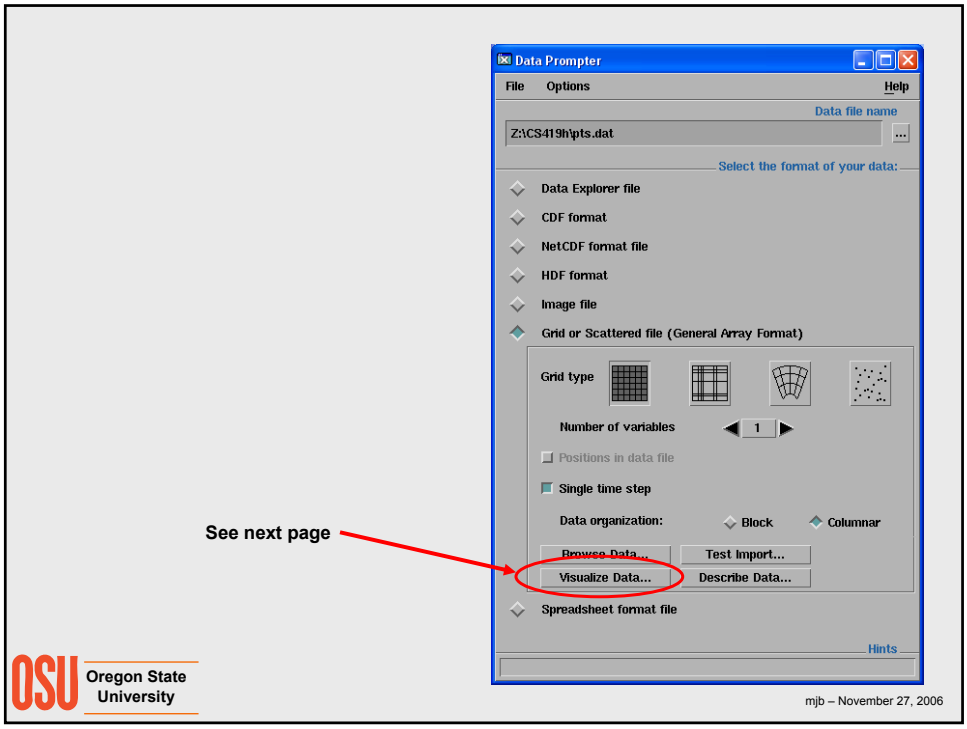

Data Prompter
File
Options
Help
Data file name
Z:\CS419h\pts.dat
Select the format of your data:
Data Explorer file
CDF format
NetCDF format file
HDF format
Image file
Grid or Scattered file (General Array Format)
Grid type
Number of variables
1
Positions in data file
Single time step
Data organization:
Block
Columnar
Browse Data...
Test Import...
Visualize Data...
Describe Data...
Spreadsheet format file
Hints


File Browser: Z:\CS419h\pts.dat
File
Mark
Page
Search
Help
Byte Offsets:
From top of file:
From start of line:
From mark:
Line Offsets:
From top of file:
From mark:


Data Prompter
File
Options
Help
Data file name
Z:\CS419h\pts.dat
Select the format of your data:
Data Explorer file
CDF format
NetCDF format file
HDF format
Image file
Grid or Scattered file (General Array Format)
Grid type
Number of variables
1
Positions in data file
Single time step
Data organization:
Block
Columnar
Browse Data...
Test Import...
Visualize Data...
Describe Data...
Spreadsheet format file
Hints


Message Window
File
Edit
Execute
Commands
Options
Help
Begin Execution
Begin Execution
[0: worker here [420]
Object Description:
Input object is a Field, the basic data carrying structure in DX.
There are 32768 data items, each is of type float (4-byte or real*4).
The positions are enclosed within the box defined by the corner points:
[0 0 0] and [31 31 31]
Data range is:
minimum = 0.01, maximum = 399.48, average = 28.4054
Input is not ready to be rendered because the Field does not have colors yet.
Use the "AutoColor", "AutoGreyScale", or "Color" modules to add colors.
ECHO:


Data Prompter
File
Options
Help
Data file name
Z:\CS419h\pts.dat
Select the format of your data:
Data Explorer file
CDF format
NetCDF format file
HDF format
Image file
Grid or Scattered file (General Array Format)
Grid type
Number of variables
1
Positions in data file
Single time step
Data organization:
Block
Columnar
Browse Data...
Test Import...
Visualize Data...
Describe Data...
Spreadsheet format file
Hints
See next page
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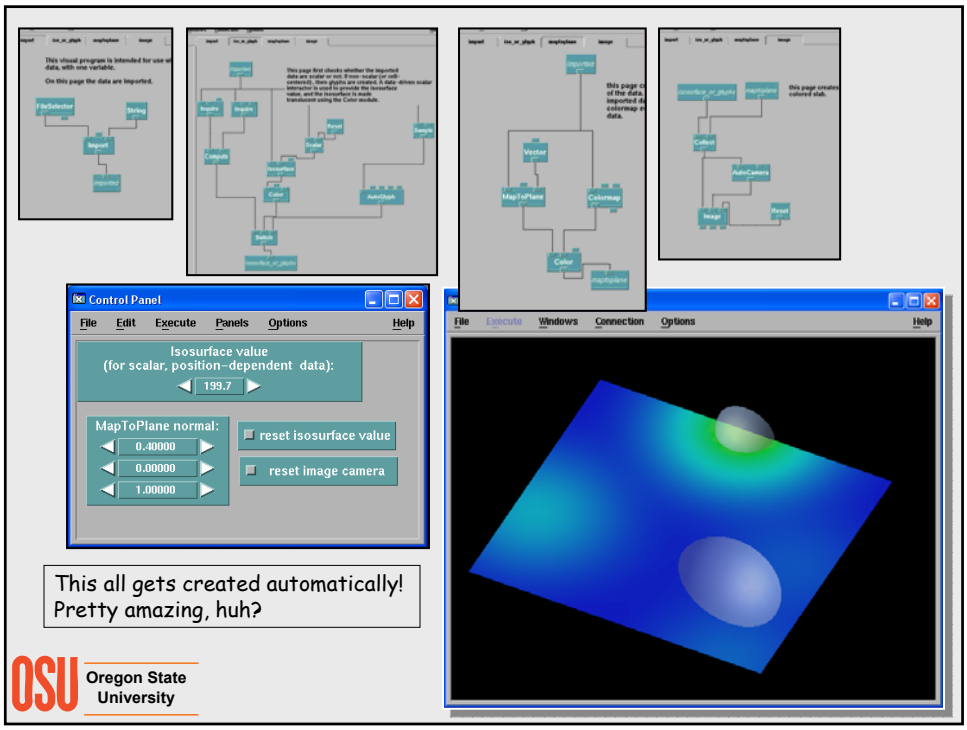
Control Panel
File
Edit
Execute
Panels
Options
Help
Isosurface value
(for scalar, position-dependent data):
199.7
MapToPlane normal:
0.40000
0.00000
1.00000
reset isosurface value
reset image camera
File
Execute
Windows
Connection
Options
Help
This all gets created automatically!
Pretty amazing, huh?
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Terrain Visualization .general File

```
file = Z:\OpenDX\or.dat
grid = 201 x 105
format = ascii
interleaving = record
majority = column
field = field0
structure = scalar
type = float
dependency = positions
positions = regular, regular, 0, 1, 0, -1

end
```

2D

Scalar

Regular positions

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Vector Field Visualization .general File

```
file = Z:\OpenDX\vecs.dat
grid = 16 x 16 x 16
format = ascii
interleaving = record-vector
majority = column
field = velocity
structure = 3-vector
type = float
dependency = positions
positions = regular, regular, regular, 0, 1, 0, 1, 0, 1

end
```

3D

3-element Vector

Regular positions

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Visualizing Points on a Scattered Grid (e.g., Digital Elevation Mapping)

West→East	South→North	Elevation
-360.78	128.438	2.25
-360.75	128.428	2.31
-360.80	128.405	2.20
-360.81	128.370	1.99
-360.91	128.369	1.75
-361.00	128.359	1.65
-361.16	128.354	1.77
-361.21	128.344	1.70
-361.25	128.344	1.76
. . .		

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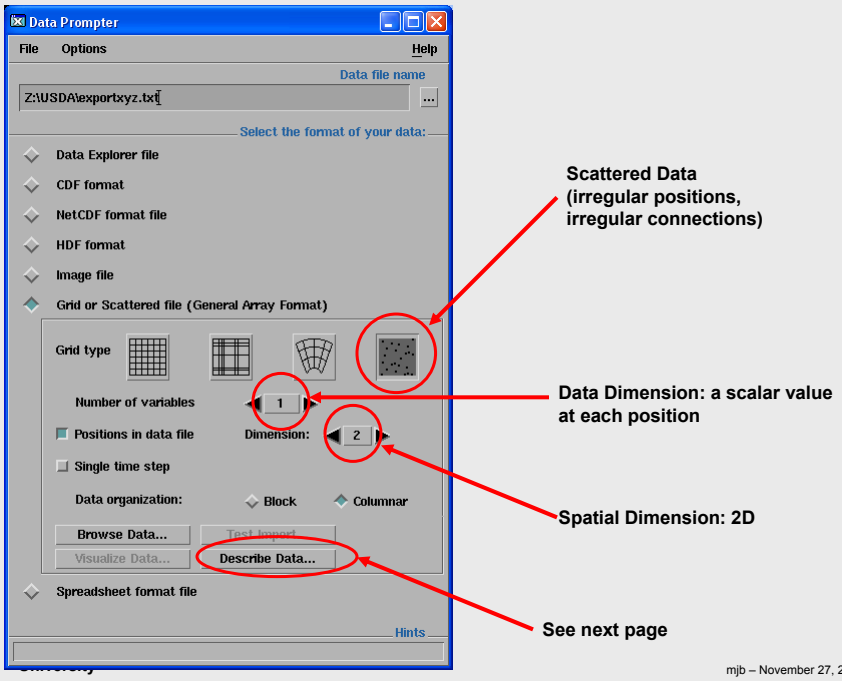
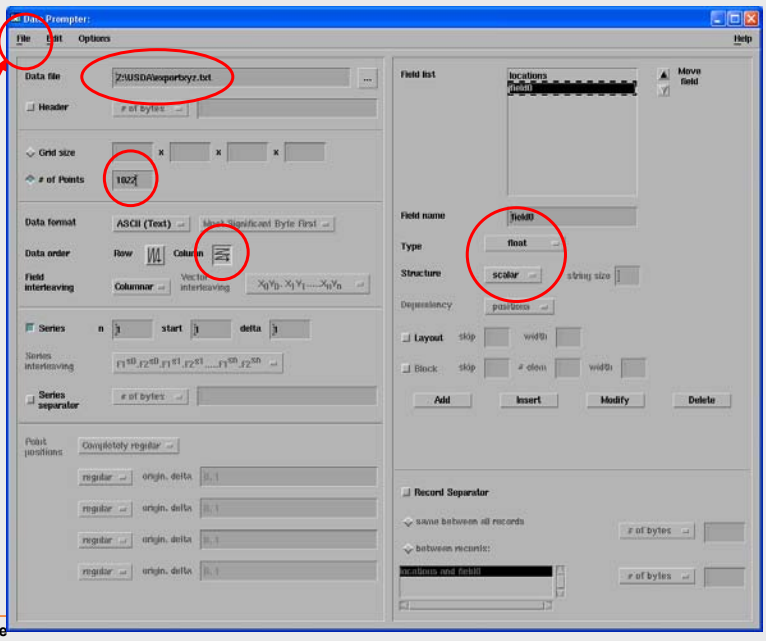


OSU

File → Save as…



A Scattered Grid .general File

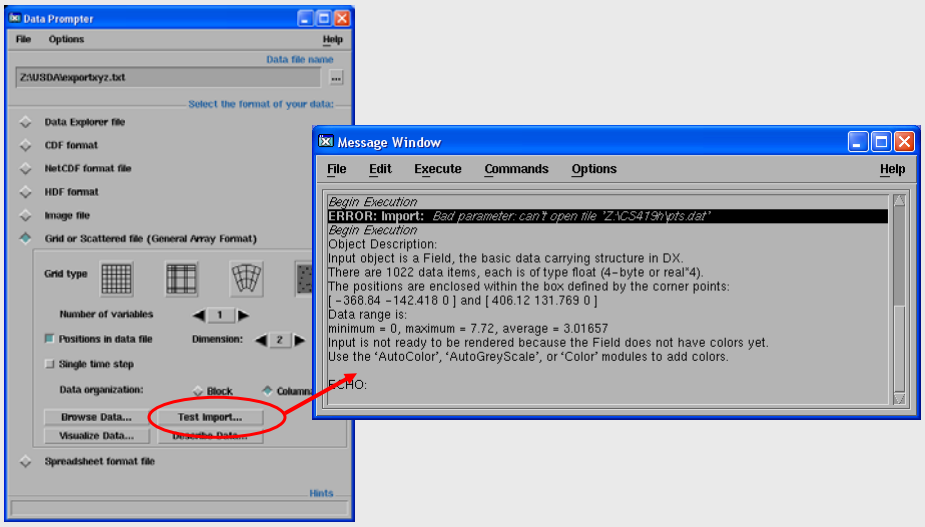
```
file = Z:\OpenDX\exportxyz.dat
points = 1022
format = ascii
interleaving = field
field = locations, field0
structure = 2-vector, scalar
type = float, float

end
```

A 1D list

Each entry has a location and data values

Each location has 2 values (X,Y). Each data is a single value (scalar).



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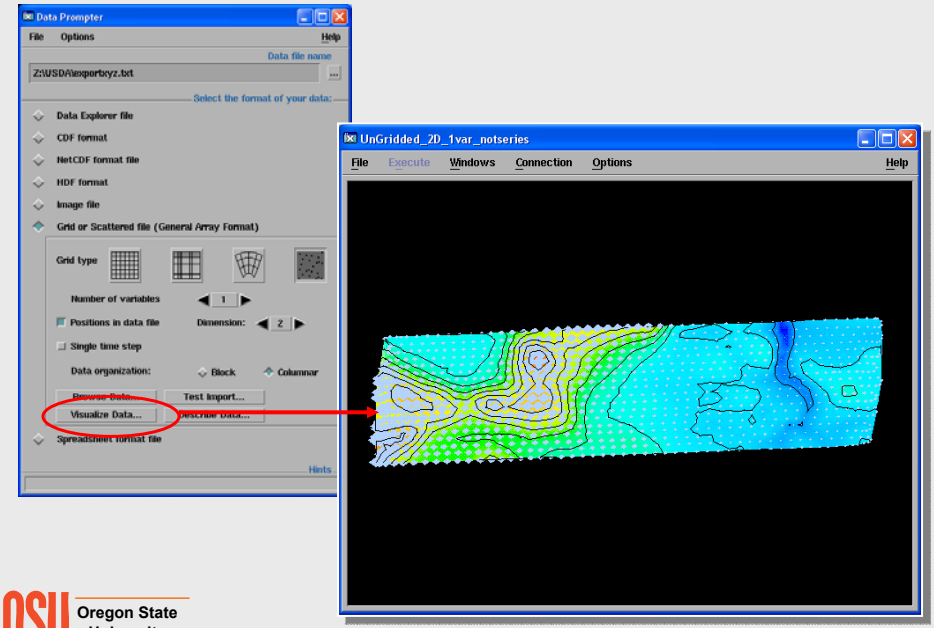

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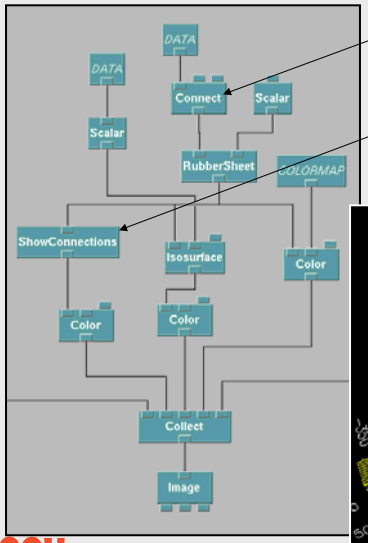
Visualizing Points from a Scattered Grid (e.g., Digital Elevation Mapping)

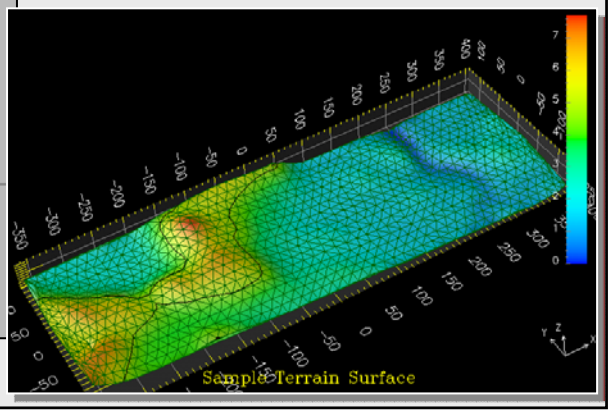


Realization

Connect creates triangles from scattered points.

Realization

ShowConnections creates graphics to show how the scattered point connections were made.



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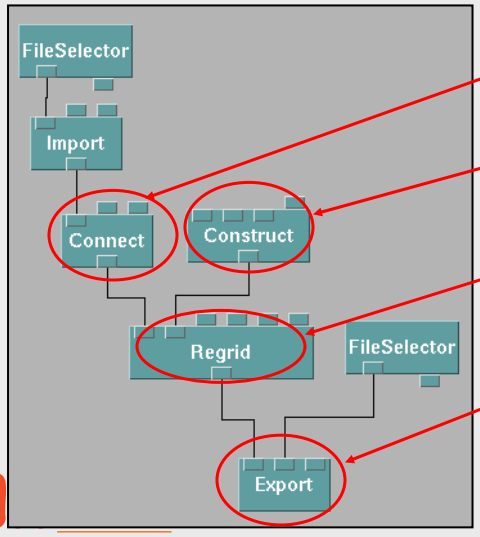
Regridding a Dataset

(especially good for writing out a Connect'ed Scattered Grid as a Rectangular Array)

You might be doing this to downsize a dataset or to create a regular grid from a scattered grid



If Scattered data, route through Connect first.

Creates a new grid to project the data onto

Projects the original data onto the new grid

Writes out the new grid data file

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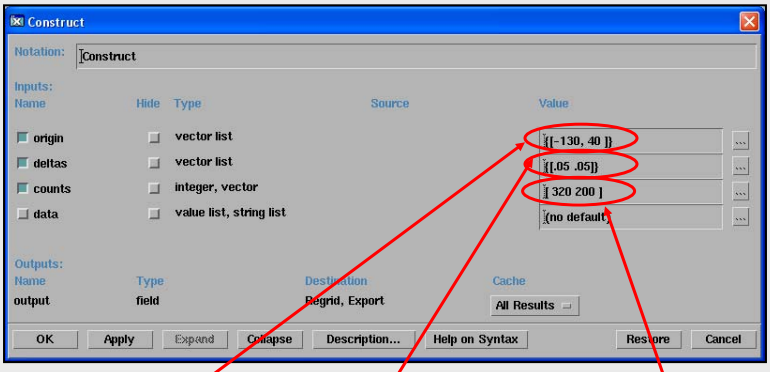
Regridding a Dataset



Coordinates at the lower corner of the dataset

Step size in each dimension

How many steps to make in the grid

Note: the upper corner coordinates will be "origin + (counts-1)*delta"

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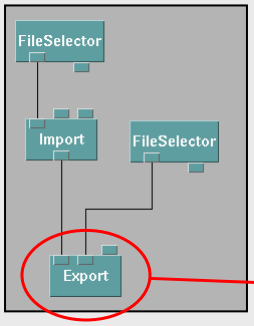
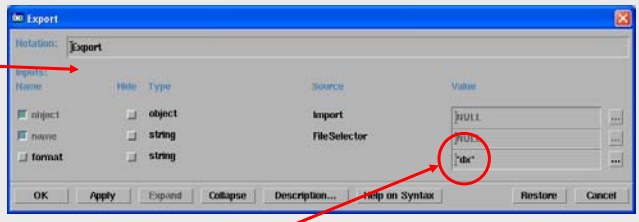
Writing a .general Dataset as a Native OpenDX .dx Dataset



The .dx file format embeds the data description information, the positions, and the data values in one file. This makes it easier to keep track of and easier to give to other people.



Says that you want to Export the data in a native OpenDX .dx file form.

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Send comments and suggestions on these notes to:

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2117 Kelley Engineering Center
Corvallis, OR 97331-5501
541-737-2542
FAX: 541-737-1300
mjb@cs.oregonstate.edu
http://eecs.oregonstate.edu/~mjb

"These are not the modules you are looking for."

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"An OpenDX User You Shall Be"