

A Tour of the OOF2 GUI via A Simple Example Problem

A Simple Example



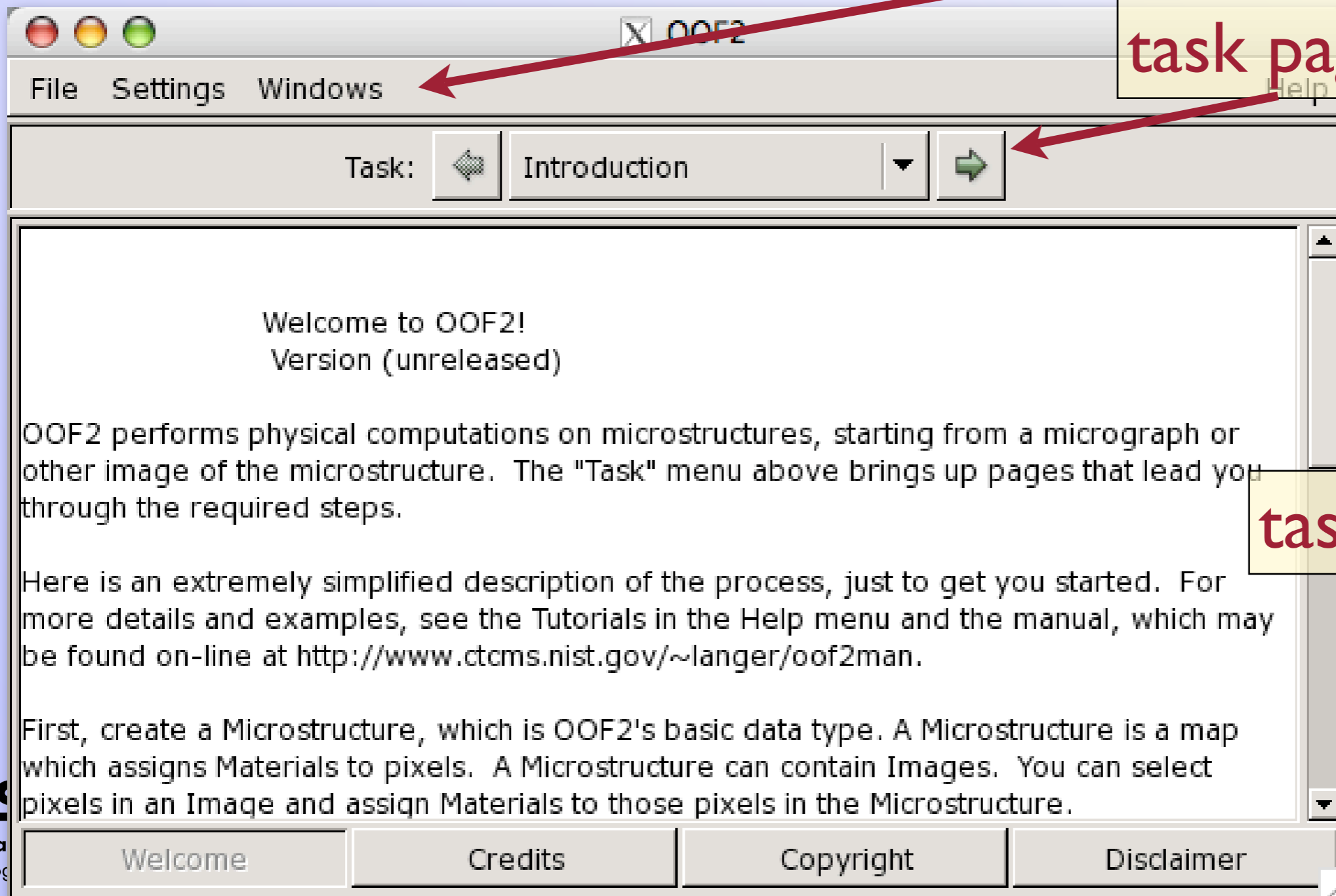
oofdemo.png

Start OOF2 by typing in a terminal window:

```
% oof2 --image oofdemo.png
```

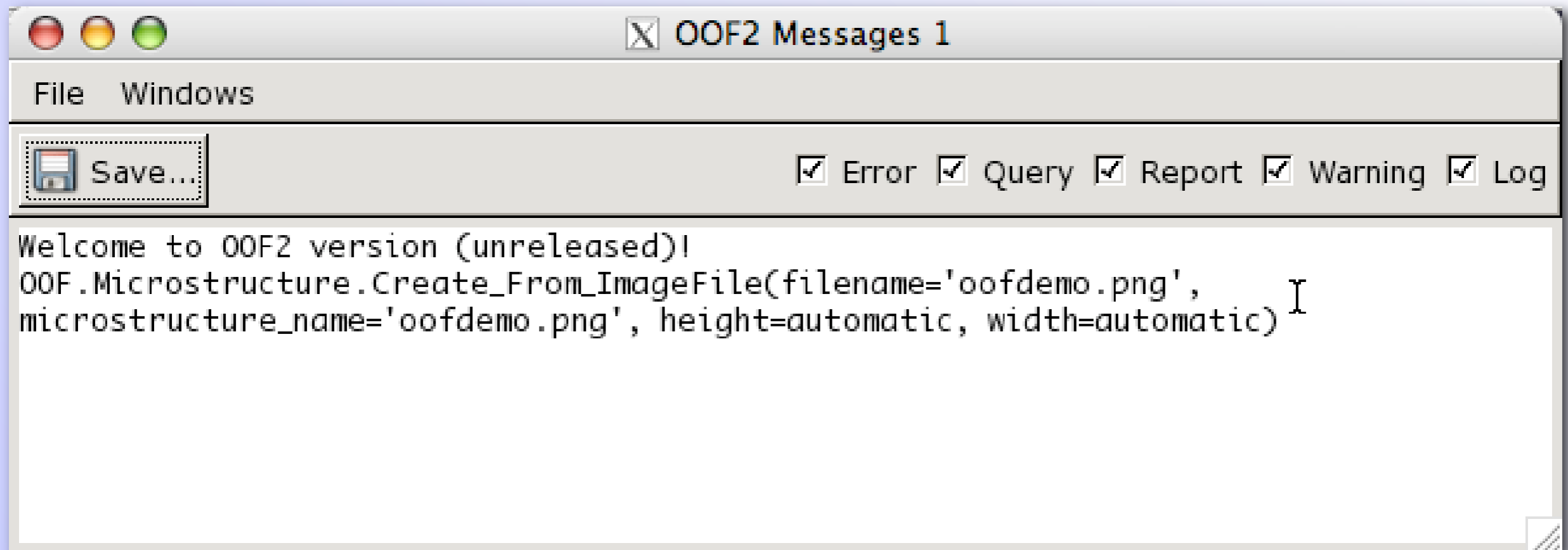
menu bar

task page chooser



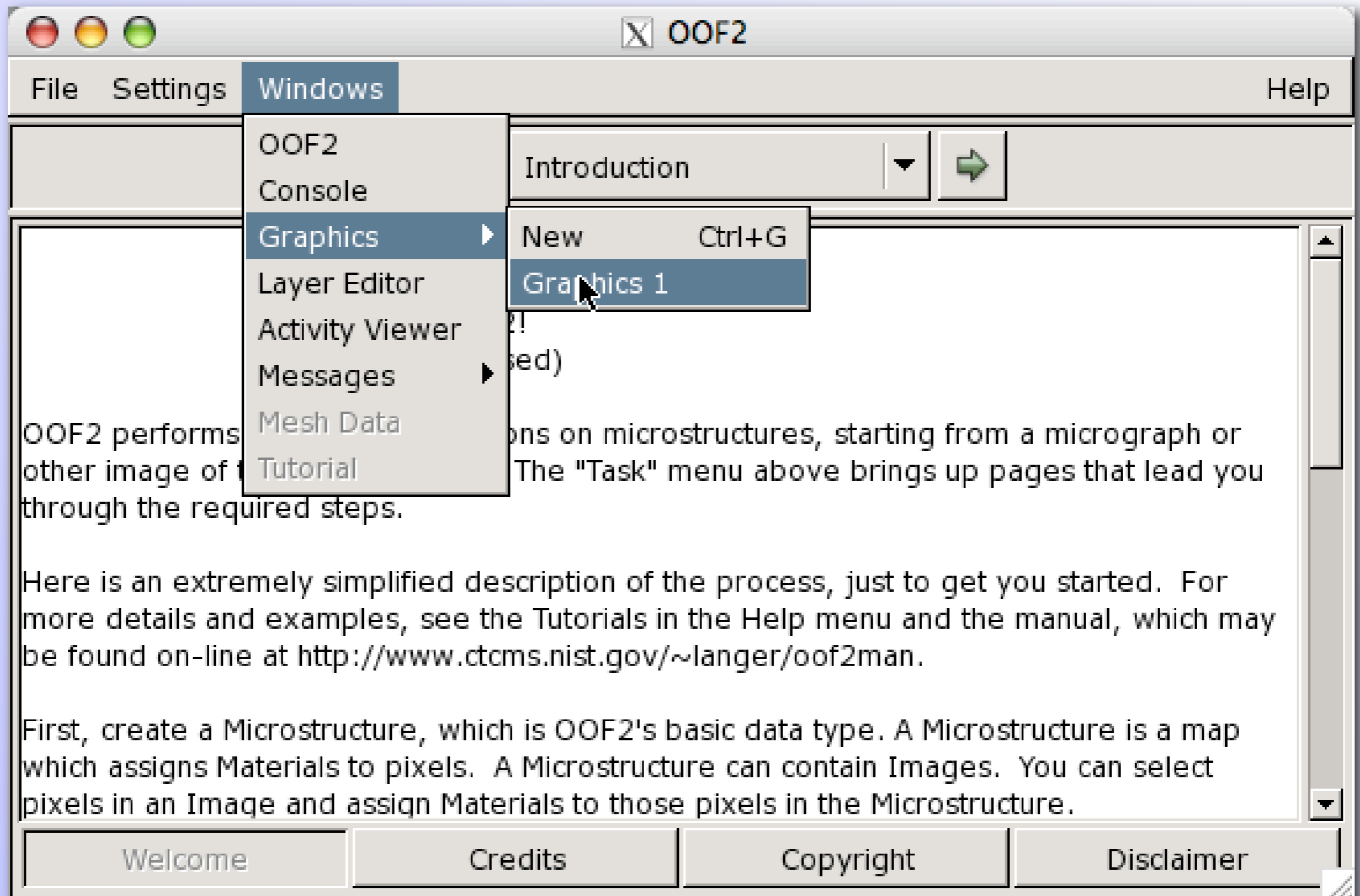
task page

The Message Window



All consequential OOF2 commands have a text form that appears in the message window, can be saved in a file, edited, and reloaded. The file is a python script.

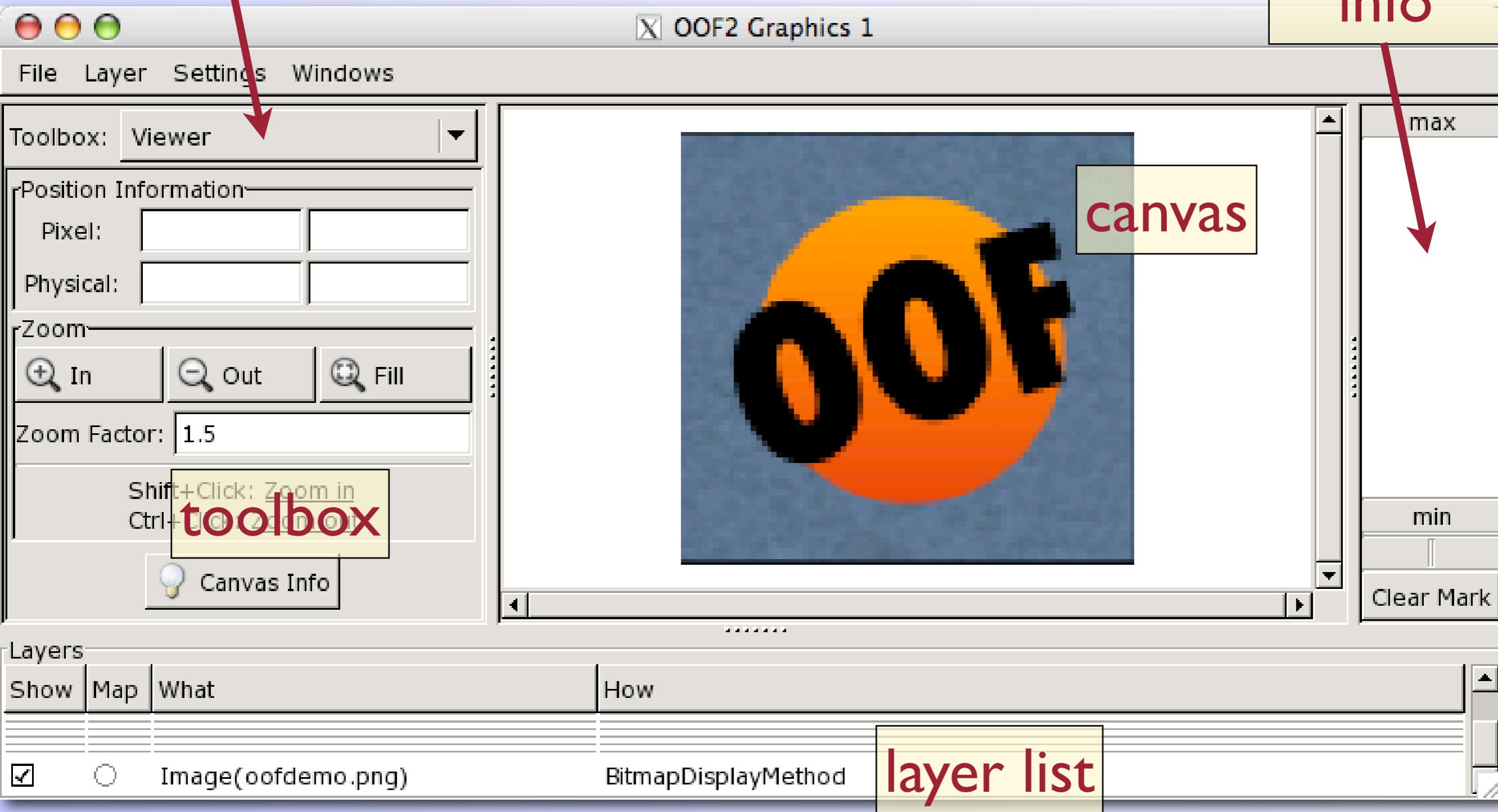
Open a Graphics Window



The OOF2 Graphics Window

toolbox chooser

contour info



Switch to the Microstructure Page

object chooser

Task: **Microstructure**

Microstructure= **oofdemo.png**

New... New from Image New from Image File

Rename... Copy... Delete Save...

Microstructure Info

Pixel size: 85x81
Physical size: 85x81
Images:
oofdemo.png

info area

Pixel Groups

New...
Rename...
Copy...
Delete
 Meshable

No pixel groups defined!

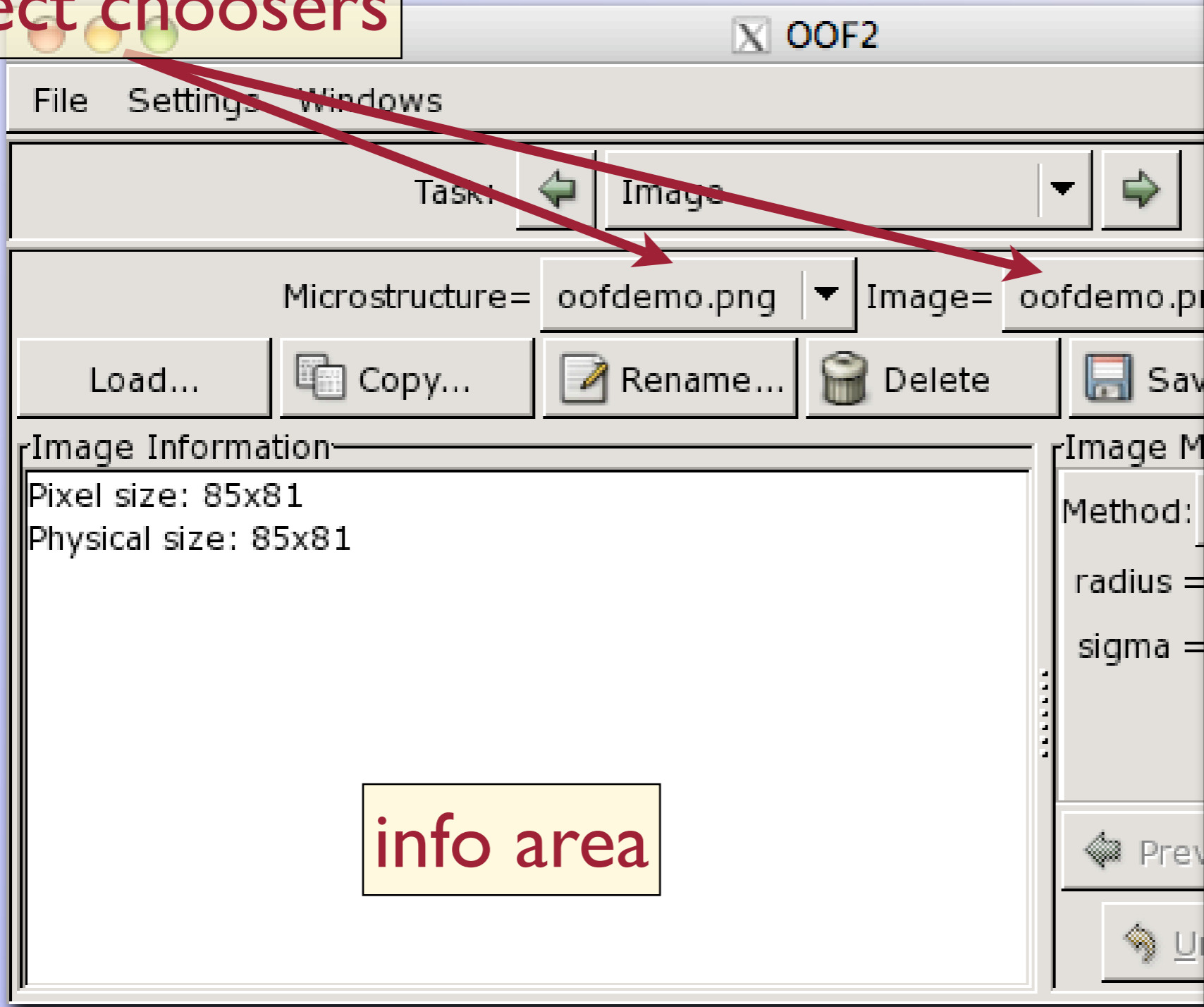
pixel group operations

Add
Remove
Clear
Info

The Image Page

object choosers

image modification tools



info area



A Slightly Sharper Image

X OOF2 Graphics 1



Select Pixels in the Image

pixel
selection
tools

X OOF2 Graphics 1

File Edit Settings Windows

Toolbox

Viewer

Pixel Info

Pixel Selection

Skeleton Info

Skeleton Selection

Move Nodes

Pin Nodes

Mesh Info

Mesh Cross Section

Method:

range =

Undo

History

down --

--

up

16.8804

28.35

Layers

Show

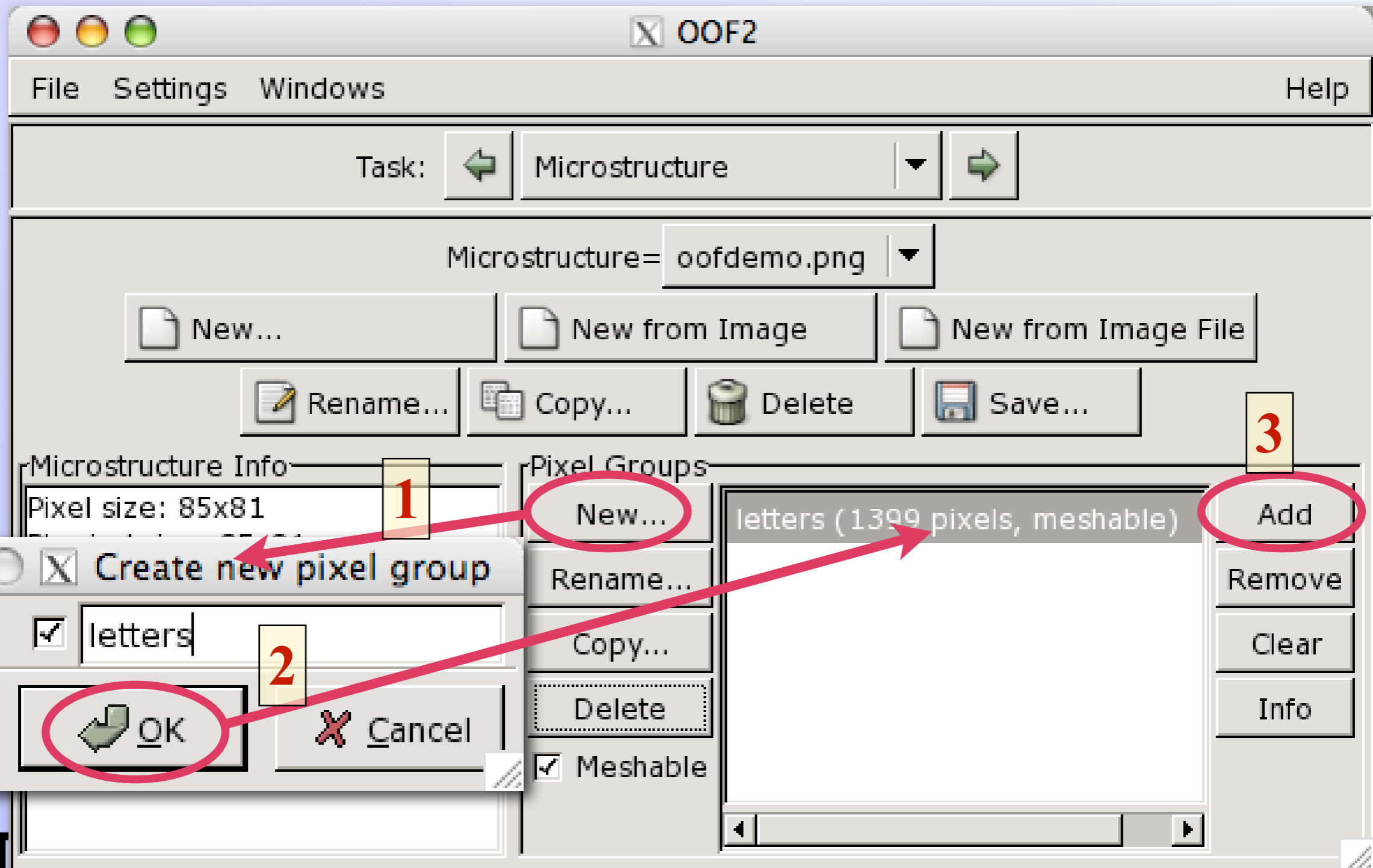
Map

What

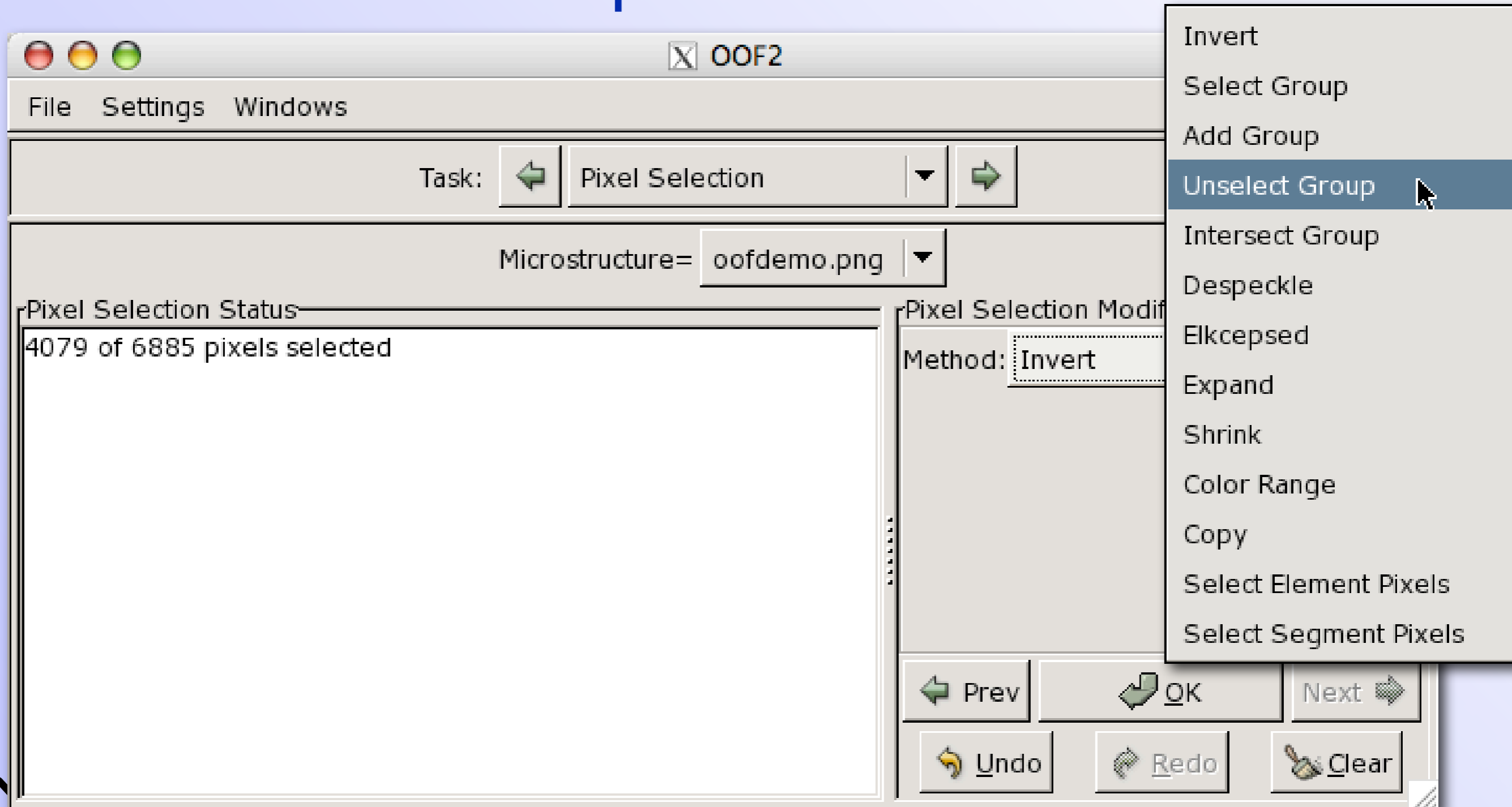
How



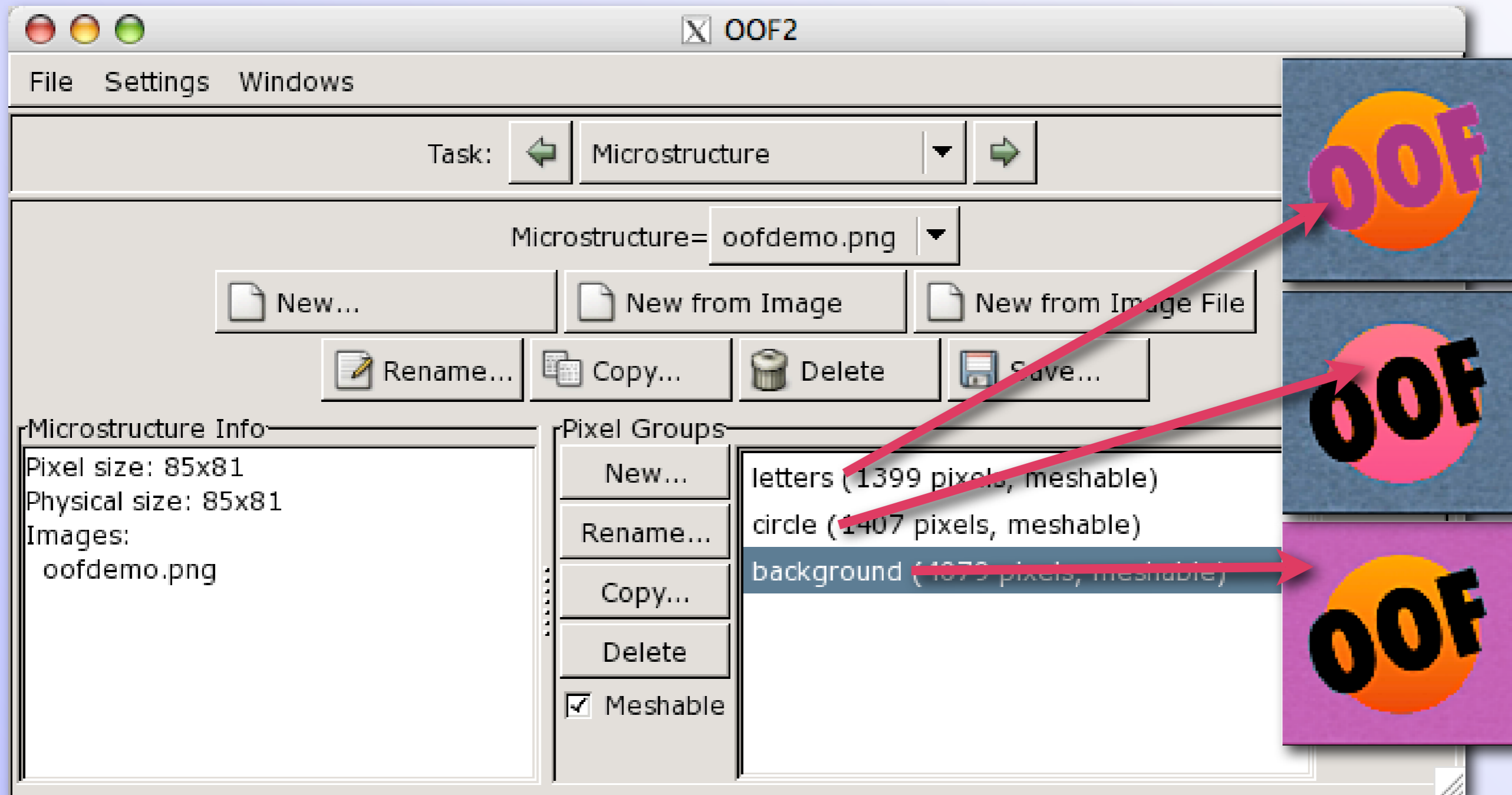
Create a new Pixel Group and add the selected pixels to it.



The Pixel Selection task page contains mouseless pixel selection tools

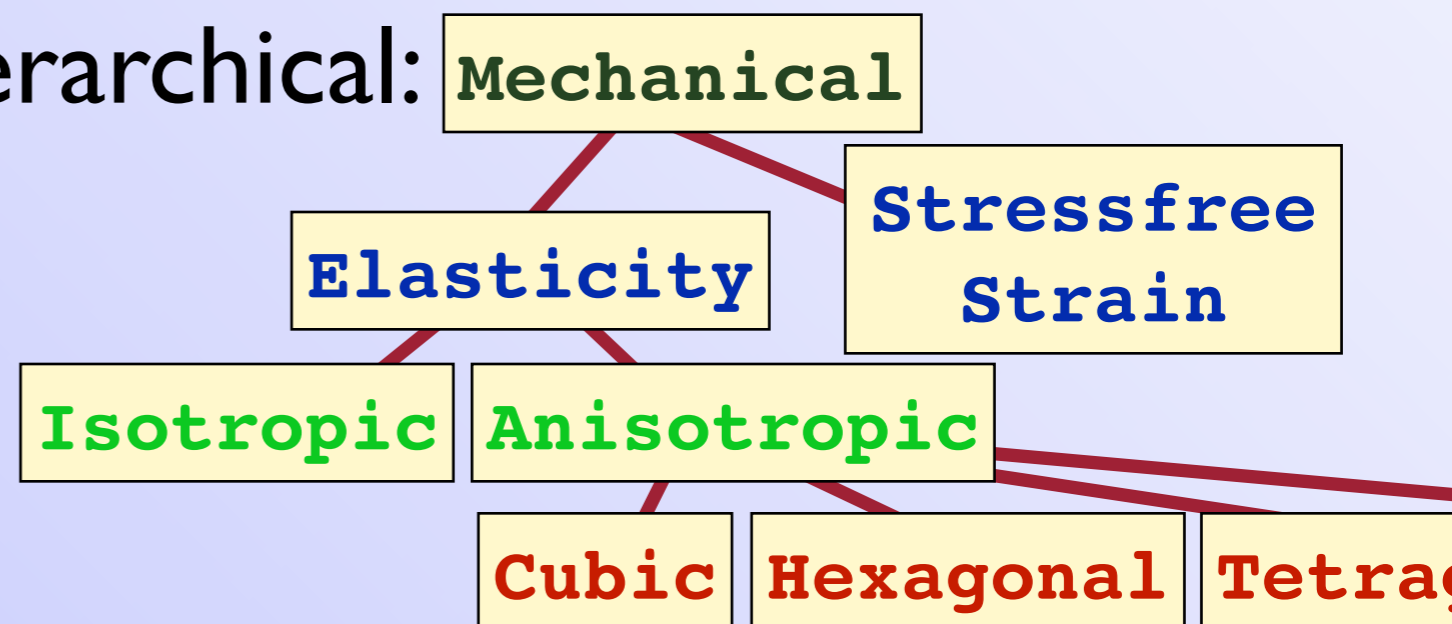


All pixels have been grouped.
(Pixel groups are useful, but not required.)

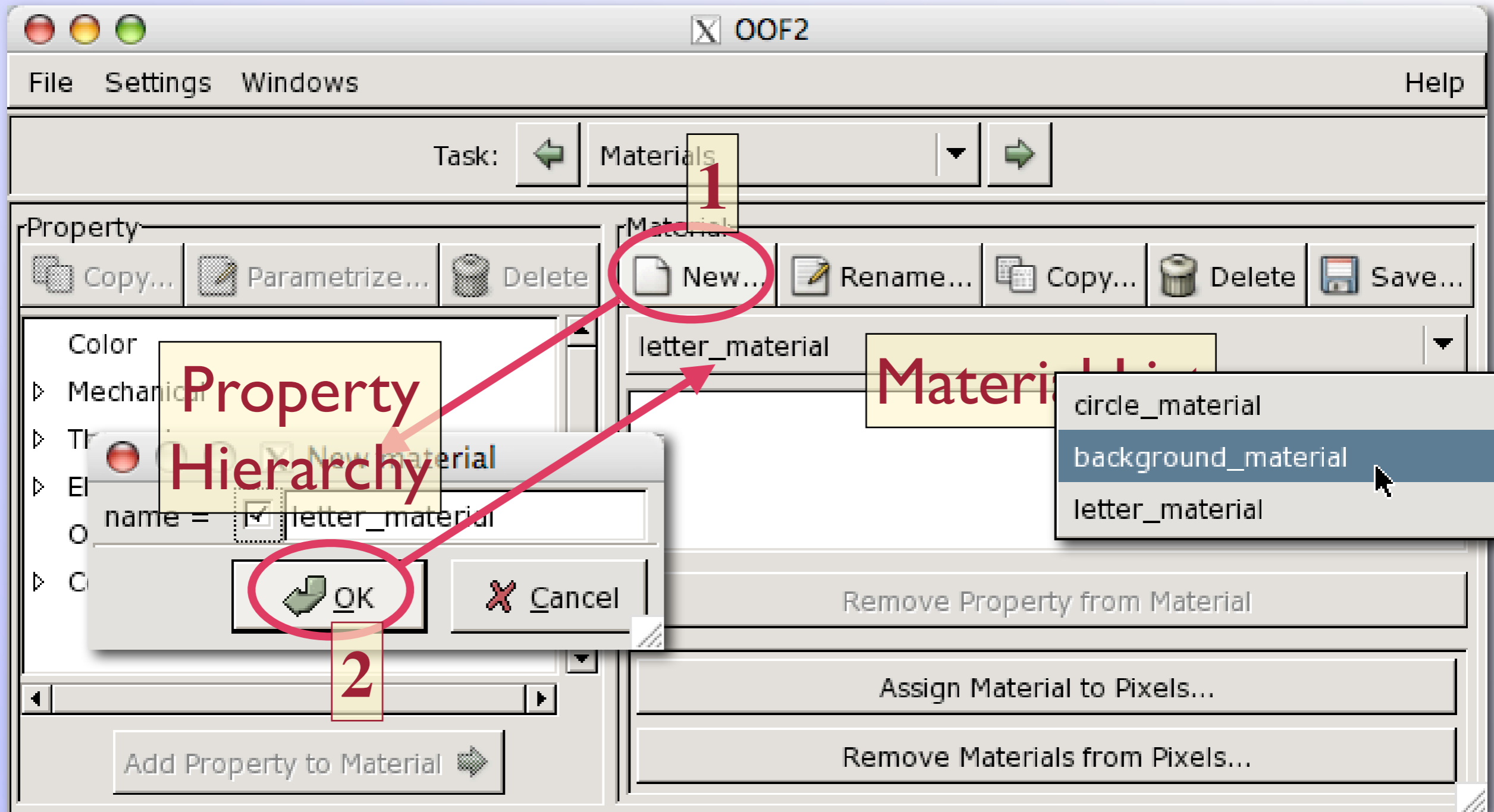


00F2 Materials

- ◆ A **Material** is a named collection of (named) **Properties**.
- ◆ Example **Properties**:
 - ◆ Elastic Modulus
 - ◆ Thermal Expansion Modulus
 - ◆ Color
 - ◆ Orientation
- ◆ Properties are hierarchical:



Create Materials



Create Properties, Assign to Materials

The image shows the OOF2 software interface with several windows and panels. The 'Copy property Mechanical:Ela:' window is open, showing 'new_name = stiff' and 'OK' and 'Cancel' buttons. The 'Materials' panel shows a tree view with 'stiff' selected under 'Mechanical > Elasticity > Isotropic'. The 'Material' panel shows 'letter_material' with 'Mechanical:Elasticity:Isotropic:stiff' selected. The 'Parametrize Mechanical:Elasticity:Isotropic' window is open, showing a table for the Cij matrix and 'OK' and 'Cancel' buttons. Red circles and arrows highlight the following steps:

1. Clicking the 'Copy...' button in the 'Materials' panel.
2. Clicking the 'OK' button in the 'Copy property' dialog.
3. Clicking the 'Parametrize...' button in the 'Materials' panel.
4. Clicking the 'Lame' option in the 'Parametrize' dialog.
5. Clicking the 'OK' button in the 'Parametrize' dialog.
6. Clicking the 'Add Property to Material' button in the 'Materials' panel.

Cij	
1	20.0
2	
3	
4	9.75
5	9.75
6	

Assign Materials to Pixels in the Microstructure

The screenshot shows the OOF2 software interface with the 'Materials' task selected. The 'Property' panel on the left shows a tree view with 'Electric', 'Orientation', 'Couplings', and 'ThermalExpansion'. The 'Material' panel on the right shows a list of properties: 'letter_material', 'Mechanical:Elasticity:Isotropic:stiff', 'Color:dark', and 'Couplings:ThermalExpansion:Isotropic'. A dialog box titled 'Assign material letter_m' is open, showing 'microstructure = oofdemo.png' and 'pixels = letters'. A context menu is open over the 'letters' selection, with 'letters' highlighted. The 'Assign Material to Pixels...' button in the background is circled in red and labeled '1', and the 'OK' button in the dialog is circled in red and labeled '3'.

Display the Assigned Materials

The screenshot displays the OOF2 Graphics 1 application window. The 'Layer' menu is open, with the 'New...' option highlighted by a red circle and a yellow callout box containing the number '1'. The main graphics area shows a pixelated image of a yellow and black archway against a blue background. Below the main window, the 'OOF2 Graphics Layer Editor' dialog is open. It features a 'Displayed Object' section with 'category = Microstructure' and 'object = oofdemo.png'. The 'Display Methods' section has 'Material' selected. At the bottom of the dialog, there are buttons for 'New...', 'Edit...', 'Copy', and 'Delete'. A yellow callout box labeled 'Layer Editor' points to the dialog. The main window's menu bar includes 'File', 'Layer', 'Settings', and 'Windows'. The Layer Editor's menu bar includes 'File', 'Settings', and 'Windows'. The main window's toolbar includes 'New...', 'Edit...', 'Delete', 'Hide', 'Show', 'Hide Contour Map', 'Show Contour Map', 'Raise', 'Lower', and 'Reorder All'. The Layer Editor's toolbar includes 'New...', 'Edit...', 'Copy', and 'Delete'. The main window's status bar includes 'Destination = Graphics_1' and a 'Send' button.

1

OOF2 Graphics 1

File Layer Settings Windows

New... Ctrl+N

Edit... Ctrl+E

Delete

Hide Ctrl+H

Show Ctrl+S

Hide Contour Map

Show Contour Map

Raise

Lower

Reorder All

OOF2 Graphics Layer Editor

File Settings Windows

Displayed Object

category = Microstructure

object = oofdemo.png

Display Methods

Material

Layer Editor

New... Edit... Copy Delete

New Layer

Destination = Graphics_1 Send

The Layer Editor

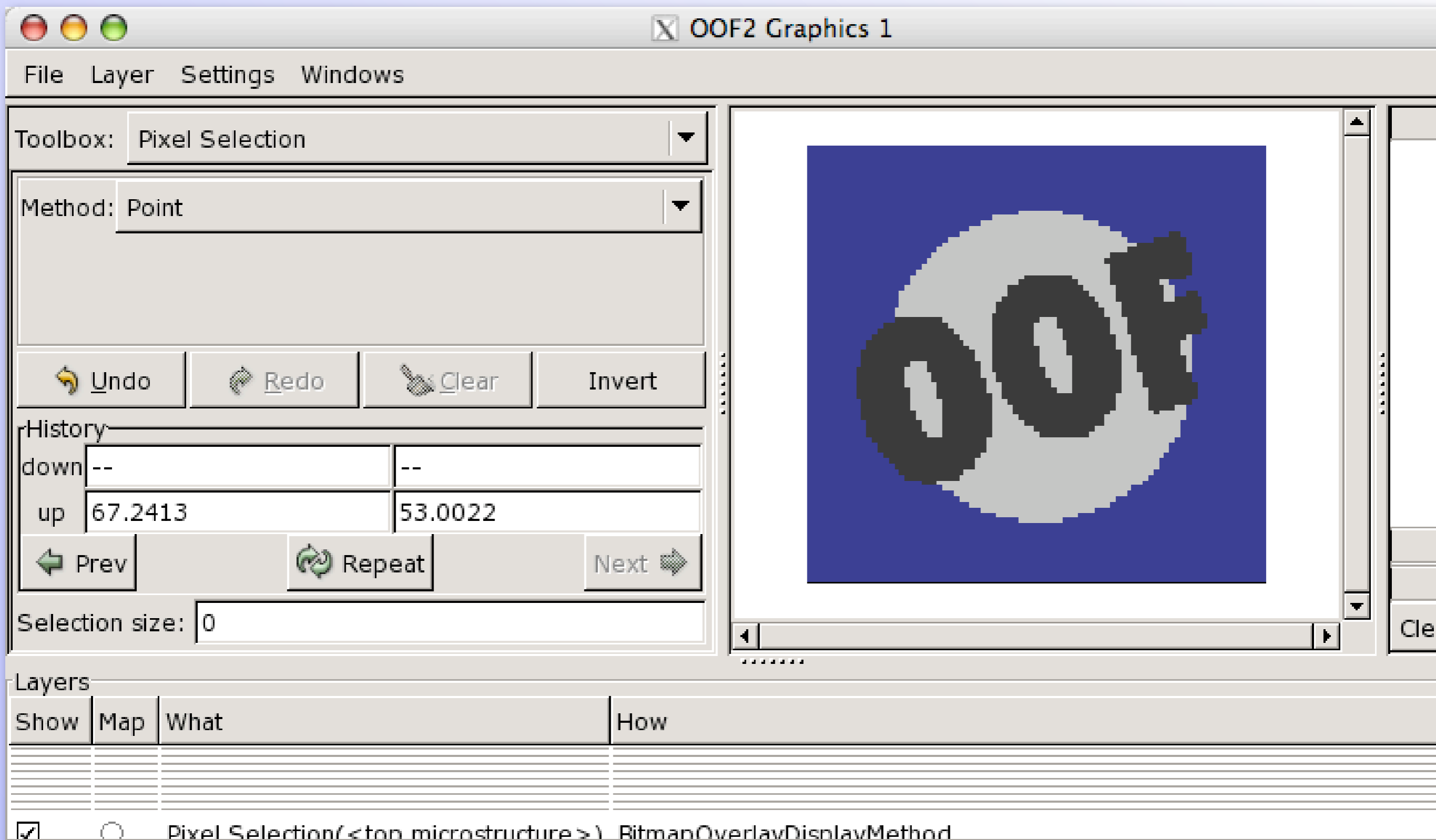
The screenshot shows the OOF2 Graphics Layer Editor window. The interface includes a menu for selecting a category, a list of display methods, and a configuration panel for a selected method. Red annotations and arrows guide the user through the following steps:

- 1. Select category**: A red circle highlights the 'category =' dropdown menu in the 'Displayed Object' section. A red arrow points from this circle to the 'Microstructure' option in the dropdown list.
- 2**: A red circle highlights the 'New' button in the 'Display Methods' section. A red arrow points from this circle to the 'Material' option in the 'Display Methods' list.
- 3. Select Display Method**: A red circle highlights the 'Material' option in the 'Display Methods' list. A red arrow points from this circle to the 'Material' option in the 'New Display Method for Microstructure' dialog box.
- 4**: A red circle highlights the 'OK' button in the 'New Display Method for Microstructure' dialog box. A red arrow points from this circle to the 'Material' option in the 'Display Methods' list.

The 'New Display Method for Microstructure' dialog box shows the following configuration:

- Method: Material
- no_material = Gray
- no_color = RGBColor
- Red: 0
- Green: 0
- Blue: 1

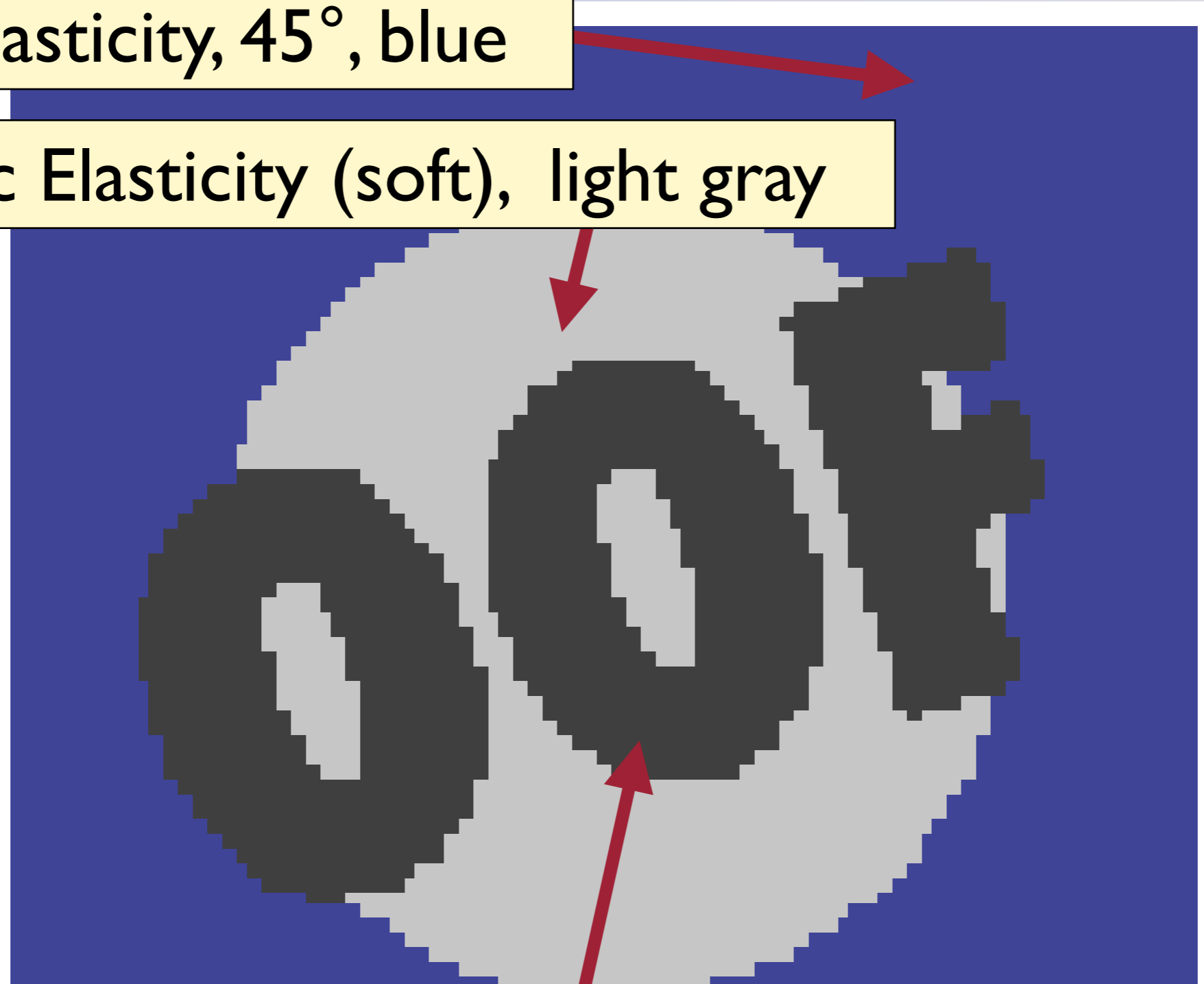
Material Color displayed in the Graphics Window



The Material Map

Cubic Elasticity, 45° , blue

Isotropic Elasticity (soft), light gray



Isotropic Elasticity (hard), thermal expansion, dark gray

The Pixel Info Toolbox

OOOF2 Graphics 1

File Layer Settings Windows

Toolbox: Pixel Info

x= 51
y= 20

Update Clear

image= oofdemo.png:oofdemo.png

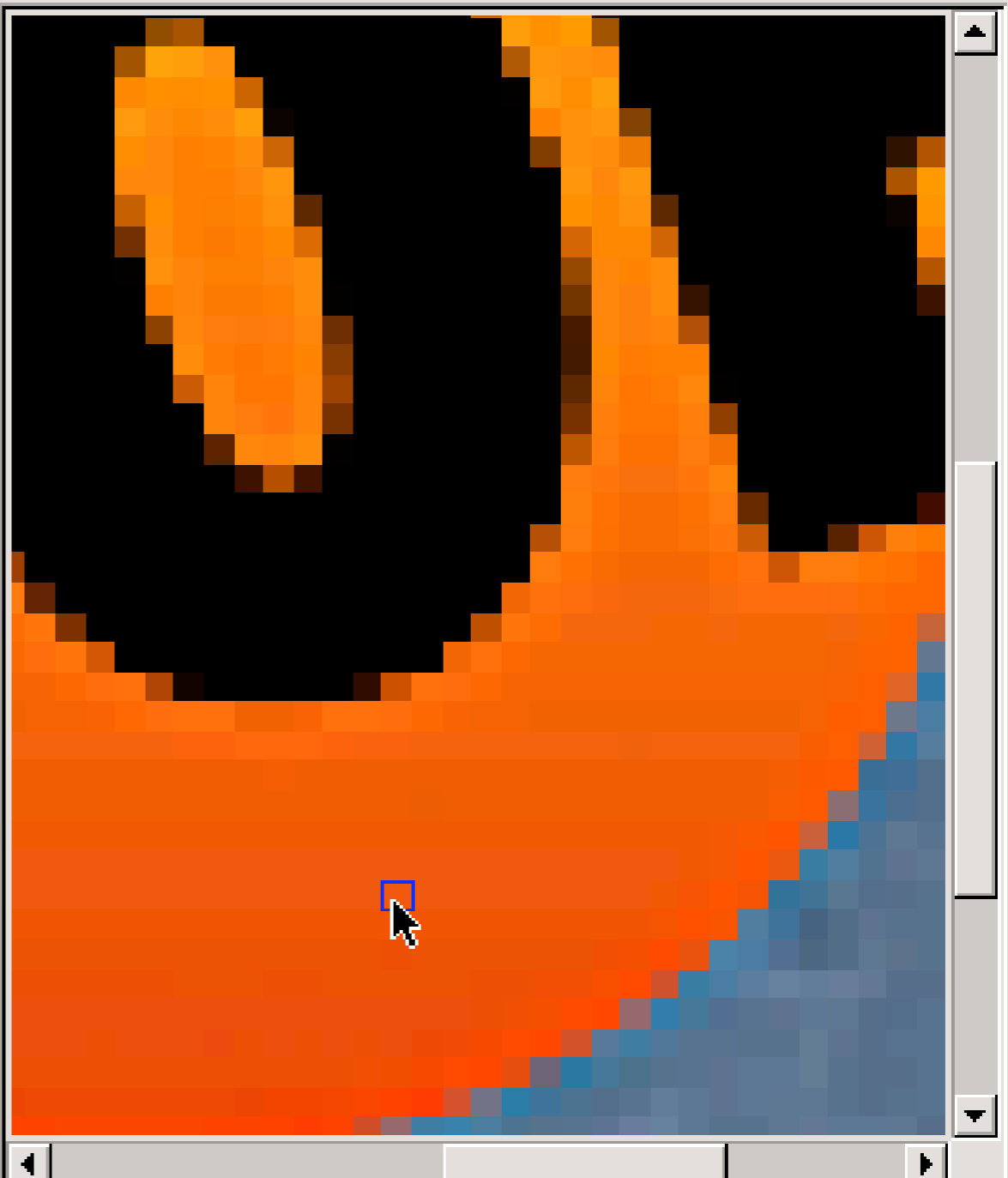
RGB HSV

red= 0.92475776302738999
green= 0.25926604104676892
blue= 0.060120546272983903

microstructure= oofdemo.png
circle

pixel groups=

material= circle_material



Layers

Show	Map	What	How
<input type="checkbox"/>	<input type="radio"/>	Microstructure(oofdemo.png)	MicrostructureMaterialDisplay
<input checked="" type="checkbox"/>	<input type="radio"/>	Image(oofdemo.png)	BitmapDisplayMethod

Create a Skeleton

The screenshot shows the OOF2 software interface with the 'Skeleton' task selected. The 'Task' dropdown is set to 'Skeleton'. The 'Microstructure' is 'oofdemo.png' and the 'Skeleton' is 'skeleton'. The 'New...' button is circled in red and labeled with a yellow box containing the number '1'. A red arrow points from this button to the 'New skeleton' dialog box. The dialog box has the following fields: 'name' (checkbox 'automatic'), 'x_elements' (10), 'y_elements' (10), and 'skeleton_geometry' (QuadSkeleton). The 'OK' button is circled in red and labeled with a yellow box containing the number '2'. A red arrow points from the 'OK' button to the 'Skeleton Modification' panel. The 'Skeleton Modification' panel shows a grid of blue and black pixels with a red grid overlay. The 'Skeleton Status' panel shows: No. of Nodes: 121, No. of Elements: 100, No. of triangles: 0, No. of quads: 100. The 'Skeleton Modification' panel has a 'Preview' button at the bottom left.

File Settings Windows Help

Task: Skeleton

Microstructure= oofdemo.png Skeleton= skeleton

New... Simple... Rename... Copy... Delete Save...

Skeleton Status

No. of Nodes: 121
No. of Elements: 100
No. of triangles: 0
No. of quads: 100

Skeleton Modification

method:
targets:
criterion:
degree:
alpha:
Preview

New skeleton

name = automatic

x_elements = 10

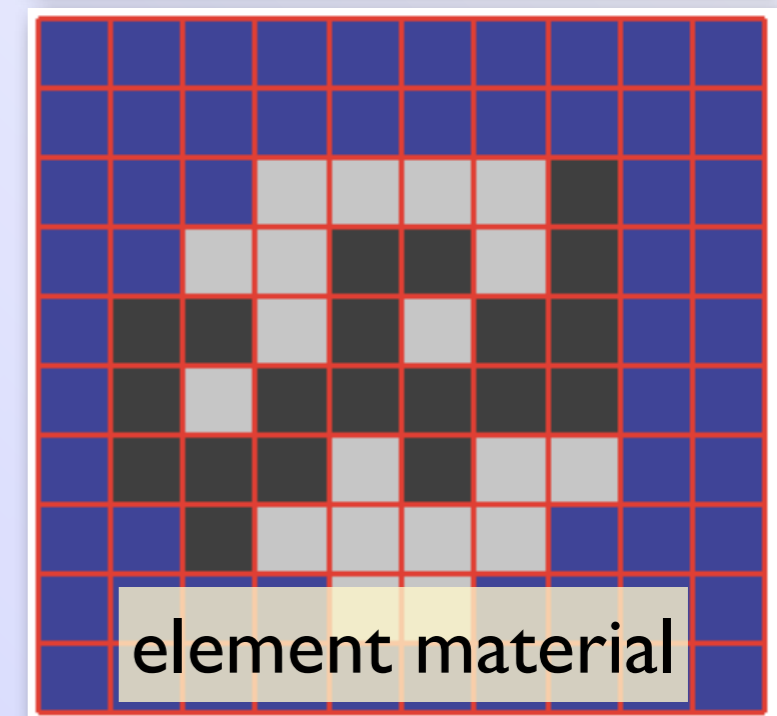
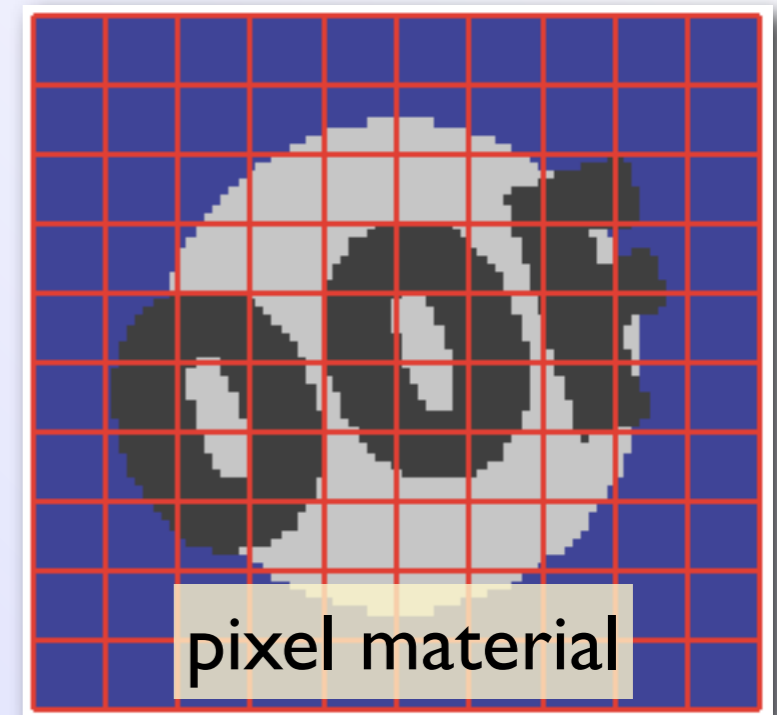
y_elements = 10

skeleton_geometry = QuadSkeleton

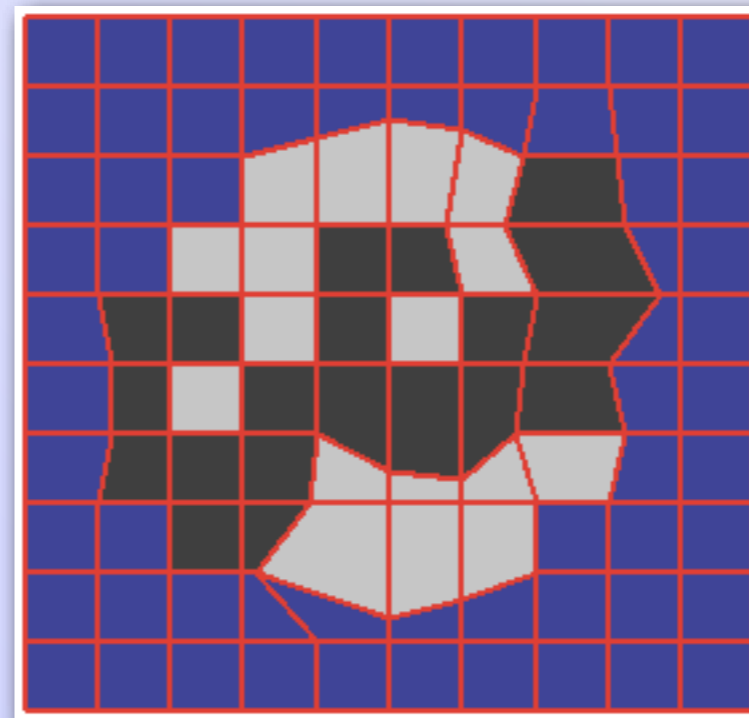
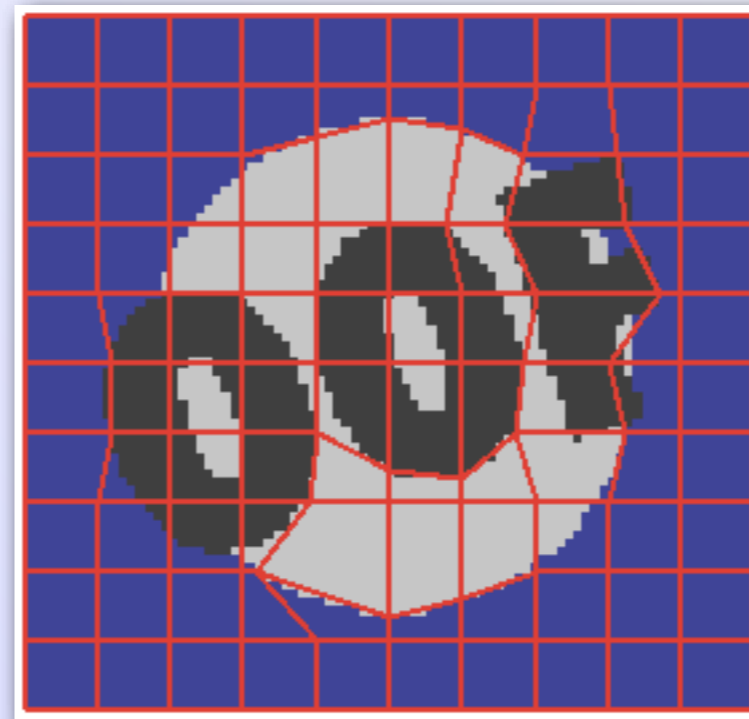
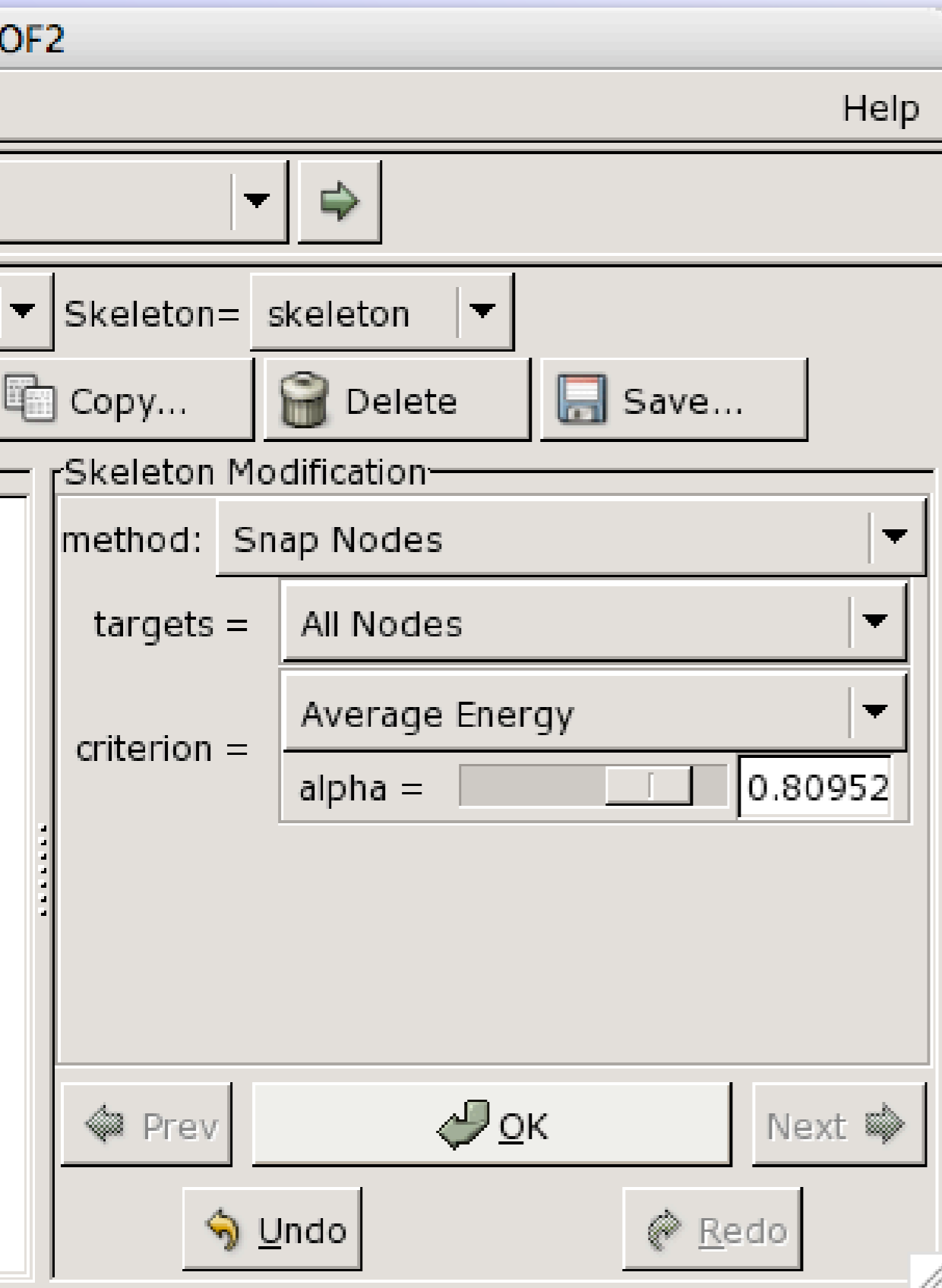
OK Cancel

Adapt the Skeleton to the Microstructure

- ◆ Element material is determined by dominant pixel material.
- ◆ Skeleton needs to be adjusted in order to be a good representation of the Microstructure.
 - ◆ Refine (subdivide) elements.
 - ◆ Move nodes.
 - ◆ Remove bad elements.



Snapping Nodes

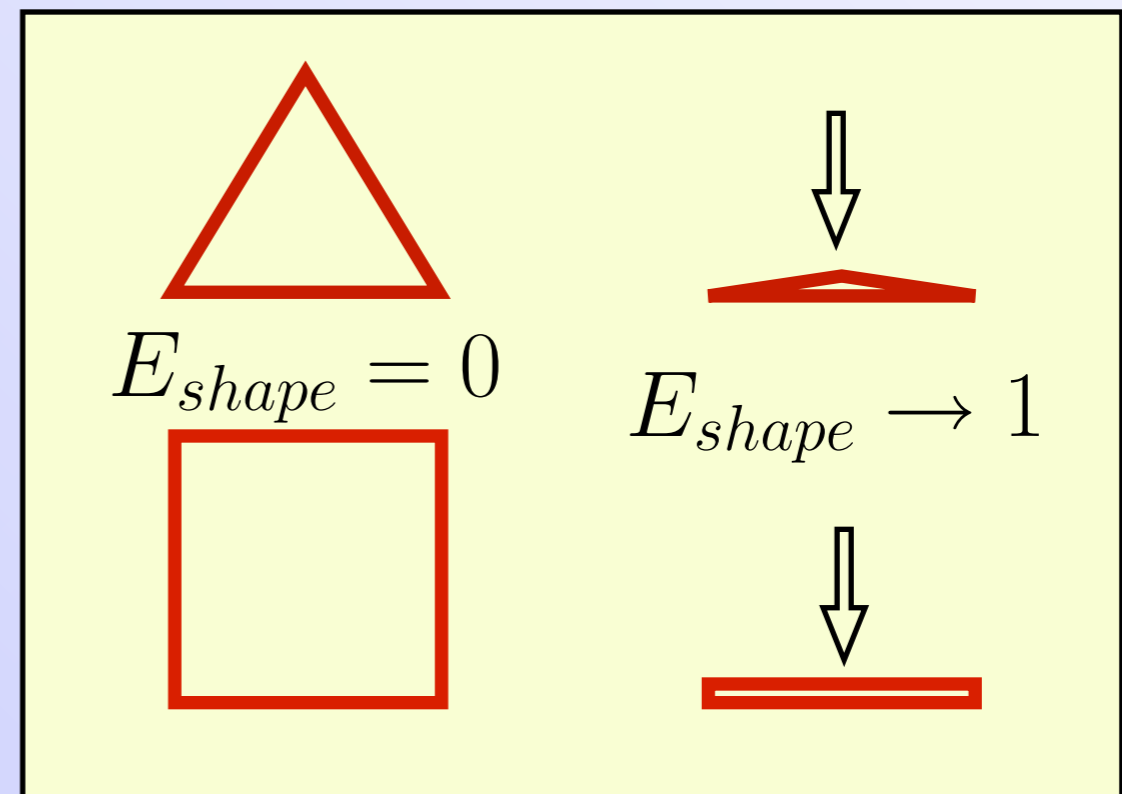
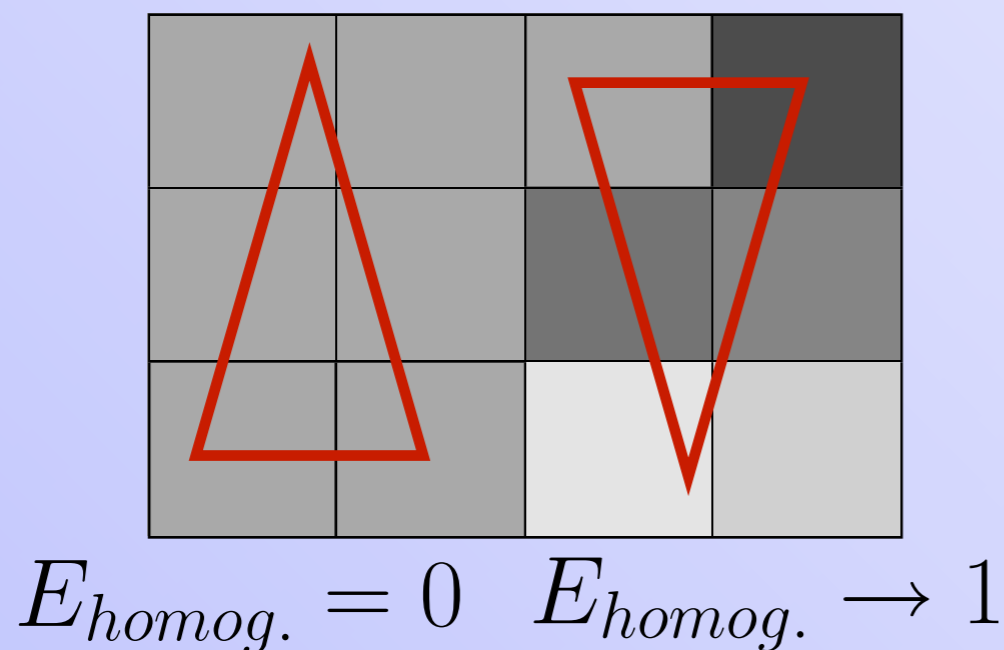


Moves nodes to boundaries between pixels of different types, if doing so will reduce the “effective energy”.

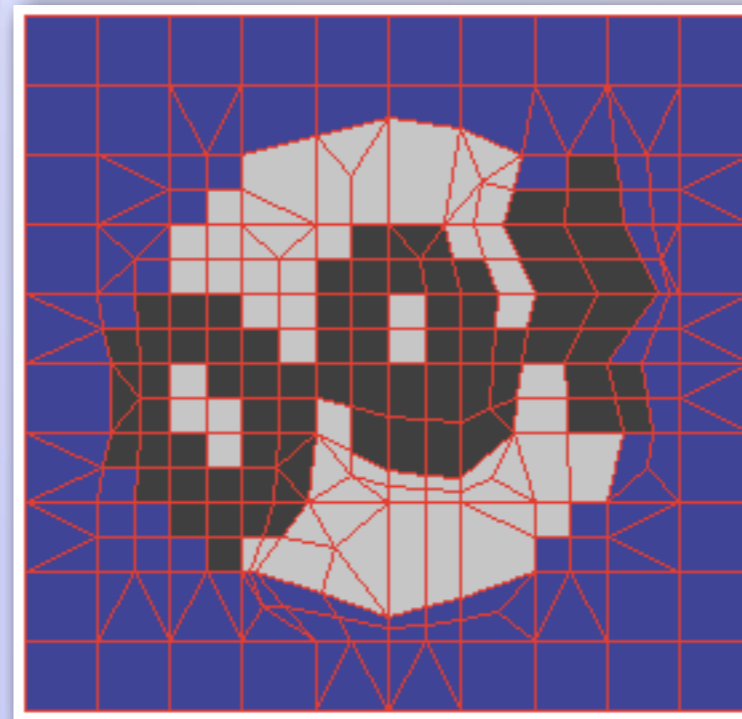
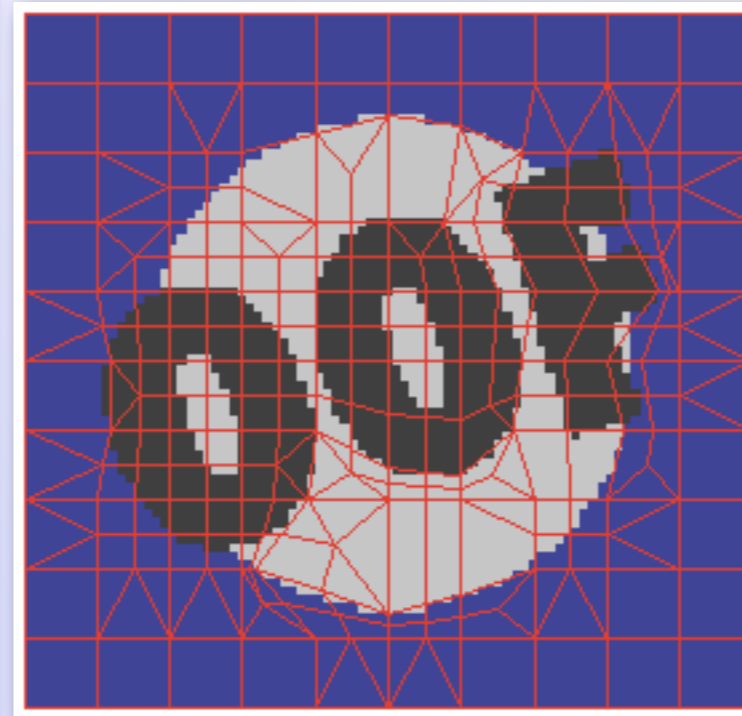
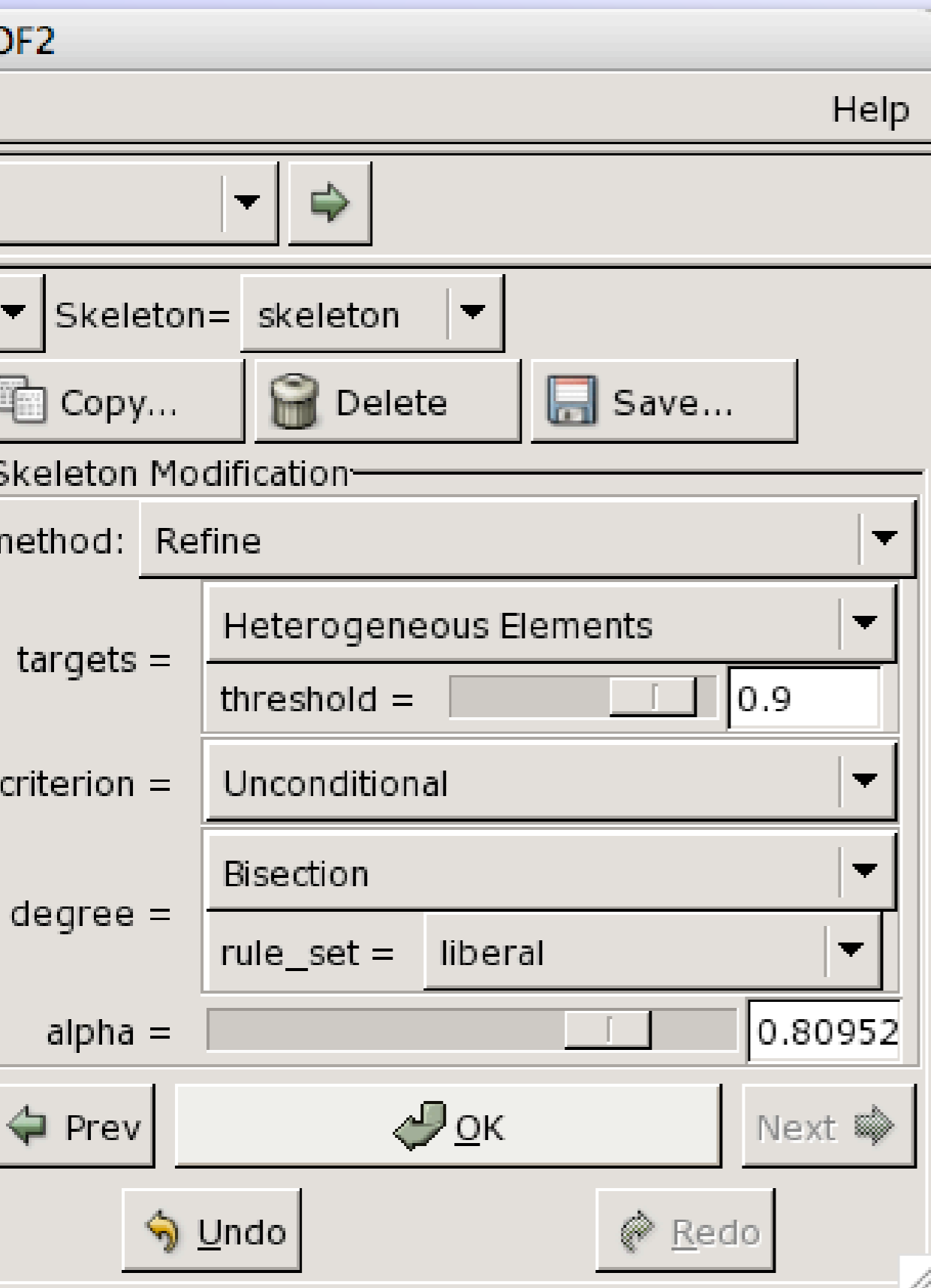
Effective Energy E of a Skeleton Element

- ◆ Good elements have small E .
- ◆ Many operations try to reduce E .
- ◆ E depends on element homogeneity & shape.

$$E = \alpha E_{\text{homog.}} + (1 - \alpha) E_{\text{shape}}$$



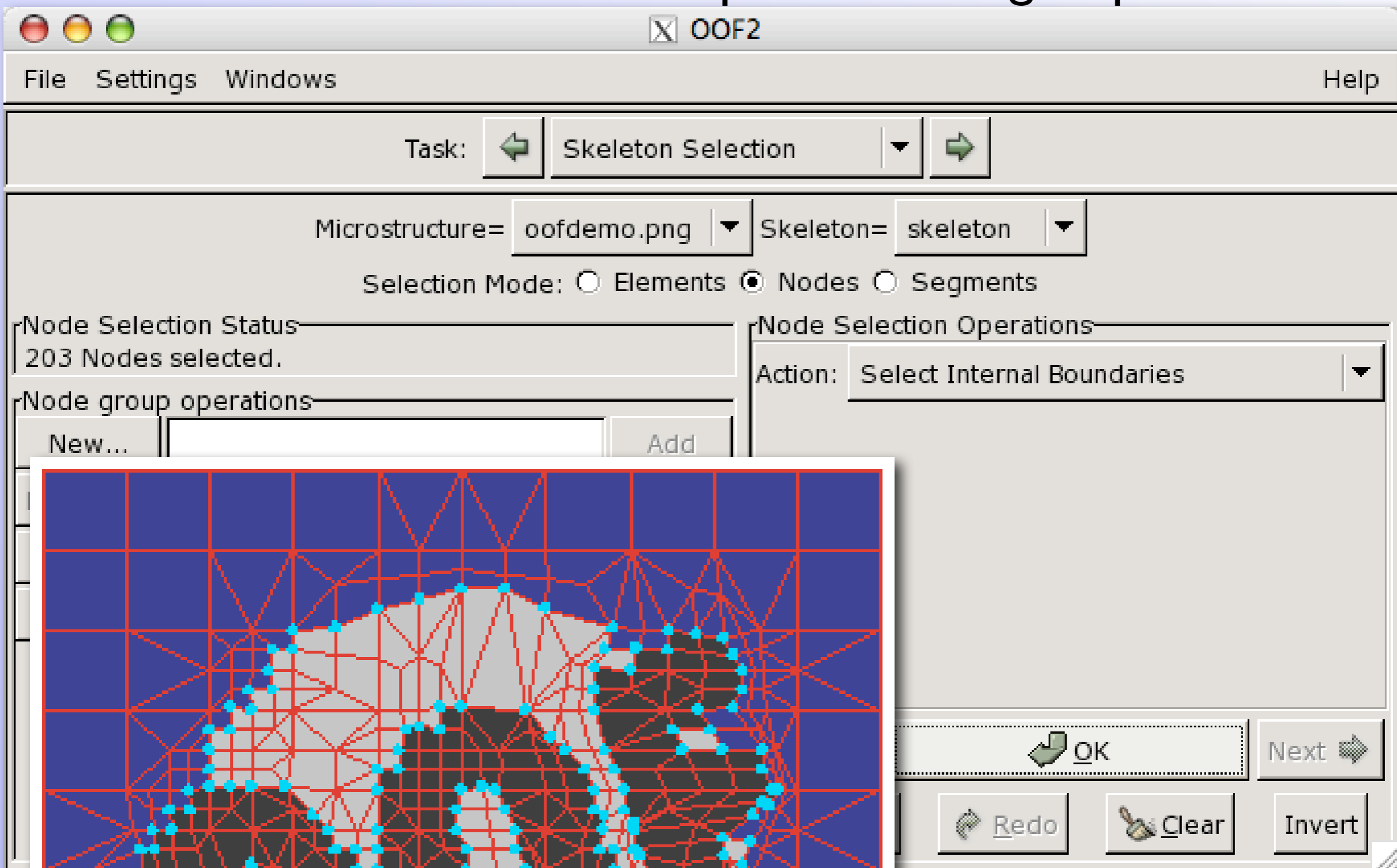
Refining Elements



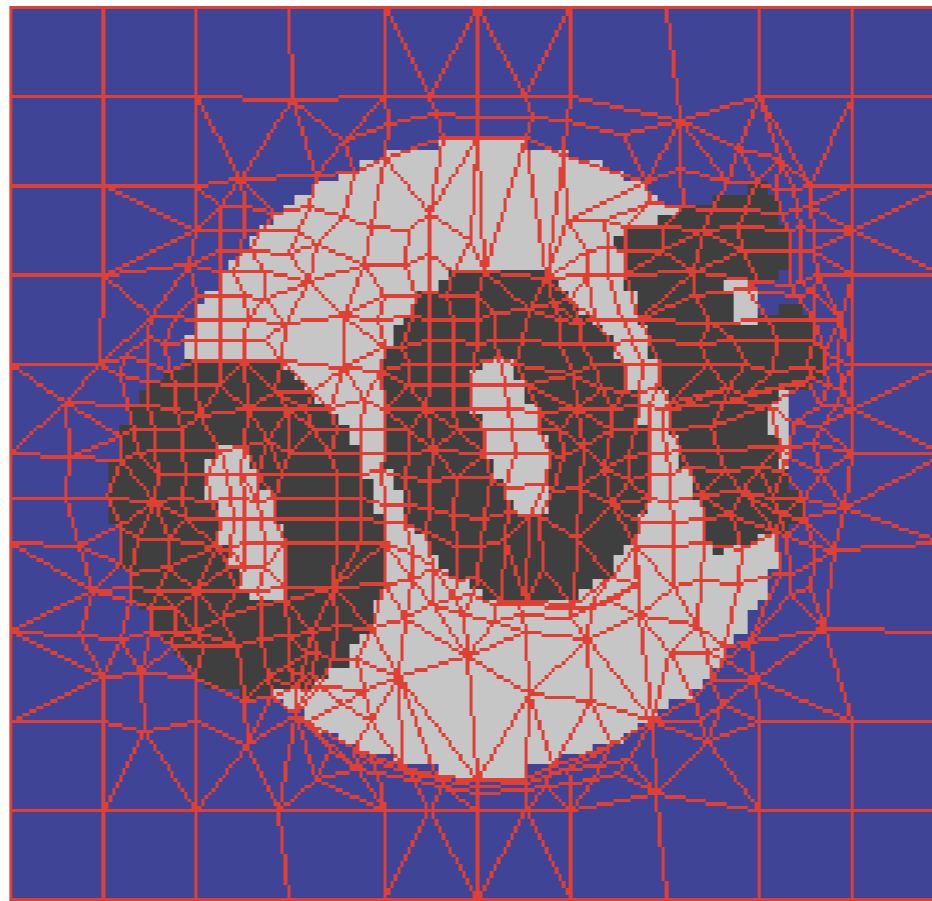
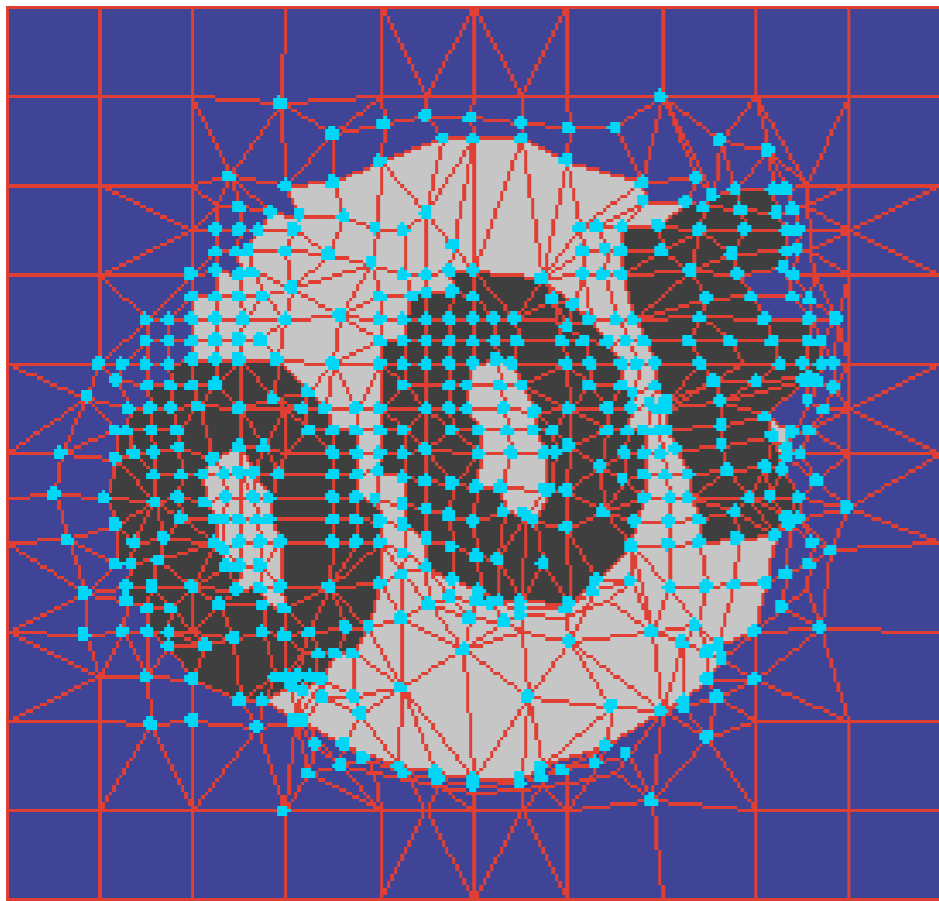
Subdivide elements according to various criteria: high E, heterogeneous, selected, hetero. edges, etc.

Skeleton Selection Page

Select skeleton components and group them.



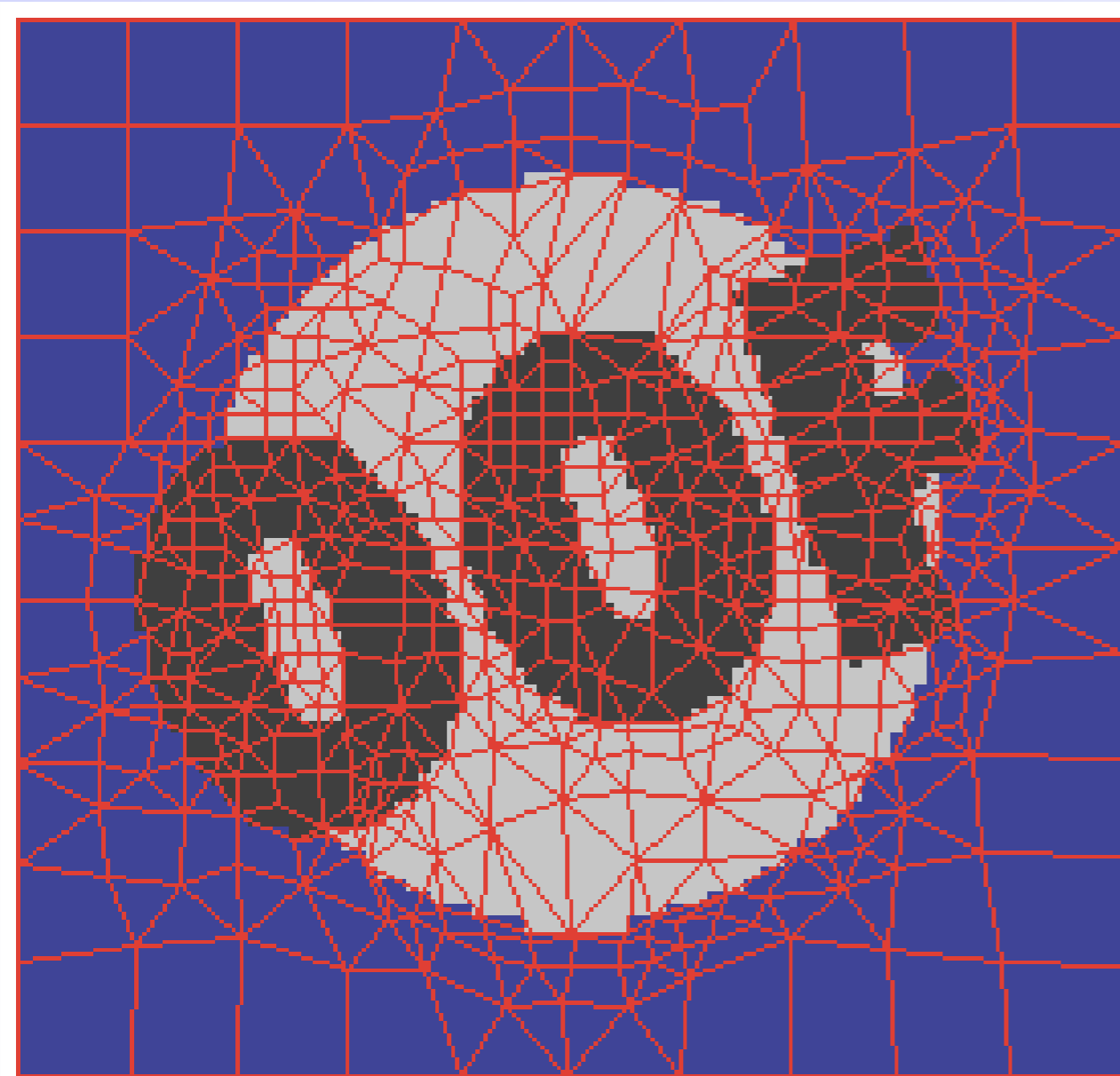
Annealing Selected Nodes



Move nodes
at random
to reduce E .

Final Skeleton

(After using a few additional tools...)

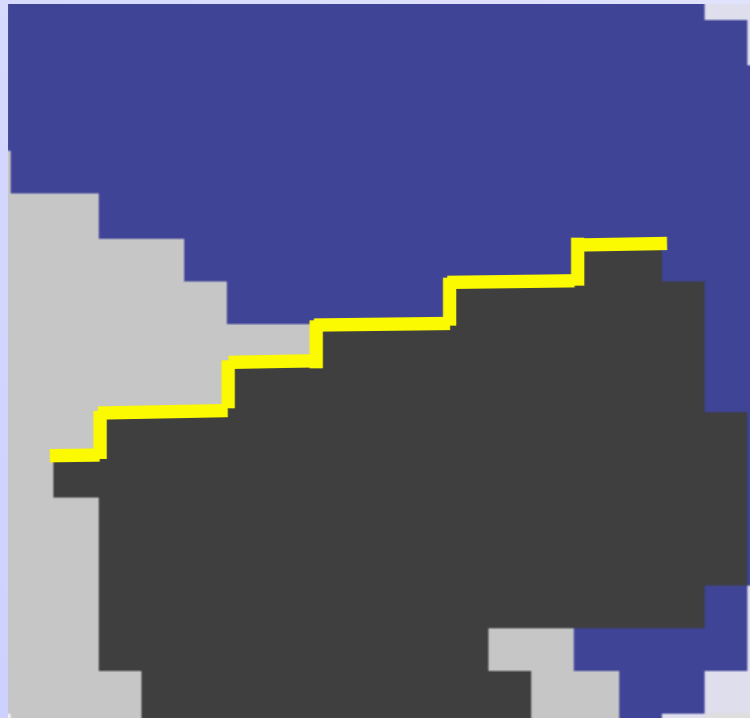


Is this good enough?

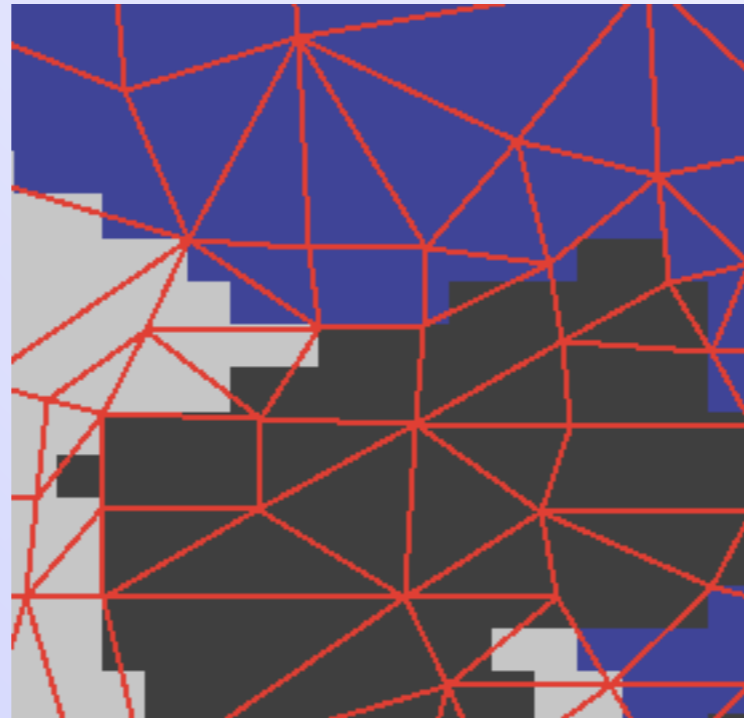
When to Stop?

- ◆ Micrograph is an approximation of reality.
- ◆ Material Map is an approximation of Micrograph.
- ◆ Skeleton is an approximation of Material Map.
- ◆ Finite Element solution is an approximate solution on the Skeleton.
- ◆ There's no point in resolving nonphysical pixel level detail!

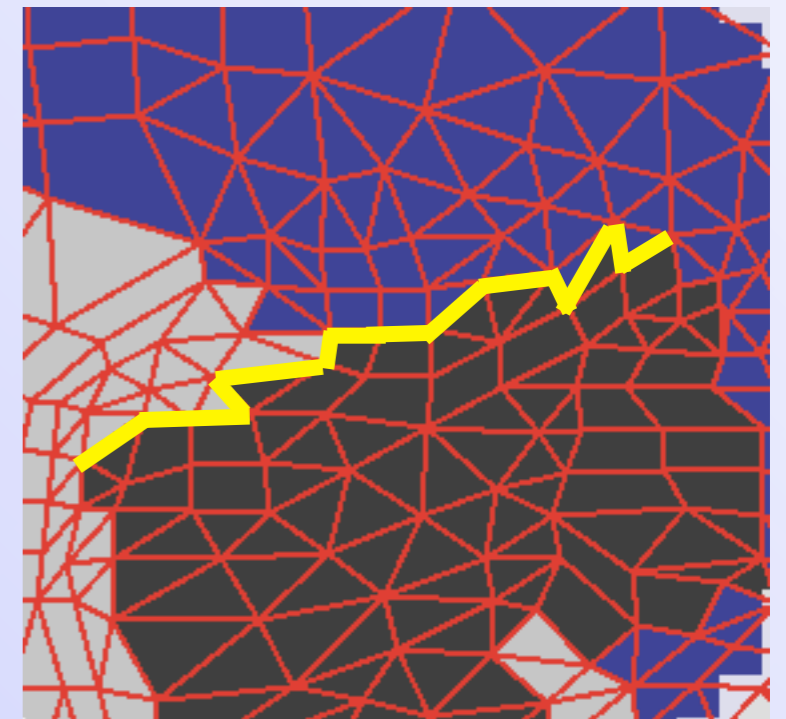
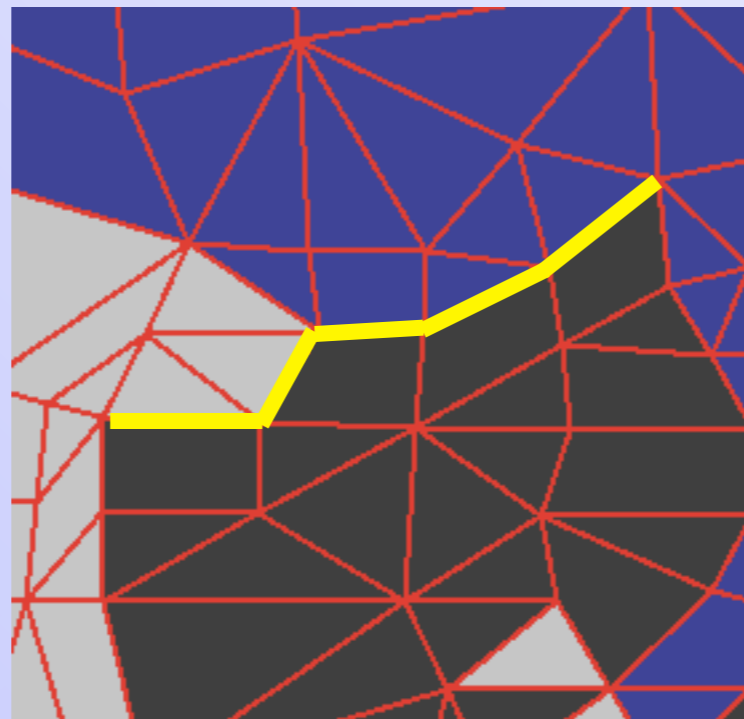
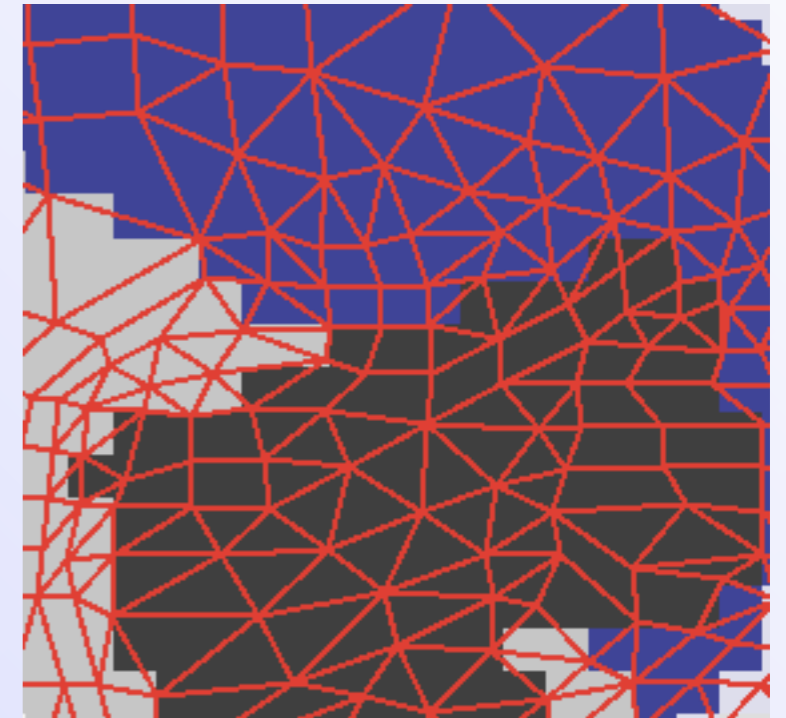
Material Map



Coarse Skeleton



Over-refined Skeleton



The FE Mesh Page

The screenshot displays the 'FE Mesh' task page in a software application. A dialog box titled 'Create a new mesh' is open, allowing the user to configure mesh parameters. The dialog includes a 'name' field (set to 'automatic'), 'mapping order' (1), 'interpolation order' (2), '3-sided element' (T3_6), and '4-sided element' (Q4_8). The 'OK' button is highlighted with a red circle and a callout '4'. A red arrow points from the 'New...' button in the 'Microstructure' section (callout '1') to the dialog box. Other callouts include '2' for the 'mapping order' dropdown, '3' for the 'interpolation order' dropdown, and '4' for the 'OK' button. The background interface shows the 'FE Mesh' task, 'Microstructure' (oofdemo.png), 'Skeleton' (skeleton), and 'Mesh' (mesh) dropdowns. Below these are buttons for 'New...', 'Rename...', 'Copy...', 'Delete', and 'Save...'. The 'Mesh Information' panel shows: No. of Nodes: 2014, No. of Elements: 3 sided element: 4 sided element: The 'Element Operations' panel shows 'Method: Adaptive Mesh Refinement' and 'Z-Z Estimator'.

Define, Activate, & Initialize Fields

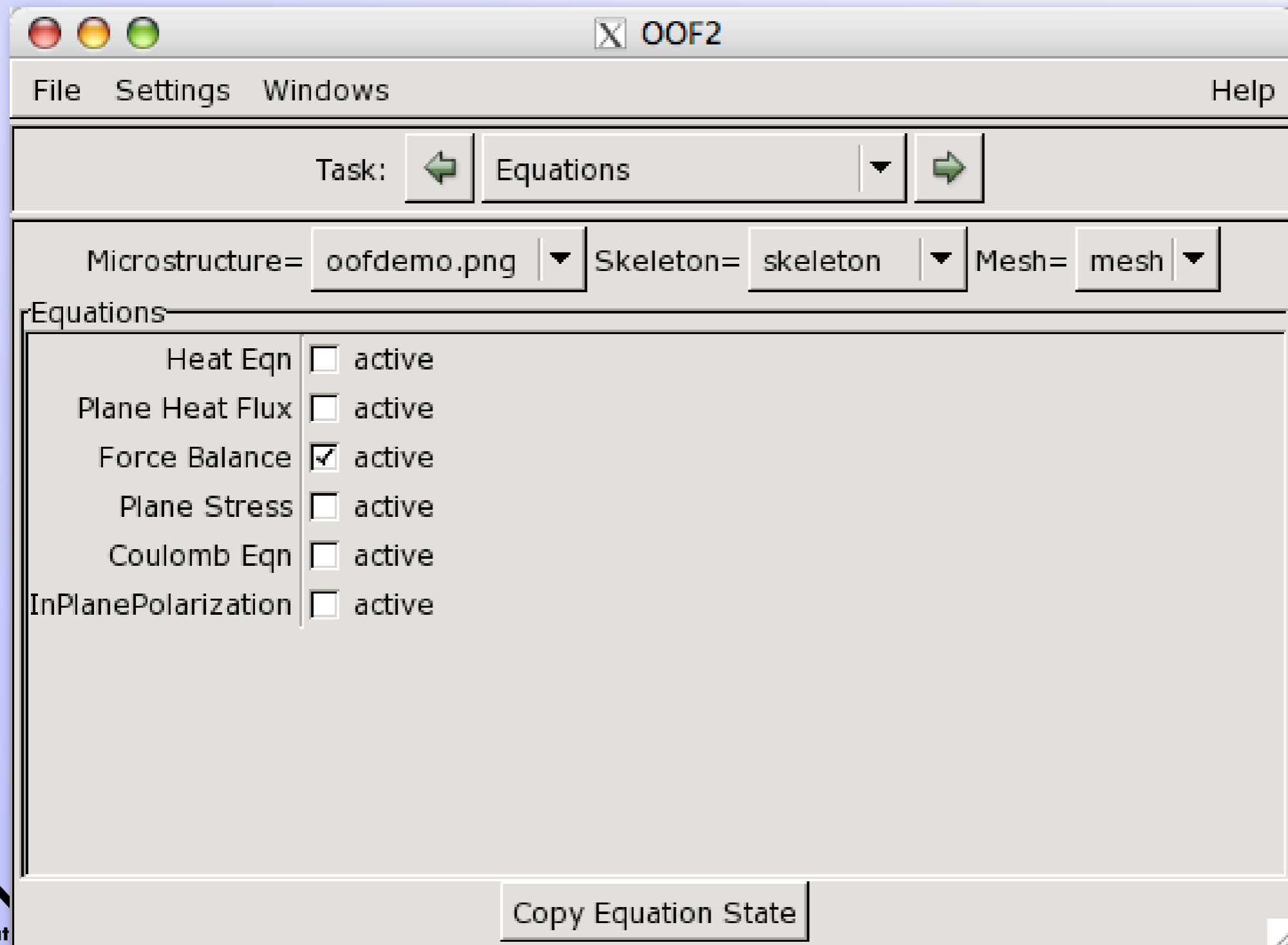
- Defined fields have values.
- Active fields will be solved for.

The screenshot shows the OOF2 software interface. At the top, the window title is 'OOF2'. The menu bar includes 'File', 'Settings', 'Windows', and 'Help'. Below the menu bar, there is a 'Task:' dropdown menu set to 'Fields'. Underneath, there are three dropdown menus for 'Microstructure=' (oofdemo.png), 'Skeleton=' (skeleton), and 'Mesh=' (mesh). The 'Fields' section contains a table with three rows: 'Temperature', 'Displacement', and 'Voltage'. Each row has three checkboxes: 'defined', 'active', and 'in-plane'. 'Temperature' has 'defined' checked. 'Displacement' has 'defined', 'active', and 'in-plane' checked. 'Voltage' has none checked. Below this is the 'Field Initialization' section, which contains a table with two columns: 'Field' and 'Initializer'. The 'Temperature' row shows '0.1' in the 'Initializer' column, while the 'Displacement' row shows '<uninitialized>'. At the bottom of the 'Field Initialization' section, there are two buttons: 'Set Initializer...' and 'Copy Field State...'. A small dialog box titled 'Initial' is open, showing 'initializer = Constant' and 'value = 0.1'. A dropdown menu is also visible, showing 'Constant', 'XYFunction', and 'Other Mesh'.

Field	defined	active	in-plane
Temperature	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Displacement	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Voltage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Field	Initializer
Temperature	0.1
Displacement	<uninitialized>

Choose which Equations to solve



Set Boundary Conditions

The image shows a screenshot of the OOF2 software interface. The main window is titled 'OOF2' and has a menu bar with 'File', 'Settings', and 'Windows'. Below the menu bar is a 'Task:' section with a left arrow and the text 'Boundary Conditions'. The main workspace shows 'Microstructure=' with a dropdown menu set to 'oofdemo.png' and 'Skeleton=' with a dropdown menu set to 'skele'. Below this is a 'Profile' table with columns 'Name' and 'Profile'. A yellow box with red text 'Profiles (reusable named functions)' is overlaid on the profile table. To the right, a 'New Boundary Condition' dialog box is open. It has a 'name =' field with a checkbox and the text 'automatic'. Below this is a dropdown menu set to 'Dirichlet'. The 'field =' dropdown is set to 'Displacement', and the 'field_component =' dropdown is set to 'x'. The 'equation =' dropdown is set to 'Force_Balance', and the 'eqn_component =' dropdown is set to 'Continuum Profile'. A yellow box with red text 'Choose Profile' is overlaid on the 'equation =' dropdown. Below this is a list of boundary types: 'top', 'right', 'left', 'bottom', 'topleft', 'bottomleft', 'topright', and 'bottomright'. A yellow box with red text 'Choose Boundary' is overlaid on the 'bottom' option. A yellow box with red text 'Boundary Conditions' is overlaid on the 'OK' button. A yellow box with red text '1' is overlaid on the 'New...' button in the bottom toolbar. A red arrow points from the '1' box to the 'name =' field. A yellow box with red text '2' is overlaid on the 'field_component =' dropdown. A yellow box with red text '3' is overlaid on the 'OK' button.

Profiles
(reusable named functions)

Choose Profile

Choose Boundary

Boundary Conditions

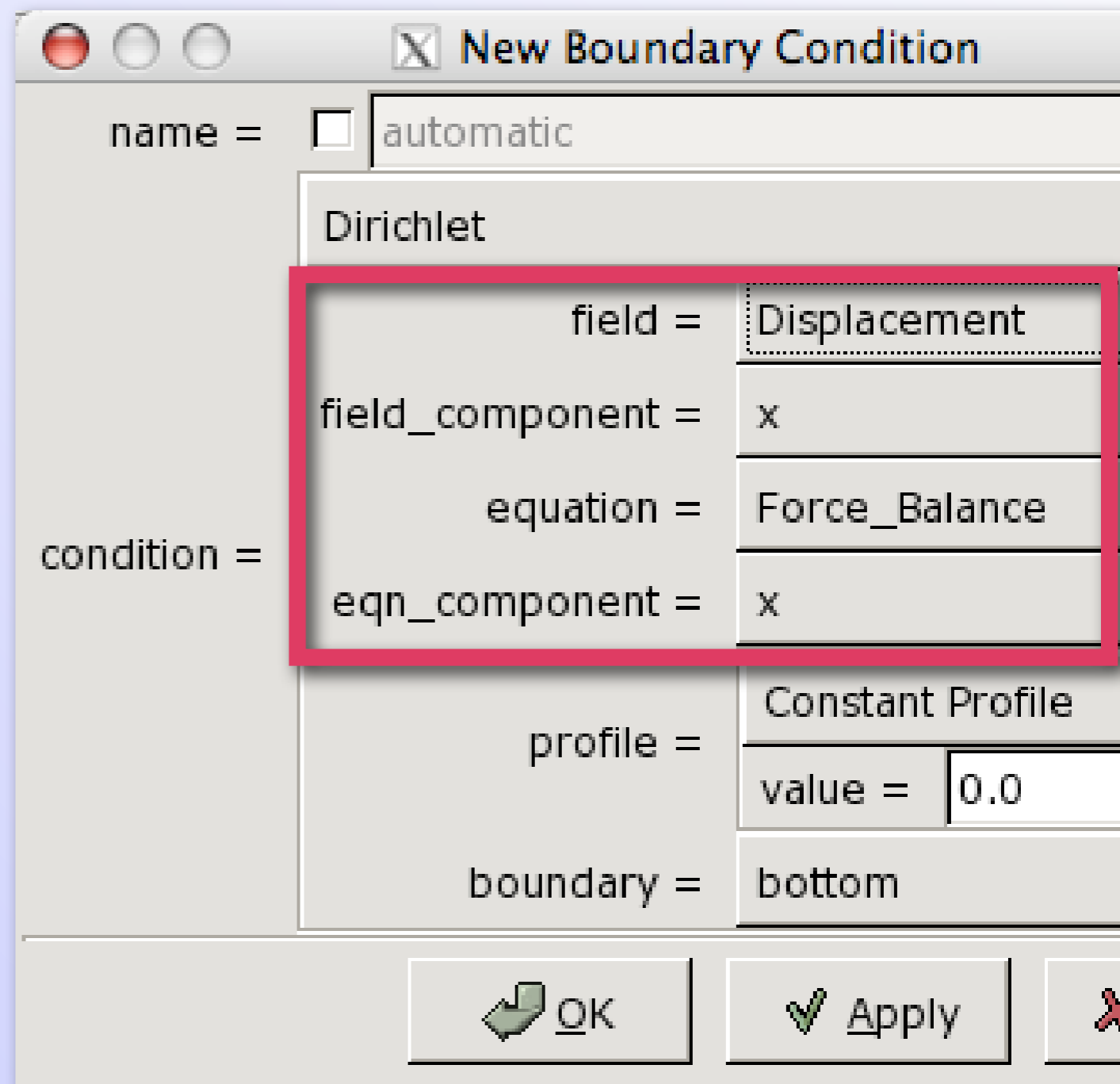
1

2

3

Why is it necessary to specify both a Field *and* an Equation for Dirichlet BCs?

- ◆ The Field specifies which degrees of freedom to hold fixed.
- ◆ One equation must be eliminated for each fixed degree of freedom.
- ◆ Arbitrary coupling terms make it unclear which equation to eliminate.



The Solver Page

File Settings Windows

Task: Solver

Microstructure= Skeleton=

Mesh Status

Stiffness Matrix: Symmetric
Solver: CGSolver
(max_iterations=1000,tolerance=1e-14)
(
)
Solution Status: completed

Message:
CG converged!
residual = 9.59799e-14 number of
completed iterations = 381

Solver

LinearDriver

method =

Solved Mesh alone

Solve

Contour Displays

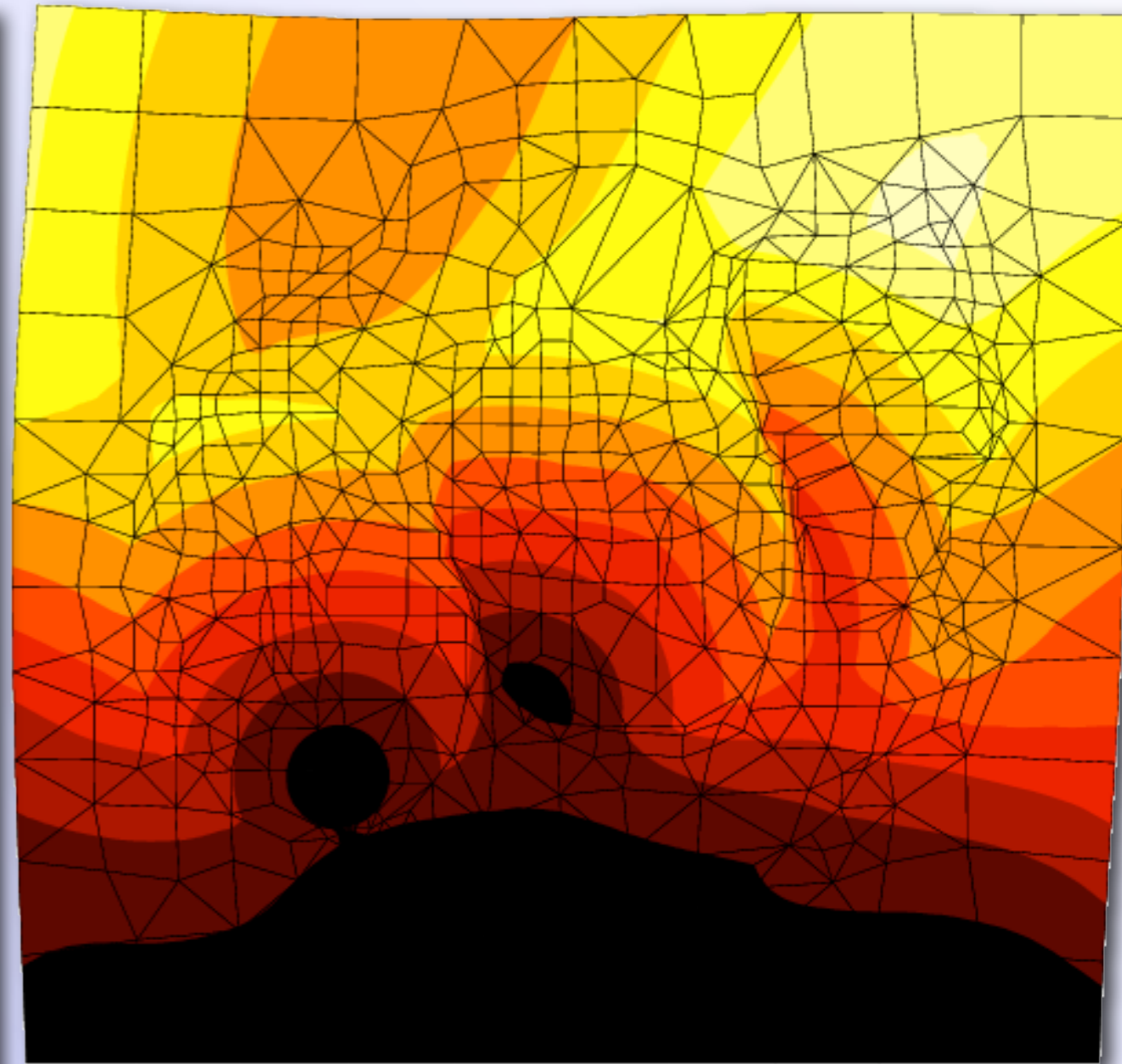
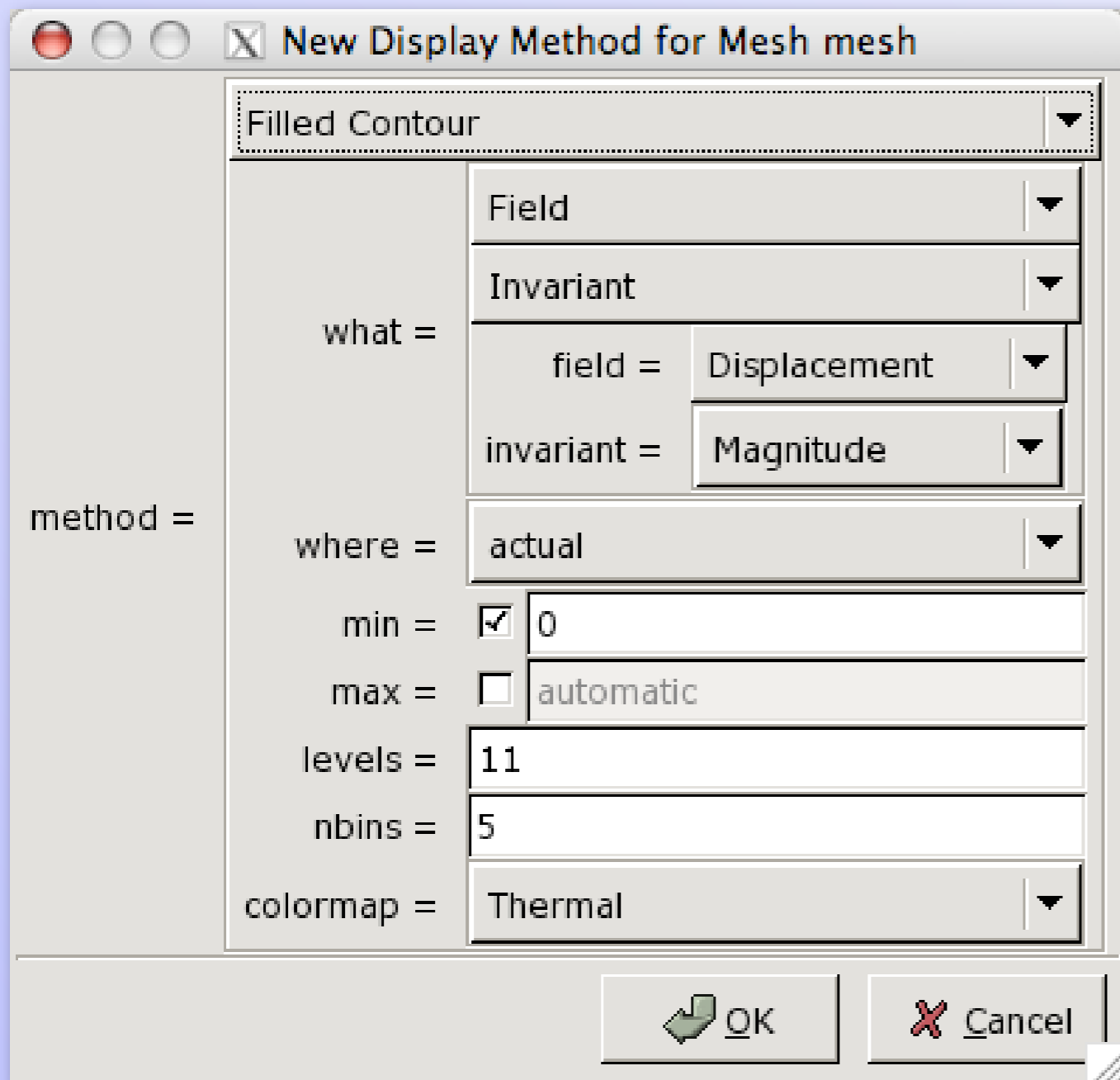
The image shows a software interface with several windows. The main window has a menu bar with 'File', 'Layer', 'Settings', and 'Windows'. A 'Toolbox' window is open, showing 'Position Info', 'Pixel:', 'Physical:', 'Zoom', and 'Zoom Factor' options. A 'Displayed Object' window is open, showing 'category = Mesh', 'object = skeleton', and 'mesh' in a dropdown menu. A 'New Display Method for Mesh mesh' dialog box is open, showing a 'method =' dropdown menu with 'Filled Contour' selected. A red circle highlights the 'New...' button in the layer list, with a red arrow pointing to the 'Filled Contour' option in the dialog box. Another red arrow points from the 'Mesh(mesh)' layer in the list to the 'New Layer' button.

Method	Color	Width
Element Edges		
Material Color		
Solid Fill		
Contour Line		
Filled Contour		
Info		
Cross Section		

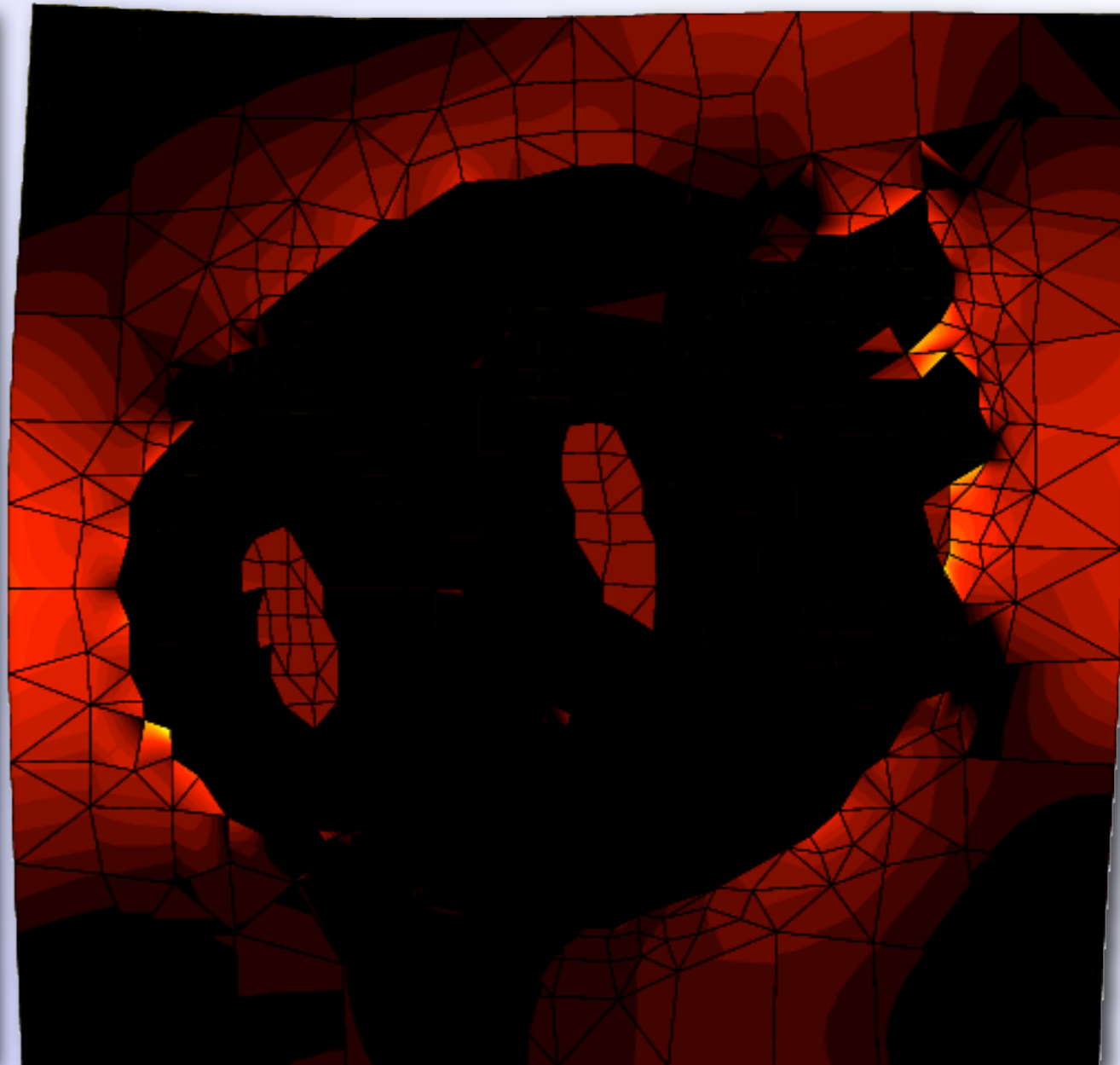
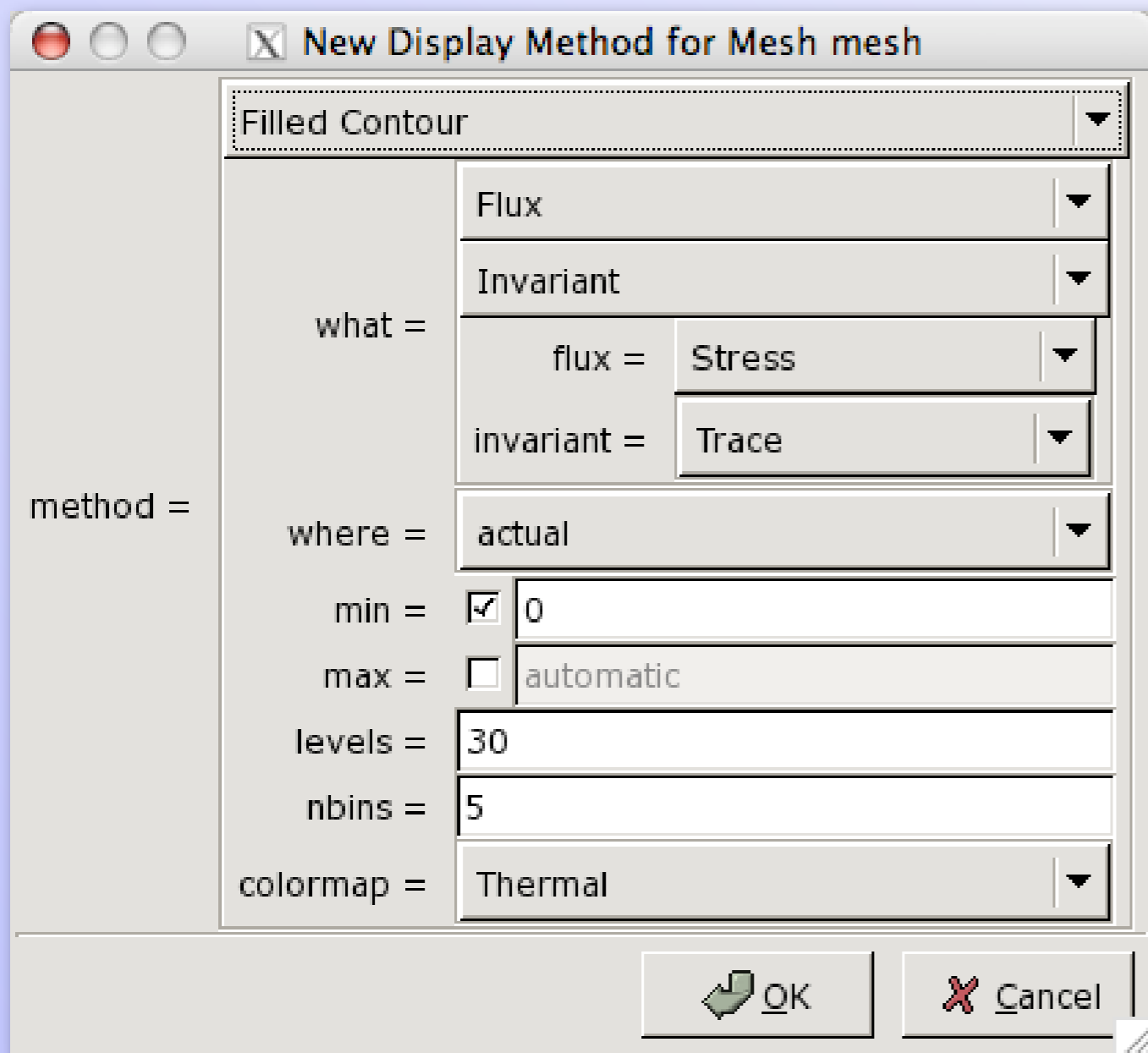
Layer	Object	Method
<input checked="" type="checkbox"/>	Mesh(mesh)	MeshEdgeDisplay
<input type="checkbox"/>	Skeleton(skeleton)	SkeletonEdgeDisplay
<input checked="" type="checkbox"/>	Image(oofdemo.png)	BitmapDisplayMethod

Double-click, or use Layer/Edit menu

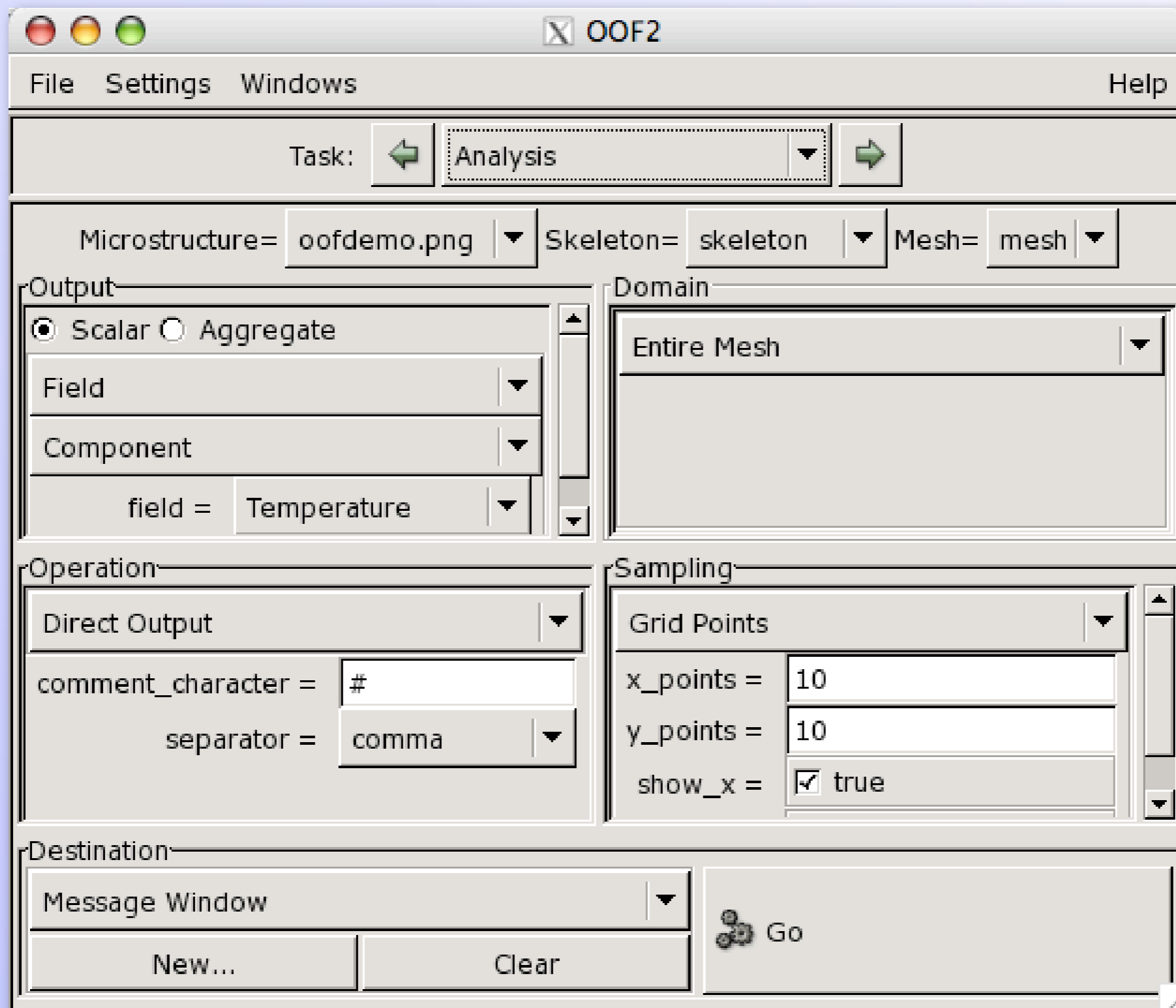
Magnitude of the Displacement Field



Trace of the Stress (Tensile only)



The Analysis Page



Output:
scalar or
multicom-
ponent

Domain:
entire mesh,
group, or
cross section

Operation:
direct or
statistical
output

Sampling:
interpolated on
grid or line,
at pixels,
integrated over
elements ...

For more examples, see the built-in tutorials.

For details, see the on-line manual.

<http://www.ctcms.nist.gov/~langer/oof2man/index.html>