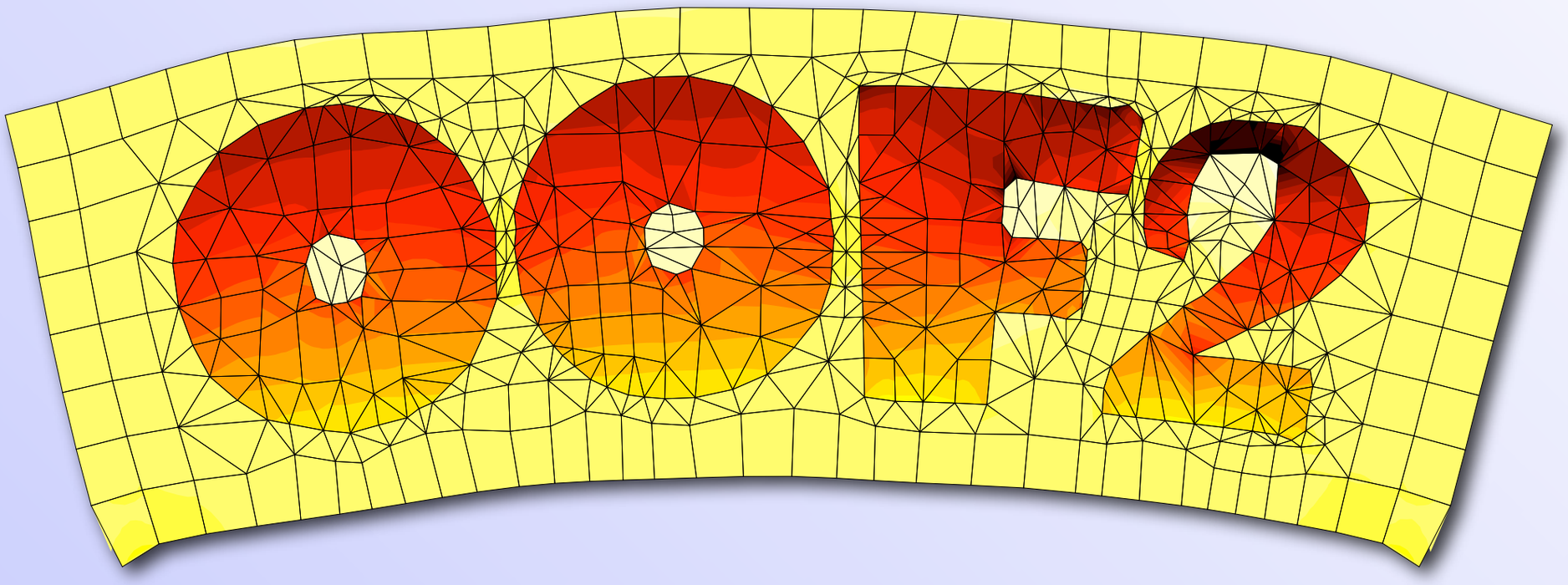
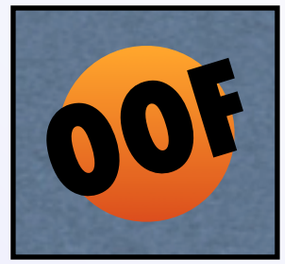


A Tour of the OOF2 GUI via A Simple Example Problem

National Institute of Standards and Technology
Technology Administration, U.S. Department of Commerce

A Simple Example



oofdemo.png

Start OOF2 by typing in a terminal window:

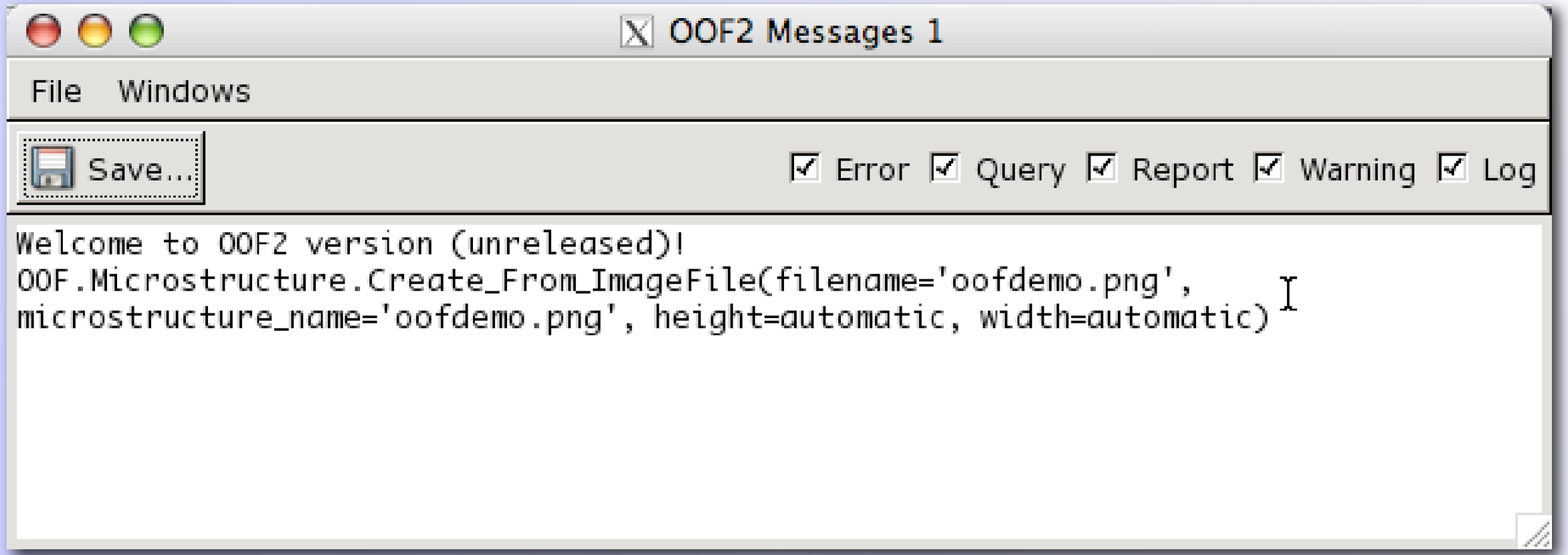
% `oof2 --image oofdemo.png`

menu bar

task page chooser

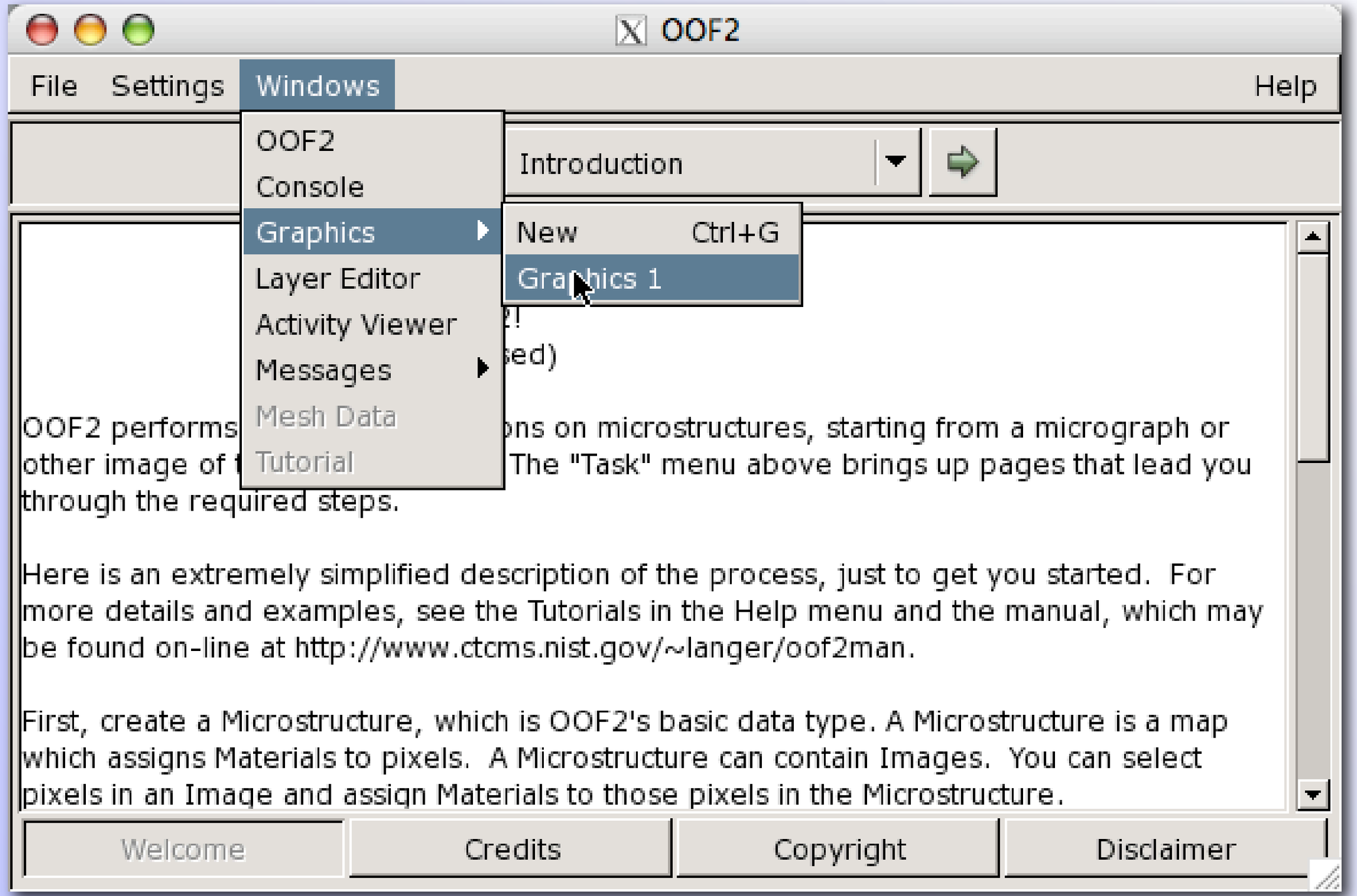
task page

The Message Window

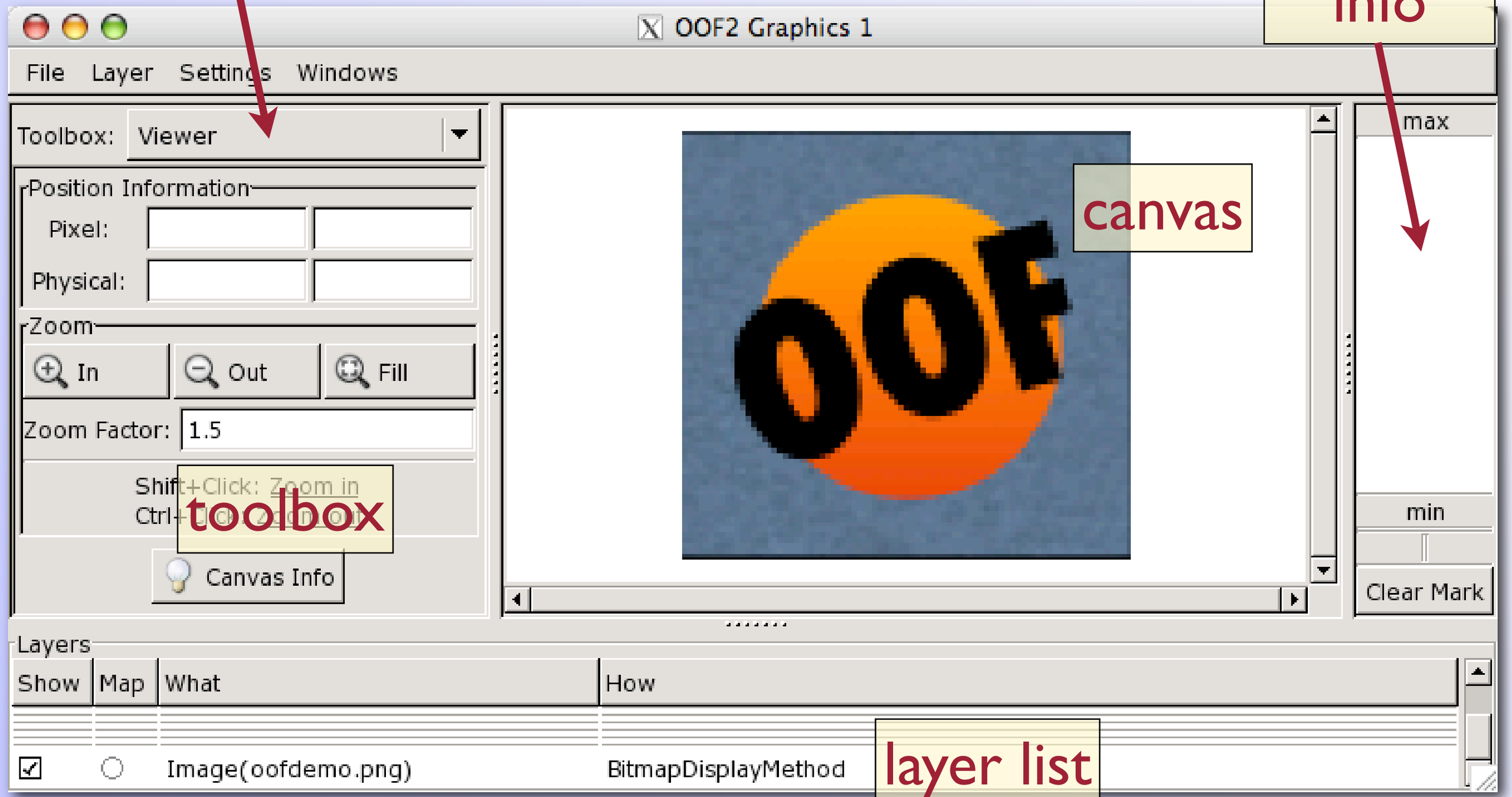


All consequential OOF2 commands have a text form that appears in the message window, can be saved in a file, edited, and reloaded. The file is a python script.

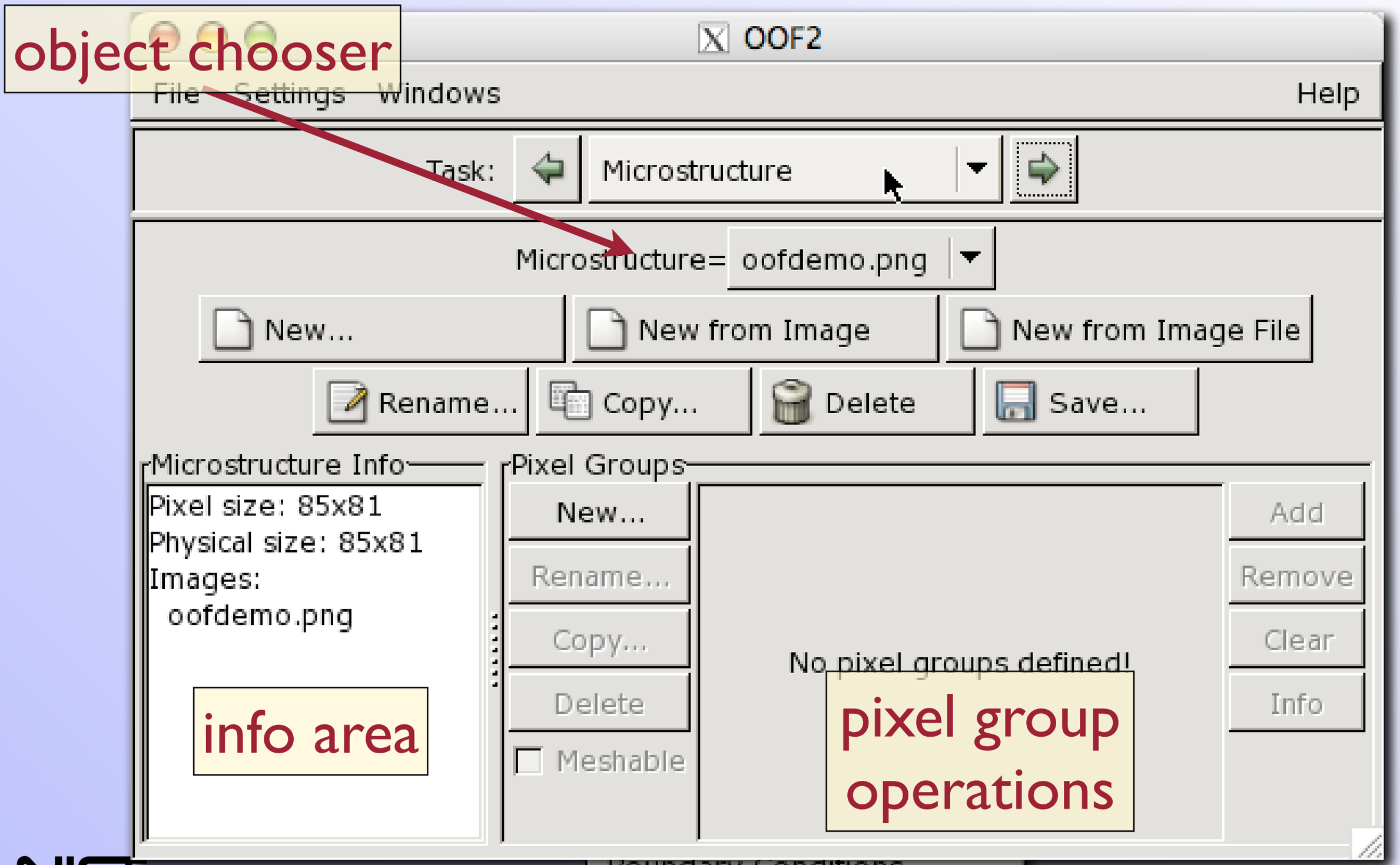
Open a Graphics Window



The OOF2 Graphics Window



Switch to the Microstructure Page

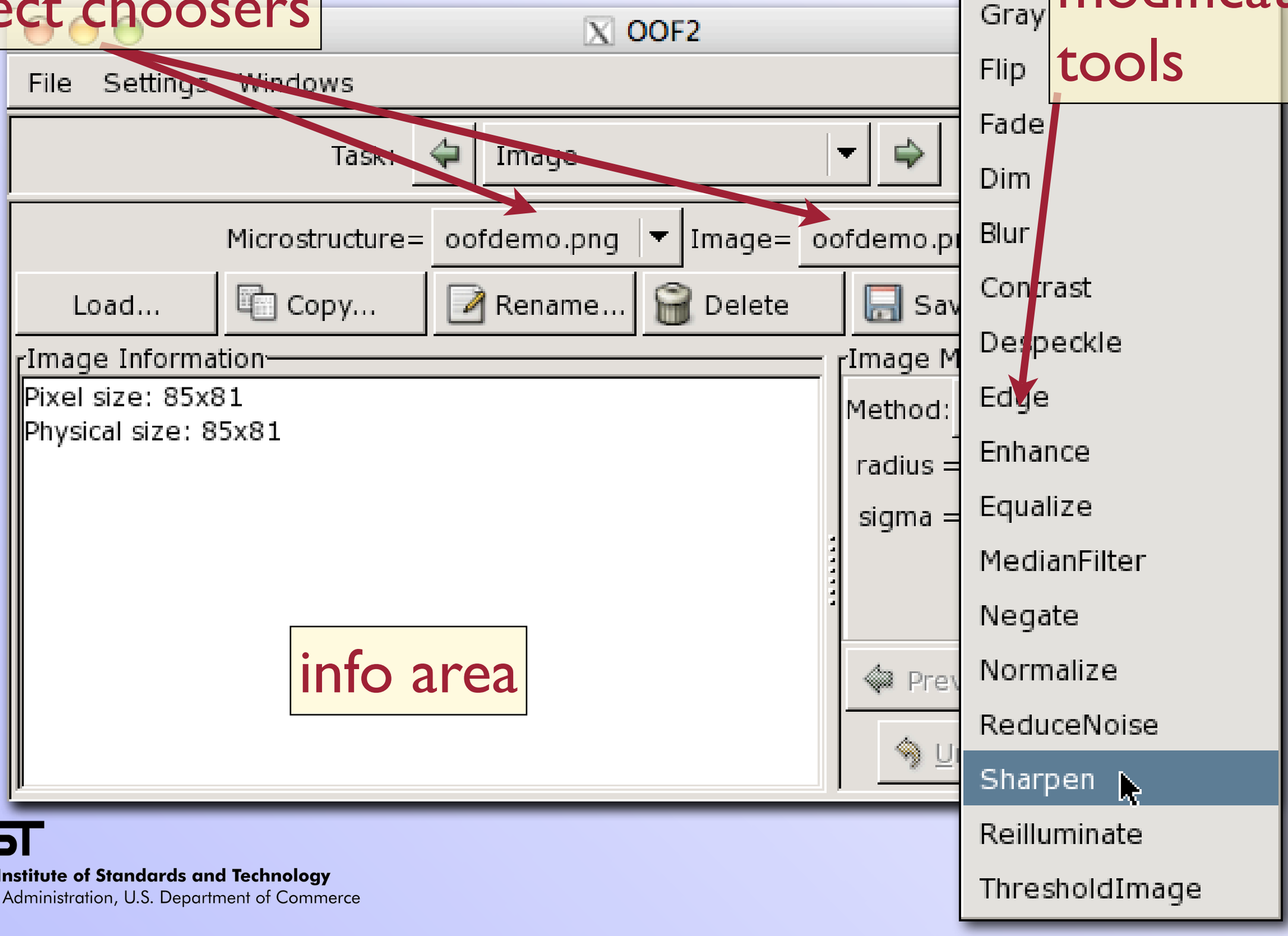


The Image Page

object choosers

image modification tools

info area

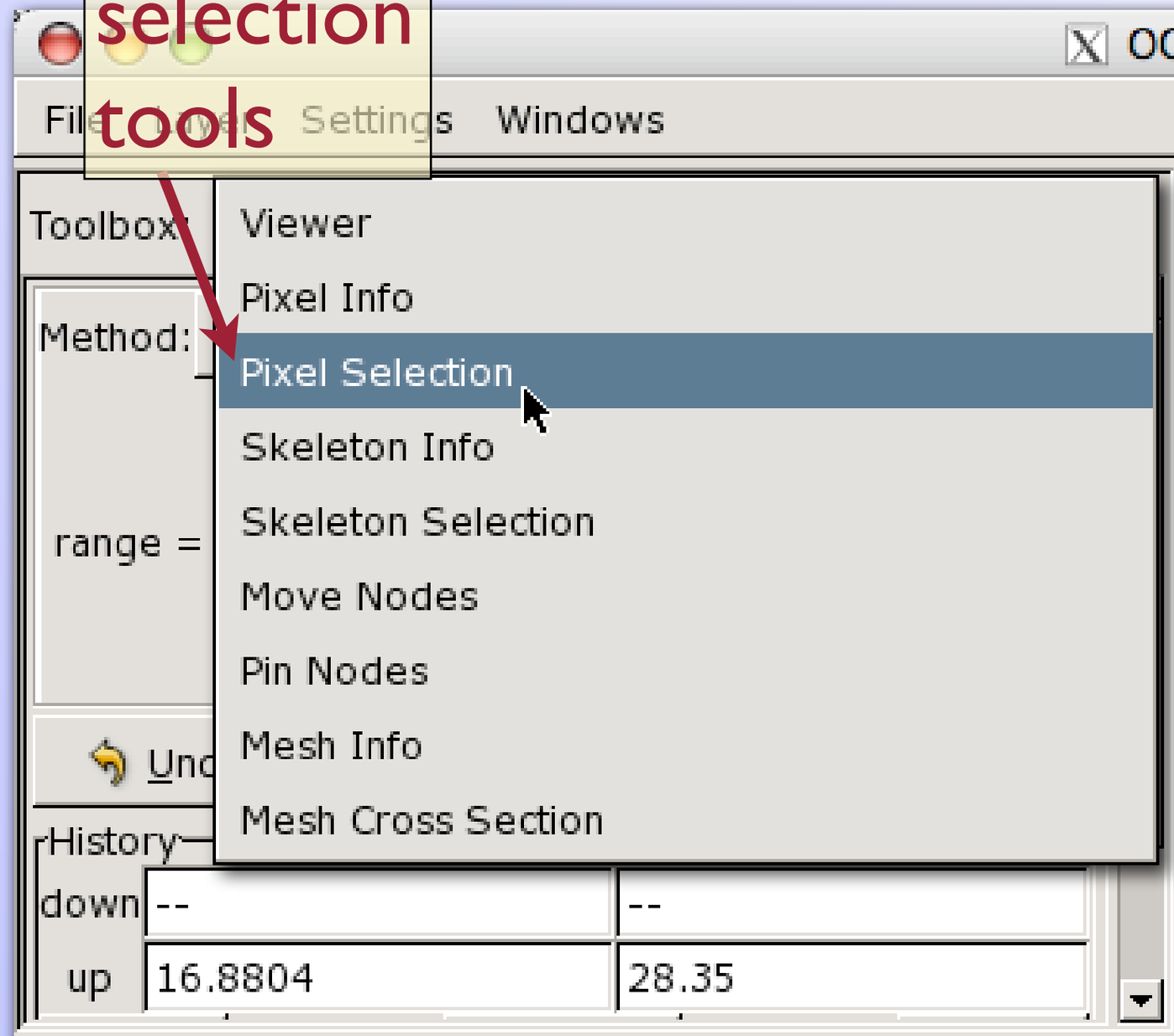


A Slightly Sharper Image

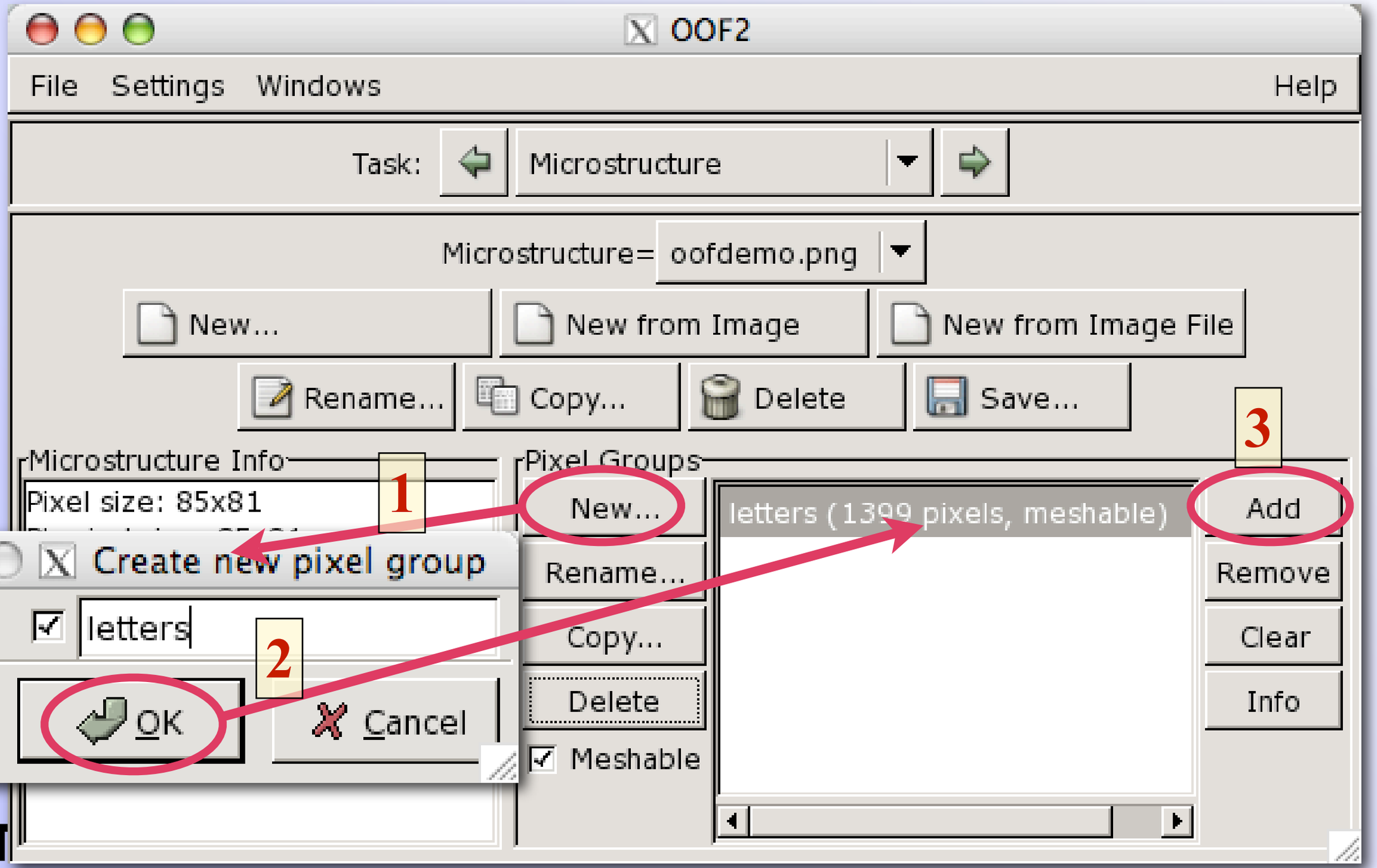
OOF2 Graphics 1

Select Pixels in the Image

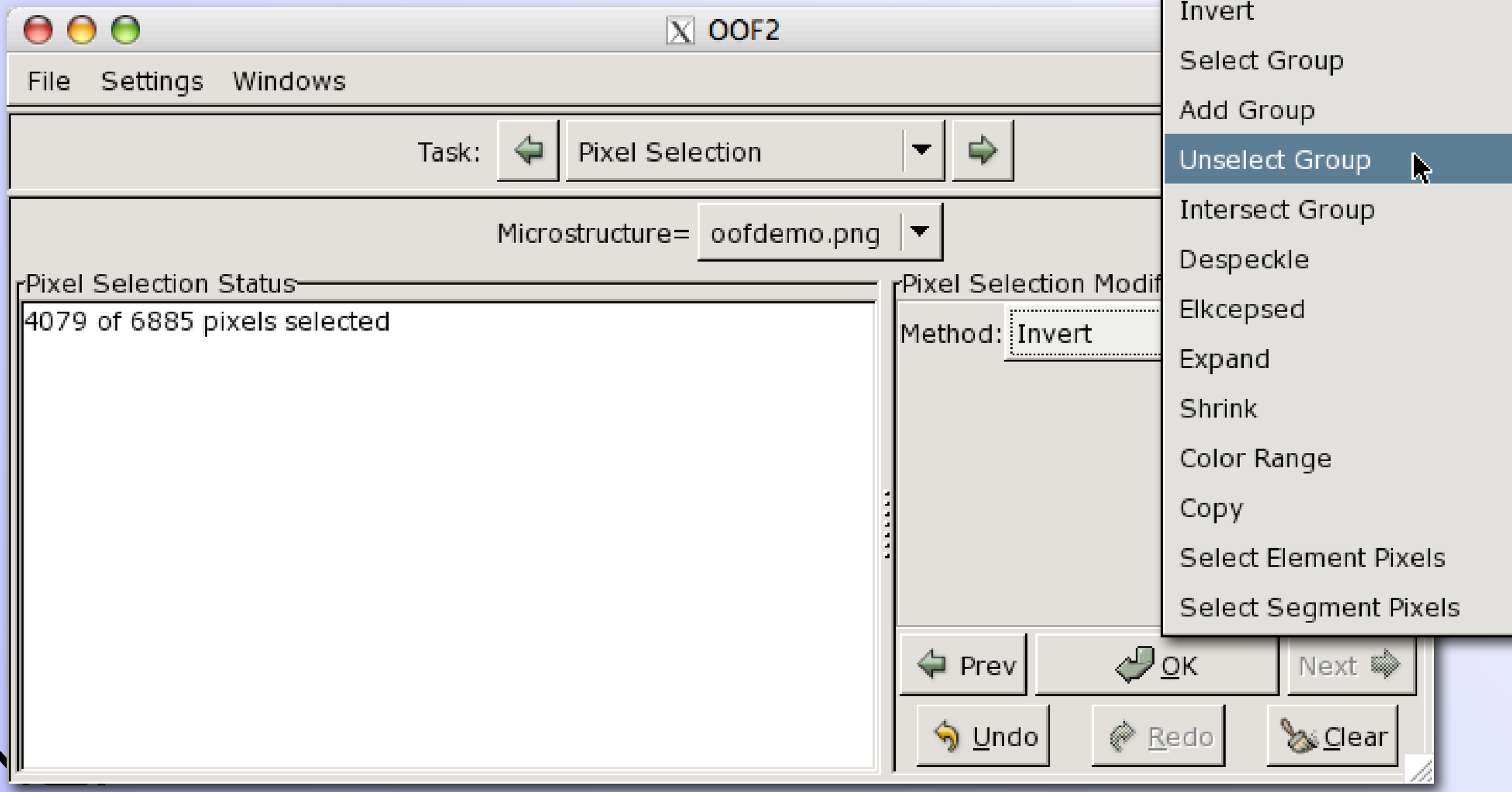
pixel selection tools



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

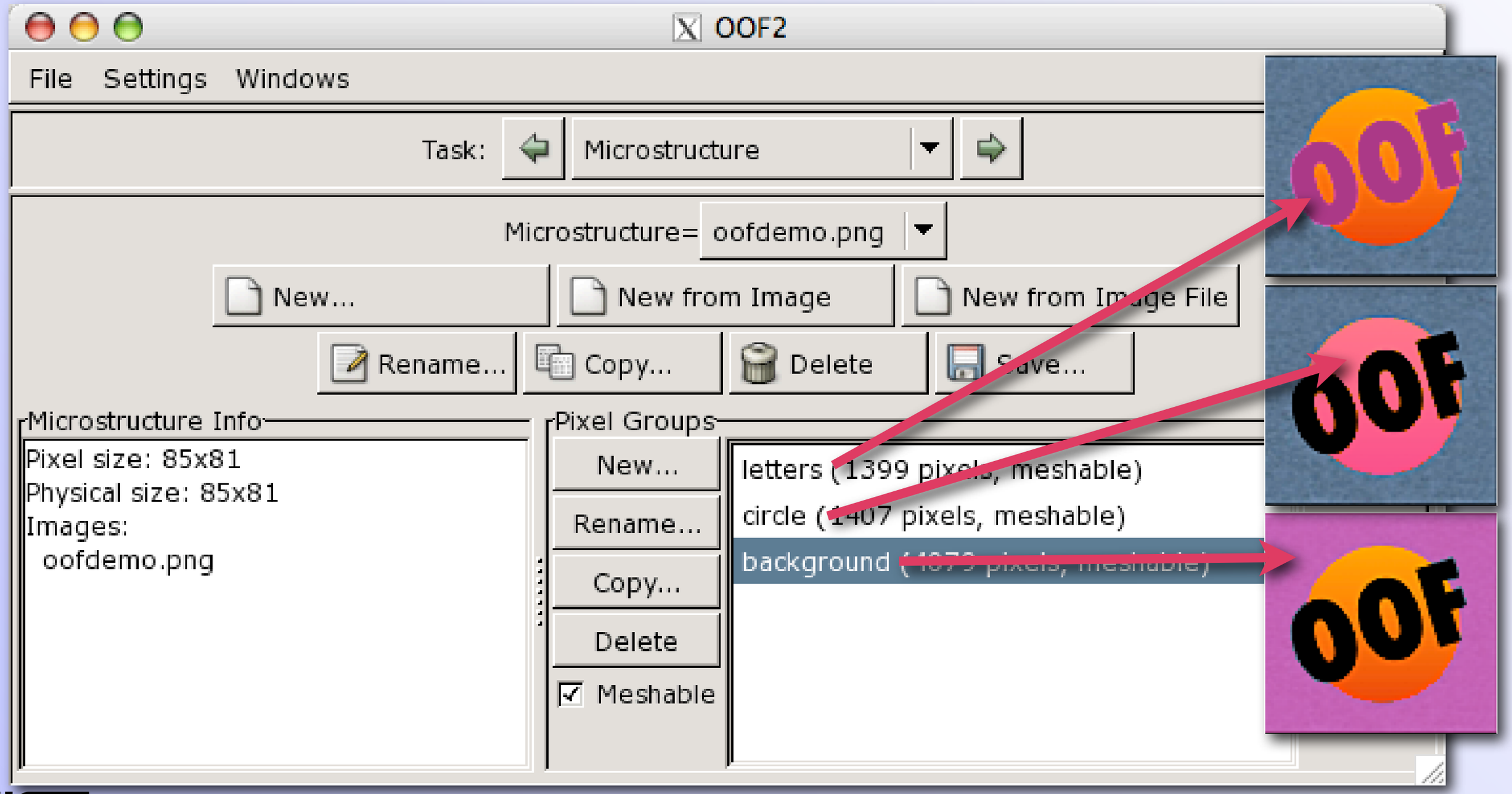


The Pixel Selection task page contains mouseless pixel selection tools



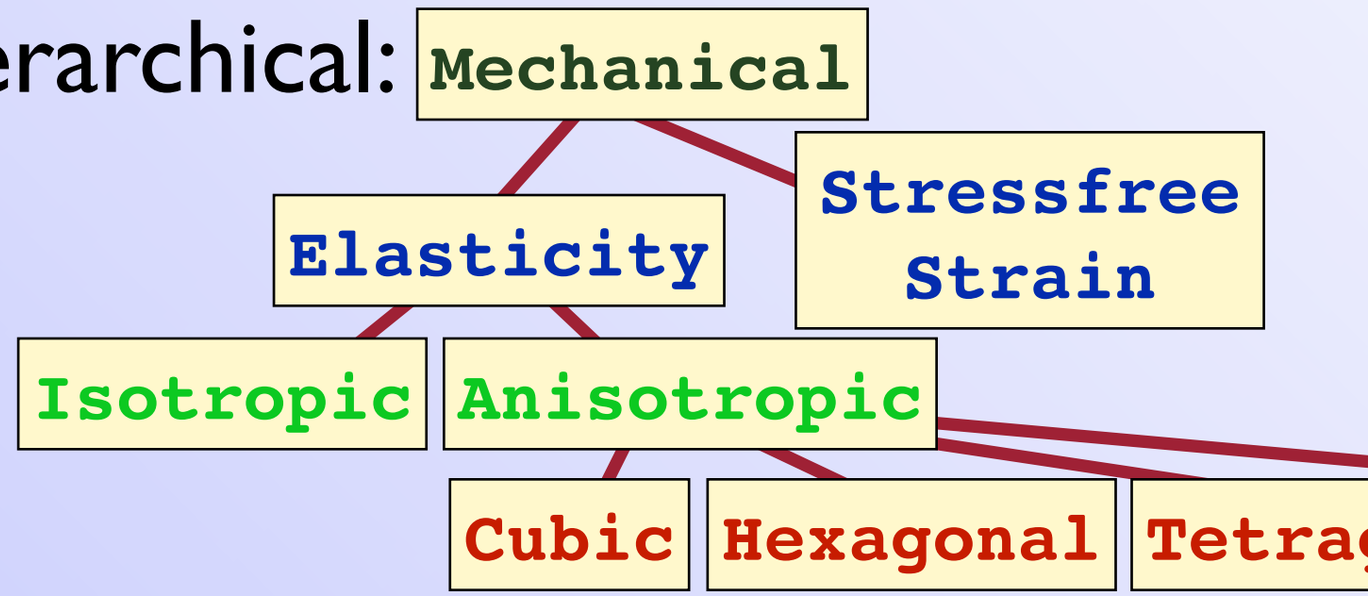
All pixels have been grouped.

(Pixel groups are useful, but not required.)

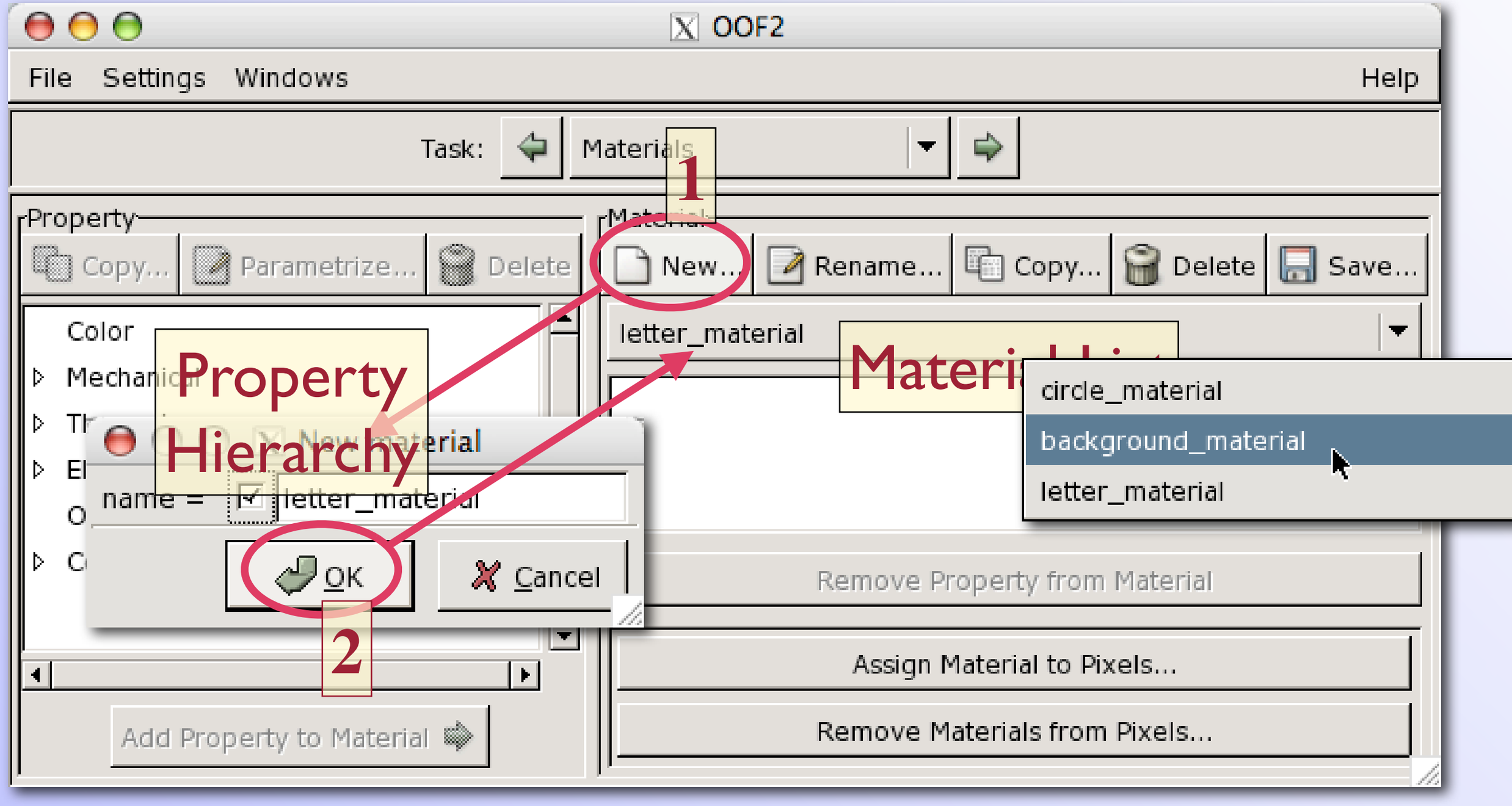


OOF2 Materials

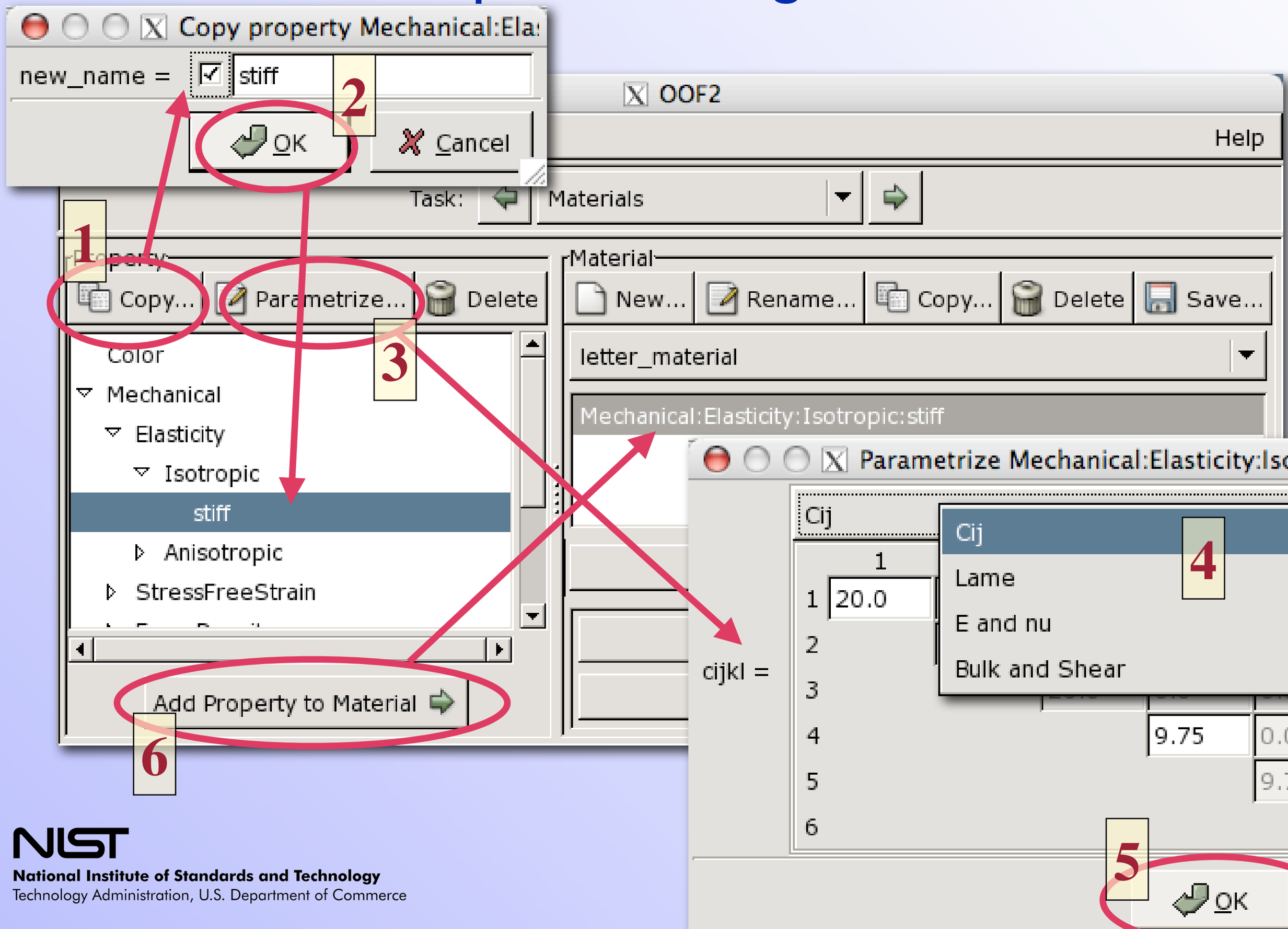
- A `Material` is a named collection of (named) `Properties`.
- Example `Properties`:
  - Elastic Modulus
  - Thermal Expansion Modulus
  - Color
  - Orientation
- Properties are hierarchical:



Create Materials



Create Properties, Assign to Materials



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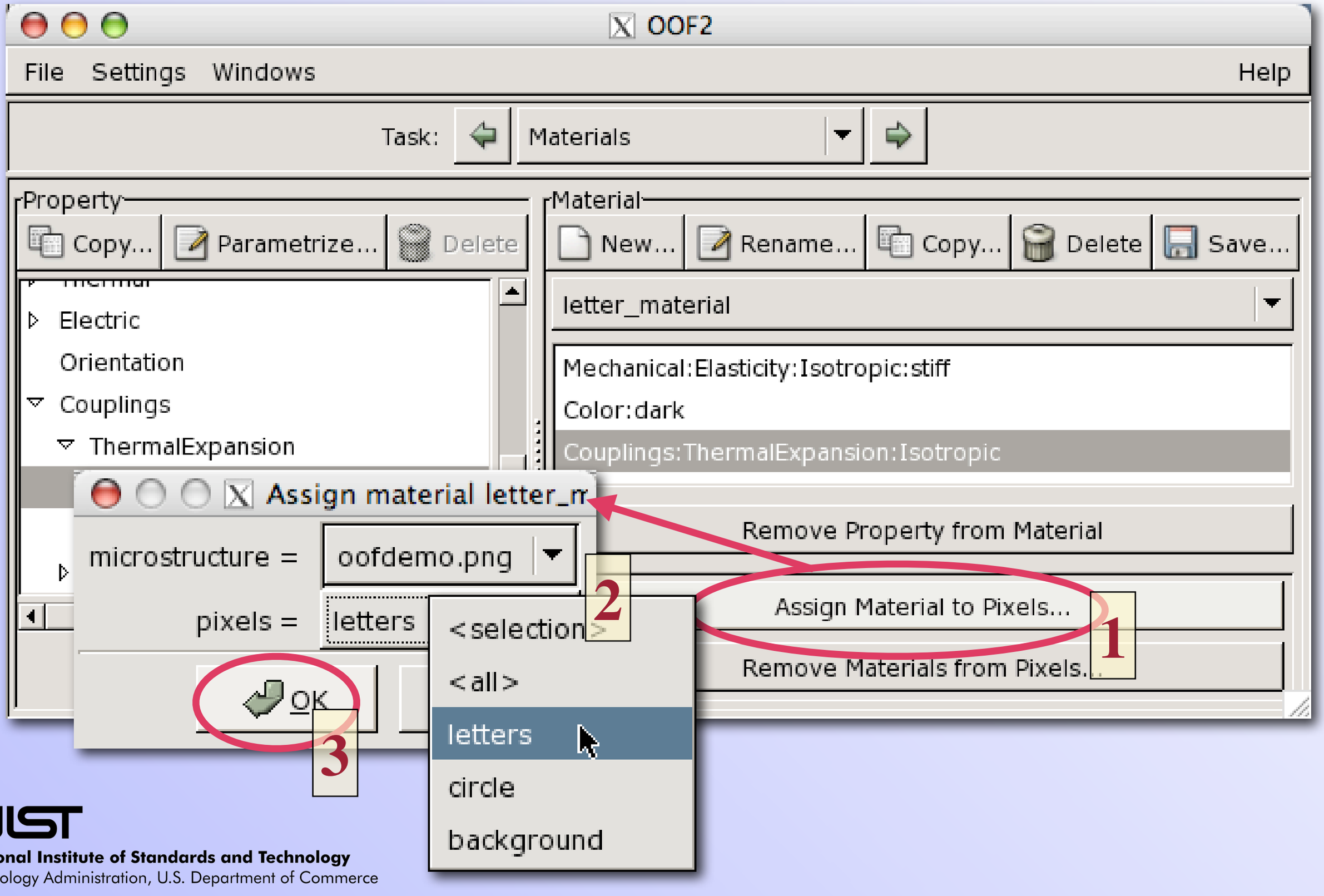
Technology Administration, U.S. Department of Commerce

Assign Materials to Pixels in the Microstructure



Display the Assigned Materials

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

Toolbo
Metho
Clear
Invert
Histor
down
up 67.2413
Prev
Selection size: 0
Layers
Show Map What

OOF2 Graphics Layer Editor

File Settings Windows

Displayed Object
category = Microstructure
object = oofdemo.png

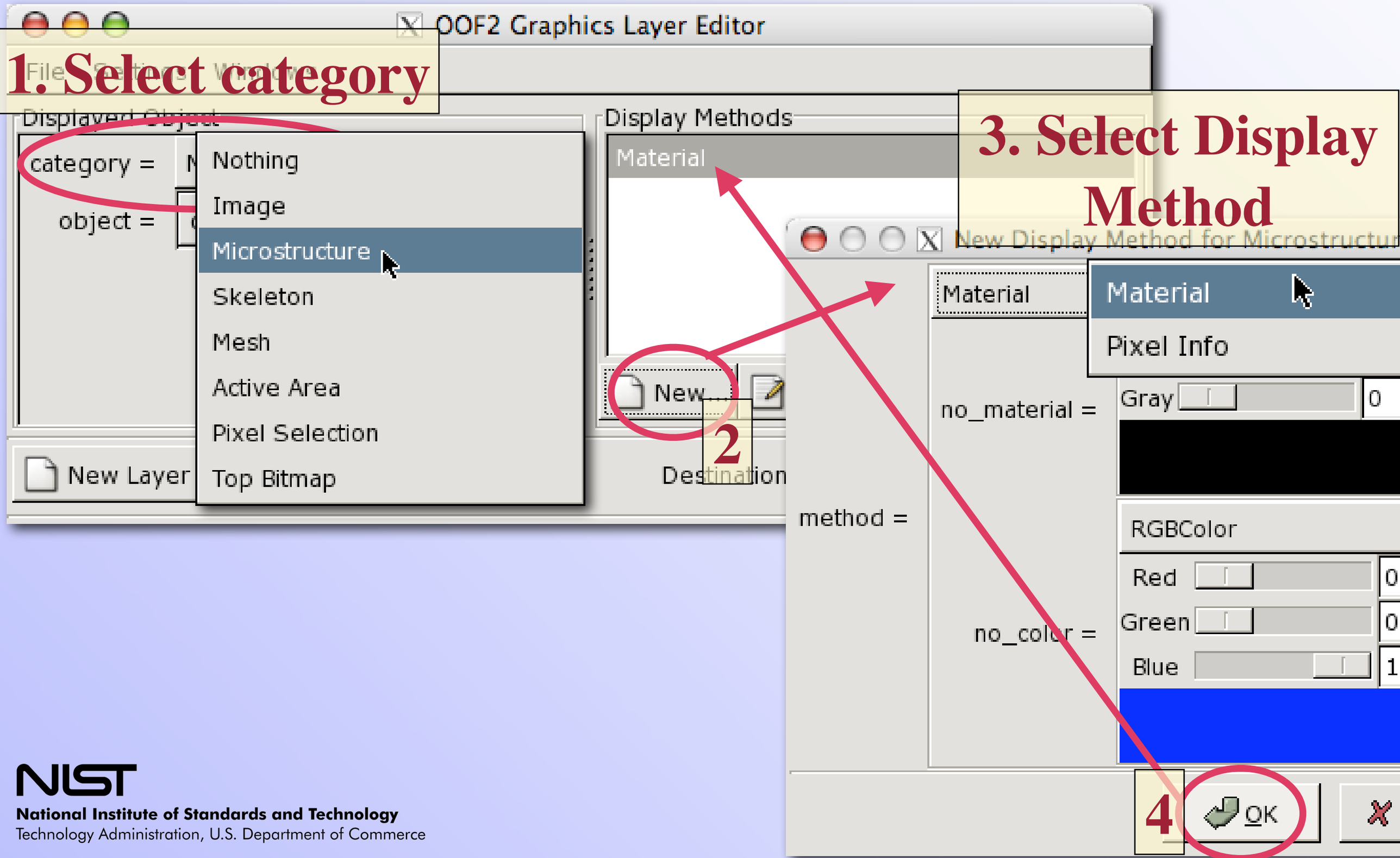
Display Methods
Material
New... Edit... Copy Delete

Layer Editor

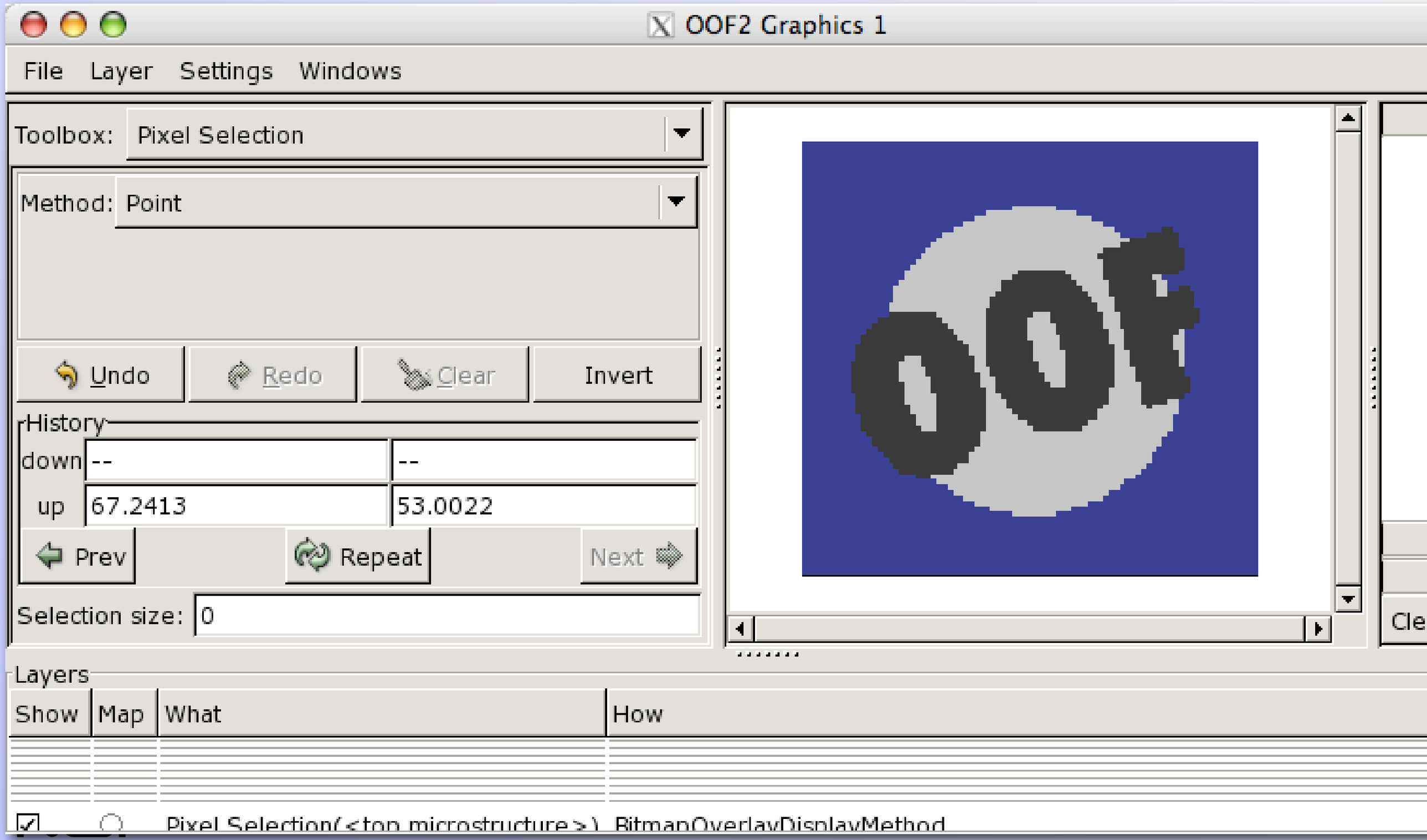
New Layer
Destination= Graphics_1
Send

National Institute of Stand
Technology Administration, U.S

The Layer Editor



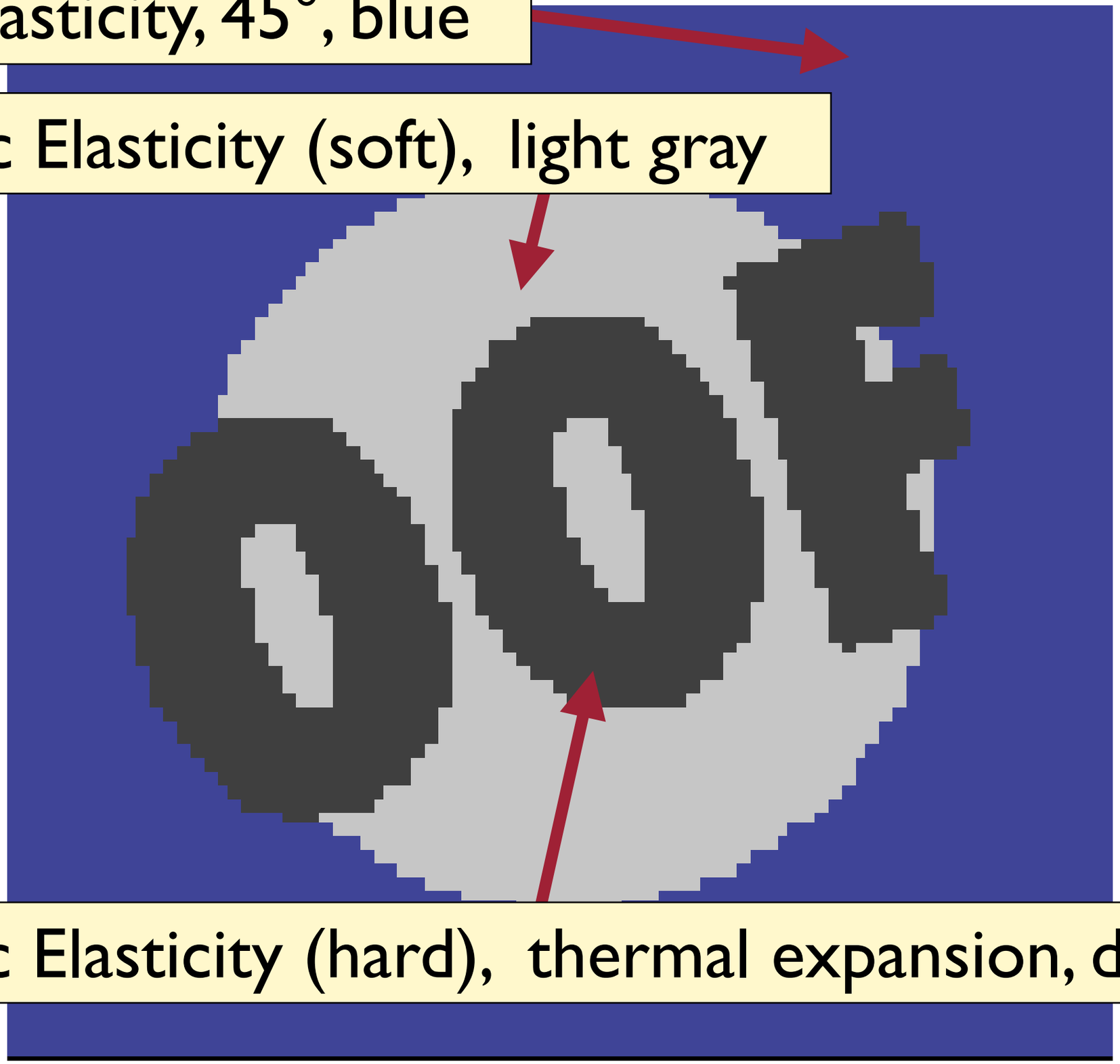
Material Color displayed in the Graphics Window



The Material Map

Cubic Elasticity, 45°, blue

Isotropic Elasticity (soft), light gray



Isotropic Elasticity (hard), thermal expansion, dark gray

The Pixel Info Toolbox

OOF2 Graphics 1

File Layer Settings Windows

Toolbox: Pixel Info

x= 51

y= 20

Update Clear

image= oofdemo.png:oofdemo.png

RGB HSV

red= 0.9247577630273899

green= 0.2592660410467689

blue= 0.06012054627298390

microstructure= oofdemo.png

pixel groups= circle

material= circle_material

max

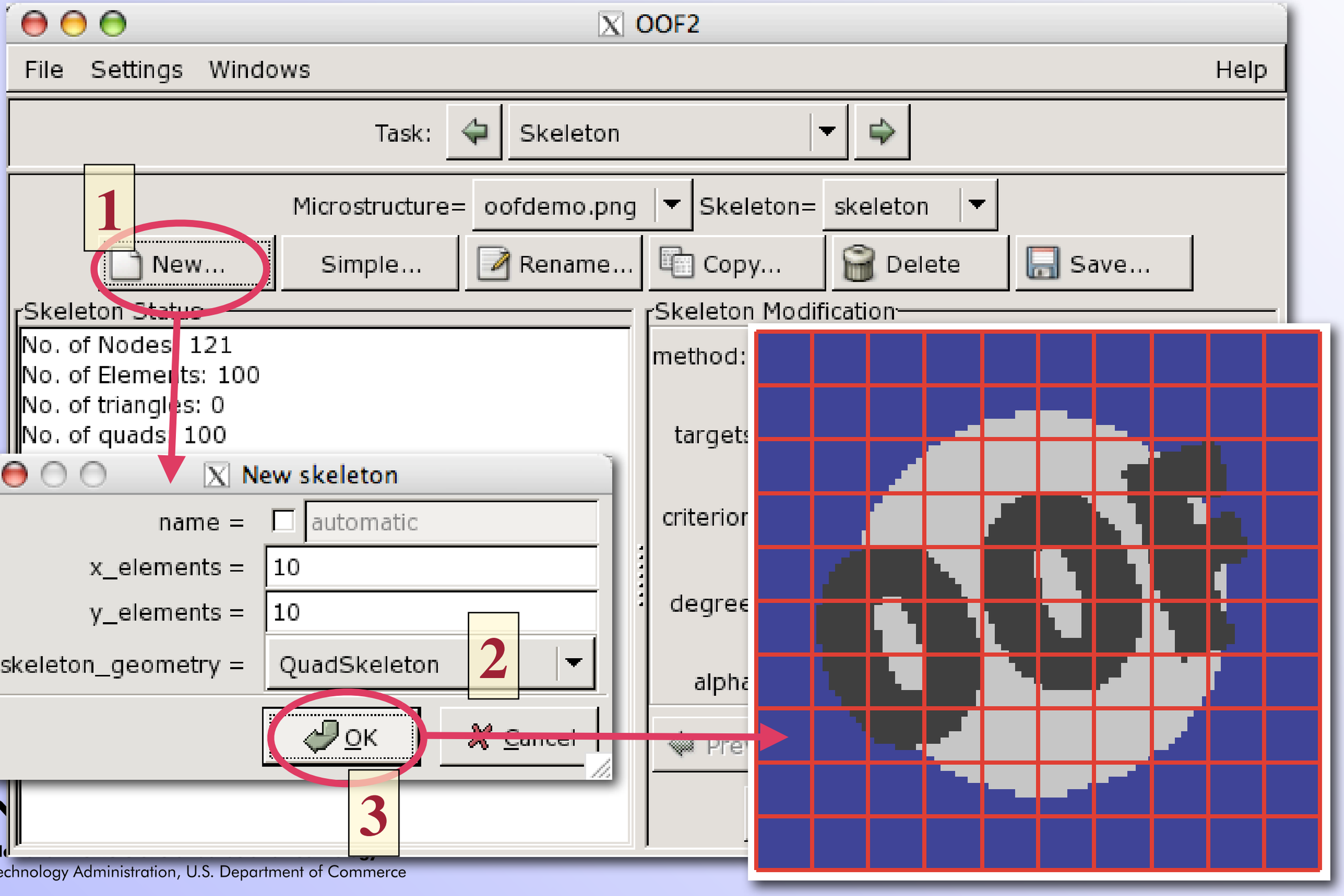
min

Clear M

Layers

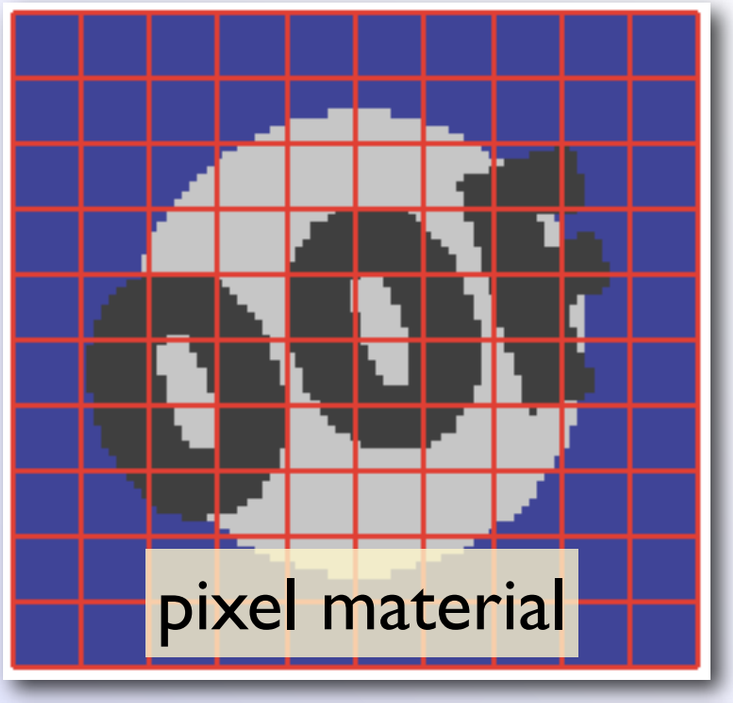
Show	Map	What	How
☐	○	Microstructure(oofdemo.png)	MicrostructureMaterialDisplay
☑	○	Image(oofdemo.png)	BitmapDisplayMethod

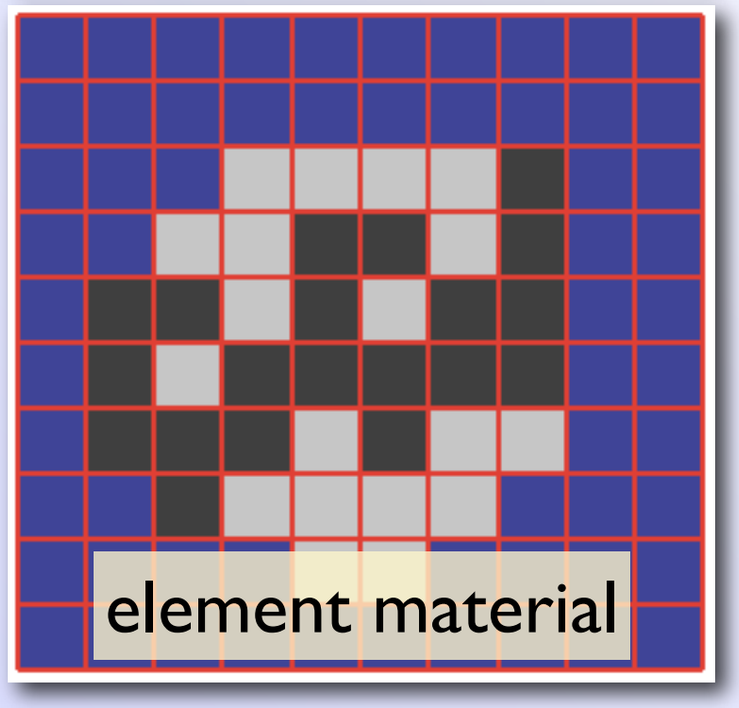
Create a Skeleton



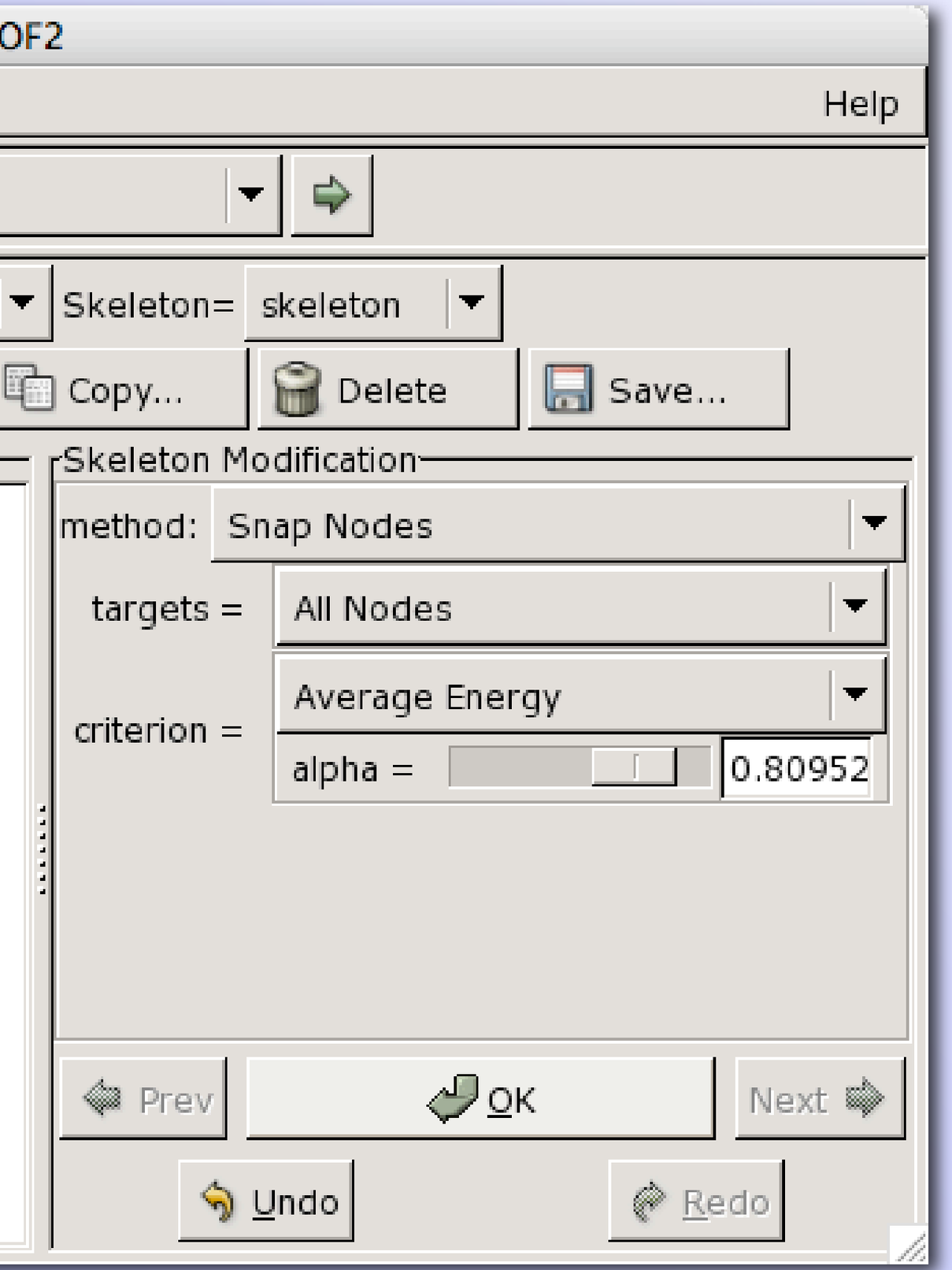
Adapt the Skeleton to the Microstructure

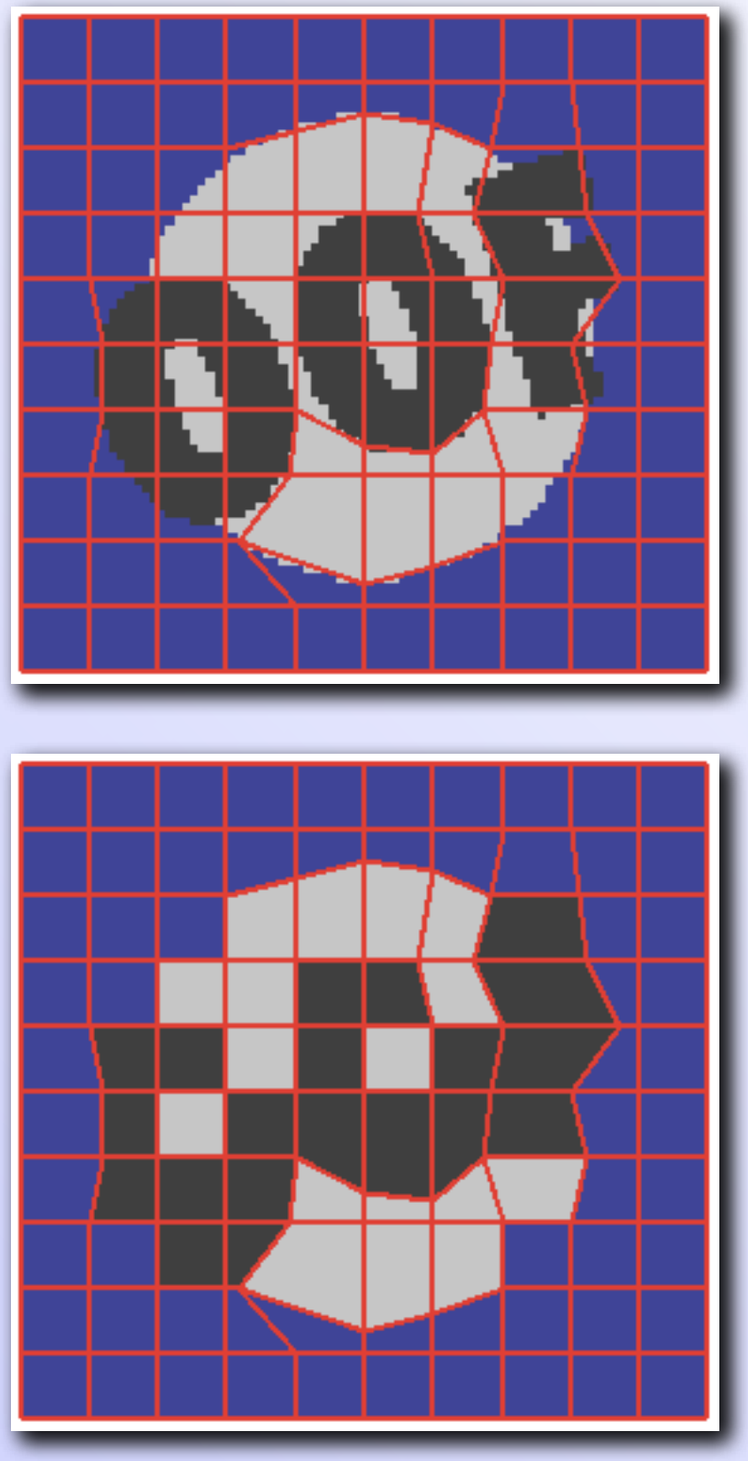
- Element material is determined by dominant pixel material.
- Skeleton needs to be adjusted in order to be a good representation of the Microstructure.
  - Refine (subdivide) elements.
  - Move nodes.
  - Remove bad elements.





Snapping Nodes



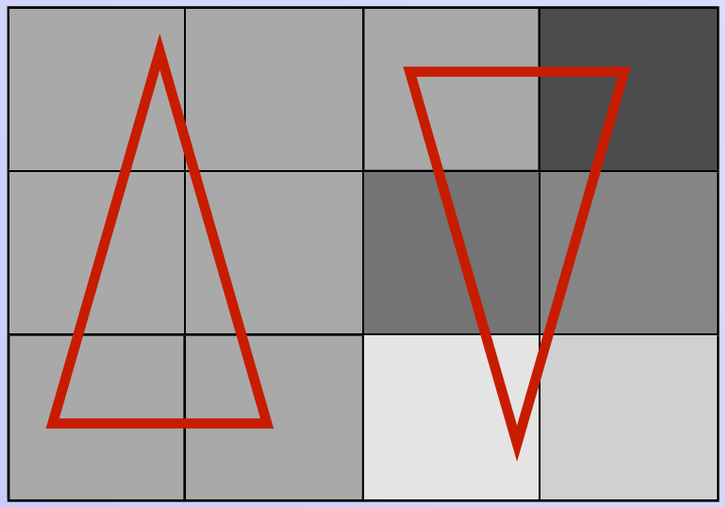


Moves nodes to boundaries between pixels of different types, if doing so will reduce the "effective energy".

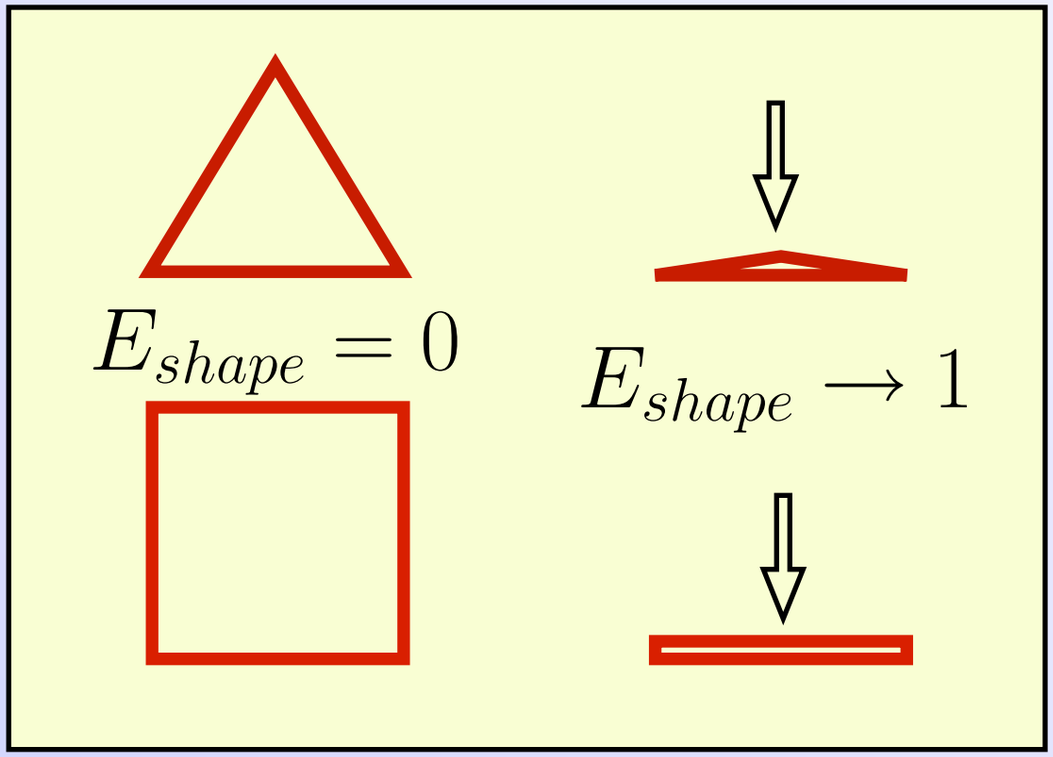
Effective Energy E of a Skeleton Element

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

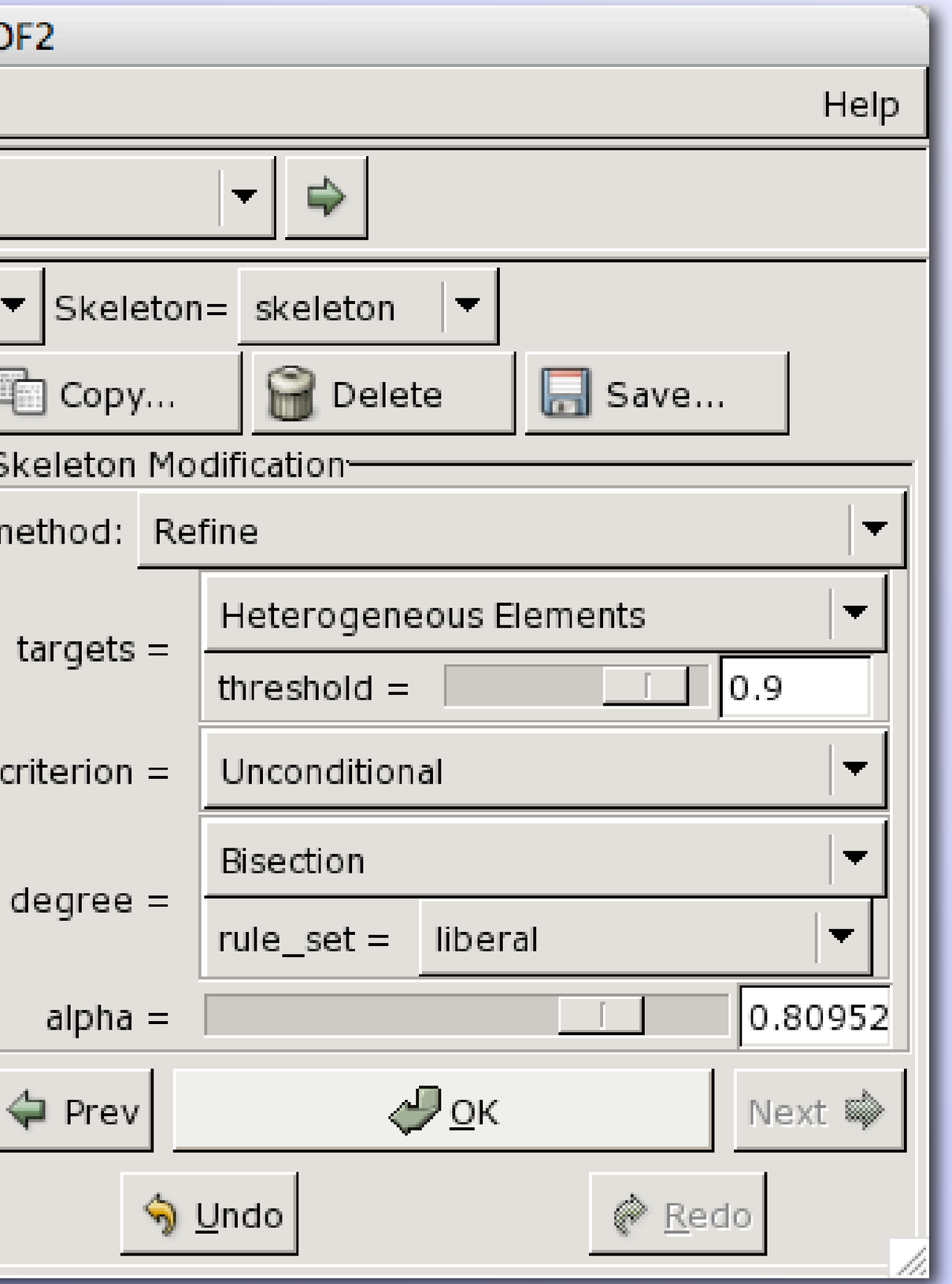
$$E = \alpha E_{\text{homog.}} + (1 - \alpha) E_{\text{shape}}$$

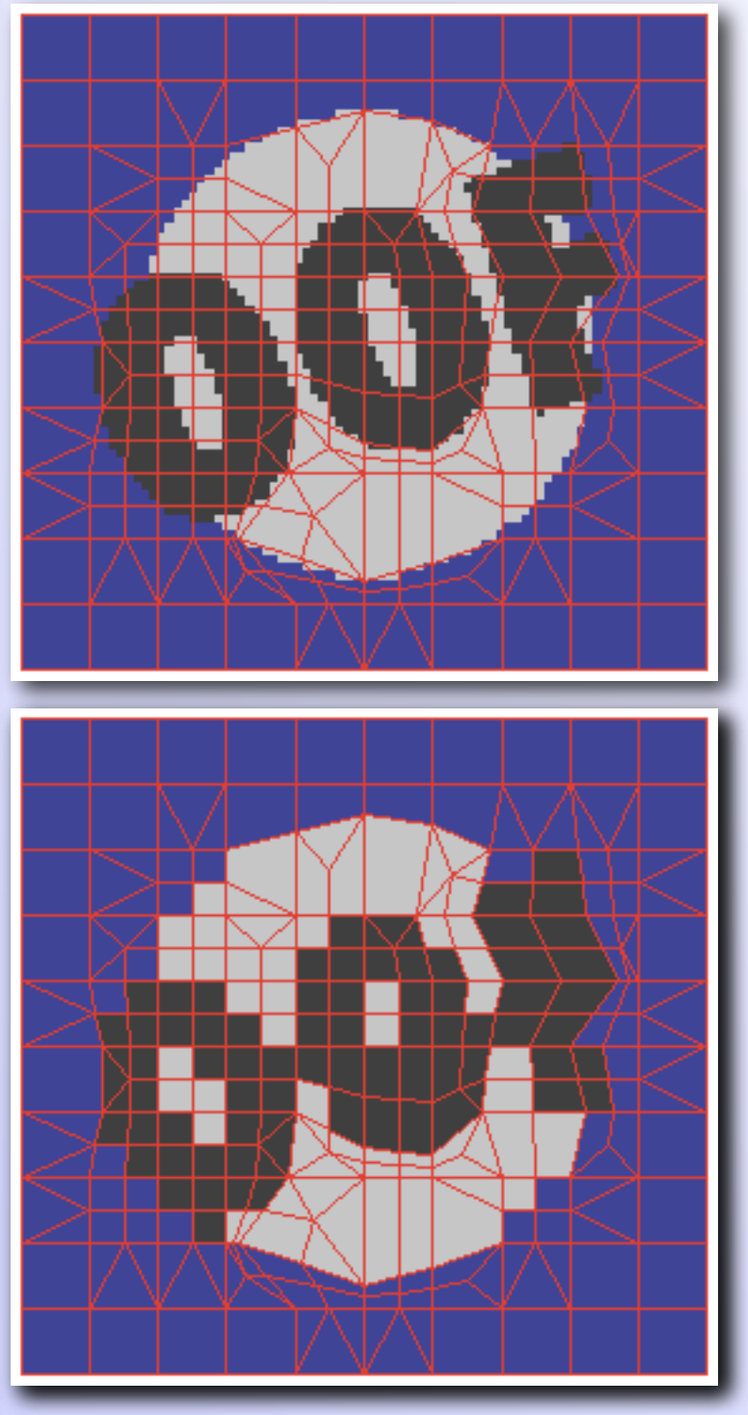


$E_{homog.} = 0 \quad E_{homog.} \to 1$



Refining Elements

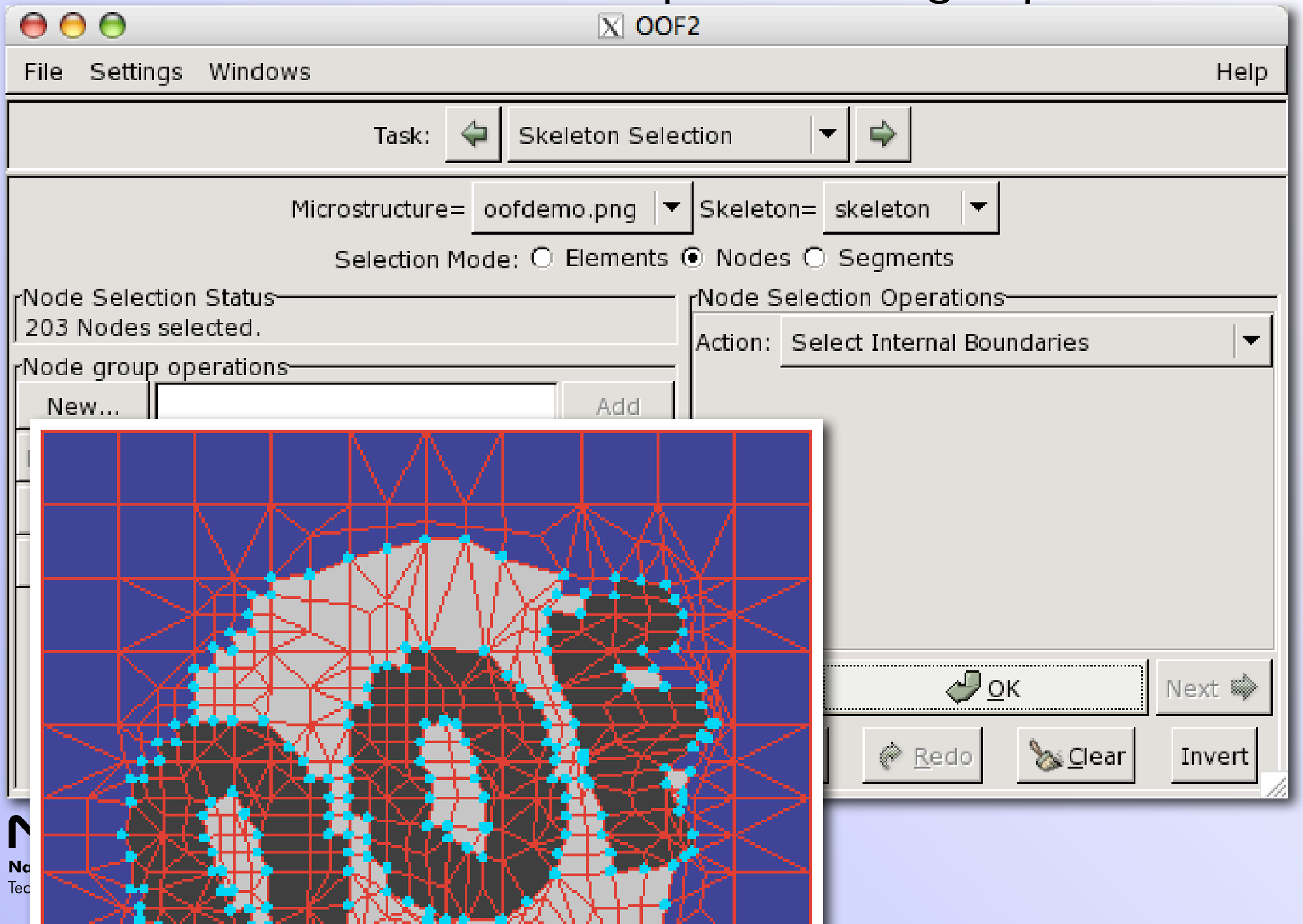




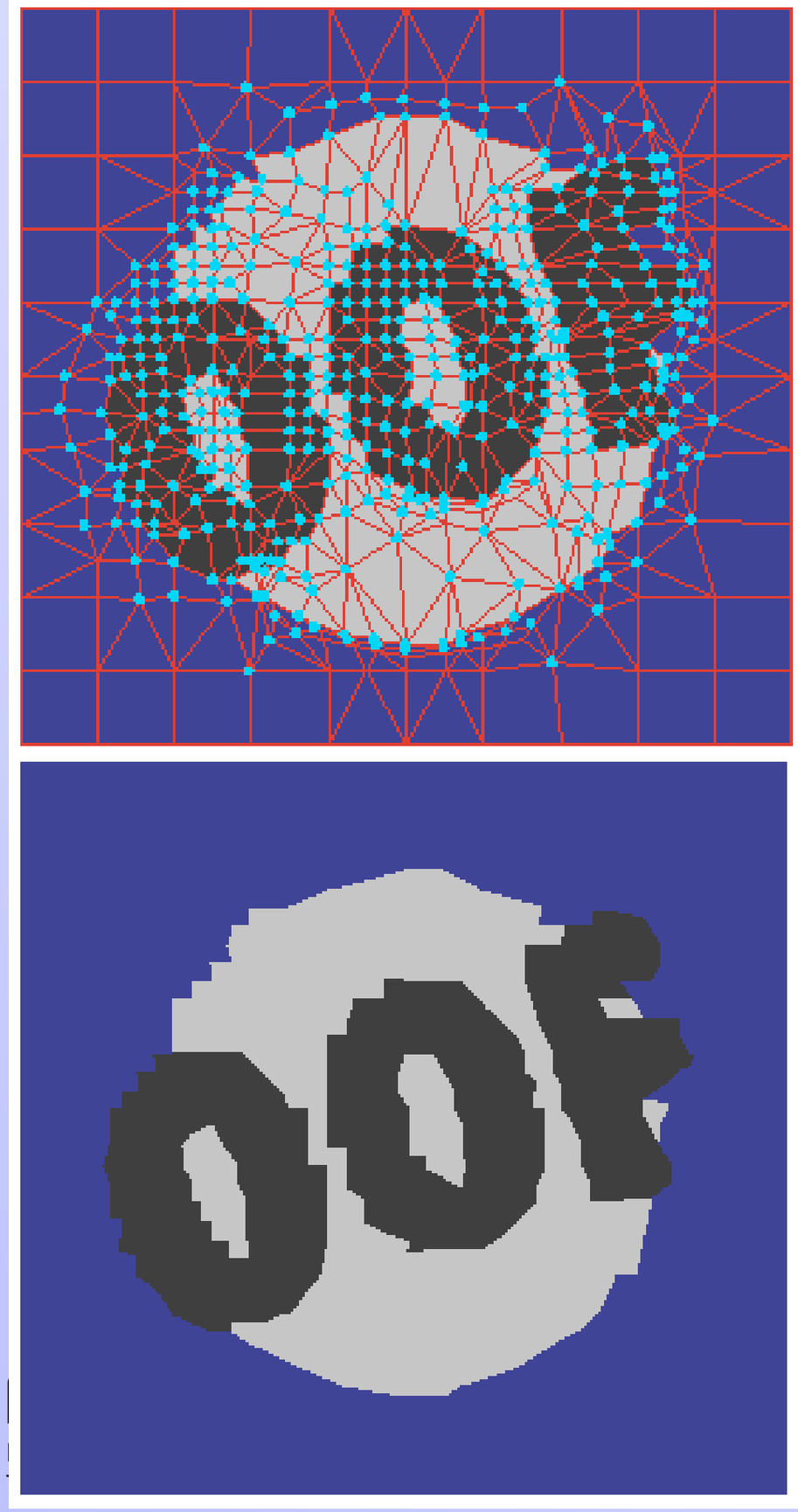
Subdivide elements according to various criteria: high E, heterogeneous, selected, hetero. edges, etc.

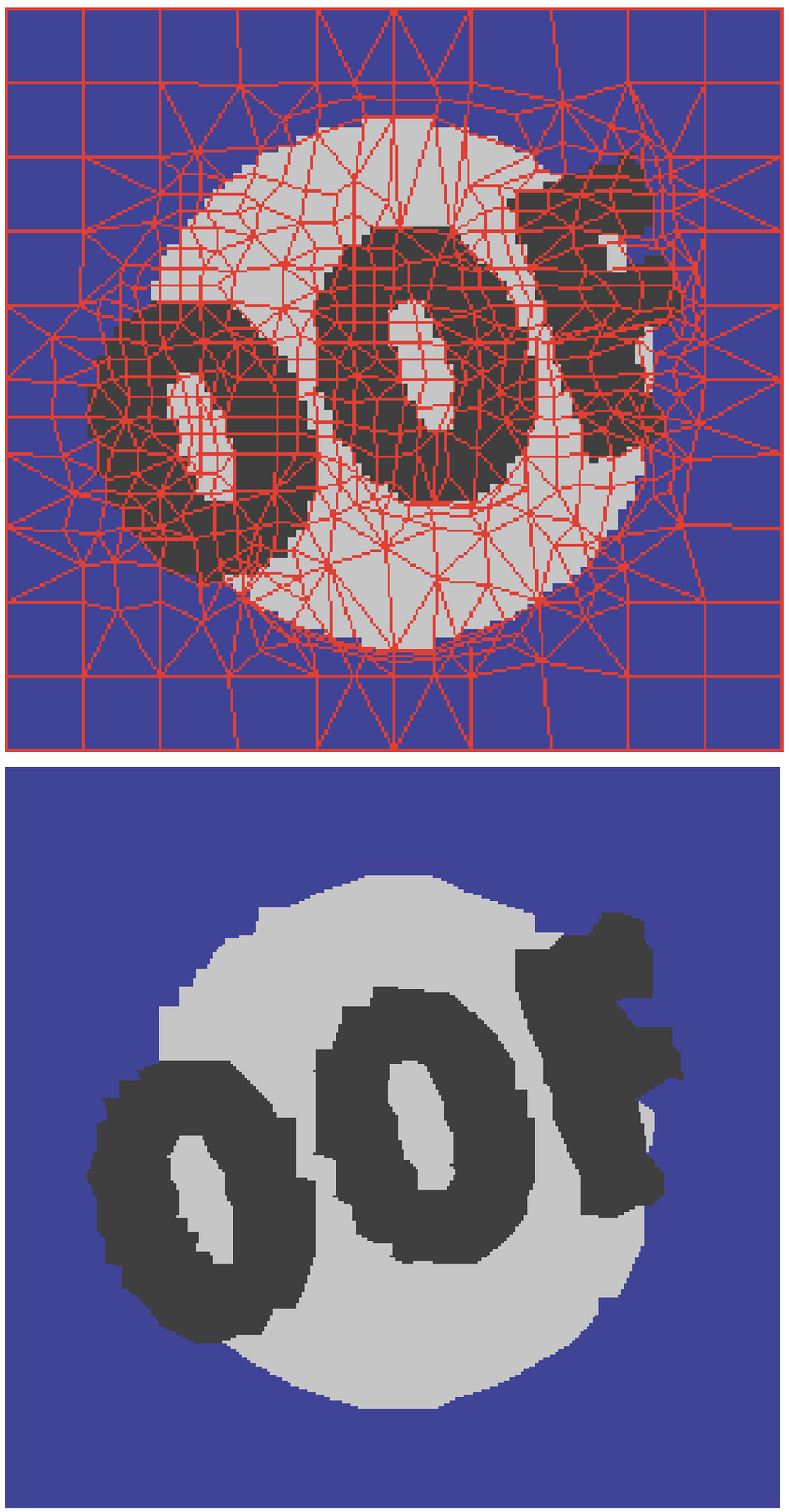
Skeleton Selection Page

Select skeleton components and group them.



Annealing Selected Nodes

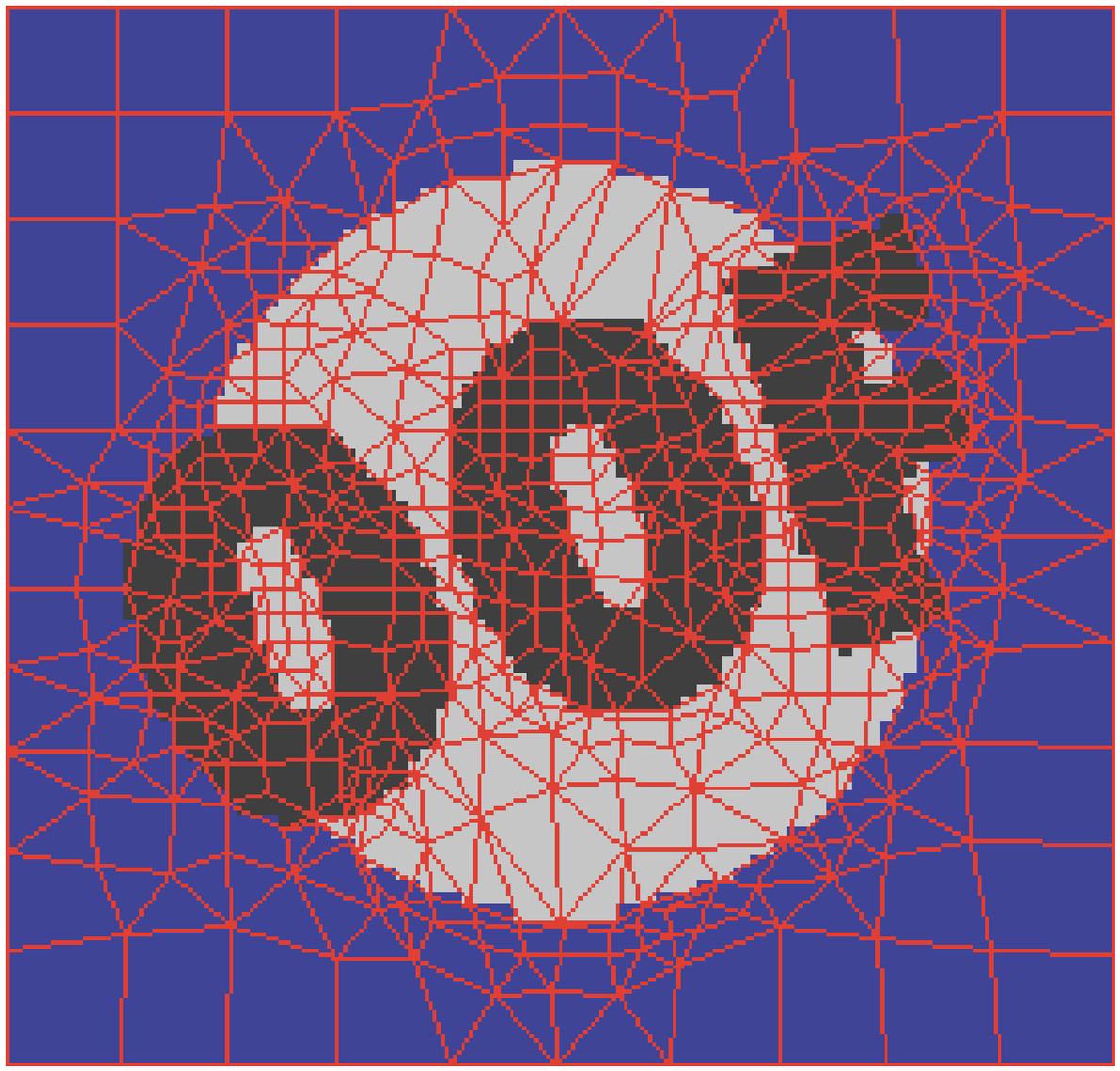




Move nodes at random to reduce E.

Final Skeleton

(After using a few additional tools...)



Is this good enough?

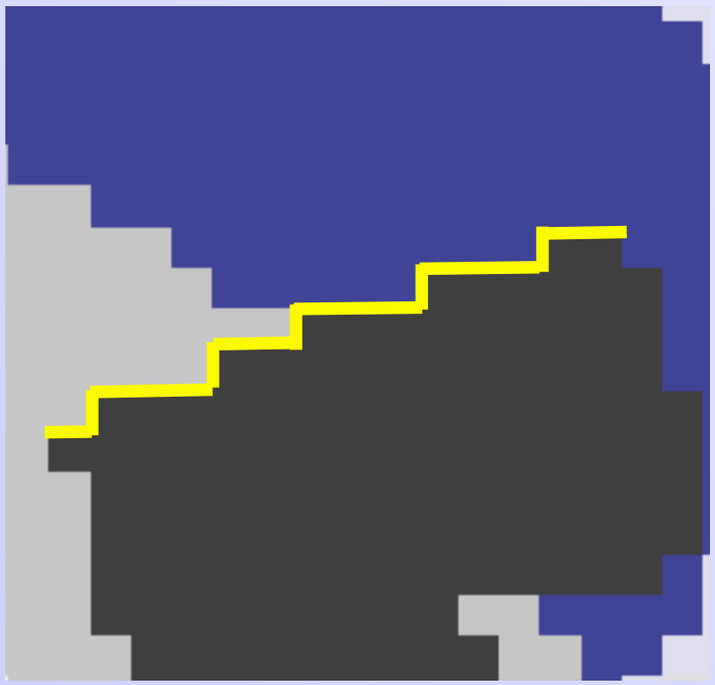
When to Stop?

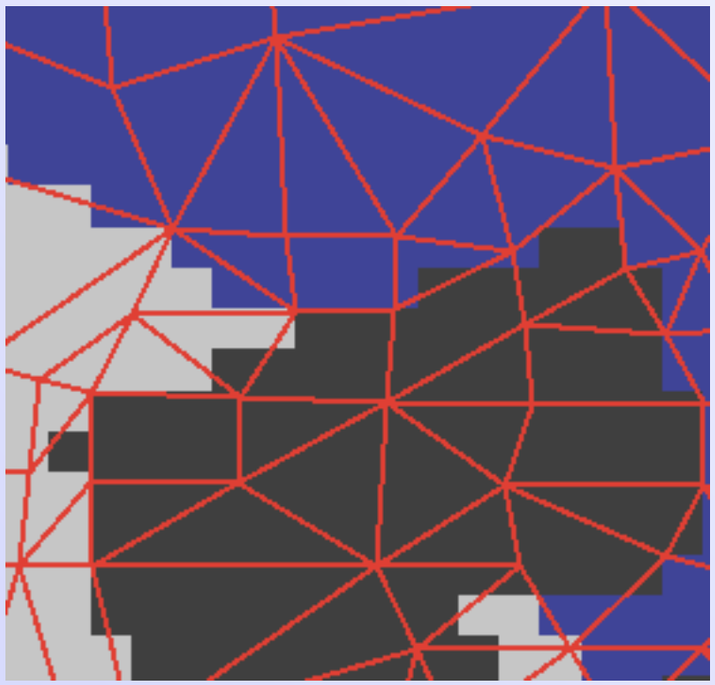
- Micrograph is an approximation of reality.
- Material Map is an approximation of Micrograph.
- Skeleton is an approximation of Material Map.
- Finite Element solution is an approximate solution on the Skeleton.
- There's no point in resolving nonphysical pixel level detail!

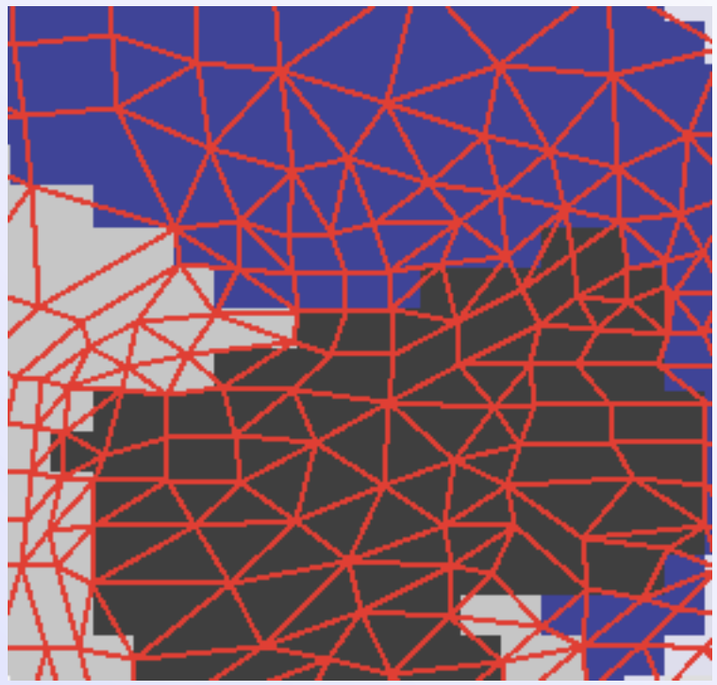
Material Map

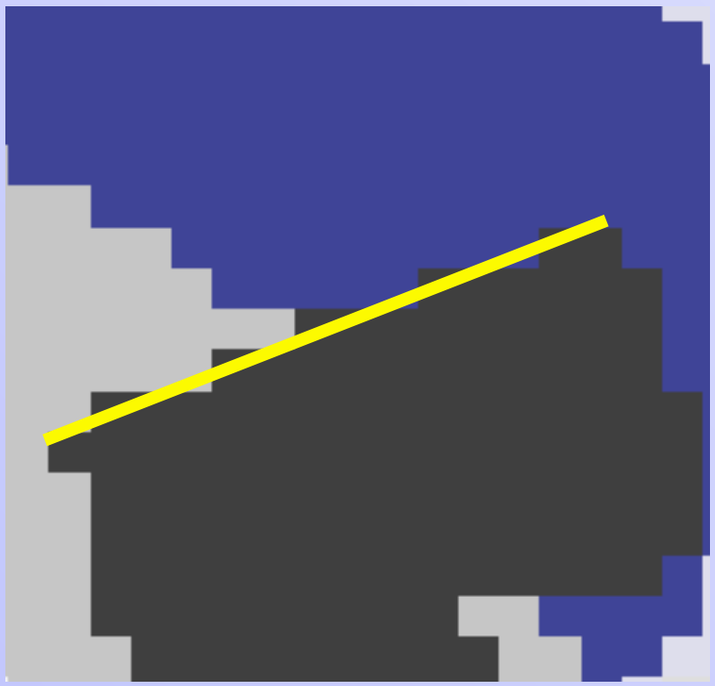
Coarse Skeleton

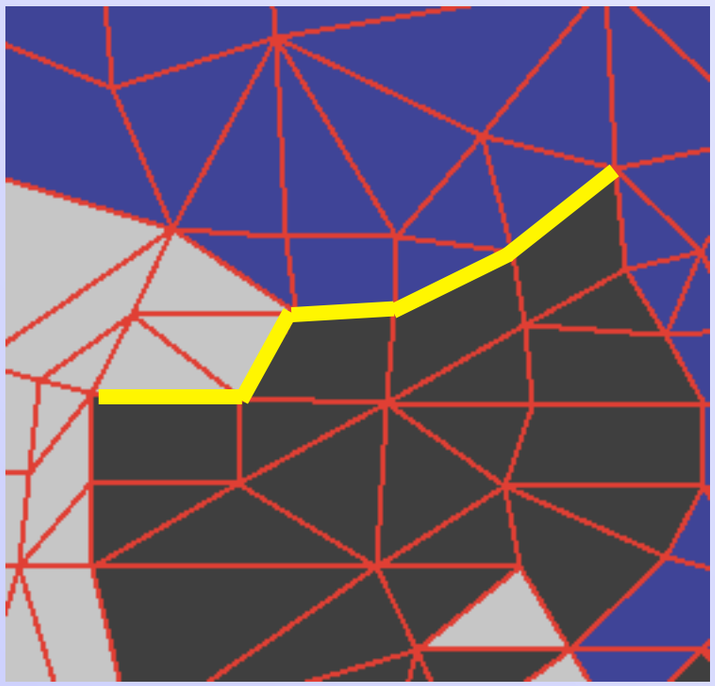
Over-refined Skeleton

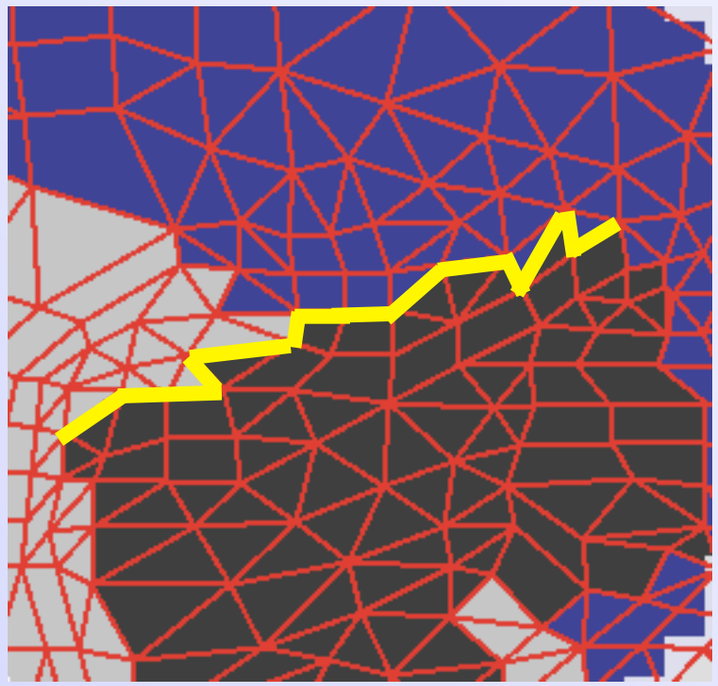




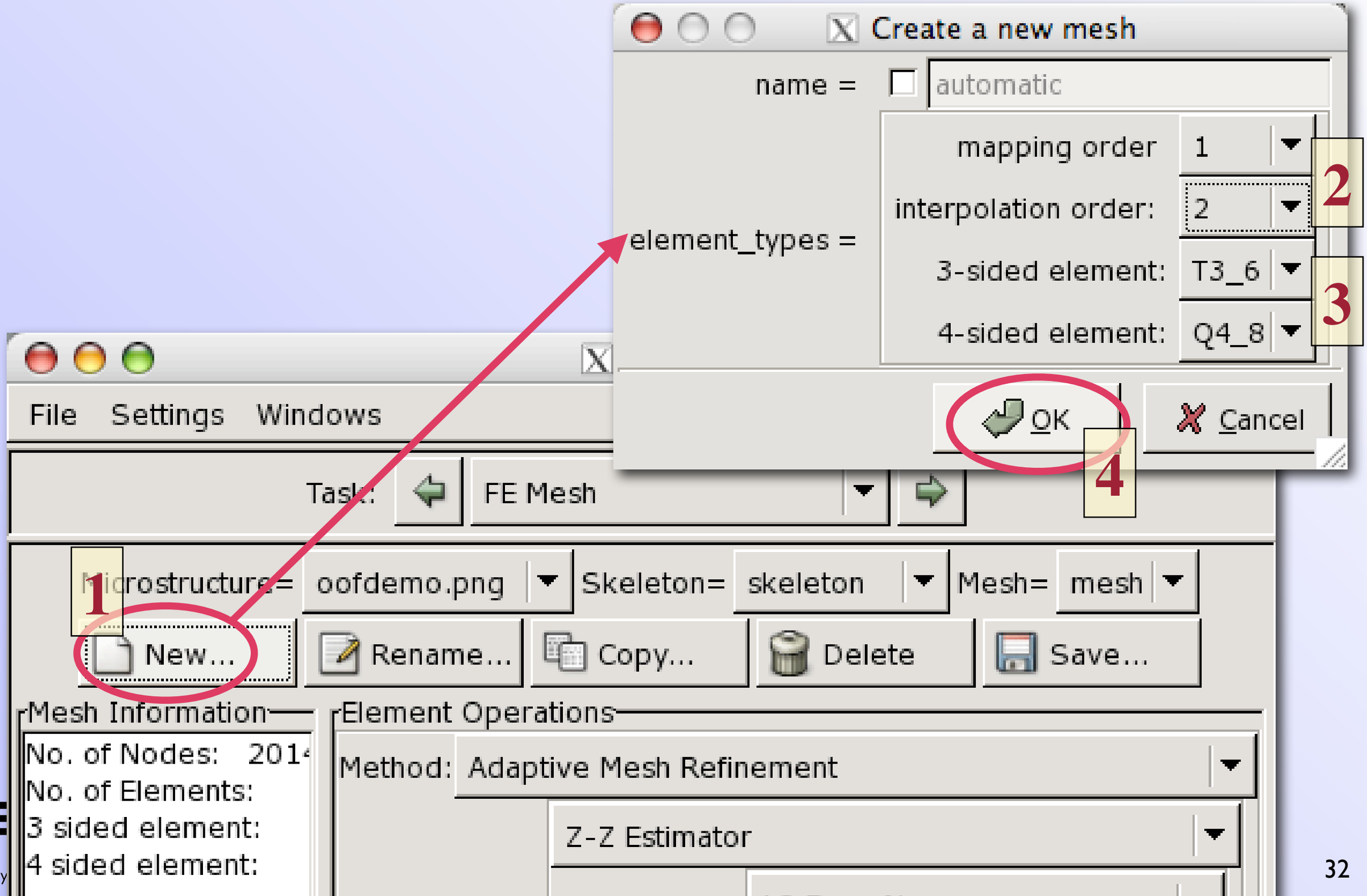








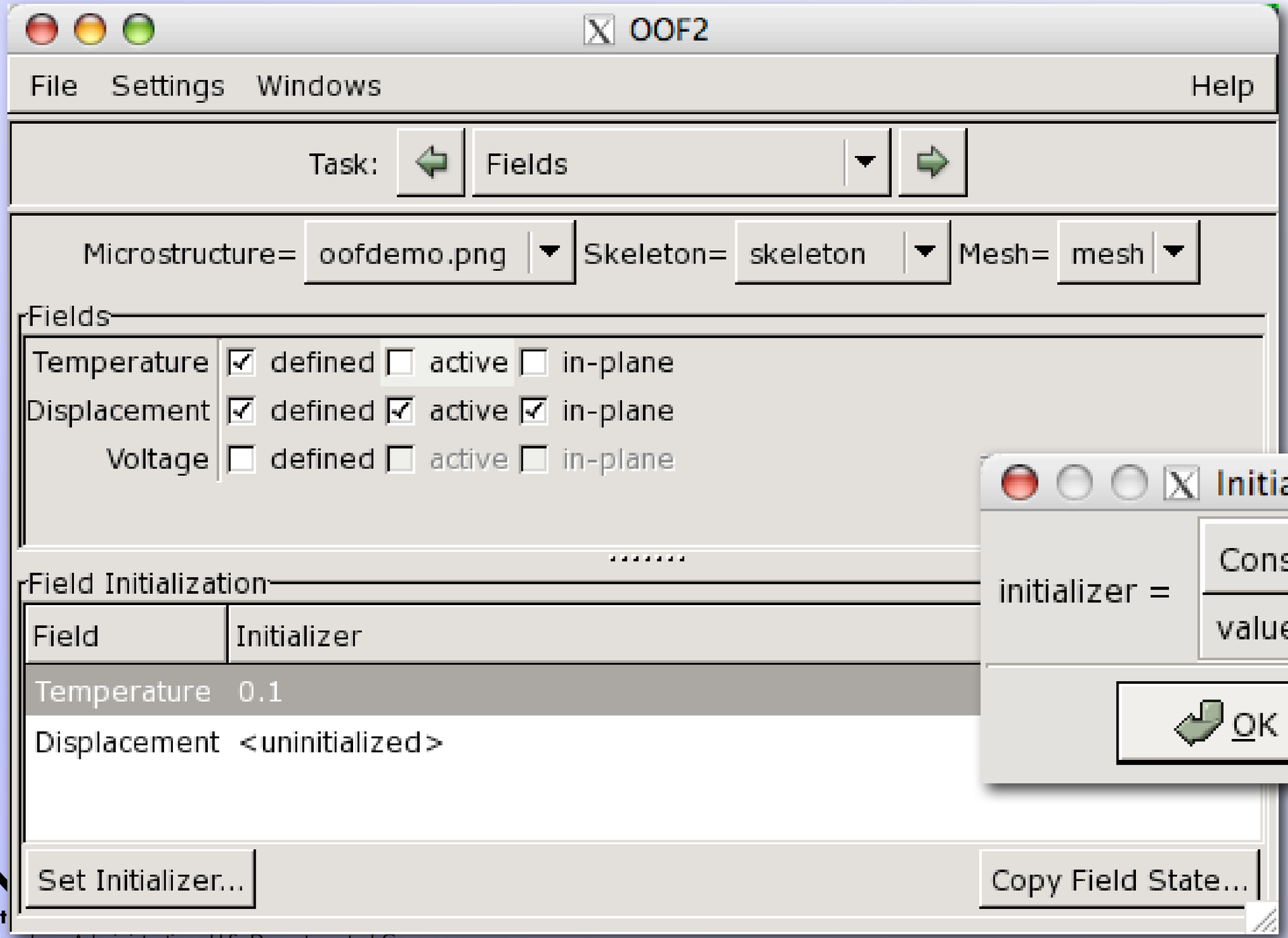
The FE Mesh Page



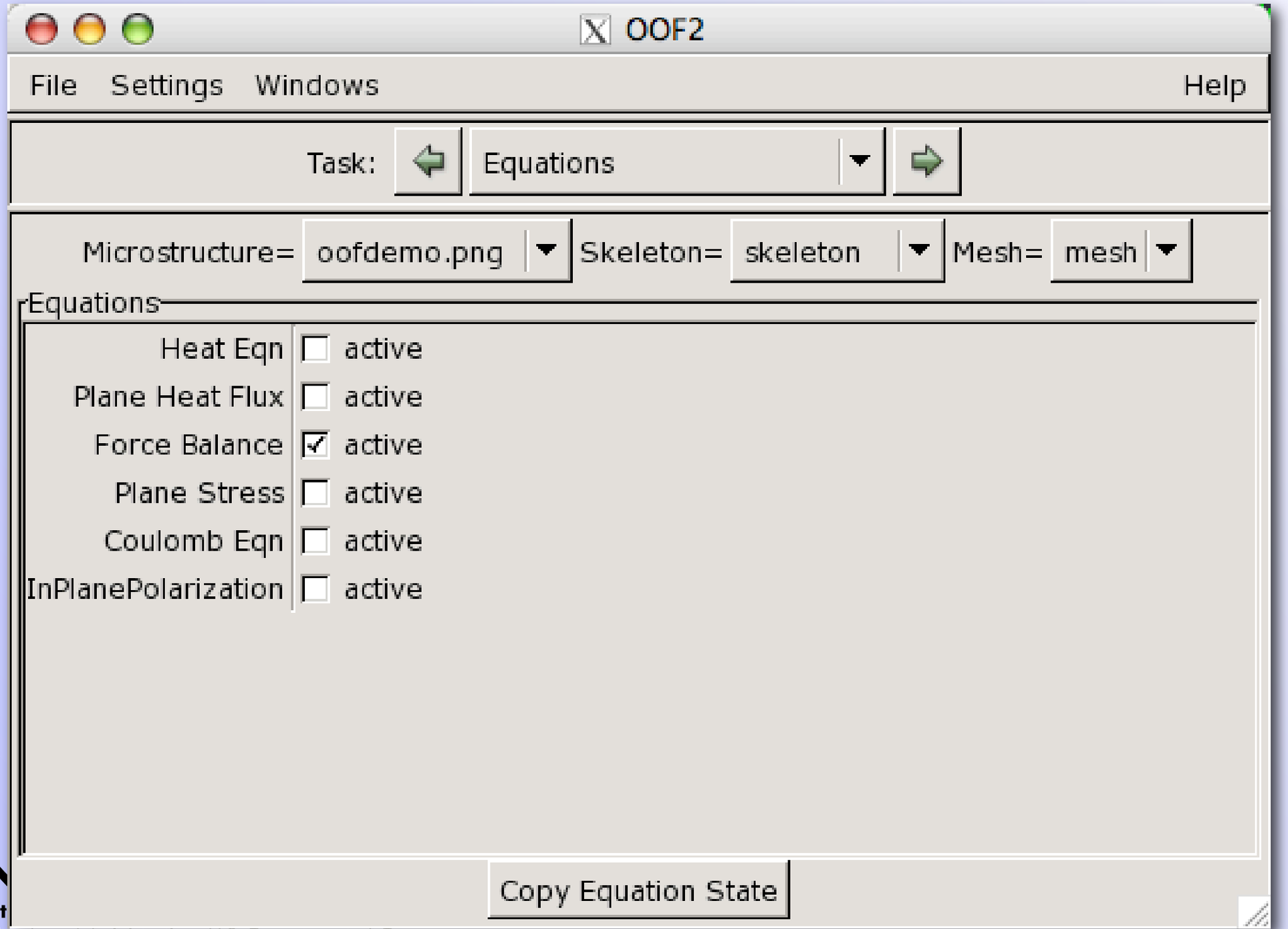
National Technology

Define, Activate, & Initialize Fields

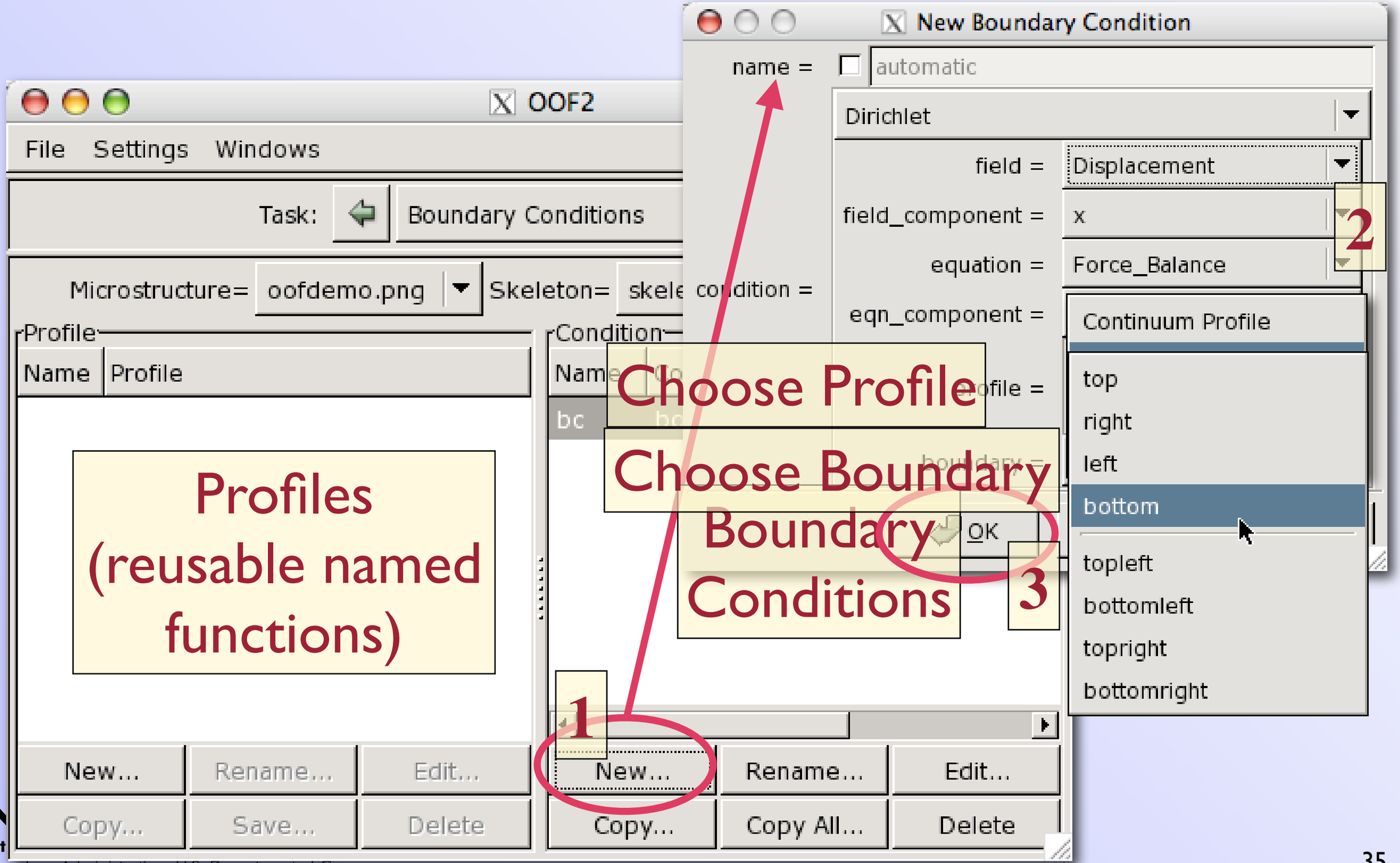
- Defined fields have values.
- Active fields will be solved for.



Choose which Equations to solve

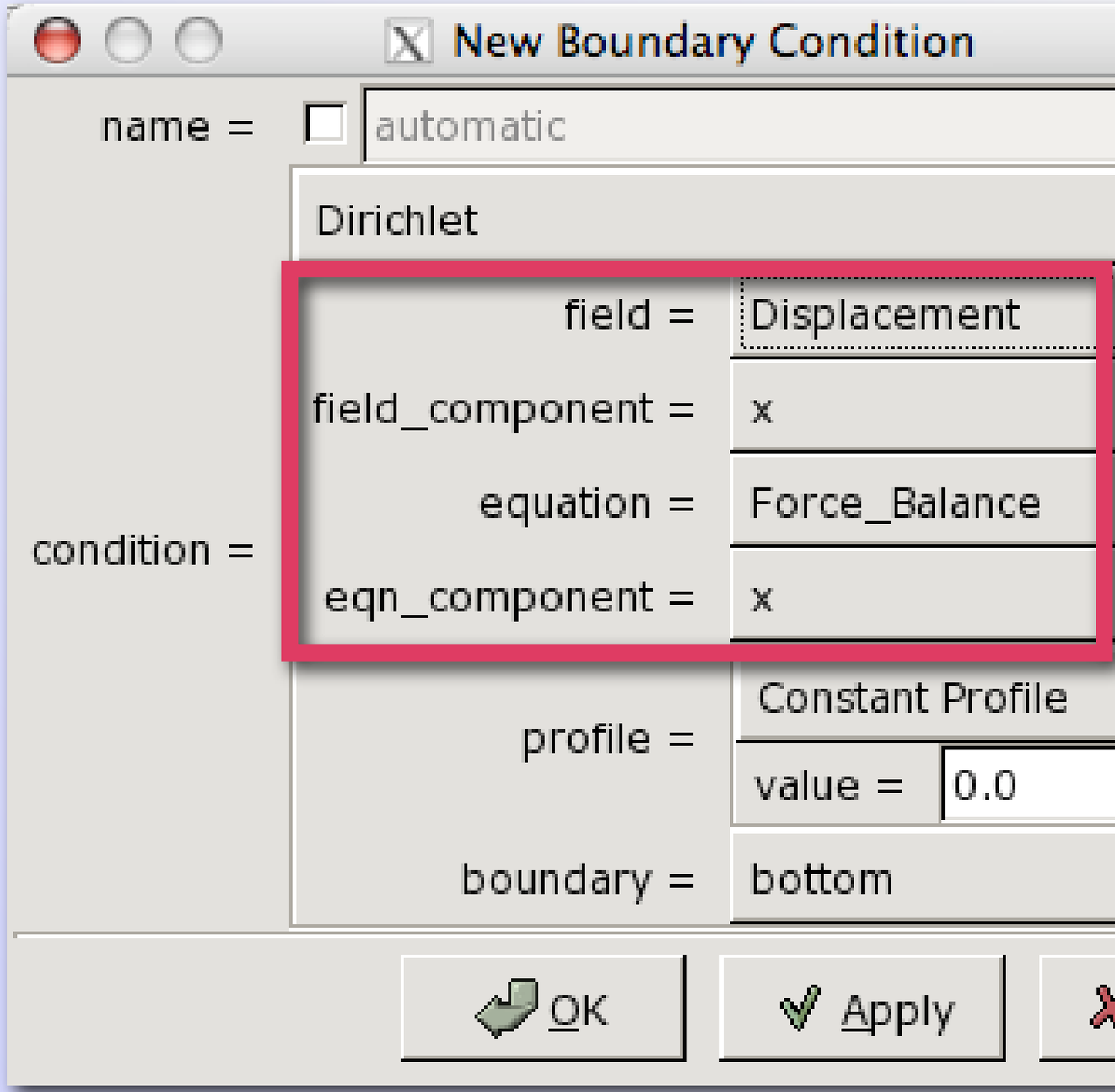


Set Boundary Conditions

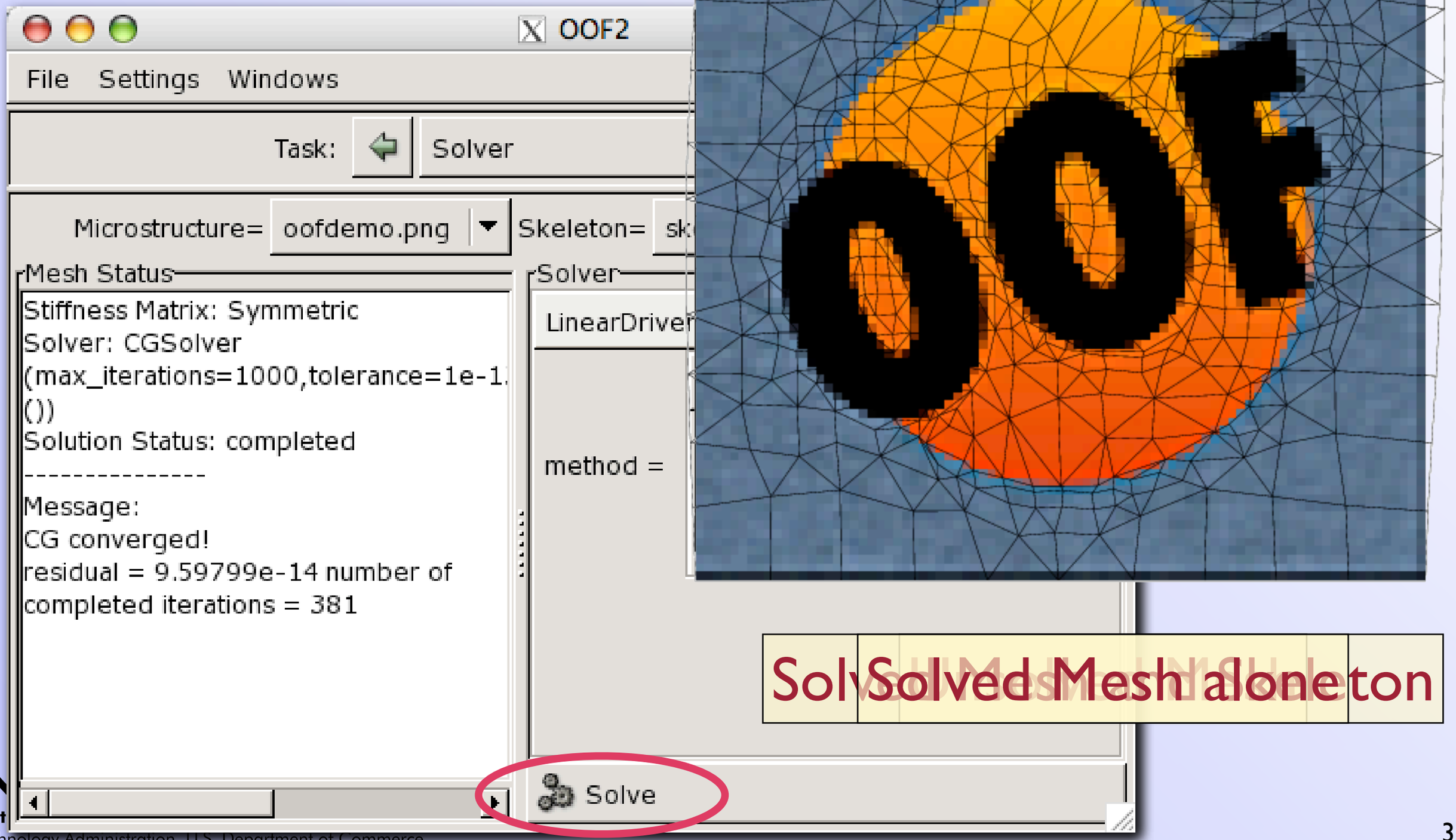


Why is it necessary to specify both a Field *and* an Equation for Dirichlet BCs?

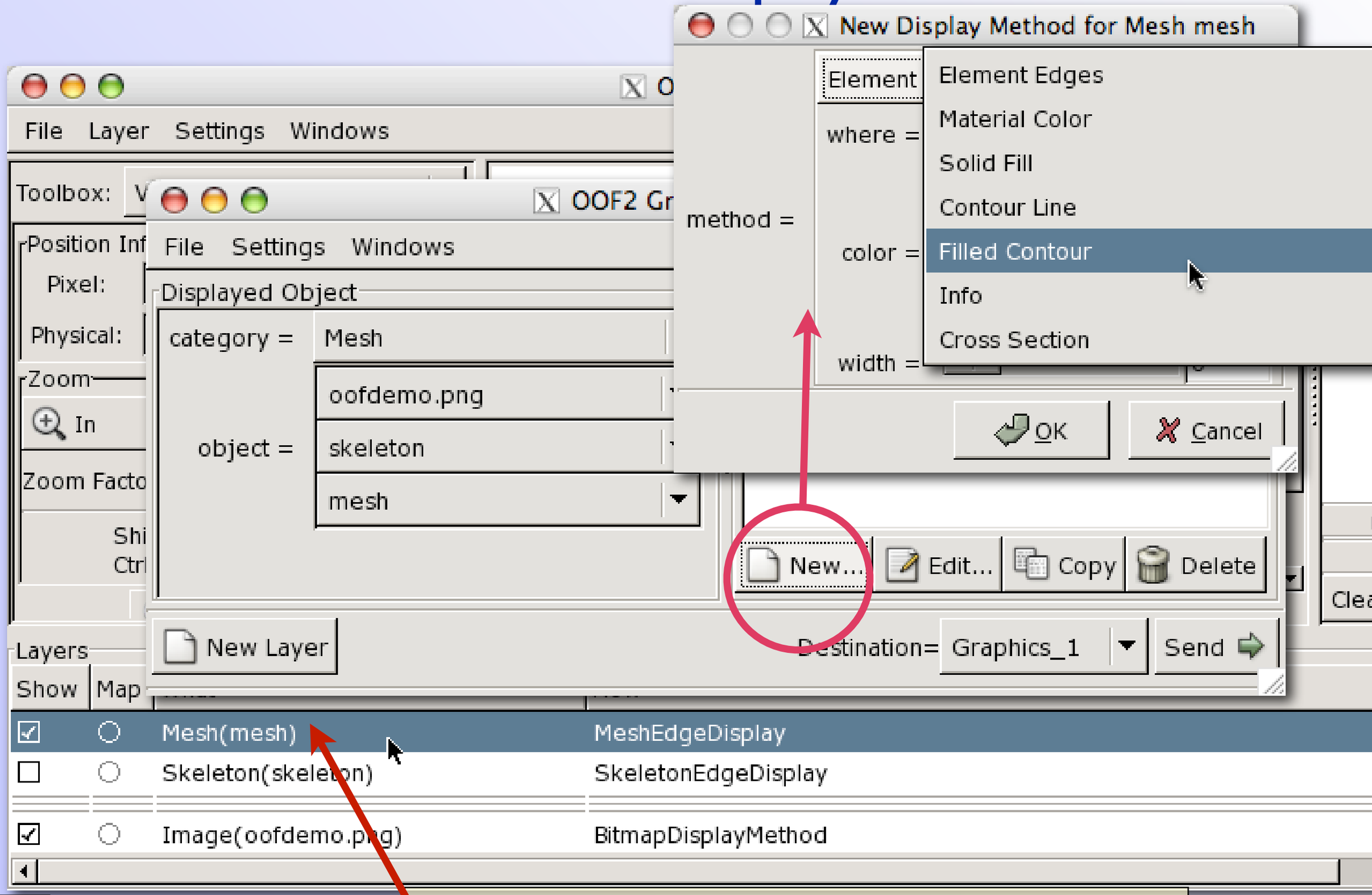
- The Field specifies which degrees of freedom to hold fixed.
- One equation must be eliminated for each fixed degree of freedom.
- Arbitrary coupling terms make it unclear which equation to eliminate.



The Solver Page

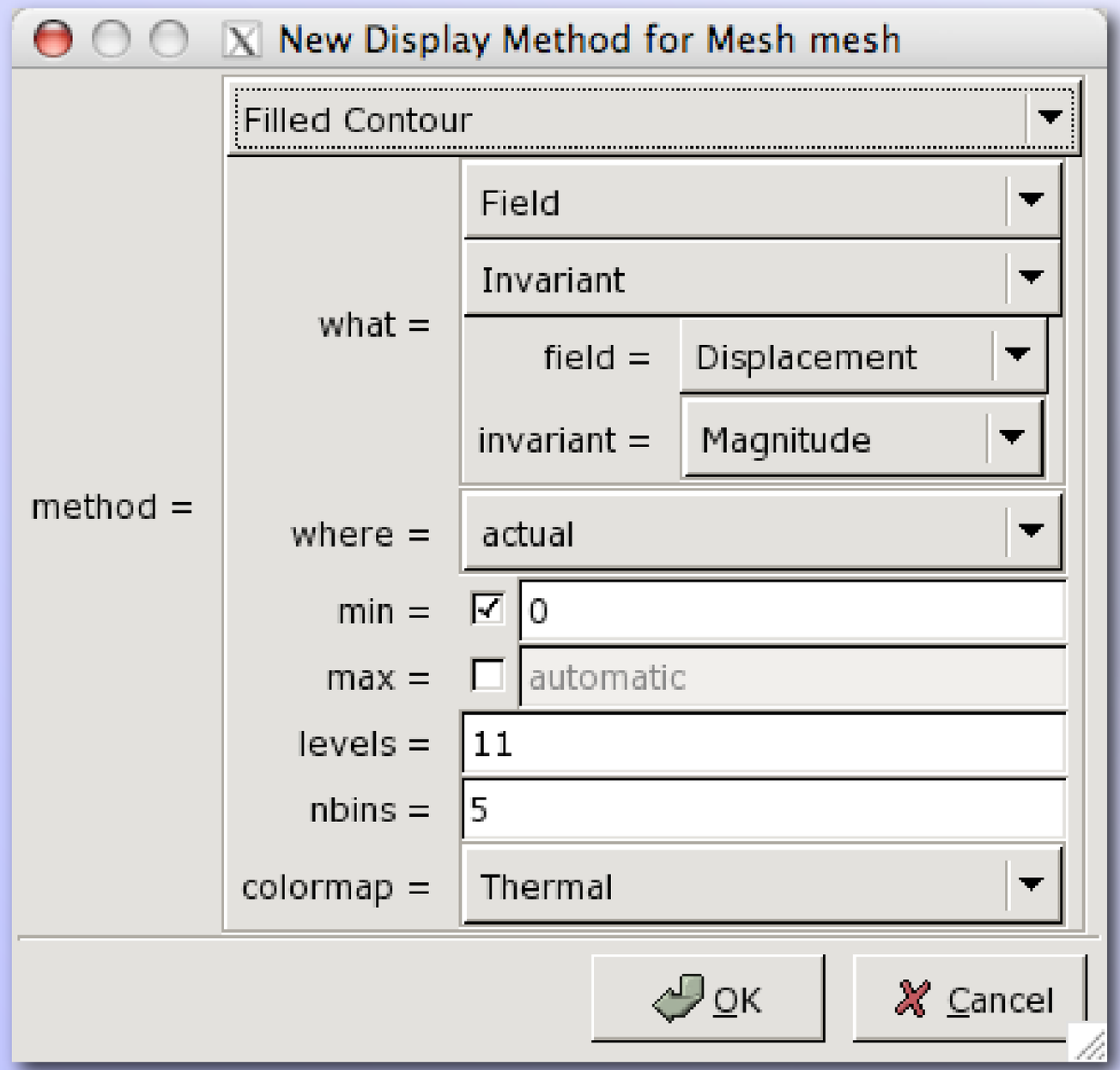


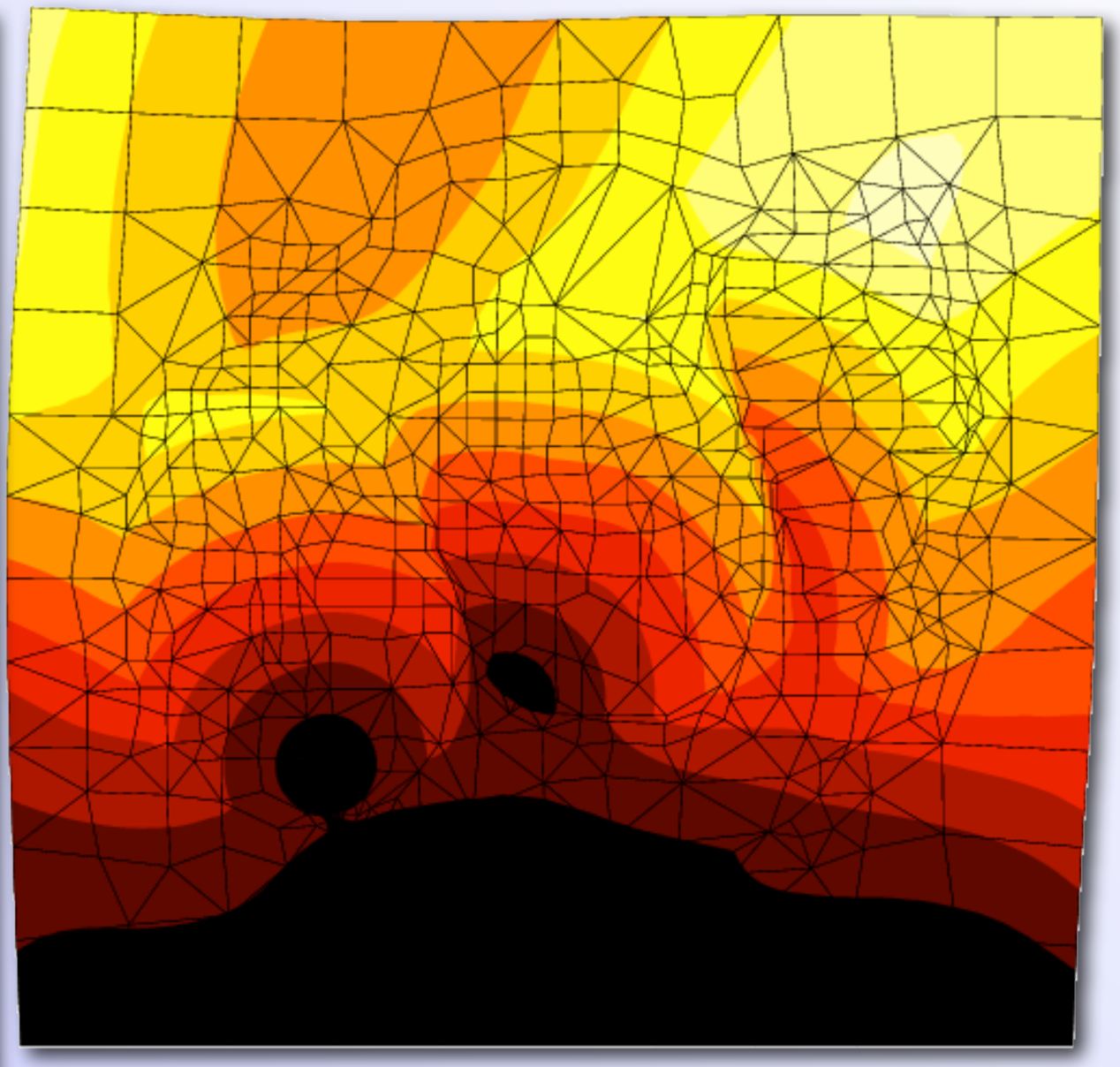
Contour Displays



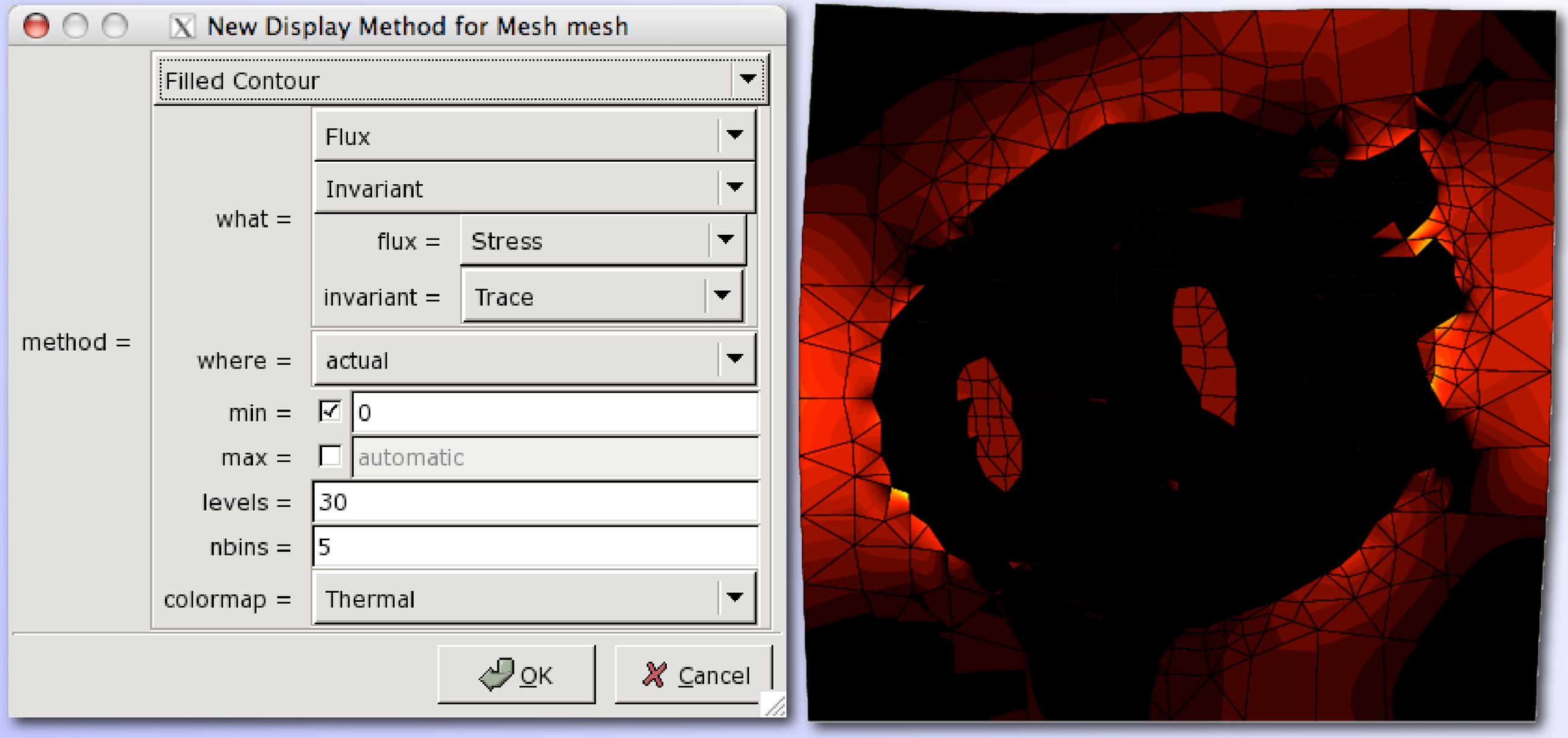
Double-click, or use Layer/Edit menu

Magnitude of the Displacement Field





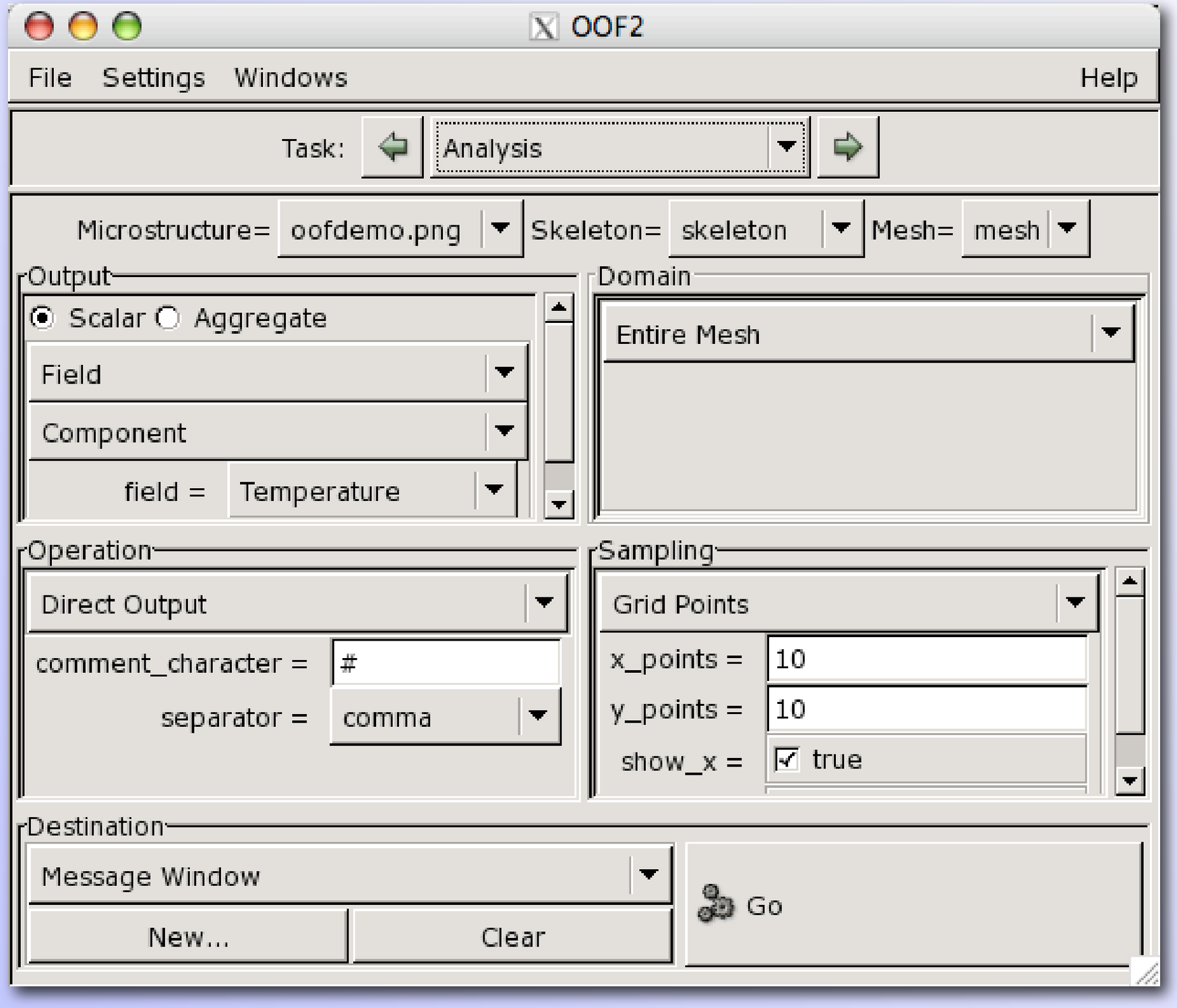
Trace of the Stress (Tensile only)



The Analysis Page

Output: scalar or multicom-ponent

Operation: direct or statistical output



Domain: entire mesh, group, or cross section

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`