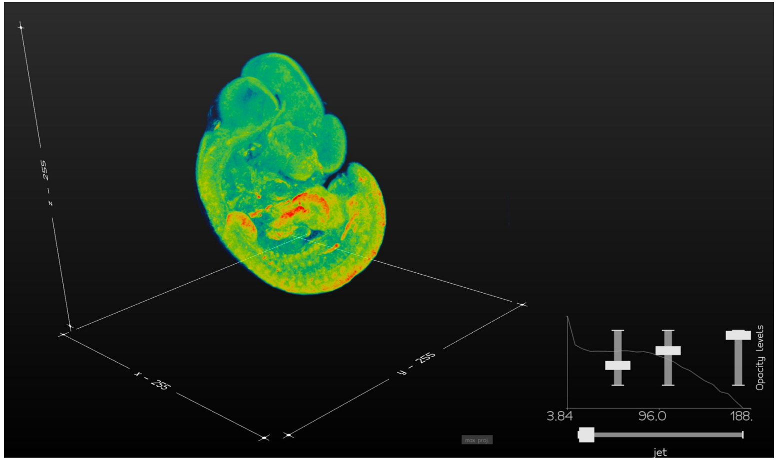
vədo

A python module for scientific **analysis** and **v**isualization of **əd o**bjects



Marco Musy, Johannes Soltwedel

EMBL, Physics of Life, BIAS Course - August 2023

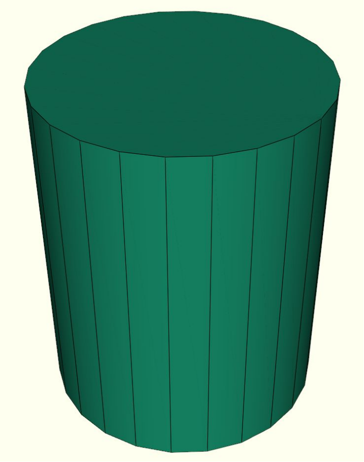
Why?

`matplotlib` is not very useful in 3D

VTK is a fantastic library… but it has a steep learning curve.

```
import vtk


def main():
    colors = vtk.vtkNamedColors()
    # Set the background color.
    bkg = map(lambda x: x / 255.0, [26, 51, 102, 255])
    colors.SetColor("BkgColor", *bkg)

    # This creates a polygonal cylinder model with eight circumferential
    # facets.
    cylinder = vtk.vtkCylinderSource()
    cylinder.SetResolution(8)

    # The mapper is responsible for pushing the geometry into the graphics
    # library. It may also do color mapping, if scalars or other
    # attributes are defined.
    cylinderMapper = vtk.vtkPolyDataMapper()
    cylinderMapper.SetInputConnection(cylinder.GetOutputPort())

    # The actor is a grouping mechanism: besides the geometry (mapper), it
    # also has a property, transformation matrix, and/or texture map.
    # Here we set its color and rotate it -22.5 degrees.
    cylinderActor = vtk.vtkActor()
    cylinderActor.SetMapper(cylinderMapper)
    cylinderActor.GetProperty().SetColor(colors.GetColor3d("Tomato"))
    cylinderActor.RotateX(30.0)
    cylinderActor.RotateY(-45.0)

    # Create the graphics structure. The renderer renders into the render
    # window. The render window interactor captures mouse events and will
    # perform appropriate camera or actor manipulation depending on the
    # nature of the events.
    ren = vtk.vtkRenderer()
    renWin = vtk.vtkRenderWindow()
    renWin.AddRenderer(ren)
    iren = vtk.vtkRenderWindowInteractor()
    iren.SetRenderWindow(renWin)

    # Add the actors to the renderer, set the background and size
    ren.AddActor(cylinderActor)
    ren.SetBackground(colors.GetColor3d("BkgColor"))
    renWin.SetSize(300, 300)
    renWin.SetWindowName('CylinderExample')

    # This allows the interactor to initalize itself. It has to be
    # called before an event loop.
    iren.Initialize()

    # We'll zoom in a little by accessing the camera and invoking a "Zoom"
    # method on it.
    ren.ResetCamera()
    ren.GetActiveCamera().Zoom(1.5)
    renWin.Render()

    # Start the event loop.
    iren.Start()


if __name__ == '__main__':
    main()
```

```
import vedo
vedo.Cylinder().show()
```



…not only visualization!

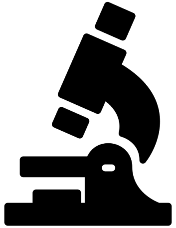
(paraview can already do it)

Vedo makes working with VTK a lot easier. I do understand VTK (or at least I think I do), but it is still a lot of work to get something simple done!

R. de Bruin, Delft Univ. of Tech

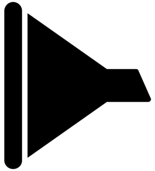
Where?

vedo sits somewhere in here



TB

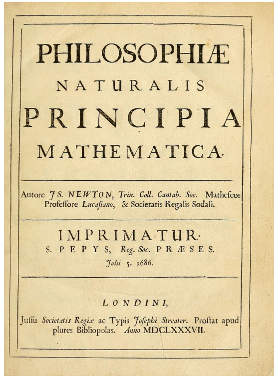
Preprocessing
Raw Data



GB

Postprocessing
Data analysis

MB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Jussu Societatis Regiæ ac Typis Josephi Streater. Prostat apud plures Bibliopolas. Anno MDCLXXXVII.

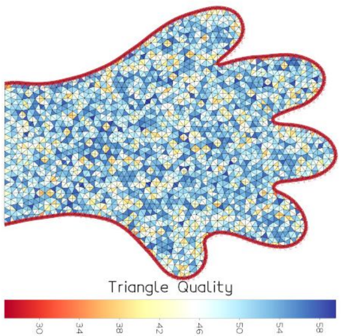
“A 3D-powered version of `matplotlib`”

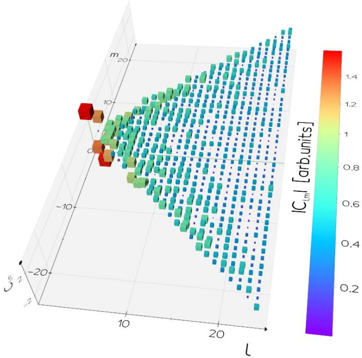
“A handy day-to-day tool for the researcher”

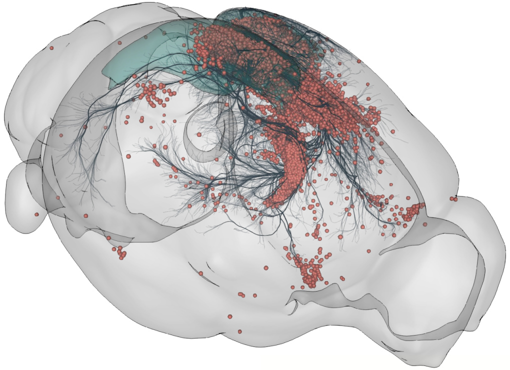
It can prove useful with any type of data having a spatio-temporal structure

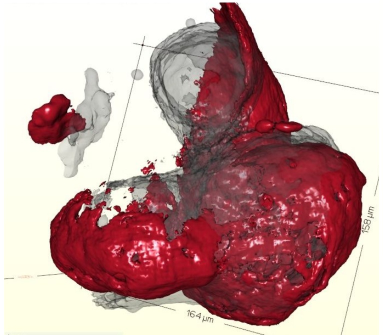
What can *you* do with it?

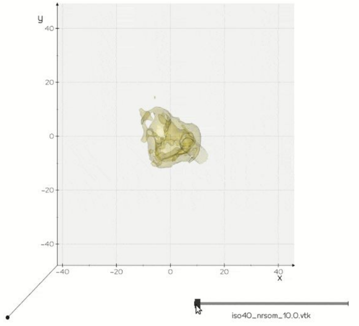
- Work with polygonal meshes and point clouds
- Morphometrics (mesh warp, cut, connect, ...)
- Analysis of 3D images and tetrahedral meshes
- 2D/3D plotting and histogramming.
- Integration with other external libraries (`Qt`, `napari`, `trimesh`, `pymeshlab`, `SHTools` ...)
- Jupyter and Colab environments are supported
- `Command Line Interface` (CLI) as quick viz tool
- Export/exchange 3D interactive scenes to file
- Create interactive animations
- Generate publication-quality renderings



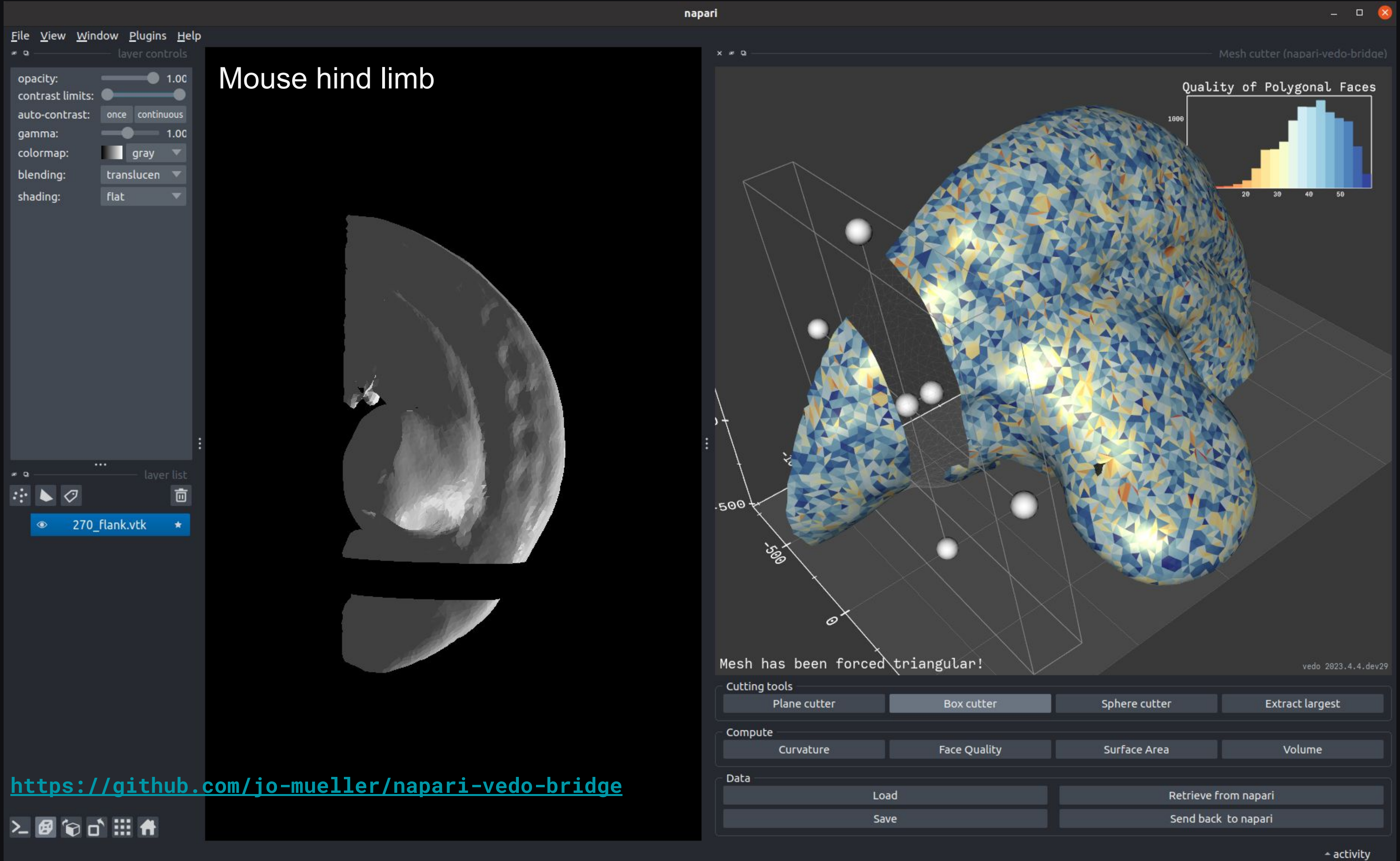








Mouse hind limb



https://github.com/jo-mueller/napari-vedo-bridge

How?

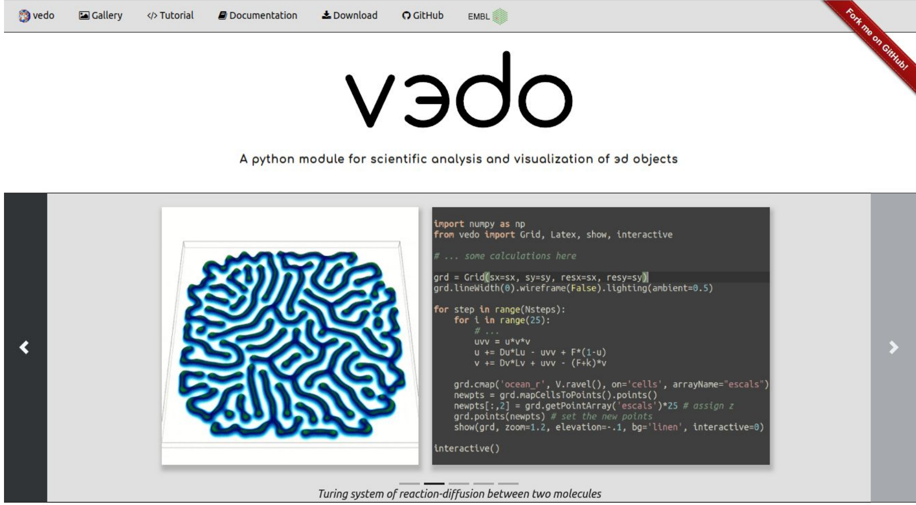
- Install:

  `pip install vedo`

- Documentation:

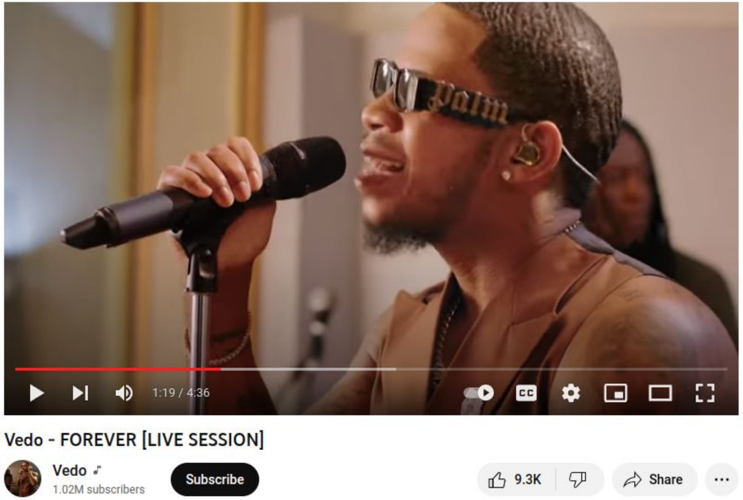
  https://vedo.embl.es/

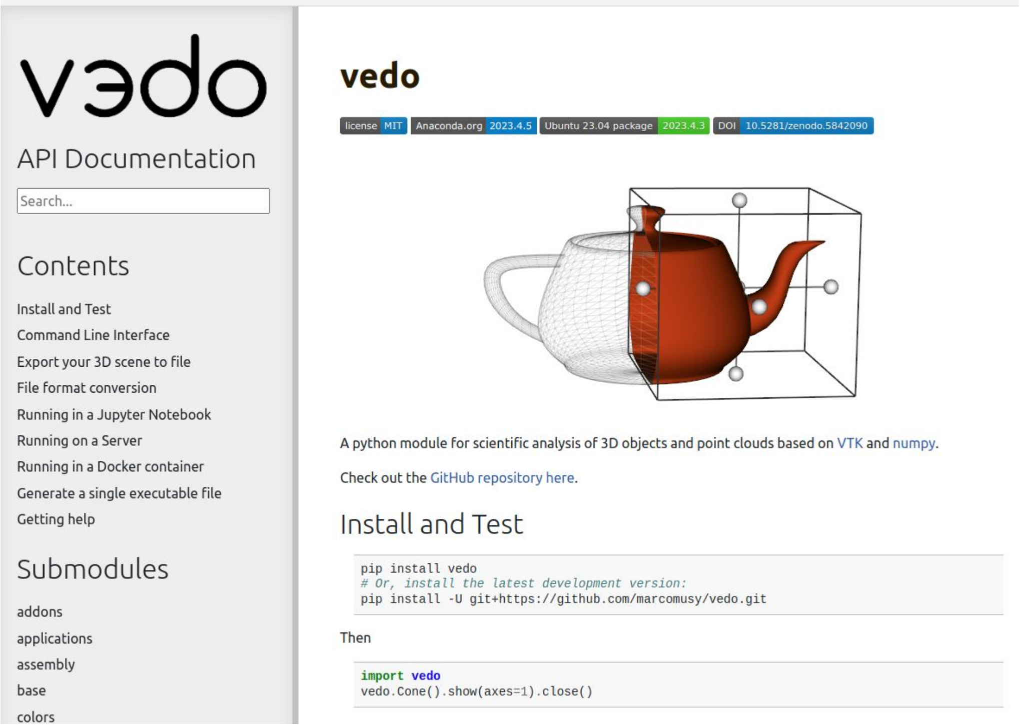
- **350+** examples as reference
  - Designed to be short and intuitive (most are <30 lines)
  - **Searchable** `vedo --search string`
  - **Runnable** `vedo --run examplename`



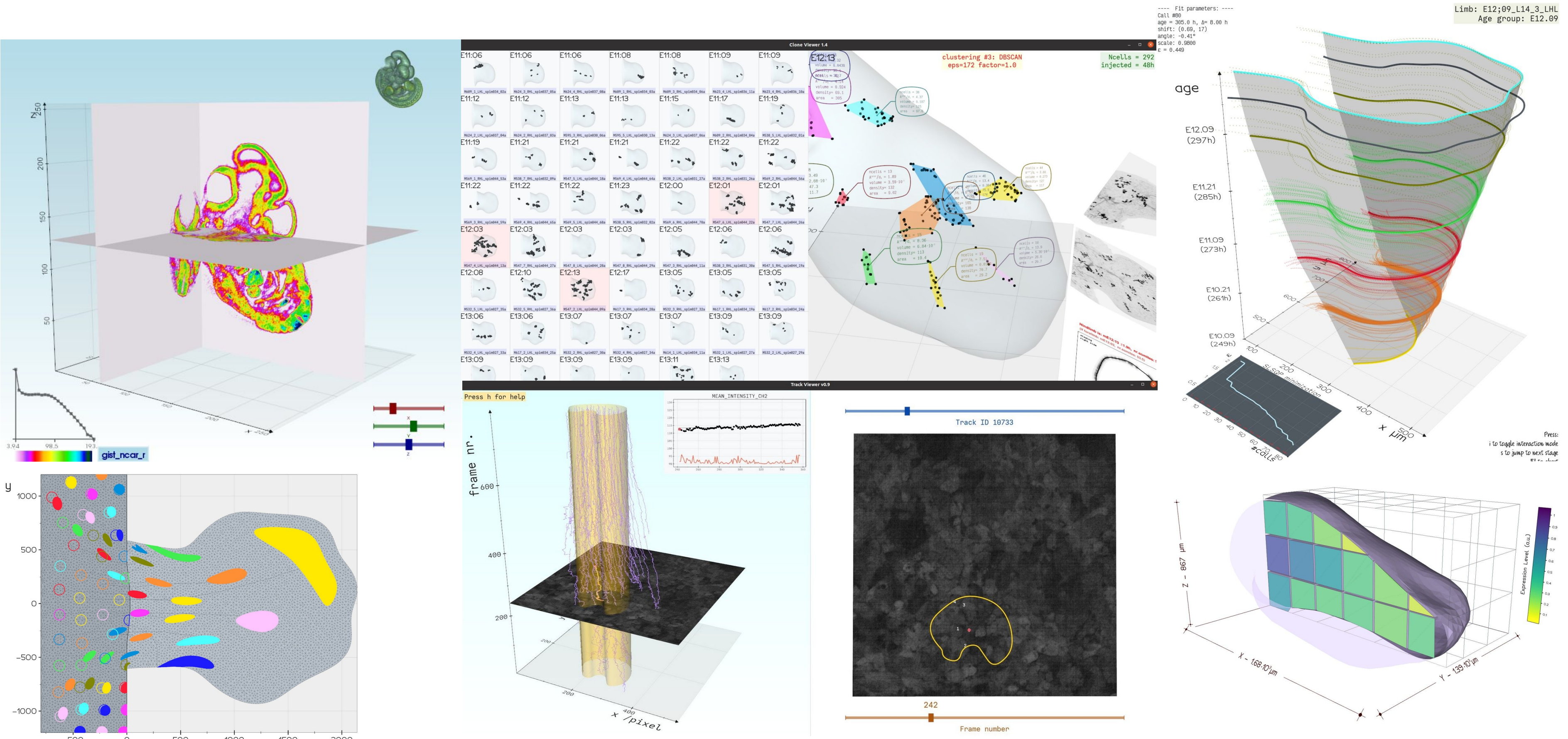
Turing system of reaction-diffusion between two molecules

API documentation is found at vedo.embl.es/docs





Play with your own data (if you have it at hand!)



Conclusion

- Proved very useful in diverse applications
- Documented API with many examples
- **Happy to offer support!**

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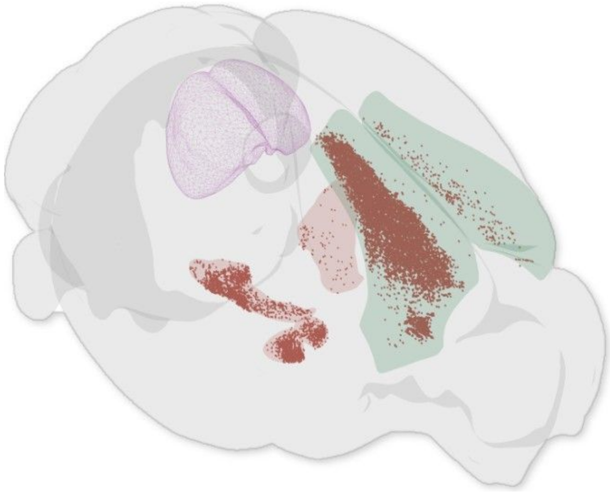
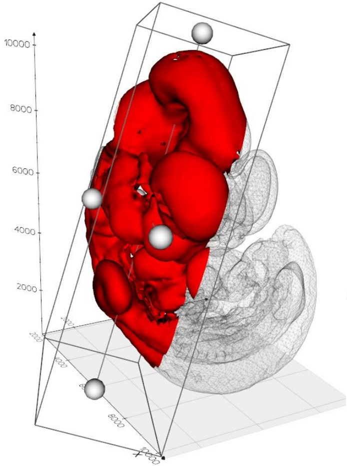
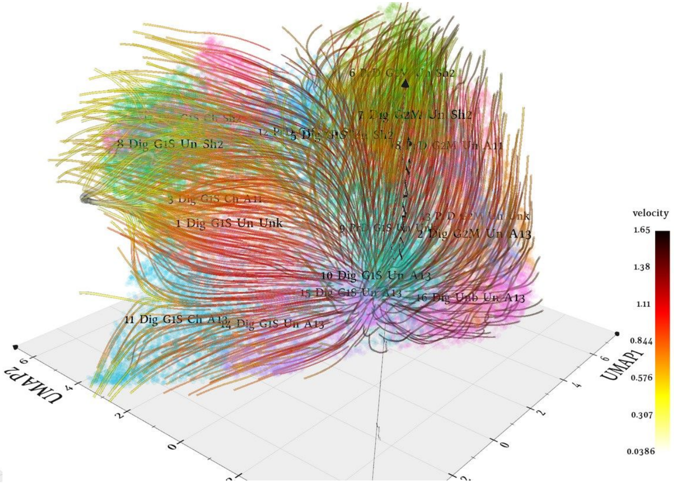
https://vedo.embl.es/

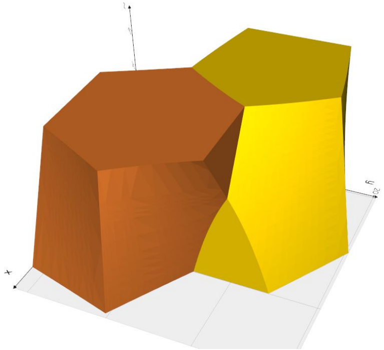






Pol BIAS, August 2023

vedo practicals



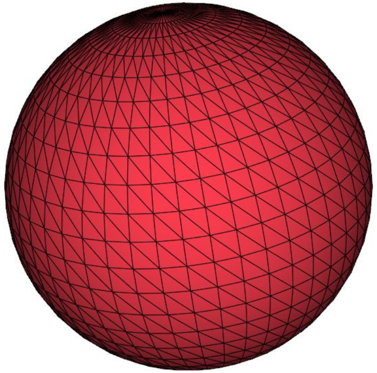
```
> pip install vedo
```

01-basics.ipynb

Basic Geometric Objects

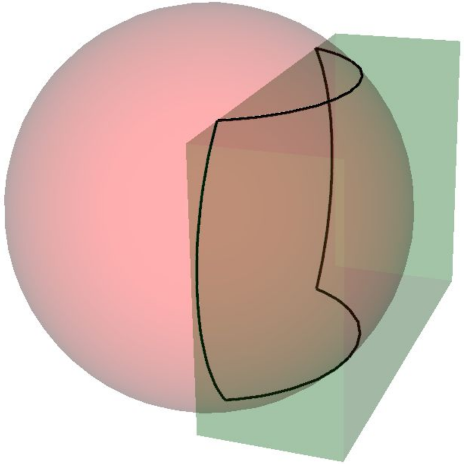
```python
from vedo import *

settings.default_backend = "vtk"

sphere = Sphere().linewidth(1)

plt = Plotter()
plt += sphere
plt.show()
plt.close()
```

In Jupyter notebooks



Press “h” in rendering window

```python
# Create a sphere and a box
sphere = Sphere(r=1.5).c("red5", 0.2)
box = Box(pos=(1,0,0)).triangulate().c("green5", 0.2)

# Find the intersection between the two
intersection = sphere.intersect_with(box).lw(4)

plt += [sphere, box, intersection]
```

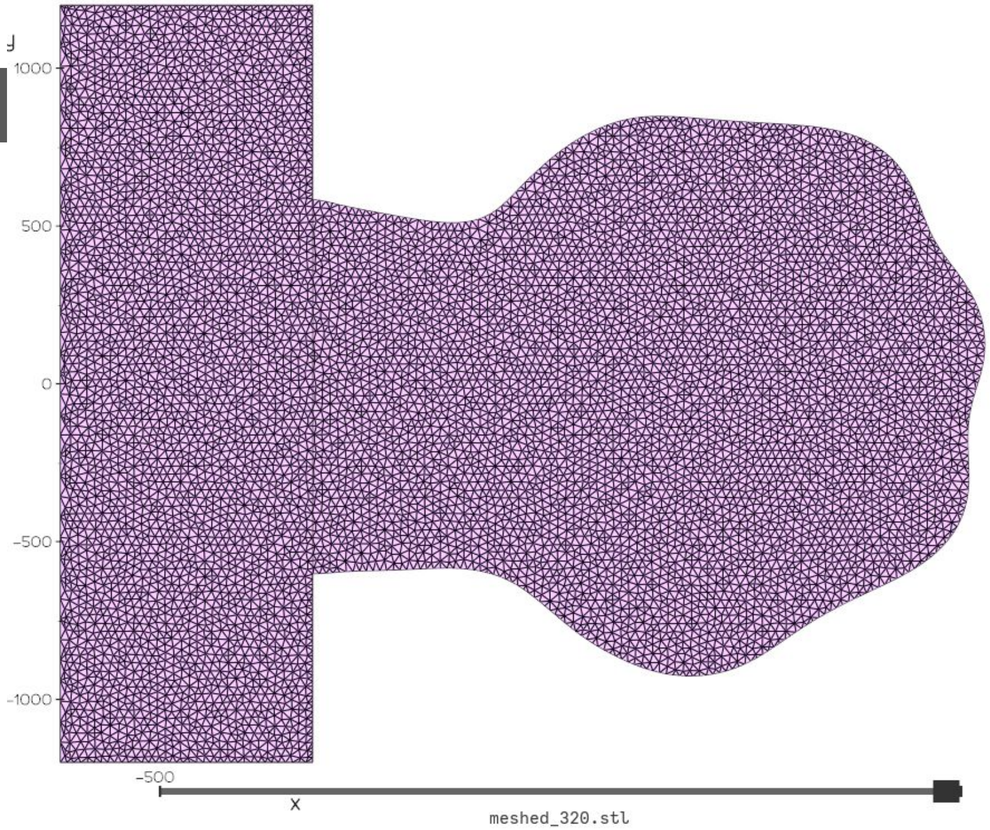


Plotting made simple

```
> vedo -s data/meshed_*.stl
```

Or in a script:

```python
from vedo import load
from vedo.applications import Browser

meshes = load("../data/meshed_*.stl")

for i in range(len(meshes)):
    meshes[i].color(i).linewidth(1)

bro = Browser(meshes, size=(1600,800))
bro.show()
bro.close()
```

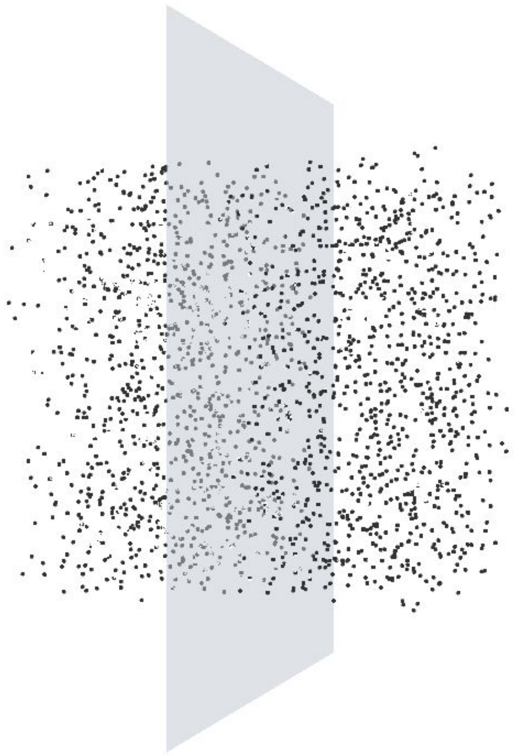


`scripts/01-vis_serie.py`

Point Clouds & Polygonal Meshes

Create a point cloud and cut it

```
points = np.random.rand(2000, 3)

pts = Points(points)
pln = Plane(pos=(0.5, 0.5, 0.6), normal=(1, 0, 0), s=(1.5, 1.5))

show(pts, pln).close()
```



Create a point cloud and cut it

```
pts.cut_with_plane((0.5, 0.5, 0.6))
```

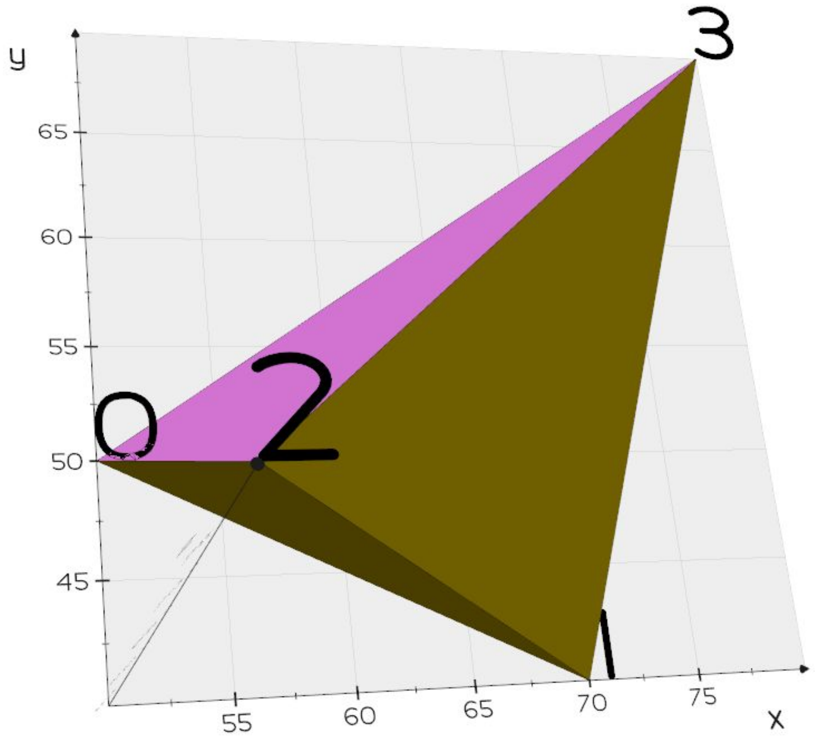
🔥 Can you create a normal distributed cloud and cut the points inside a cylinder?

Hint: search the [API docs]() for "cylinder"

Build a polygonal mesh manually

```python
from vedo import Mesh, show

# Define the vertices and faces that make up the mesh
verts = [(50,50,50), (70,40,50), (50,40,80), (80,70,50)]
faces = [(0,1,2), (2,1,3), (1,0,3)]

# Build the polygonal Mesh object from the vertices and faces
mesh = Mesh([verts, faces])

# Set the backcolor of the mesh to violet
# and show edges with a linewidth of 2
mesh.backcolor('violet').linecolor('tomato').linewidth(2)

# Create labels for all vertices in the mesh showing their ID
labs = mesh.labels('id').c('black')

# Print the points and faces of the mesh as numpy arrays
print('points():', mesh.points())
print('faces() :', mesh.faces())

# Show the mesh, vertex labels, and docstring
show(mesh, labs, viewup='z', axes=1).close()
```

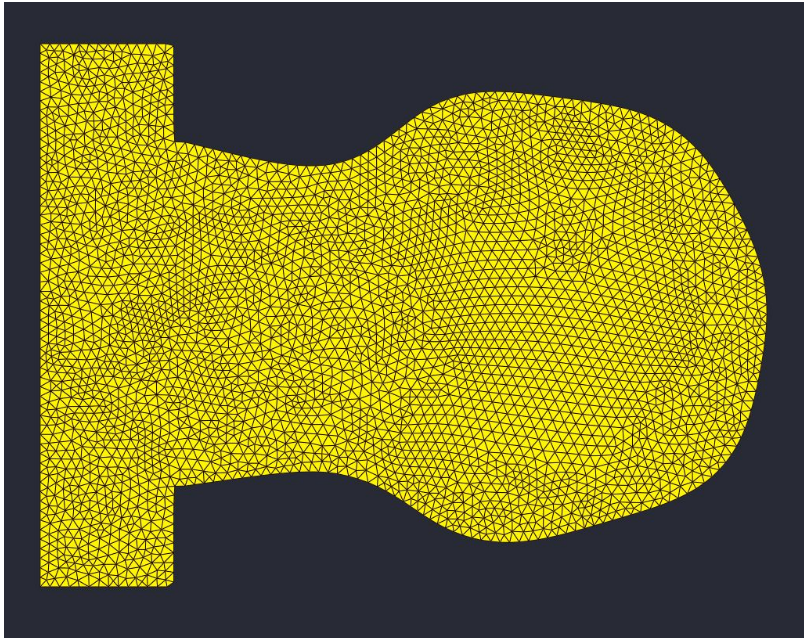
`vedo --run buildmesh`



Create a polygonal mesh

```
# Read data
faces = np.load(faces_path)
verts = np.load(verts_path)
```

```
msh = Mesh([verts, faces]).linewidth(1)
```



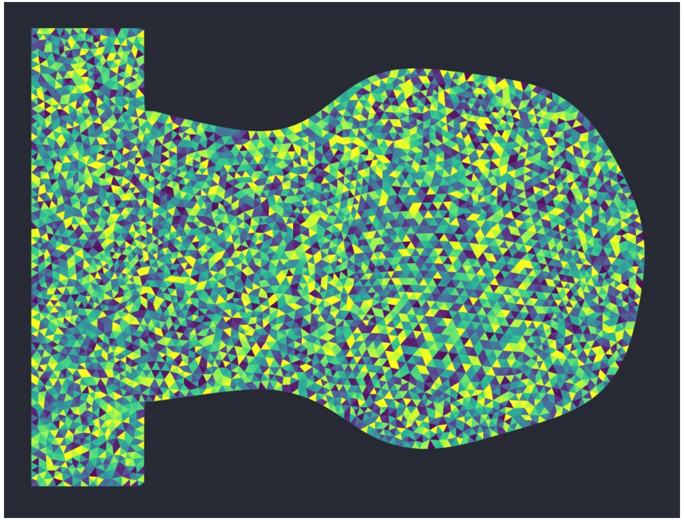
05-gene_mesh.ipynb

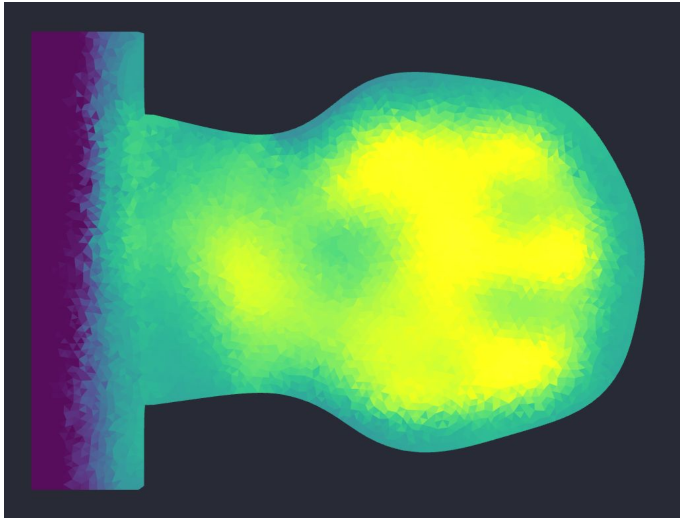
Add gene data associated to cells

```
# Adding scalar values
n = faces.shape[0] # number of faces
values = np.random.random(n)
msh.celldata["fake_data"] = values
```

🔥 Can you add the gene expression data to the mesh?

Use ../data/gene_data.npy

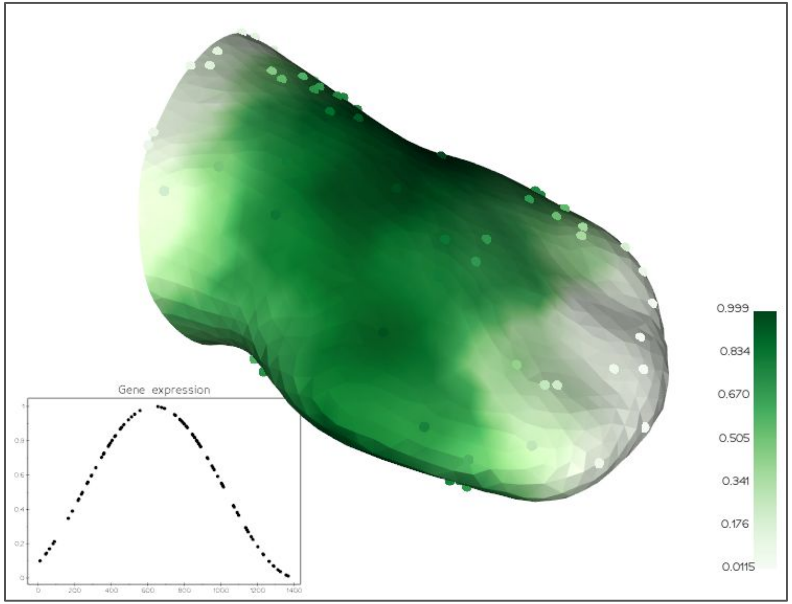




Interpolate data from sparse measurements in 3D

Let’s assume that we know the expression of a gene in 100 positions

```python
import numpy as np
from vedo import dataurl, Mesh, Points, show
from vedo.pyplot import plot

# Load a mesh of a mouse limb at 12 days of development
msh = Mesh(dataurl + "290.vtk")

# Pick 100 points where we measure the value of a gene expression
ids = np.random.randint(0, msh.npoints, 100)
pts = msh.points()[ids]        # slice the numpy array
x = pts[:, 0]                  # x coordinates of the points
gene = np.sin((x+150)/500)**2  # we are making this up!

# Create a set of points with those values
points = Points(pts, r=10).cmap("Greens", gene)

# Interpolate the gene data onto the mesh, by averaging the 5 closest points
msh.interpolate_data_from(points, n=5).cmap("Greens").add_scalarbar()

# Create a graph of the gene expression as function of x-position
gene_plot = plot(x, gene, lw=0, title="Gene expression").as2d(scale=0.5)

# Show the mesh, the points and the graph
show(msh, points, gene_plot)
```

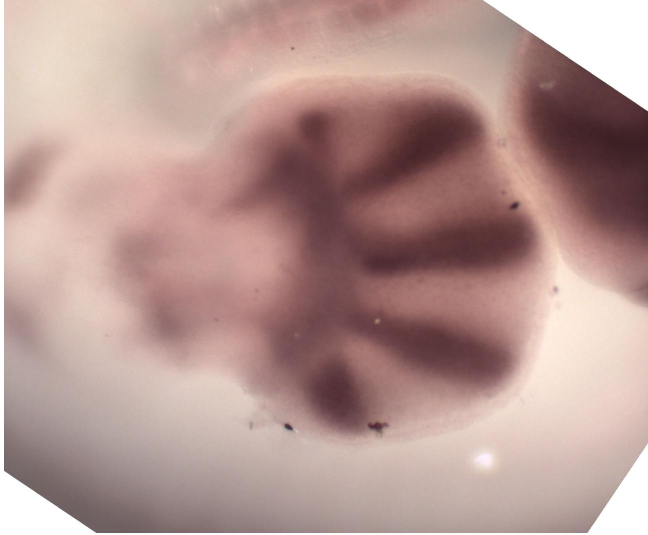


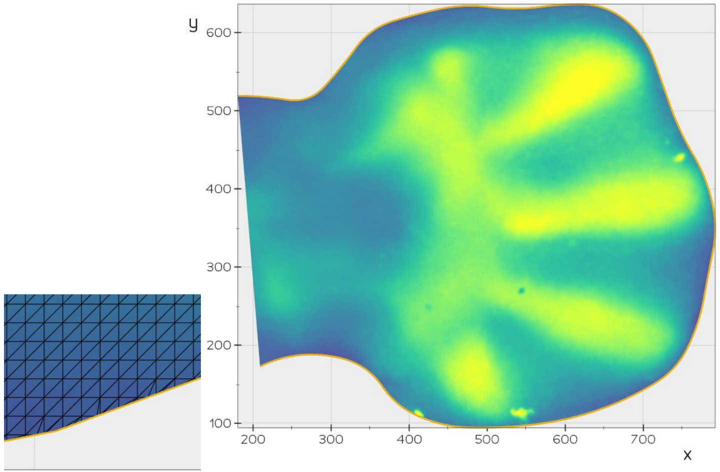
07-grab_scalars.ipynb

Mesh from a JPG image

Manually select a contour and extract a **polygonal mesh** from the input image

```
from vedo import Picture, settings, show
from vedo.applications import SplinePlotter

settings.default_backend = "vtk"

pic = Picture("data/sox9_exp.jpg").bw()

plt = SplinePlotter(pic)
plt.show(mode="image", zoom='tight')
outline = plt.line
plt.close()

print("Cutting with outline...")
msh = pic.tomesh().triangulate().cmap("viridis_r")
cut_msh = msh.clone().cut_with_point_loop(outline)

cut_msh.interpolate_data_from(msh, n=3)
show(cut_msh, outline, axes=1).close()
```



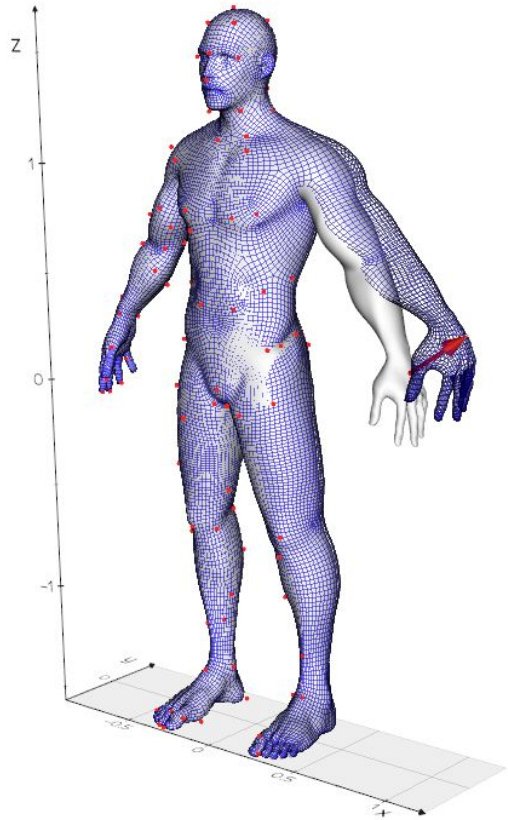


08-warp_mesh.ipynb

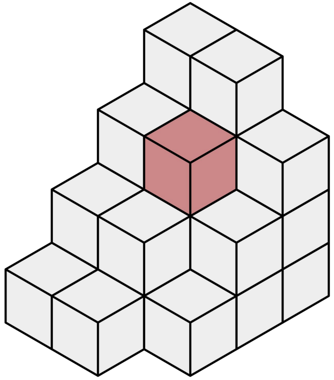
Warp a Mesh (non-linear registration)

All points stay fixed while a single point in space moves as the arrow indicates

```python
from vedo import dataurl, Mesh, Arrows, show

# Load a mesh
mesh = Mesh(dataurl+"man.vtk").color("white")

# Create a heavily decimated copy with about 200 points
# (to speed up the computation)
mesh_dec = mesh.clone().triangulate().decimate(n=200)

sources = [[0.9, 0.0, 0.2]]  # this point moves
targets = [[1.2, 0.0, 0.4]]  # ...to this.
for pt in mesh_dec.points():
    if pt[0] < 0.3:          # while these pts don't move
        sources.append(pt)   # (e.i. source = target)
        targets.append(pt)

# Create the arrows representing the displacement
arrow = Arrows(sources, targets)

# Warp the mesh
mesh_warped = mesh.clone().warp(sources, targets)
mesh_warped.c("blue").wireframe()

# Show the meshes and the arrow
show(mesh, mesh_warped, arrow, axes=1)
```



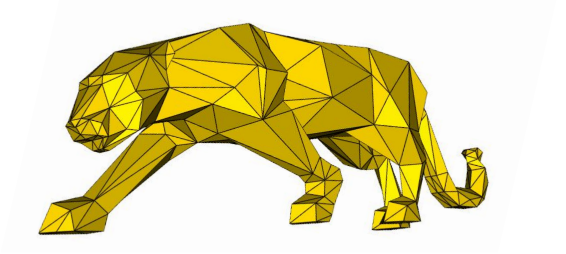
Volumes
(eg TIFF stacks)

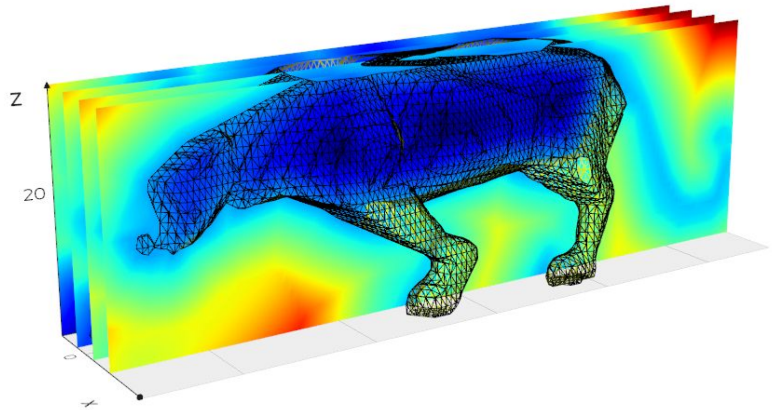


Compute distance from a mesh

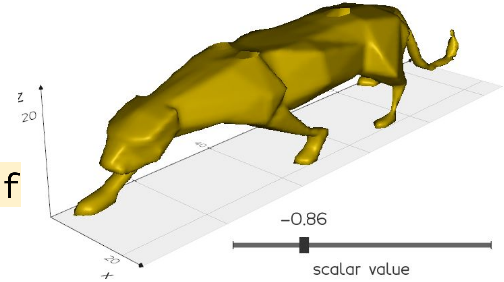
..and save it as a tiff stack

```python
from vedo import *

msh = Mesh(dataurl + "panther.stl")

vol = msh.signed_distance(dims=[25,125,25])
iso = vol.isosurface(0.0)

plt = Plotter()
plt += iso.wireframe()

for i in range(0, 25, 5):
    plt += vol.xslice(i).cmap("jet")

vol.write("panther.tif")
plt.show(axes=1)
```






```
> vedo panther.tif
```

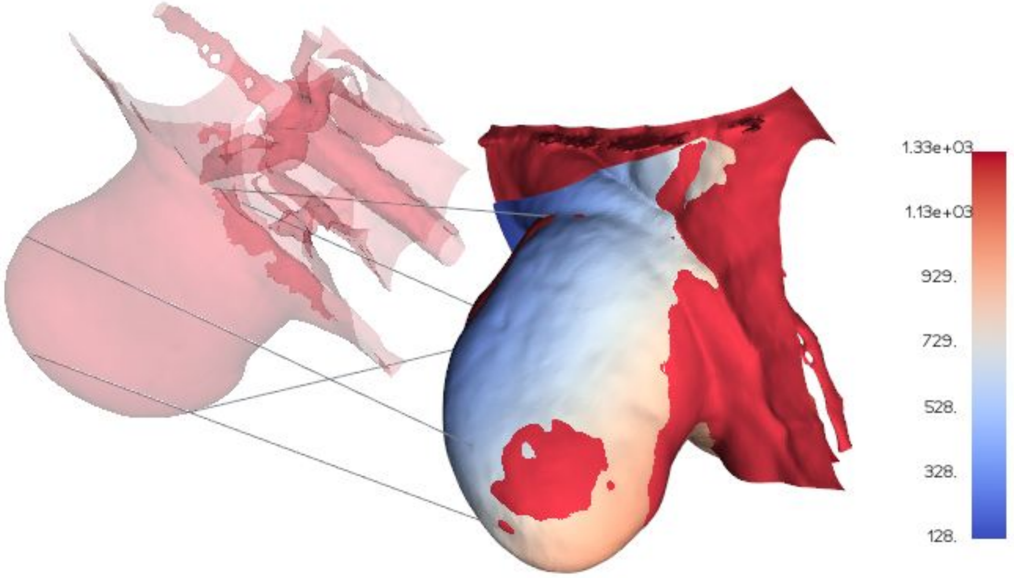


Extras: Linear vs Non-Linear Registration

Naive registration (ICP) might fail!

Try to:

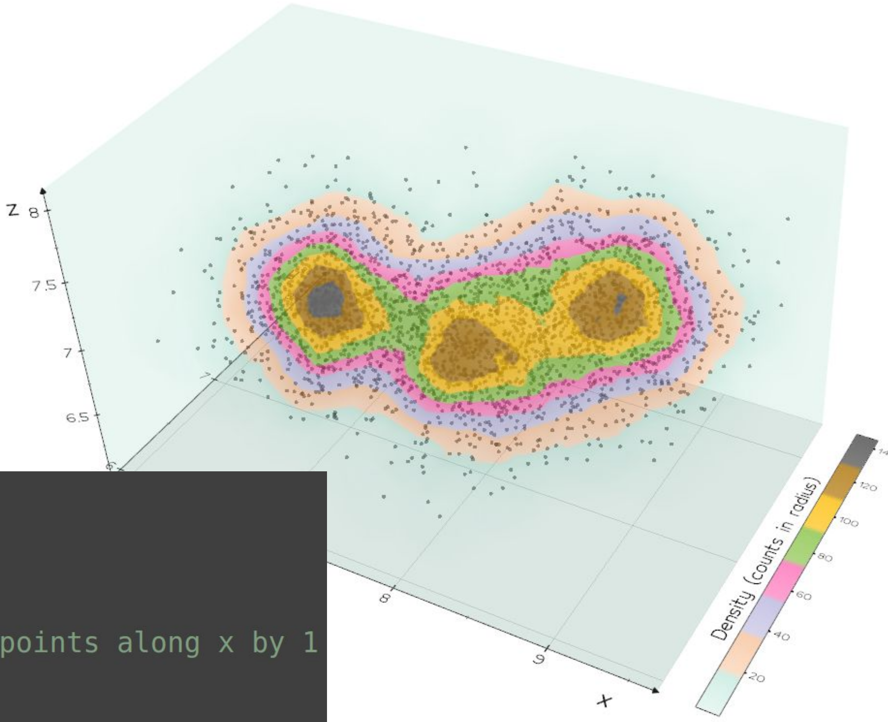
1. Inspect the meshes
2. Identify landmark points
3. Warp one mesh onto the other



Compute point density

..from a point cloud:

`14-cells_segment.ipynb`




```python
from vedo import *

n = 3000
p = np.random.normal(7, 0.3, (n,3))
p[:int(n*1/3) ] += [1,0,0]       # shift 1/3 of the points along x by 1
p[ int(n*2/3):] += [1.7,0.4,0.2]

pts = Points(p, alpha=0.5)

# Create a Volume from the points representing the points density
vol = pts.density(radius=0.25).cmap('Dark2').alpha([0.1,1])
vol.add_scalarbar3d(title='Density (counts in radius)', c='k')

show(pts, vol, __doc__, axes=1).close()
```

Conclusion

- Proved very useful in diverse applications
- Documented API with many examples
- **Happy to offer support!**

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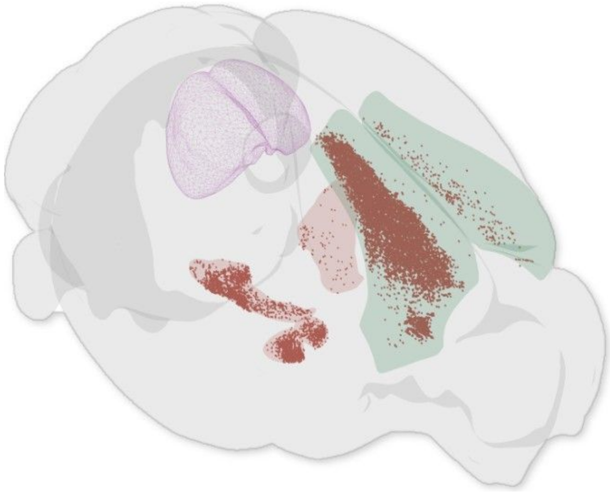
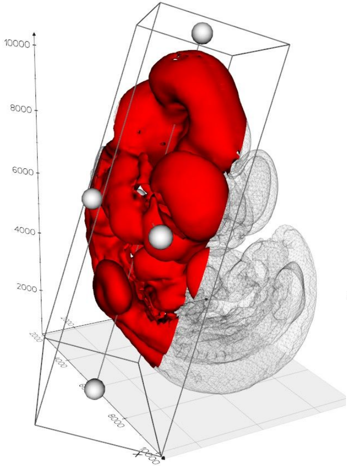
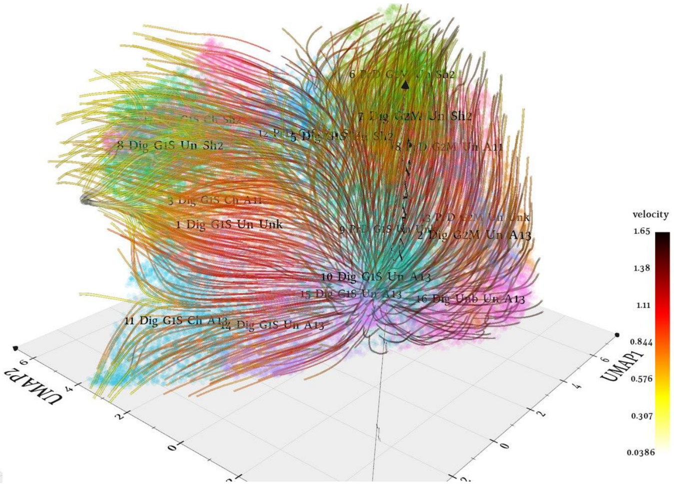


https://vedo.embl.es/





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