ISO2Mesh

a “one-liner” 3D mesh generator

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iso2mesh website: http://iso2mesh.sf.net

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• TODOs and Roadmap
Brain vessel network microscopy

Fang et al., Optics Express, 16(22) 17530-17541, 2008.
X-ray/Optical breast imaging

Fang et al., IEEE TMI, 28(1) 30-42, 2009.
Multi-modal brain imaging

- segmentation
  - surface extraction
  - FreeSurfer
    - iso2mesh
      - resample
        - surface extraction
          - surface extraction
            - 3D FEM mesh with brain structures

- Head surface
- Brain
- Cortex surface
Meshing from gray scale images
Validation for a mesh-based MC

A side-cut fiber
Implicit functions

\[ g(\vec{r}, \vec{r}_s) = \frac{\exp(jk|\vec{r} - \vec{r}_s|)}{4\pi|\vec{r} - \vec{r}_s|} \]
From 2008 to 2010:

>4000 total downloads
  (3/4 from matlab file exchange)
~450 registered users
7500 unique visits from 82 regions

Range of applications:
- optical imaging
- computer vision
- high energy physics
- glacier geology
- ...
How is iso2mesh different

• Designed for simplicity
• Highly modularized
• Cross-platform
• Matlab(7.0+)/Octave(3.0+) compatible
• Fast; fine-grained granularity
• Build on open-source software
• Free and open-source

CGAL
http://www.cgal.org/

Tetgen
http://tetgen.berlios.de/

JMeshLib
http://jmeshlib.sf.net
Example #1 – Hello World!

```matlab
hw = imread('helloworld.png');
hw3d = 1-repmat(hw, [1 1 50]);

% create 3D mesh
[node, elem, face] = v2m(hw3d, 0.7, 5, 40);

% mesh with denser surface
[node, elem, face] = v2m(hw3d, 0.7, 2, 40);
```
Hello World in gray-scale

hw = imread('helloworld_gray.png');
hw3d = 255 - repmat(hw, [1 1 50]);
[node, elem, face] = v2m(hw3d, 128, 2, 40);
Hello World again ...

```
opt.radbound=4; % set surface triangle maximum size
opt.distbound=0.2; % set max distance that deviates from the level-set
[node,elem,face]=v2m(hw3d,128,opt,40);
```
Example #2 – A rat head

load rathead.mat
% mesh rat head image with 'surf. simplify' approach (t=1.9s)
tic; [node, elem, face] = v2m(rat>0, 0.5, 0.2, 30, 'simplify'); toc

% extract surface with cgalsurf and gen 3D mesh with tetgen  t=(0.6s)
tic; [node, elem, face] = v2m(rat>0, 0.5, 2, 30, 'cgalsurf'); toc
% extract surface with cgalmesher  (t=0.7s)
tic; [node, elem, face] = v2m(rat>0, 0.5, 2, 30, 'cgalmesh'); toc
– surface smoothing

euinode=sms(node,face,iter,alpha);

Laplacian
iter=2
iter=4
iter=6
iter=8

Laplacian+HC

Low-pass

Bade et al., Simu. and Vis., 289-304, 2006
re-mesh and up-sampling

[newno,newfc]=remeshsurf(node,face,1);
newno=sms(newno,newfc(:,1:3),3,0.5);
plotmesh(newno,newfc);
Example #3 – A sphere in a box

% first create a gray-scale field representing distance from the sphere center
dim=60;
[xi,yi,zi]=meshgrid(0:0.5:dim,0:0.5:dim,0:0.5:dim);
dist=sqrt((xi-30).^2+(yi-30).^2+(zi-30).^2);
clear xi yi zi;
[v0,f0]=vol2restrictedtri(dist,20,[60 60 60],60*60*20,30,2,2,40000);
v0=(v0-0.5)*0.5;
% iso2mesh will also produce a surface for the bounding box, remove it
facecell=finddisconnsurf(f0);
sphsurf=facecell{1};
if( sum((v0(sphsurf(1,1),:)-[30 30 30]).^2) > 25*25 )
    sphsurf=facecell{2};
end
trisurf(sphsurf,v0(:,1),v0(:,2),v0(:,3)); % plot the sphere surface
axis equal;
idx=unique(sphsurf);  % this is the index of all the nodes on the sphere
% show the histogram of the displacement error for the nodes on the sphere
r0=sqrt((v0(idx,1)-30).^2+(v0(idx,2)-30).^2+(v0(idx,3)-30).^2);
figure;hist(r0,100);
% we only take the nodes on the surface
[no,el]=removeisolatednode(v0,sphsurf);
[no,el]=meshcheckrepair(no,el);
Sphere in a box – phase 2

% first create a gray-scale field representing distance from the sphere center
dim=60;
[xi,yi,zi]=meshgrid(0:0.5:dim,0:0.5:dim,0:0.5:dim);
dist=sqrt((xi-30).^2+(yi-30).^2+(zi-30).^2);
clear xi yi zi;
[v0,f0]=vol2restrictedtri(dist,20,[60 60 60],60*60*20,30,2,2,40000);
v0=(v0-0.5)*0.5;
% iso2mesh will also produce a surface for the bounding box, remove it
facecell=finddisconnsurf(f0);
sphsurf=facecell{1};
if( sum((v0(sphsurf(1,1,:),:)-[30 30 30]).^2) > 25*25 )
    sphsurf=facecell{2};
end
trisurf(sphsurf,v0(:,1),v0(:,2),v0(:,3)); % plot the sphere surface
axis equal;
idx=unique(sphsurf);  % this is the index of all the nodes on the sphere
% show the histogram of the displacement error for the nodes on the sphere
r0=sqrt((v0(idx,1)-30).^2+(v0(idx,2)-30).^2+(v0(idx,3)-30).^2);
figure;hist(r0,100);
% we only take the nodes on the surface
[no,el]=removeisolatednode(v0,sphsurf);
[no,el]=meshcheckrepair(no,el);

ISO2MESH_SESSION='demo_sph3_';

srcpos=[30. 30. 0.];  % set the center of the ROI
fixednodes=[30.,30.,0.1; 30 30 30];  % add control points so we can refine mesh densities
nodesize=[ones(size(no,1),1) ; 0.2; 4];  % set target edge size of 1 for all nodes on the sph
r0=sqrt((v0(idx,1)-30).^2+(v0(idx,2)-30).^2+(v0(idx,3)-30).^2);
figure;hist(r0,100);
% only take the nodes on the surface
[no,el]=removeisolatednode(v0,sphsurf);
[no,el]=meshcheckrepair(no,el);

[nfull] = [no;fixednodes];  % append additional control points
[node3,elem3,face3]=surf2mesh([nfull,nodesize],el,[0 0 0],[61 61 61],1,8,[30 30 30],[],[2 2 2 6 6 6 6]);
% ^- add node size as the last column to node
% ^- max volume
% ^- edge sizes at the 8 corners of the bounding box
[node3,elem3]=sortmesh(srcpos,node3,elem3,1:4);  % reorder the nodes/elements so that the nodes near each order
% are more clustered in the memory
elem3(:,1:4)=meshreorient(node3,elem3(:,1:4));  % reorient elements to ensure the volumes are positive
Example #4 – side-cut fiber
%% angular resolution
dt=pi/40;
t=0:dt:2*pi-dt;

%% parameters of a side-cut fiber
h=100;r1=20;r2=25;
a=-1;b=0;c=1;d=-h; % a*x+b*y+c*z=d

%% key nodes of a side-cut fiber
n1=[r1*sin(t(:)) r1*cos(t(:)) zeros(size(t(:)))];
n2=[r2*sin(t(:)) r2*cos(t(:)) zeros(size(t(:)))];
n3=[r1*sin(t(:)) r1*cos(t(:)) -d-(a*r1*sin(t(:))+b*r1*cos(t(:)))/c];
n4=[r2*sin(t(:)) r2*cos(t(:)) -d-(a*r2*sin(t(:))+b*r2*cos(t(:)))/c];
no=[n1;n2;n3;n4];

%% PLCs of the side-cut fiber
clear fc;
count=1;
for i=1:length(t)-1
    % the last number in each cell is the surface id
    fc{count}={[i+length(t) i+3*length(t) i+3*length(t)+1 i+length(t)+1],1}; count=count+1;
    fc{count}={[i i+2*length(t) i+2*length(t)+1 i+1],2}; count=count+1;
end
i=length(t);
fc{count}={[i+length(t) i+3*length(t) 1+3*length(t) i+length(t)],1}; count=count+1;
fc{count}={[i i+2*length(t) 1+2*length(t) i+1],2}; count=count+1;

fc{count}={[1:1+length(t)-1,3];count=count+1; % bottom inner circle
fc{count}={[1:length(t):1+length(t)+2-1 nan fliplr(1:1+length(t)-1)],4};count=count+1; % button outer circle
fc{count}={[1:length(t)*2:1+length(t)*3-1,5];count=count+1; % top inner circle
fc{count}={[1:length(t)*3:1+length(t)*4-1 nan fliplr(1:length(t)*2:1+length(t)*3-1)],6}; % top outer circle

%% mesh generation of the cladding for the side-cut fiber
[node,elem,face]=surf2mesh(no,fc,min(no),max(no),1,50,[0 0 1],[],0);
plotmesh(node,elem,'x>0 | y>0');
Example #5: Vessel network
Example #6 – Collins brain atlas

Collins, IEEE TMI, 17(3), 1998
Full head mesh and simulation
iso2mesh: a 3D surface and volumetric mesh generator for matlab/octave

- iso2mesh is a matlab/octave-based meshing toolbox. It can create 3D tetrahedral finite element (FE) mesh from iso-surfaces and 3D binary volumetric images such as segmented MRI/CT scans.
- iso2mesh is an open-source software developed by Qianqian Fang at the Photon Migration Lab, Martinos Center for Biomedical Imaging, Massachusetts General Hospital (Harvard Medical School).
- A sibling project, metch - a mesh registration toolbox, is also hosted with this website.

Learn Qianqian's other projects

Download   Documentation   Development   Community
TODOs

• Robustness → fix or help upstream to correct a few bugs
• Set RNG seeds in CGAL utilities
• Recursive mesh refinement
• Edge sharpening
• More robust self-intersecting surface processing
• Mesh optimization
• More applications ...
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