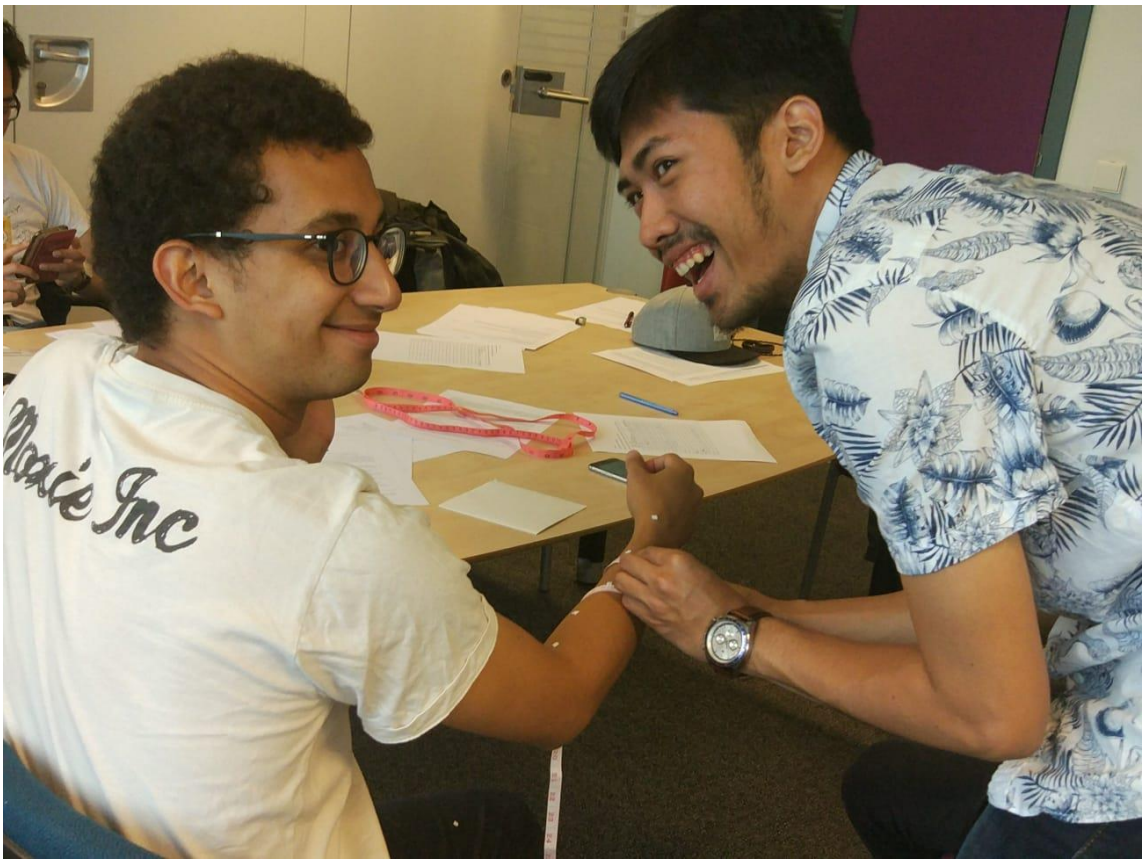
A

Photos of The Experiment


oxie Inc




3dMD

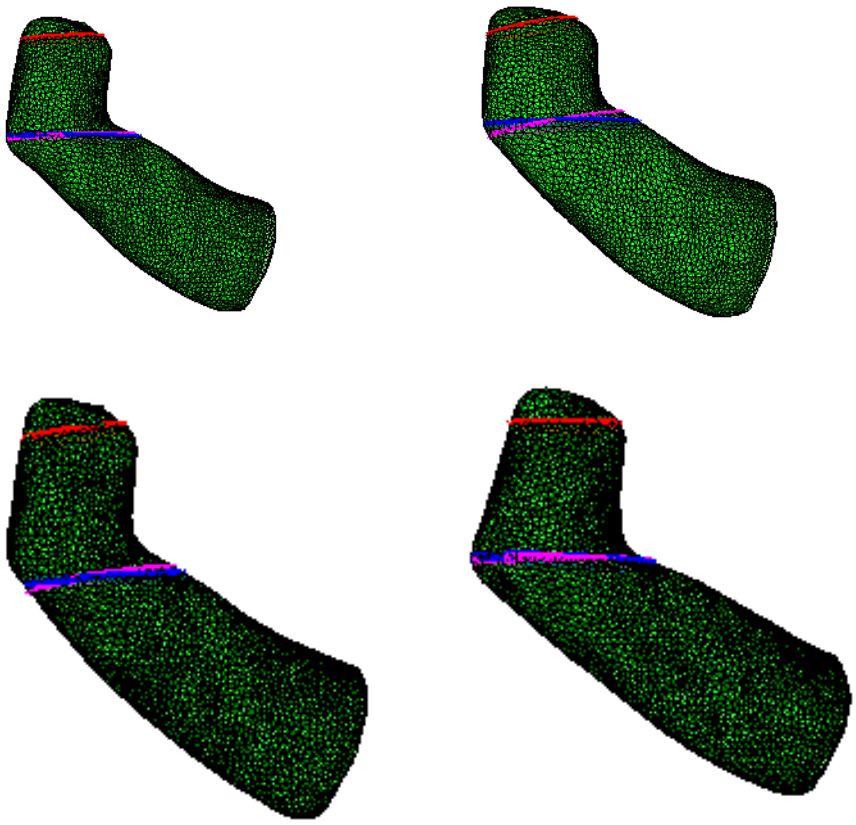
B

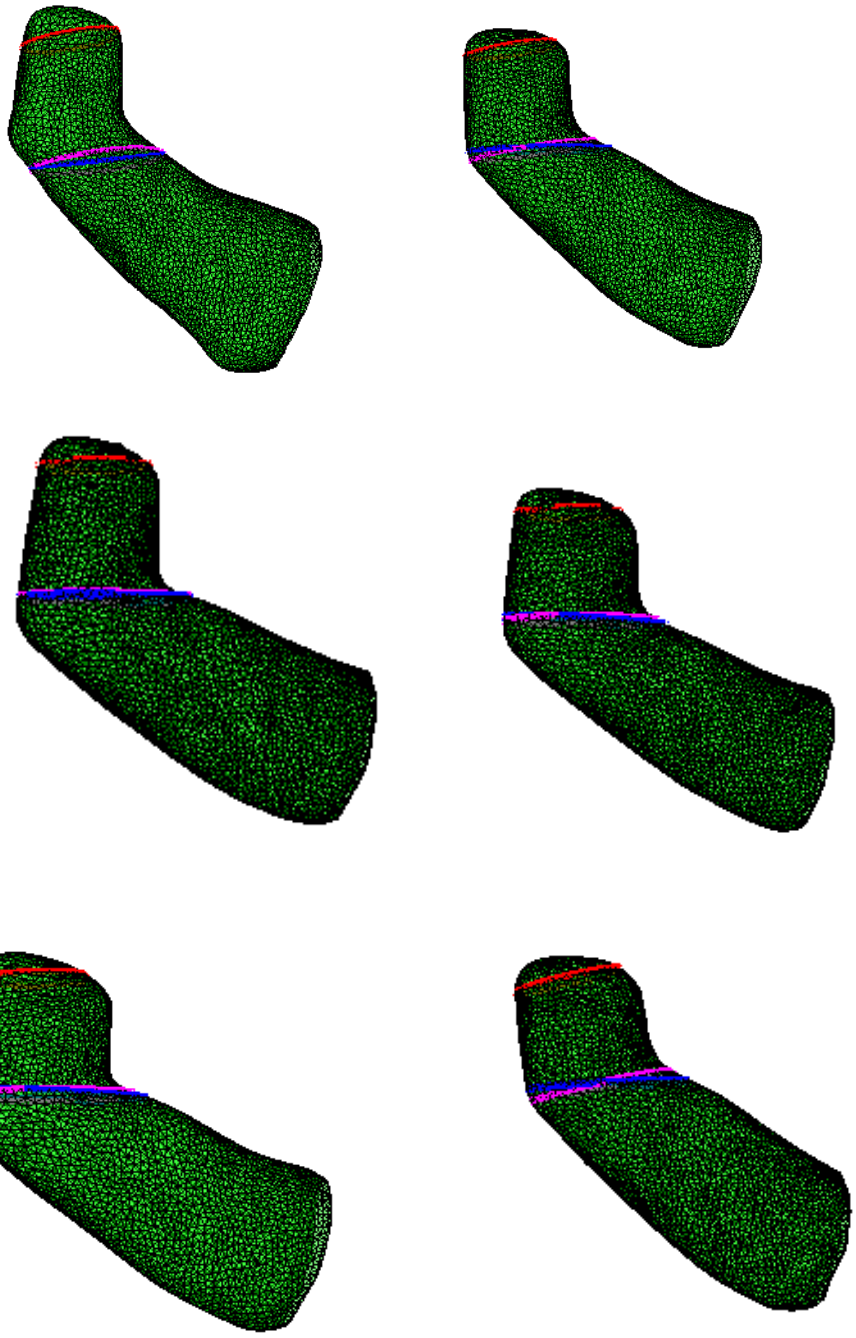
Scanned Models

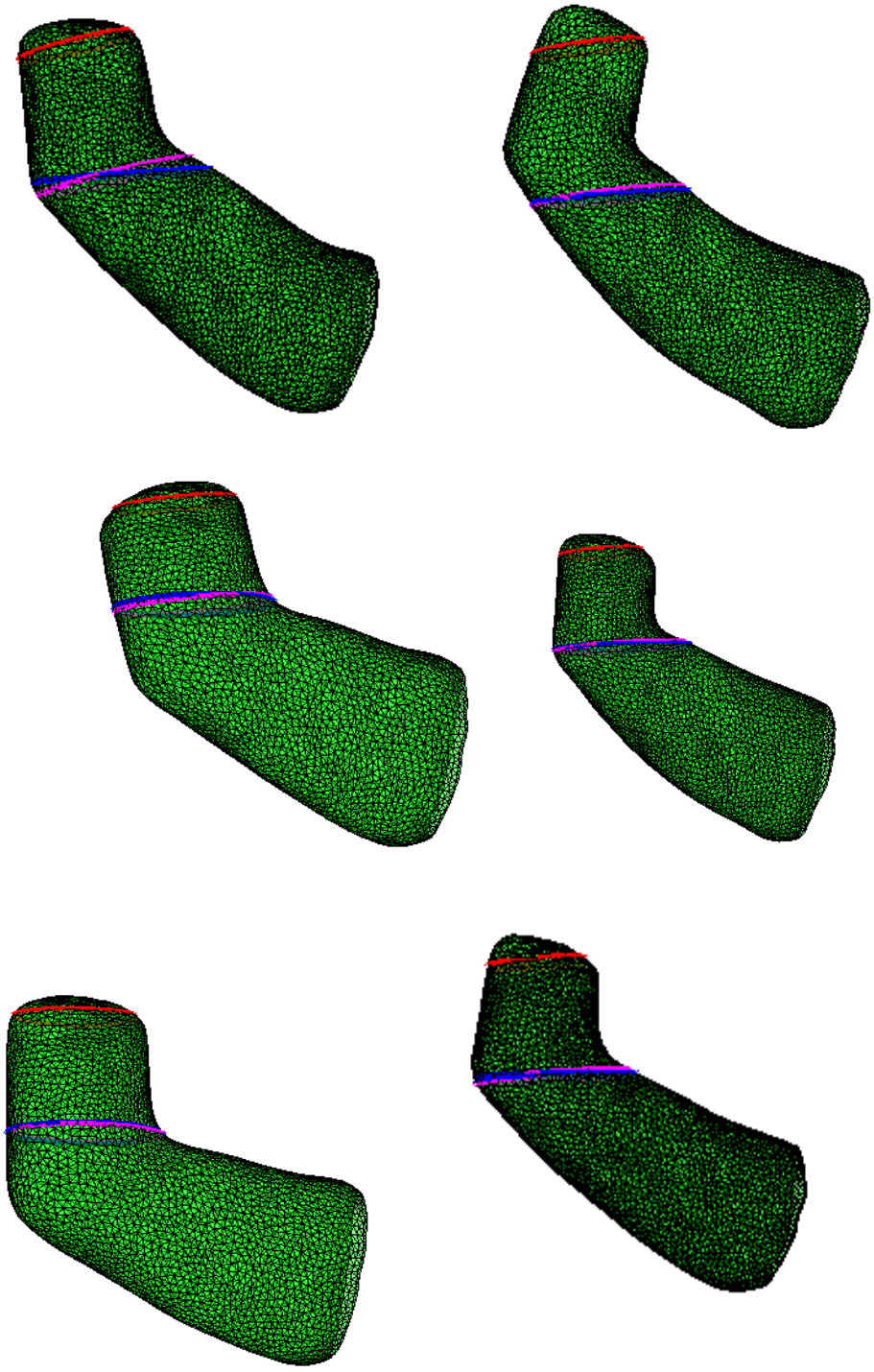
C

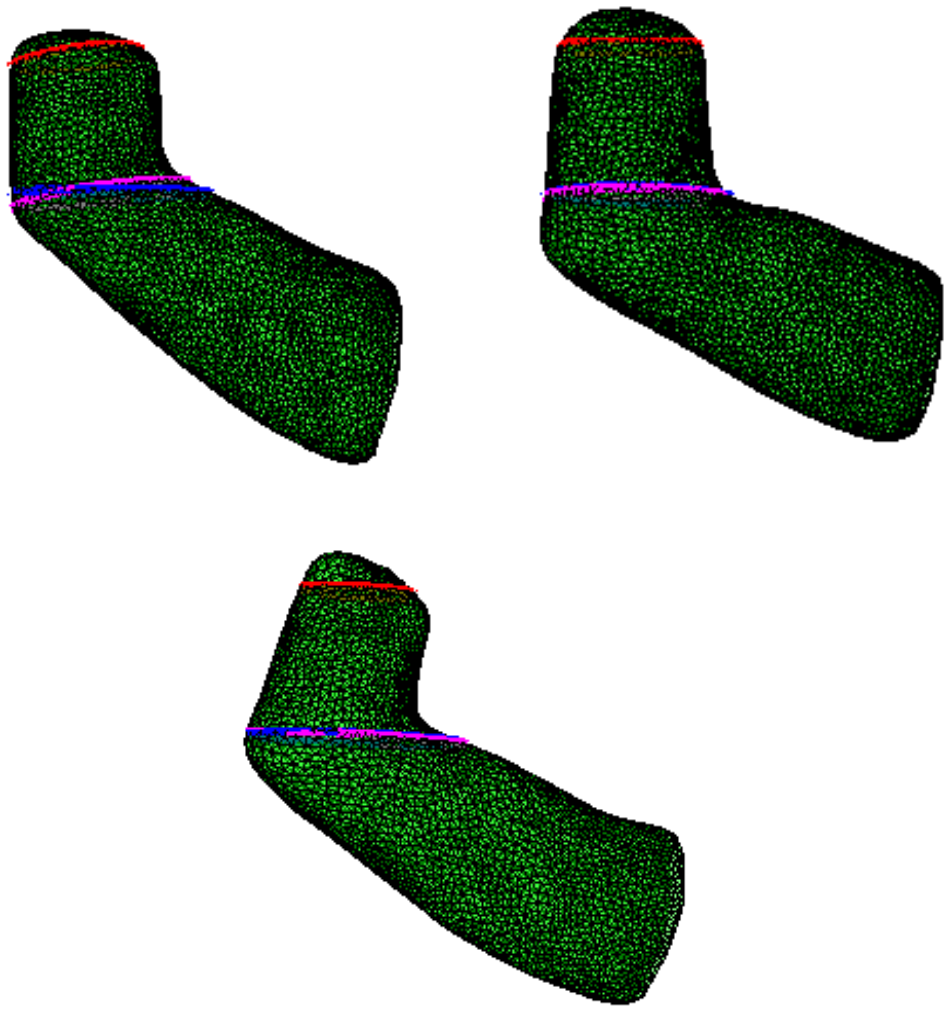
Automatic Measurement Pictures

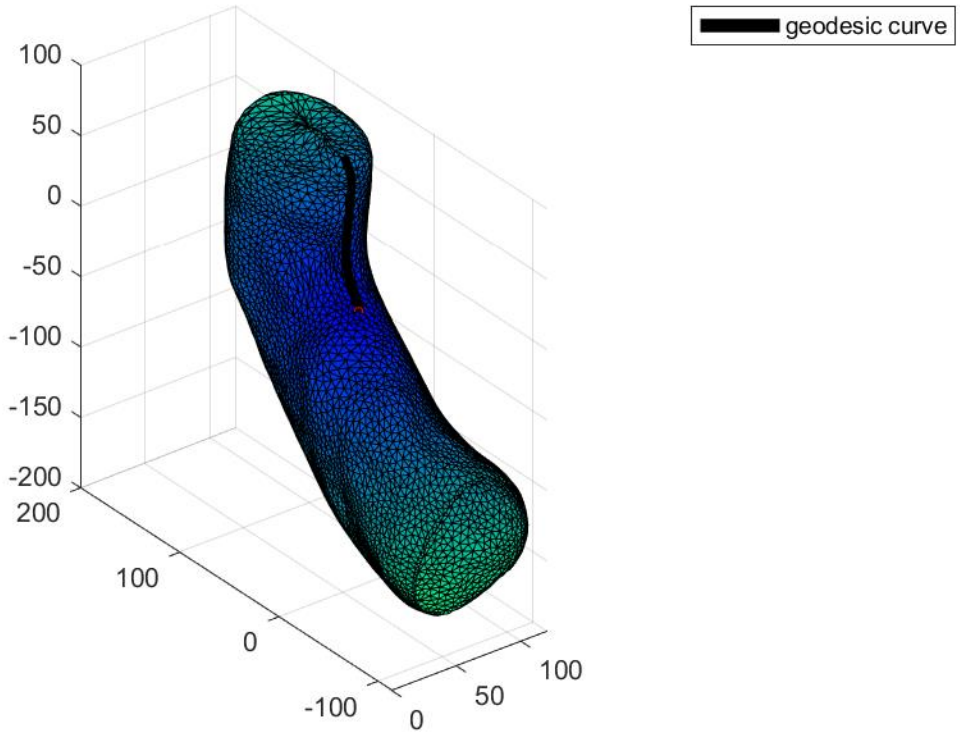
1. General SSM for 25% Cut







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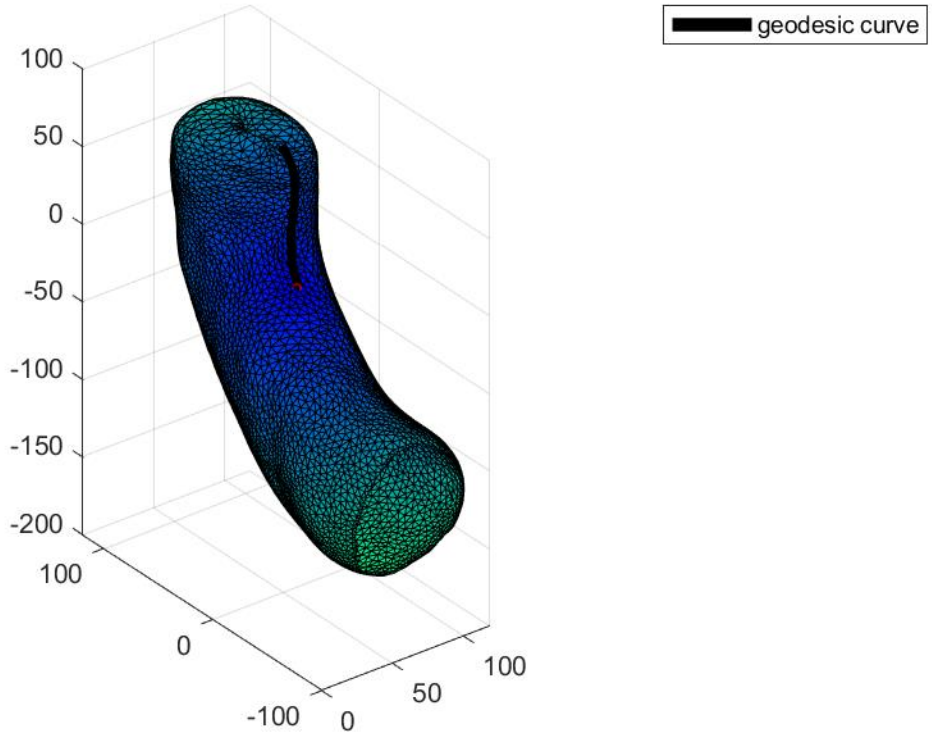
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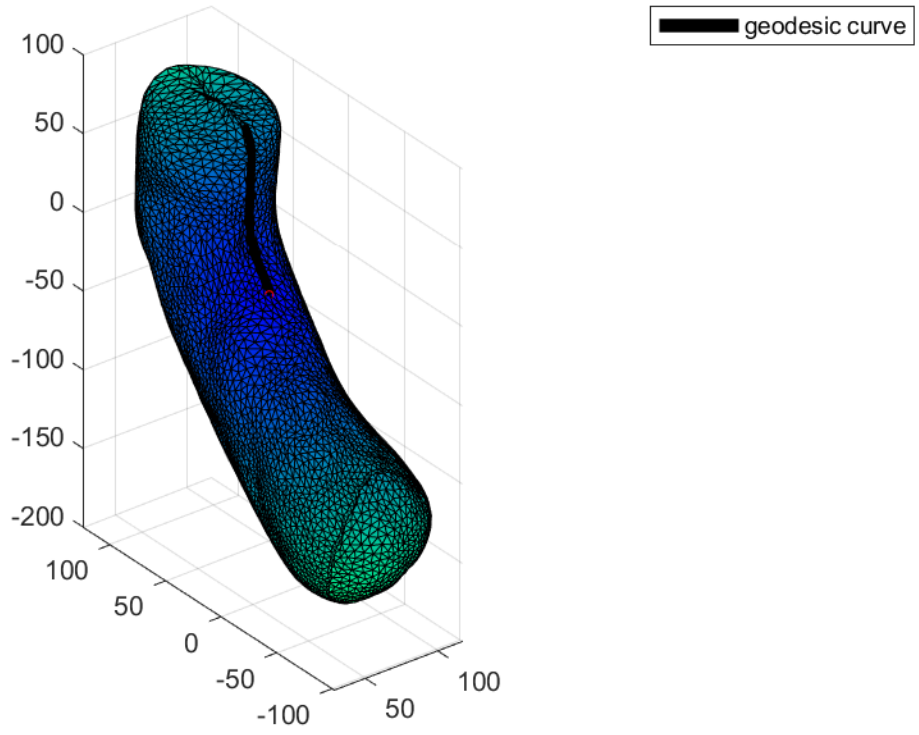
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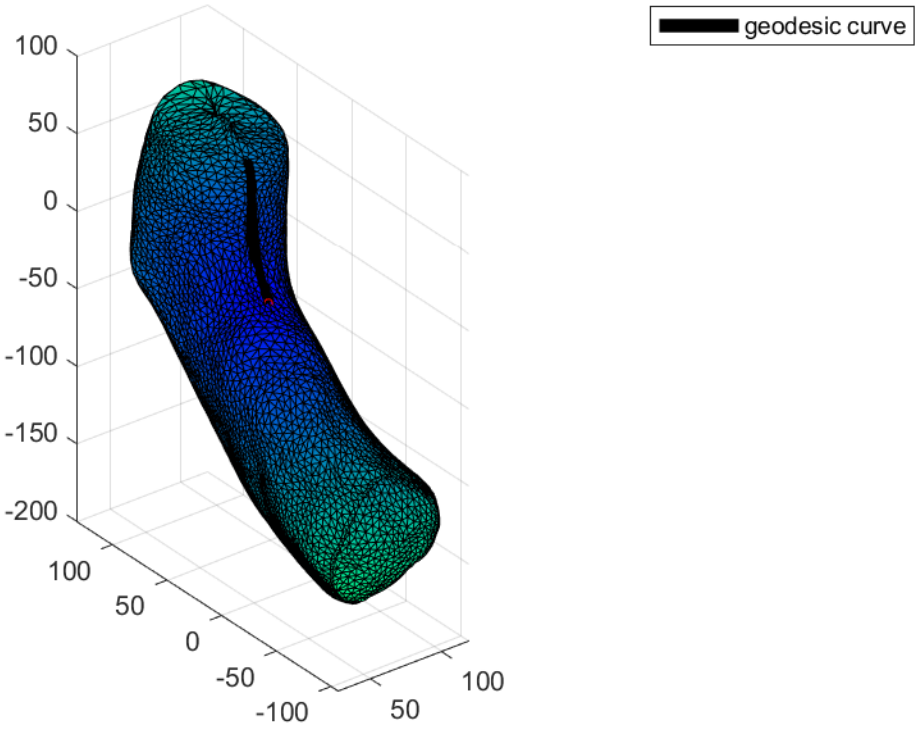
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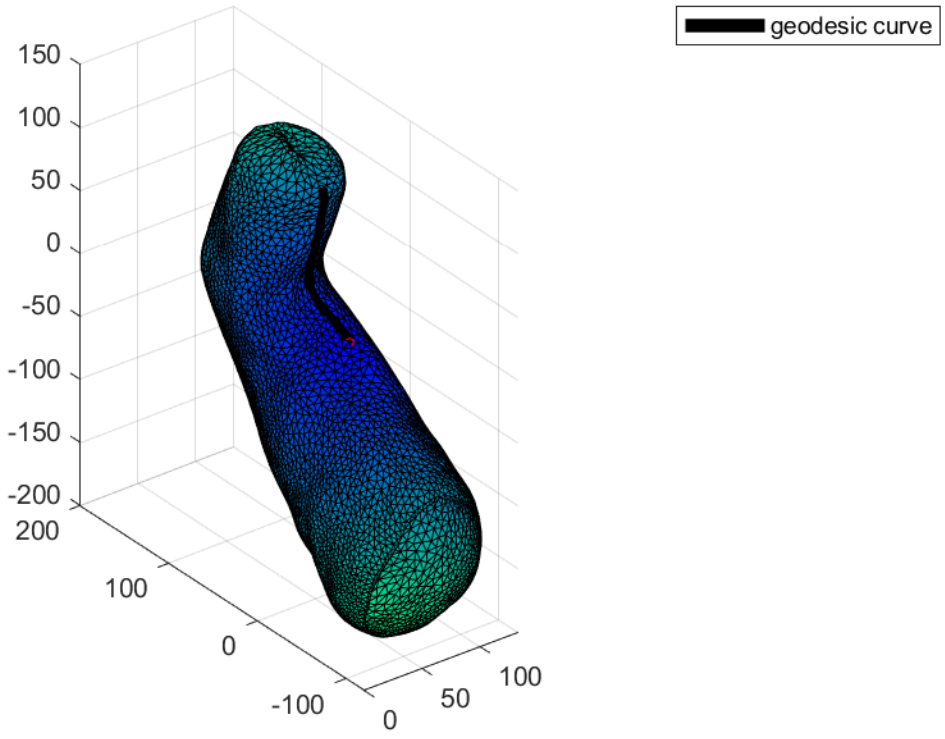
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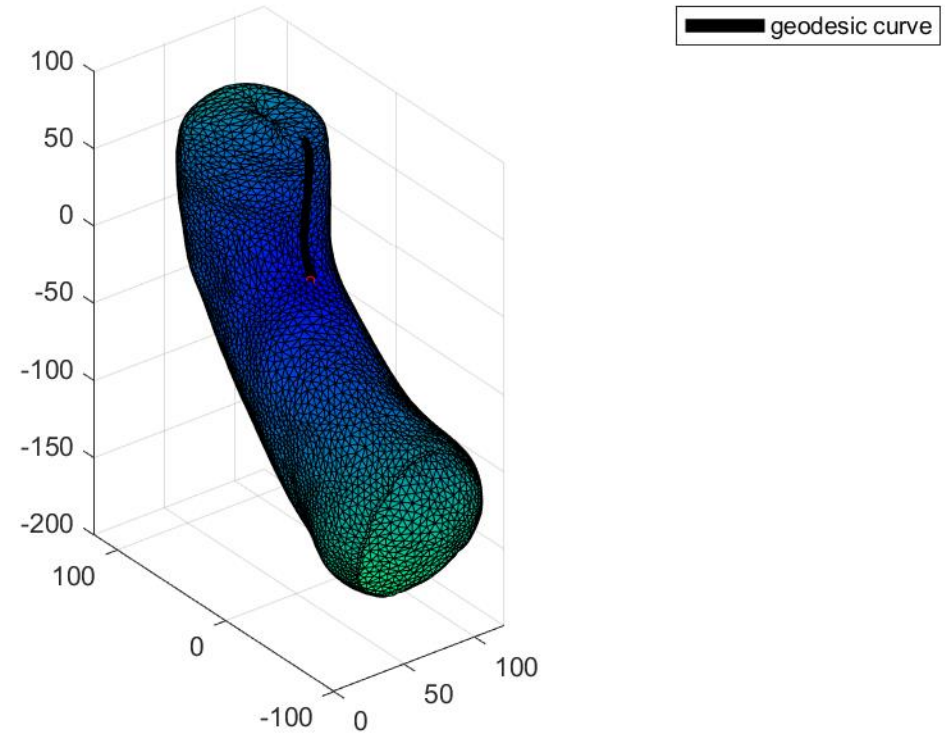
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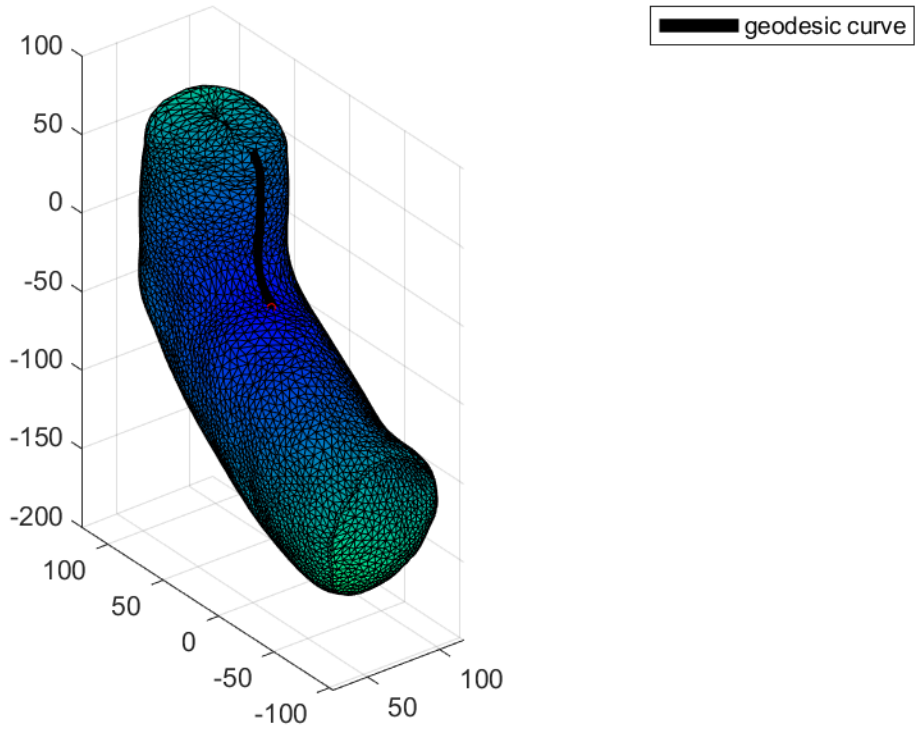
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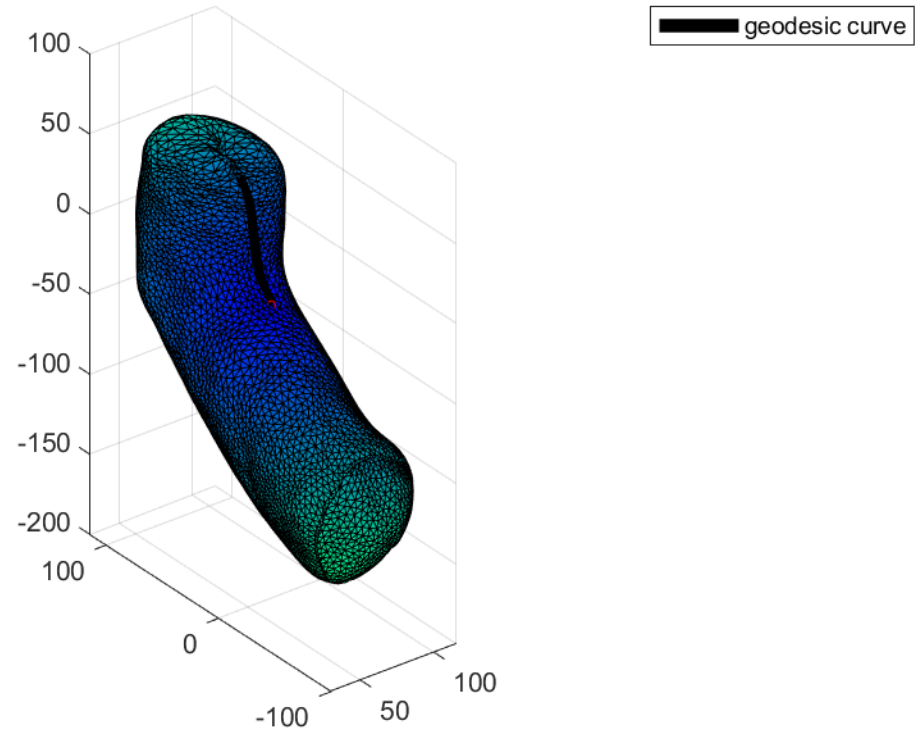
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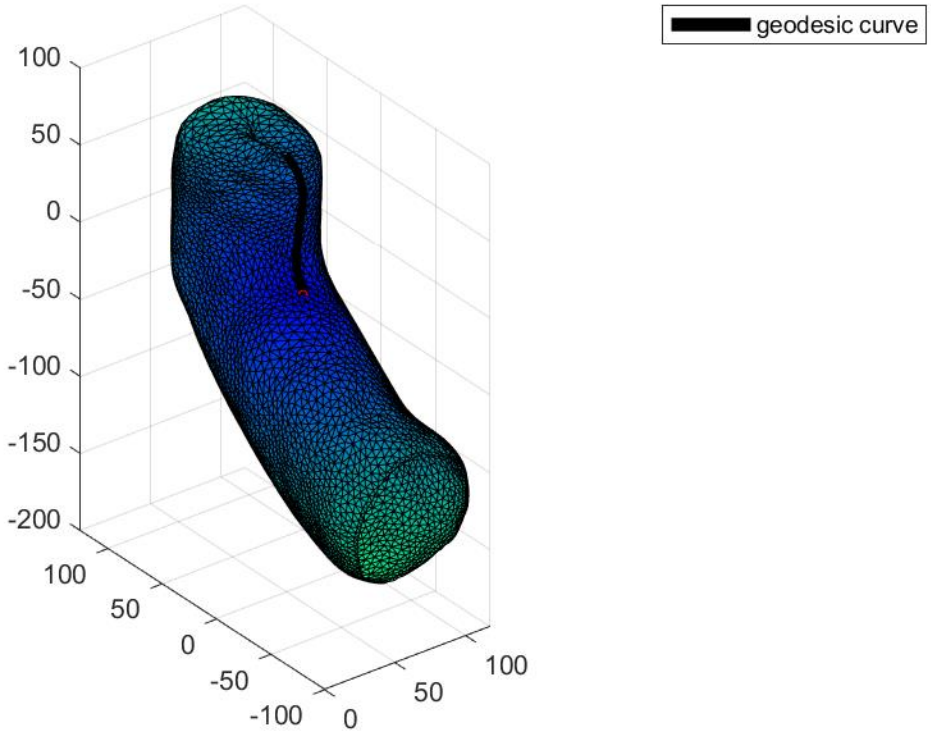
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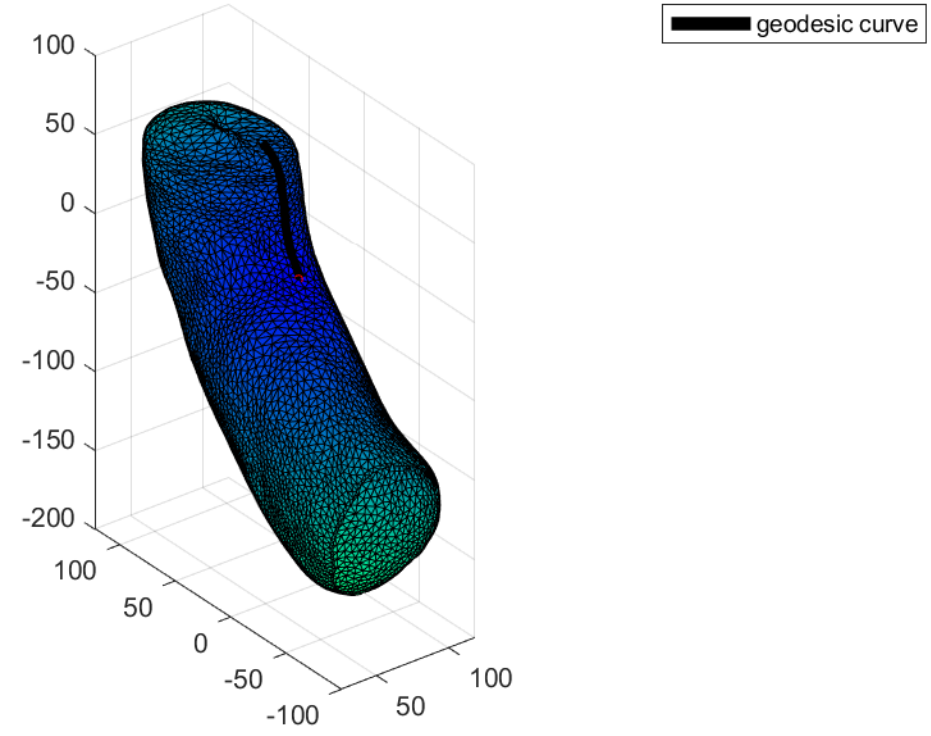
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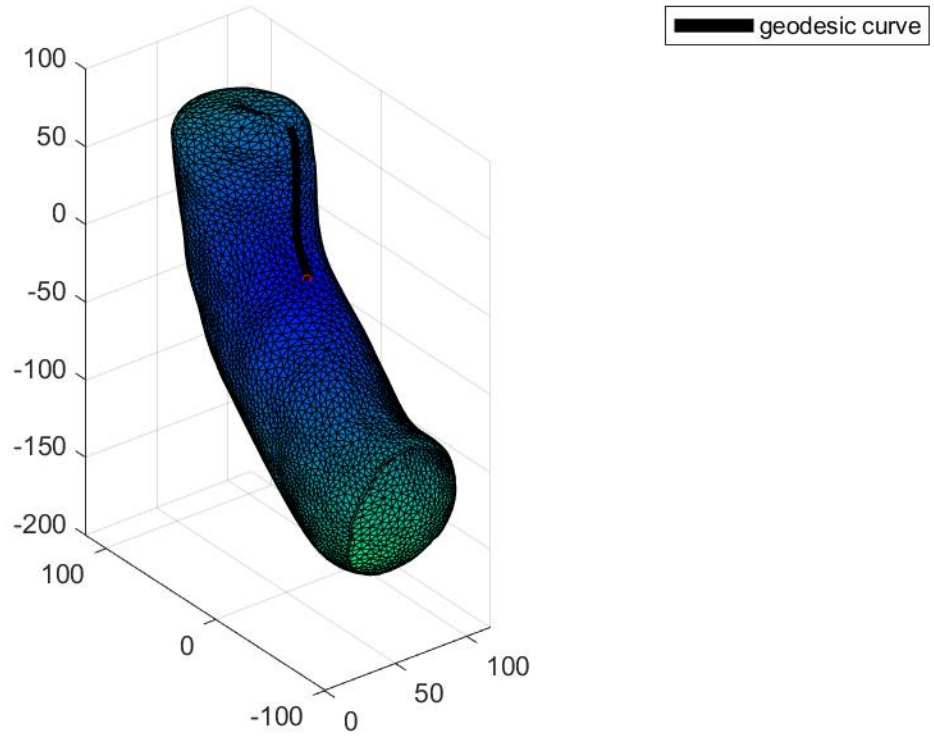
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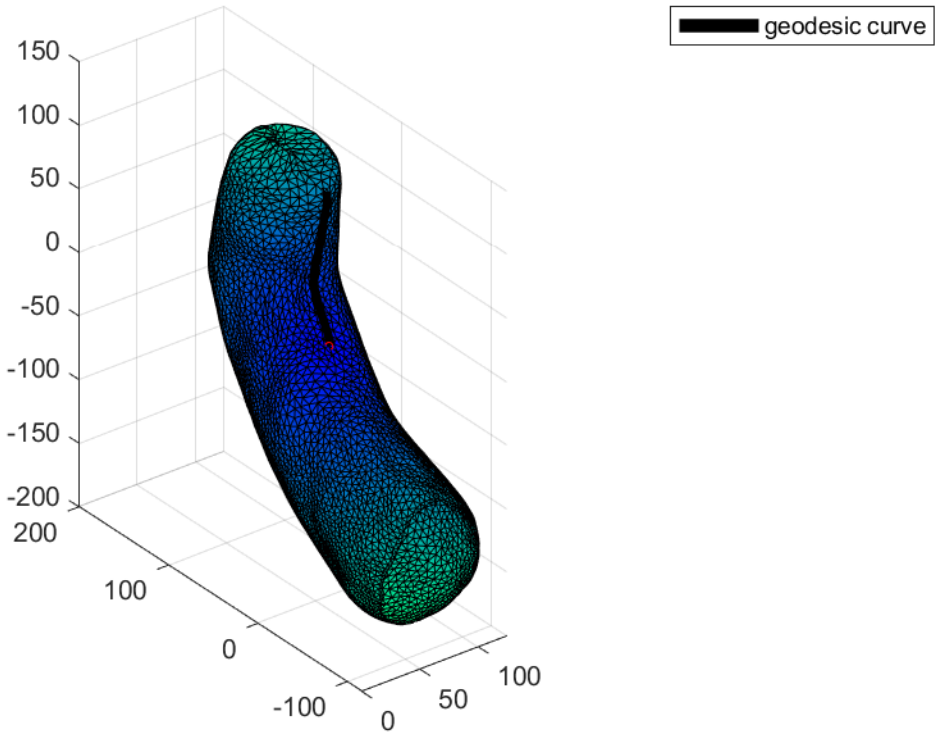
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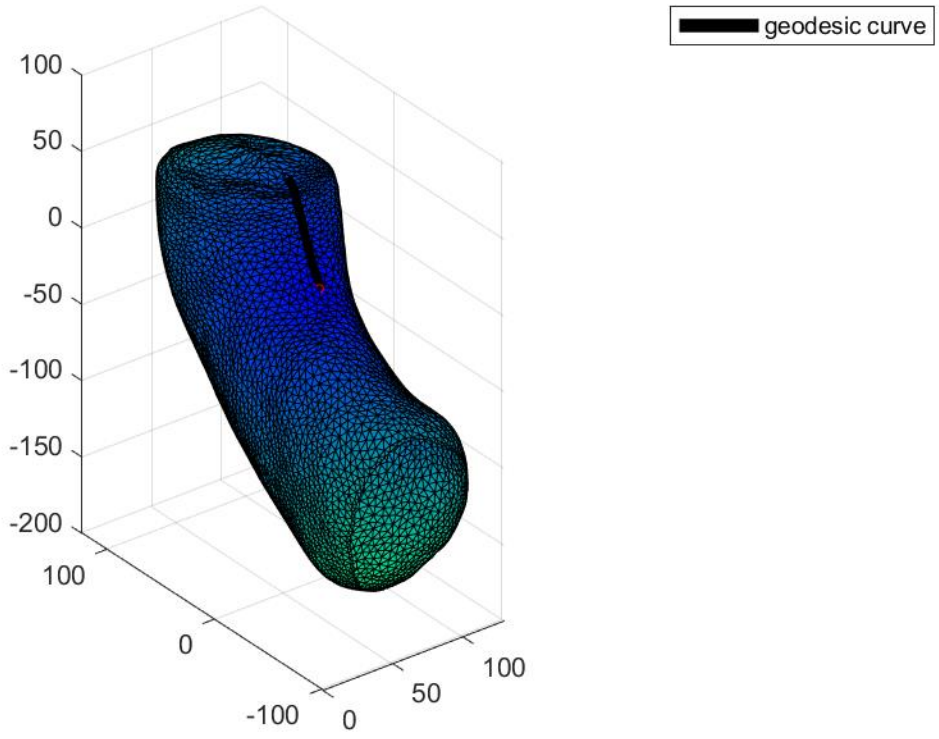
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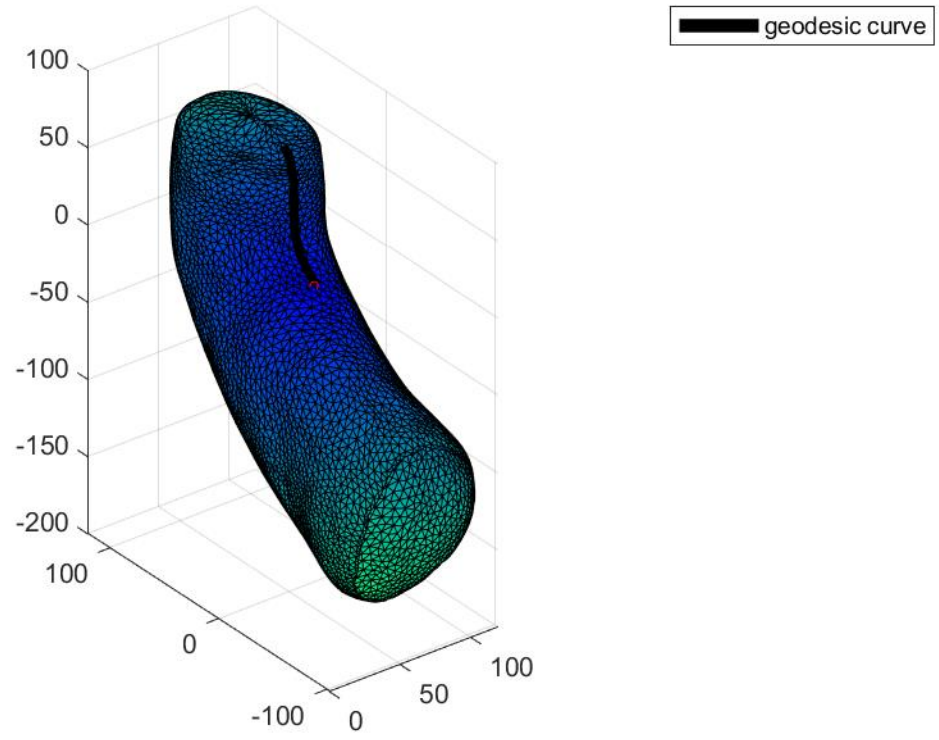
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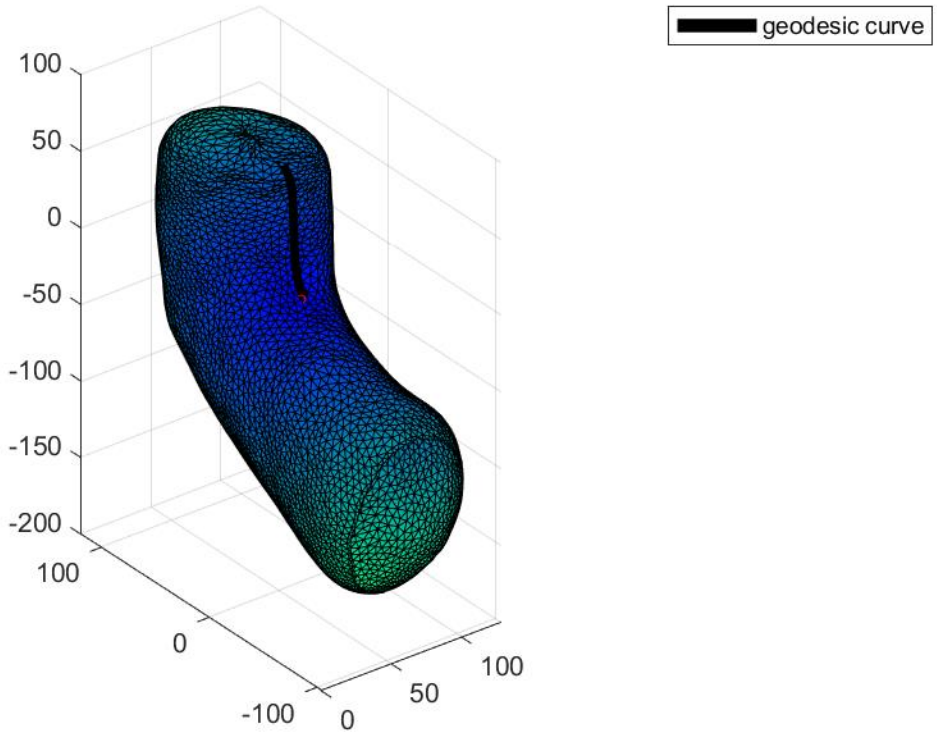
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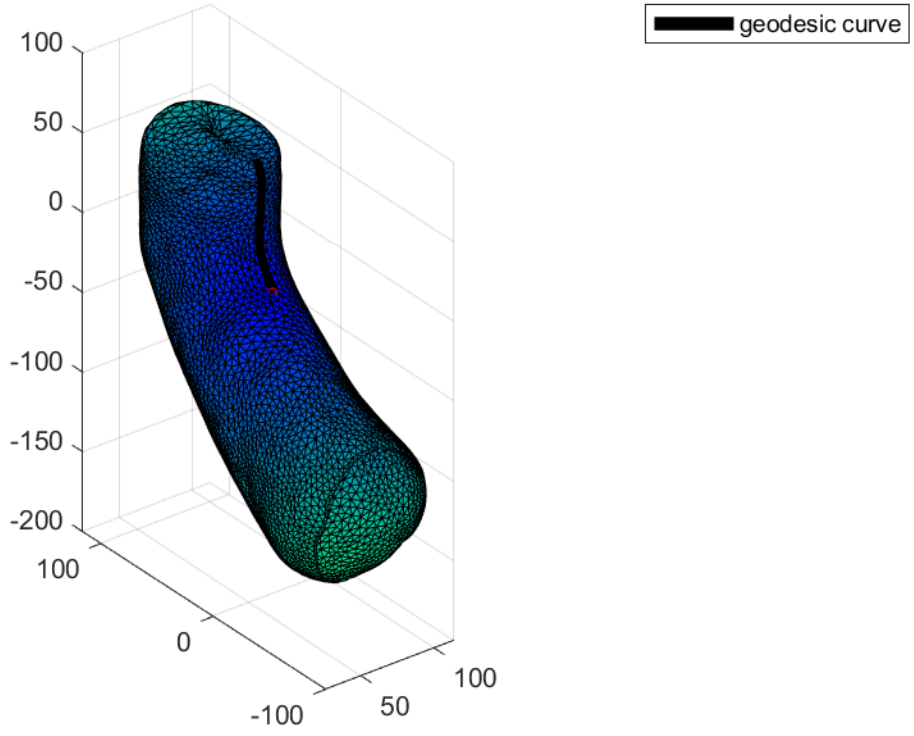
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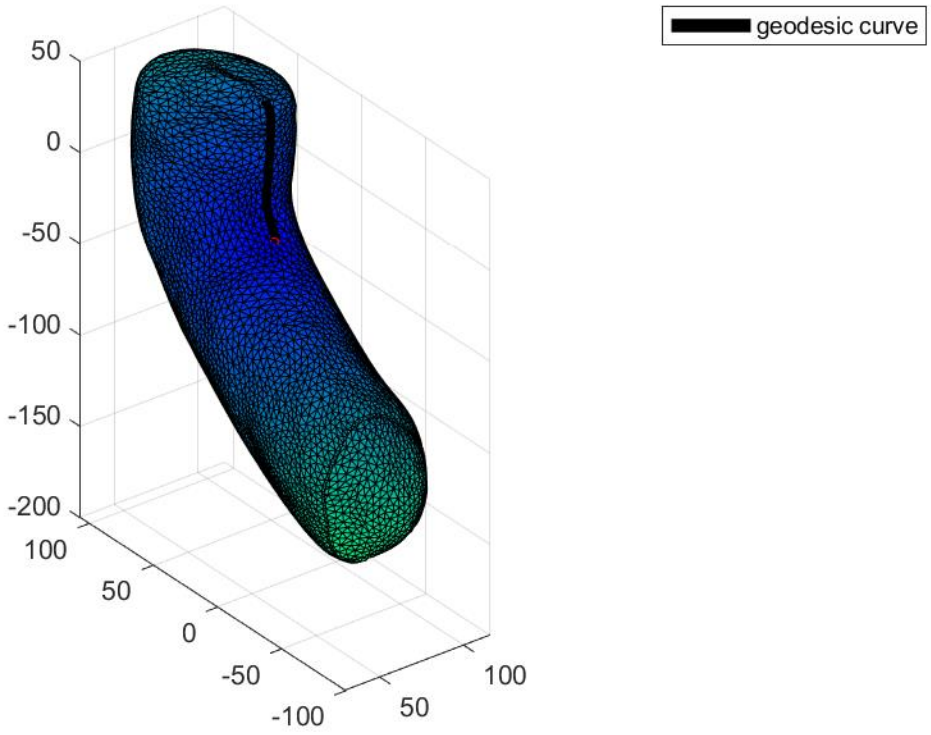
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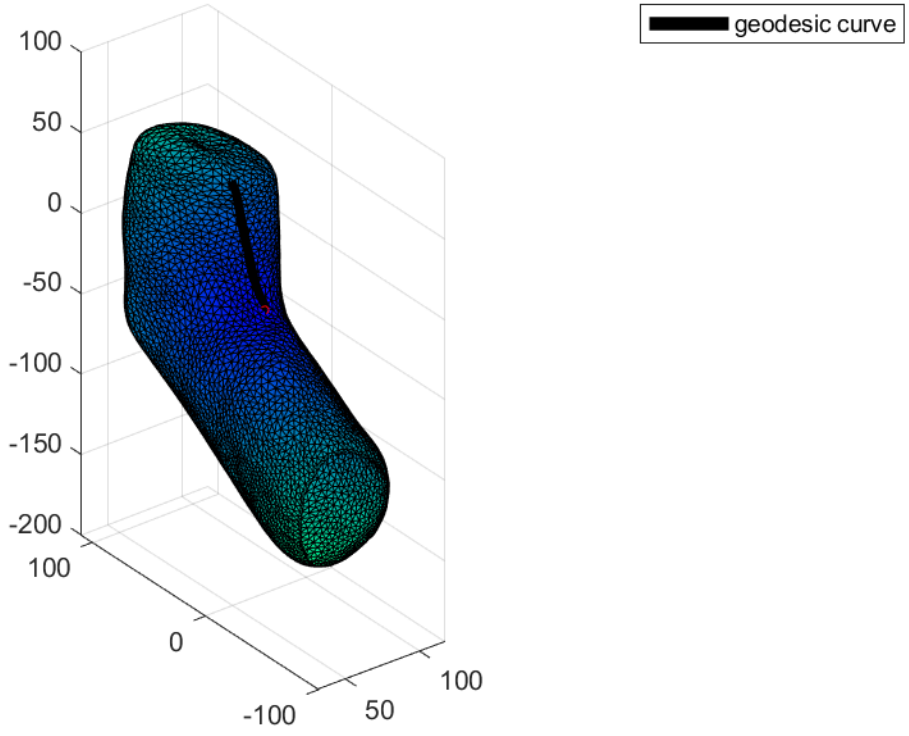
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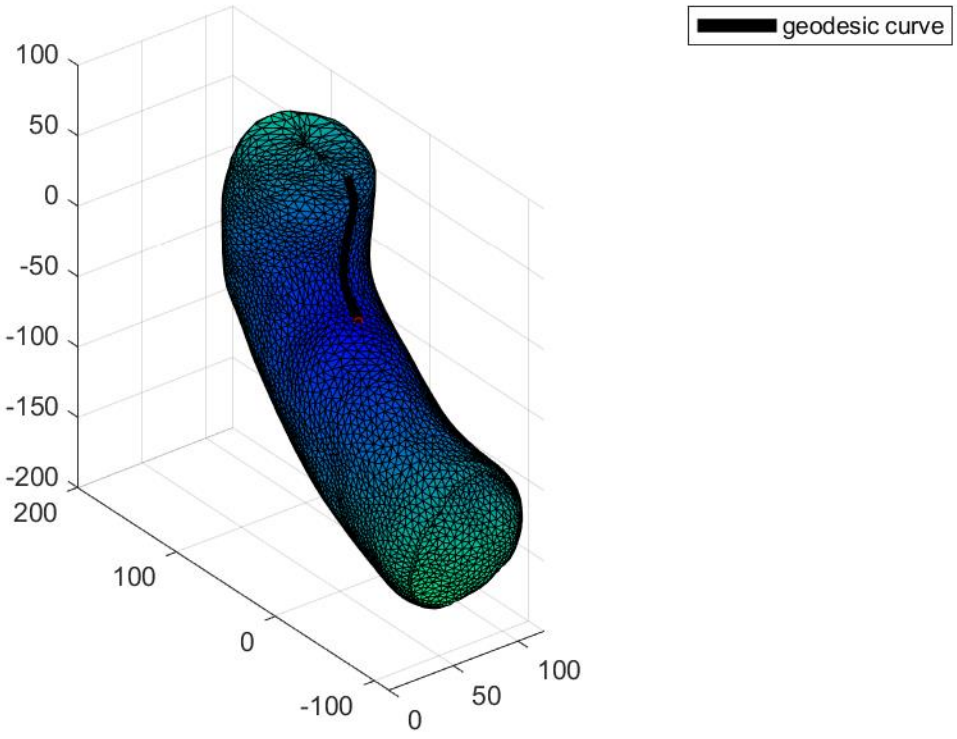
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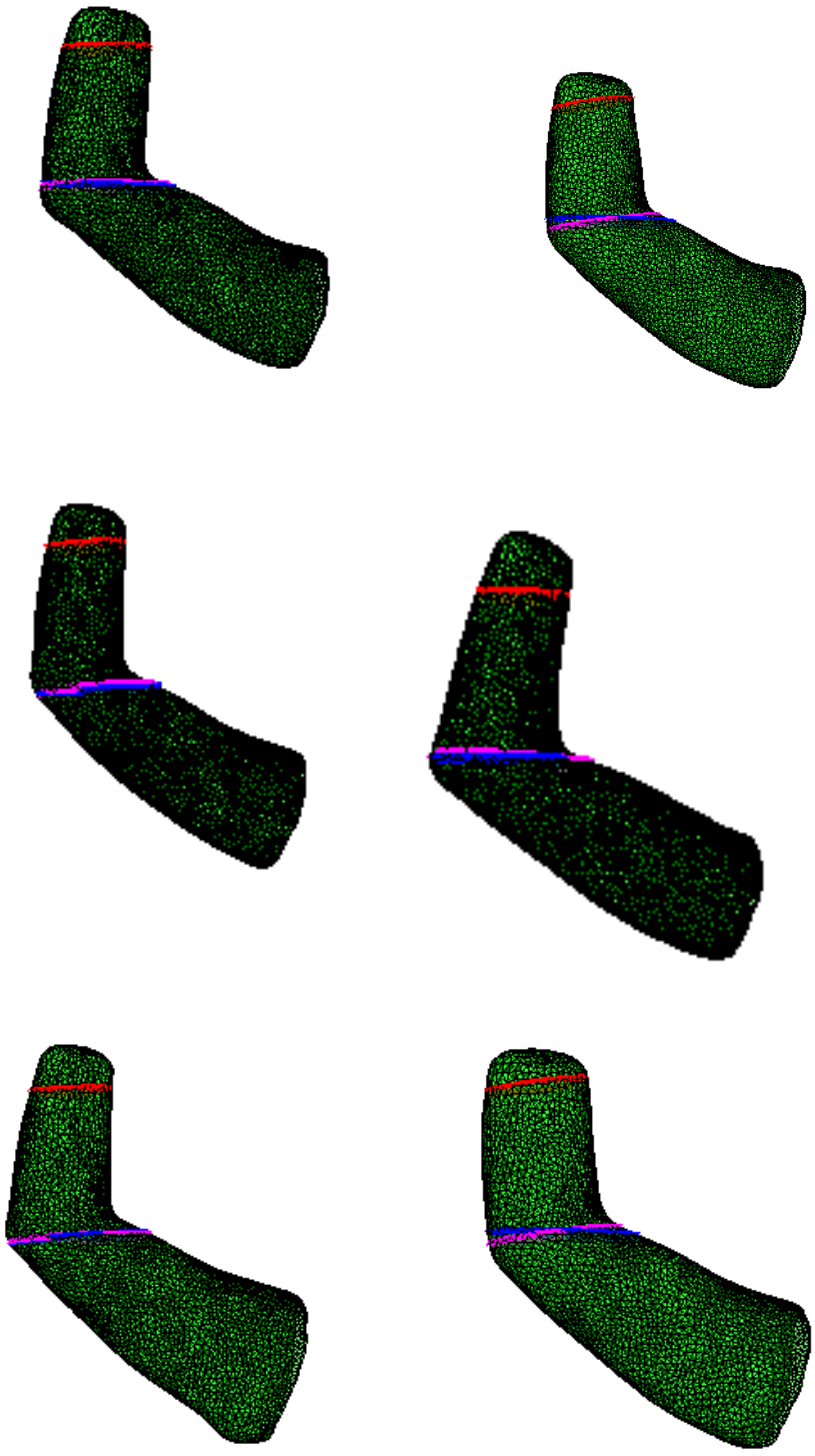
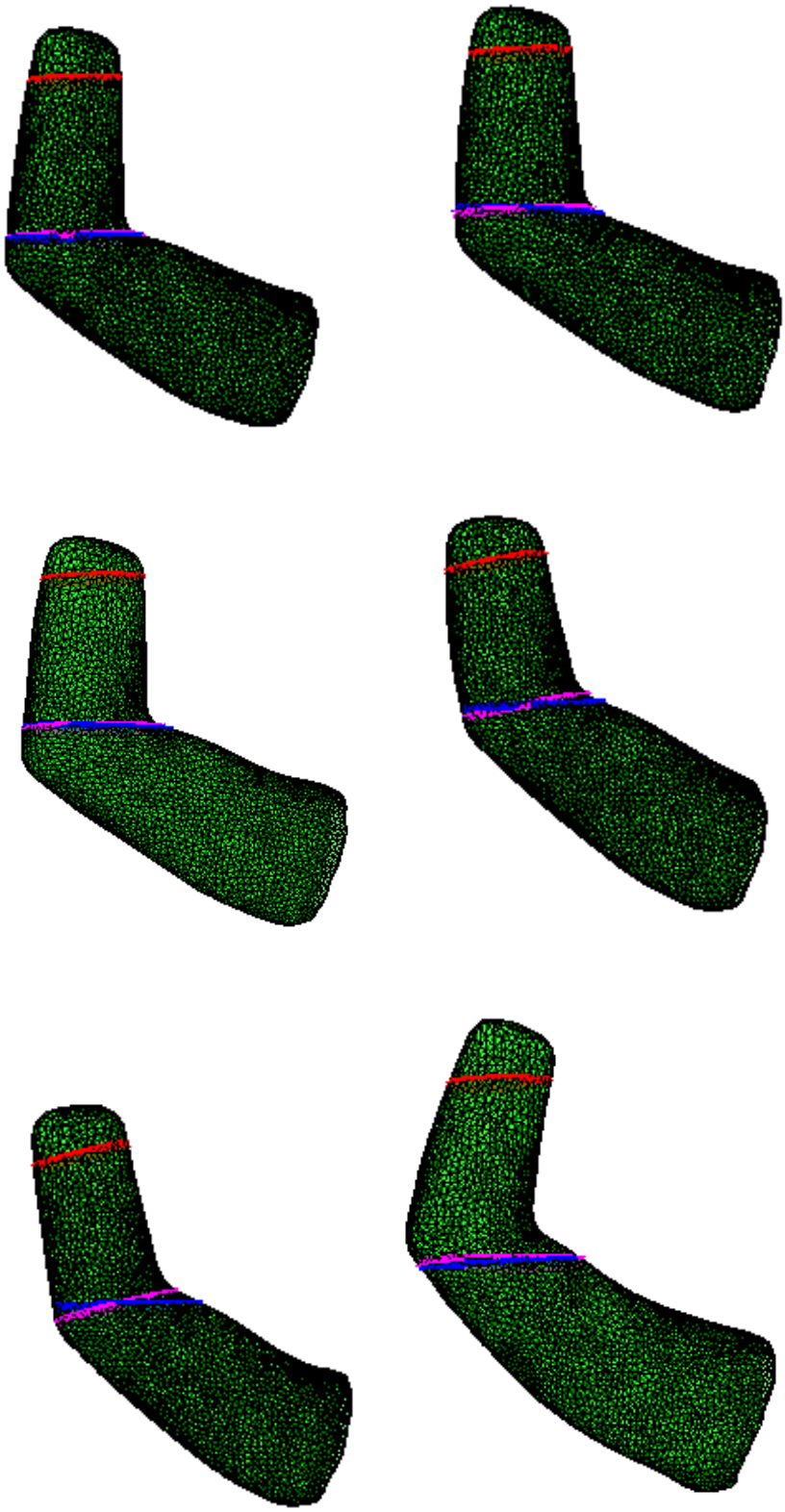
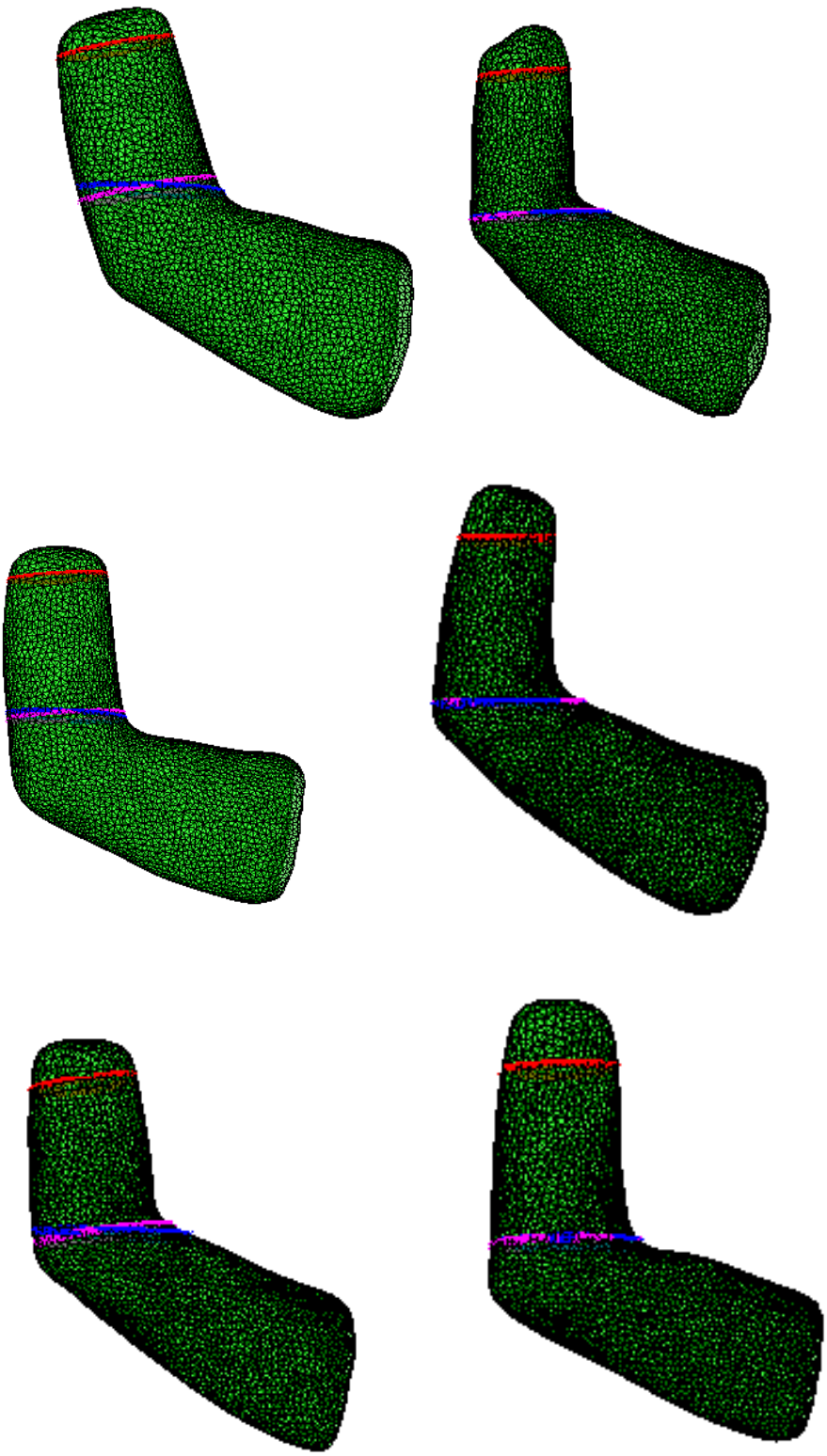
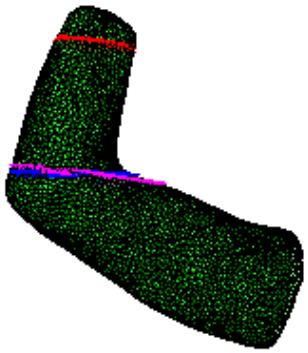
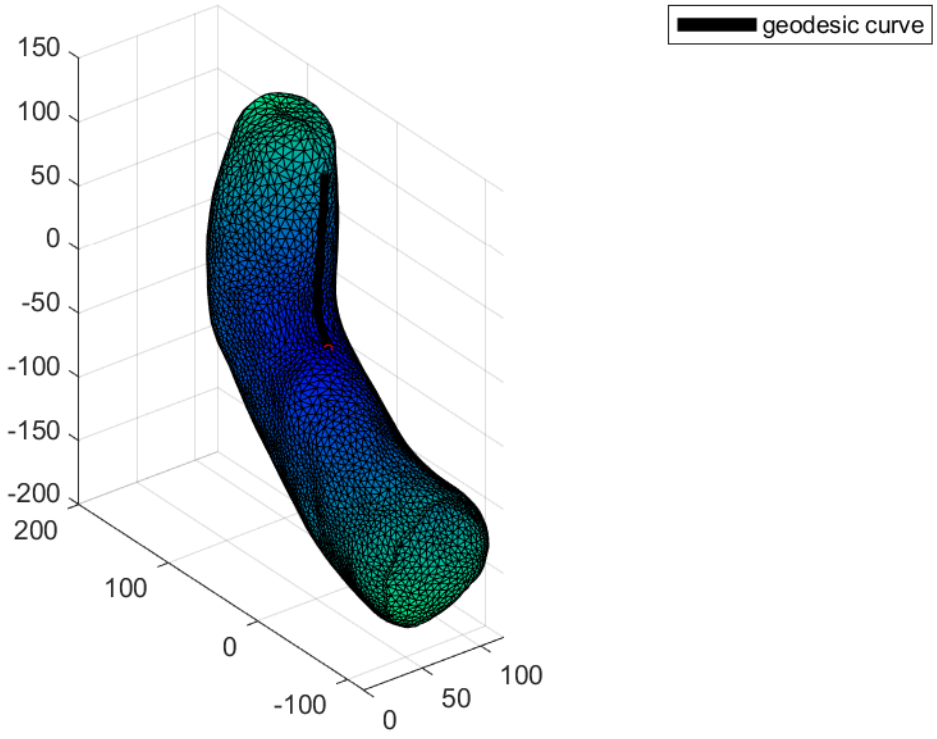
2. General SSM for 50% Cut







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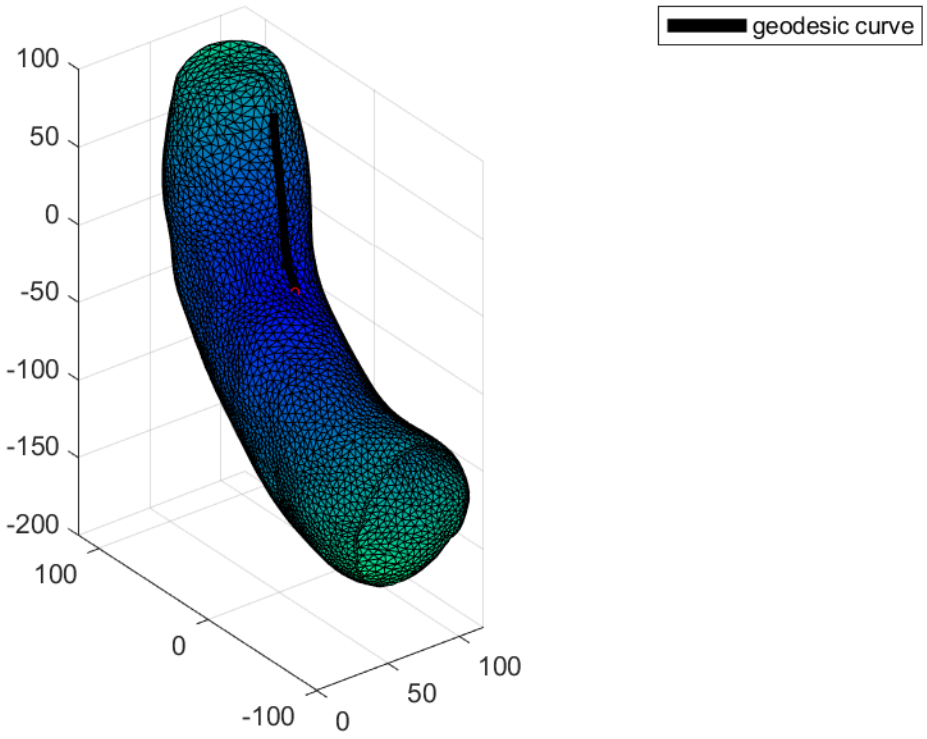
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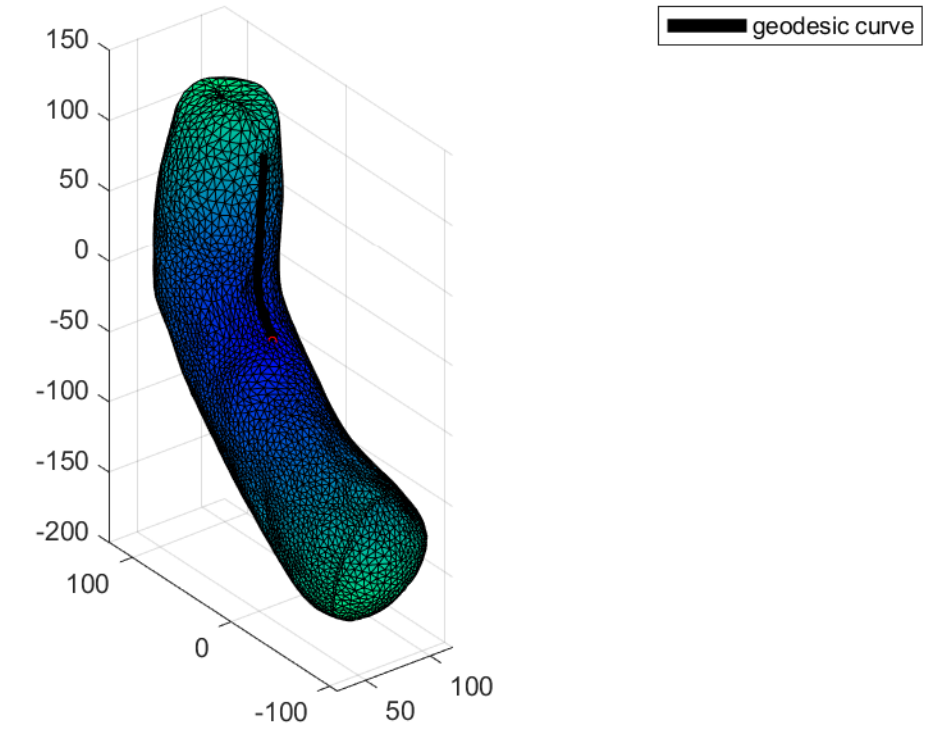
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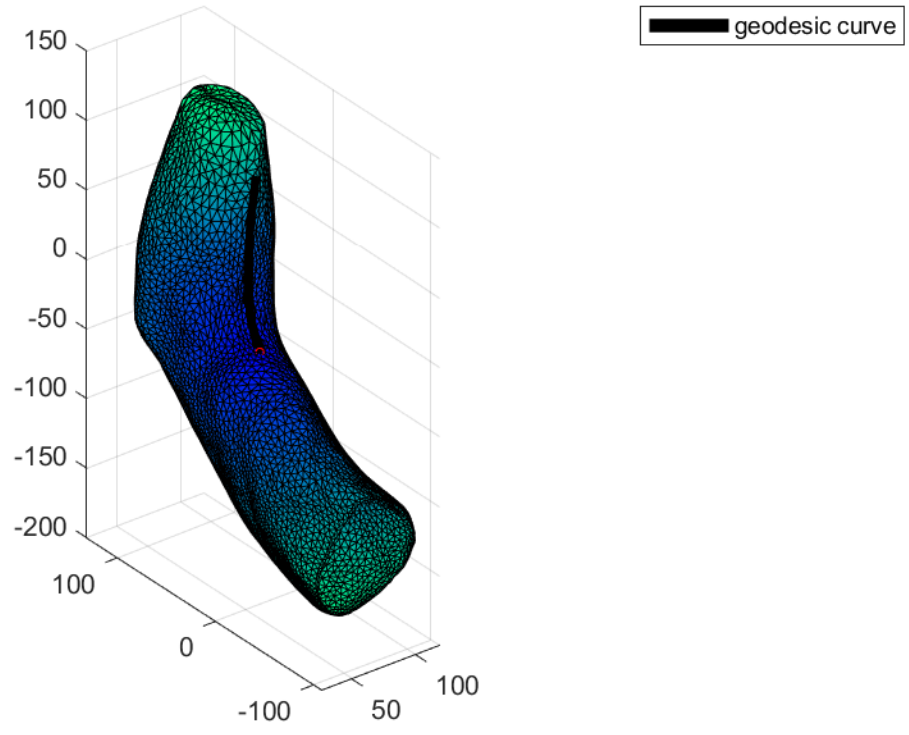
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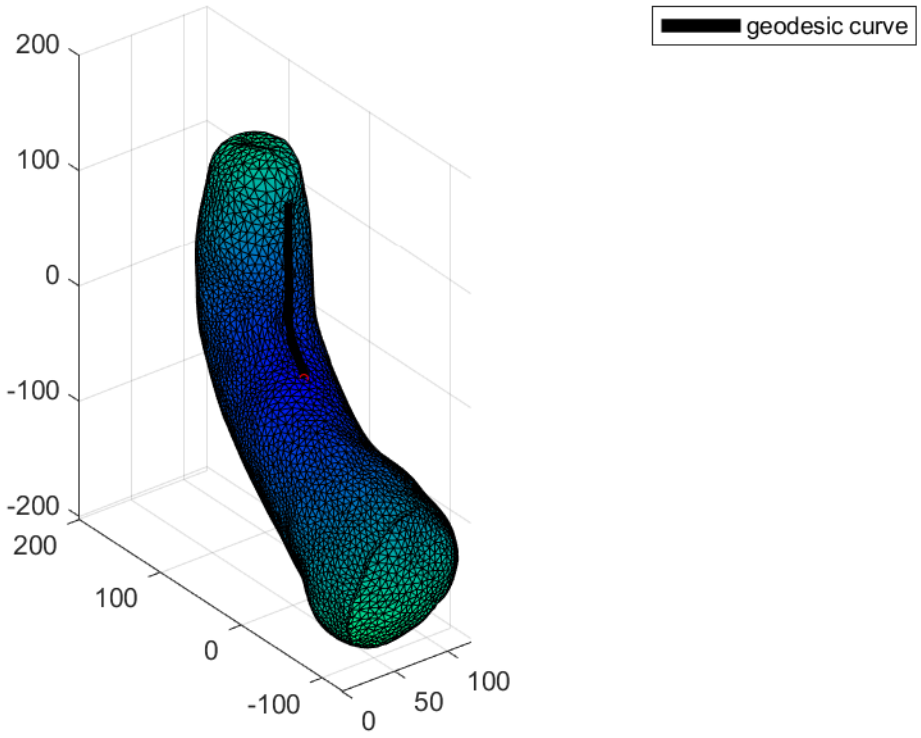
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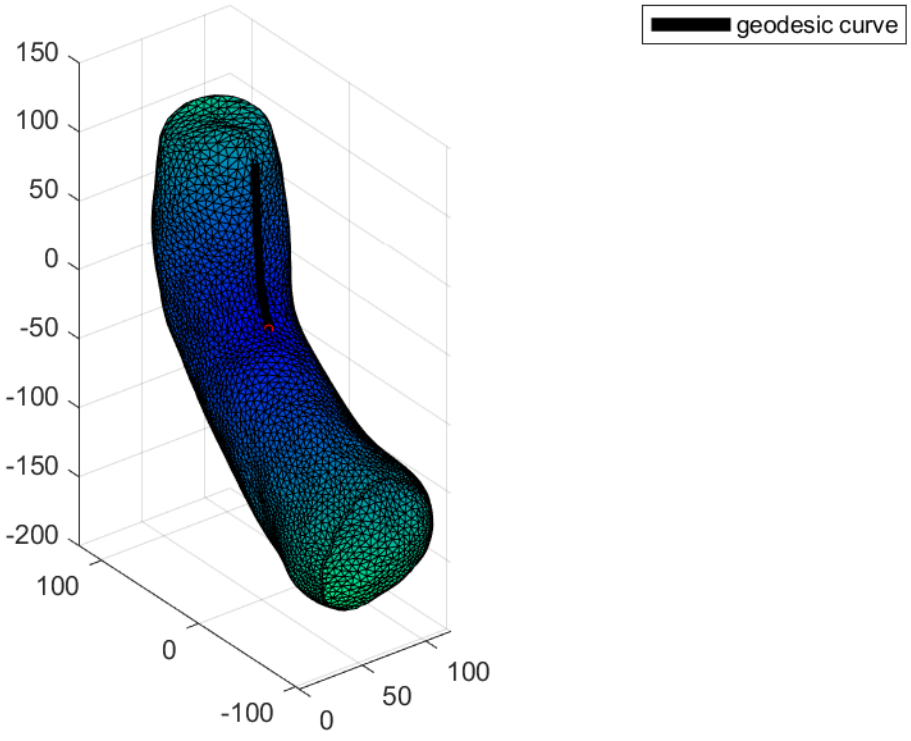
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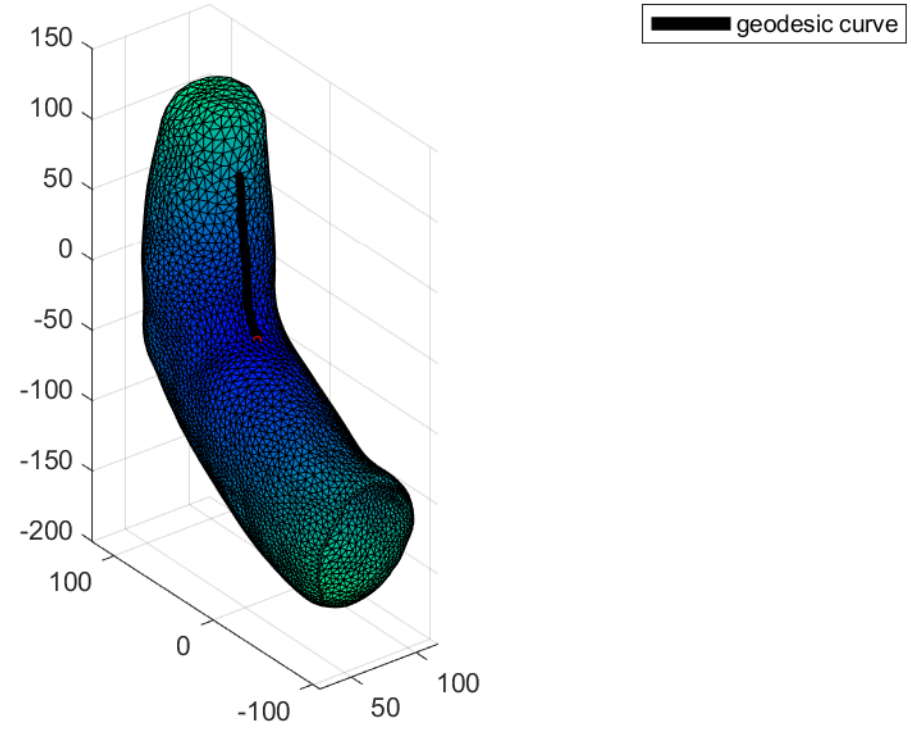
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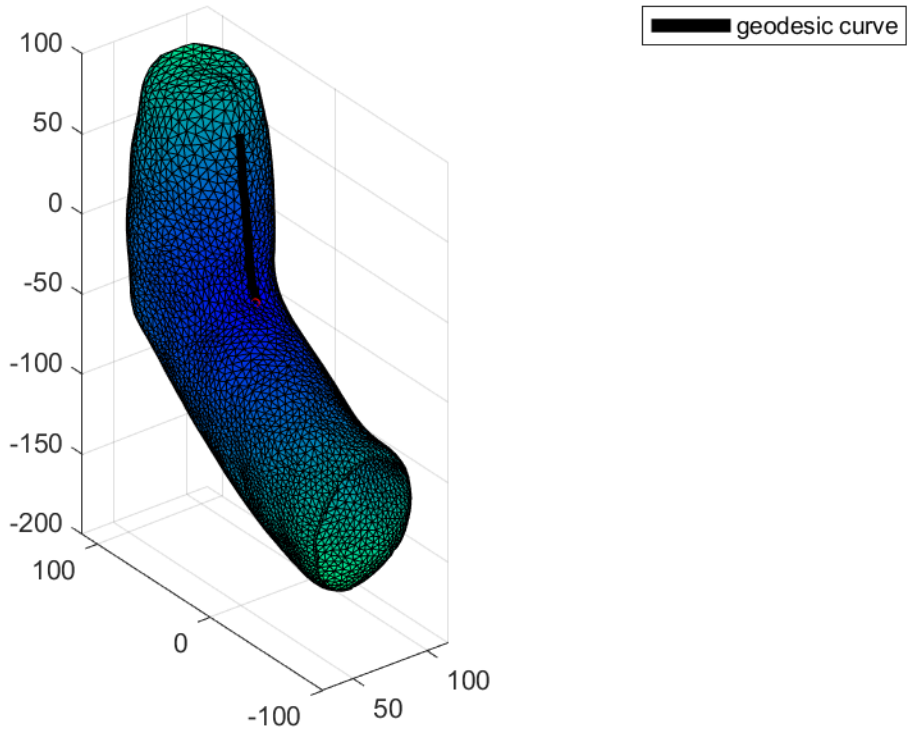
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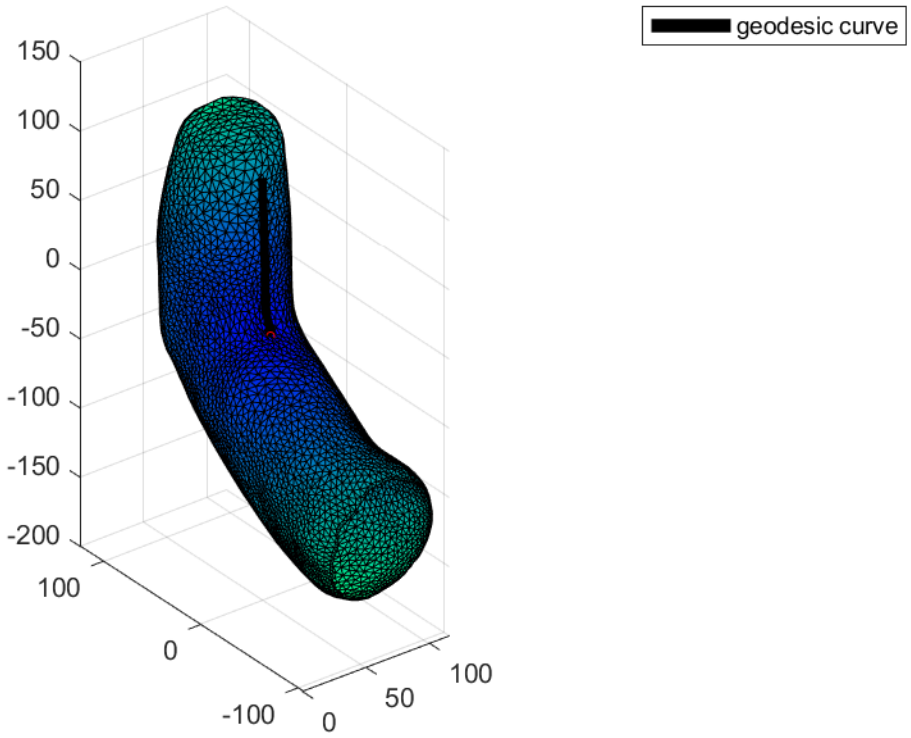
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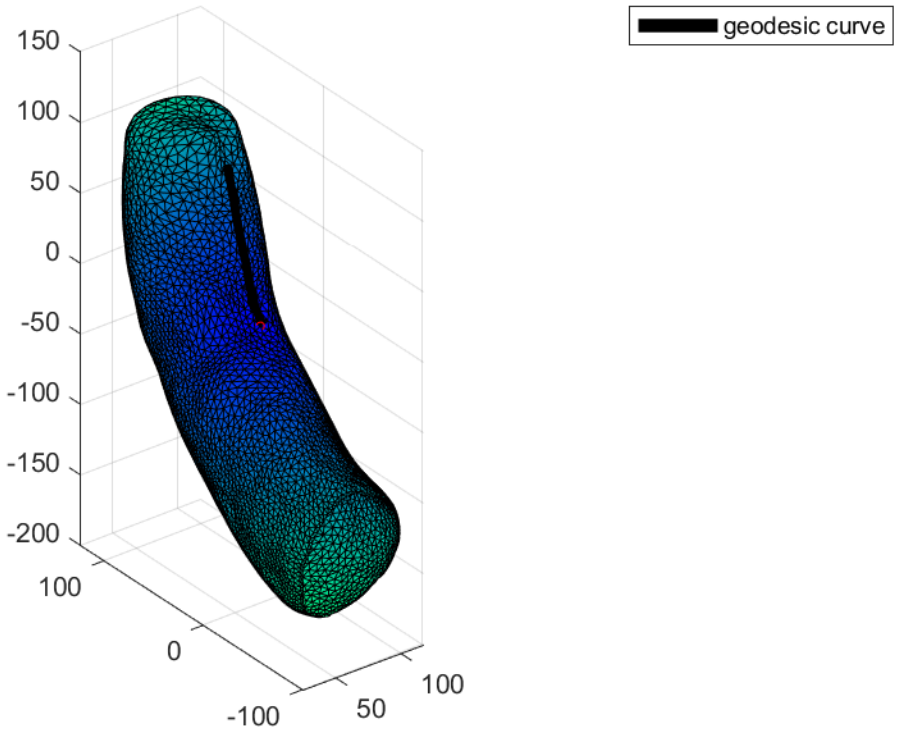
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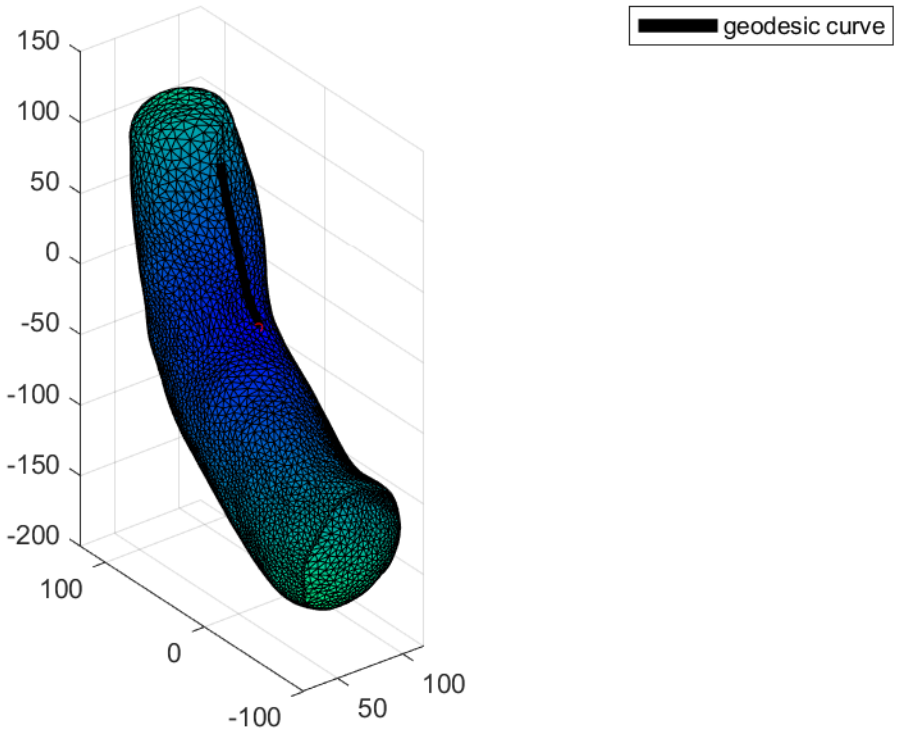
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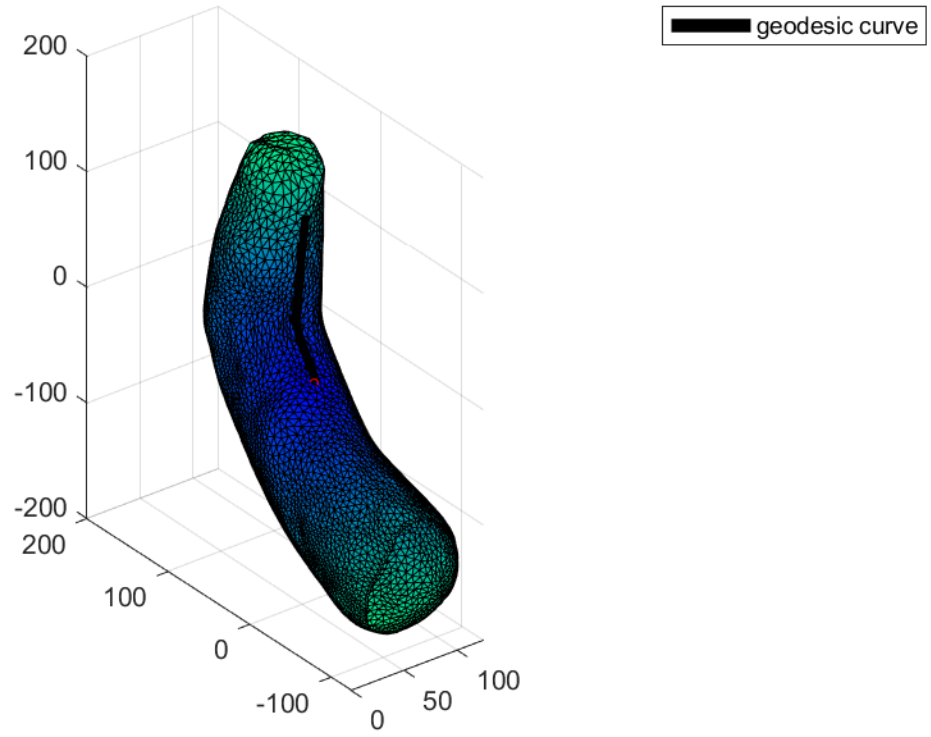
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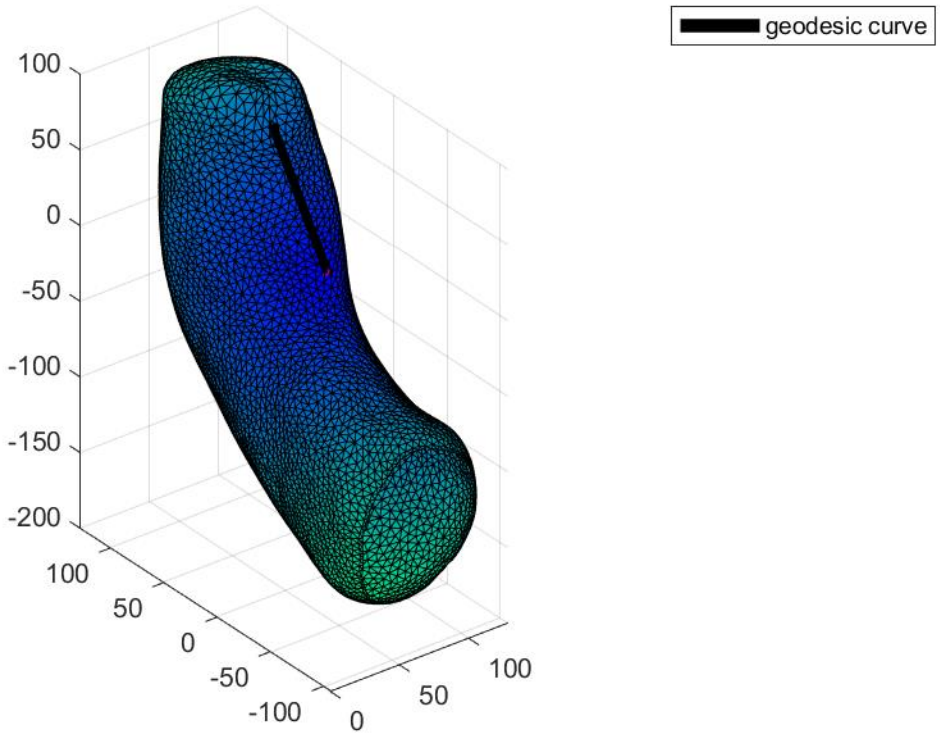
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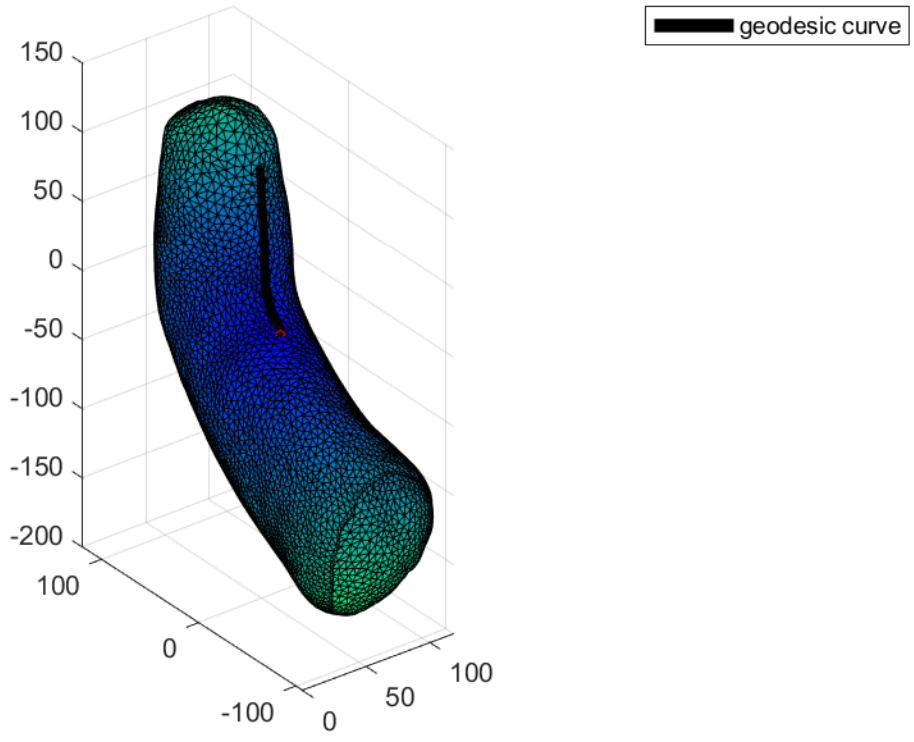
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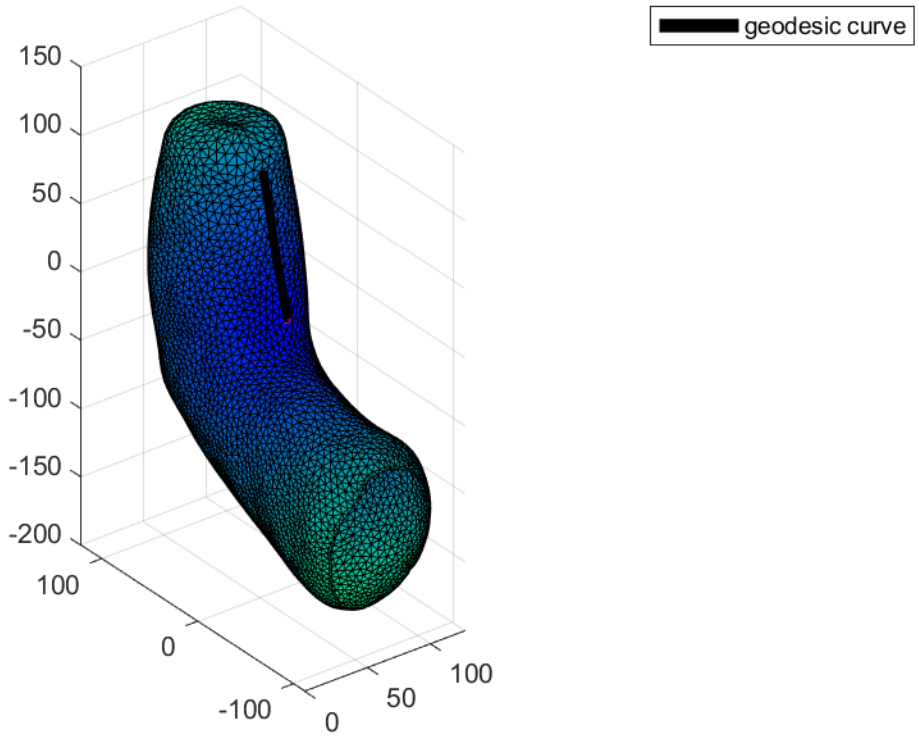
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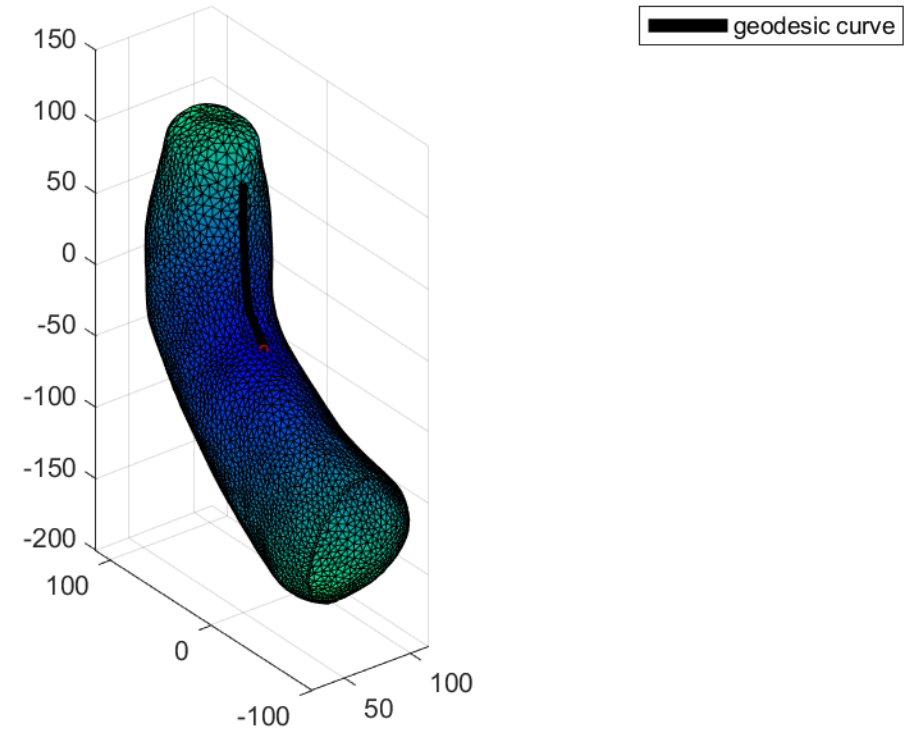
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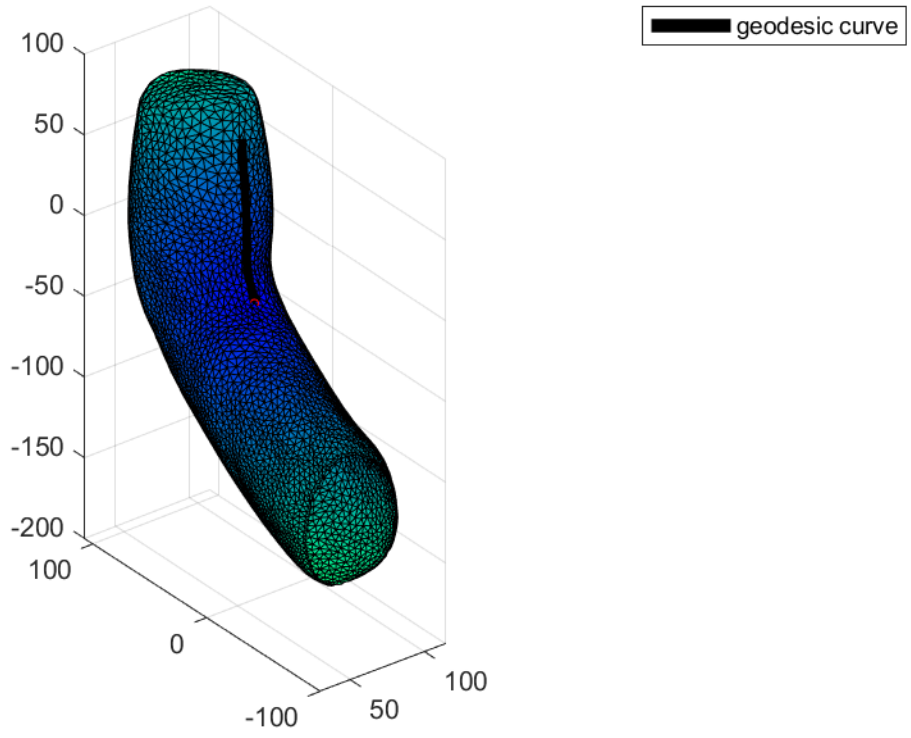
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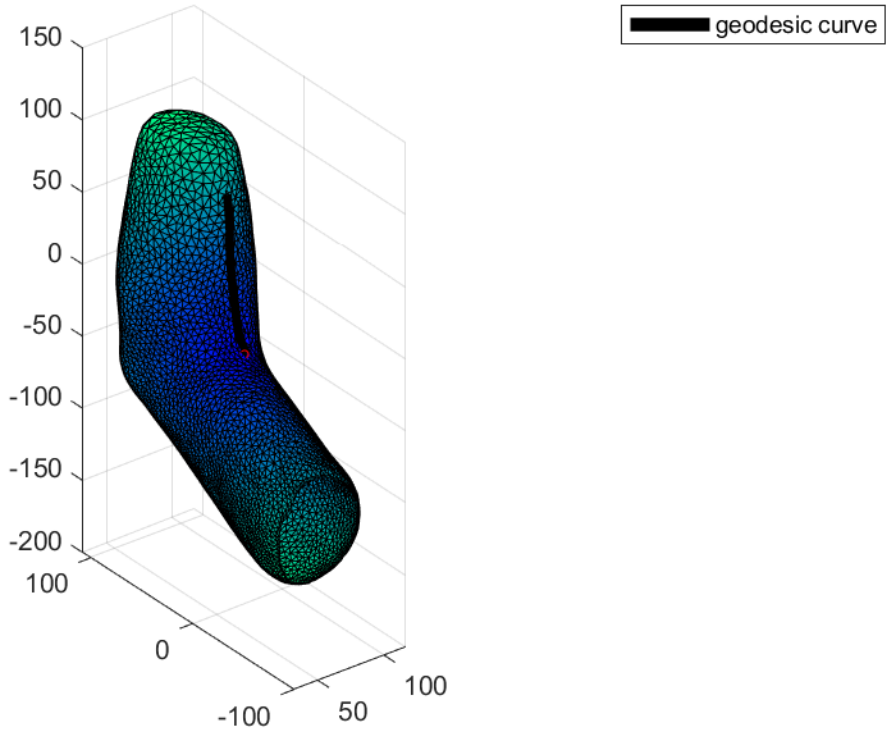
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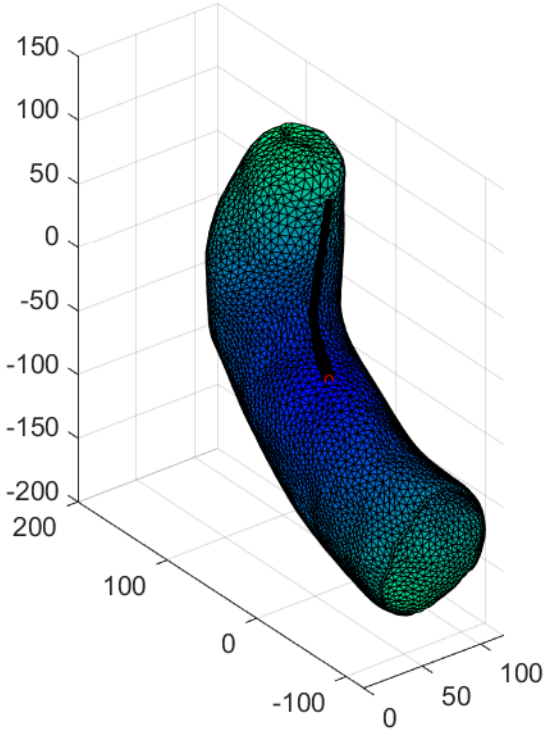
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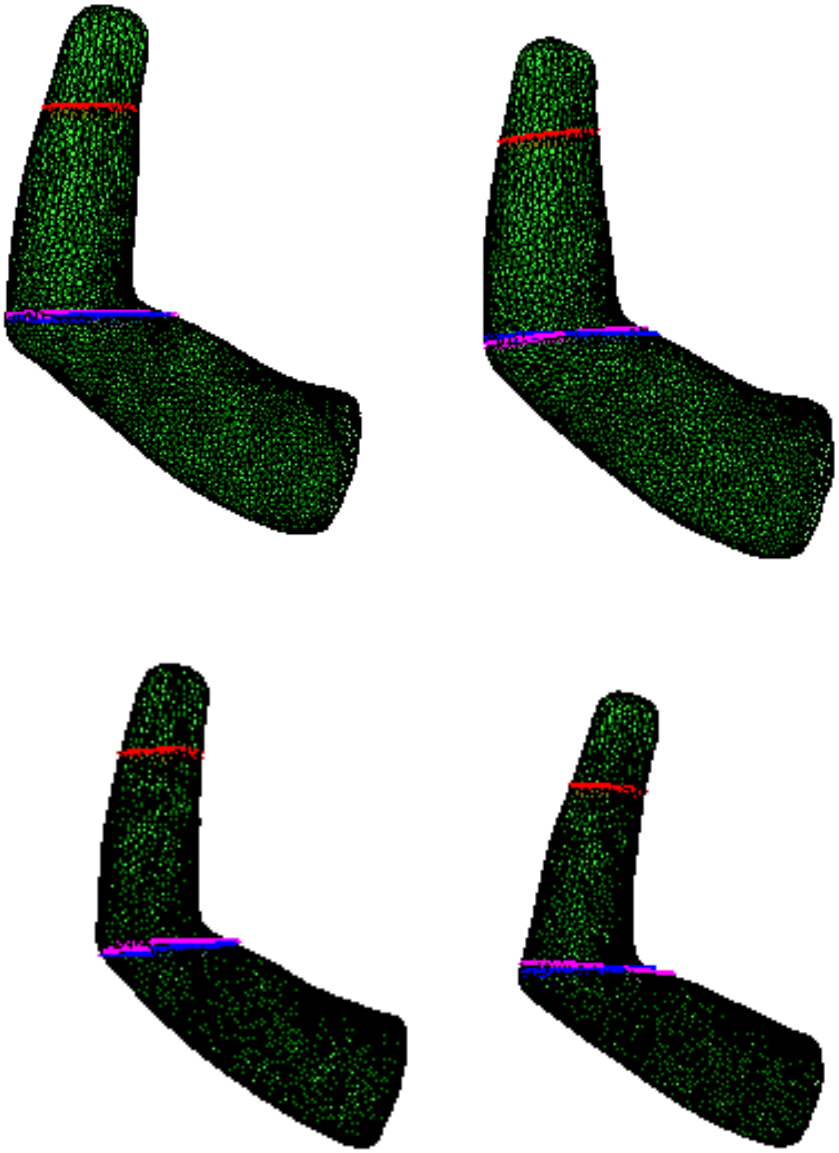
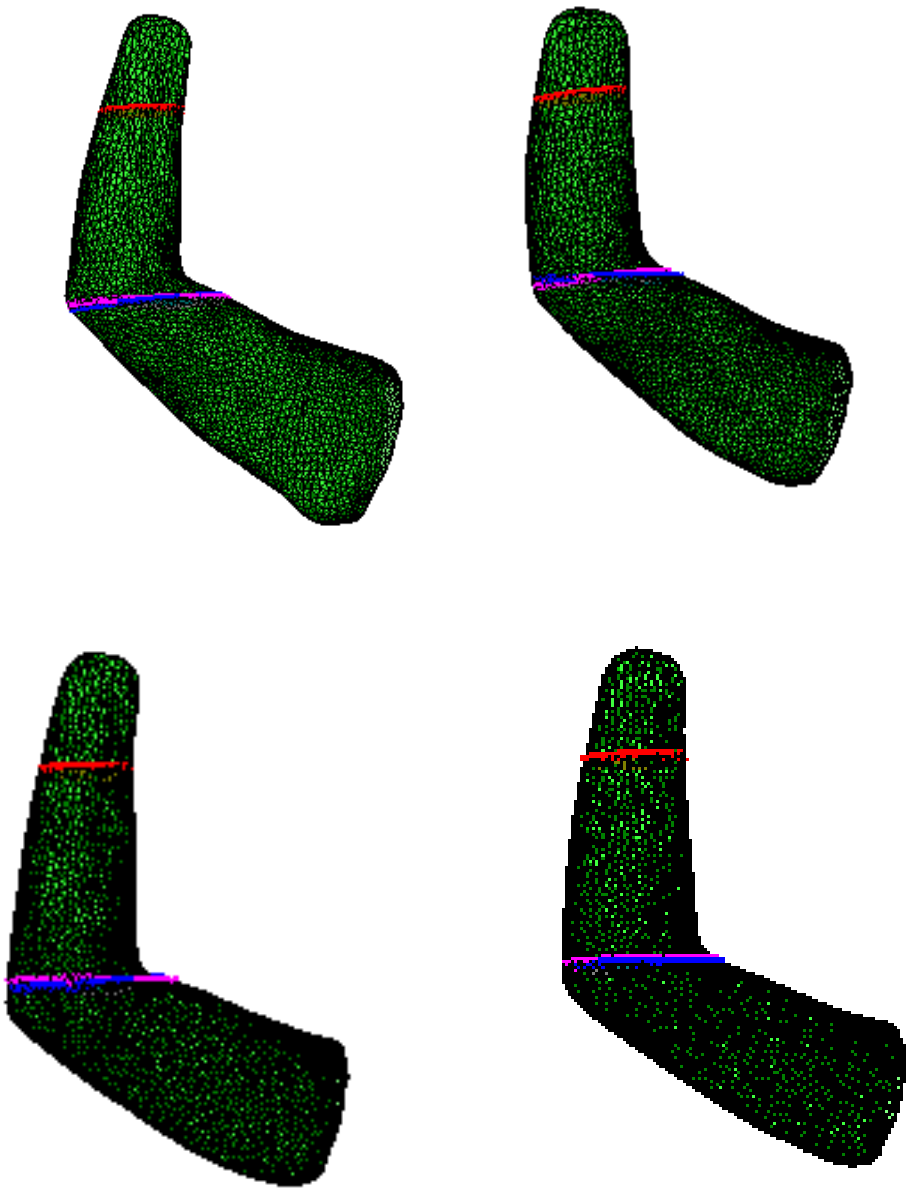
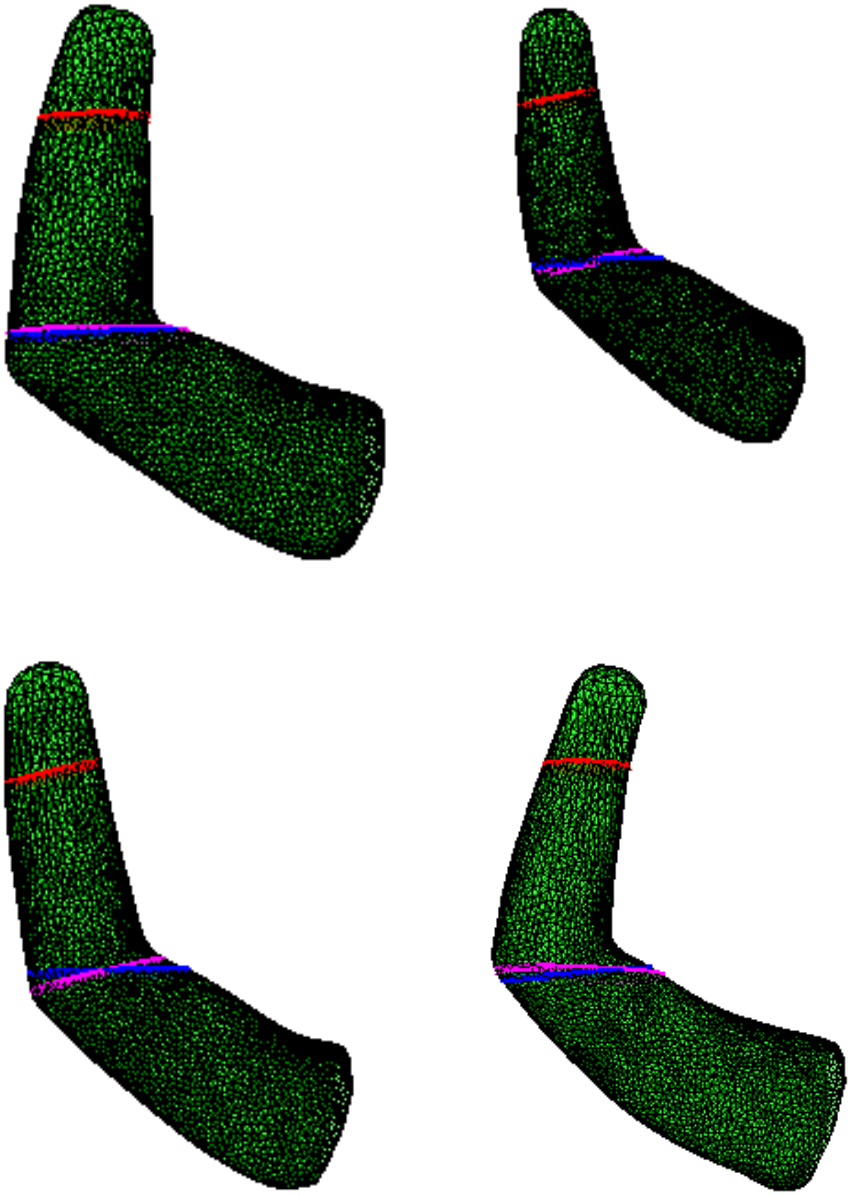
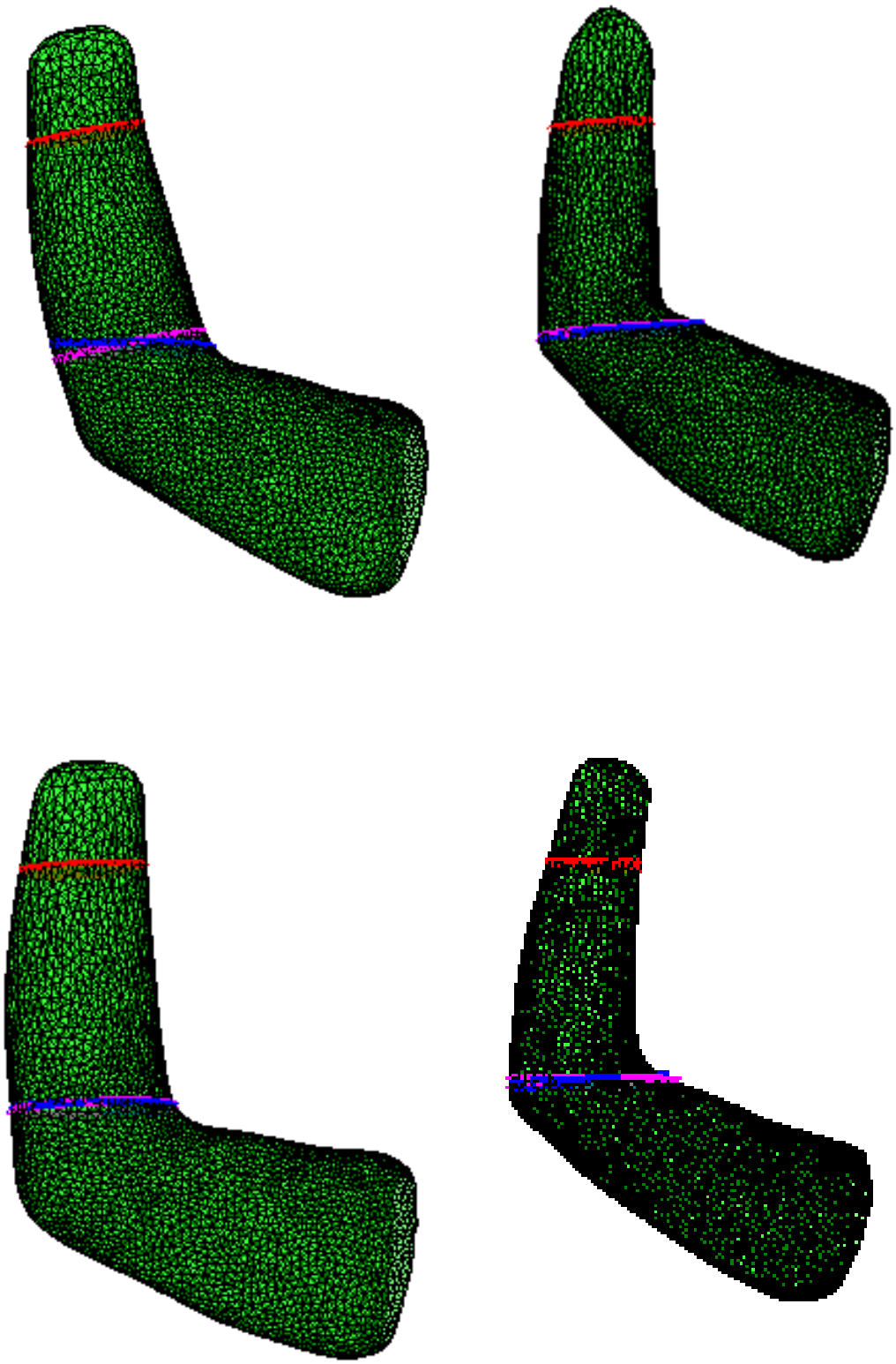
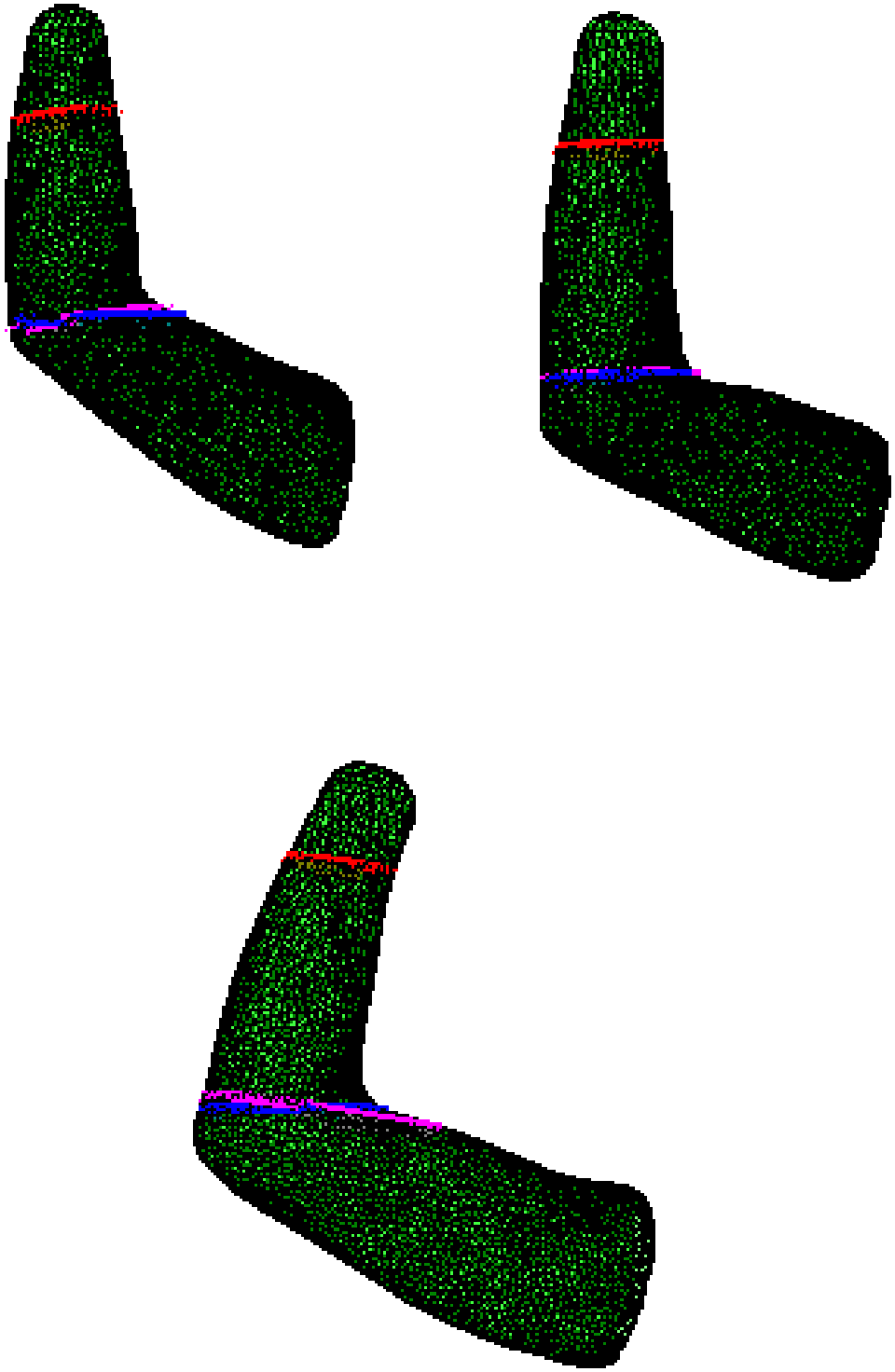
3. General SSM for 75% Cut

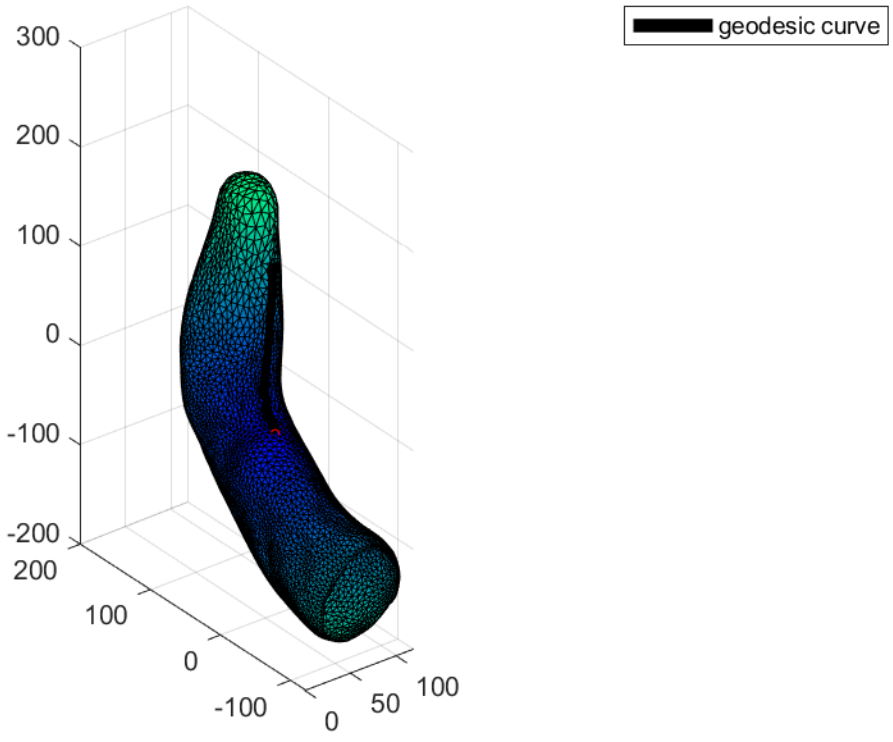








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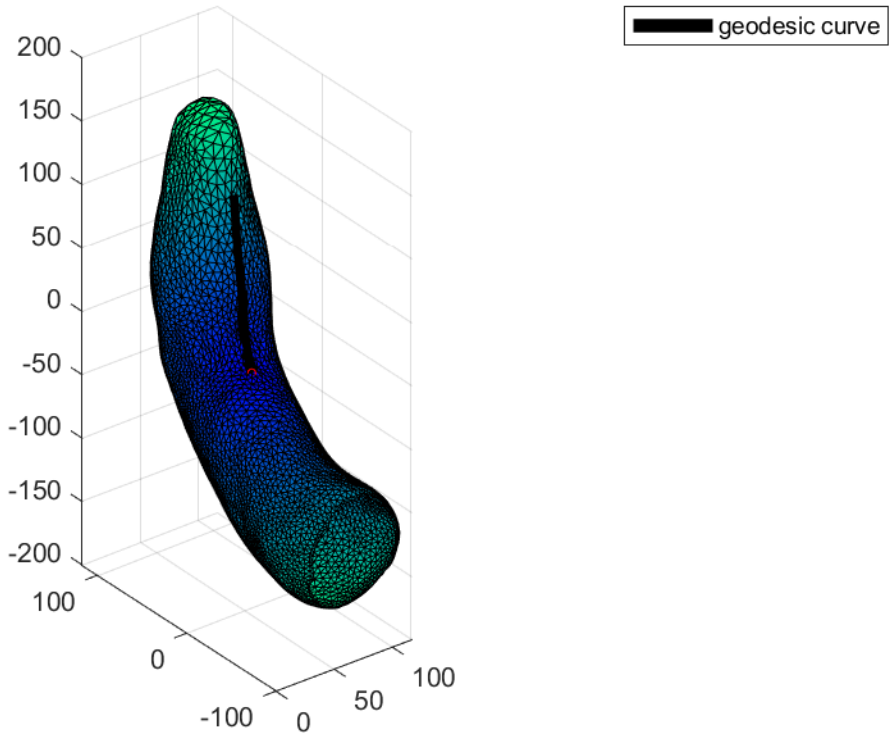
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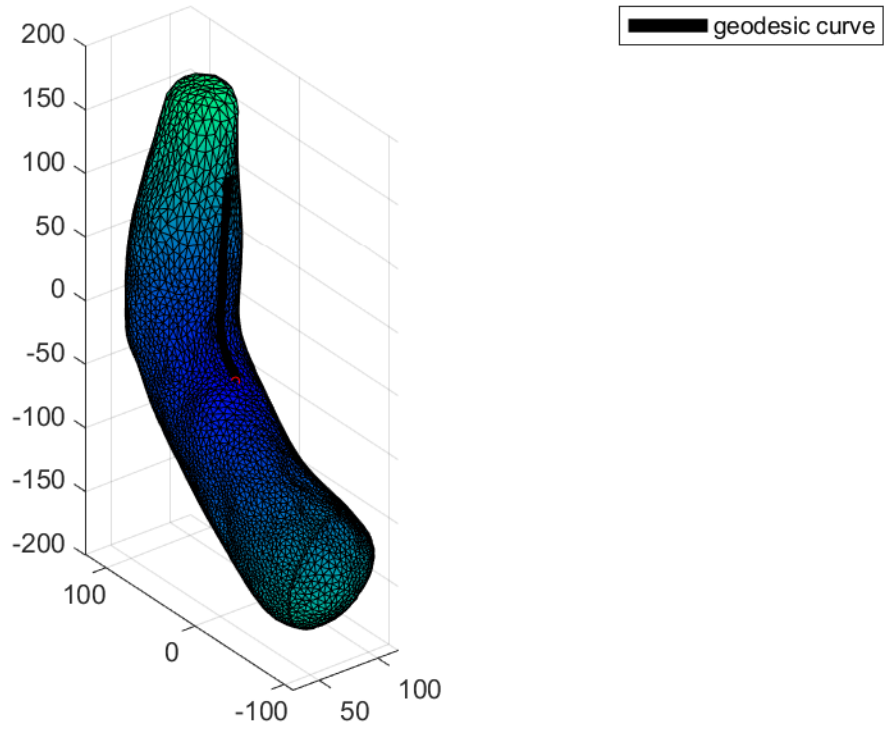
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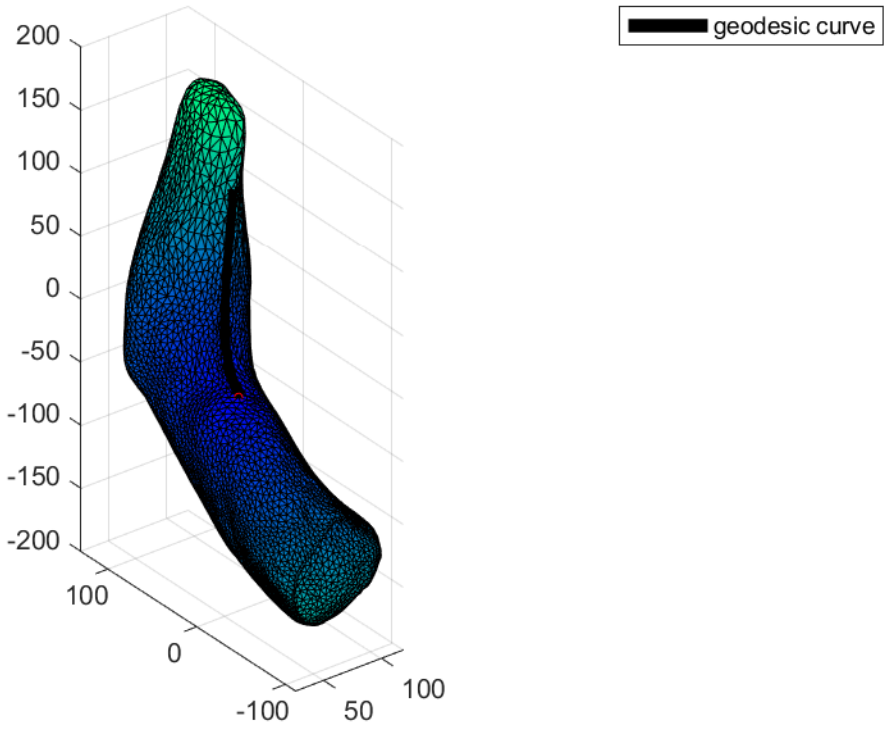
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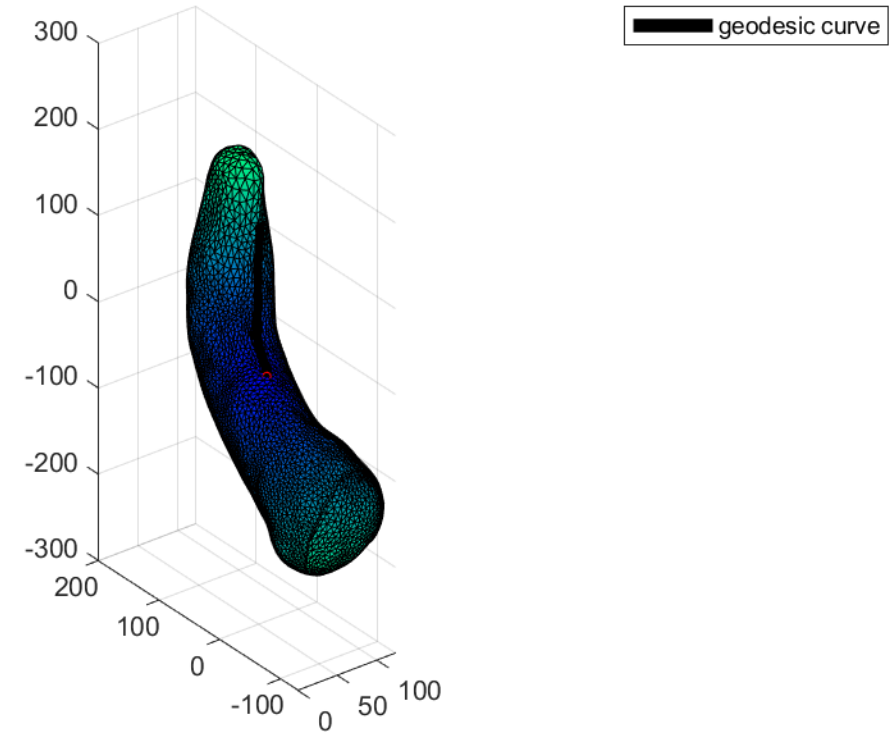
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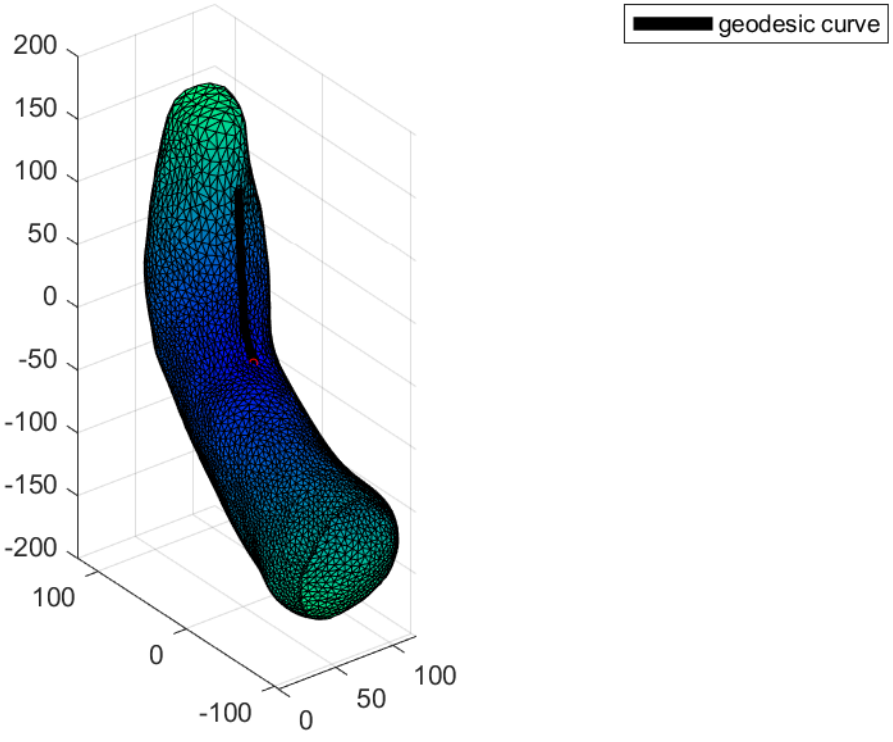
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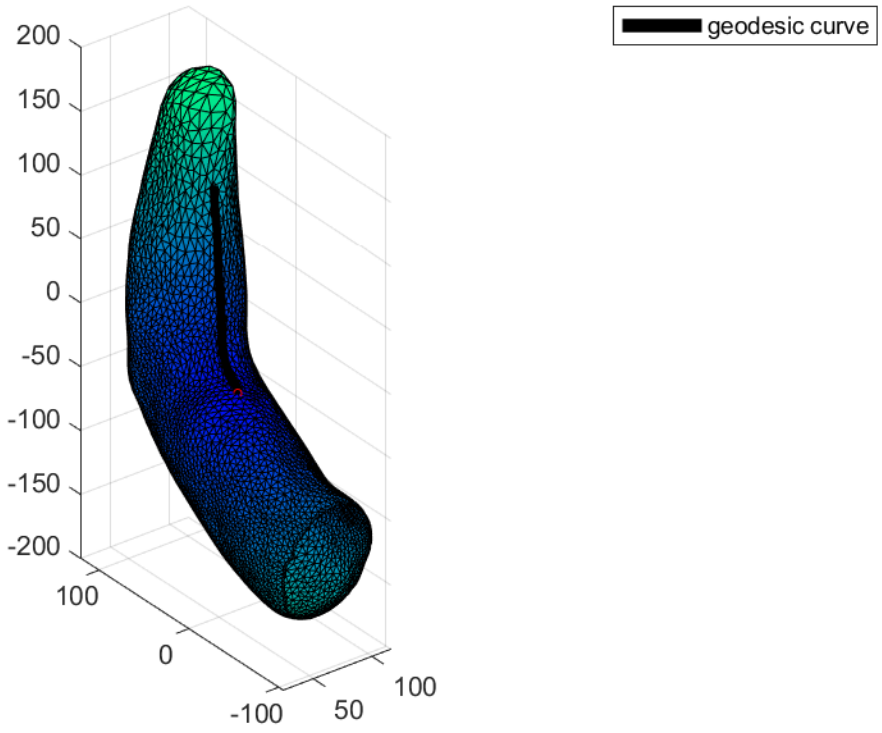
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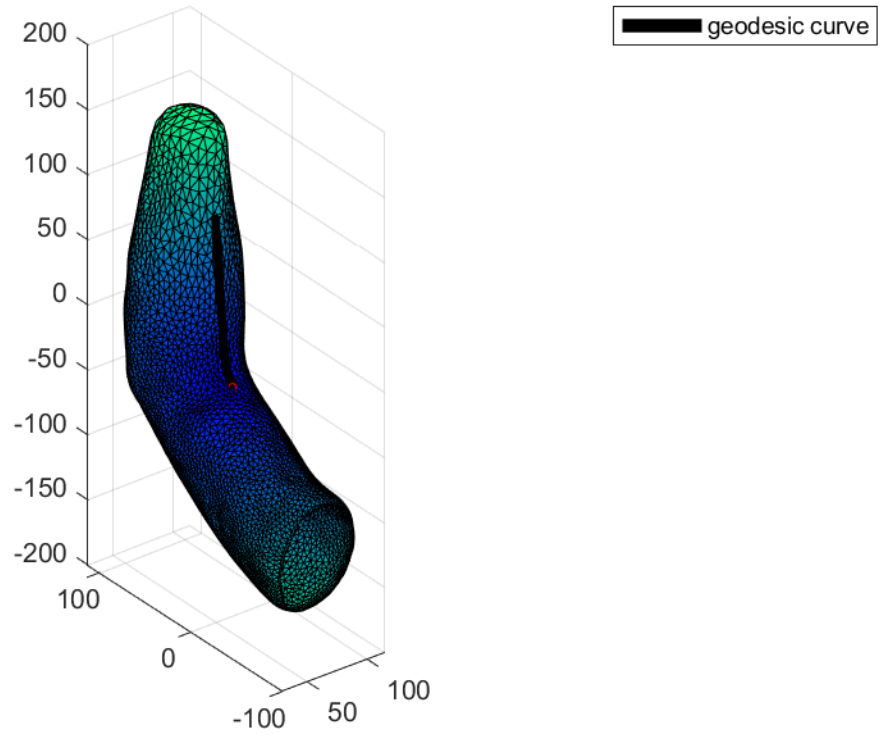
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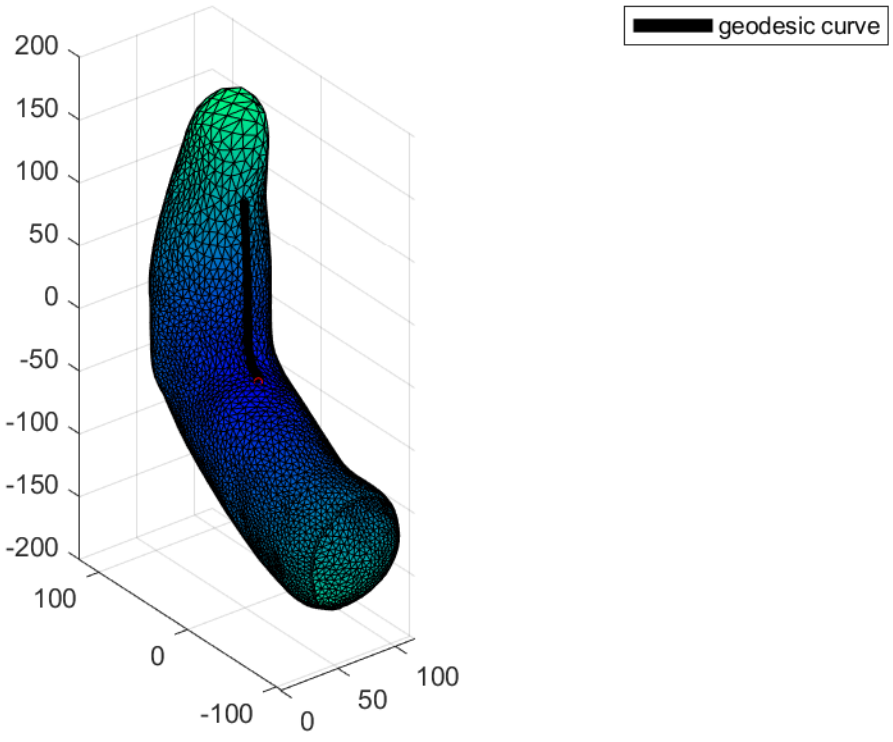
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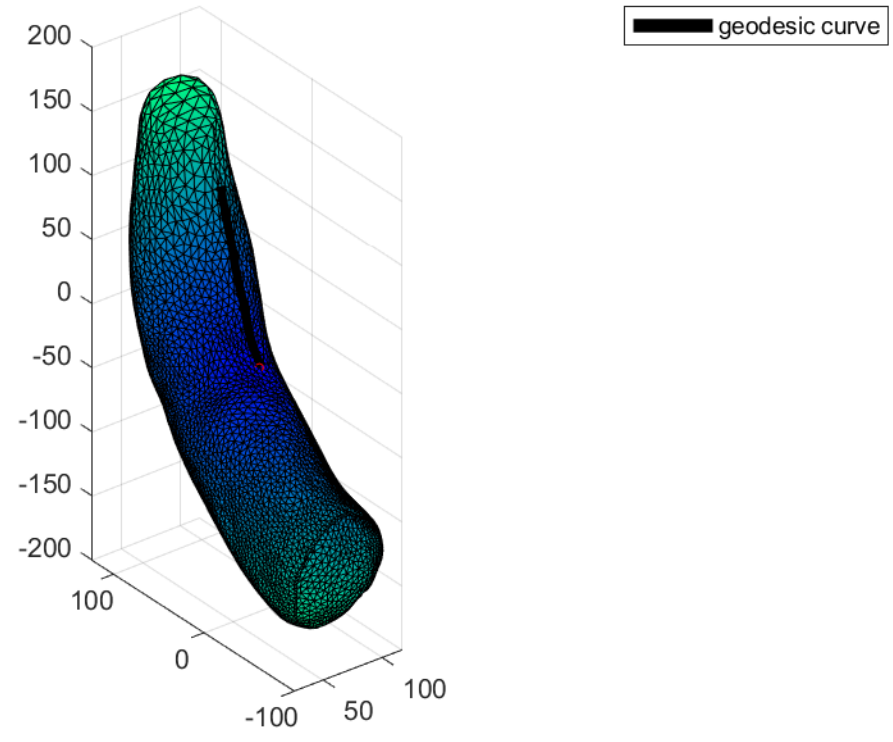
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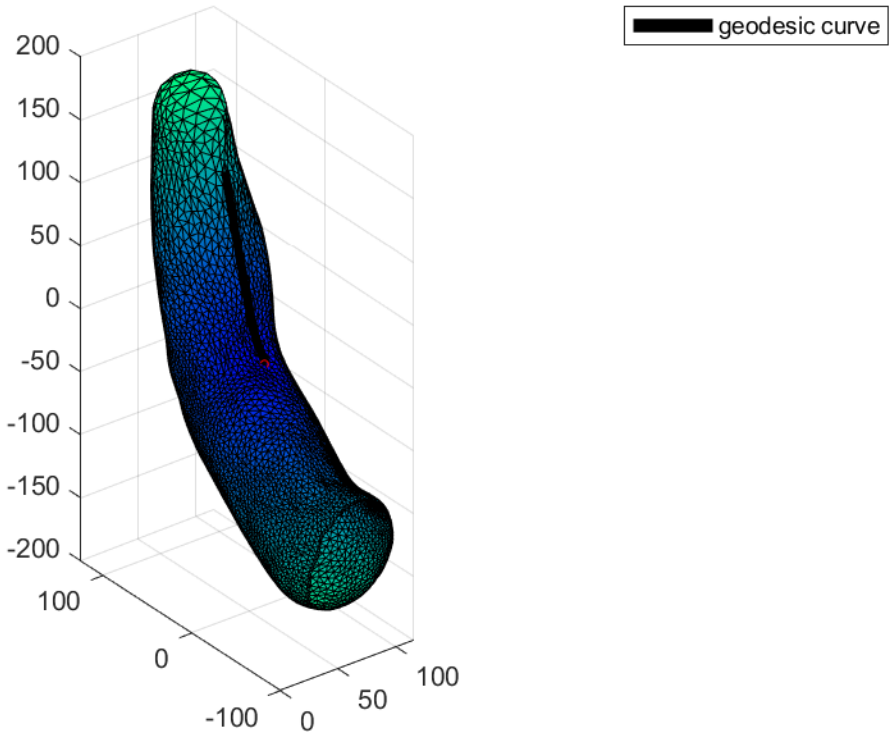
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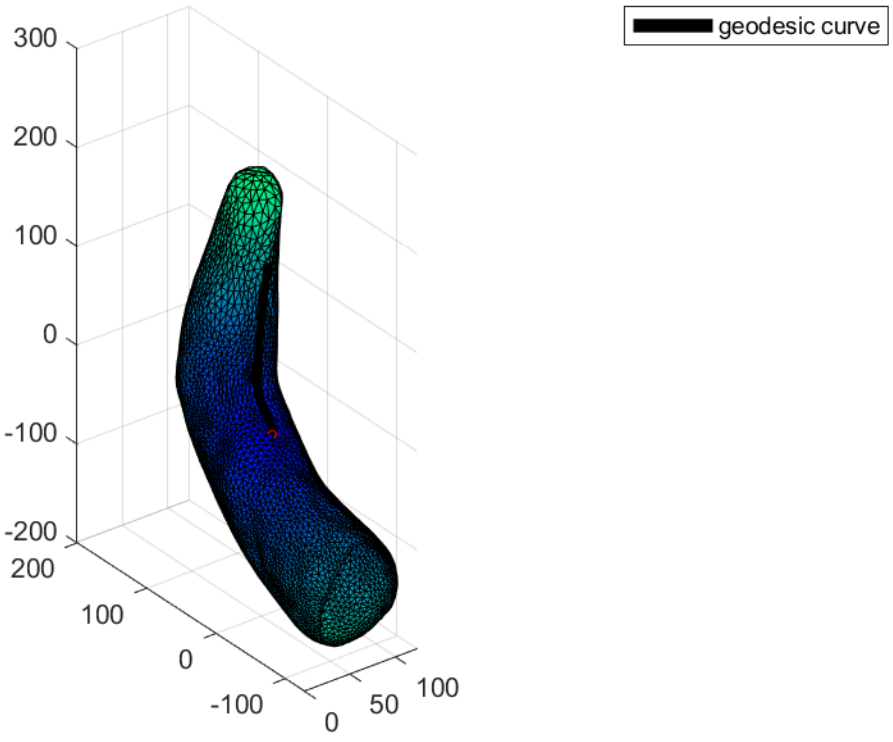
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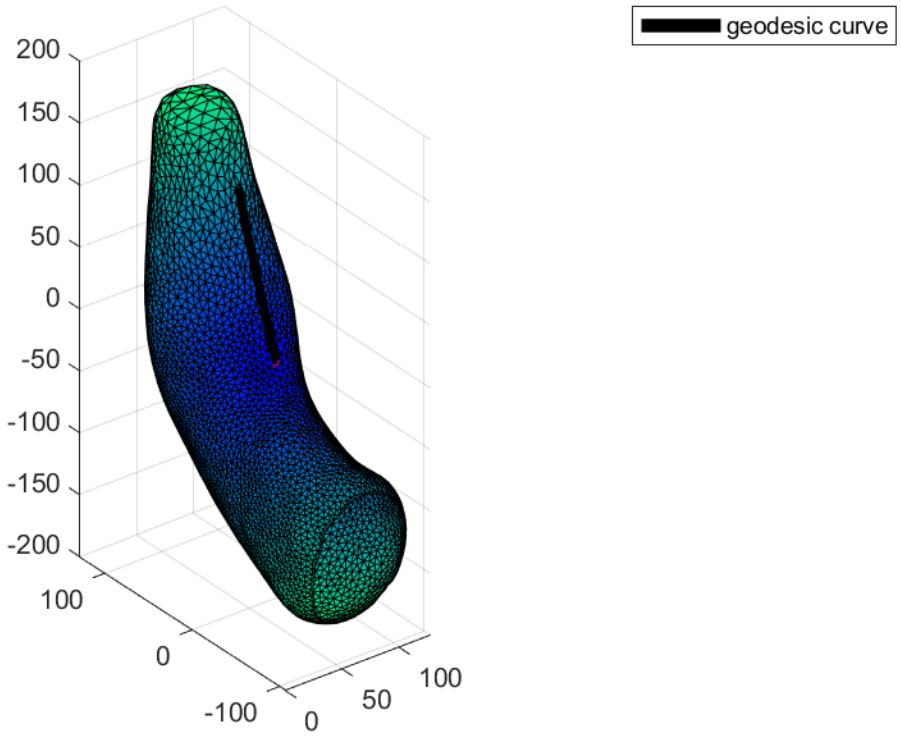
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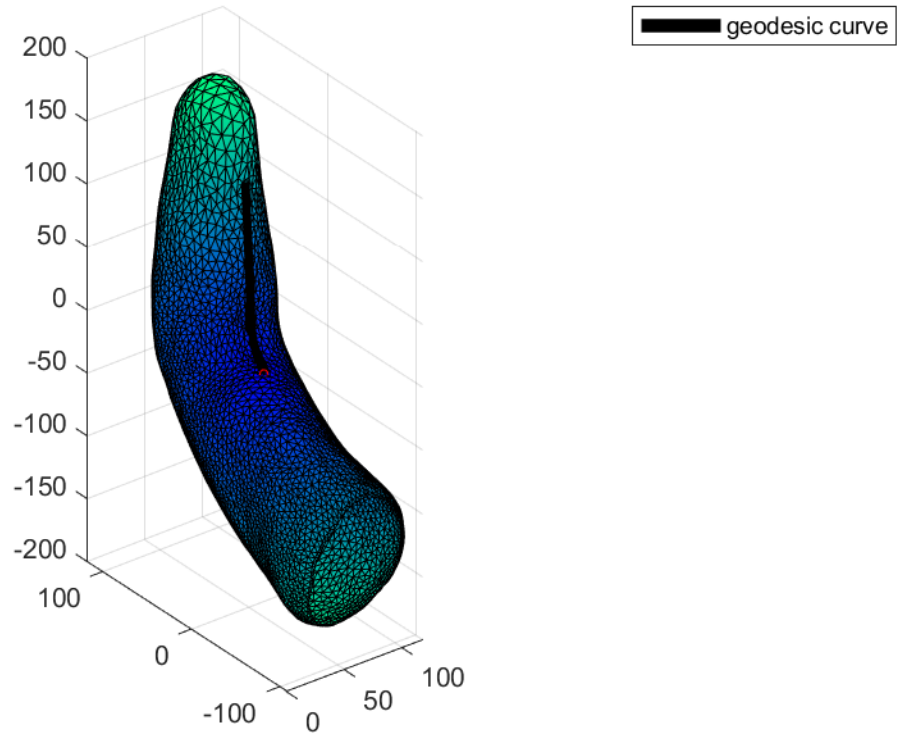
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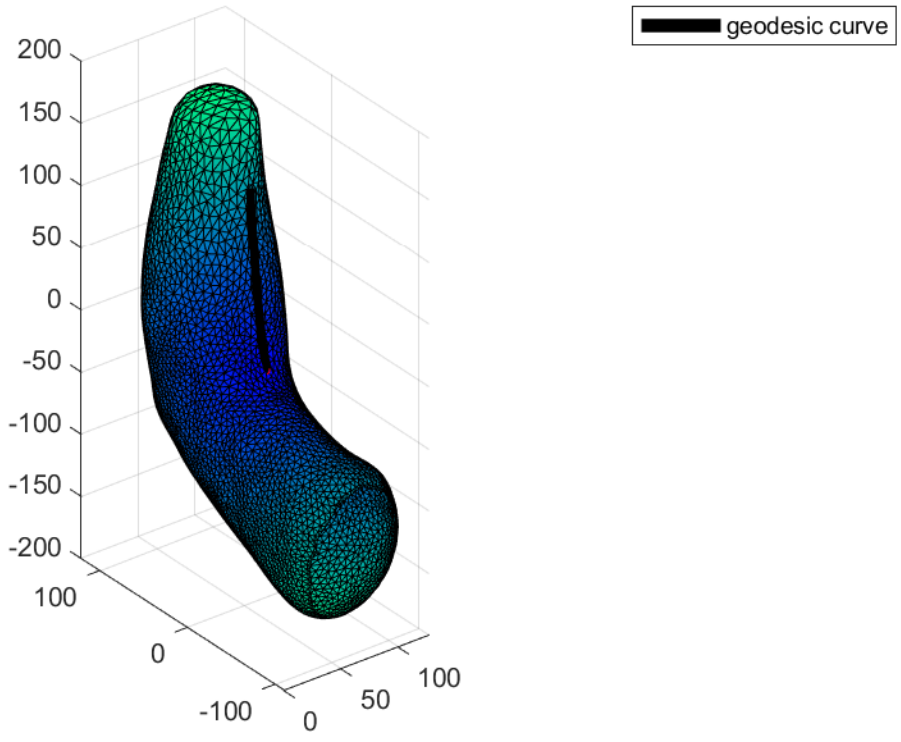
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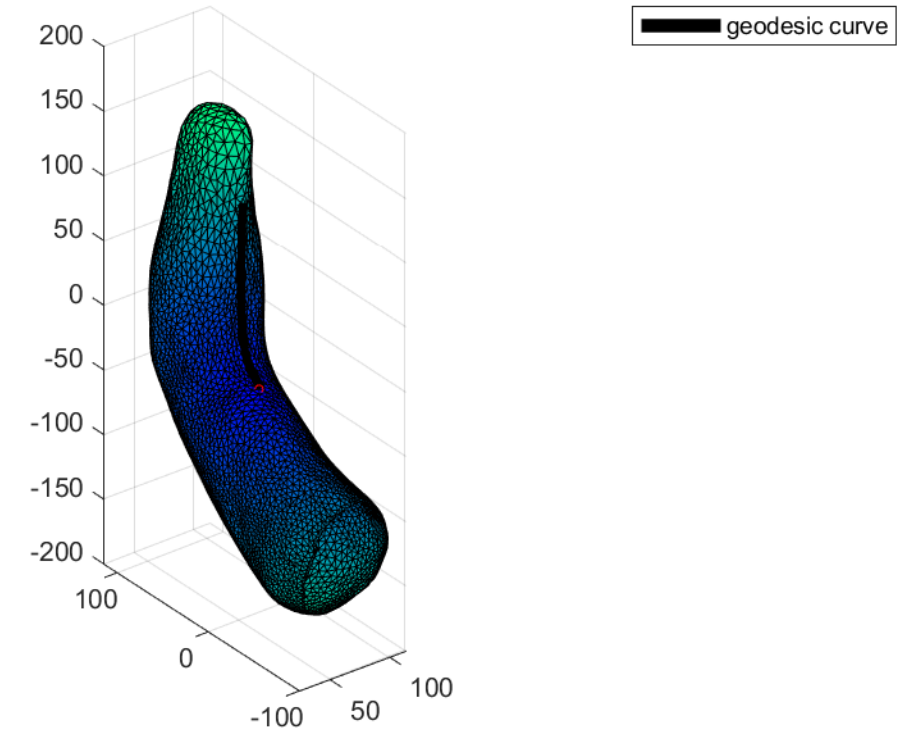
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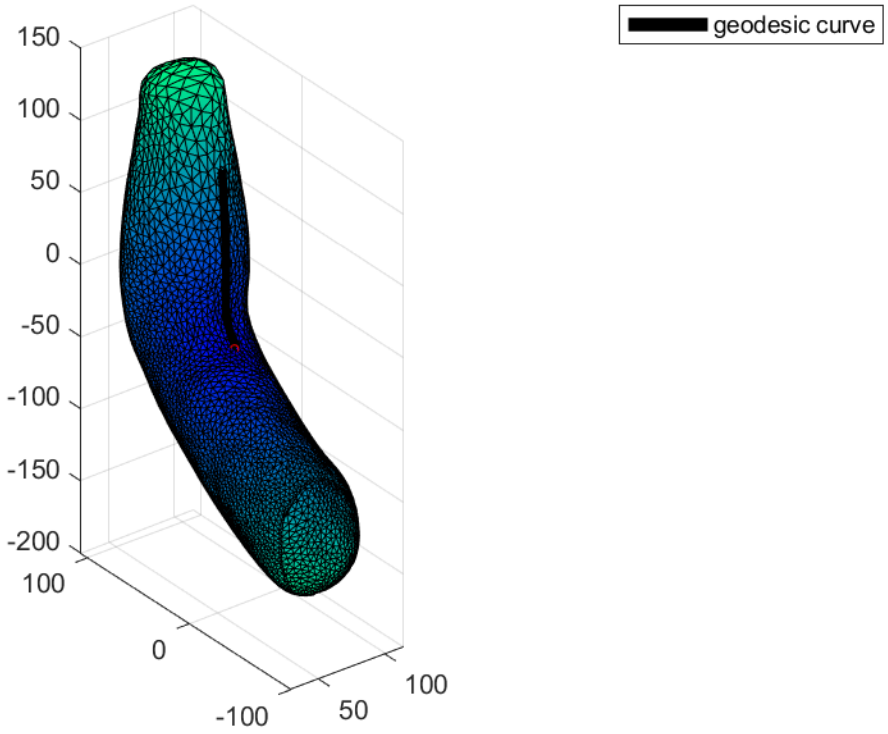
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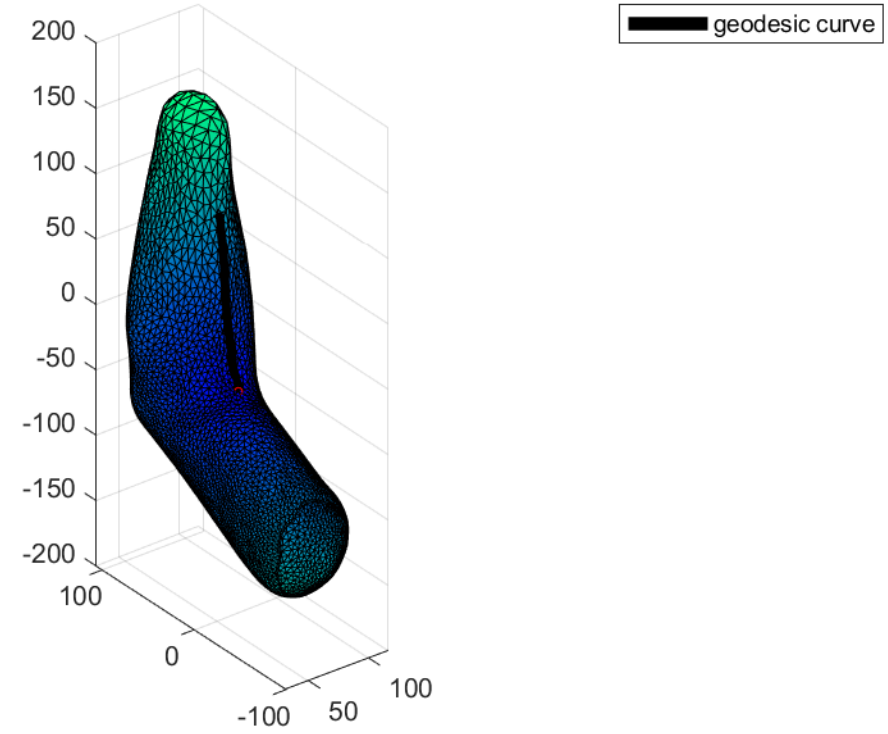
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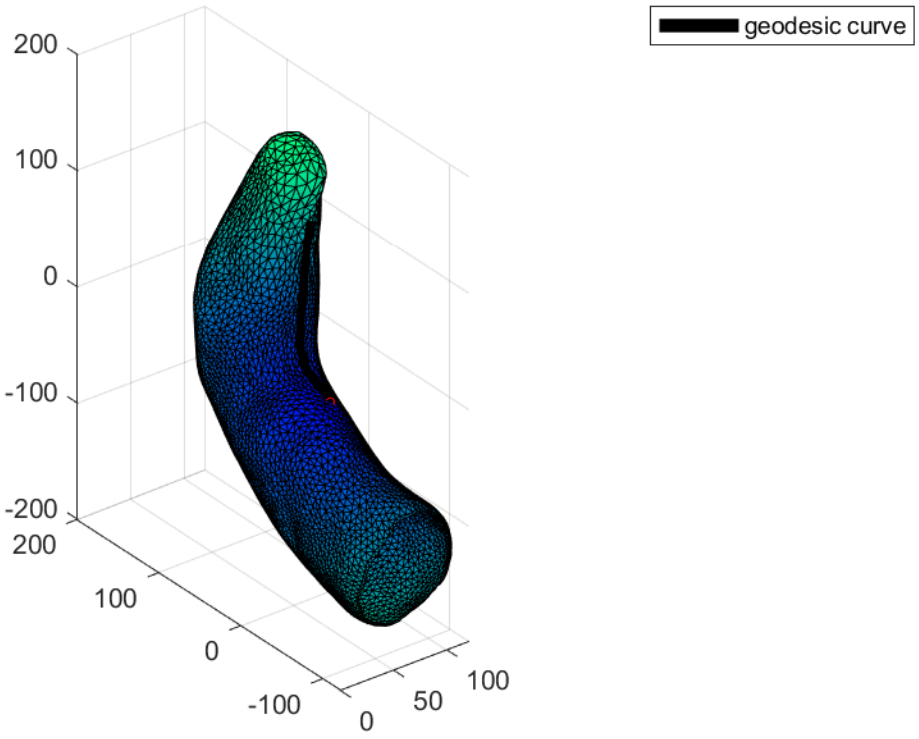
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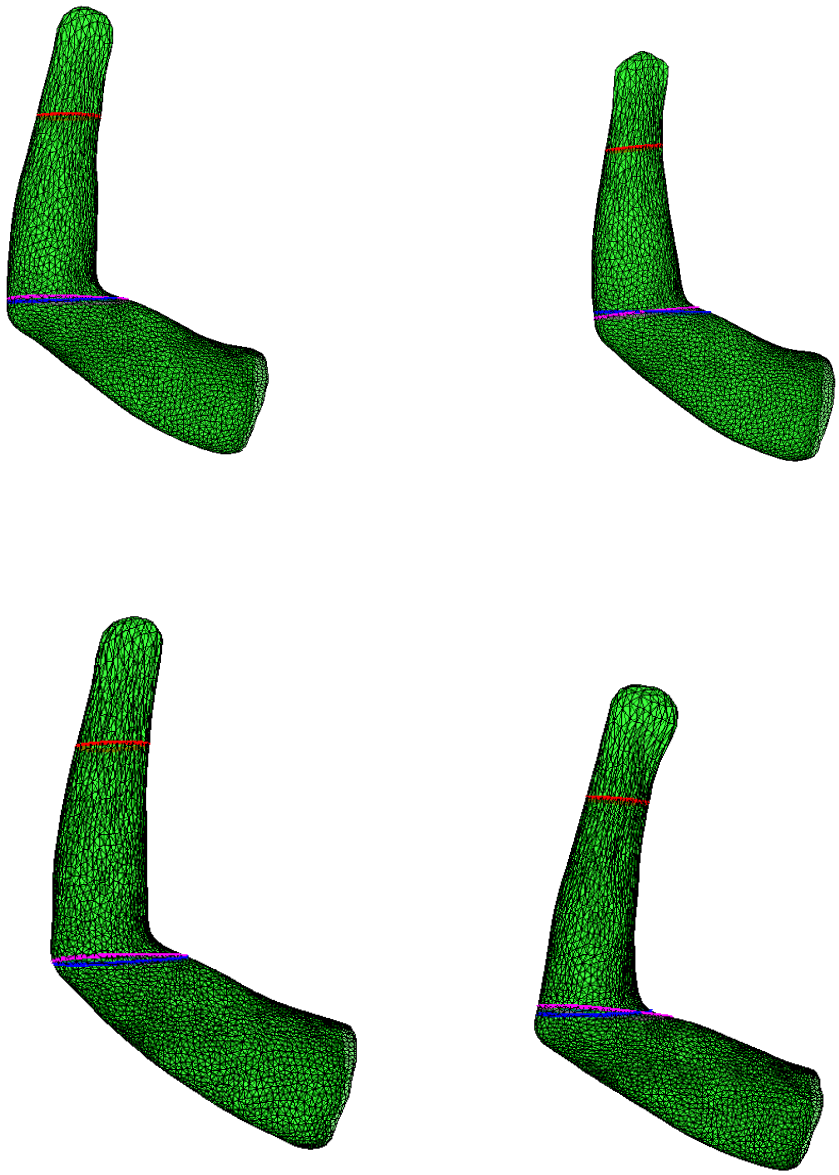
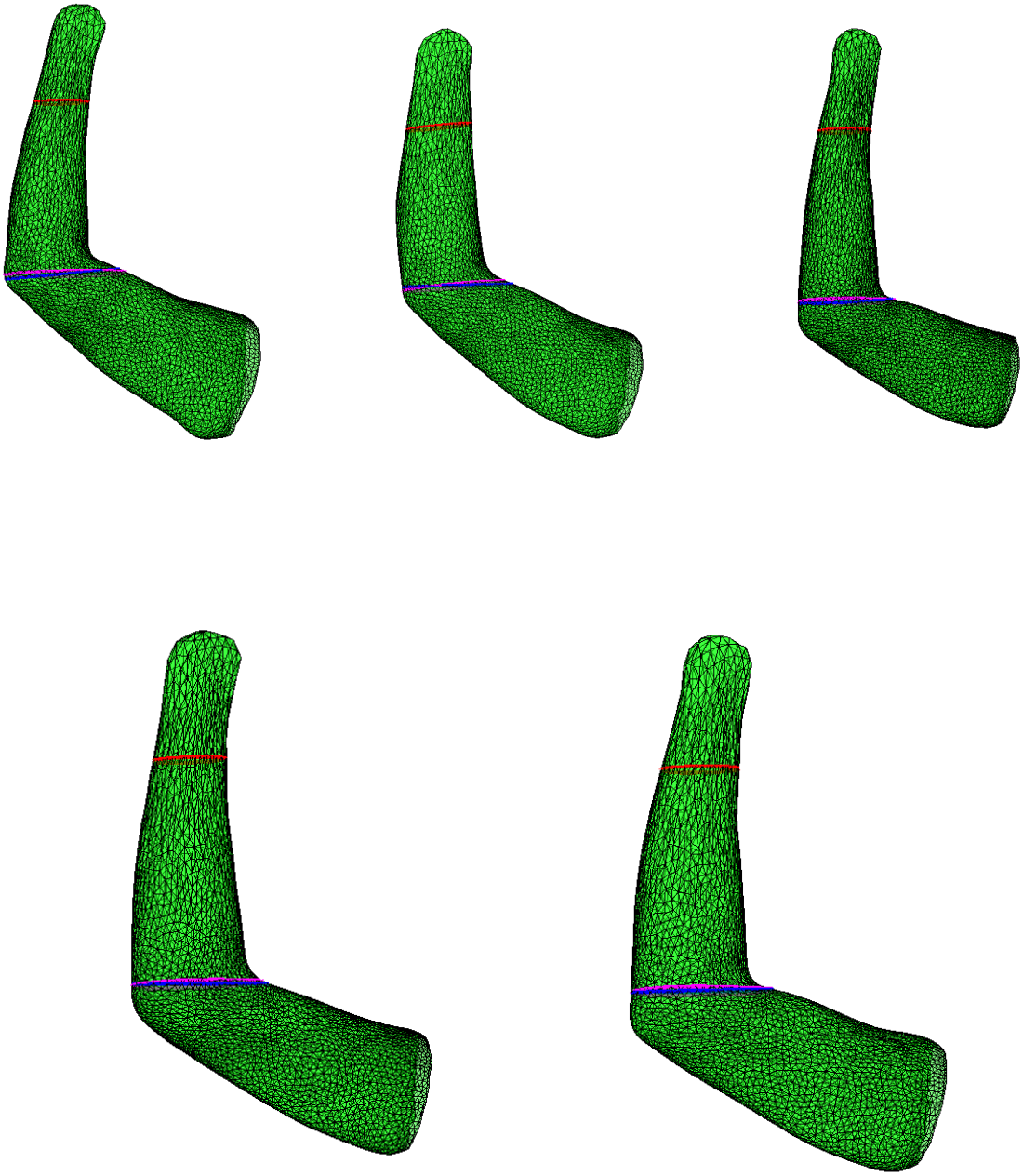
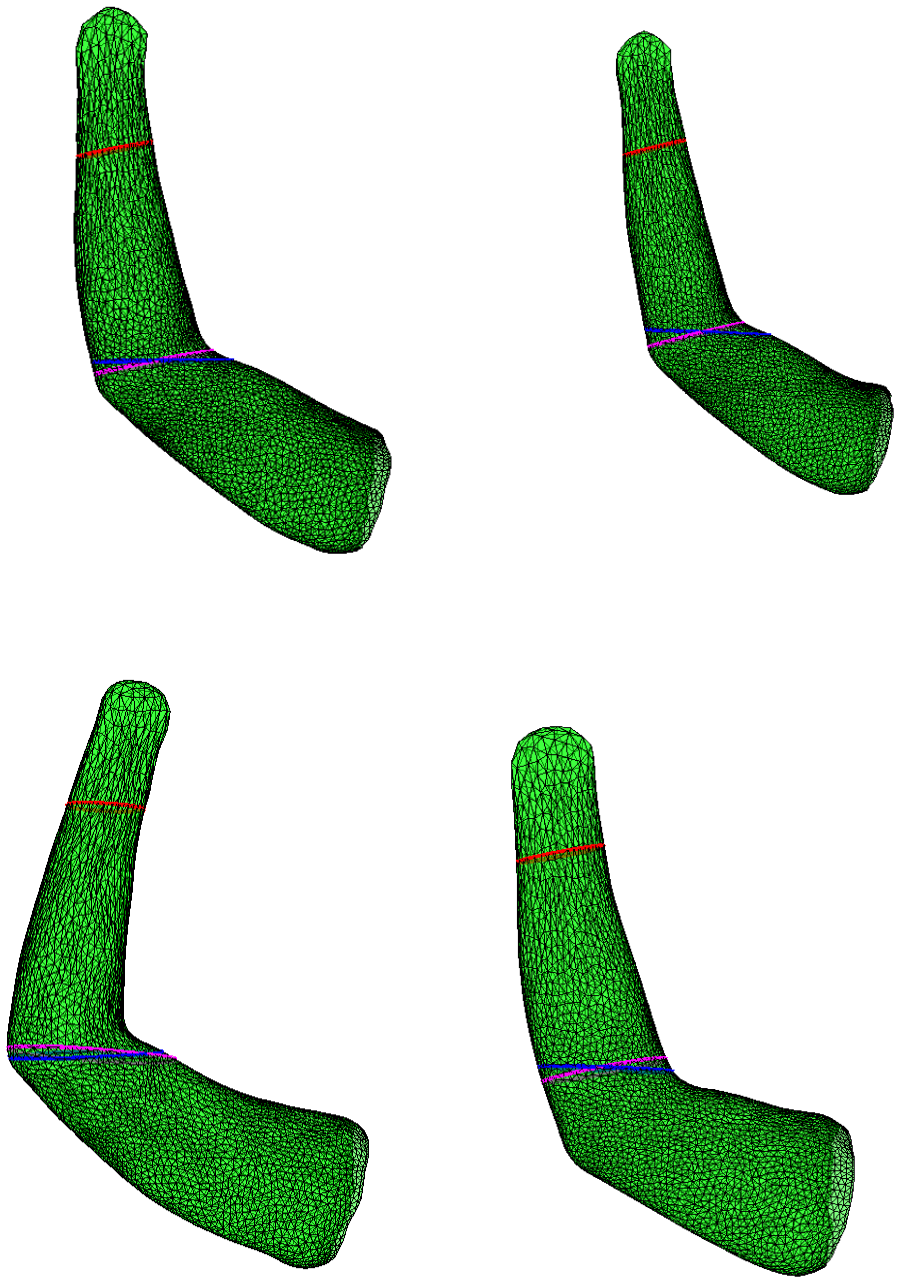
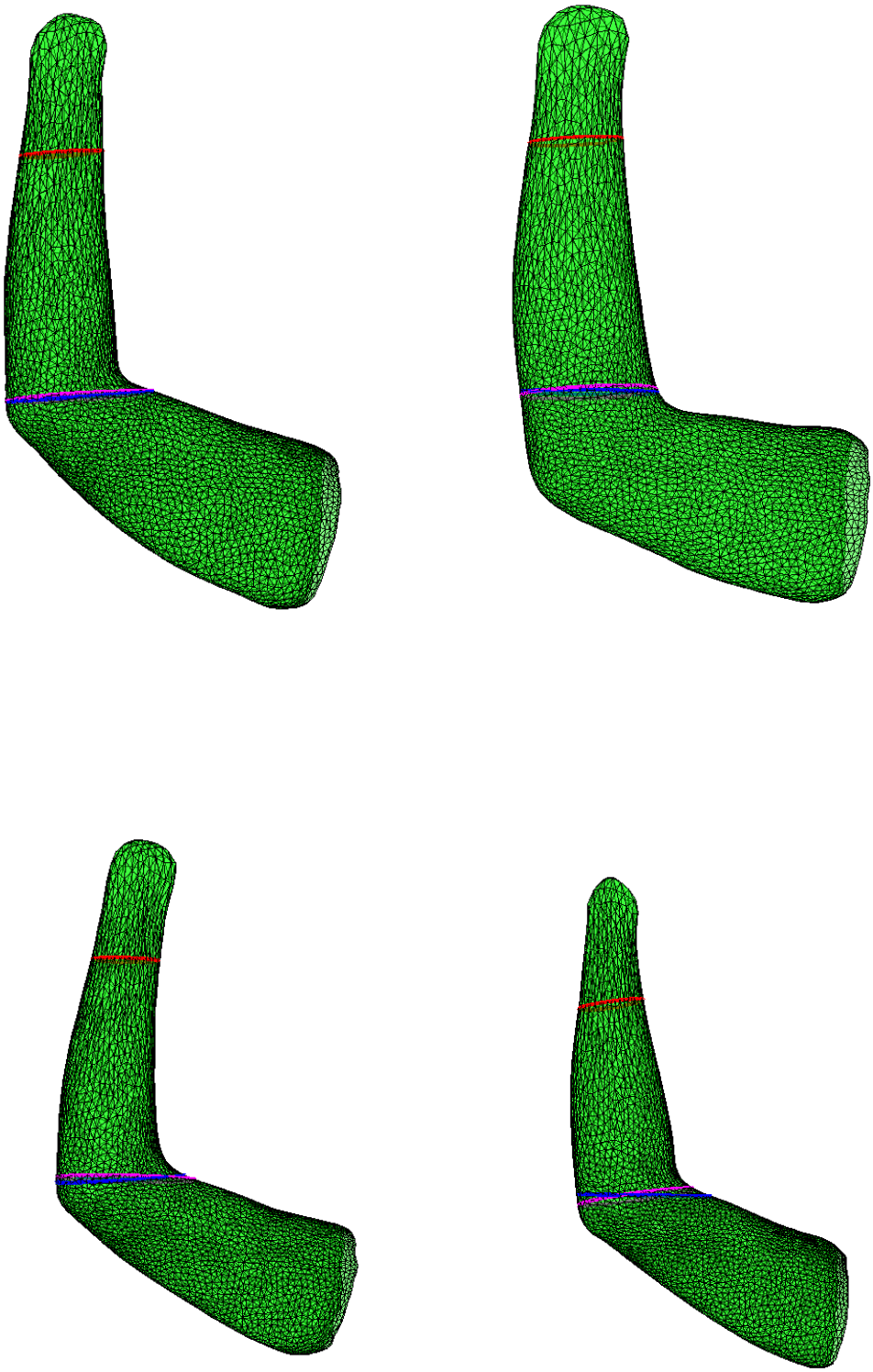
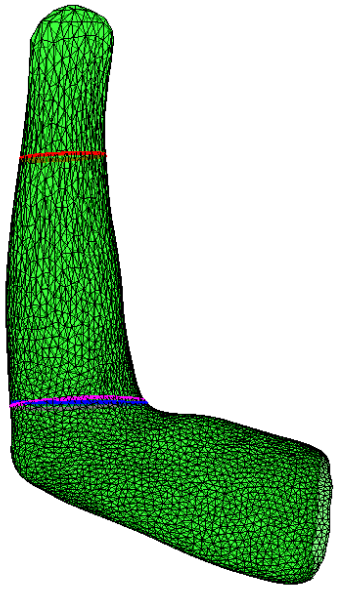
4. General SSM for Wrist Cut

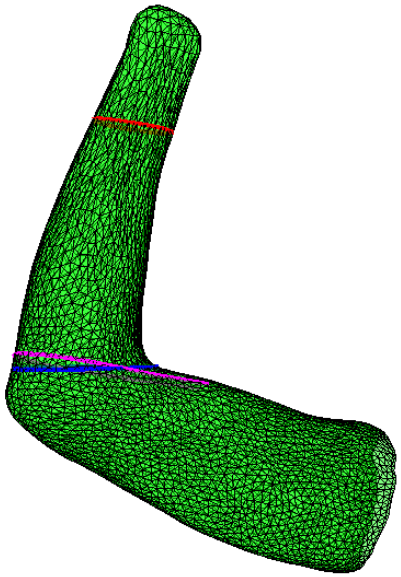


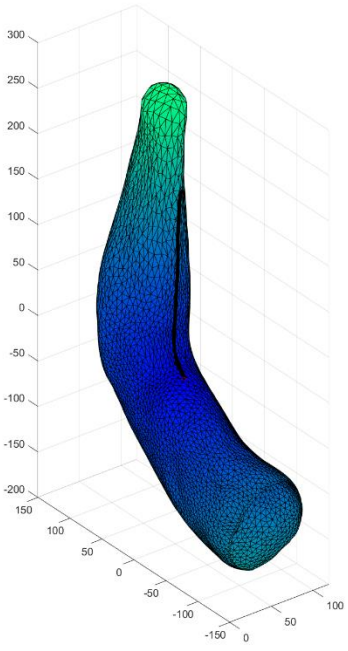








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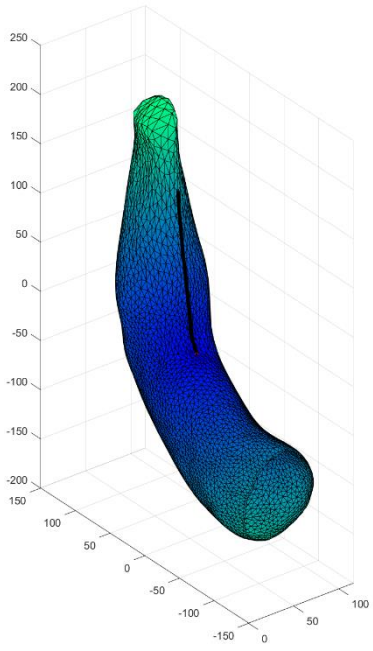
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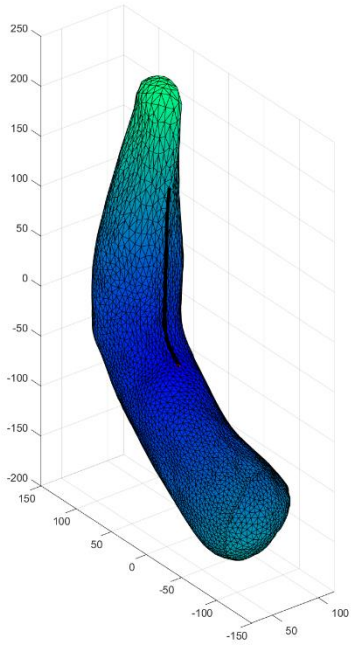
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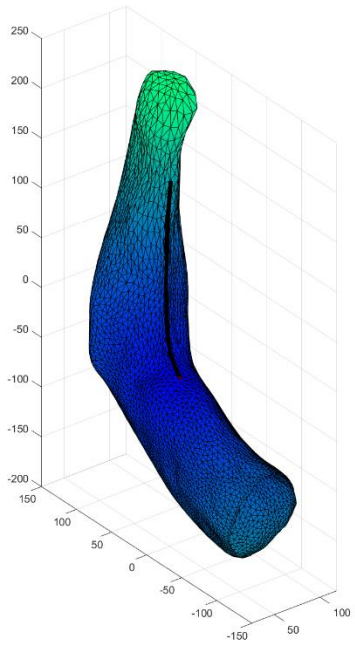
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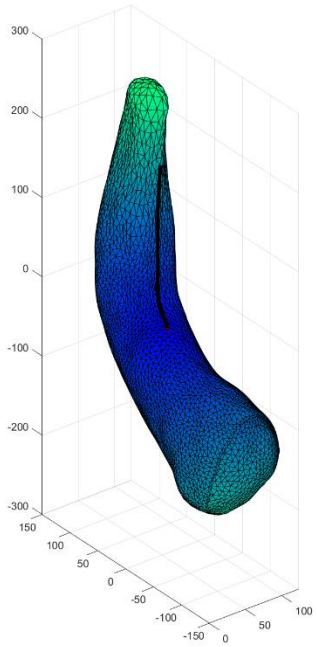
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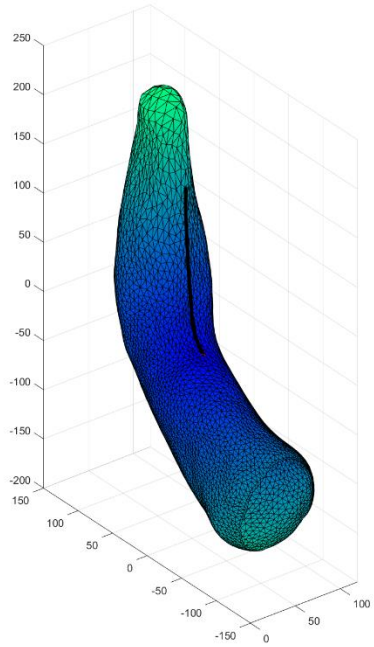
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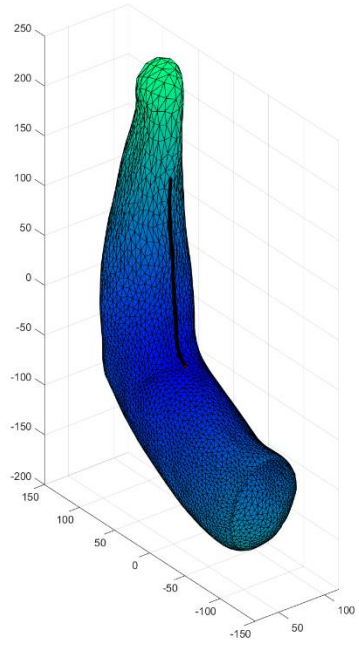
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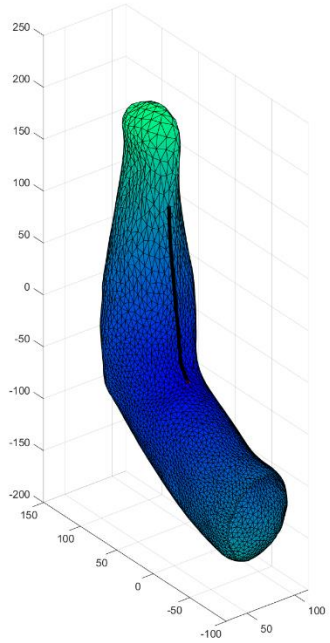
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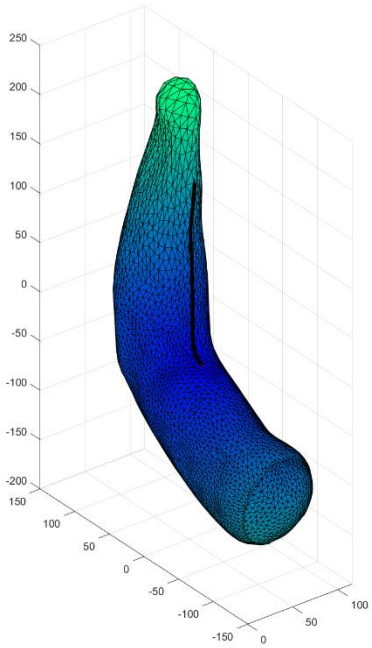
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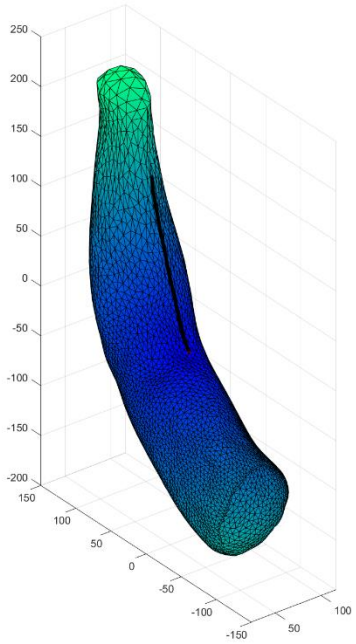
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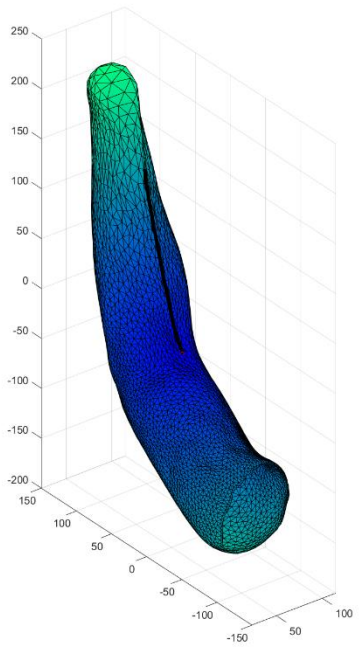
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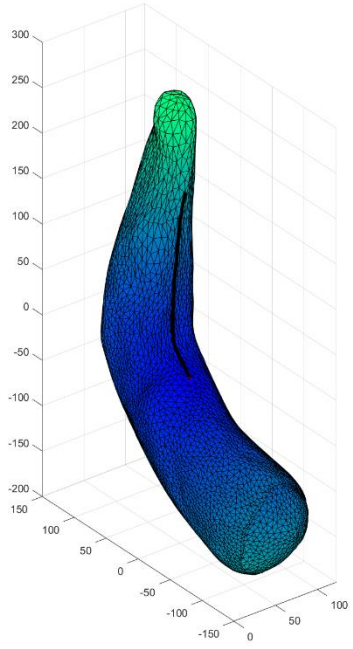
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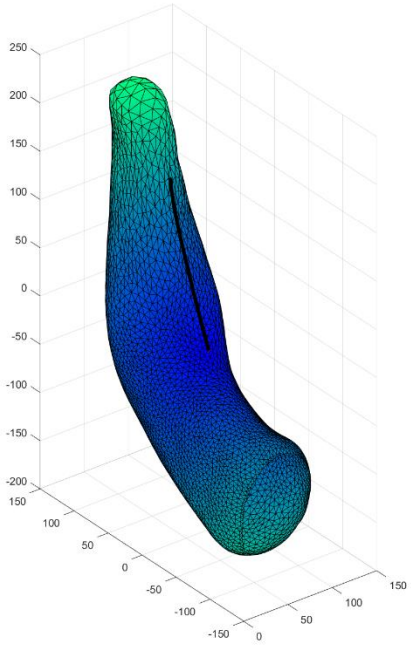
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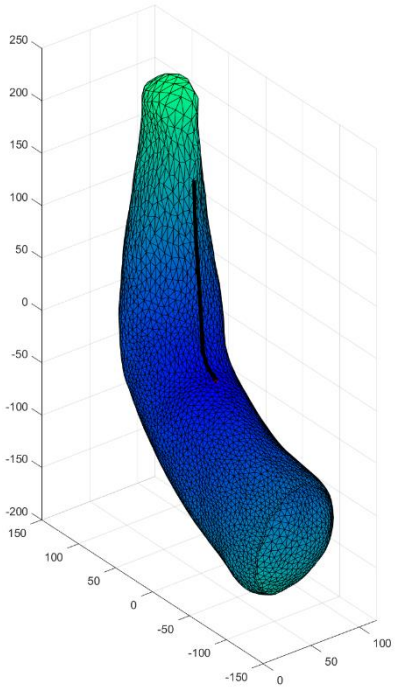
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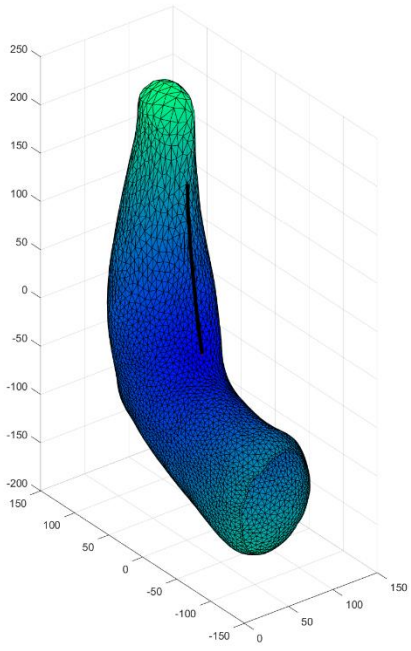
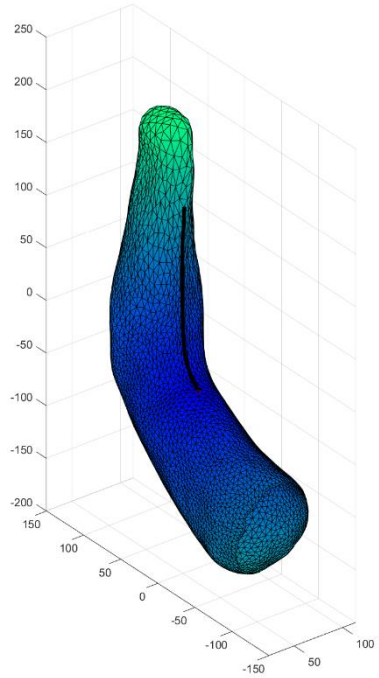
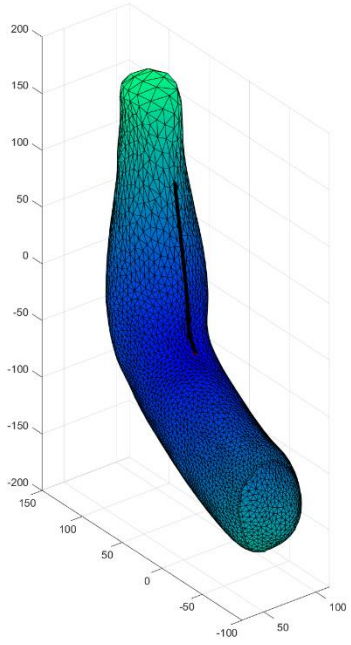
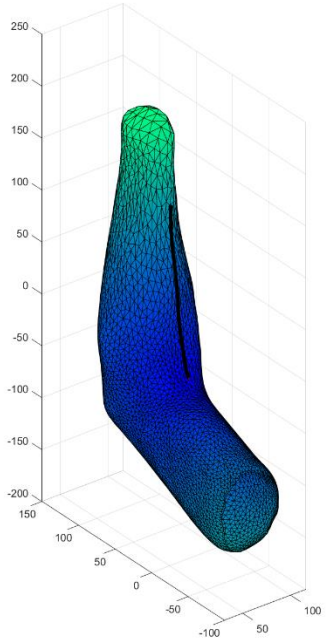

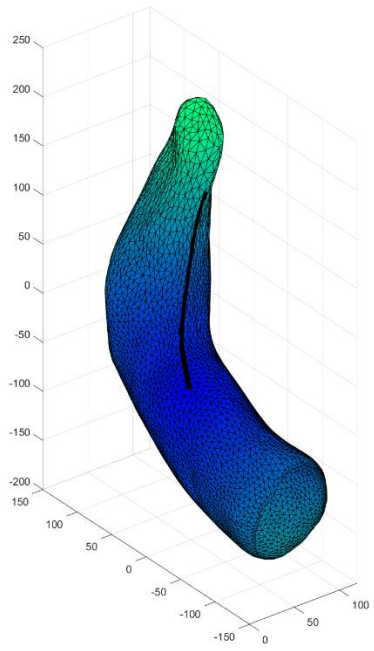
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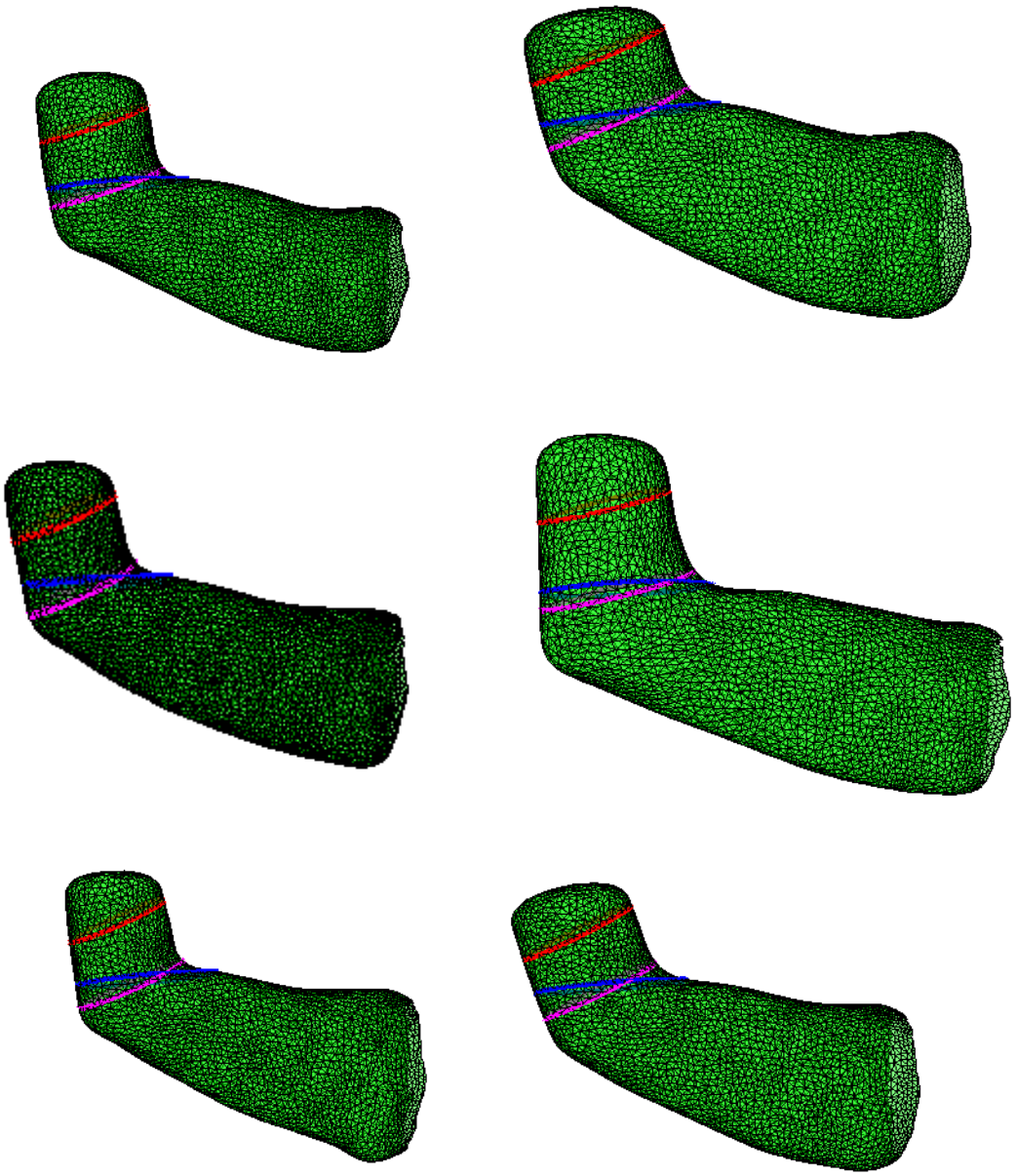
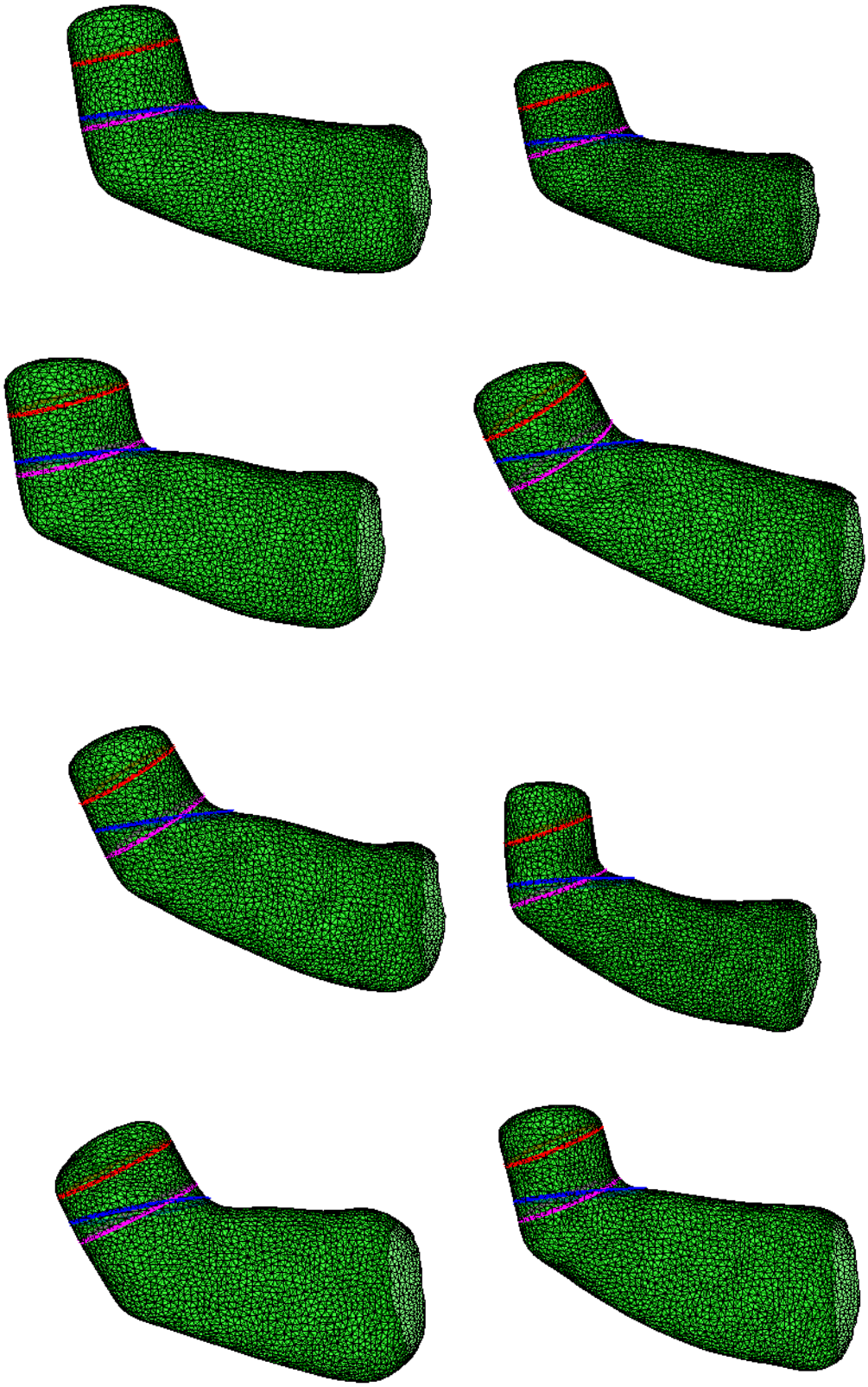
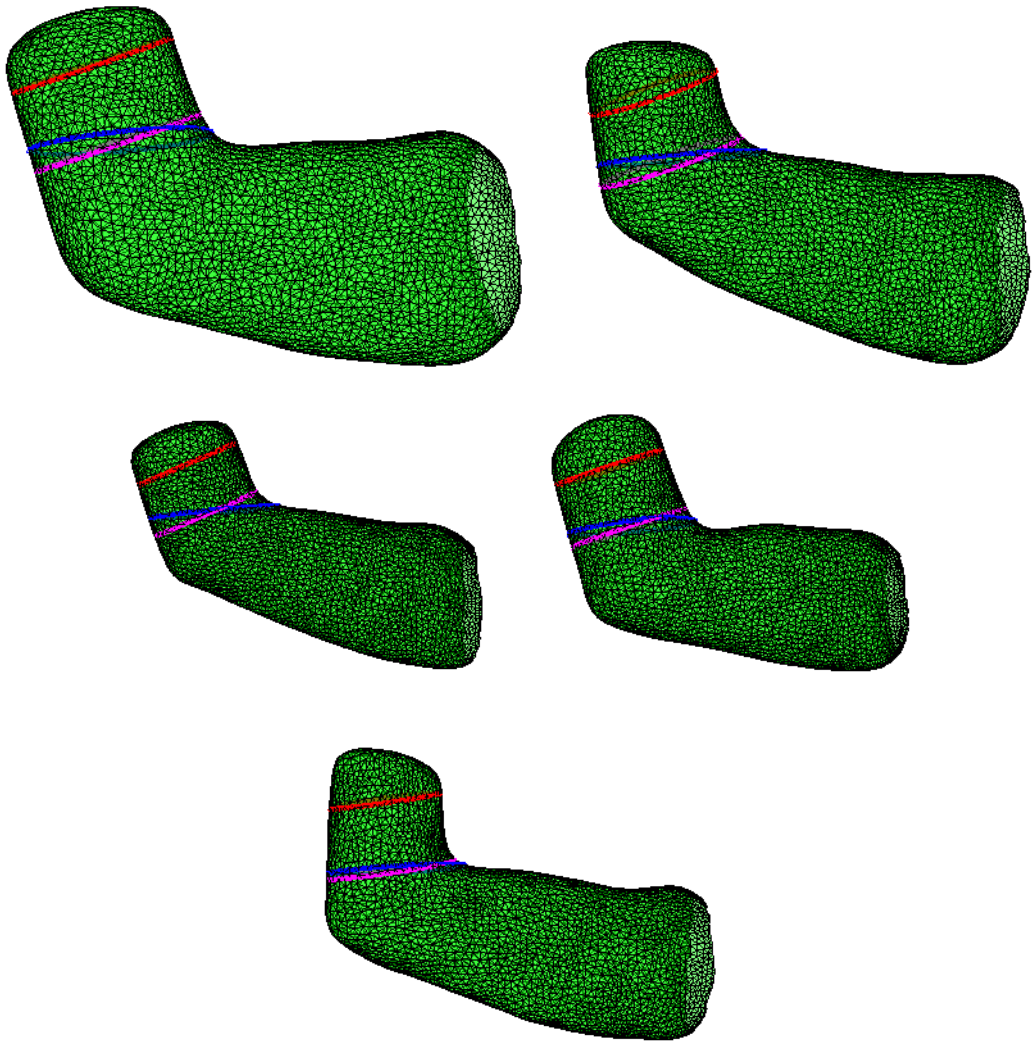
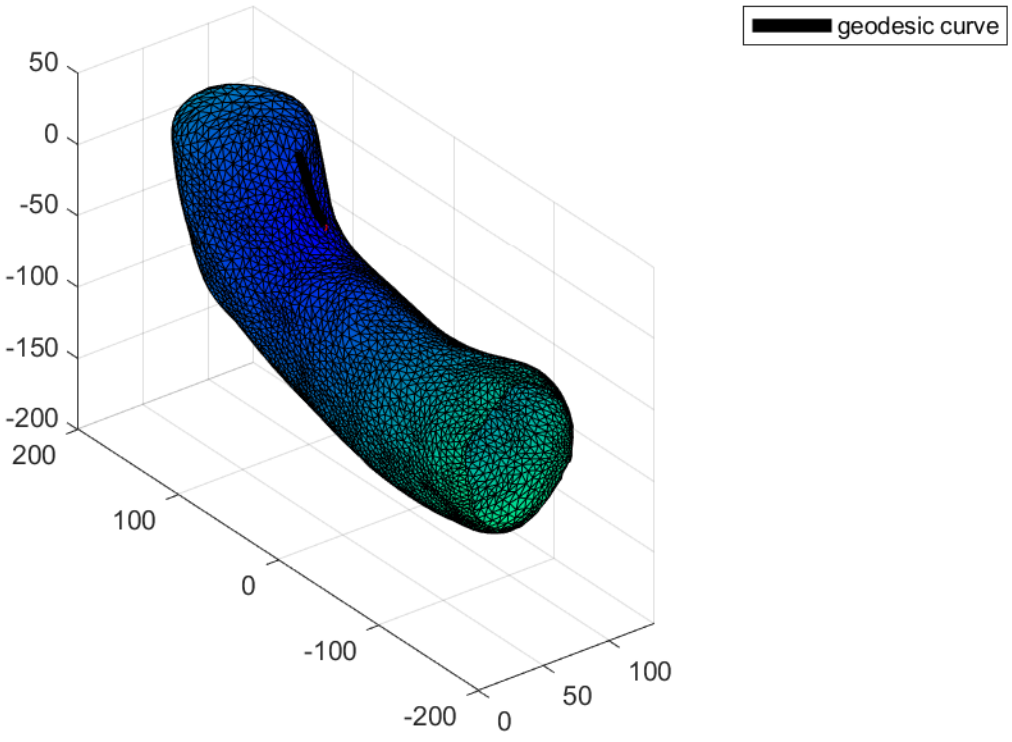
5. Specialized SSM for 25% Cut





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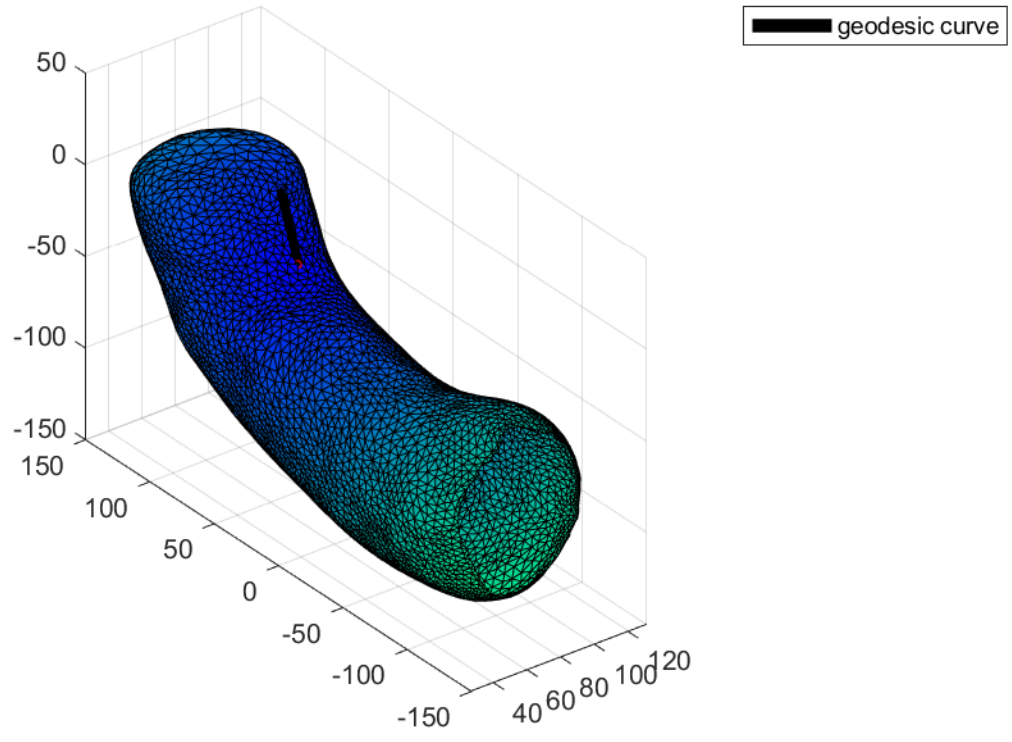
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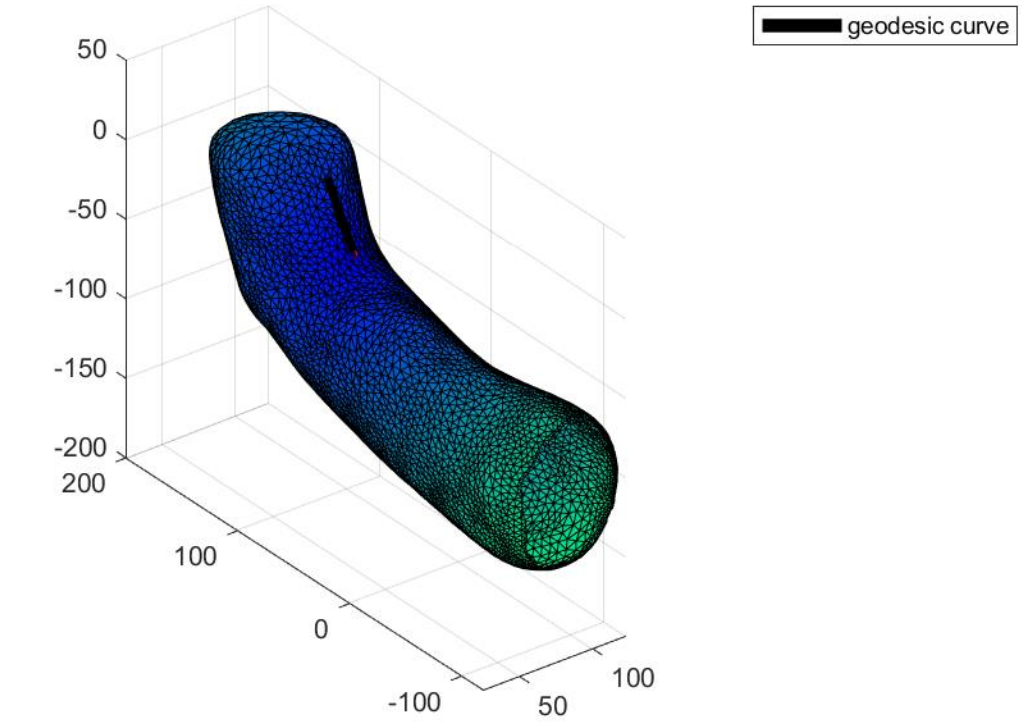
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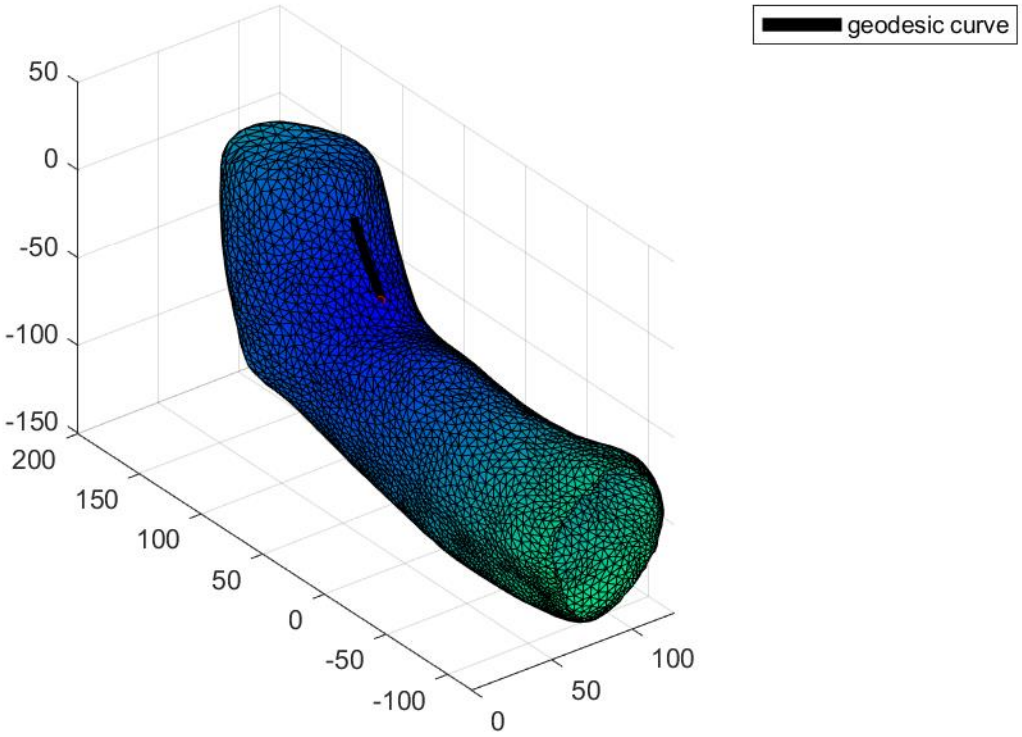
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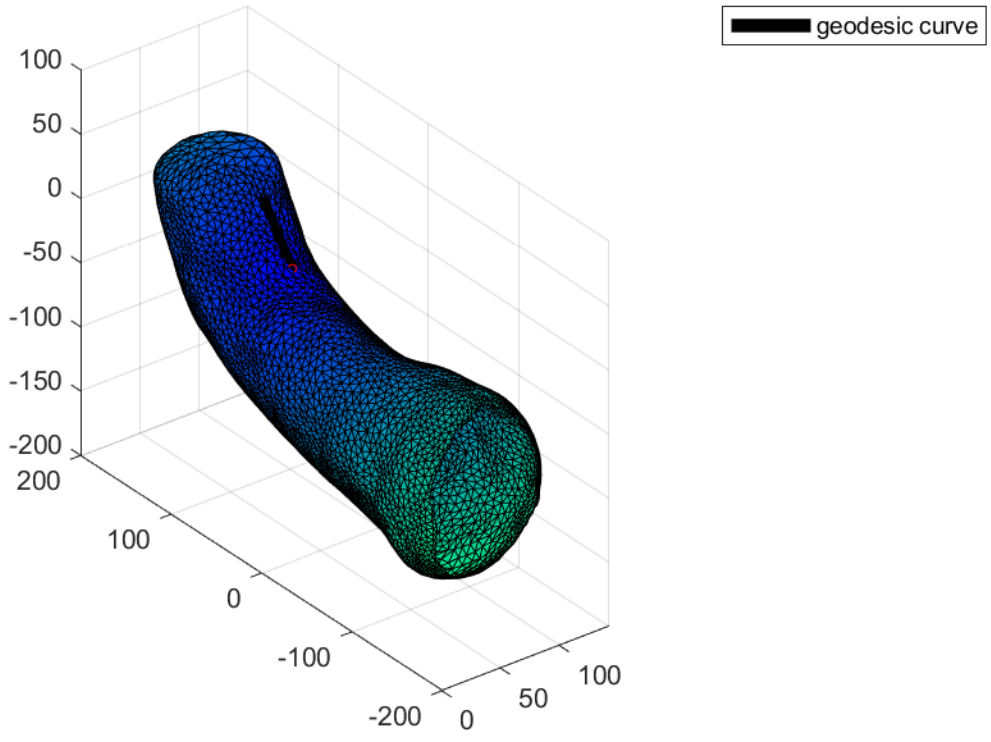
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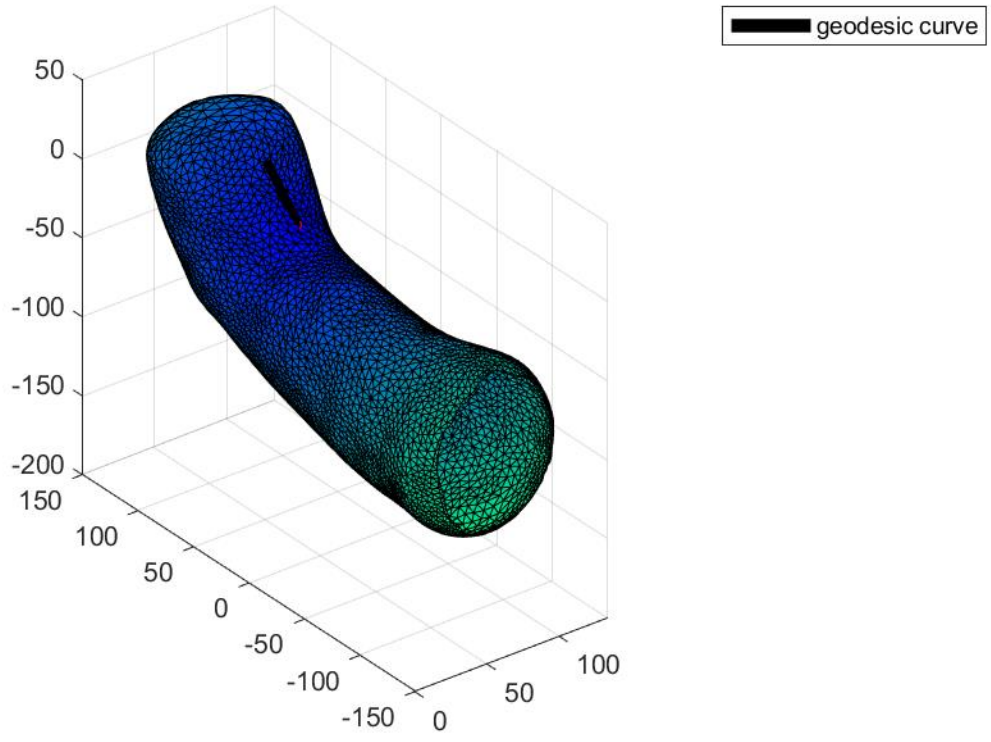
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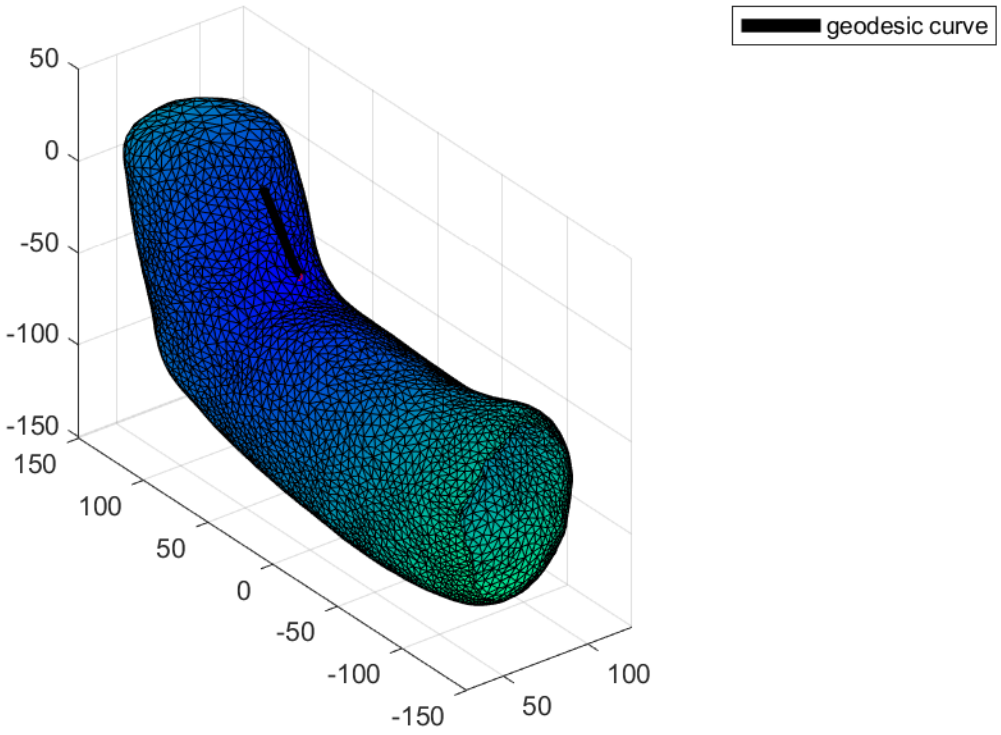
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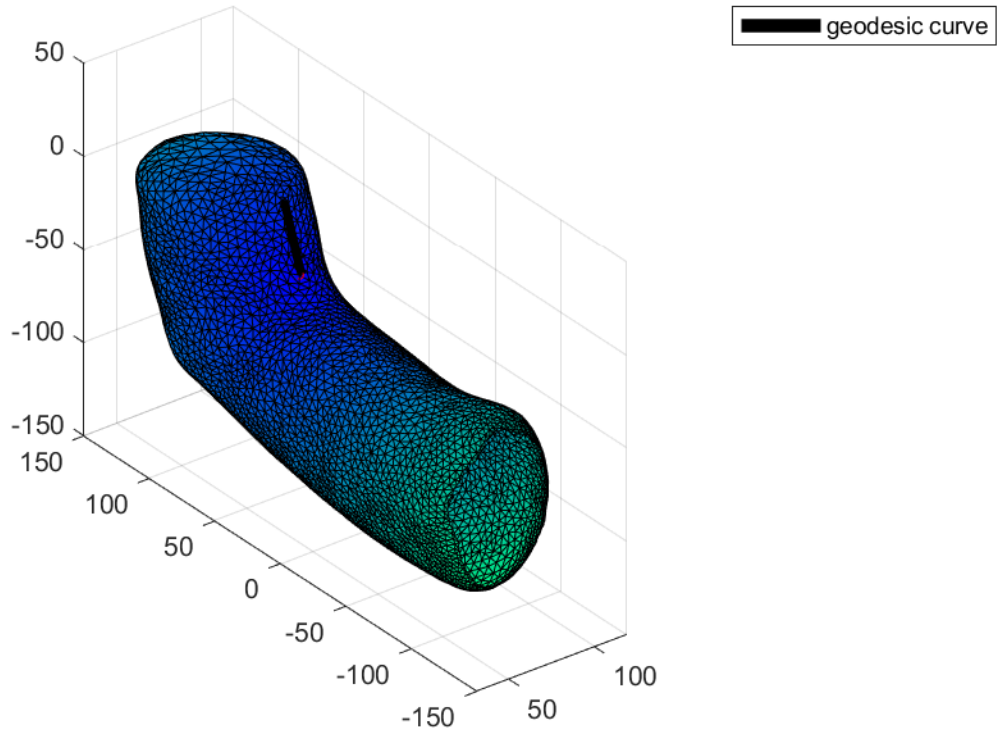
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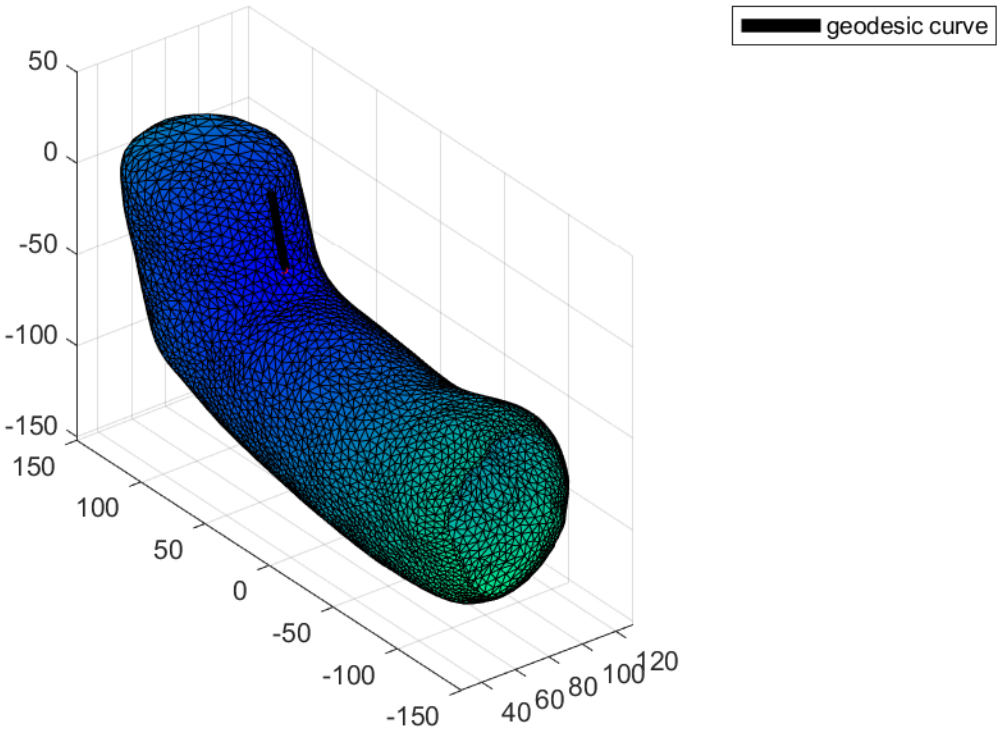
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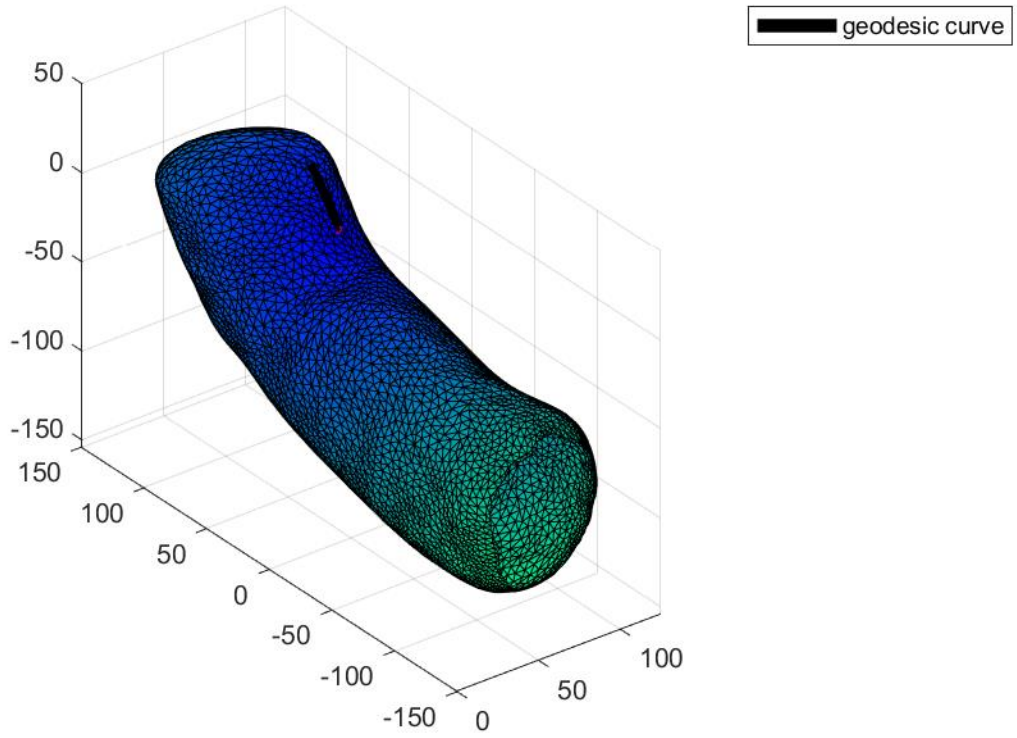
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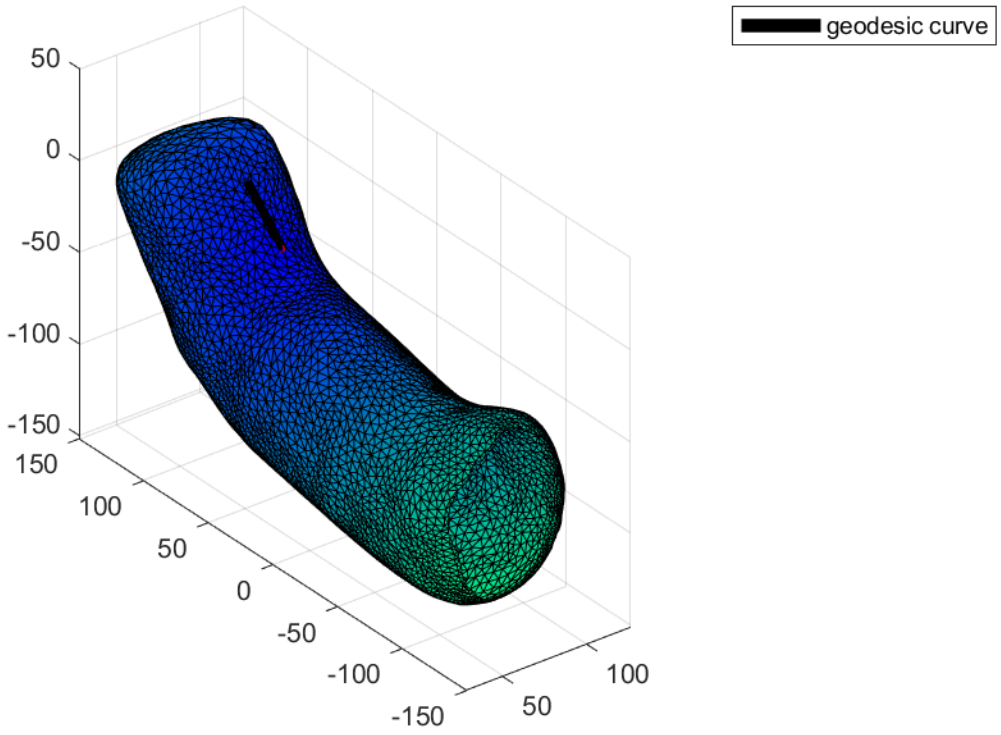
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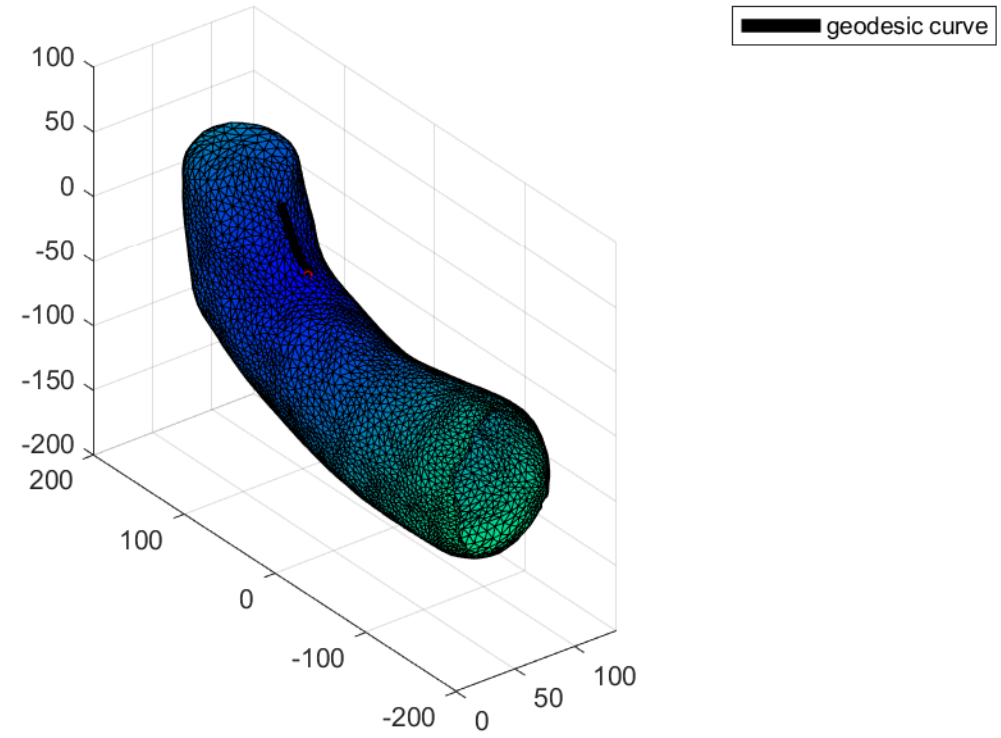
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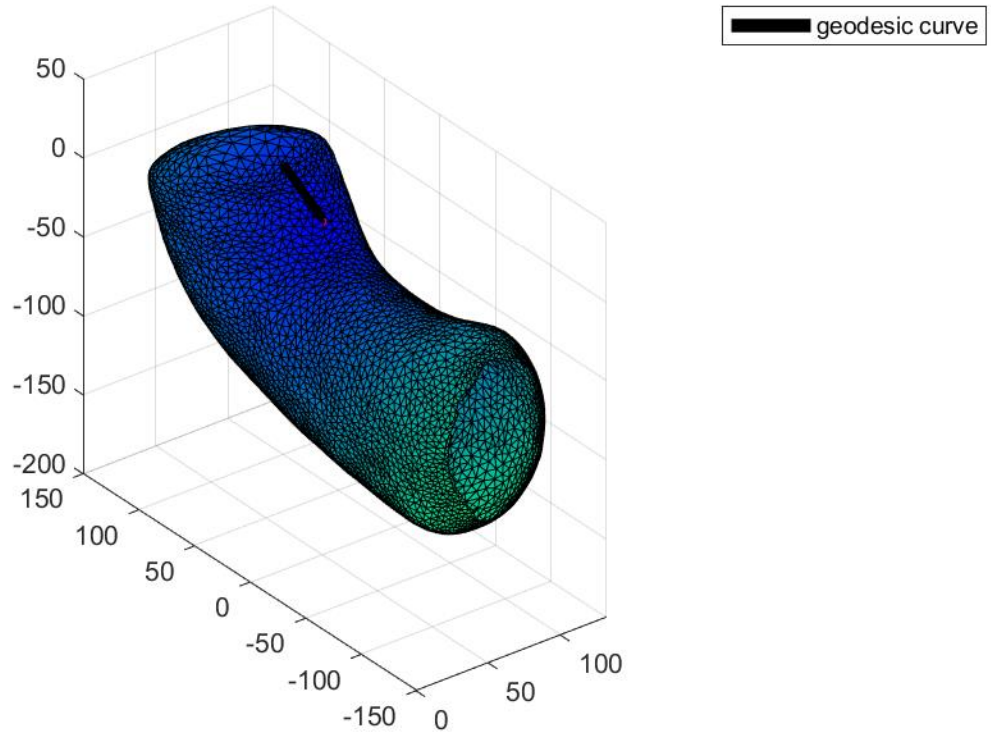
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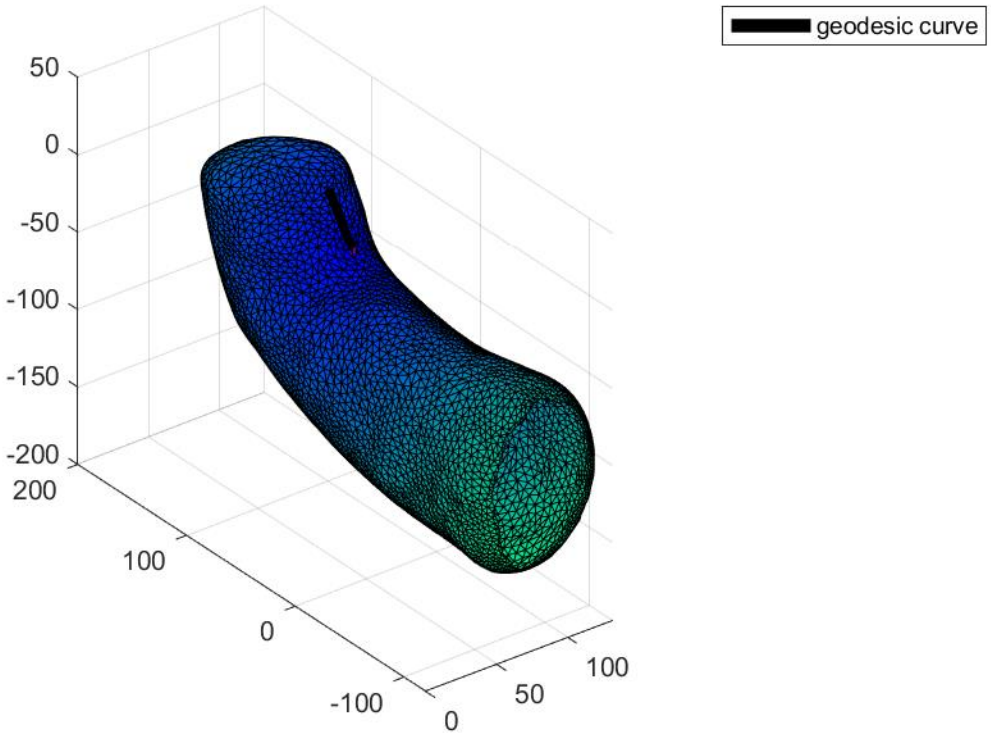
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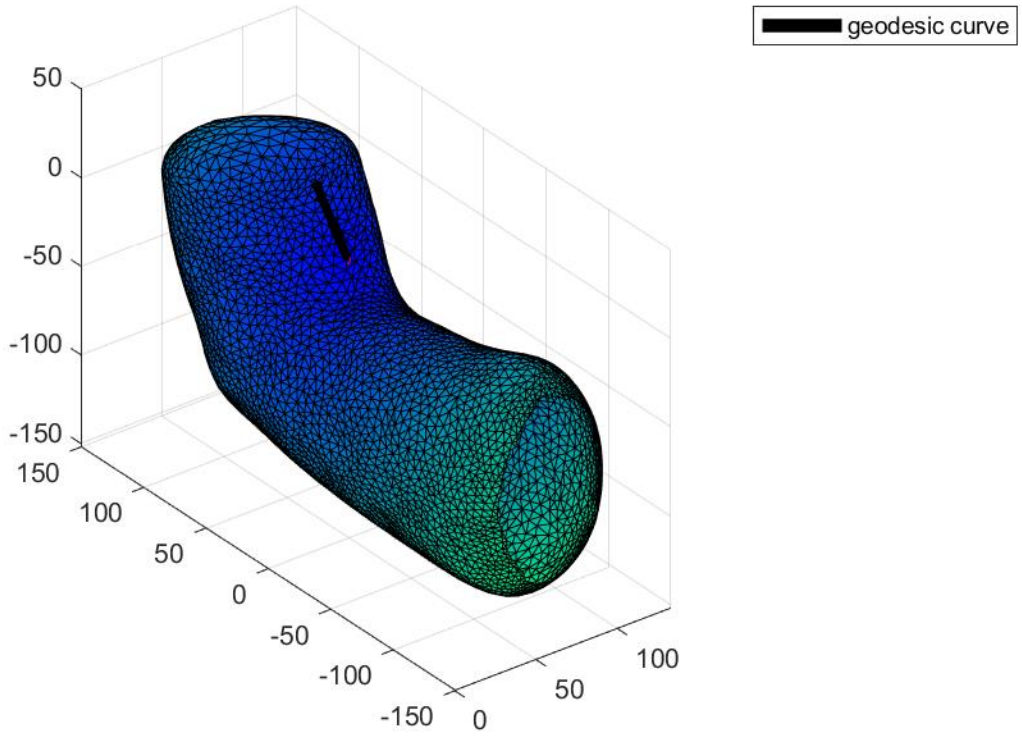
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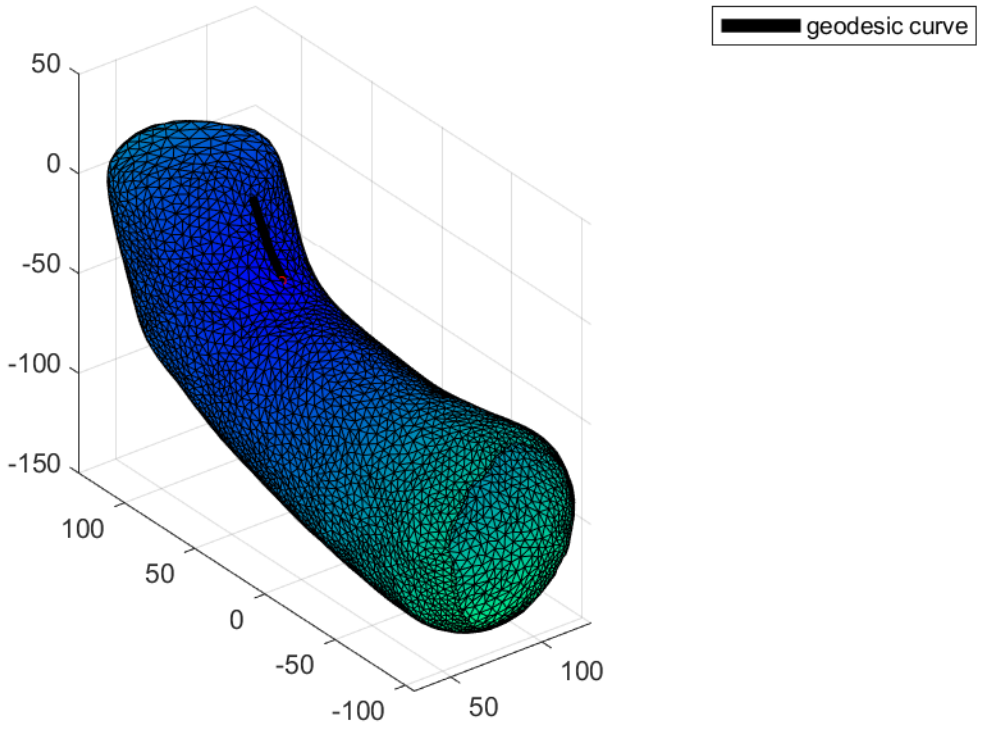
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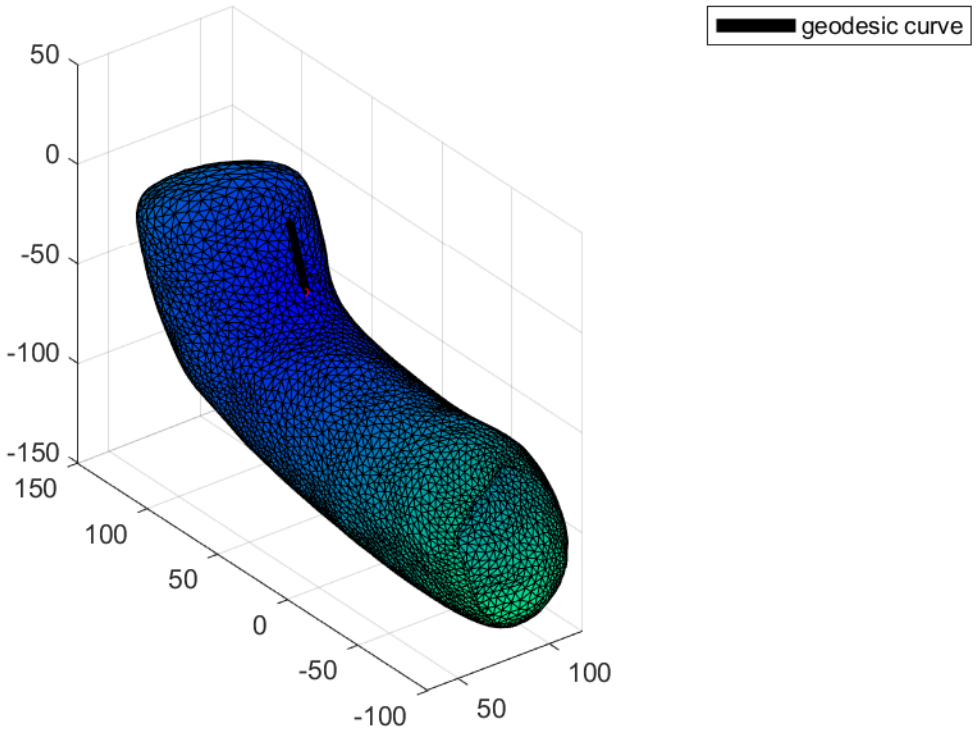
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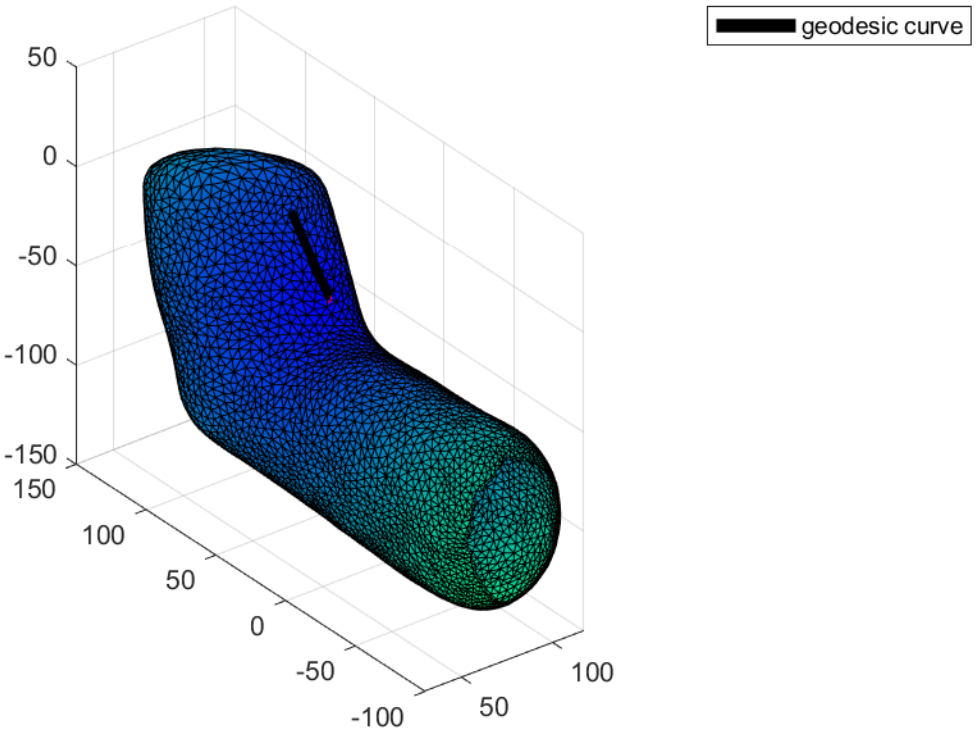
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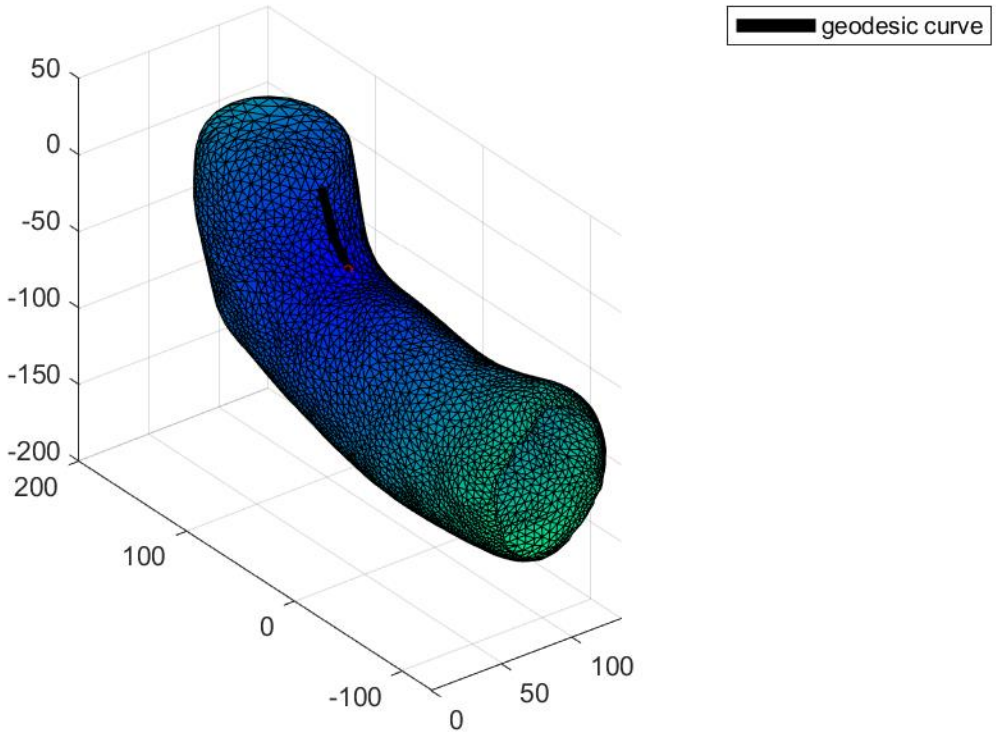
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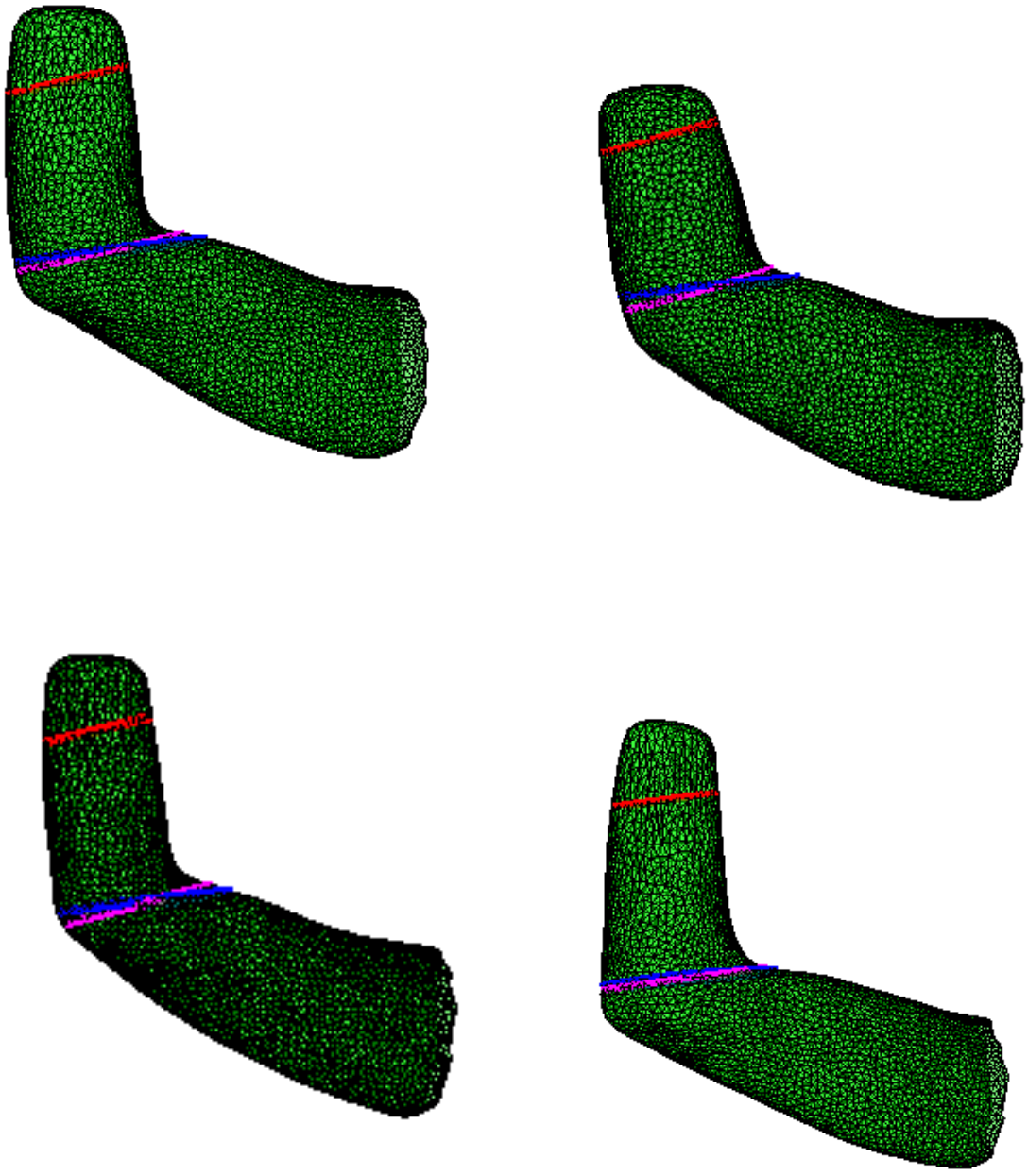
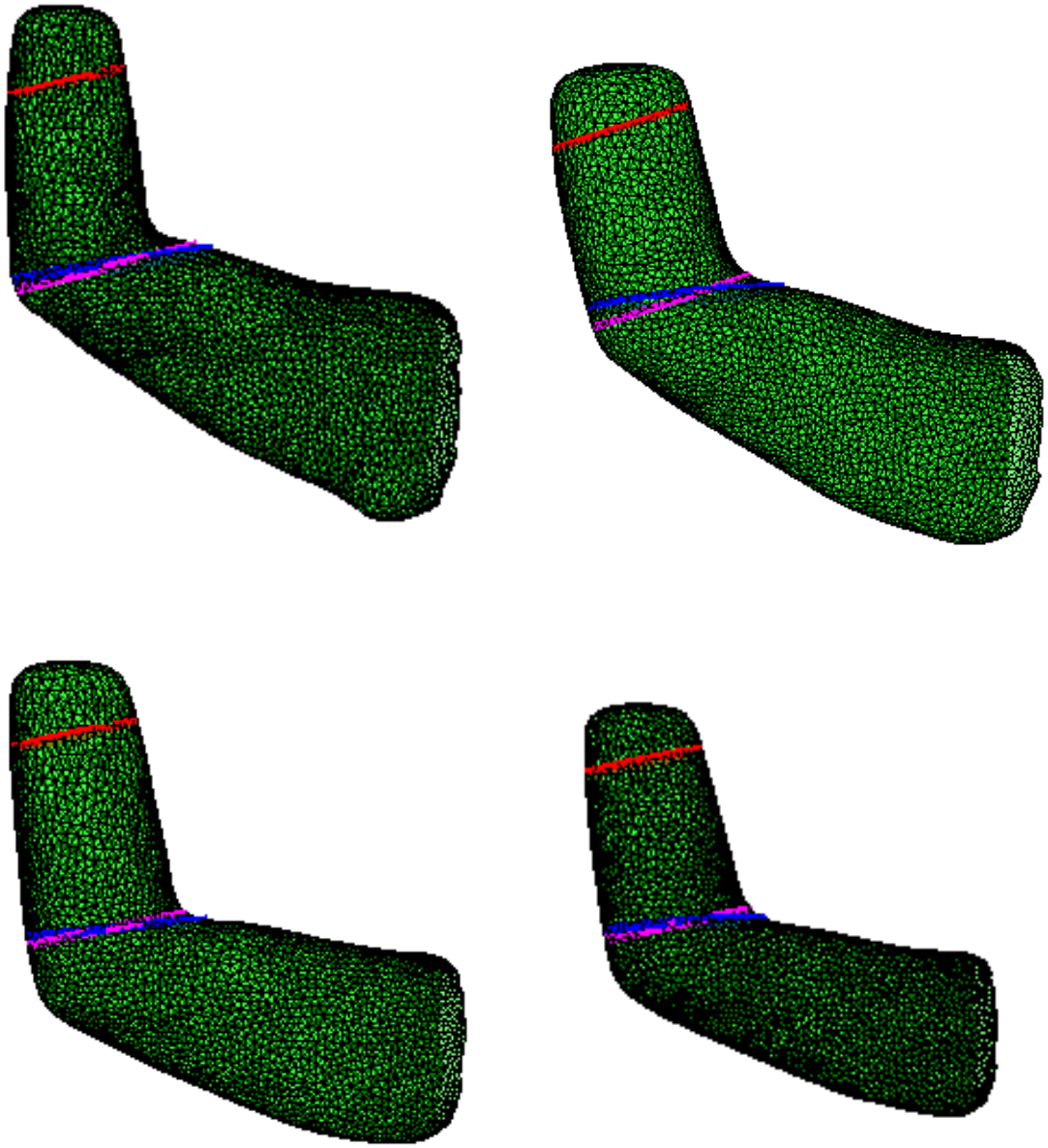
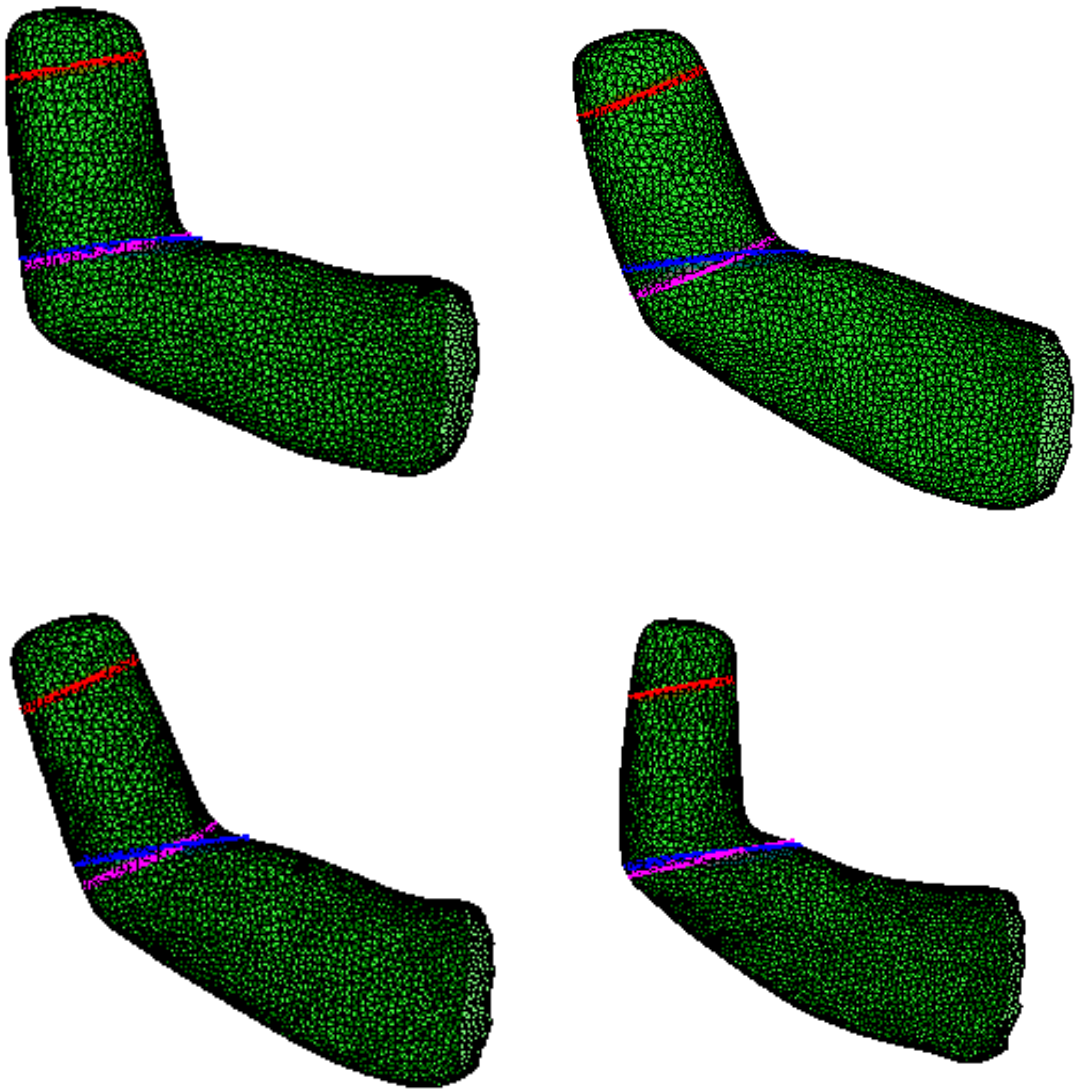
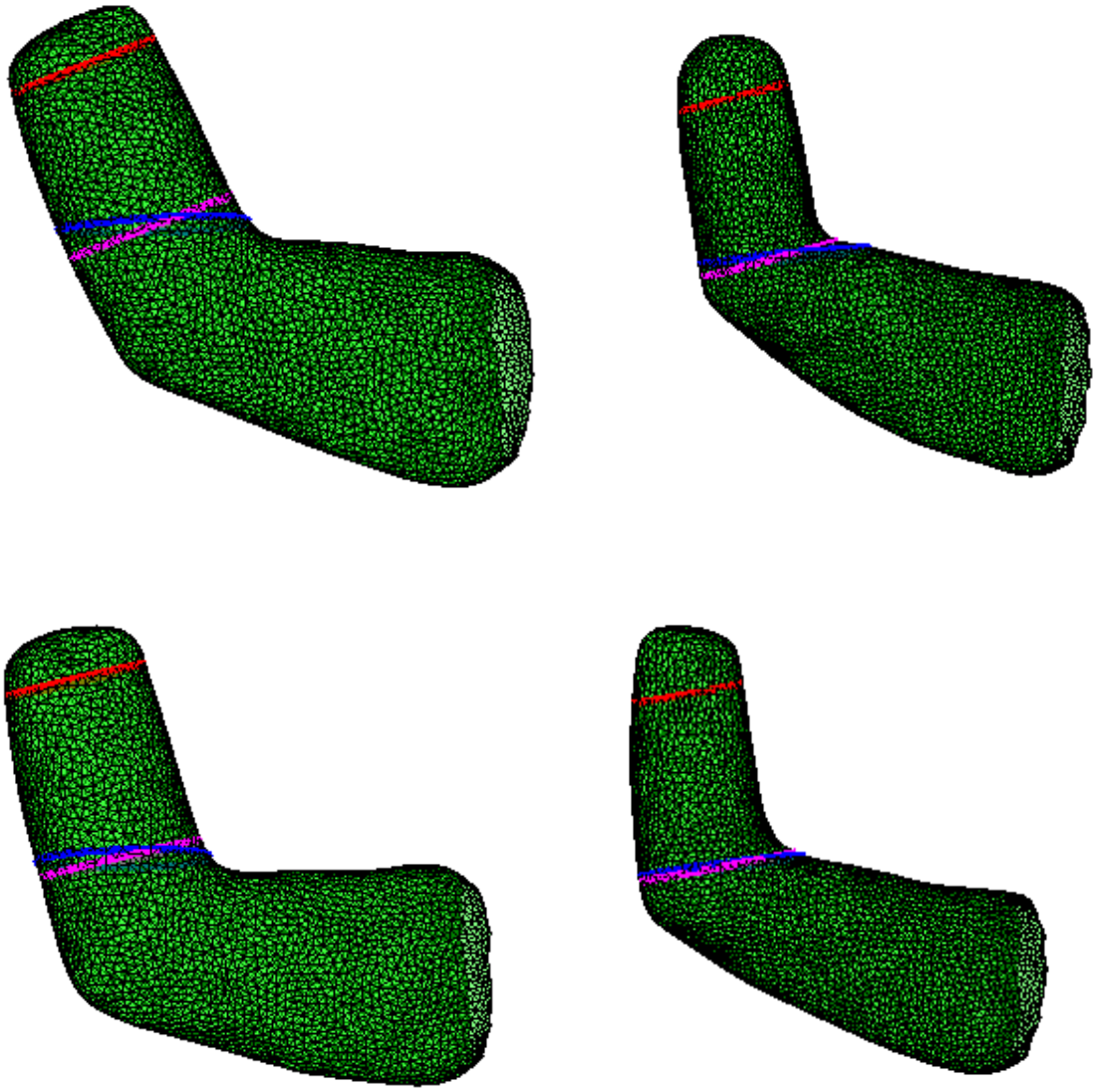
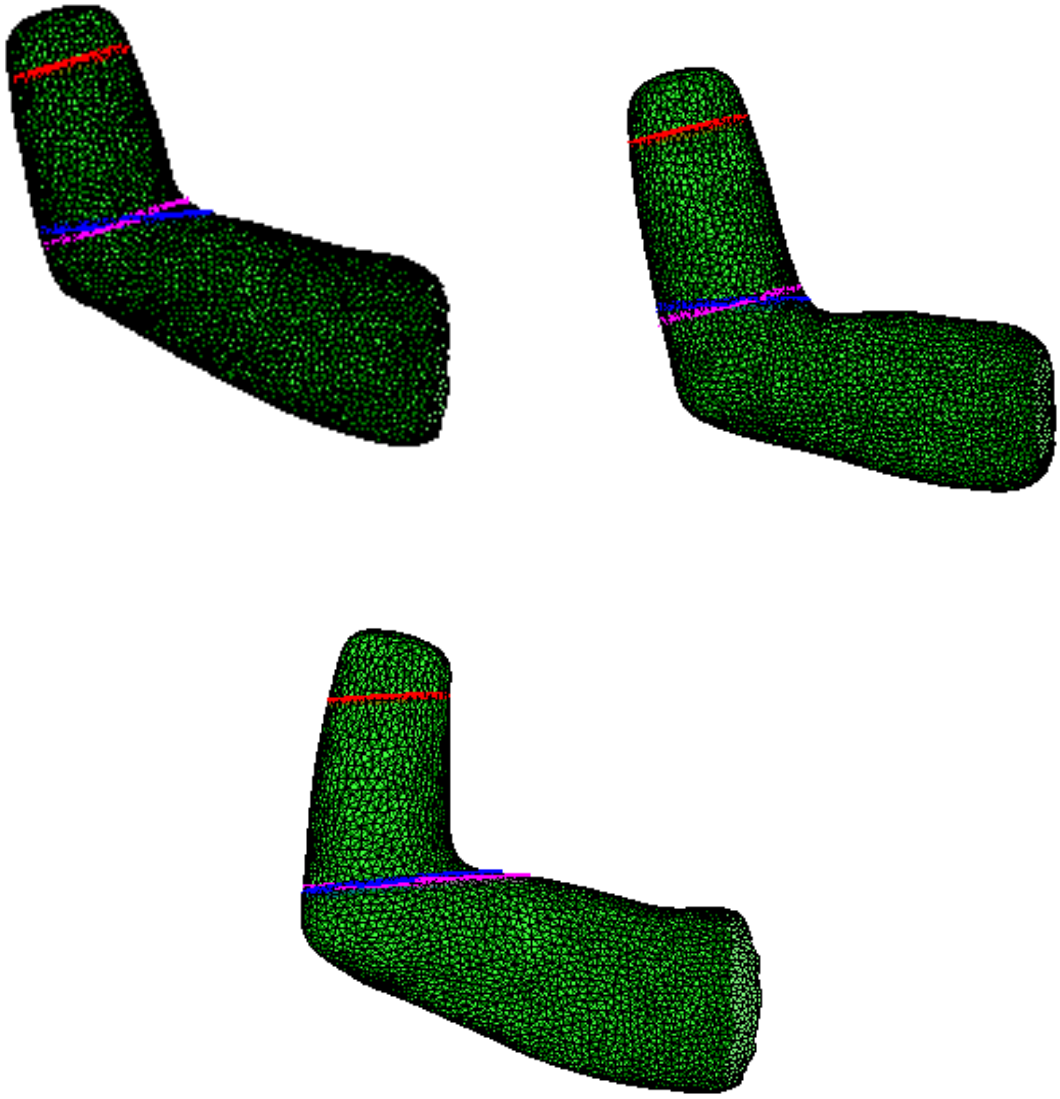
6. Specialized SSM for 50% Cut

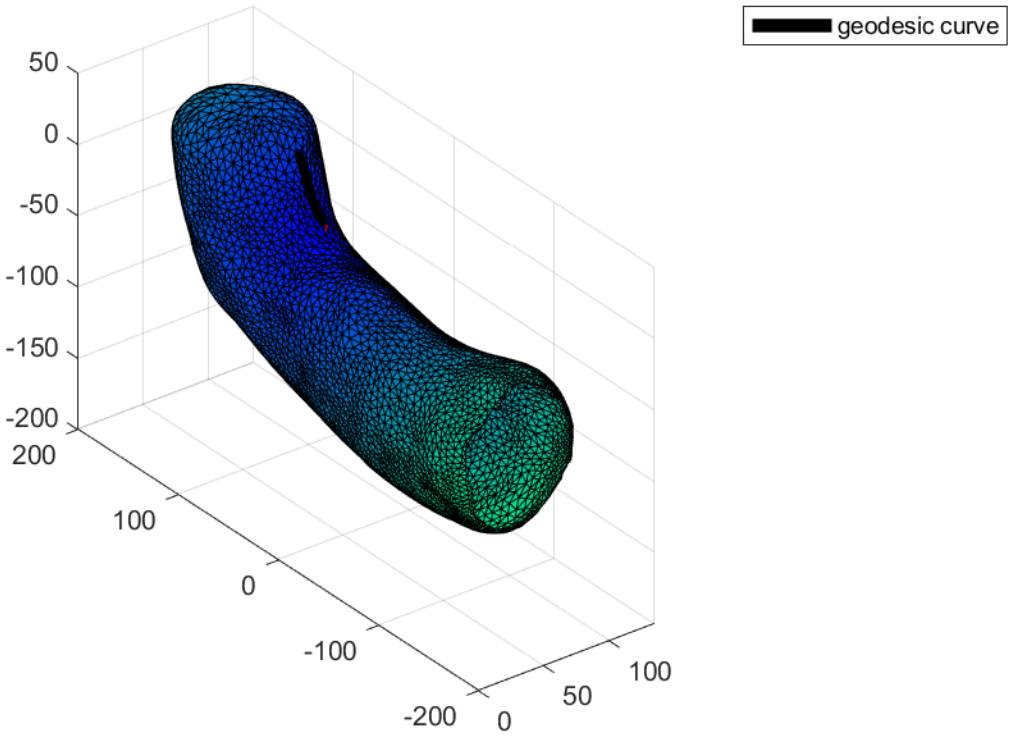








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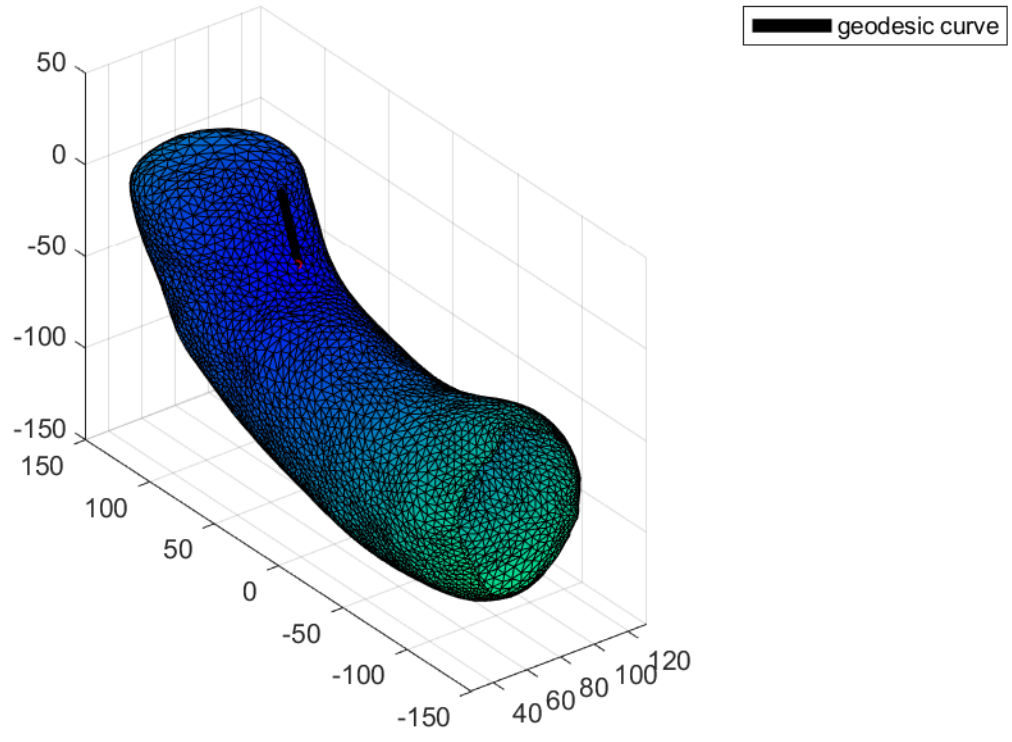
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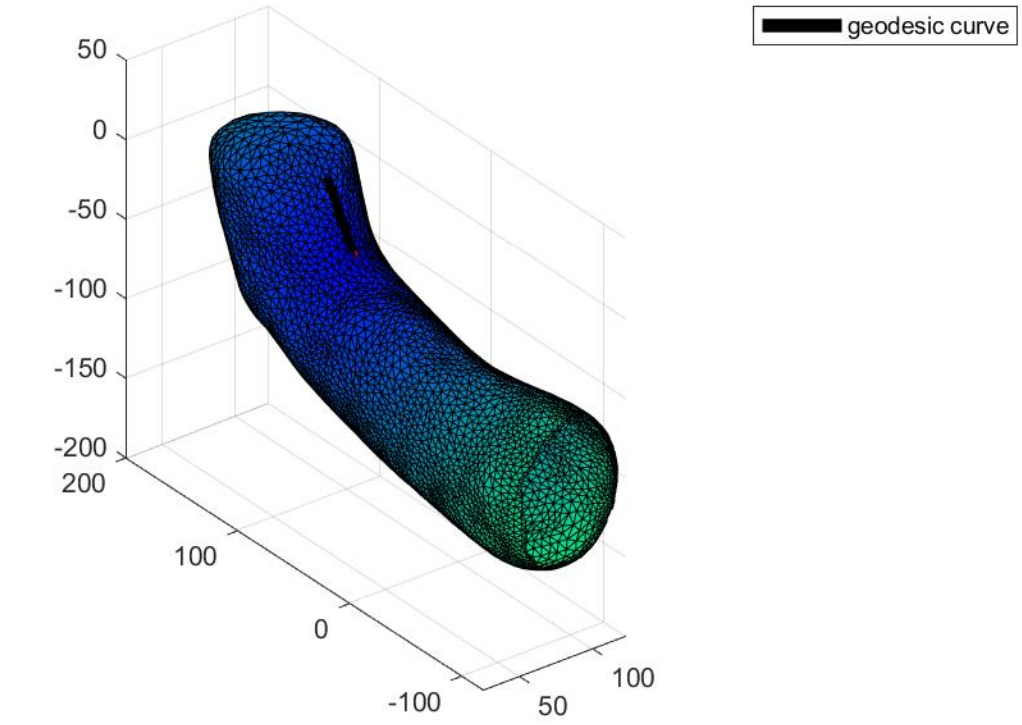
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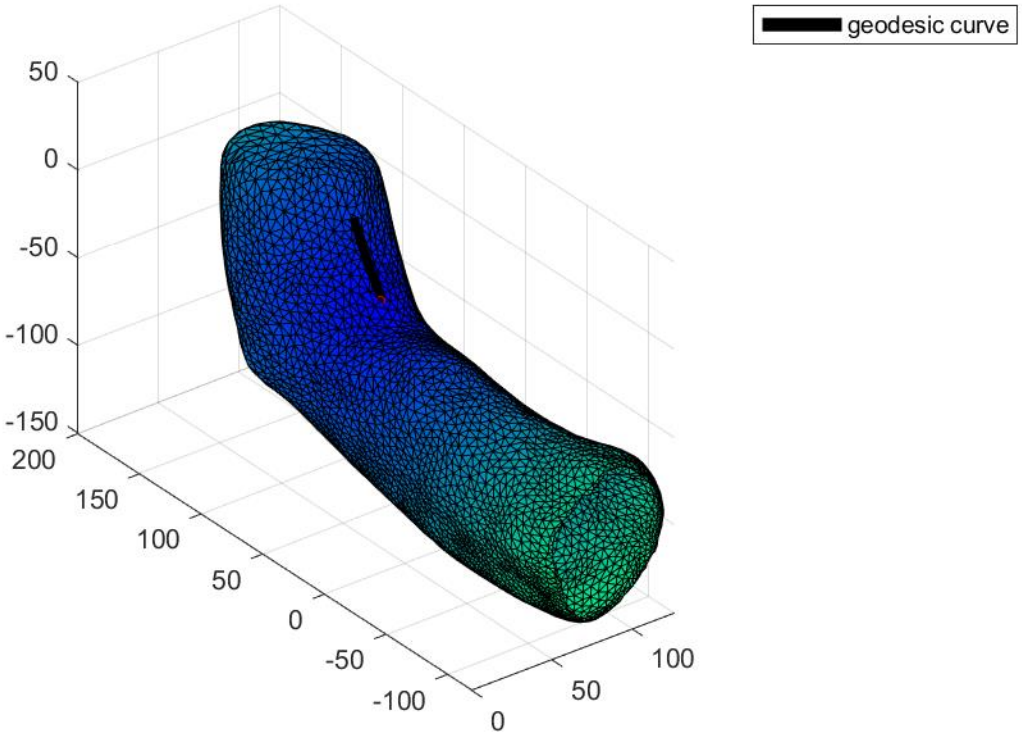
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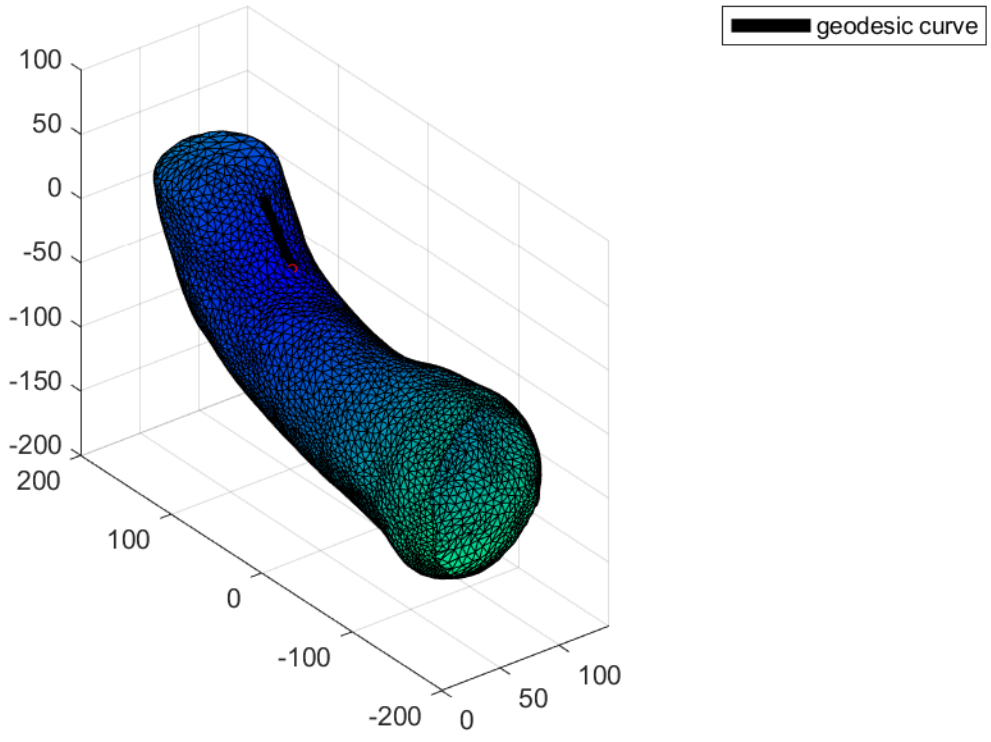
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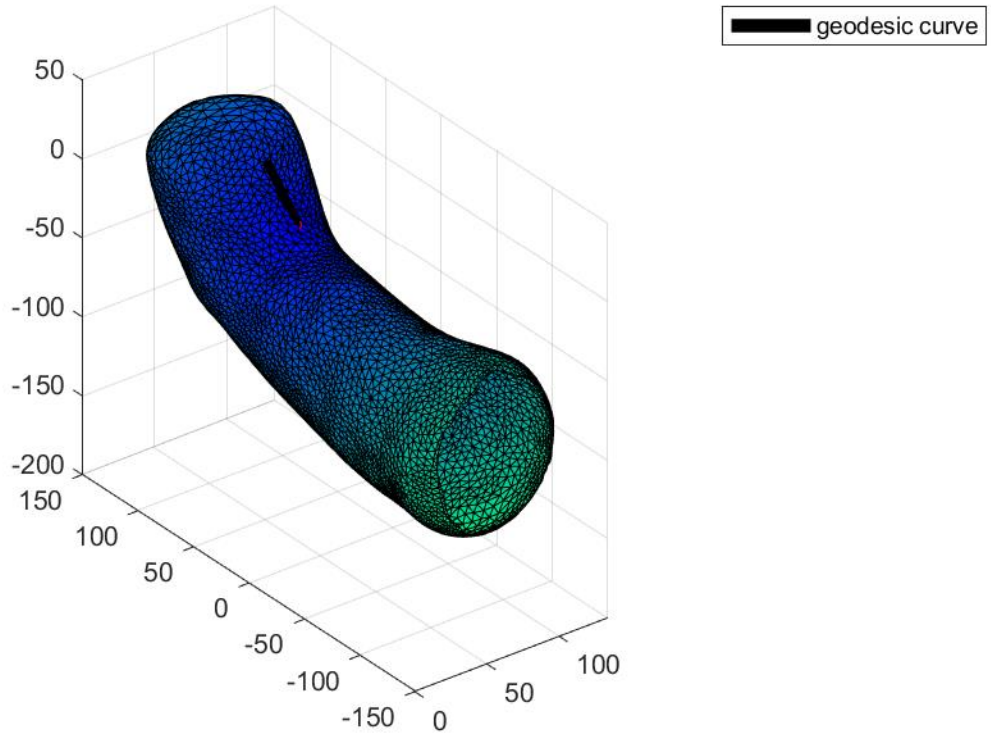
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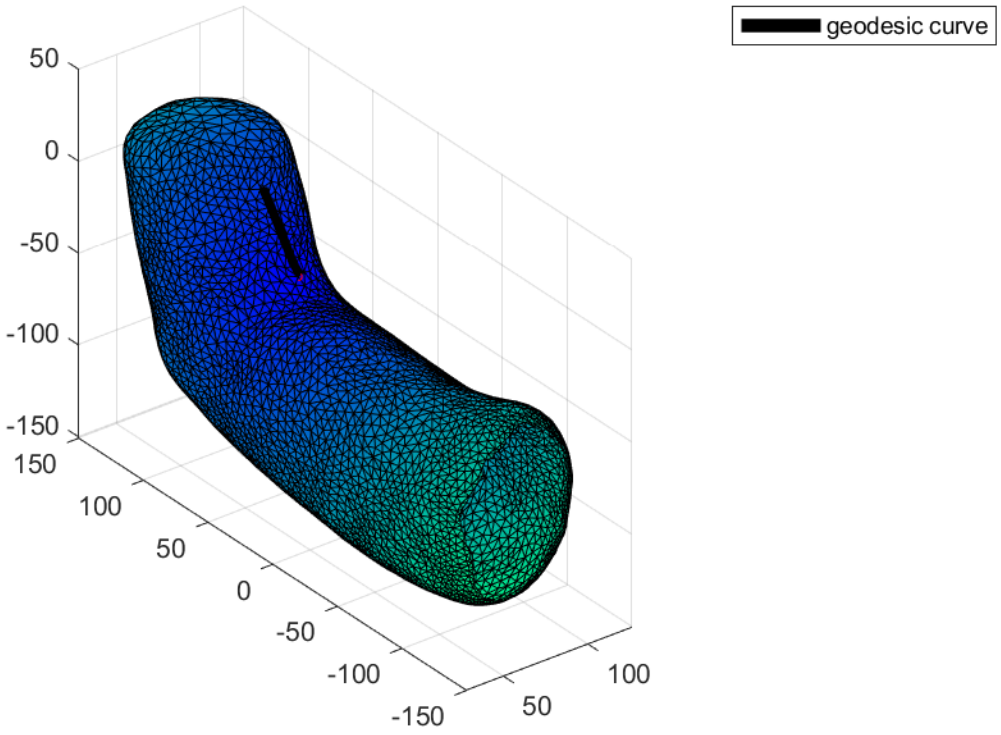
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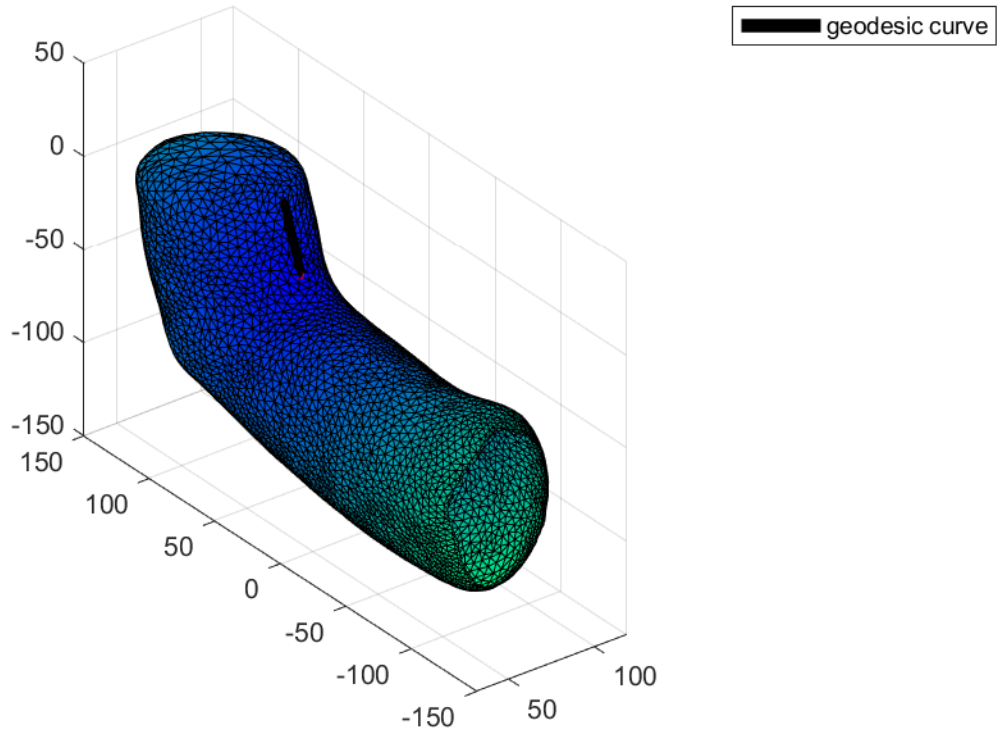
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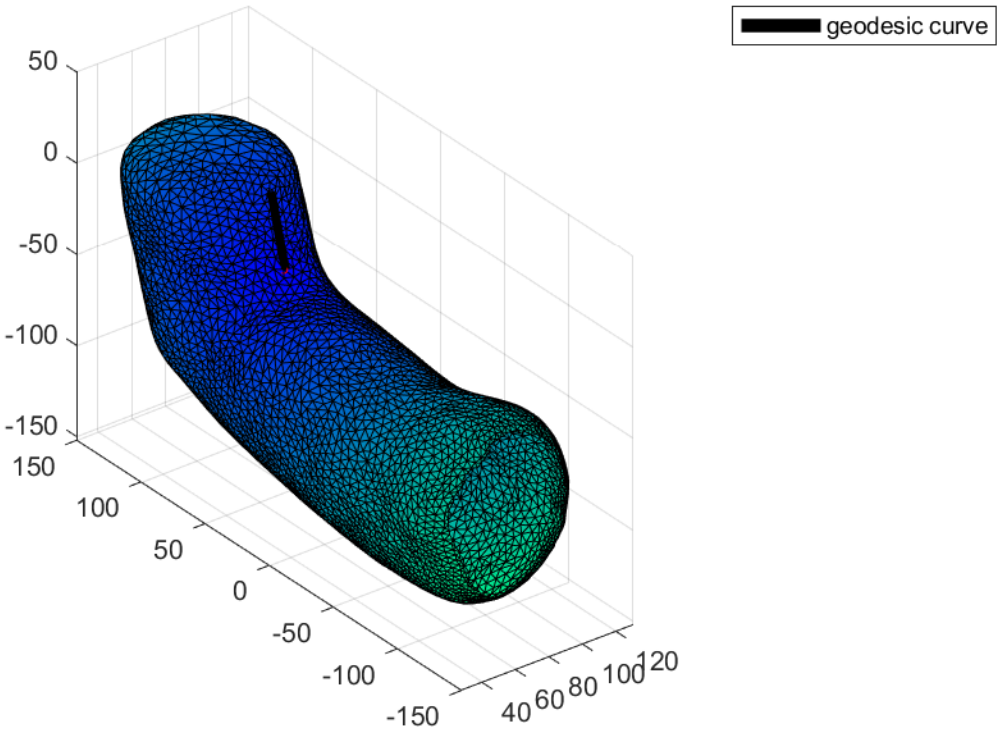
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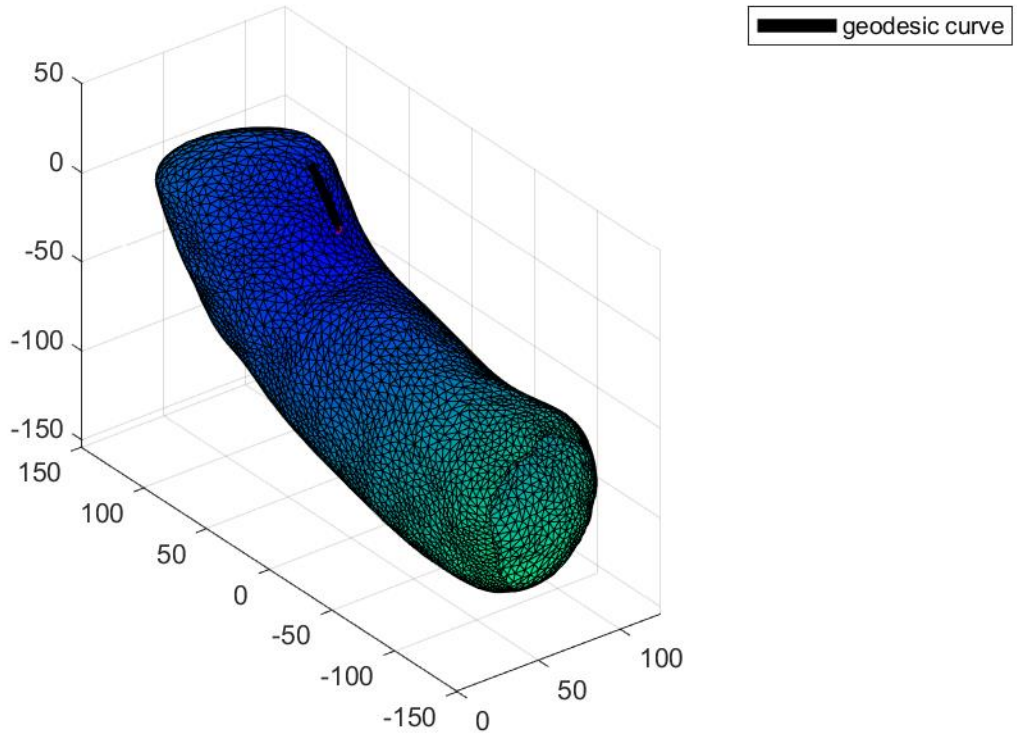
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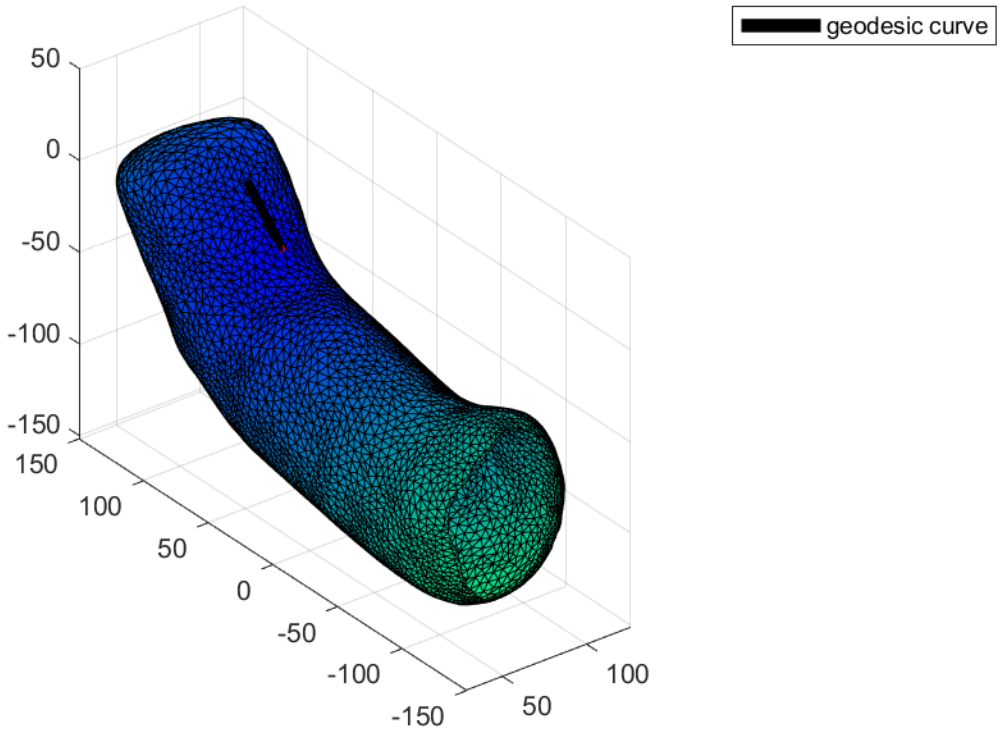
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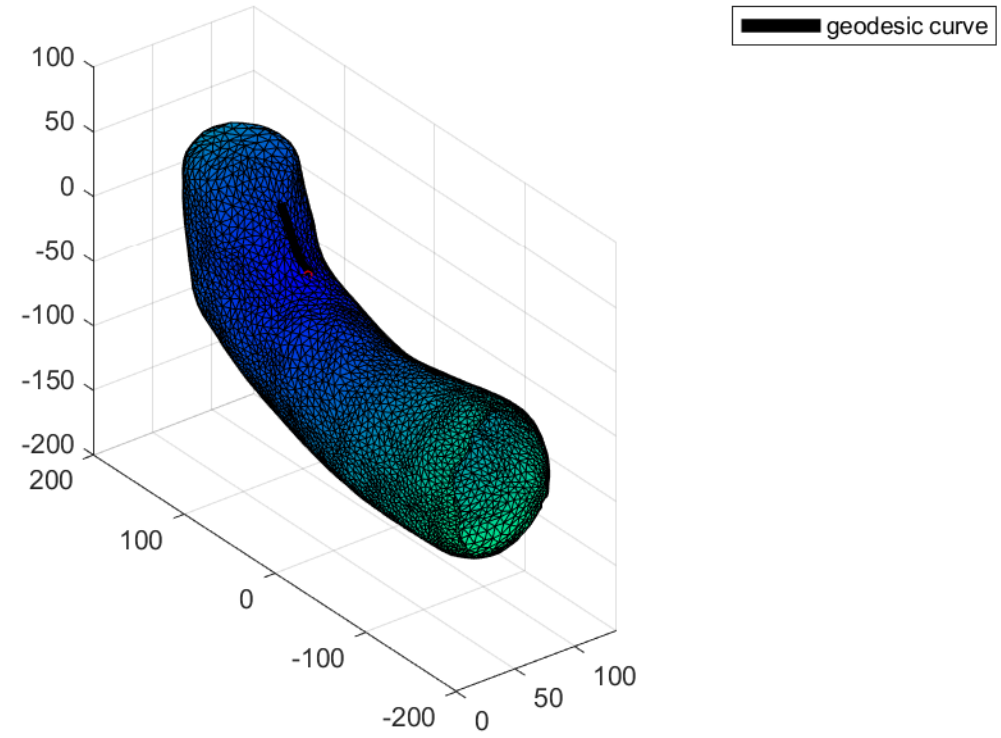
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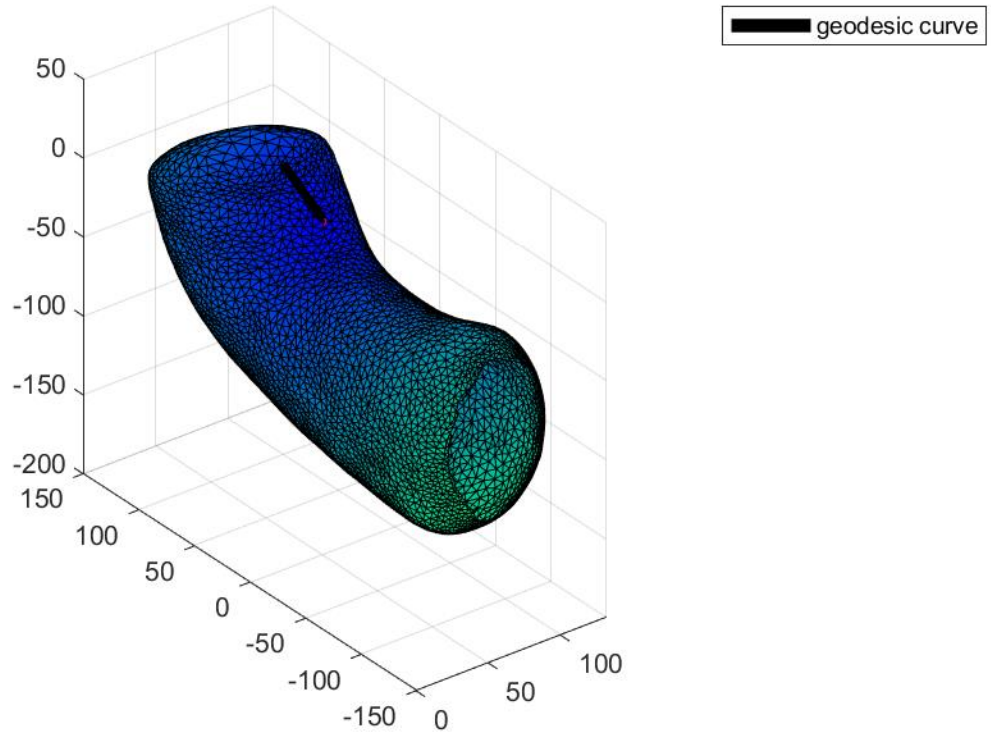
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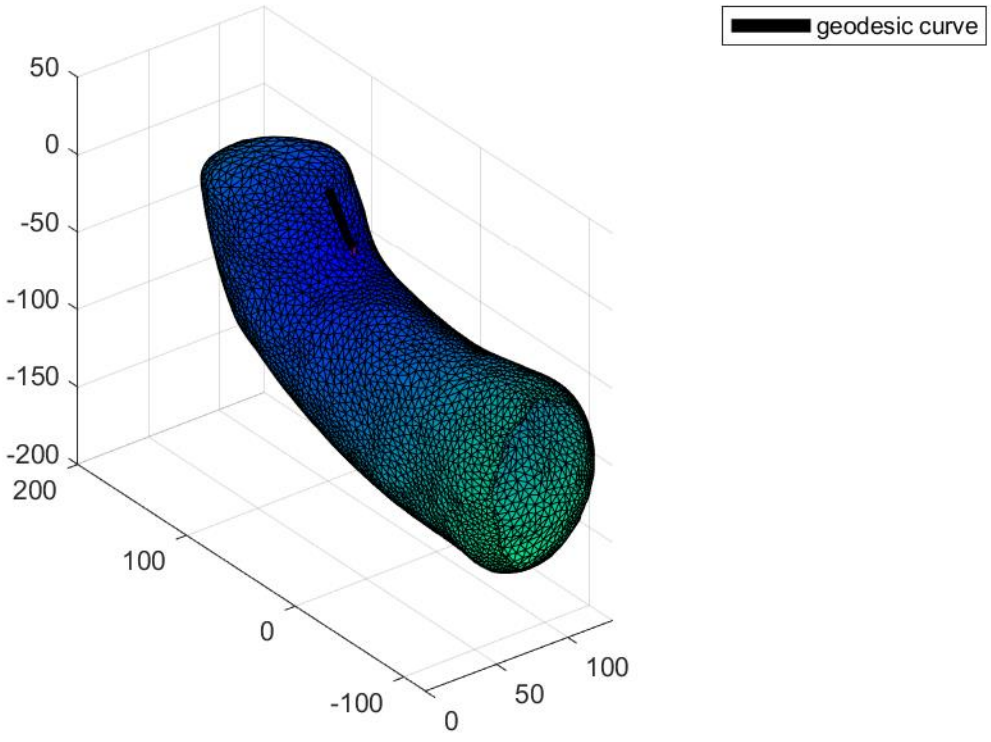
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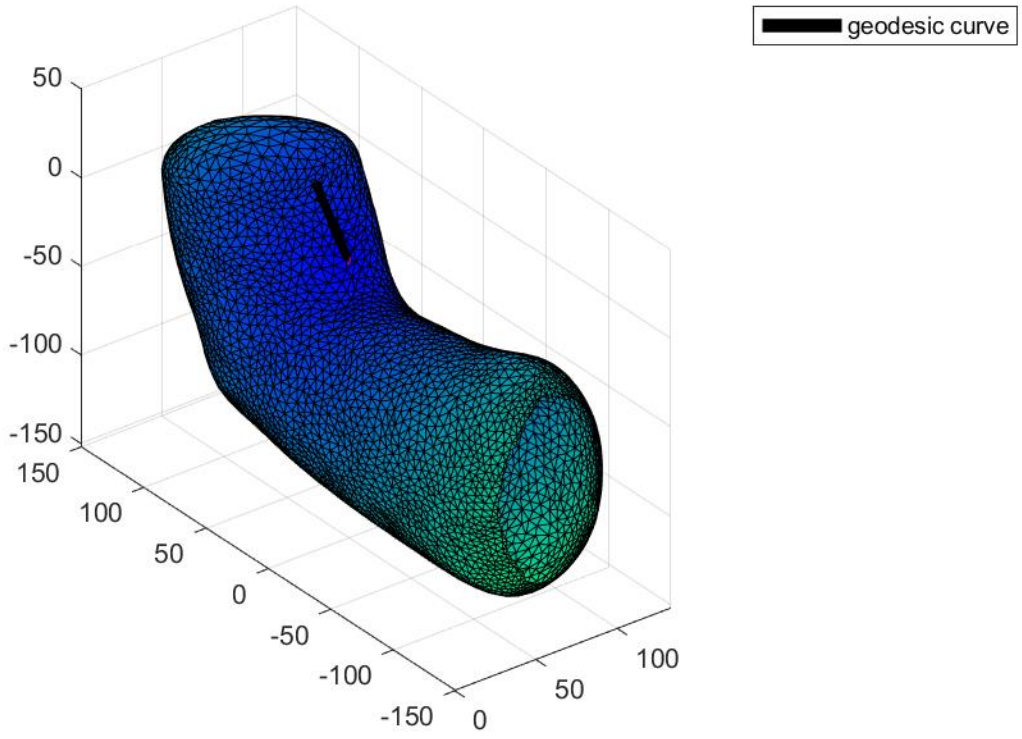
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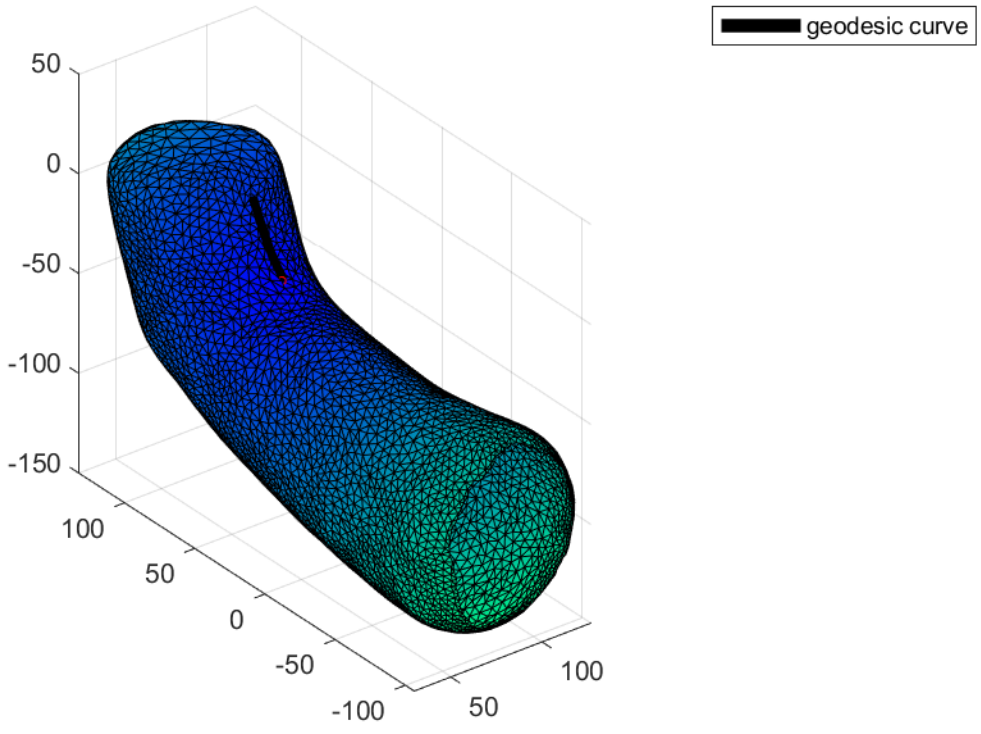
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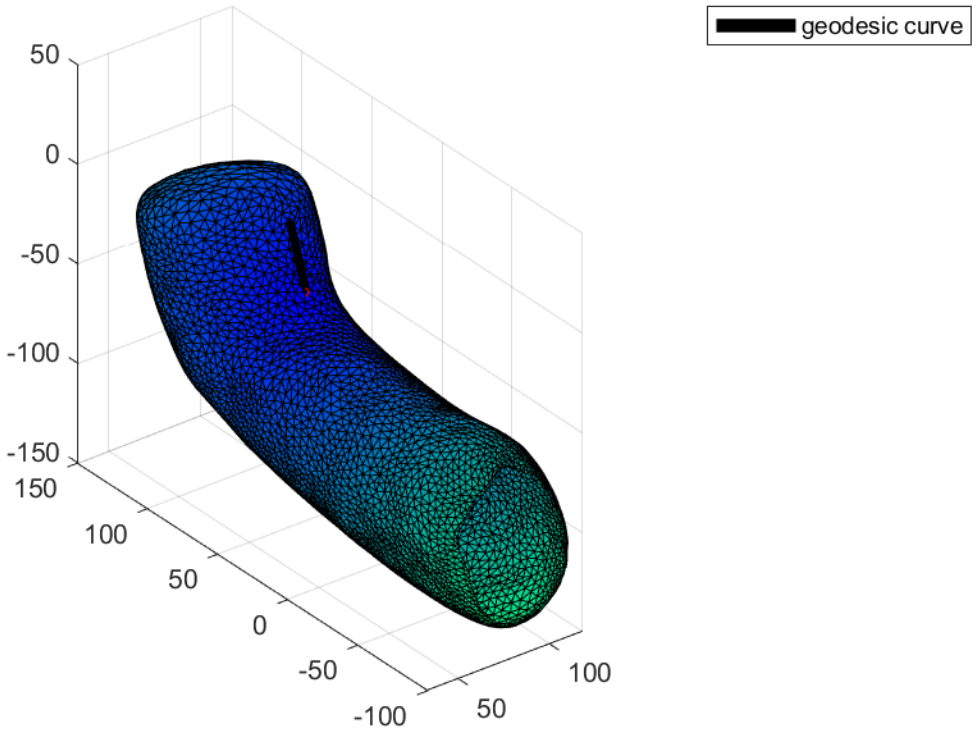
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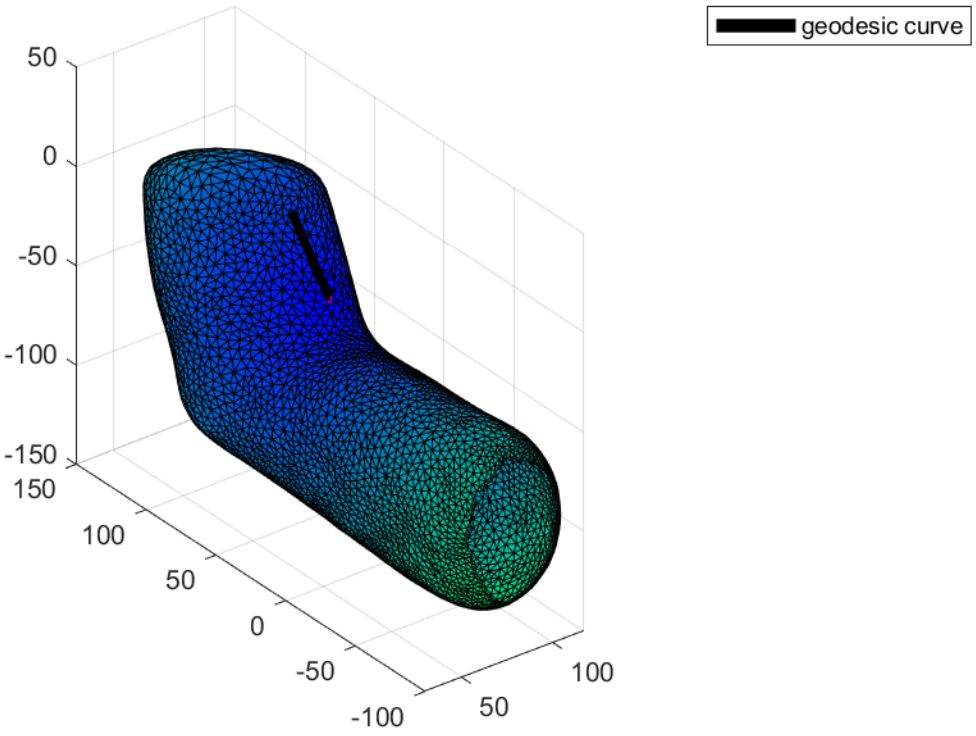
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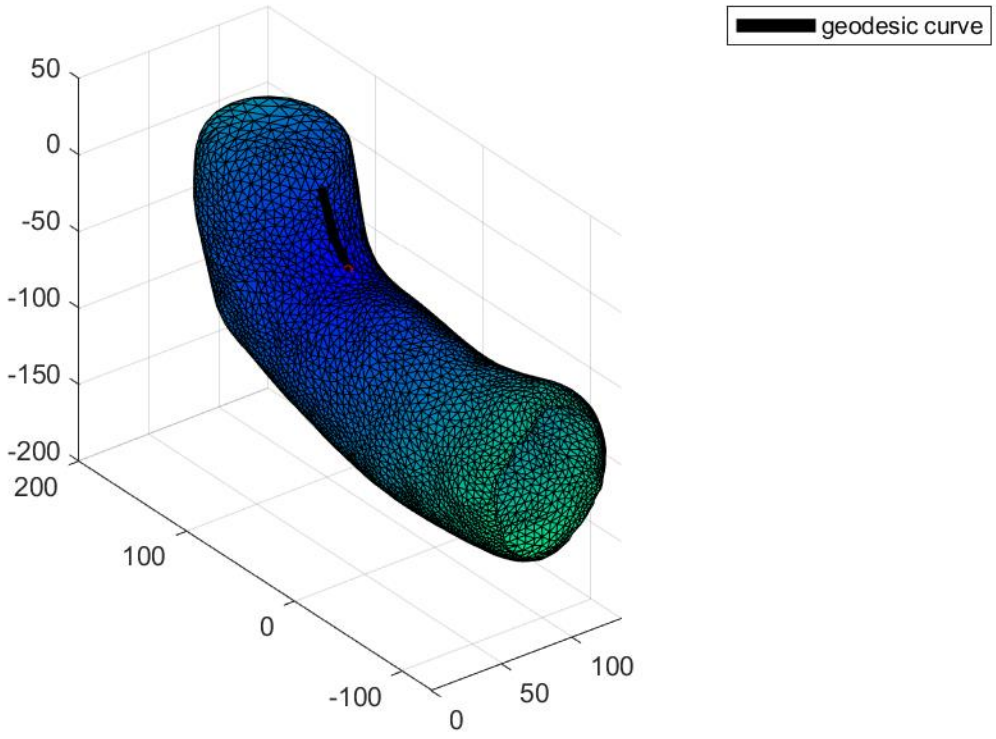
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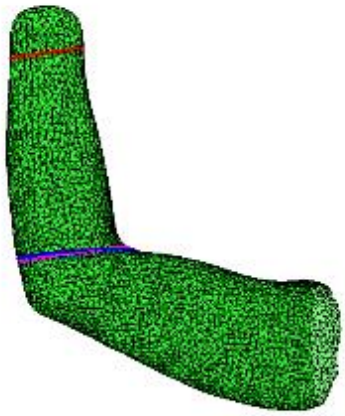
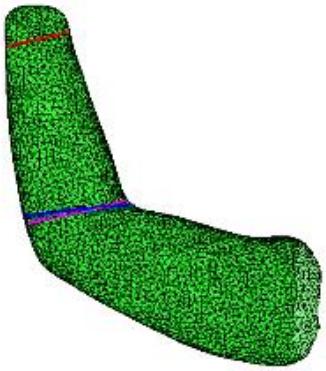
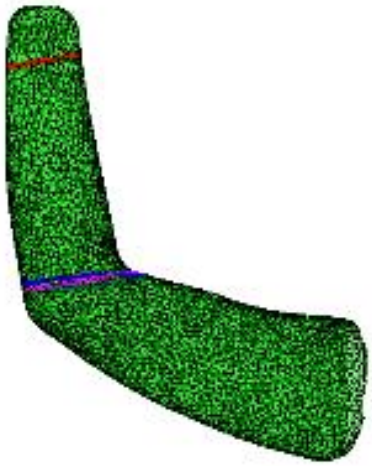
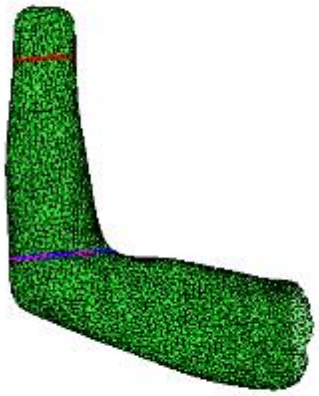
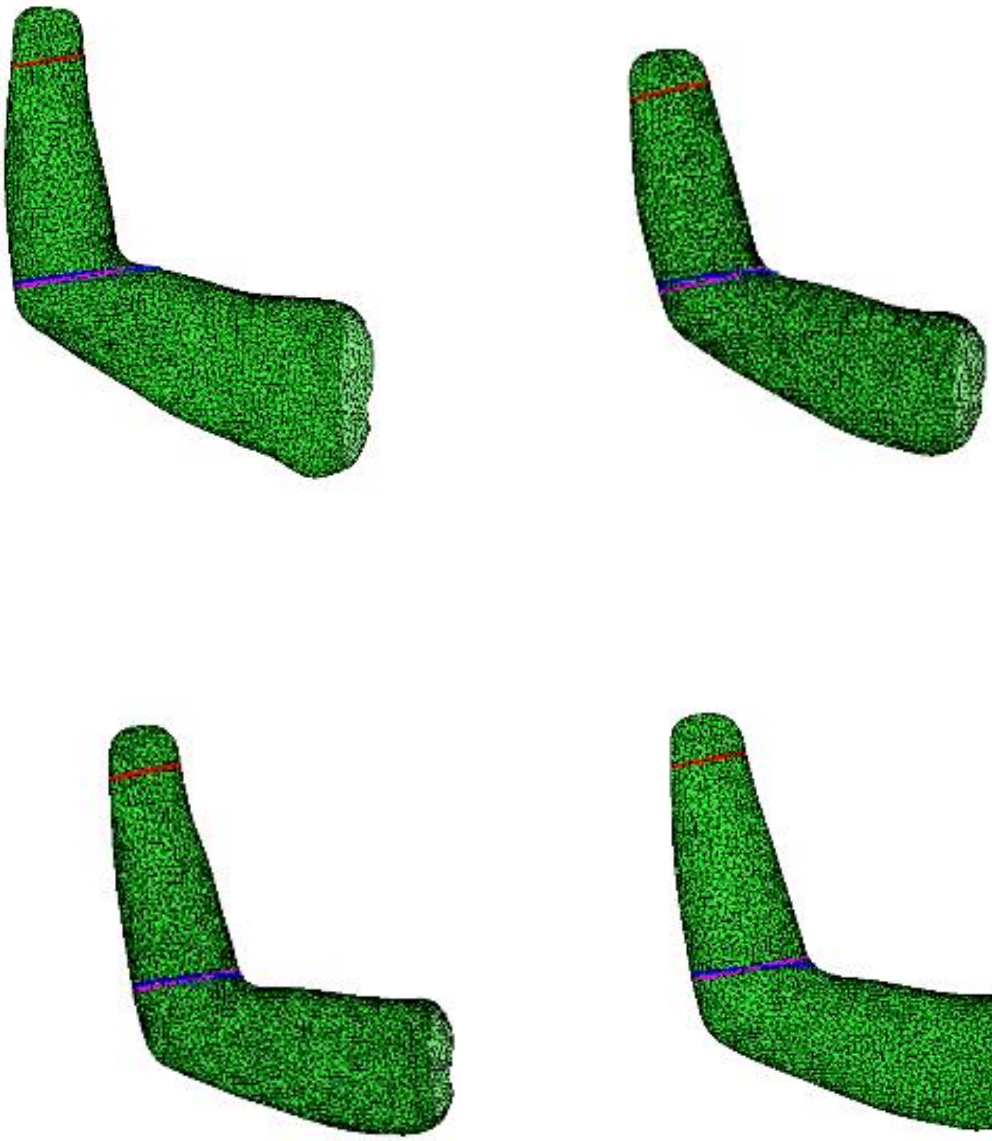
7. Specialized SSM for 75% Cut

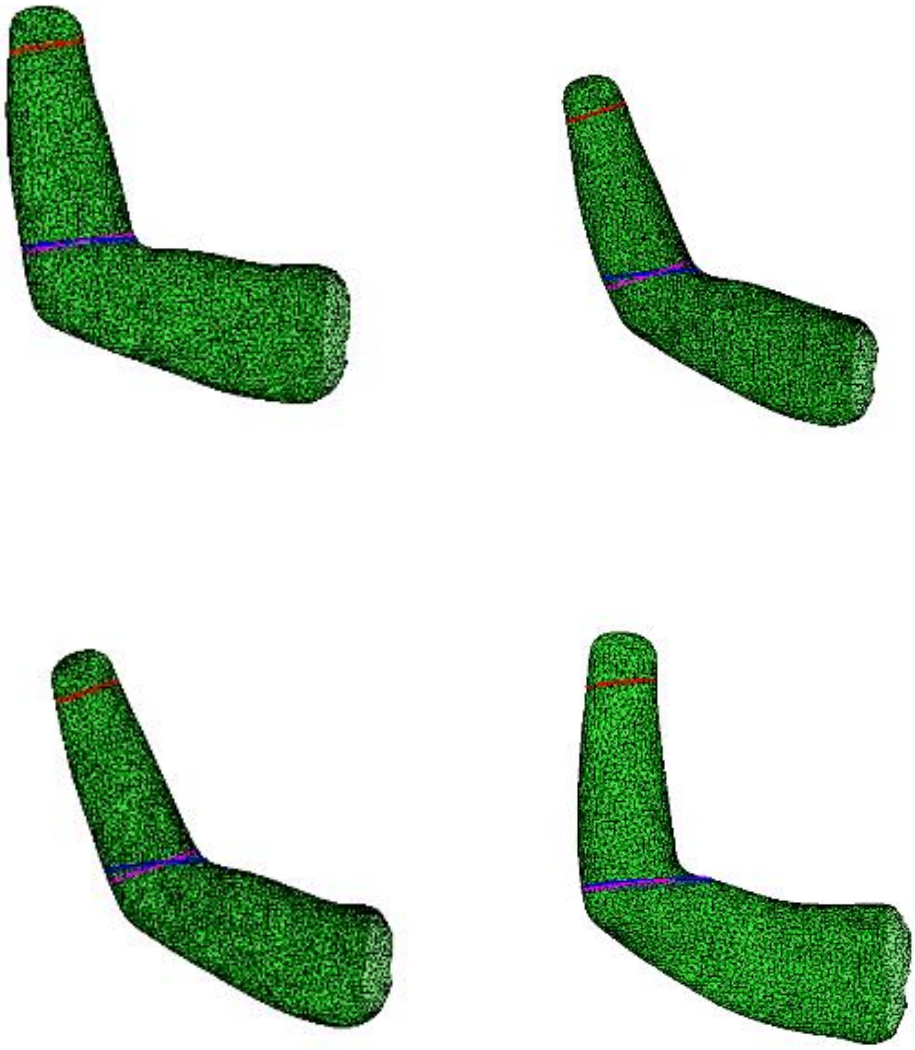


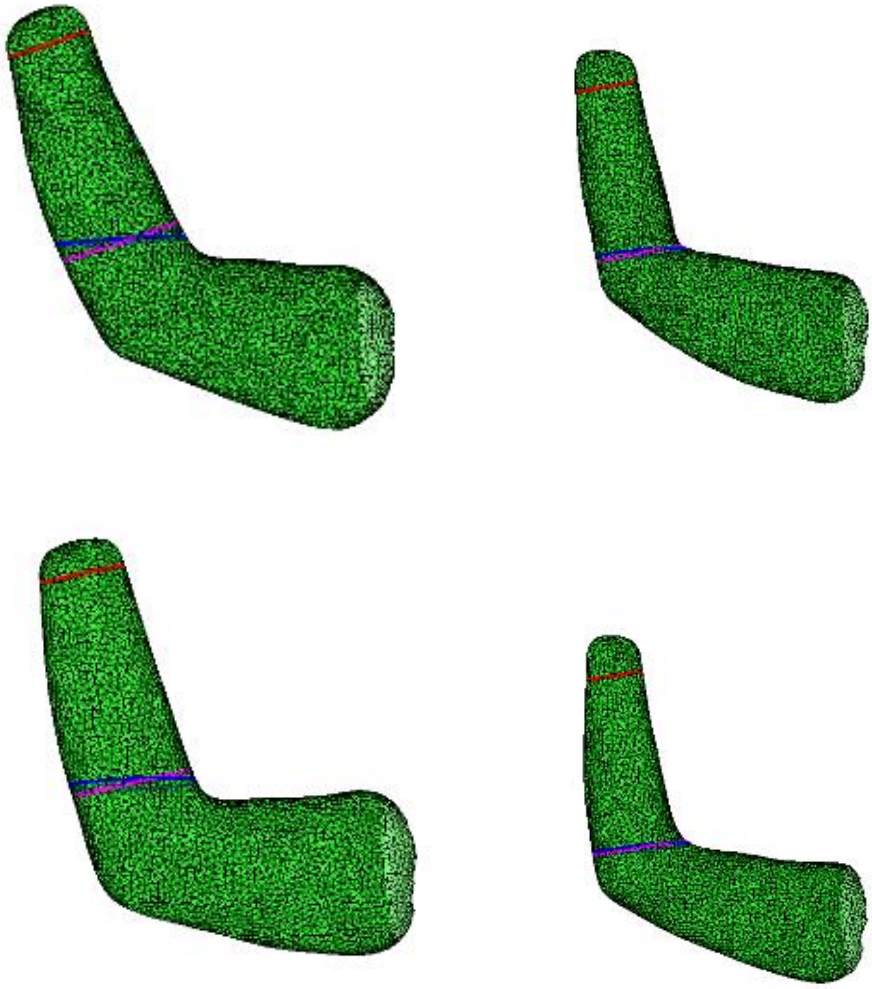


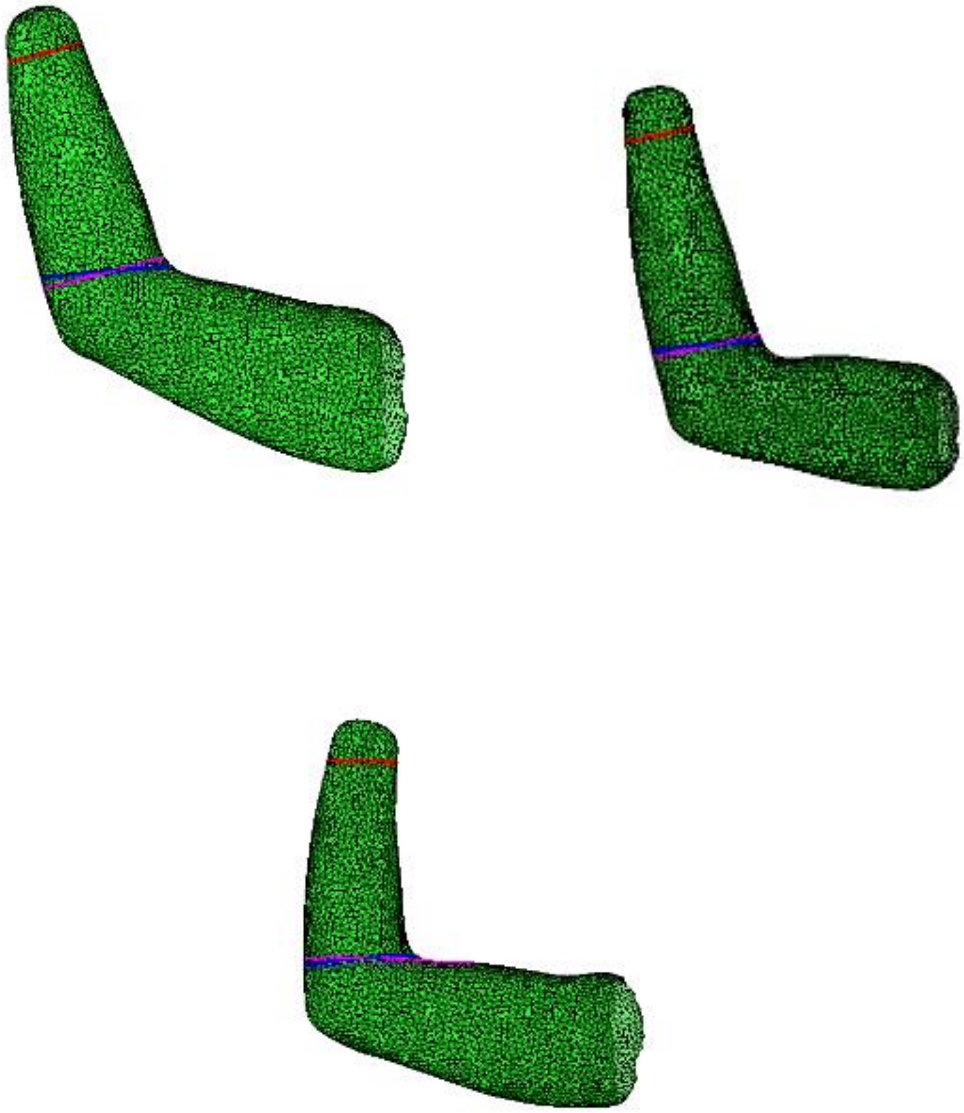


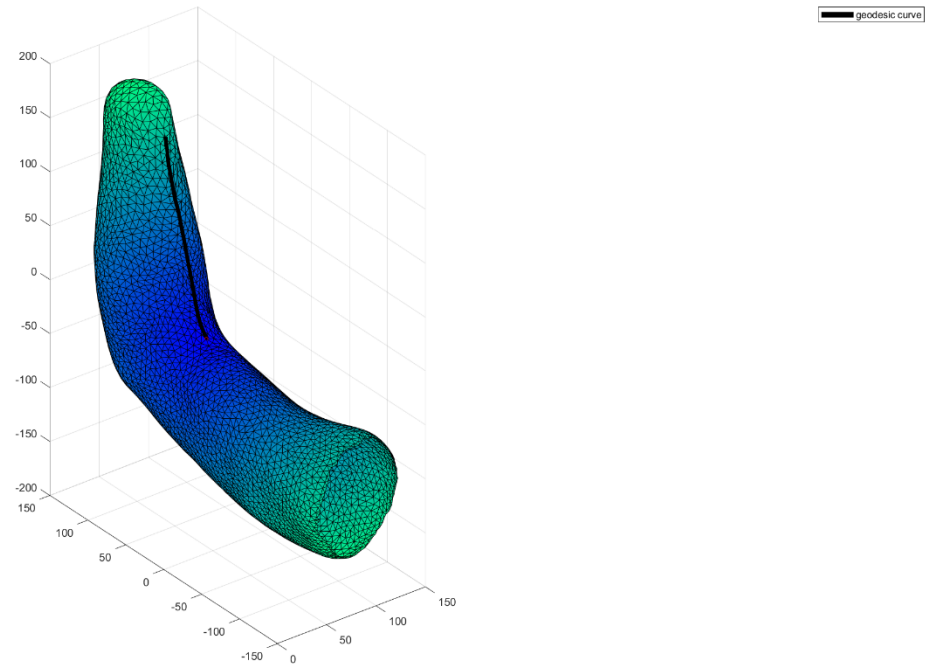








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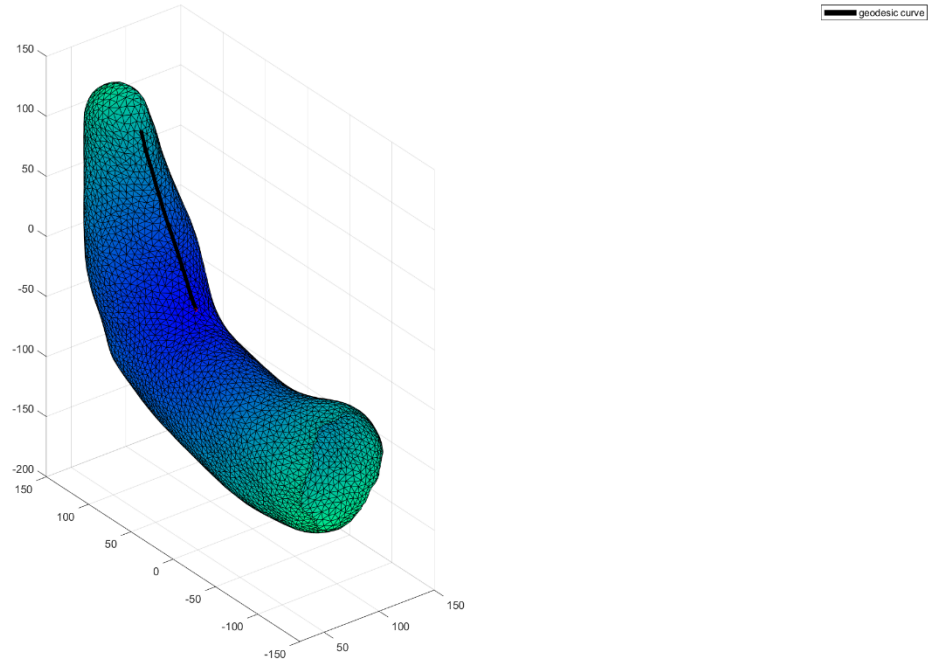
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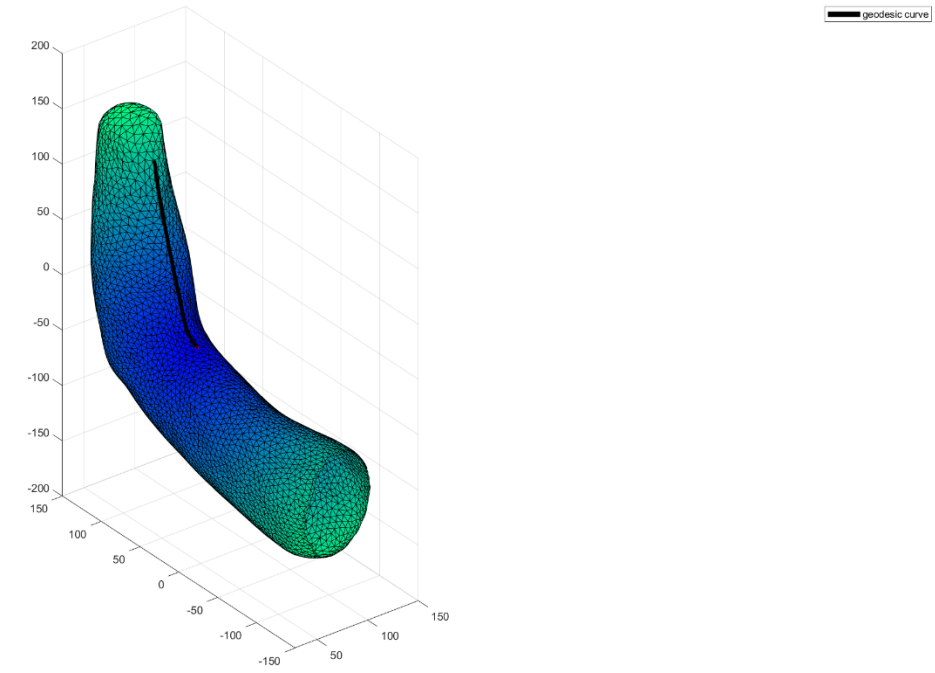
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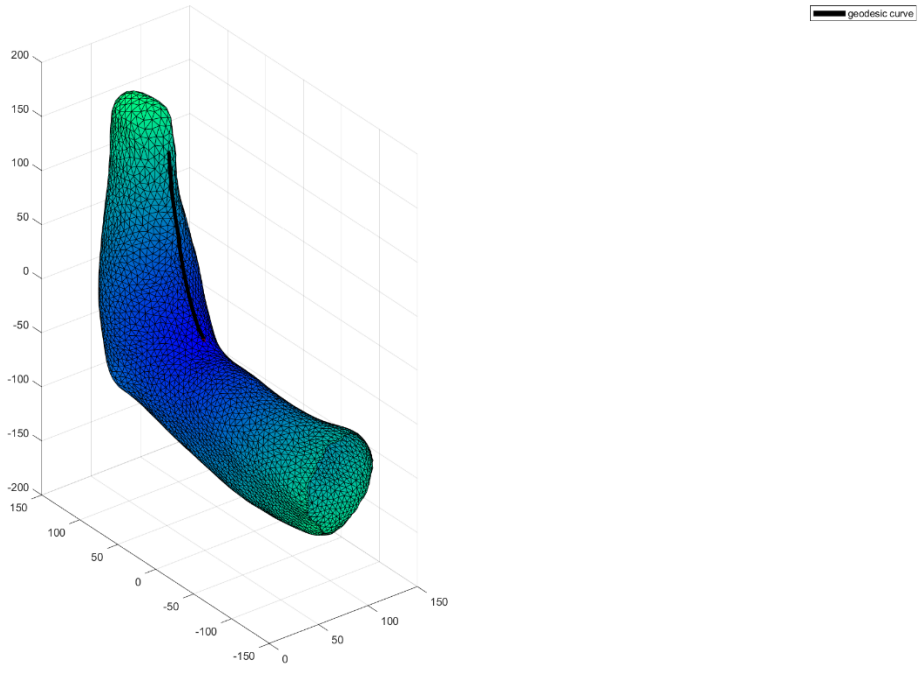
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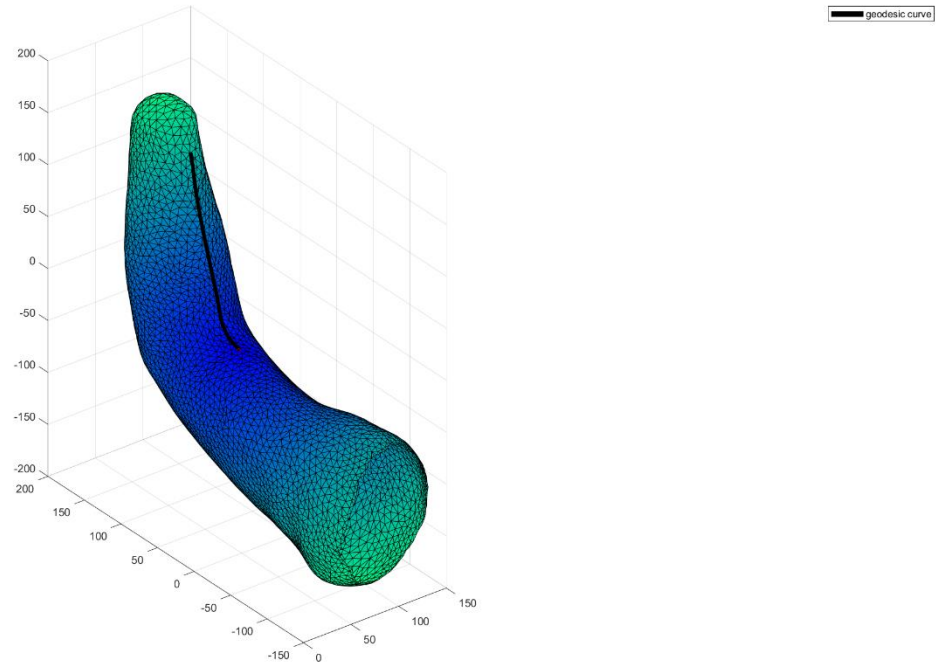
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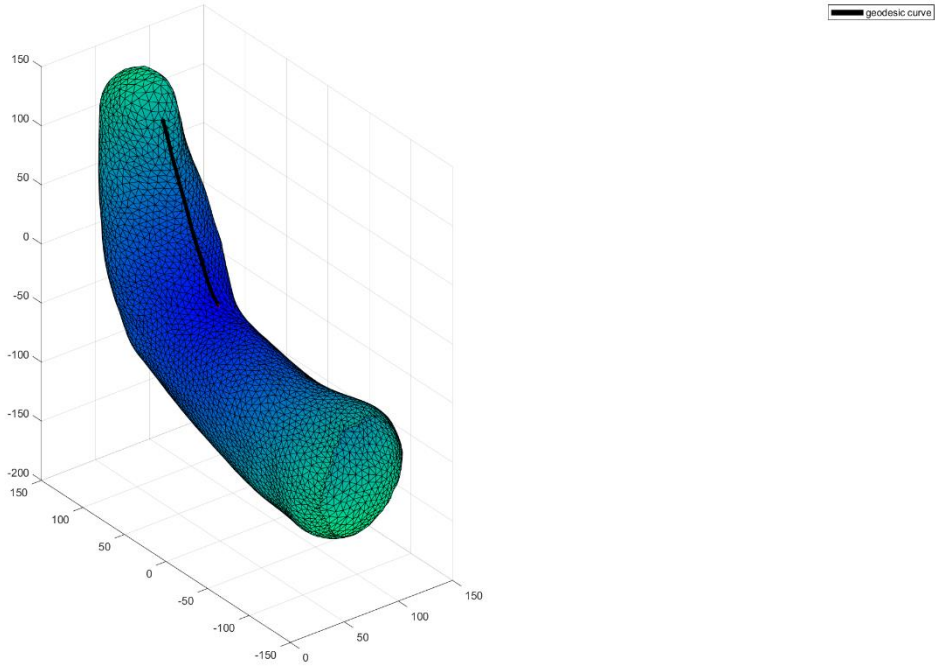
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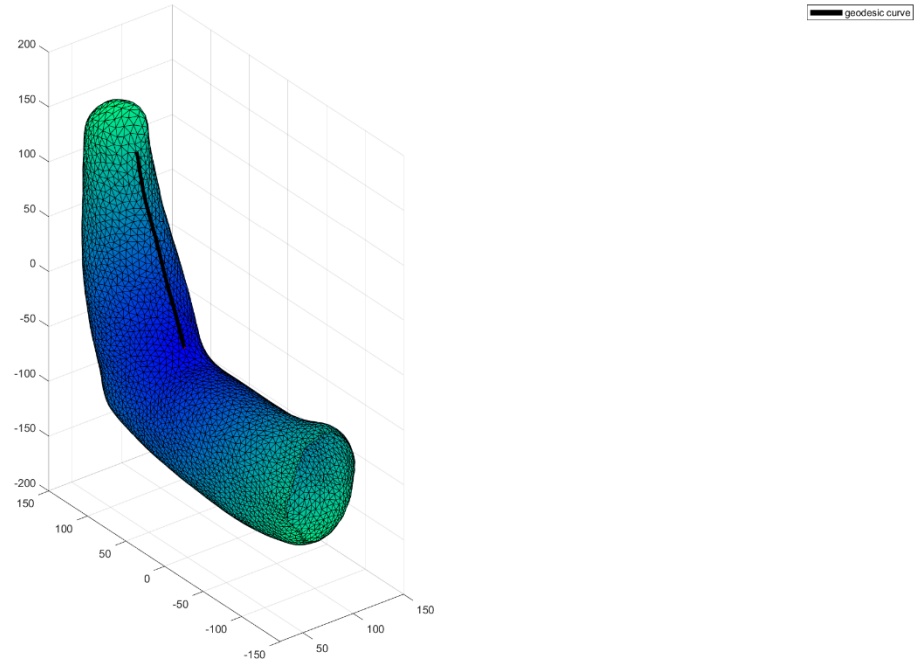
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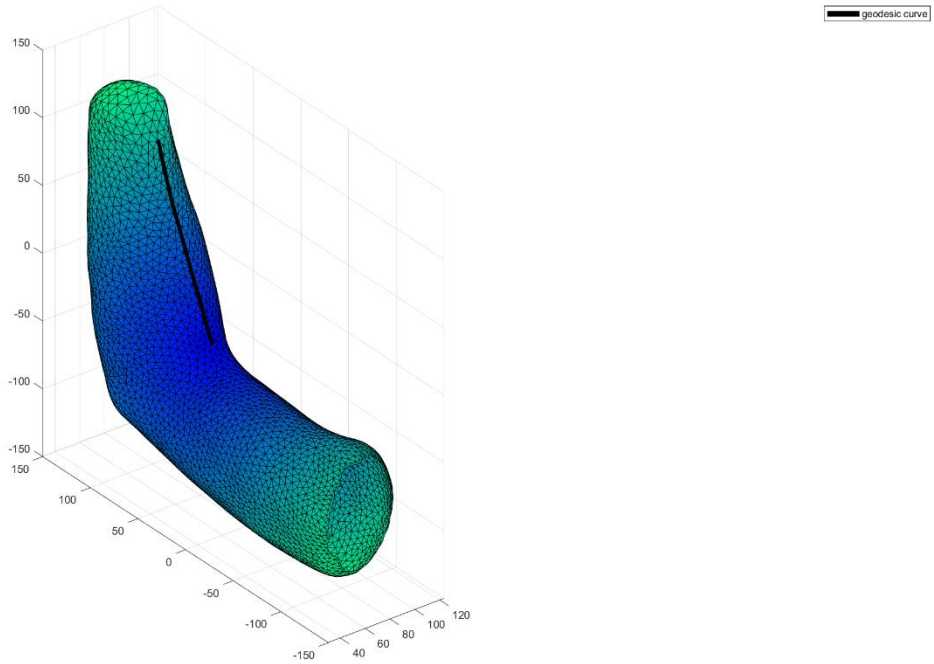
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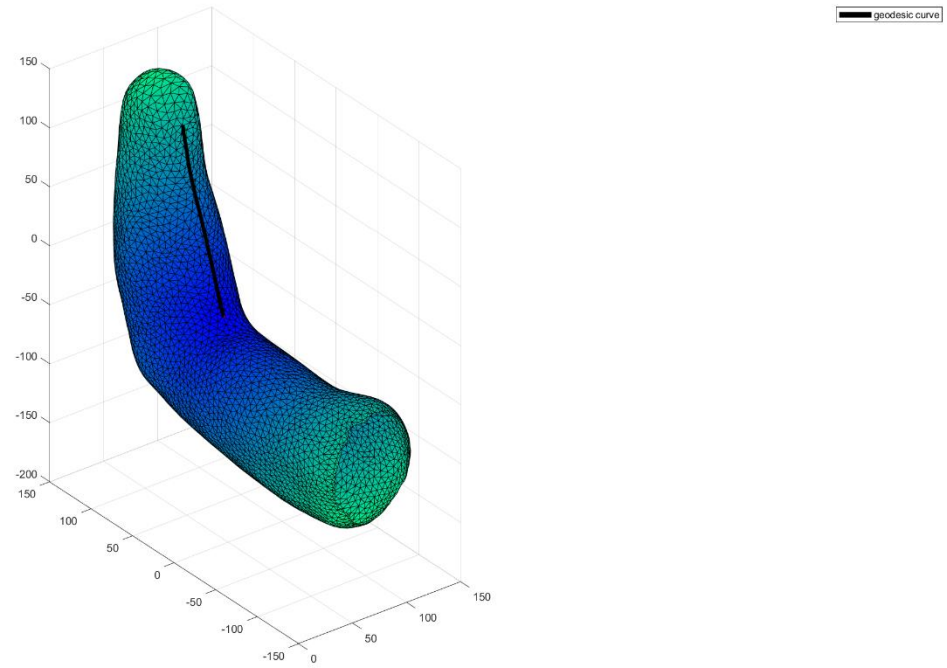
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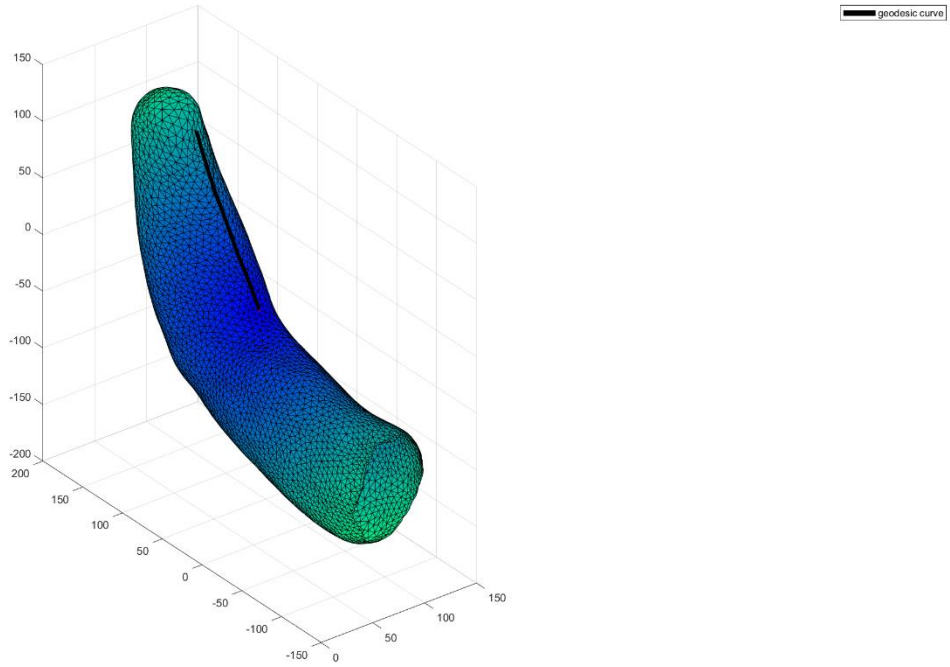
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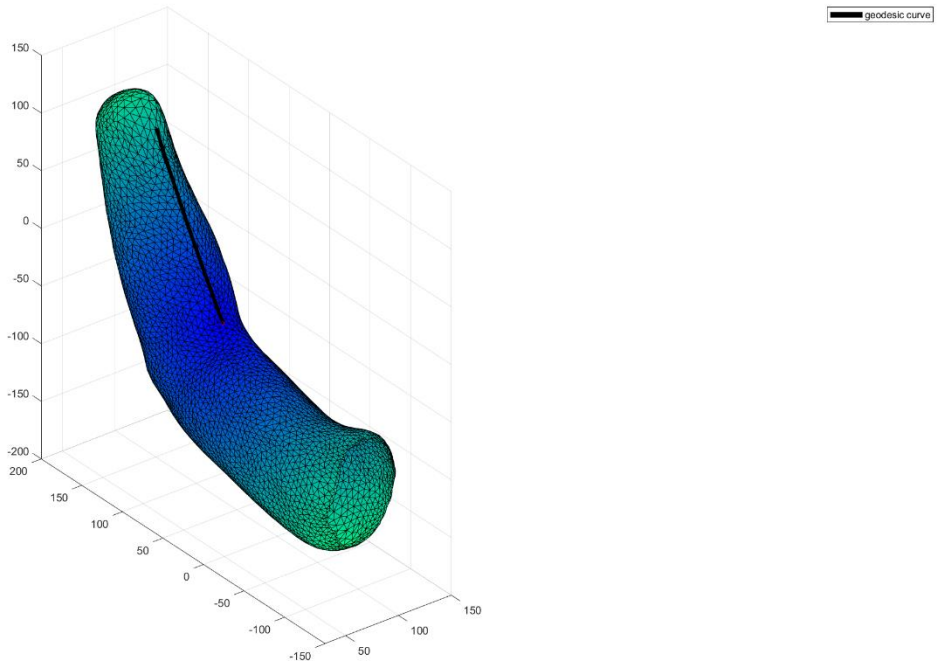
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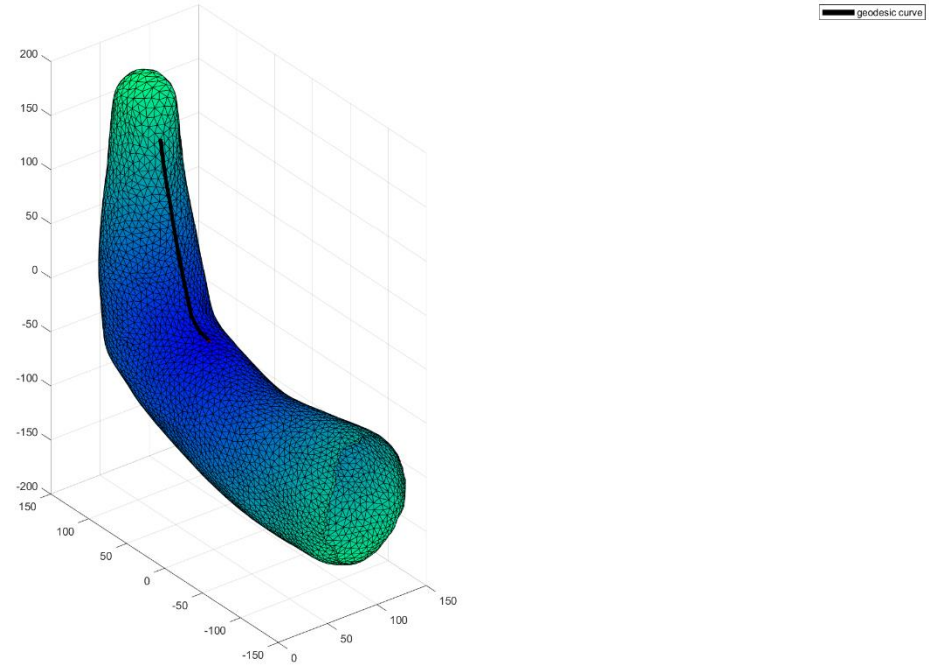
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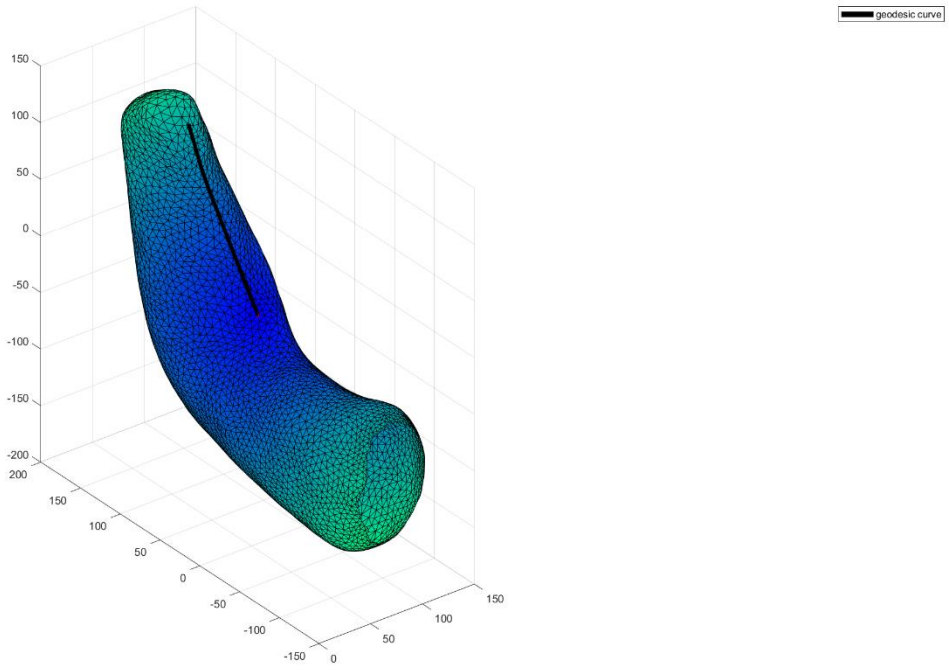
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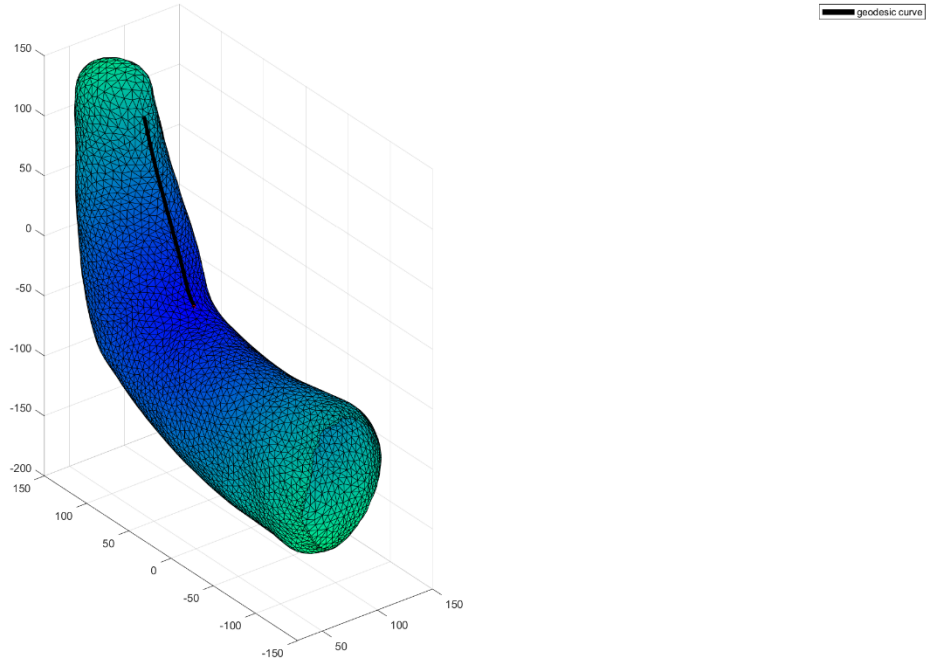
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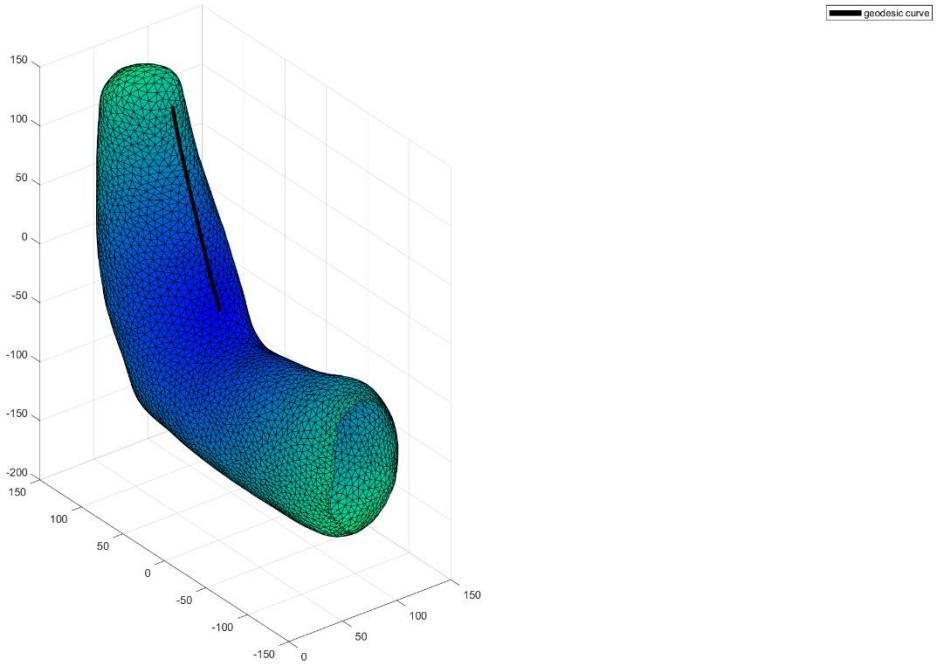
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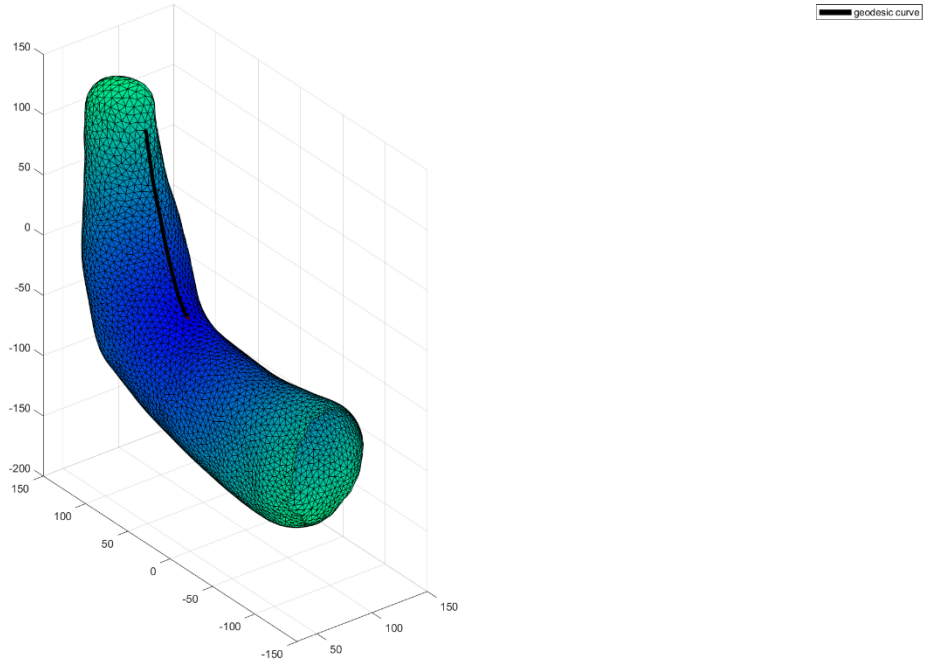
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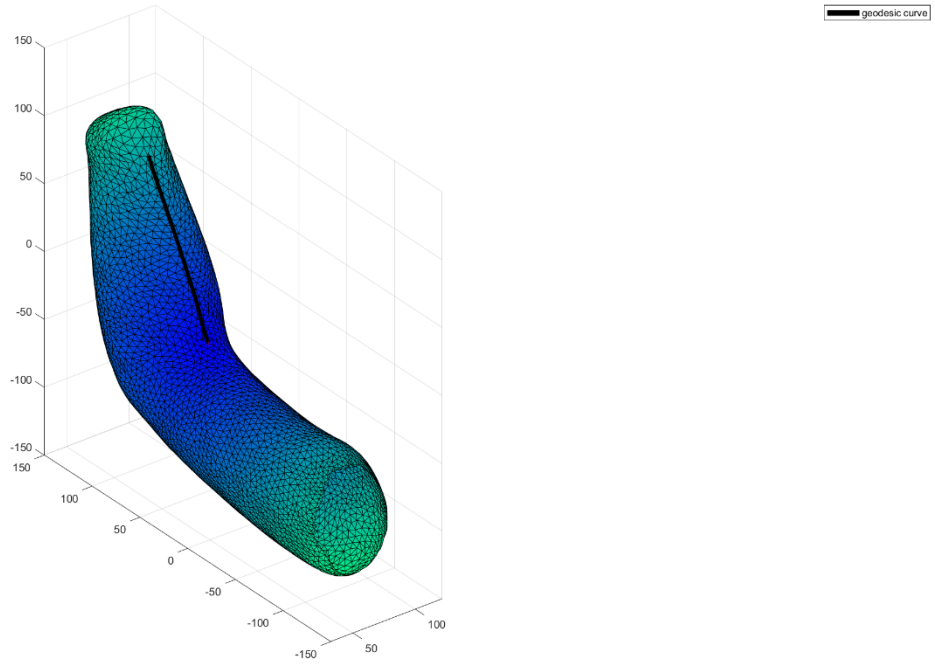
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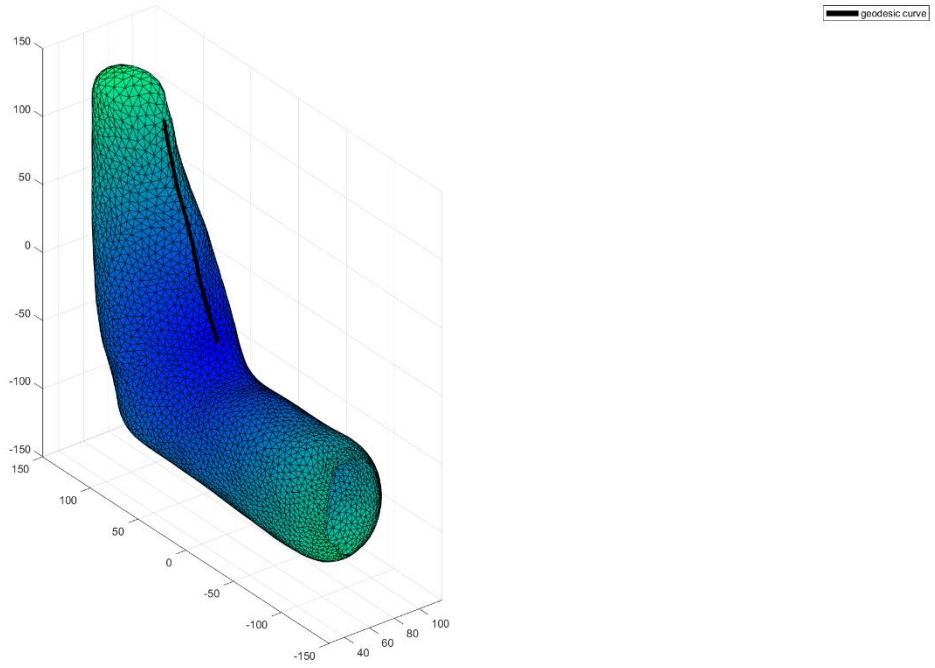
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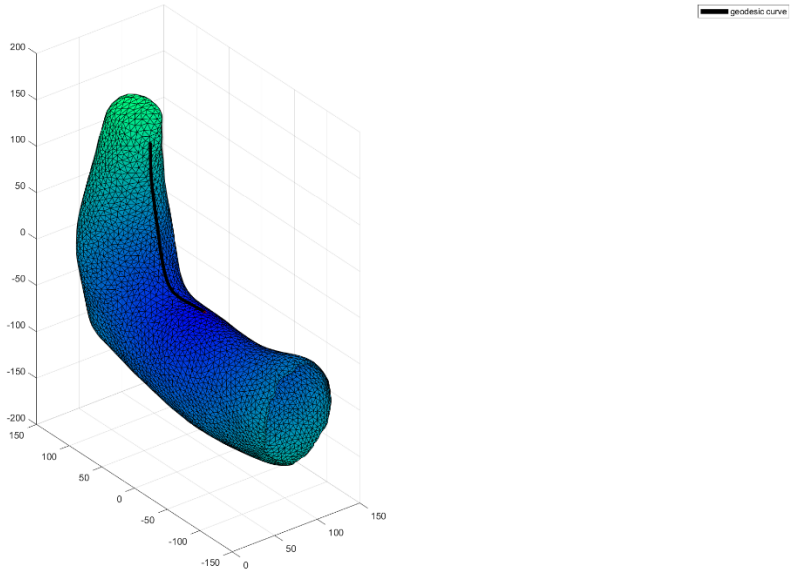
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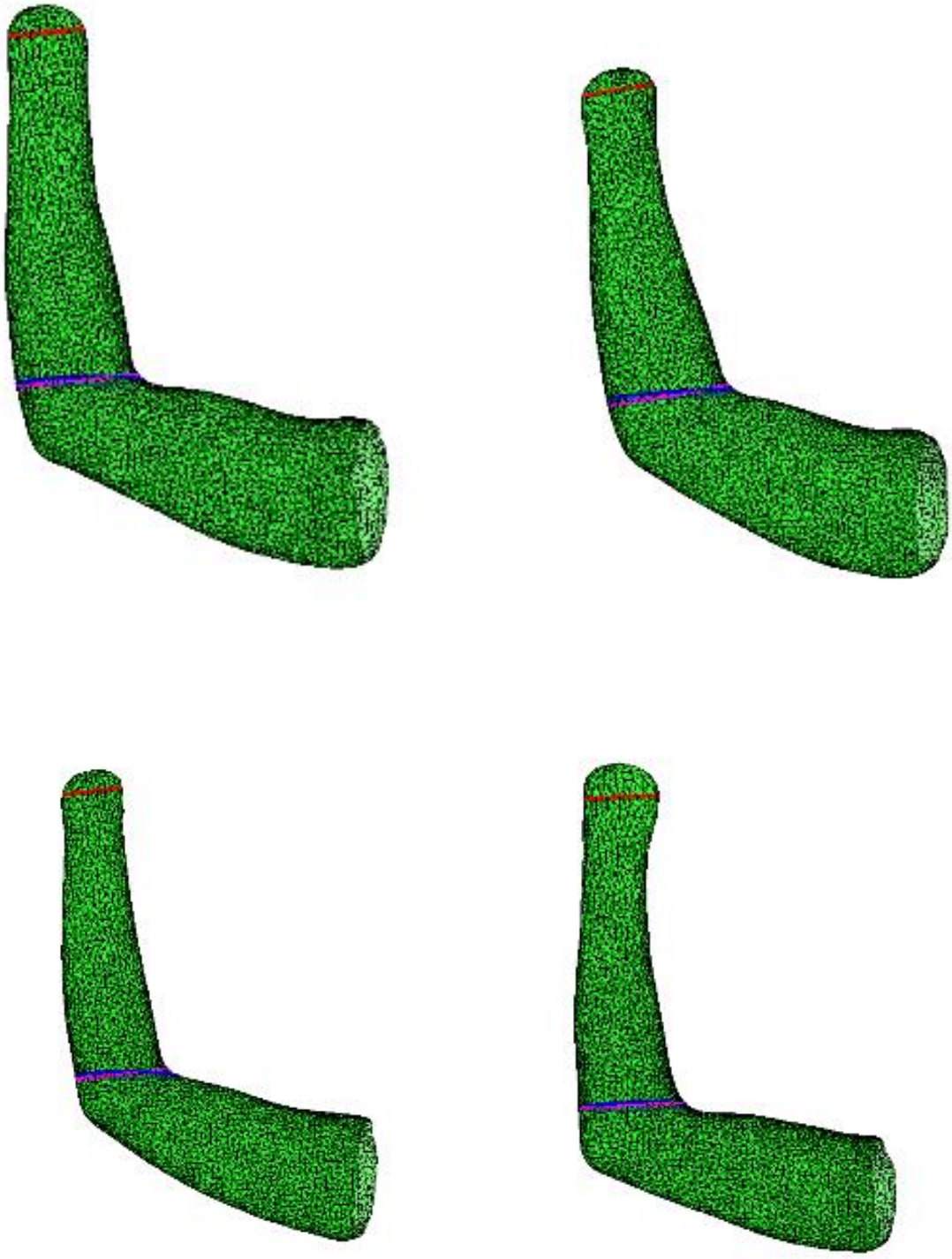
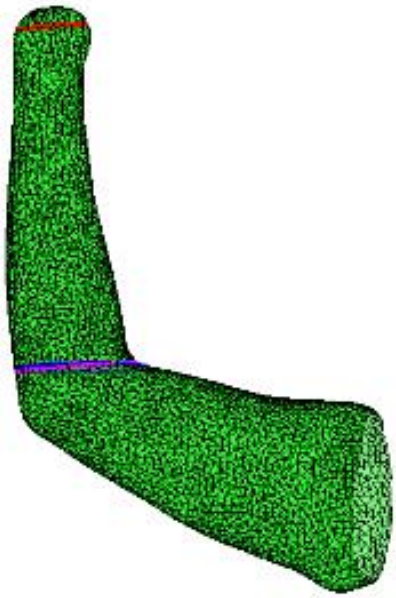
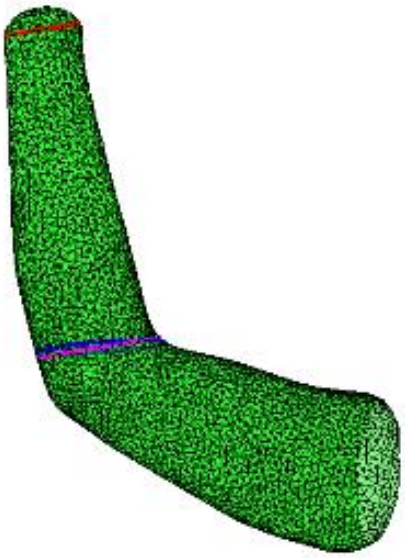
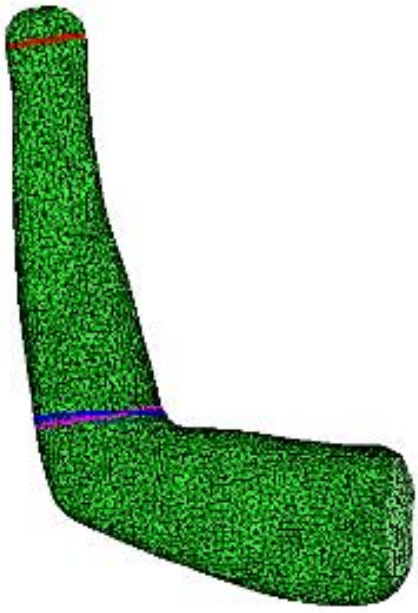
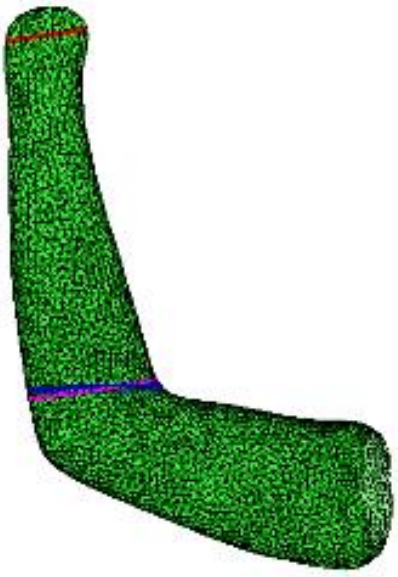
8. Specialized SSM for Wrist Cut

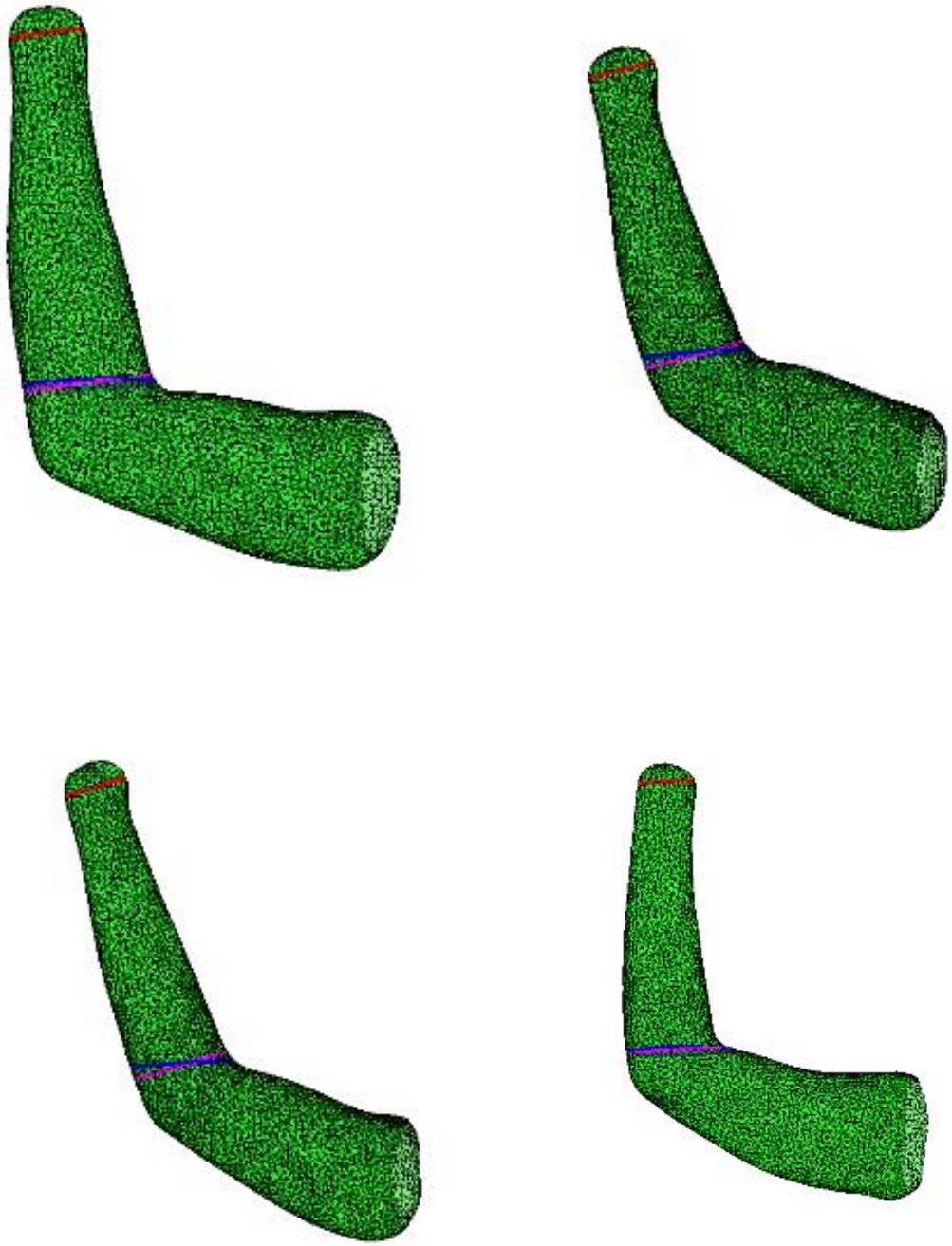


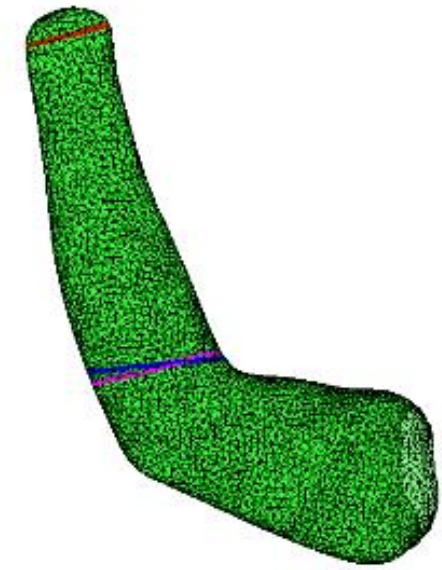
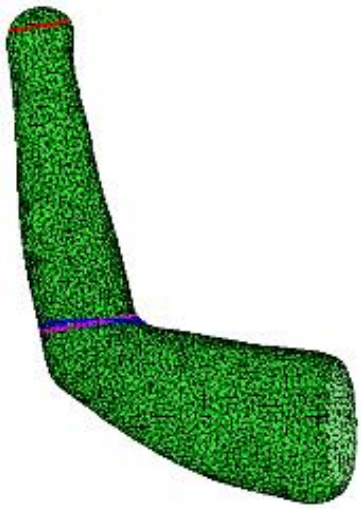
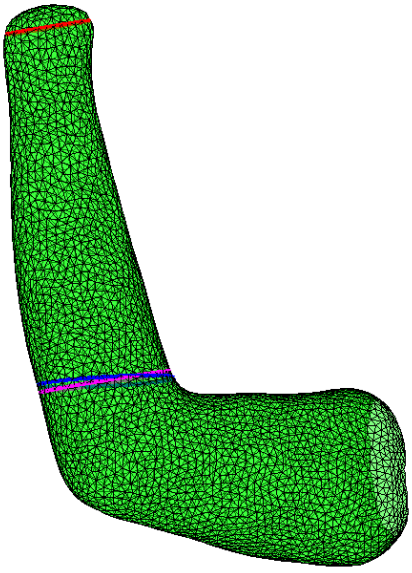
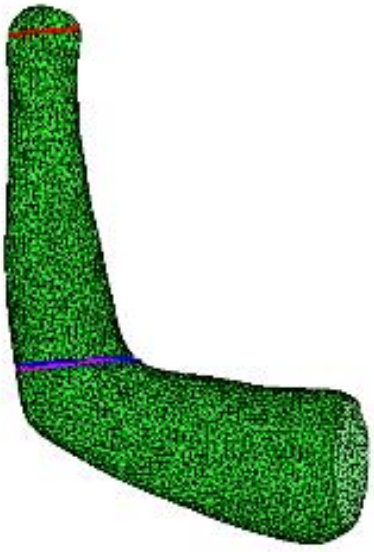


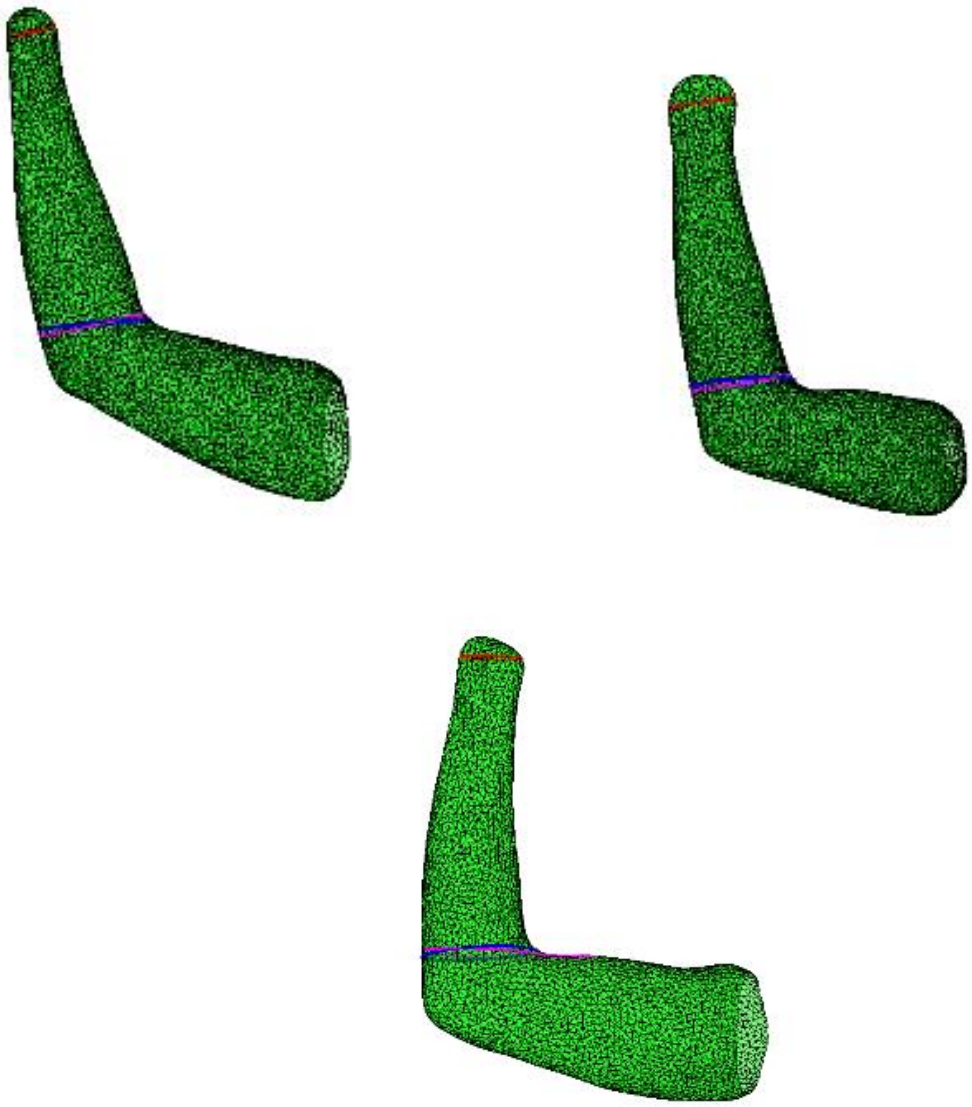


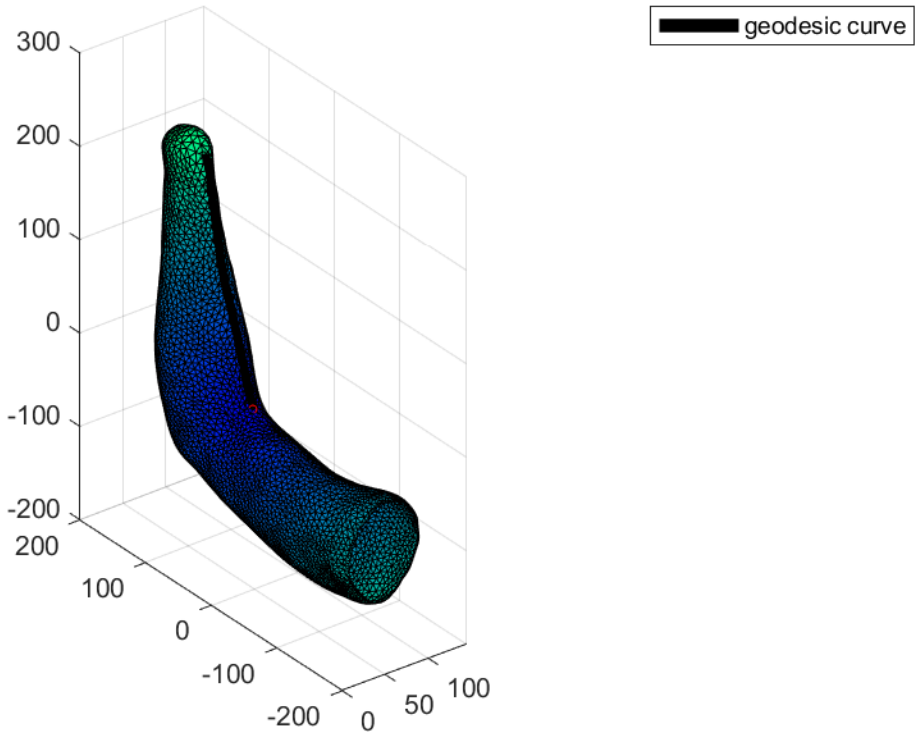






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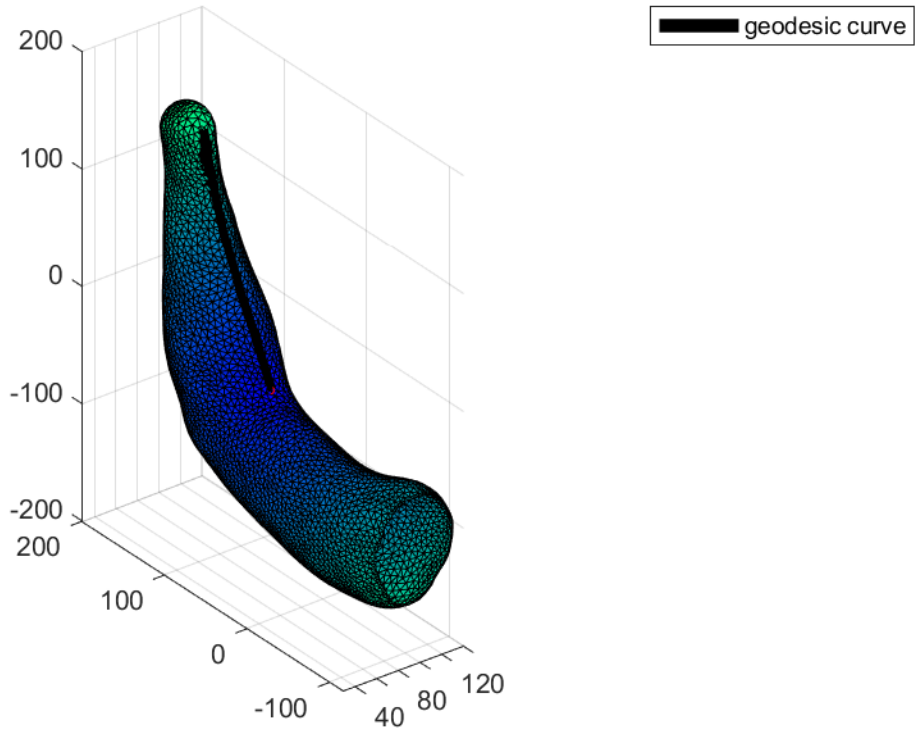
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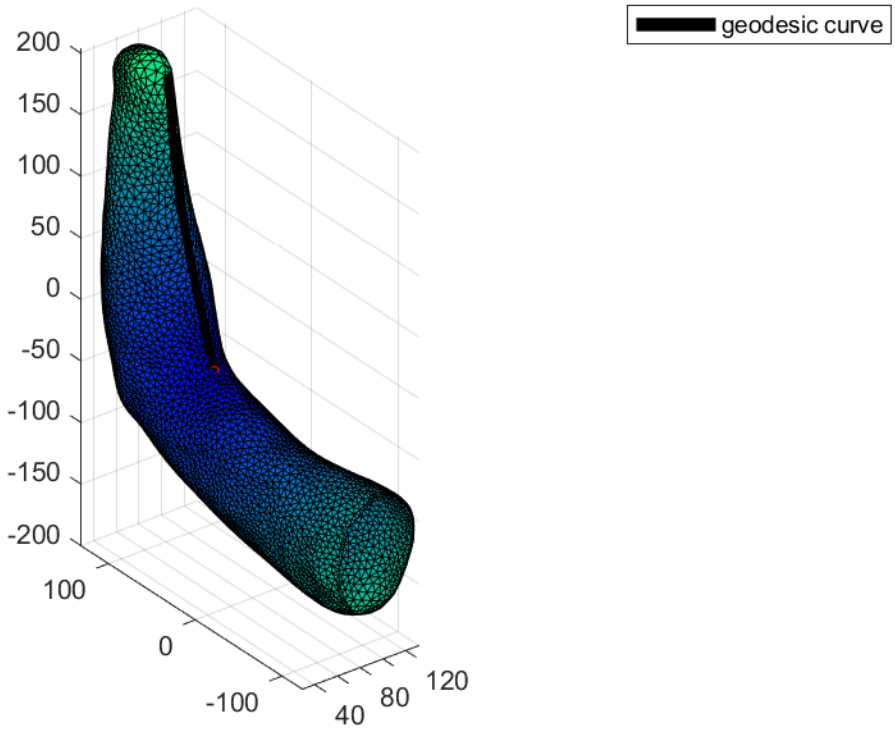
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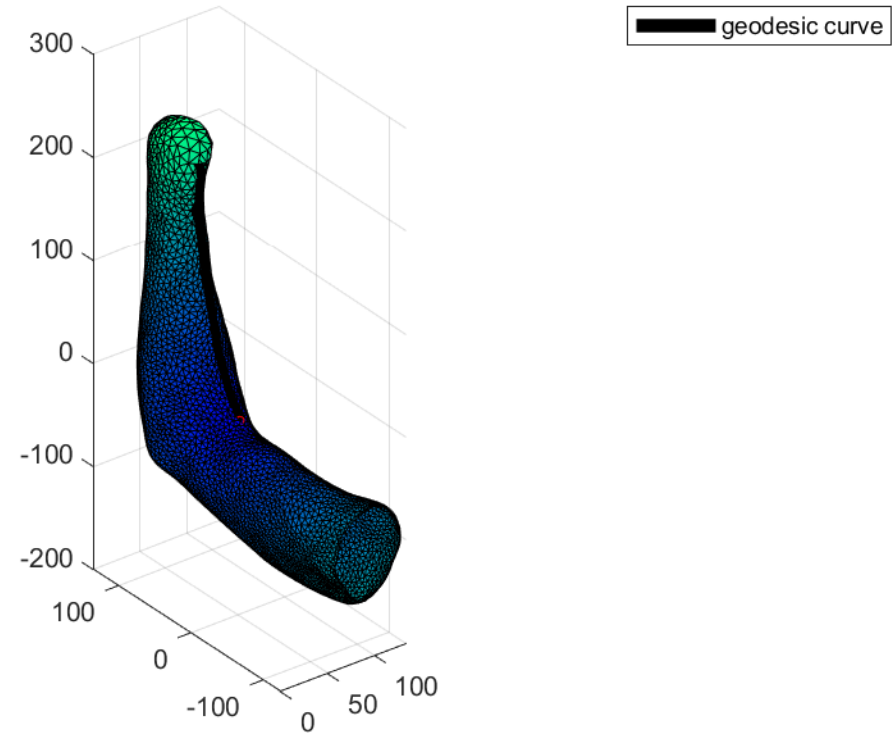
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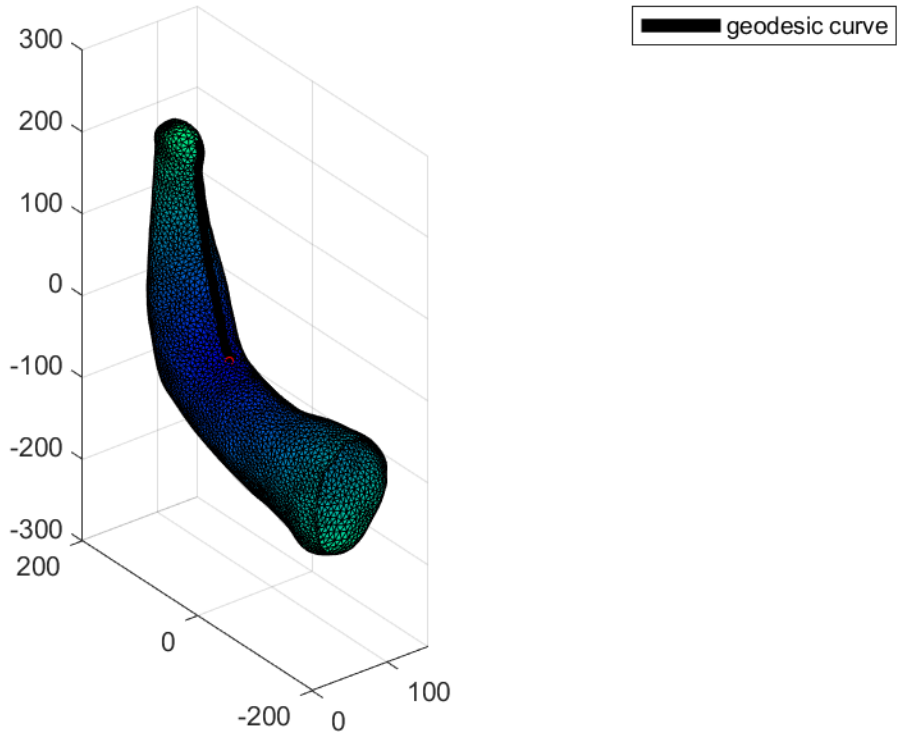
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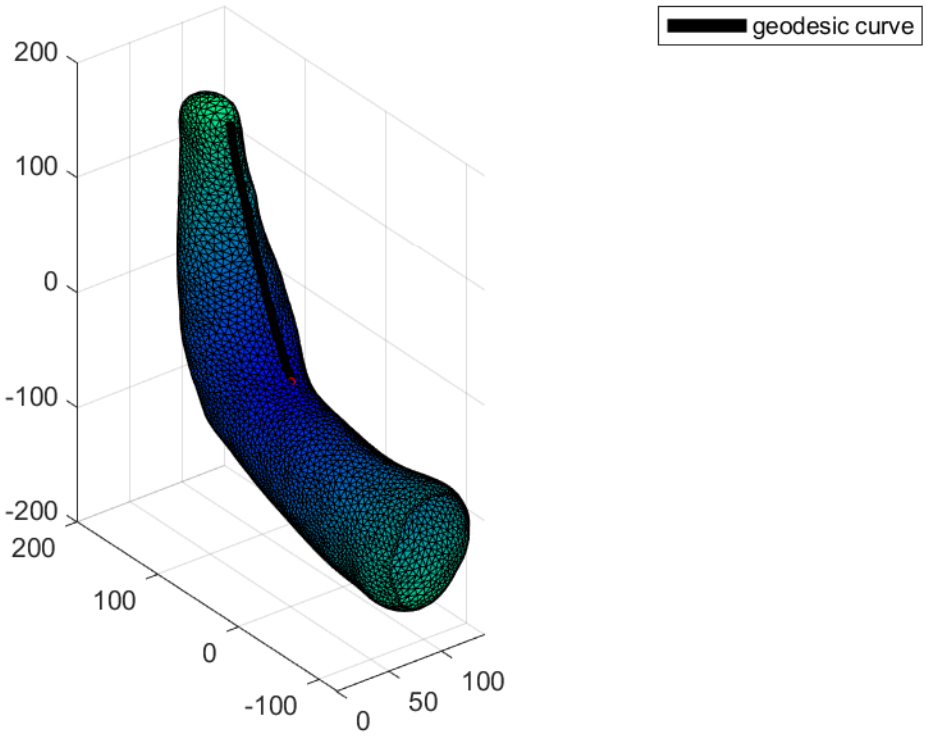
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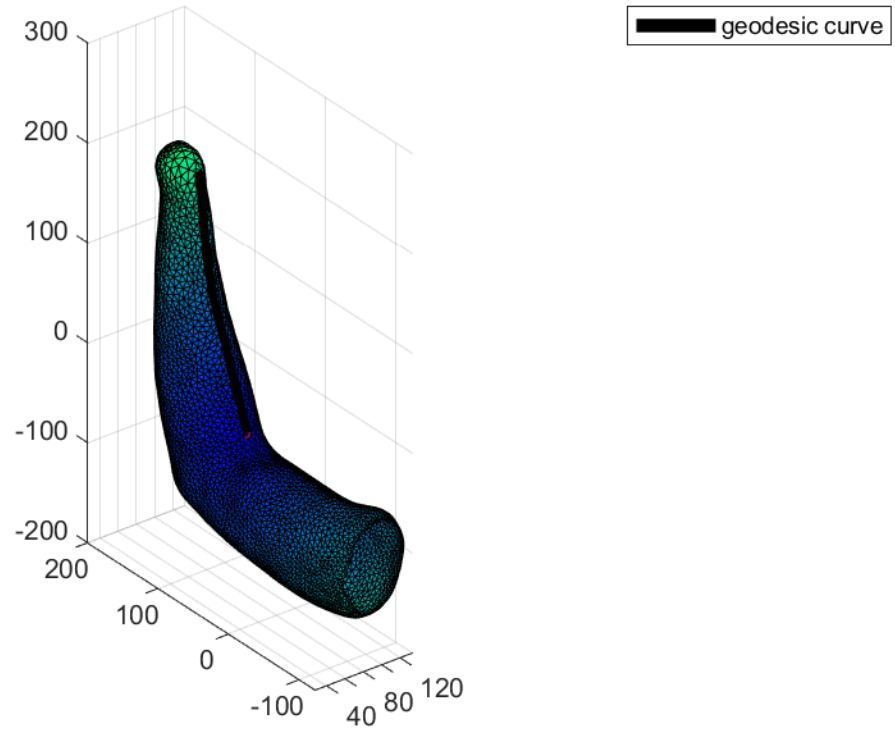
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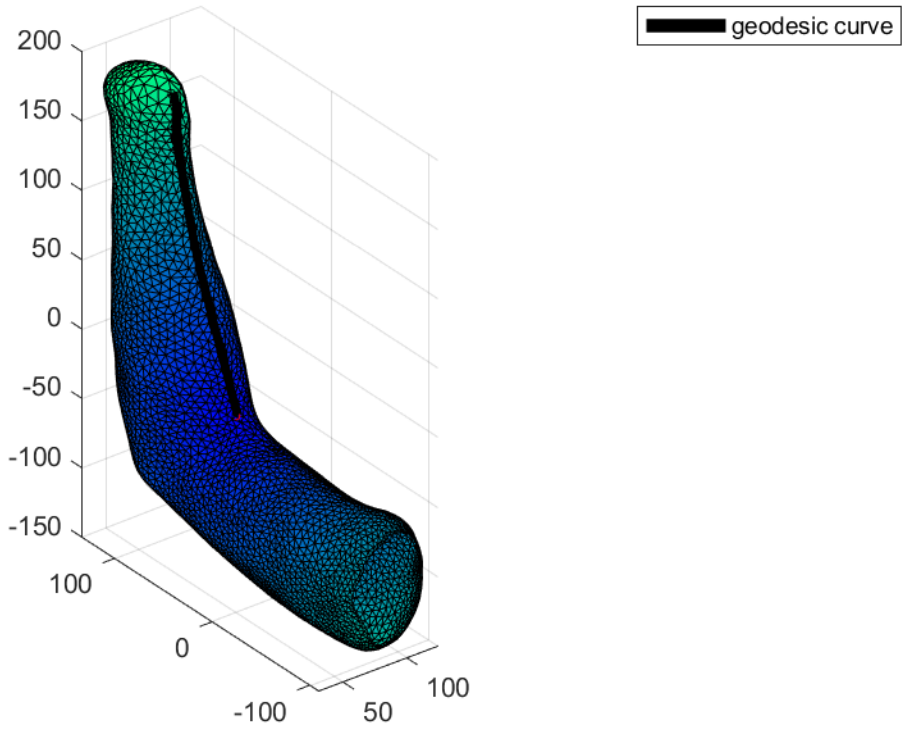
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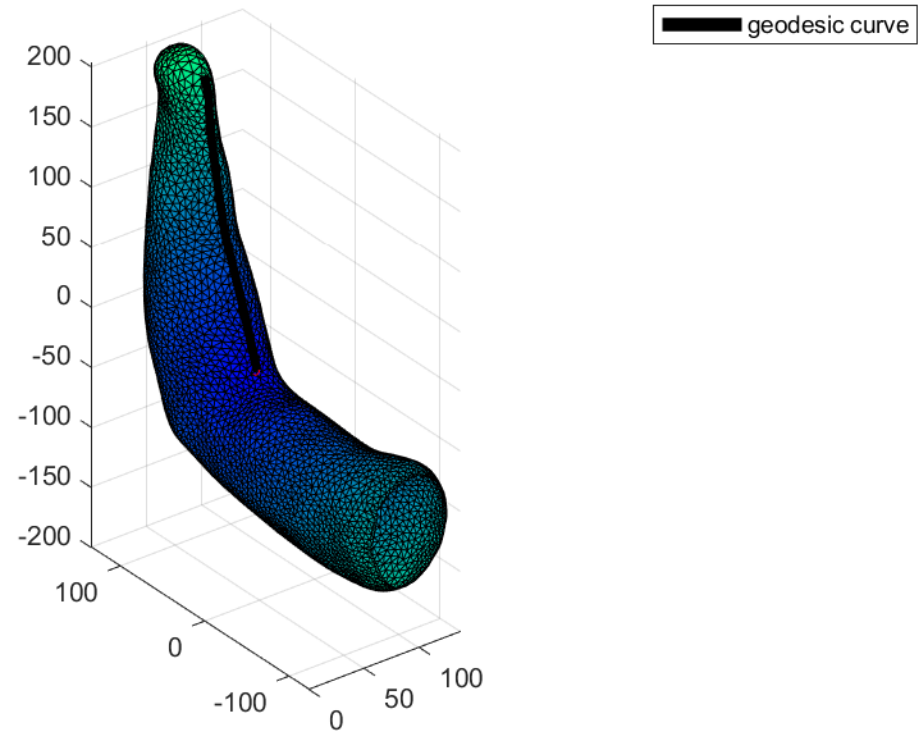
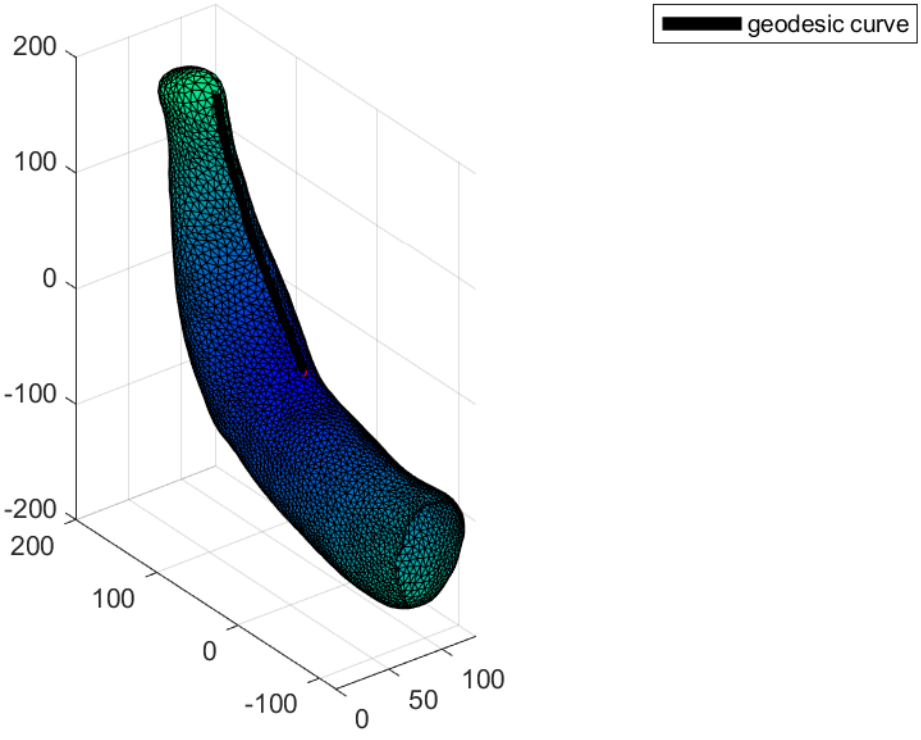
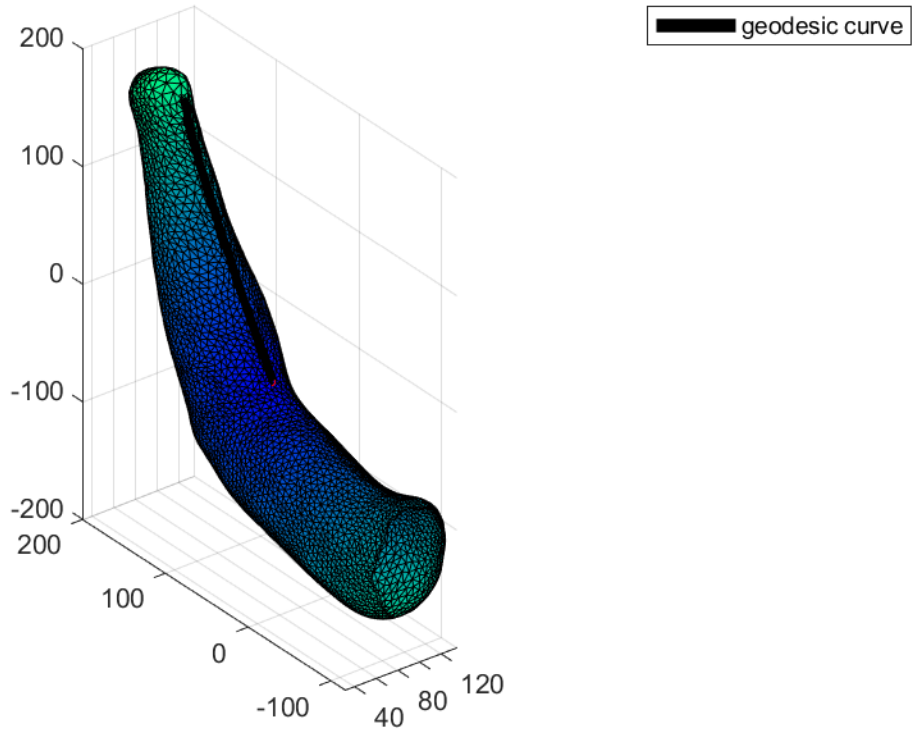
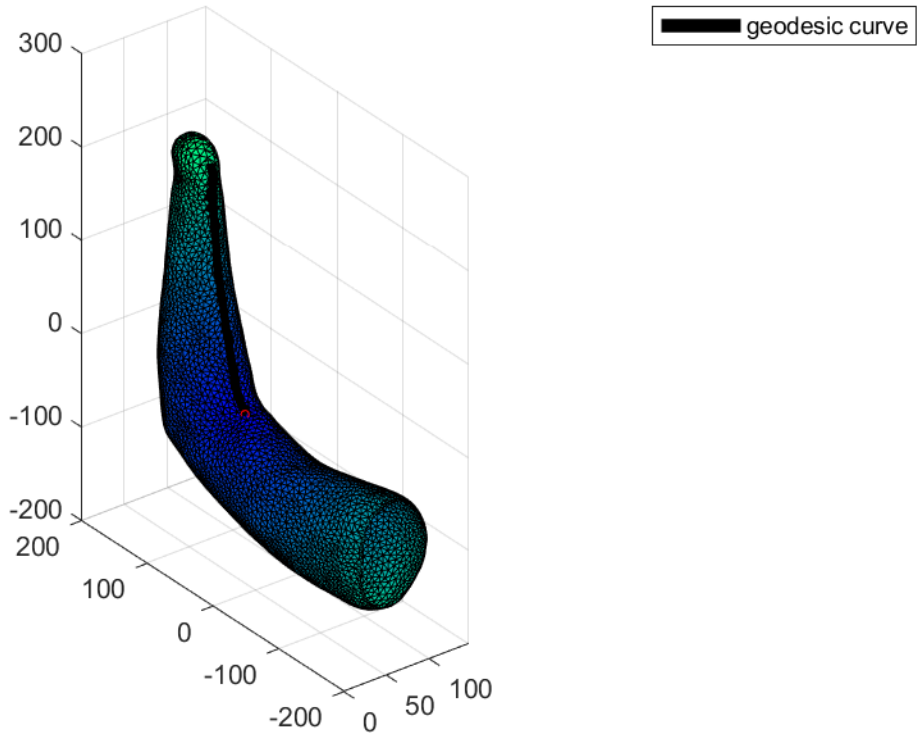
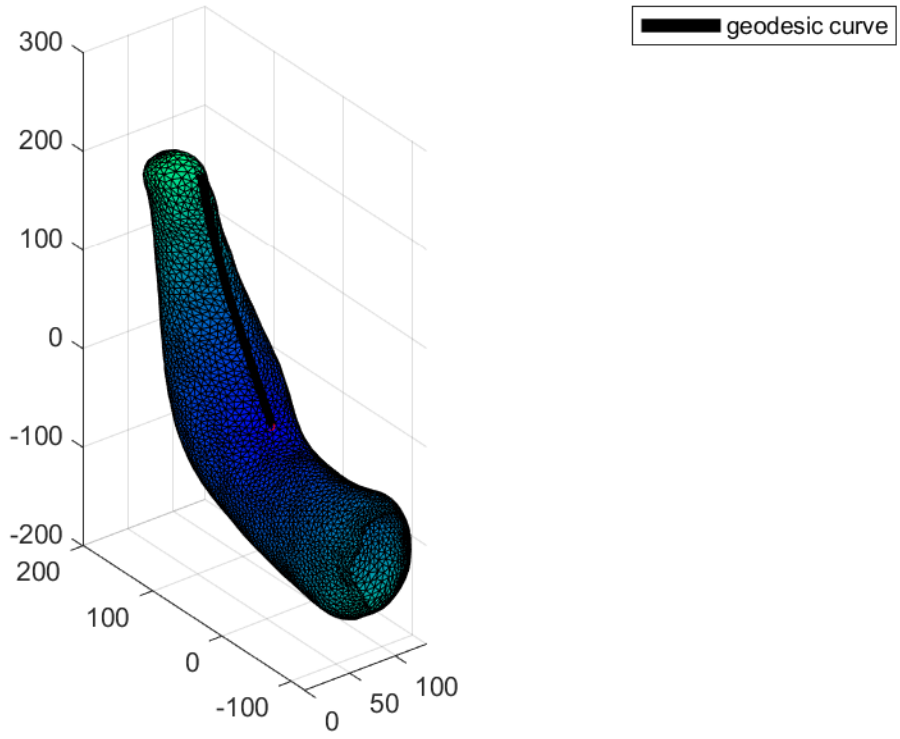
50
100

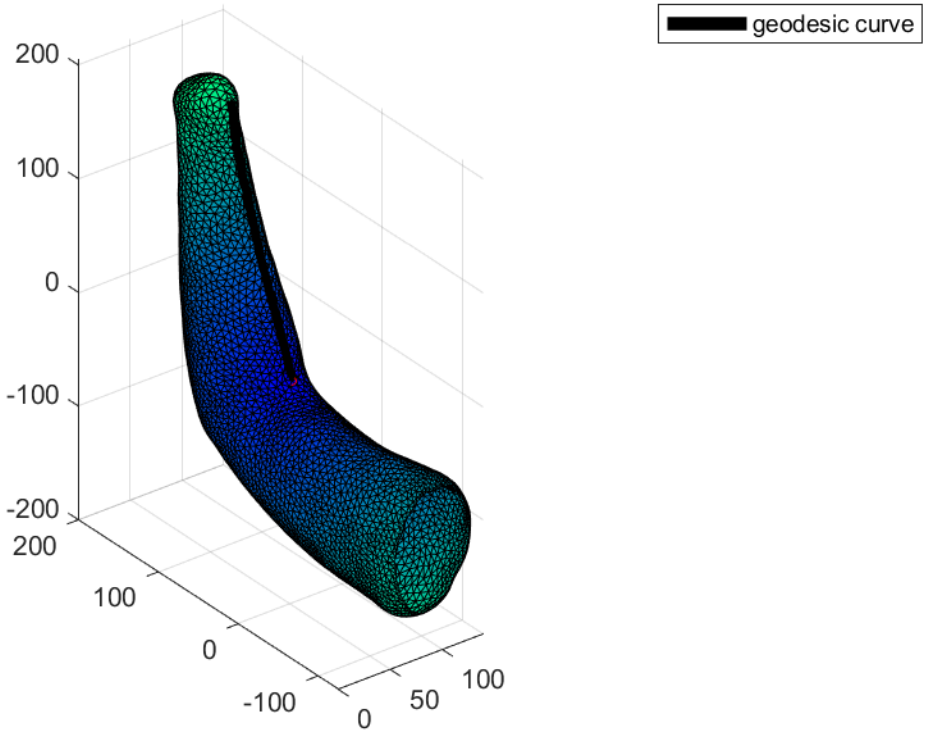

geodesic curve
200
150
100
50
0
-50
-100
-150
-200
100
0
-100
0
50
100

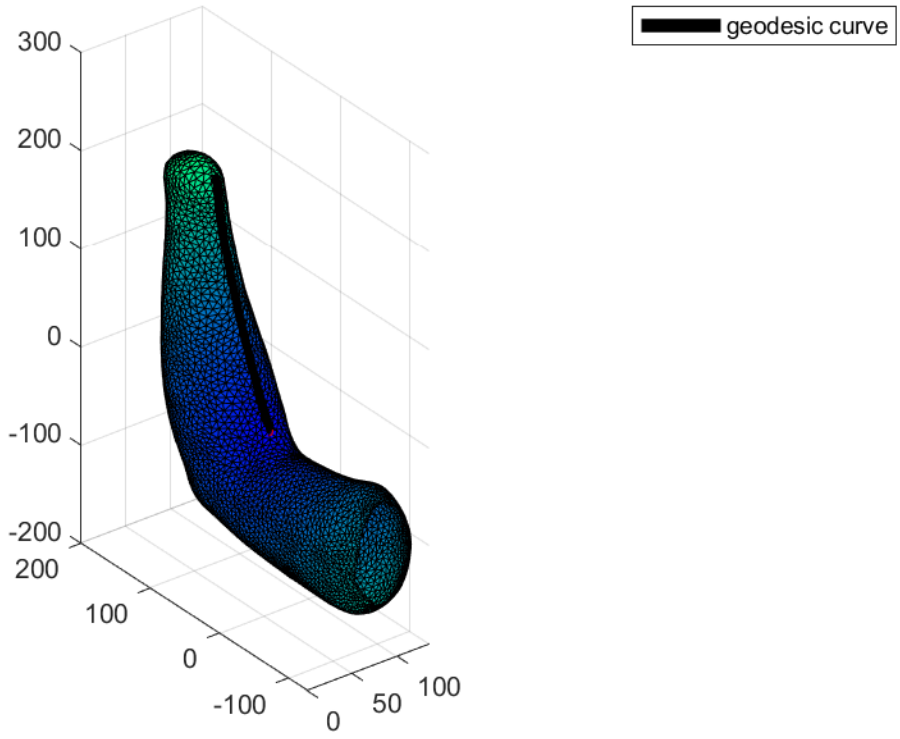

geodesic curve
200
100
0
-100
-200
200
100
0
-100
0
50
100

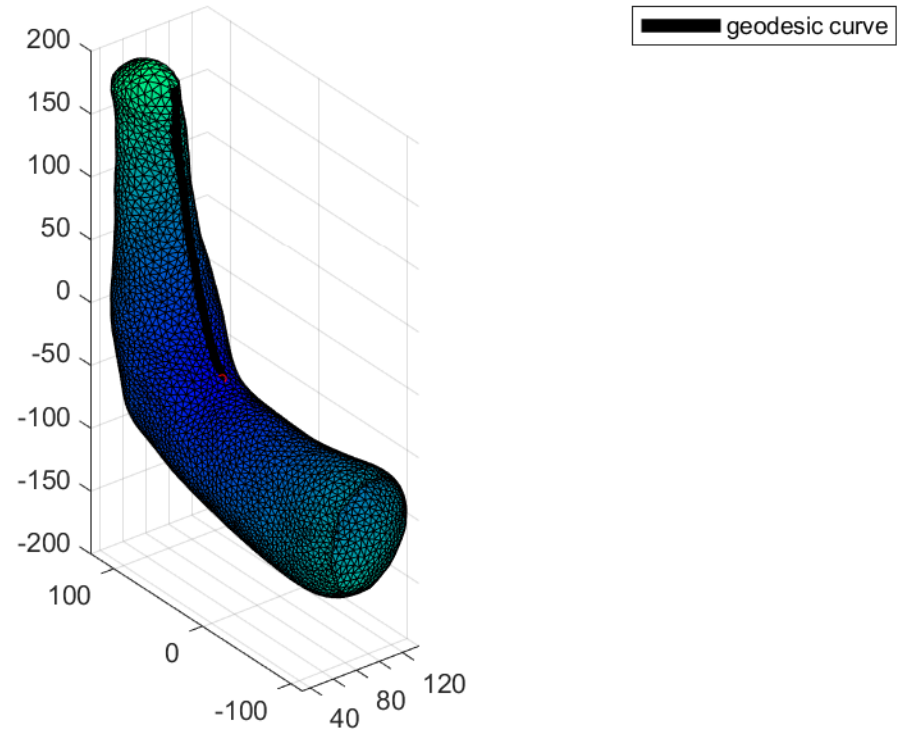

geodesic curve
200
100
0
-100
-200
200
100
0
-100
40
80
120

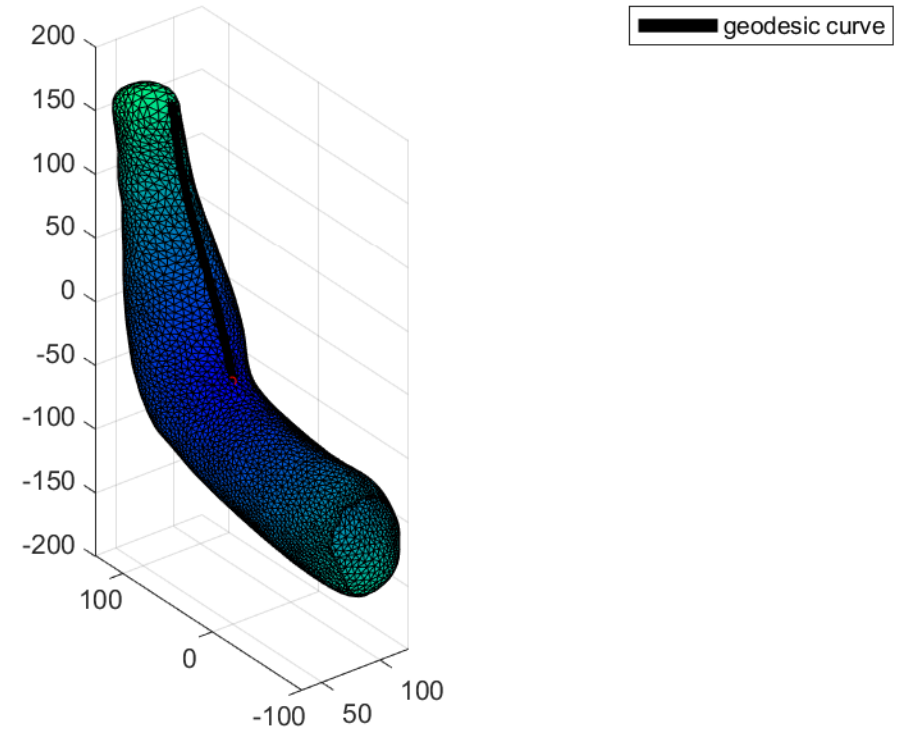

geodesic curve
300
200
100
0
-100
-200
200
100
0
-100
-200
0
50
100

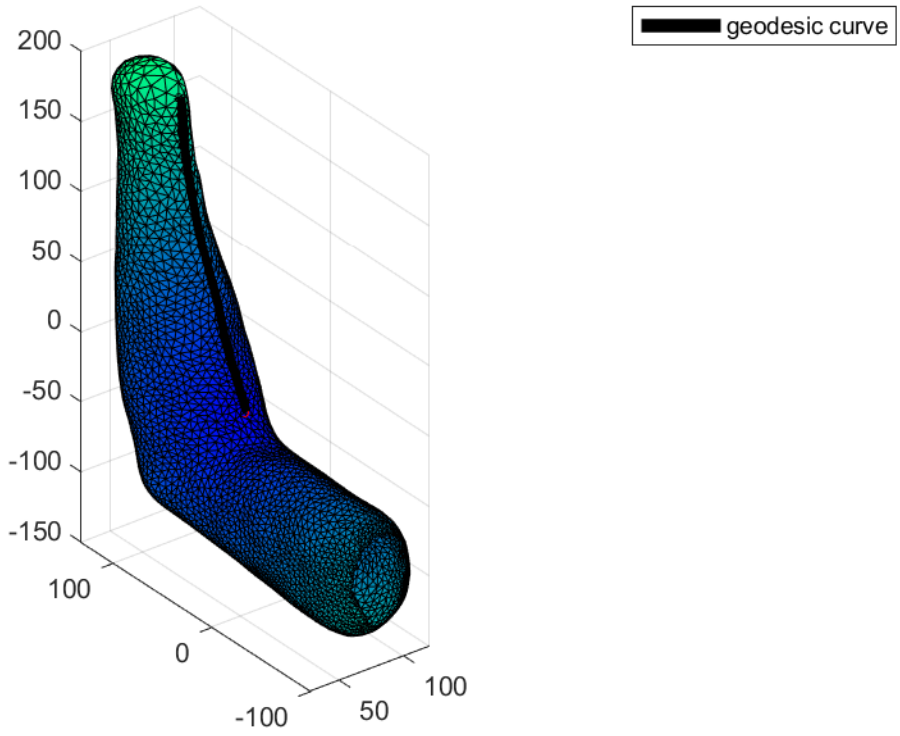

geodesic curve
300
200
100
0
-100
-200
200
100
0
-100
0
50
100

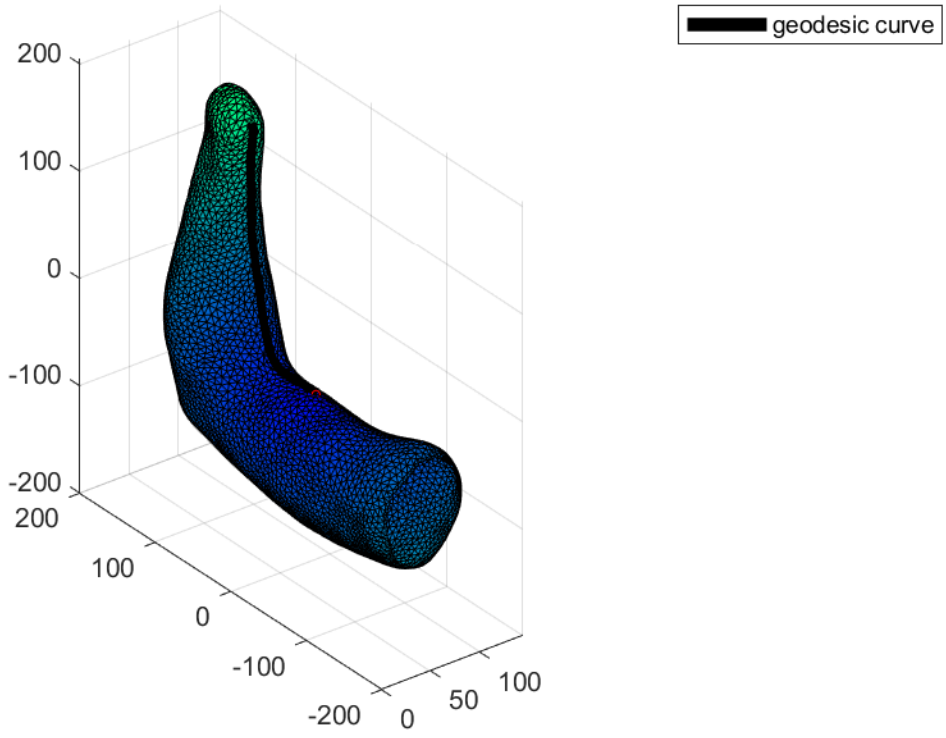

geodesic curve
200
100
0
-100
-200
200
100
0
-100
0
50
100


geodesic curve
300
200
100
0
-100
-200
200
100
0
-100
0
50
100


geodesic curve
200
150
100
50
0
-50
-100
-150
-200
100
0
-100
40
80
120


geodesic curve
200
150
100
50
0
-50
-100
-150
-200
100
0
-100
50
100


geodesic curve
200
150
100
50
0
-50
-100
-150
100
0
-100
50
100


geodesic curve
200
100
0
-100
-200
200
100
0
-100
-200
0
50
100

D

MATLAB Code

1. SSM Builder Main Code

```
%% Trial on nricp
%Gale Dewo
%must be run on directory "SEMUA CHARLIE"

%50 stl files to be read, remove duplicate vertices, reduce the vertice
%number of all files to a same value, perform nricp, align all transformed
%results to the source with the procrustes, create statistical shape model
%out of the 50 aligned transformed result.

%specify run mode, use runmode = 0 for showing the plot and running it in
%series(takes about 20 minutes)
%use runmode = 1 to run it faster (5 minutes) without showing the
%registration plot
%savefigure = 1 if we want to save all the figures

runmode=1;
savefigure=0;
N=7;
filetype='ply';

%reference model number
%specify all struct

tic
if filetype=='ply'
stlFiles = dir('*.ply');
else
stlFiles = dir('*.stl');
end

numfiles = length(stlFiles);
tempfiles=32;
mydata = cell(1, numfiles);
registered = cell(1, numfiles);
X = cell(1, numfiles);
```

```
for k = 1:numfiles
  %read STL files to faces and vertices
  if filetype=='ply'
  [mydata{k}.vertices,mydata{k}.faces] = read_ply(stlFiles(k).name);
  else
  [mydata{k}.faces,mydata{k}.vertices] = stlread(stlFiles(k).name);
  end
  %remove duplicate vertices

[mydata{k}.vertices,mydata{k}.faces]=patchslim(mydata{k}.vertices,mydata{k}.f
aces);

  %reduce vertices count, faster matching
  %NOTES: try to add more points to result in MyCrustOpen func
  %[mydata{k}.faces,mydata{k}.vertices] =
reducepatch(mydata{k}.faces,mydata{k}.vertices,7500);

  %create normals value
  %mydata{k}.normals=patchnormals(mydata{k});
end
%%
a=1.75*pi/9
rotz=[cos(a),-sin(a),0;
        sin(a),cos(a),0;
        0,0,1]
    for k=1:numfiles
mydata{1,k}.vertices=mydata{1,k}.vertices*rotz;
    end
a=1*pi/18
rotz=[cos(a),0,-sin(a);
    0,1,0
        sin(a),0,cos(a);
       ]
    for k=1:numfiles
mydata{1,k}.vertices=mydata{1,k}.vertices*rotz;
    end
%%
    for k=1:5
        num=3700;

Sourcex=[mydata{N}.vertices(1:num,1),mydata{N}.vertices(1:num,2),mydata{N}.ve
rtices(1:num,3)];

Targetx=[mydata{k}.vertices(1:num,1),mydata{N}.vertices(1:num,2),mydata{N}.ve
rtices(1:num,3)];
[~,~,transformm] = procrustes(Sourcex,Targetx,'Scaling',0);
mydata{k}.vertices=transformm.b*mydata{k}.vertices*transformm.T +
transformm.c(1,:);
scatter3(mydata{k}.vertices(:,1),mydata{k}.vertices(:,2),mydata{k}.vertices(:
,3),'.')
grid off
axis equal
hold on

    end
```

```
%     make plane z=0.1 and z=0
% y= 0 y=0.2
% x= 0.3 x=0.5
%% RUN THE SURFACE REGISTRATION : Specify Options!
%surface normals are available and can be used.
Options.useNormals = 1;

% Specify that the source deformations should be plotted.
if runmode==1

Options.plot = 0;
else
Options.plot = 1;
end
% Ignore the boundary since it gives error on our file , the error is that
% FF returns an empty matrix when used freeBoundary function
Options.ignoreBoundary=0;

%%Loop for the non-rigid ICP for all files
%use parfor on better computers, minimal core i5
if runmode==1
parfor k=1:tempfiles
%We are now using the 12.stl as source
Source=mydata{1,N};
Target=mydata{1,k};

% Perform non-rigid ICP

%add our own iteration number
iter=500;
[registered{k}] = nonrigidICP(Target.vertices,Source.vertices,
Target.faces,Source.faces,10,1)% Options, iter,k);
end
else
for k=1:numfiles
%We are now using the 12.stl as source
Source=mydata{1,3};
Target=mydata{1,k};

% Perform non-rigid ICP

%add our own iteration number
iter=500;
[registered{k}] = nonrigidICP(Target.vertices,Source.vertices,
Target.faces,Source.faces,10,0);
end
end

toc
waktu= toc;


%%
%%Perform PCA on pointsTransformed
% pca_data=[];
```

```
% for k=1:numfiles
% pca_data = [pca_data;pointsTransformed{1,k}];
% end
% [coeff,score,latent,tsquared,explained,mu] = pca(pca_data);




%% SSM BUILDER
Source=mydata{1,3};
Xarm=[];
Yarm=[];
Zarm=[];
Targets=cell(1,tempfiles);
%align our result with procrustes
% for k=1:tempfiles
%
%     [dmat,Targets{k},transf]=procrustes(Source.vertices,registered{1,k});
% end
for k=1:tempfiles
Xarm = [Xarm,registered{1,k}(:,1)];
Yarm = [Yarm,registered{1,k}(:,2)];
Zarm = [Zarm,registered{1,k}(:,3)];
end
%%SSM builder from Manu
[ssmV,Eval,Evec,MEAN,PCcum,Modes]=SSMbuilder(Xarm,Yarm,Zarm);




%% FACE BUILDING (NOT NECESSARY?)
%Fdata=triangulation(T,Source.vertices);
M3=length(MEAN)/3;
MEANPoints=[MEAN(1:M3),MEAN((M3+1):(2*M3)),MEAN(((2*M3)+1):(3*M3))];

%specify the Faces from MyCrustOpen func
[ch]=MyCrustOpen(MEANPoints);

%dt = delaunayTriangulation(MEANPoints); %hasil bentuknya agak aneh
%[ch,v] = convexHull(dt);


% dt = delaunay(MEANPoints); %returns double, use with patch?
% DT.ConnectivityList=dt;
% DT.Points=MEANPoints;
% DT.
% [ch,v] = convexHull(DT);


%Fdata=Source.faces;

%NOTES: coba run 50 faces biar liat hasilnya bagus apa kaga si mean surface
%nya DONE
```

```
%NOTES2: parfor di non-rigid ICP DONE

%NOTES2: coba ditambahin points pas awal di patch remesh nya a.k.a.
%'reducepatch' p=7500 DONE

%NOTES3:39.stl sama 57.stl removed DONE

patch('Faces',ch,'Vertices',MEANPoints,'EdgeColor','black','FaceColor','green
','LineWidth',0.02);









%% PRINCIPAL COMPONENT
clc
clf
%load('trial7_7500.mat')
%load('trial8_3752.mat')
%load('trial8_temp40.mat')

Fdata=ch;
savefigure=0
if savefigure==1

for k=1:length(Modes)
    h=figure;
%showing the shape modes with SD-3  and SD+3
plotshapemode(k,ssmV,MEAN,Fdata)
view(0,-5);
pause(3)
 %saveas(h,sprintf('FIG_7500_%d.fig',k));
close
end
else
    k=1
    plotshapemode(k,ssmV,MEAN,Fdata)
    view(0,-5);
end

y=Eval(1:10)
x=1:10%length(Eval)
figure
plot(x,y,'--gs',...
    'LineWidth',2,...
    'MarkerSize',10,...
    'MarkerEdgeColor','b',...
    'MarkerFaceColor',[0.5,0.5,0.5])
xlabel('Principal Component')
ylabel('Variance')
```

```
%% LANDMARK SELECTION
oldFolder=cd('C:\Users\Gale Dewo\OneDrive\thesis\thesis\charlienash\MANU
test');

landmark=5

vertex_numbers=cell(1,landmark);
selectedPointsFull=zeros(1,length(MEANPoints));

%To mark for points of interest from model
for i=1:landmark
selectedPoints= brushworking(MEANPoints);
%https://nl.mathworks.com/help/matlab/creating_plots/how-patch-data-relates-
to-a-colormap.html

for k=1:length(selectedPoints)
if selectedPoints(k)==1
    vertex_numbers{i}=[vertex_numbers{i};k];
    selectedPointsFull(1,k)=1;
else
end
end

end
%%
C = double(selectedPointsFull');
p =
patch('Faces',ch,'Vertices',MEANPoints.*1000,'EdgeColor','black','FaceVertexC
Data',C);
p.FaceColor = 'interp';
% grid on
axis equal
colormap summer
```

2. SSM Fitter and Measurement Main Code

```
%% SSM FITTER
tic
localdef=1;
showlandmark=1;
depthlist=[];
depthver1=[];
depthver2=[];
 Depth=[]
 Width=[]
cd 'C:\Users\Gale Dewo\OneDrive\thesis\thesis\charlienash\MANU test'

count=19
result=cell(1,10)
Inputmesh = cell(1, numfiles)
circumferences=[];
k=1
for var=1:19
inputfiles=dir('*.ply')
input=strcat('Target_25_',num2str(var),'.ply');

[Inputmesh{k}.vertices,Inputmesh{k}.faces]=read_ply(input)

[Inputmesh{k}.vertices,Inputmesh{k}.faces]=patchslim(Inputmesh{k}.vertices,In
putmesh{k}.faces);
  Inputmesh{k}.vertices=Inputmesh{k}.vertices/1000;



%%
endmode=10
for k=1
oldFolder=cd('C:\Users\Gale Dewo\OneDrive\thesis\thesis\charlienash\MANU
test\ssm');
X=1;
for X=1:1:endmode
    if X>1
        NR2=X  ;
        SSMfit_inter=[SSMfit(:,1);SSMfit(:,2);SSMfit(:,3)];
[RMSerror,ReallignedV,transform,SSMfit,EstimatedModes]=SSMfitter(SSMfit_inter
,Fdata,ssmV,ReallignedV,Inputmesh{k}.faces,NR2)

    else
clf

h=figure;
Fdata=ch;
Fdata=double(Fdata);
[NR1,NR2]=size(Modes);
NR2=X  ;
%
[RMSerror,ReallignedV,transform,SSMfit,EstimatedModes]=SSMfitter(MEAN,Fdata,s
smV,mydata{k}.vertices,mydata{k}.faces,NR2)
```

```
[RMSerror,ReallignedV,transform,SSMfit,EstimatedModes]=SSMfitter(MEAN,Fdata,s
smV,Inputmesh{k}.vertices,Inputmesh{k}.faces,NR2)
    end
% Source1.vertices=SSMfit;
% Source1.faces=Fdata;
%
% Target1.vertices=ReallignedV;
% Target1.faces=Inputmesh{k}.faces;


%Options.useNormals = 1;

end
cd(oldFolder)

if localdef==1
%Amberg
%iter=500;
%[pointsTransformed1{k}, X1{k}] = nricp(Source1, Target1, Options, iter,k);

%Manu
[SSMfit] = nonrigidICP(ReallignedV,SSMfit, Inputmesh{k}.faces,Fdata,10,1)

clf

patch('Faces',Fdata,'Vertices',SSMfit,'EdgeColor','black','FaceColor','green'
,'FaceAlpha',0.4,'LineWidth',0.002);
else
patch('Faces',Fdata,'Vertices',SSMfit,'EdgeColor','black','FaceColor','green'
,'FaceAlpha',0.4,'LineWidth',0.002);
grid on
axis equal
end
hold
%
patch('Faces',mydata{k}.faces,'Vertices',ReallignedV,'EdgeColor','black','Fac
eColor','blue','FaceAlpha',0.3,'LineWidth',0.002);
patch('Faces',Inputmesh{k}.faces,'Vertices',ReallignedV,'EdgeColor','none','F
aceColor','blue','FaceAlpha',0.3,'LineWidth',0.002)
grid off
axis equal
% pause
SSMfit(:,2)=SSMfit(:,2)-0.3;
% result{1,count}=[SSMfit]
count=count+1;

%Notes
%RUN the non-rigid ICP
%local pca shape modes
%try to make different cut length first
%target should be uniformly meshed
%make a regression model to start from
%
if showlandmark==1
clf
```

```
C = double(selectedPointsFull');
%
% REGRESSION PLANE FOR CIRCUMFERENCE %%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
[n_1,V_1,p_1]=affine_fit(SSMfit(vertex_numbers{3},:))
[n_2,V_2,p_2]=affine_fit(SSMfit(vertex_numbers{4},:))
[n_3,V_3,p_3]=affine_fit(SSMfit(vertex_numbers{5},:))
%plot the two points p_1 and p_2
plot3(p_1(1),p_1(2),p_1(3),'ro','markersize',15,'markerfacecolor','red');
plot3(p_2(1),p_2(2),p_2(3),'bo','markersize',15,'markerfacecolor','blue');
plot3(p_3(1),p_3(2),p_3(3),'bo','markersize',15,'markerfacecolor','green');
%plot the normal vector
h1 =
quiver3(p_1(1),p_1(2),p_1(3),n_1(1)/3,n_1(2)/3,n_1(3)/3,'r','linewidth',2)
h2 =
quiver3(p_2(1),p_2(2),p_2(3),n_2(1)/3,n_2(2)/3,n_2(3)/3,'b','linewidth',2)
h3 =
quiver3(p_3(1),p_3(2),p_3(3),n_3(1)/3,n_3(2)/3,n_3(3)/3,'b','linewidth',2)


%plot the two adjusted planes
[X,Y] = meshgrid(linspace(-0.05,0.25  ,3));

%first plane
surf(X,Y, - (n_1(1)/n_1(3)*X+n_1(2)/n_1(3)*Y-
dot(n_1,p_1)/n_1(3)),'facecolor','red','facealpha',0.5);
hold on
% out1=intersectPlaneSurf(p_1,n_1,SSMfit(:,1),SSMfit(:,2),SSMfit(:,3))
% hold on
surf(X,Y, - (n_2(1)/n_2(3)*X+n_2(2)/n_2(3)*Y-
dot(n_2,p_2)/n_2(3)),'facecolor','blue ','facealpha',0.5);
hold on
% out2=intersectPlaneSurf(p_2,n_2,SSMfit(:,1),SSMfit(:,2),SSMfit(:,3))
% hold on
[S1,S2] = meshgrid([-0.15  0 0.1]);
%generate the pont coordinates
X = p_3(1)+[S1(:) S2(:)]*V_3(1,:)';
Y = p_3(2)+[S1(:) S2(:)]*V_3(2,:)';
Z = p_3(3)+[S1(:) S2(:)]*V_3(3,:)';
%plot the plane
surf(reshape(X,3,3),reshape(Y,3,3),reshape(Z,3,3),'facecolor','blue','facealp
ha',0.5);

xlabel('x');
ylabel('y');
zlabel('z');
axis equal
%compute the angle between the planes in [0 90] degrees
angle = acosd(dot(n_1,n_2));
if angle>90
    angle = 180-angle;
end
angle

p =
patch('Faces',ch,'Vertices',SSMfit,'EdgeColor','black','FaceVertexCData',C);
p.FaceColor = 'interp';
```

```
colormap summer
grid off
axis equal



% PLANE INTERSECT 1 %%%%%%%%%%%%%%%%%%%%%%%%%%%
plane1=fourpoint(n_1,p_1);
plane2=fourpoint(n_2,p_2);

Surfacesource=[];
Surfacesource.vertices=SSMfit;
Surfacesource.faces=Fdata;

Surface1=[];
Surface1.vertices=plane1;
Surface1.faces=[1,2,3,;2,3,4];

Surface2=[];
Surface2.vertices=plane2;
Surface2.faces=[1,2,3,;2,3,4];

[~,Inters1]=SurfaceIntersection(Surfacesource,Surface1);
% Inters1.vertices(:,3) = -0.15; % project the contour lines on a single
plane
[~,Inters2]=SurfaceIntersection(Surfacesource,Surface2);
% Inters2.vertices(:,3) = -0.175; % project the contour lines on a single
plane

centerp1=[mean(Inters1.vertices(:,1));mean(Inters1.vertices(:,2));mean(Inters
1.vertices(:,3))]'
centerp2=[mean(Inters2.vertices(:,1));mean(Inters2.vertices(:,2));mean(Inters
2.vertices(:,3))]'
centerlinevec=[centerp2-centerp1]'

p75=centerlinevec'*0.75+centerp1;
p50=centerlinevec'*0.5+centerp1;
p25=centerlinevec'*0.25+centerp1;

plane1=fourpoint(centerlinevec,centerp1);
plane2=fourpoint(centerlinevec,centerp2);

plane75=fourpoint(centerlinevec,p75);
plane50=fourpoint(centerlinevec,p50);
plane25=fourpoint(centerlinevec,p25);



Surfacesource=[];
Surfacesource.vertices=SSMfit;
Surfacesource.faces=Fdata;

Surface1=[];
Surface1.vertices=plane1;
Surface1.faces=[1,2,3,;2,3,4];
```

```
Surface3=[];
Surface3.vertices=plane2;
Surface3.faces=[1,2,3,;2,3,4];

Surface75=[];
Surface75.vertices=plane75;
Surface75.faces=[1,2,3,;2,3,4];

Surface50=[];
Surface50.vertices=plane50;
Surface50.faces=[1,2,3,;2,3,4];

Surface25=[];
Surface25.vertices=plane25;
Surface25.faces=[1,2,3,;2,3,4];

[~,Inters1]=SurfaceIntersection(Surfacesource,Surface1);
circumference100=jarak(Inters1);
% Inters1.vertices(:,3) = -0.145; % project the contour lines on a single
plane

[~,Inters3]=SurfaceIntersection(Surfacesource,Surface3);
circumference0a=jarak(Inters2);
circumference0b=jarak(Inters3);
% Inters2.vertices(:,3) = -0.205;
% Inters3.vertices(:,3) = -0.215;

[~,Inters75]=SurfaceIntersection(Surfacesource,Surface75);
circumference25=jarak(Inters75);
% Inters75.vertices(:,3) = -0.185;

[~,Inters50]=SurfaceIntersection(Surfacesource,Surface50);
circumference50=jarak(Inters50);
% Inters75.vertices(:,3) = -0.175;

[~,Inters25]=SurfaceIntersection(Surfacesource,Surface25);
circumference75=jarak(Inters25);
% Inters75.vertices(:,3) = -0.165;
%%
% plot the results
figure(1); clf; hold on
S=Surfacesource; trisurf(S.faces,
S.vertices(:,1),S.vertices(:,2),S.vertices(:,3),'FaceAlpha', 0.5,
'FaceColor', 'g')
% S=Surface1; trisurf(S.faces,
S.vertices(:,1),S.vertices(:,2),S.vertices(:,3),'FaceAlpha', 0.5,
'FaceColor', 'r')
% S=Surface2; trisurf(S.faces,
S.vertices(:,1),S.vertices(:,2),S.vertices(:,3),'FaceAlpha', 0.5,
'FaceColor', 'b')
% S=Surface3; trisurf(S.faces,
S.vertices(:,1),S.vertices(:,2),S.vertices(:,3),'FaceAlpha', 0.5,
'FaceColor', 'm')
```

```
% S=Surface75; trisurf(S.faces,
S.vertices(:,1),S.vertices(:,2),S.vertices(:,3),'FaceAlpha', 0.5,
'FaceColor', 'y')
% S=Surface50; trisurf(S.faces,
S.vertices(:,1),S.vertices(:,2),S.vertices(:,3),'FaceAlpha', 0.5,
'FaceColor', 'g')
% S=Surface25; trisurf(S.faces,
S.vertices(:,1),S.vertices(:,2),S.vertices(:,3),'FaceAlpha', 0.5,
'FaceColor', 'c')
S=Inters1;   line(...
  [S.vertices(S.edges(:,1),1), S.vertices(S.edges(:,2),1)]',...
  [S.vertices(S.edges(:,1),2), S.vertices(S.edges(:,2),2)]',...
  [S.vertices(S.edges(:,1),3), S.vertices(S.edges(:,2),3)]',...
  'Color', 'r','LineWidth',2);
S=Inters2;   line(...
  [S.vertices(S.edges(:,1),1), S.vertices(S.edges(:,2),1)]',...
  [S.vertices(S.edges(:,1),2), S.vertices(S.edges(:,2),2)]',...
  [S.vertices(S.edges(:,1),3), S.vertices(S.edges(:,2),3)]',...
  'Color', 'b','LineWidth',2);
S=Inters3;   line(...
  [S.vertices(S.edges(:,1),1), S.vertices(S.edges(:,2),1)]',...
  [S.vertices(S.edges(:,1),2), S.vertices(S.edges(:,2),2)]',...
  [S.vertices(S.edges(:,1),3), S.vertices(S.edges(:,2),3)]',...
  'Color', 'm','LineWidth',2);
% S=Inters75;   line(...
%   [S.vertices(S.edges(:,1),1), S.vertices(S.edges(:,2),1)]',...
%   [S.vertices(S.edges(:,1),2), S.vertices(S.edges(:,2),2)]',...
%   [S.vertices(S.edges(:,1),3), S.vertices(S.edges(:,2),3)]',...
%   'Color', 'y','LineWidth',2);
% S=Inters50;   line(...
%   [S.vertices(S.edges(:,1),1), S.vertices(S.edges(:,2),1)]',...
%   [S.vertices(S.edges(:,1),2), S.vertices(S.edges(:,2),2)]',...
%   [S.vertices(S.edges(:,1),3), S.vertices(S.edges(:,2),3)]',...
%   'Color', 'g','LineWidth',2);
% S=Inters25;   line(...
%   [S.vertices(S.edges(:,1),1), S.vertices(S.edges(:,2),1)]',...
%   [S.vertices(S.edges(:,1),2), S.vertices(S.edges(:,2),2)]',...
%   [S.vertices(S.edges(:,1),3), S.vertices(S.edges(:,2),3)]',...
%   'Color', 'c','LineWidth',2);
axis equal
view(-100,-5)
set(gca,'visible','off')
saveas(gcf,strcat('circumference_',num2str(var),'.png'))
% pause
%%
% figure(1); clf; hold on
% S=Surfacesource; trisurf(S.faces,
S.vertices(:,1),S.vertices(:,2),S.vertices(:,3),'FaceAlpha', 0.5,
'FaceColor', 'r')
%
% axis equal


% Inters1.vertices=Inters1.vertices*1000;
% Inters2.vertices=Inters2.vertices*1000;
```

```
else
end
% saveas(h,sprintf('FIG_SSMfit7500_%d.fig',k));
%

end
%% width and depth
depthlist=[];
for n=1:length(Inters1.vertices)
depthtemp=sum((centerp1-Inters1.vertices(n)).^2).^0.5;
depthlist=[depthlist depthtemp]
end

depthver11=min(depthlist)
depthver22=max(depthlist)
depthver1=[depthver1 depthver11];
depthver2=[depthver2 depthver22];
%% GEODESIC DISTANCE %%%%%%%%%%%%%%%%%%%%%%%%
B=max(Inters1.vertices(:,2))
[~, Bpoints] = ismember(B, Inters1.vertices(:, 2), 'rows');

Bmin=min(Inters1.vertices(:,2))
[~, Bminpoints] = ismember(Bmin, Inters1.vertices(:, 2), 'rows');

% endB(Bpoints,:)

startsA=[Inters1.vertices(Bpoints,:);Inters1.vertices(Bminpoints,:)];

Cpoints = dsearchn(SSMfit,startsA)

B=max(Inters3.vertices(:,2))
[~, Bpoints] = ismember(B, Inters3.vertices(:, 2), 'rows');

Bmin=min(Inters3.vertices(:,2))
[~, Bminpoints] = ismember(Bmin, Inters3.vertices(:, 2), 'rows');

% endB(Bpoints,:)

startsB=[Inters3.vertices(Bpoints,:);Inters3.vertices(Bminpoints,:)];

C2points = dsearchn(SSMfit,startsB)

%%
Dep=max(Inters1.vertices(:,1))
[~, Deppoints] = ismember(Dep, Inters1.vertices(:, 1), 'rows');

Depmin=min(Inters1.vertices(:,1))
[~, Depminpoints] = ismember(Depmin, Inters1.vertices(:, 1), 'rows');

% endB(Bpoints,:)

startsADep=[Inters1.vertices(Deppoints,:);Inters1.vertices(Depminpoints,:)];

DepXpoints = dsearchn(SSMfit,startsADep)
```

```
Dep=max(Inters3.vertices(:,1))
[~, Deppoints] = ismember(Dep, Inters3.vertices(:, 1), 'rows');

Depmin=min(Inters3.vertices(:,1))
[~, Depminpoints] = ismember(Depmin, Inters3.vertices(:, 1), 'rows');

% endB(Bpoints,:)

startsDep=[Inters3.vertices(Deppoints,:);Inters3.vertices(Depminpoints,:)];

Dep2points = dsearchn(SSMfit,startsDep)

DepA1=SSMfit(DepXpoints(1),:)
DepA2=SSMfit(DepXpoints(2),:)
DepB1=SSMfit(Cpoints(1),:)
DepB2=SSMfit(Cpoints(2),:)
depth=sum((DepA1-DepA2).^2).^0.5
Depth=[Depth depth]
width=sum((DepB1-DepB2).^2).^0.5
Width=[Width width]

%%
cd 'C:\Users\Gale Dewo\OneDrive\thesis\thesis\charlienash\MANU test\geodesic'
idx1=0;
idx2=0;

idx1=randperm(length(vertex_numbers{1}),1);
idx2=randperm(length(vertex_numbers{2}),1);
% start_point=datasample(vertex_numbers{1},1,'Replace',false)
% end_point=datasample(vertex_numbers{2},1,'Replace',false)
start_point=vertex_numbers{1}(datasample(idx1,1))
end_point=vertex_numbers{2}(datasample(idx2,1))
%
[jarakgeodesic,jarakeuclidean]=measure_point(SSMfit.*1000,Fdata,start_point,e
nd_point)
% pause
[jarakgeodesic2,jarakeuclidean2]=measure_point(SSMfit.*1000,Fdata,Cpoints(2,1
),C2points(2,1))
saveas(gcf,strcat('geodesic1_',num2str(var),'.png'))
% pause

[jarakgeodesic3,jarakeuclidean3]=measure_point(SSMfit.*1000,Fdata,Cpoints(1,1
),C2points(1,1))
% saveas(gcf,strcat('geodesic2_',num2str(var),'.png'))
cd(oldFolder)

circumferences(var,:)=[circumference100,circumference75,circumference50,circu
mference25,circumference0a,circumference0b,jarakgeodesic,jarakeuclidean,jarak
geodesic2,jarakeuclidean2,jarakgeodesic3,jarakeuclidean3];

% pause
end
%
waktu2=toc;
```

E

Guide of Using the Code

1. Installing the required softwares :

- MATLAB 2017a with all Toolbox
- MATLAB Support for MinGW-w64 C/C++ Compiler
- Geometry Processing Toolbox by Alec Jacobson (included in the file package)
- nonrigidICP MATLAB code by Manu (included in the file package)
- Shape Model Builder by Manu (included in the file package)
- Exact geodesic for triangular meshes by Danil Kirsanov (included in the file package)
- Surface Reconstruction from scattered points cloud by Luigi Giaccari (included in the file package)
- ACVD from CREATIS
- Meshlab 2016.12

2. Using the code (Pre-MATLAB)

- Prepare surfaces from STL or PLY files.
- Remesh the surfaces by using ACVD Software. Put the files in the acvd folder. Individually, the command for using is by using command prompt in the ACVD folder “ACVD.exe filename.ply 3750 no”. The 3750 specify the number of vertices that is desired. Change number if desired. The result is output_1.ply. Use acvdauto.m for batch files. Modify the code as desired.
- Put the remeshed surface files in the main folder as the file package

3. Using the SSM Builder (MATLAB)

- Specify the type of file for STL or PLY files are used. (PLY if files are remeshed with ACVD)
- Run the code for building the SSM. Specify the source surface from the files by changing the N variable. Use runmode = 1 for fastest registration. Use runmode = 0 to see each surface registration in figure, although slower.
- Specify tempfiles for the total number of files that is going to be registered.
- To see the principal components, specify k number for the shape mode that wanted to be shown.
- After the Shape model is completed, annotate the landmark points. Specify the landmark numbers by changing the variable.
- For now, the vertex_number(1) and (2) are landmark points, vertex_number(3), (4), and(5) are belt vertices for circumference measurement.
- OPTIONAL: Insert pause commands to see the result of each step.

4. Using the SSM Fitter (MATLAB)

- Run a mat file to specify a SSM that is going to be used.
- Put the target files on the main folder. It is desirable to have the target remeshed with ACVD before.
- The naming should be specified that variable 'var' is specifying the file number. The input file naming detection is specified with 'input' variable.
- Specify using local deformation or not (1 if yes, 0 if not).
- Specify the number of shape modes that is going to be used by changing the 'endmode' variable
- Specify var = 1:numberoffiles depending on the total number of files to run, or specify var = filenumber if only specific surface is desired.
- IMPORTANT! Check the directory path. Change `cd 'C:\Users\Gale Dewo\OneDrive\thesis\thesis\charlienash\MANU test'` and `cd 'C:\Users\Gale Dewo\OneDrive\thesis\thesis\charlienash\MANU test\geodesic'` if necessary. Also change all 'oldFolder' variables to avoid directory problems.
- The result numbers are shown in variable 'circumferences', 'depthver1', and 'depthver2'
- The result figures are shown in main folder as 'circumference_xx.png' and in the geodesic folder as 'geodesic1_xx.png' with xx as the surface number.
- OPTIONAL: Uncomment the Pause lines to see the result of each step.