EXTRACTING PLACENTAL BLOOD VESSELS FROM 3-D DATA

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Math 579: Mathematical Modeling

with Dr.Jen-Mei Chang

Spring 2011

PWACA
PROJECT WITHOUT A COOL ACRONYM

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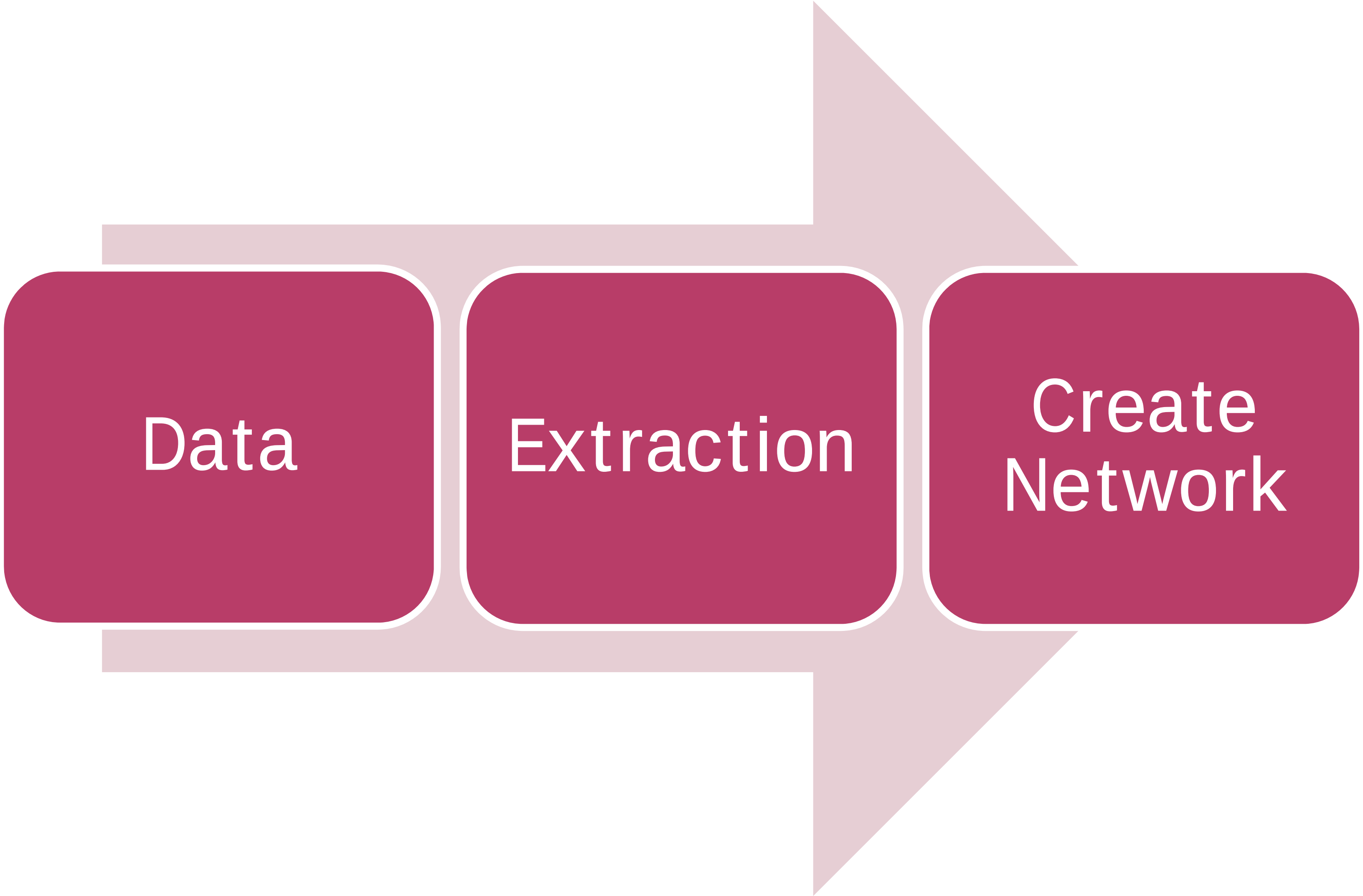
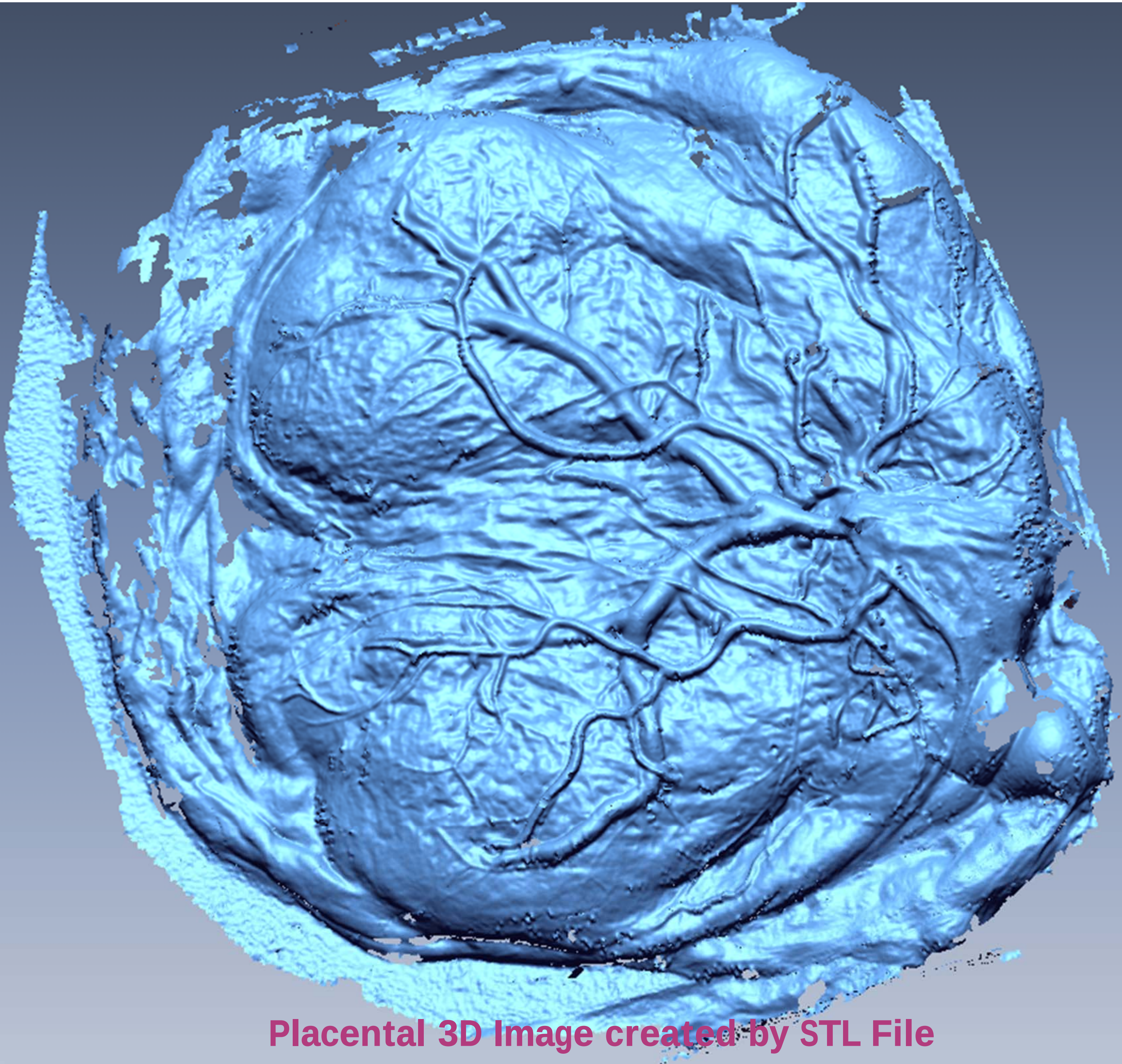
INTRODUCTION: OBJECTIVE

- We will analyze the structure of a 3D model of a human placenta, in order to extract the network of placental blood vessels that protrude above the placental surface.

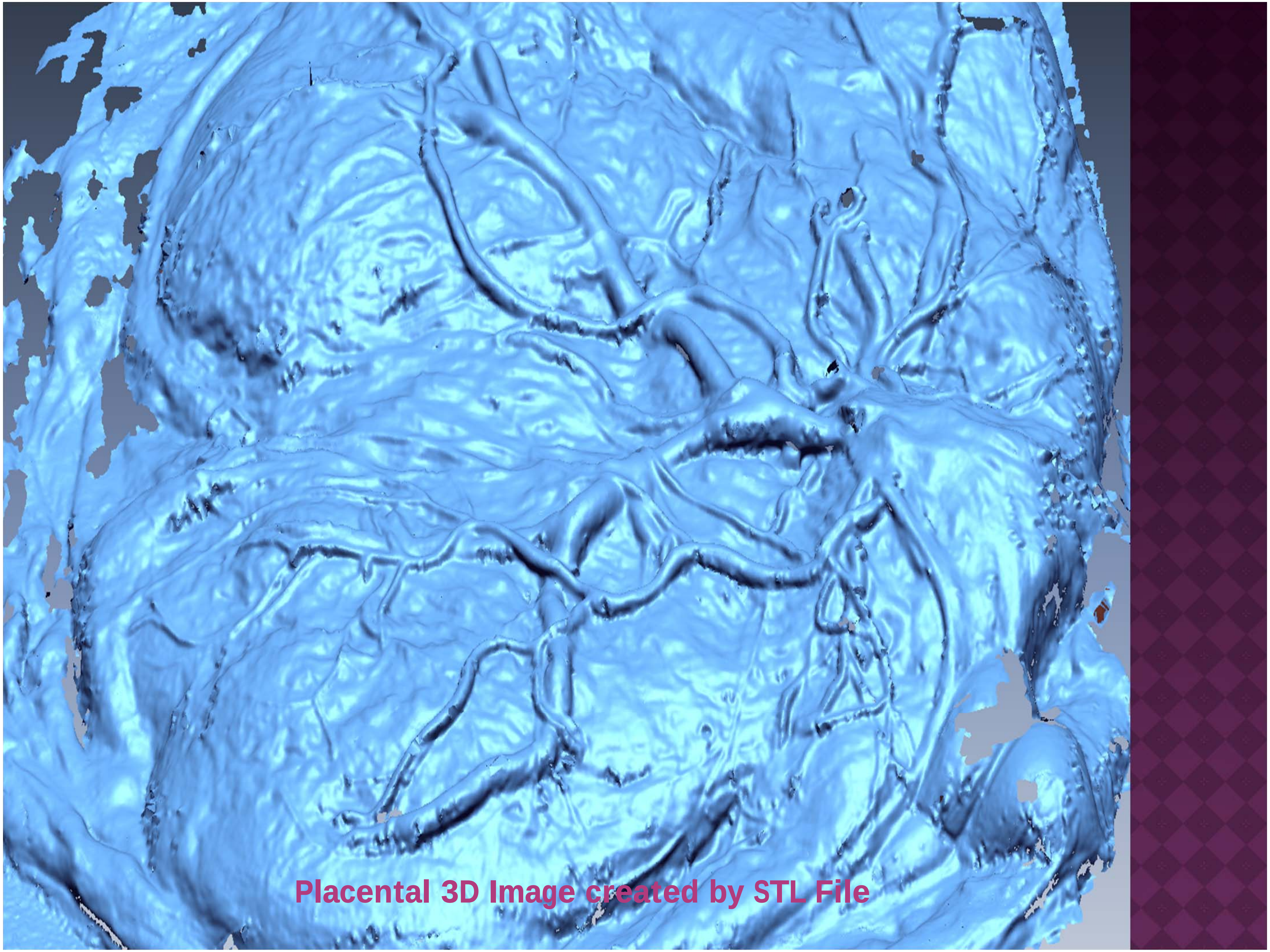
- We will reconstruct this network in 3D, to allow for blood-flow volume analysis.

INTRODUCTION: PROCESS

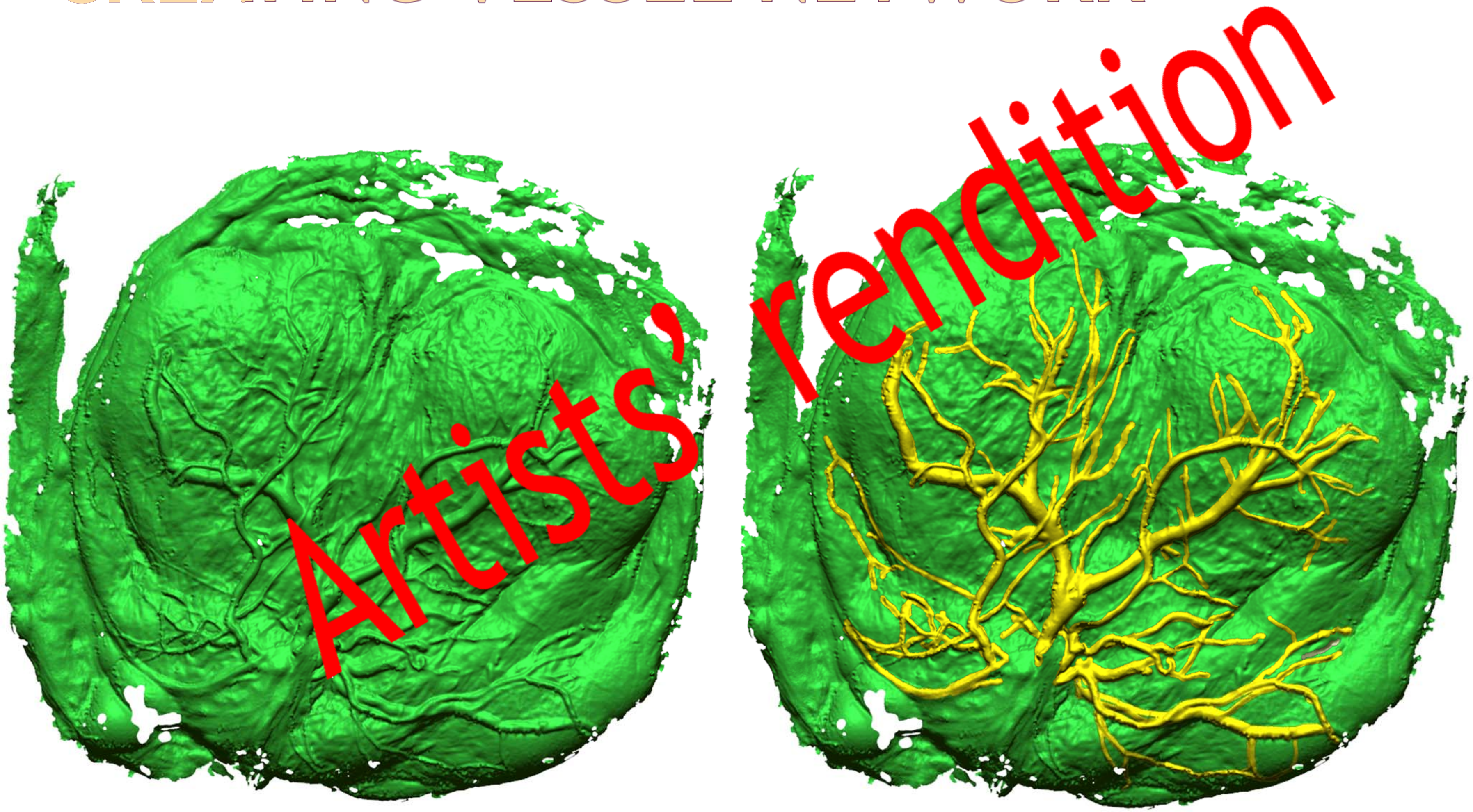




Placental 3D Image created by STL File


Placental 3D Image created by STL File

CREATING VESSEL NETWORK



3D Mesh created from STL

Vessel Extraction

RESEARCH METHOD: DATA

- The data we use is from an STL file already provided by researchers.

What is an STL file?

▪ **STL** (stereolithogrpahy) is a file format software created to store information on 3D objects, and to reproduce a physical 3D model.

▪ STL files describe only the surface geometry of a three dimensional object without any representation of color or texture.

▪ STL format specifies both ASCII and binary (more common) representations.

▪ STL file reproduces an object's 3D geometry by storing a set number of 3D triangulated surface, by the unit normal and vertices of the triangles using a 3-dimensional Cartesian coordinate system

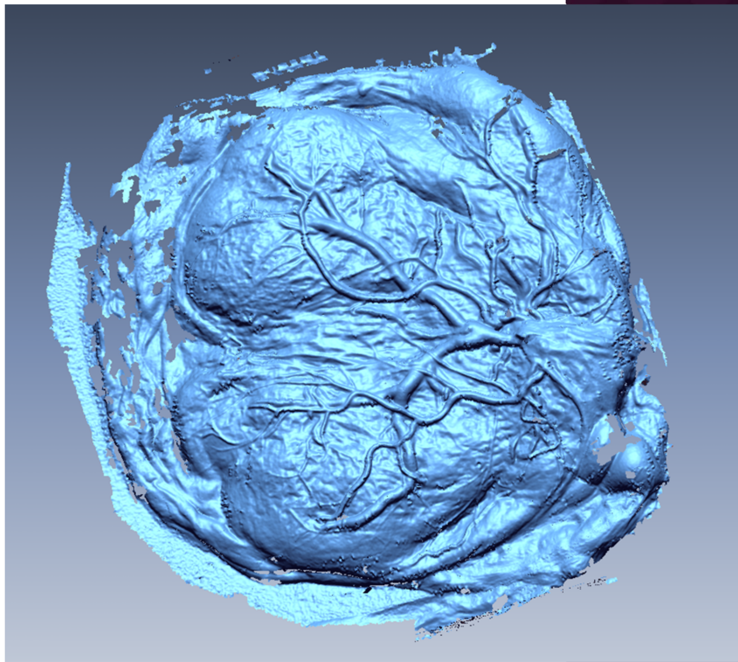
RESEARCH METHOD: DATA

STL Example: Tetrahedron

```
SOLID TRI
    FACET NORMAL 0.0 0.0 -1.0
      OUTER LOOP
        VERTEX -1.5 -1.5 1.4
        VERTEX 0.0 1.7 1.4
        VERTEX 1.5 -1.5 1.4
      ENDLOOP
    ENDFACET
    FACET NORMAL 0.0 0.88148 0.472221
      OUTER LOOP
        VERTEX -1.5 -1.5 1.4
        VERTEX 1.5 -1.5 1.4
        VERTEX 0.0 0.0 -1.4
      ENDLOOP
    ENDFACET
    FACET NORMAL -0.876814 -0.411007 0.24954
      OUTER LOOP
        VERTEX 1.5 -1.5 1.4
        VERTEX 0.0 1.7 1.4
        VERTEX 0.0 0.0 -1.4
      ENDLOOP
    ENDFACET
    FACET NORMAL 0.876814 -0.411007 0.24954
      OUTER LOOP
        VERTEX 0.0 1.7 1.4
        VERTEX -1.5 -1.5 1.4
        VERTEX 0.0 0.0 -1.4
      ENDLOOP
    ENDFACET
  ENDSOLID TRI
```

OUR PLACENTA STL

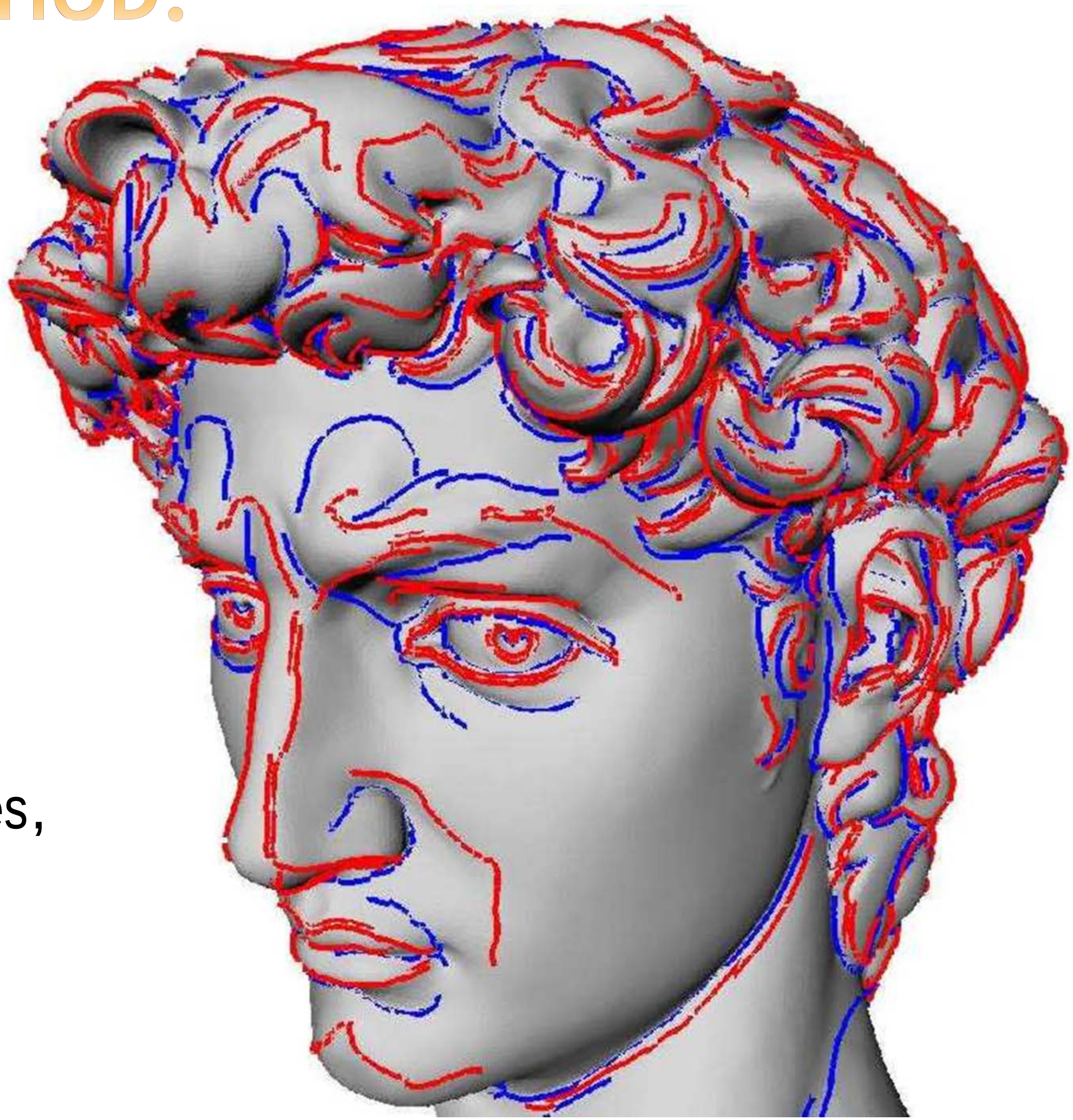
```
facet normal  3.620636e-01  9.210081e-01 -1.437154e-01
  outer loop
    vertex   5.528387e+01  1.902180e+01 -4.269304e+01
    vertex   5.478359e+01  1.926661e+01 -4.238448e+01
    vertex   5.545042e+01  1.912409e+01 -4.161794e+01
  endloop
endfacet
facet normal  3.112122e-01  9.455894e-01 -9.490848e-02
  outer loop
    vertex   5.482898e+01  1.935173e+01 -4.138762e+01
    vertex   5.545042e+01  1.912409e+01 -4.161794e+01
    vertex   5.478359e+01  1.926661e+01 -4.238448e+01
  endloop
endfacet
facet normal  1.307343e-02  9.973741e-01 -7.123253e-02
  outer loop
    vertex   5.682782e+01  1.924272e+01 -4.126116e+01
    vertex   5.651205e+01  1.912408e+01 -4.298034e+01
    vertex   5.645091e+01  1.926258e+01 -4.105225e+01
  endloop
endfacet
```



25,923 pages of data!

RESEARCH METHOD: CGAL

- Computational Geometry Algorithm Library: A library that contains algorithms for computational geometry.
- Discover **ridges** on triangulated surfaces, ie. protruding blood vessels in our placental 3D model.



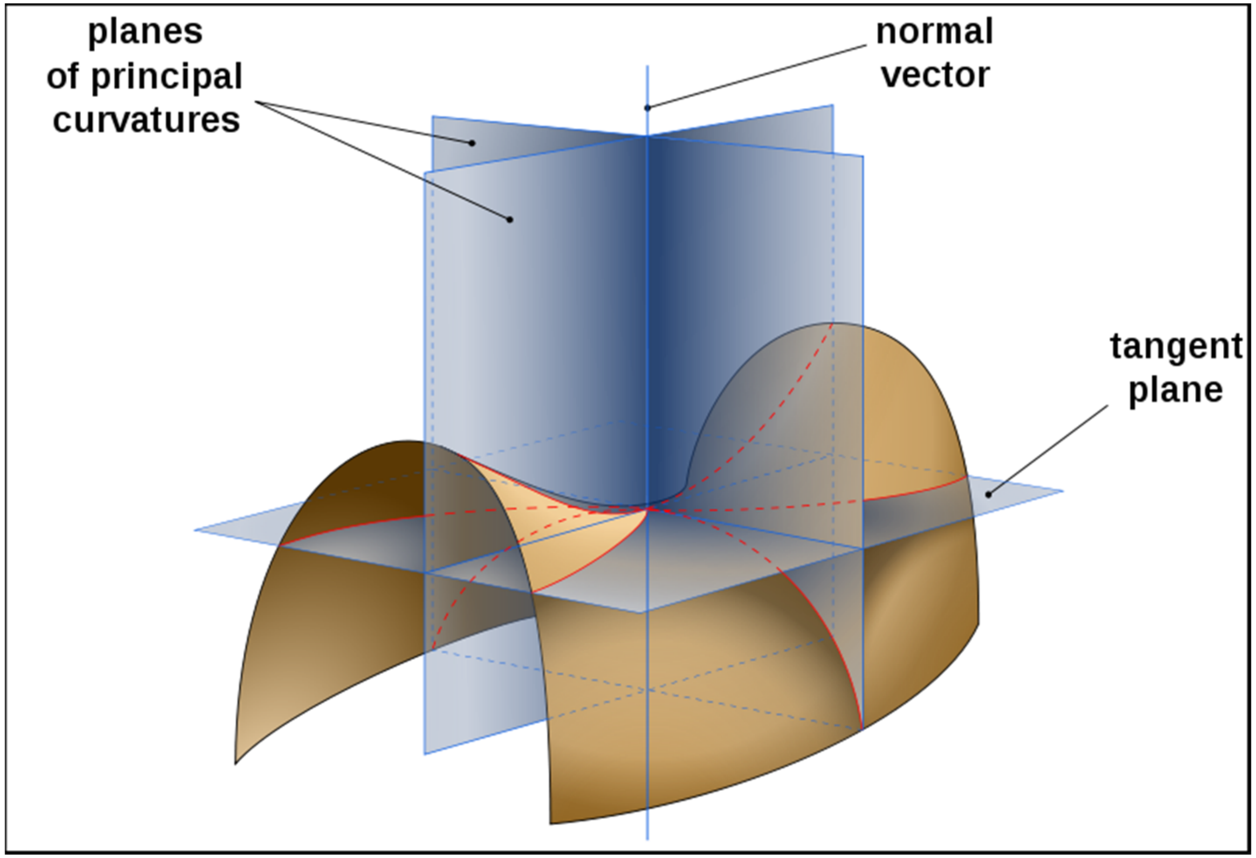
Crest ridges of *David*

RESEARCH METHOD: DISCOVERING RIDGES

- **Ridge:** Given a smooth surface, a ridge is a curve along which one of the principal curvatures has an extremum along its curvature line.

k_1, k_2 = the principal curvatures

$\langle dk_1, dk_2 \rangle$ = the inner product of the gradients of the principal curvatures



RESEARCH METHOD: EXTRACTING RIDGES

- **Max ridge point** = when the extremality coefficient vanishes, i.e. $b_0 = \langle dk_1, d_1 \rangle = 0$

- **Min ridge point** = when the extremality coefficient vanishes, i.e. $b_3 = \langle dk_2, d_2 \rangle = 0$

k_1, k_2 = the principal curvatures

$\langle dk_1, dk_2 \rangle$ = the inner product of the gradients of the principal curvatures

RESEARCH METHOD: SOFTWARE DEMO…

Too few points to perform the fitting

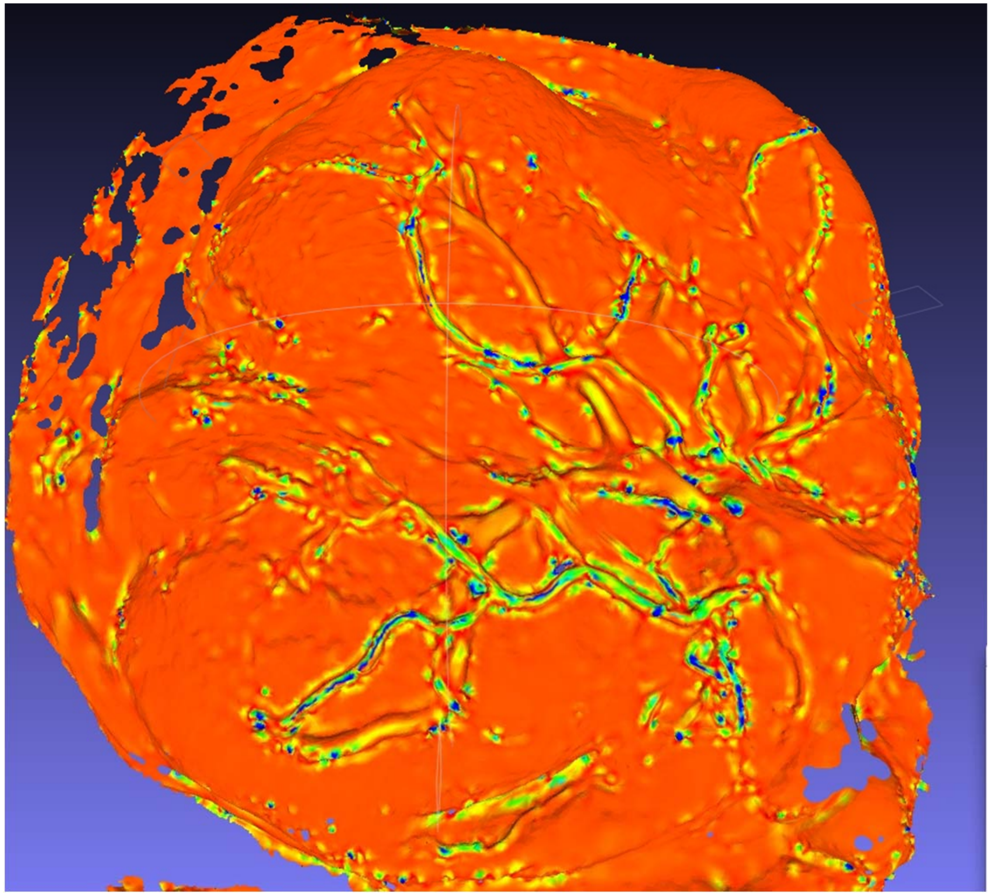
"TOO FEW POINTS TO PERFORM THE FITTING"

- What does this mean? Any suggestions?

- Our current options:
  - Re-visit CGAL Algorithm to locate and attempt to fix error
  - Create our own Algorithm to extract ridges
  - Suggestions?

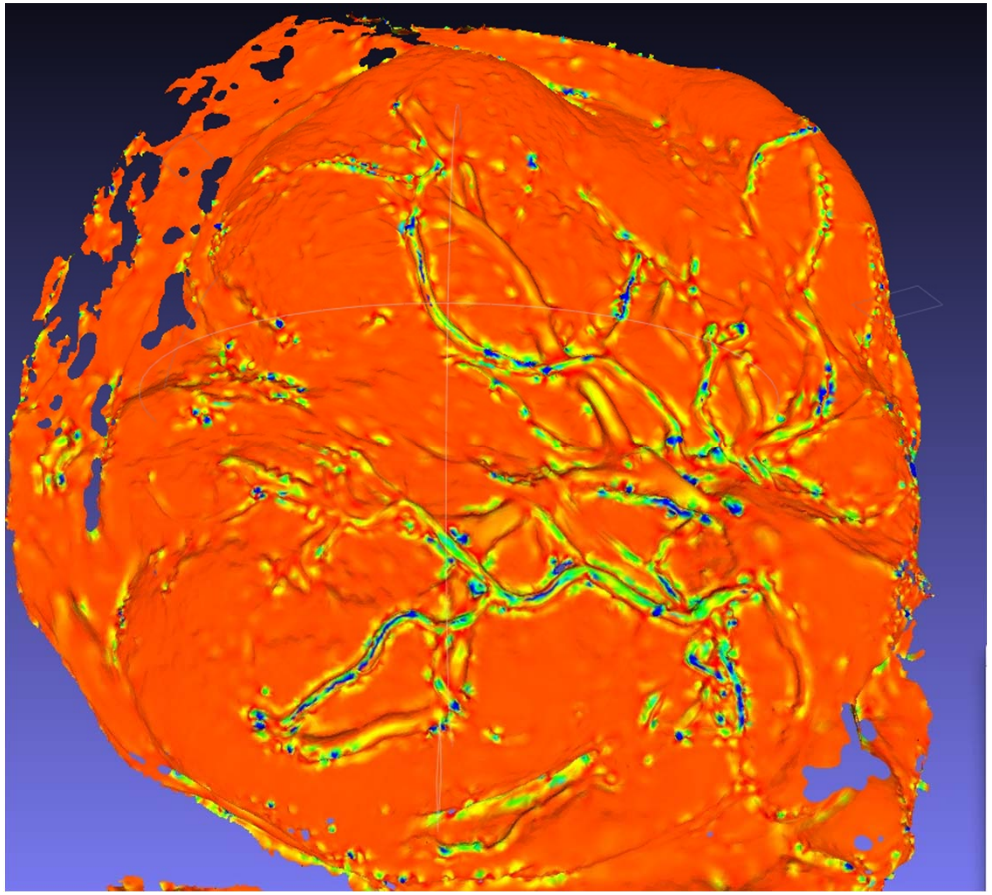
RESEARCH METHOD: BACK TO FIRST PRINCIPLES

- Calculate the underlying Gaussian curvature.
- Using extremes of curvature, pinpoint the areas that are likely candidates for vessels.
- Extract the appropriate geometry.



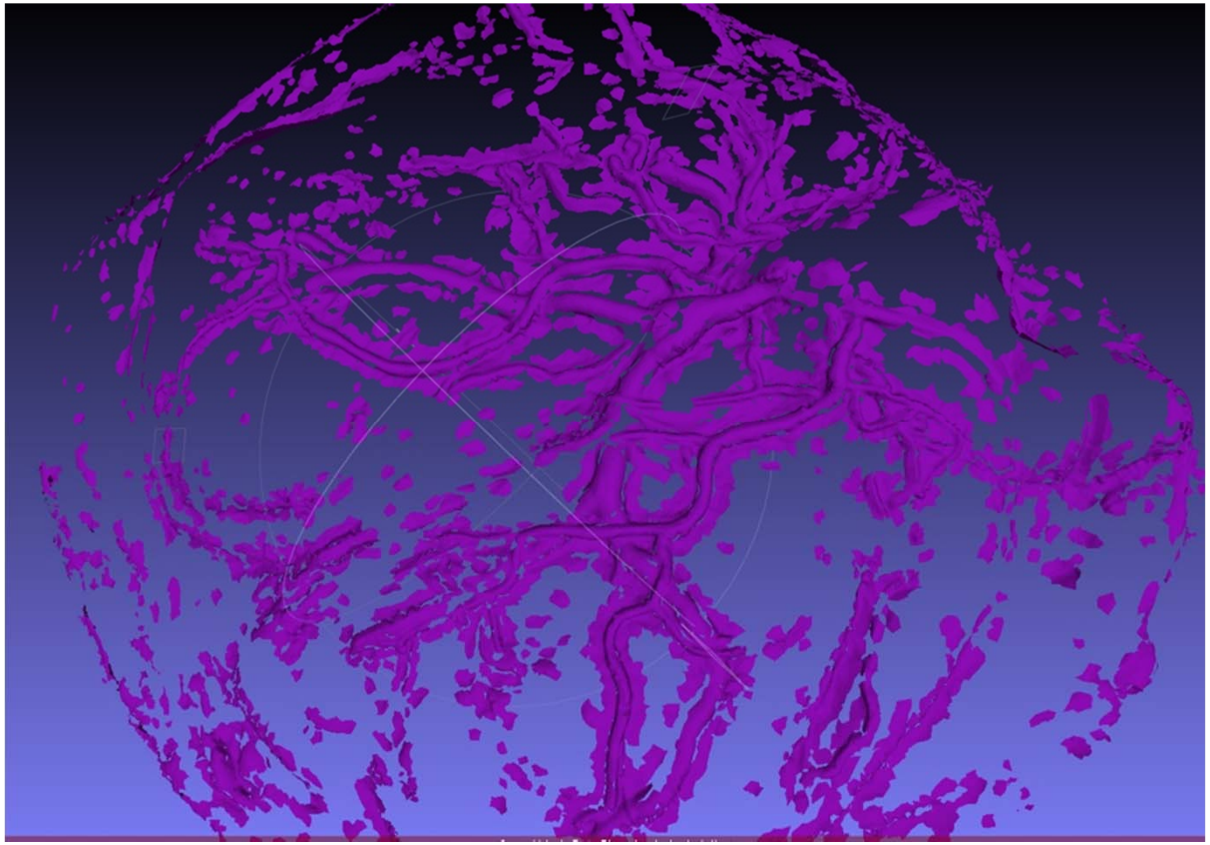
RESEARCH METHOD: CALCULATE THE UNDERLYING CURVATURE

- Colored areas have extreme curvature.
- By eliminating other areas, we can extract primary features.



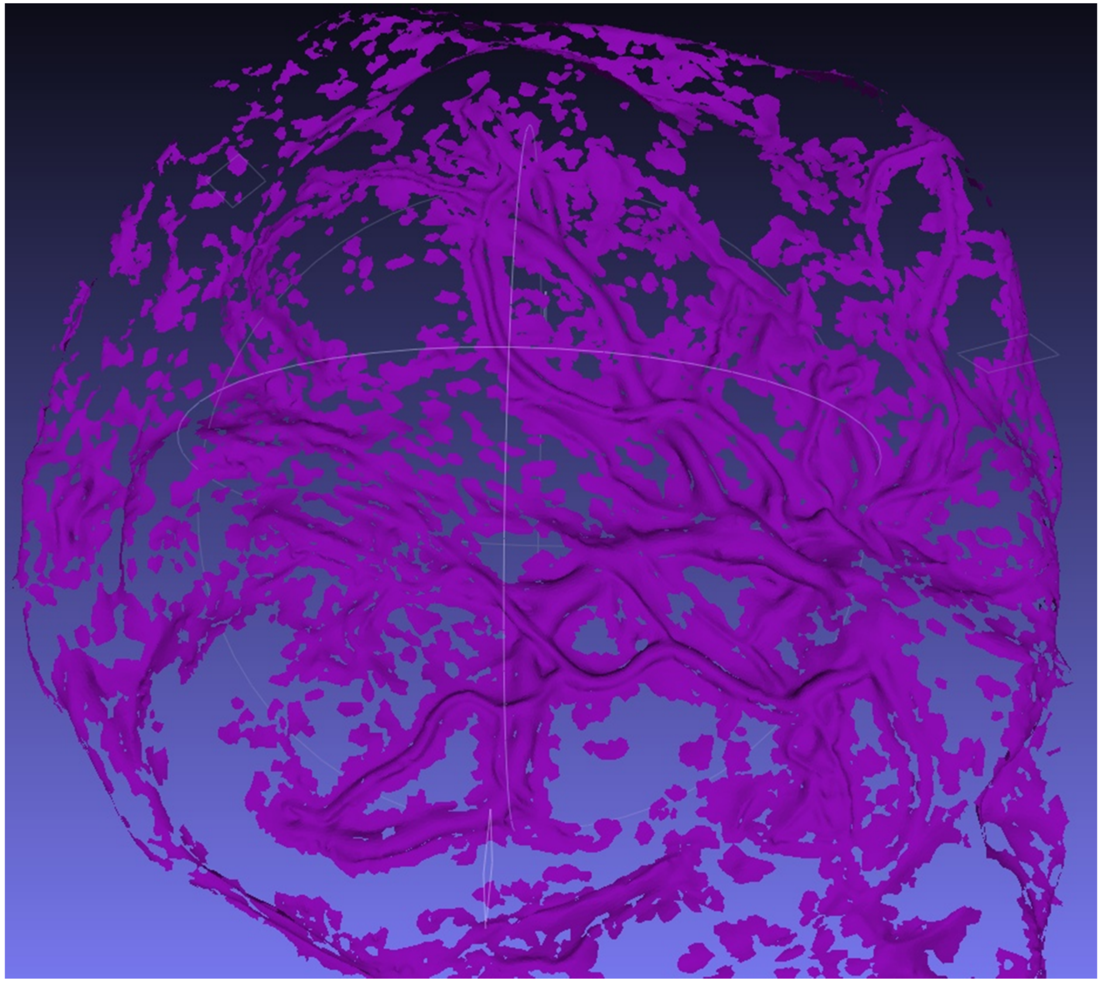
RESEARCH METHOD: PINPOINT LIKELY VESSEL LOCATIONS

- Areas of extreme curvature isolated.
- Need to work on eliminating noise in the data.



RESEARCH METHOD: USE SMOOTHING OVER THE SURFACE TO REDUCE NOISE

- May eliminate much of the superfluous geometry.
- Can be done very cheaply compared to the actual curvature calculations.`



FUTURE WORK…

- Continue researching and exploring other methods and algorithms to extract ridges from STL data
- Create vessel network

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4. **STL Files**

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   Last accessed on 03/17/11

5. **CGAL**

   Website: http://www.cgal.org/Manual/latest/doc_html/cgal_manual/Ridges_3/Chapter_main.html

   Last accessed on 03/17/11

6. **Principal Curvature**

   Website: http://en.wikipedia.org/wiki/File:Minimal_surface_curvature_planes-en.svg

   Last accessed on 03/17/11

ACKNOWLEDGEMENTS

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THANK YOU.

YOUR TURN: QUESTIONS ???

FINALLY, ALL OF US CAN ENJOY OUR

SPRING BREAK !!!