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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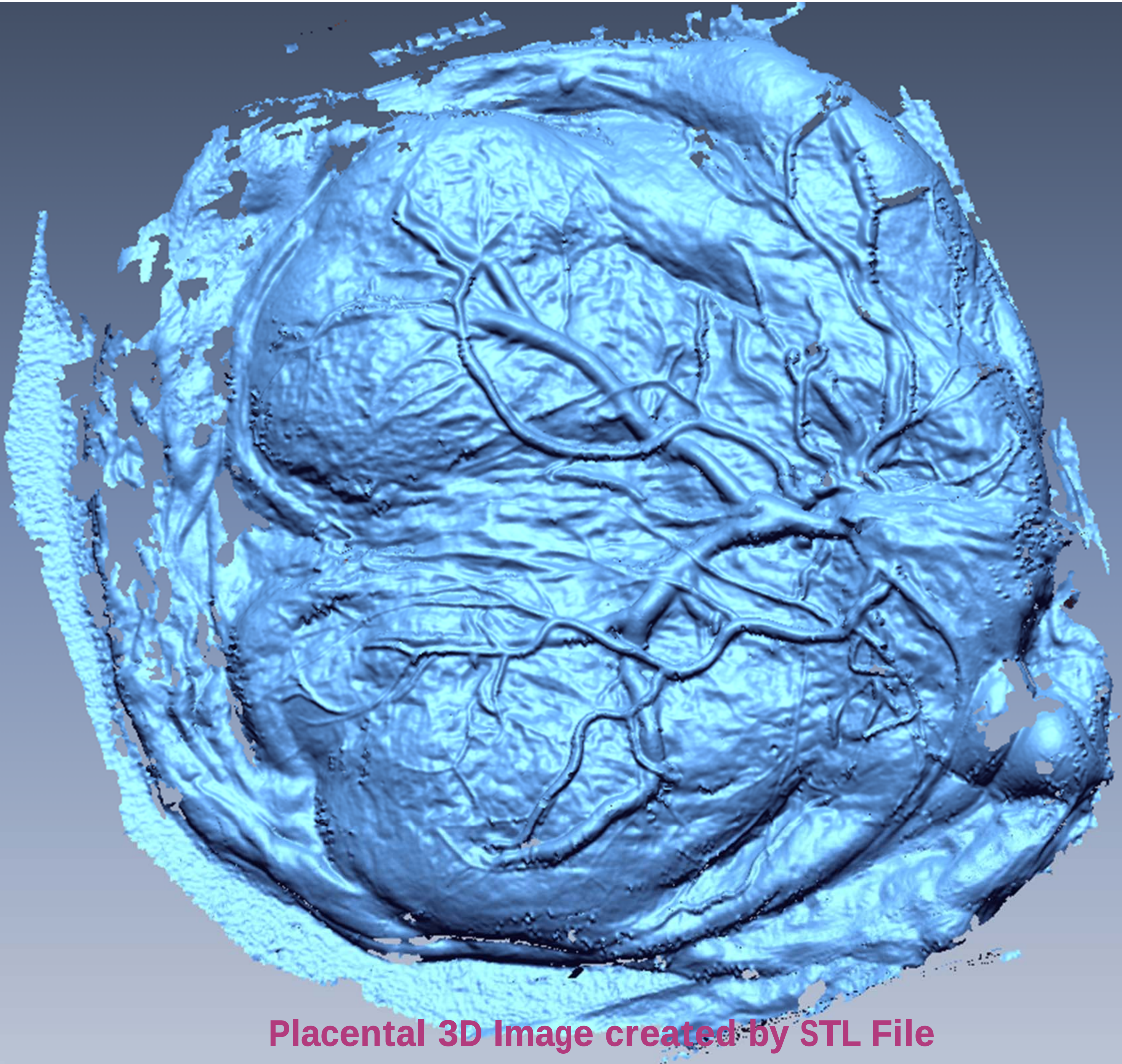
TABLE OF CONTENT

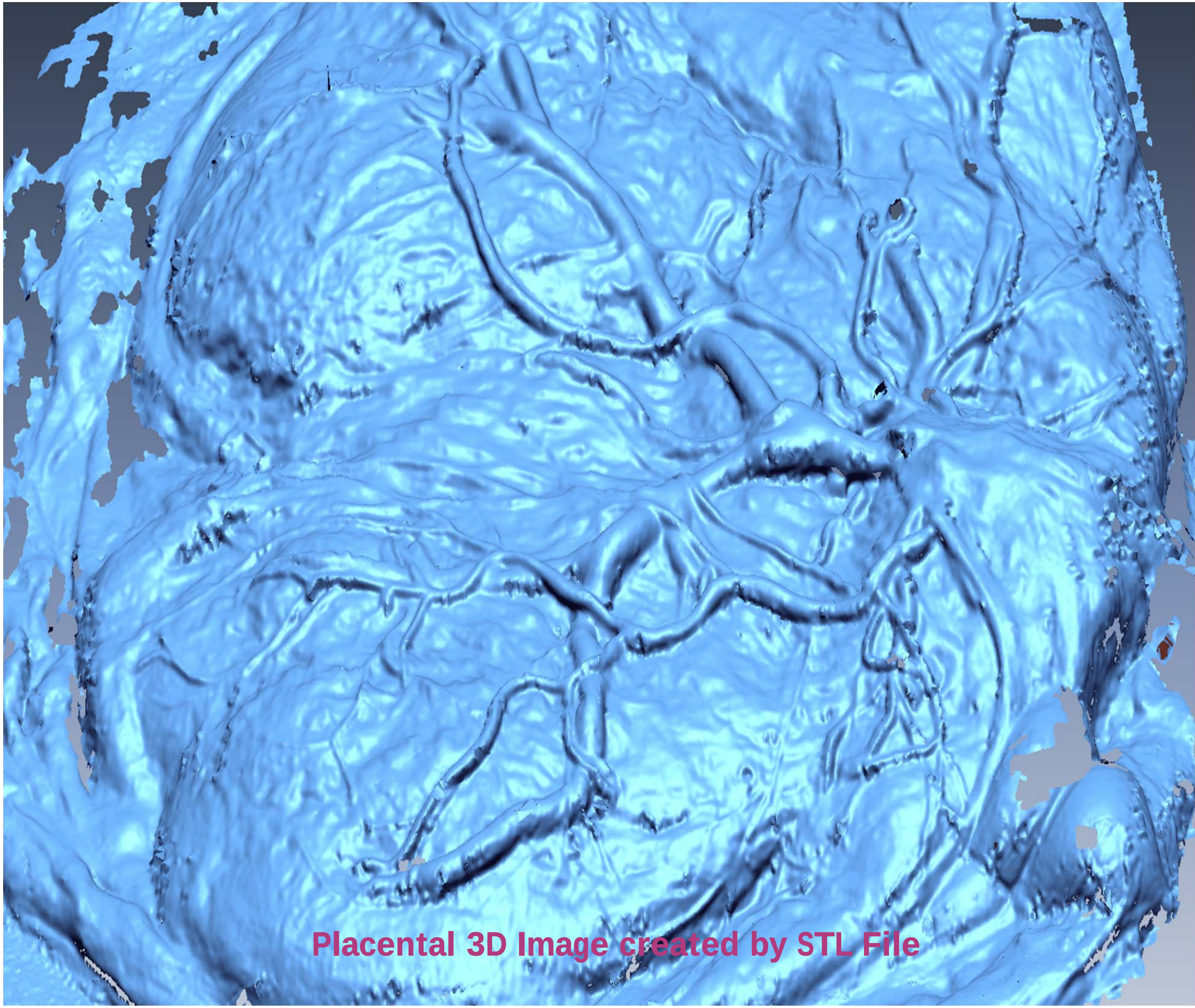
INTRODUCTION: OBJECTIVE

- 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.

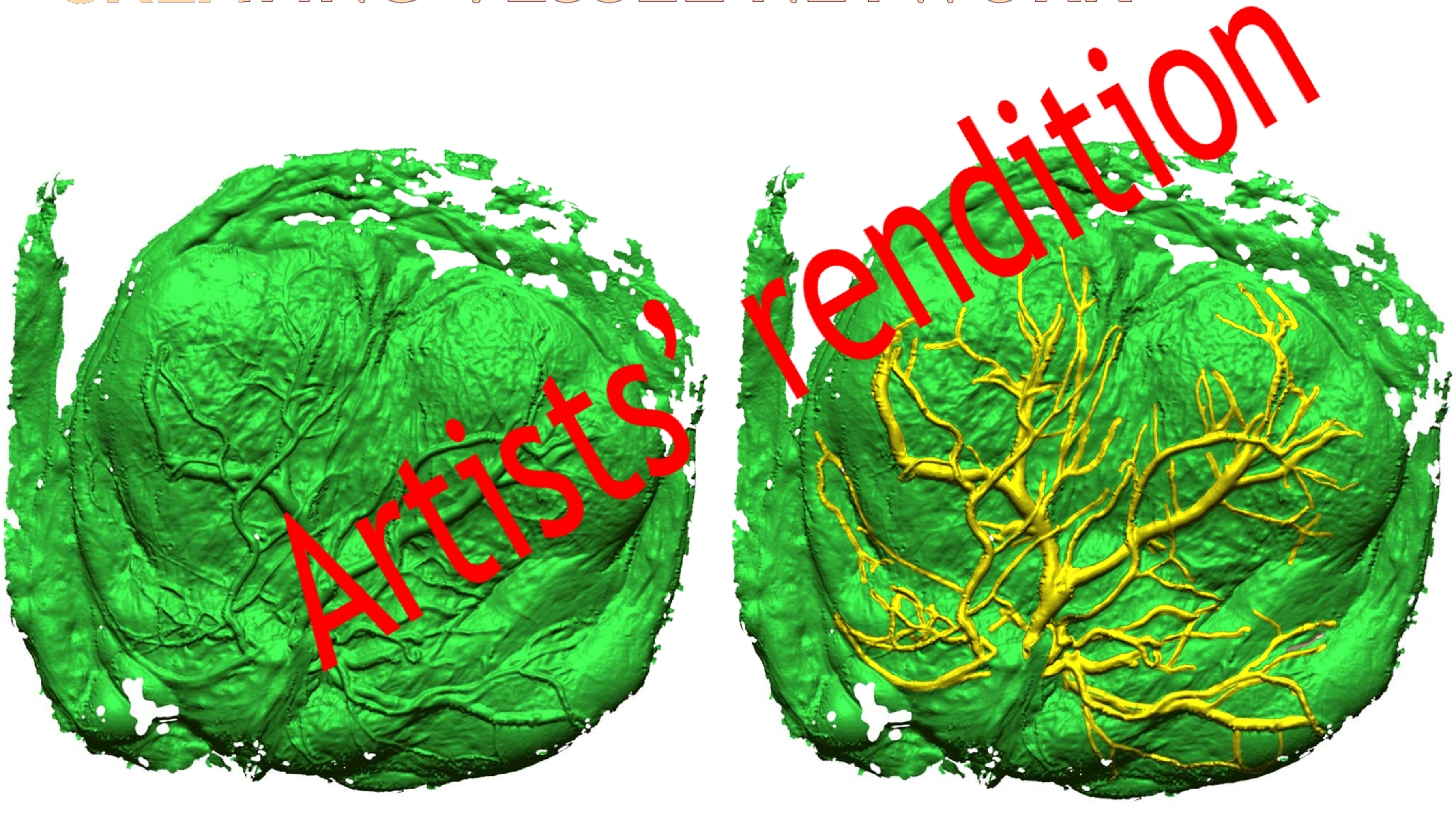


Placental 3D Image created by STL File



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

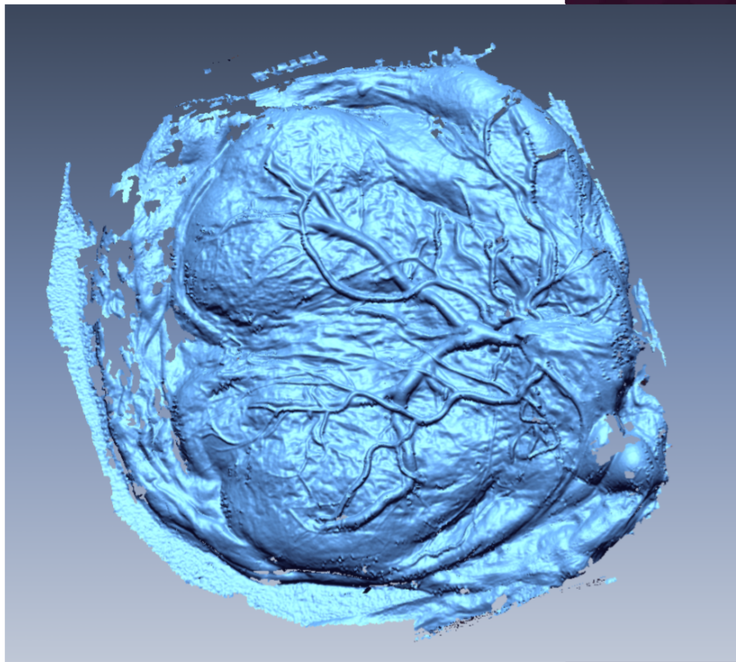
RESEARCH METHOD: DATA

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
```



199,970 triangles

Order: *Arbritary*

ATTEMPTED METHOD 1: 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.

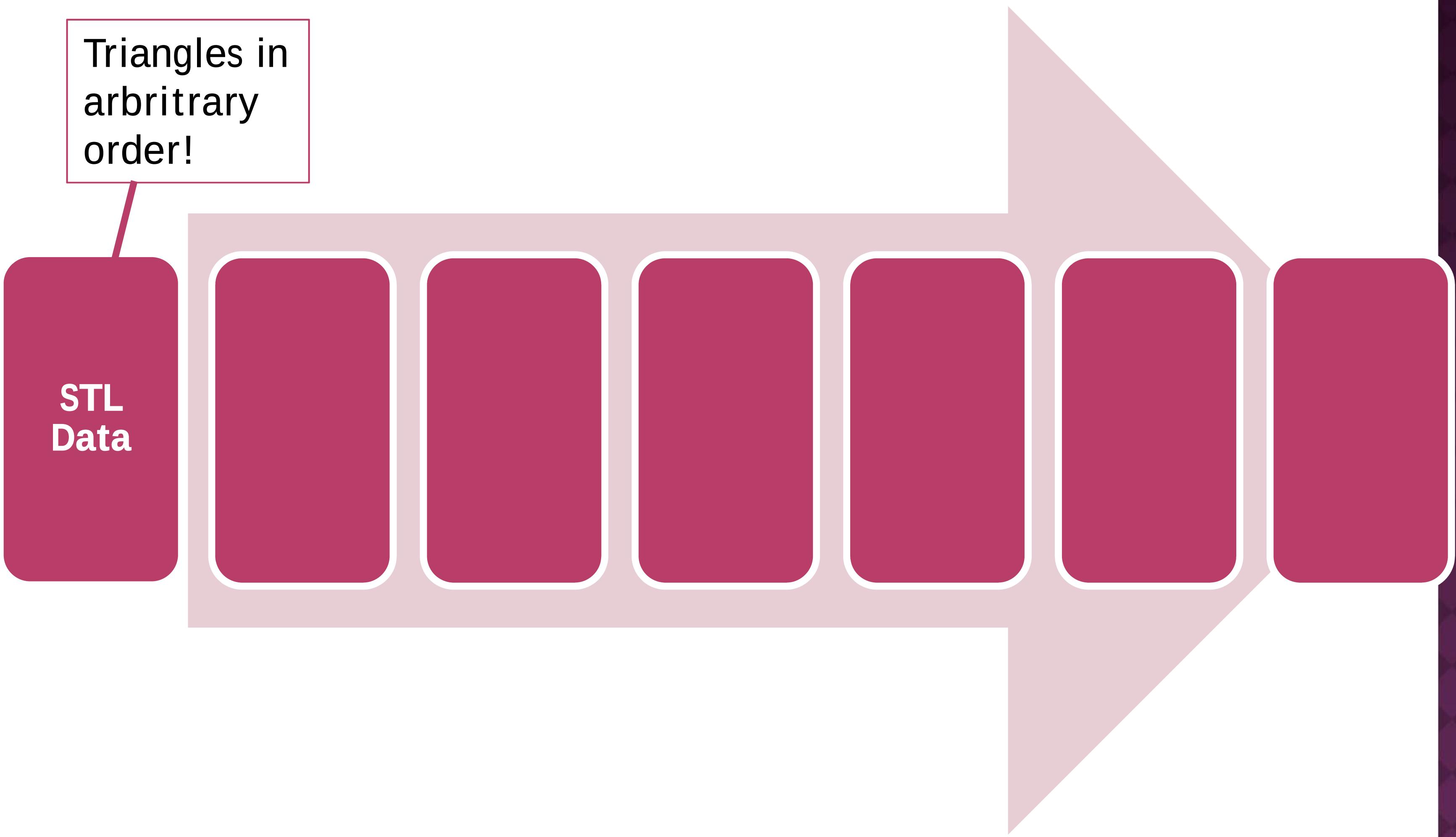
Crest ridges of *David*

RESEARCH METHOD:
SOFTWARE DEMO…

FAILED

Too few points to perform the fitting

NEIGHBORHOOD CONSTRUCTION



NEIGHBORHOOD CONSTRUCT…

Triangles in arbitrary order!

STL Data

Triangles List

199,970 triangles with 3 coordinate vertices *(x, y, z)*

~ 10 million bytes of memory

TRIANGLES LIST FROM STL DATA

Normal = 12 bytes

Vertex 1 = 12 bytes

Vertex 2 = 12 bytes

Vertex 3 = 12 bytes

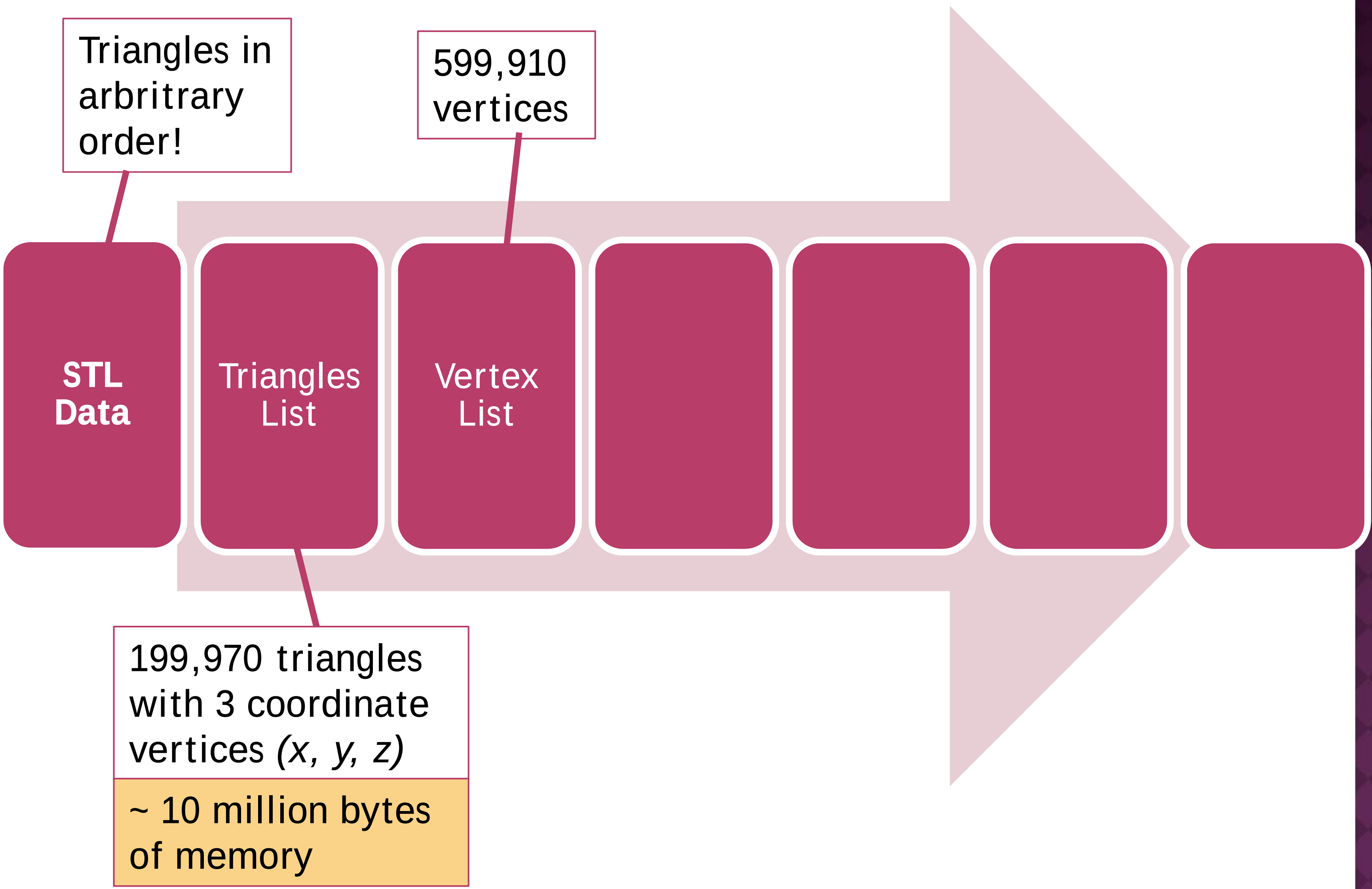
Characters = 2 bytes

TOTAL = 50 bytes per triangle

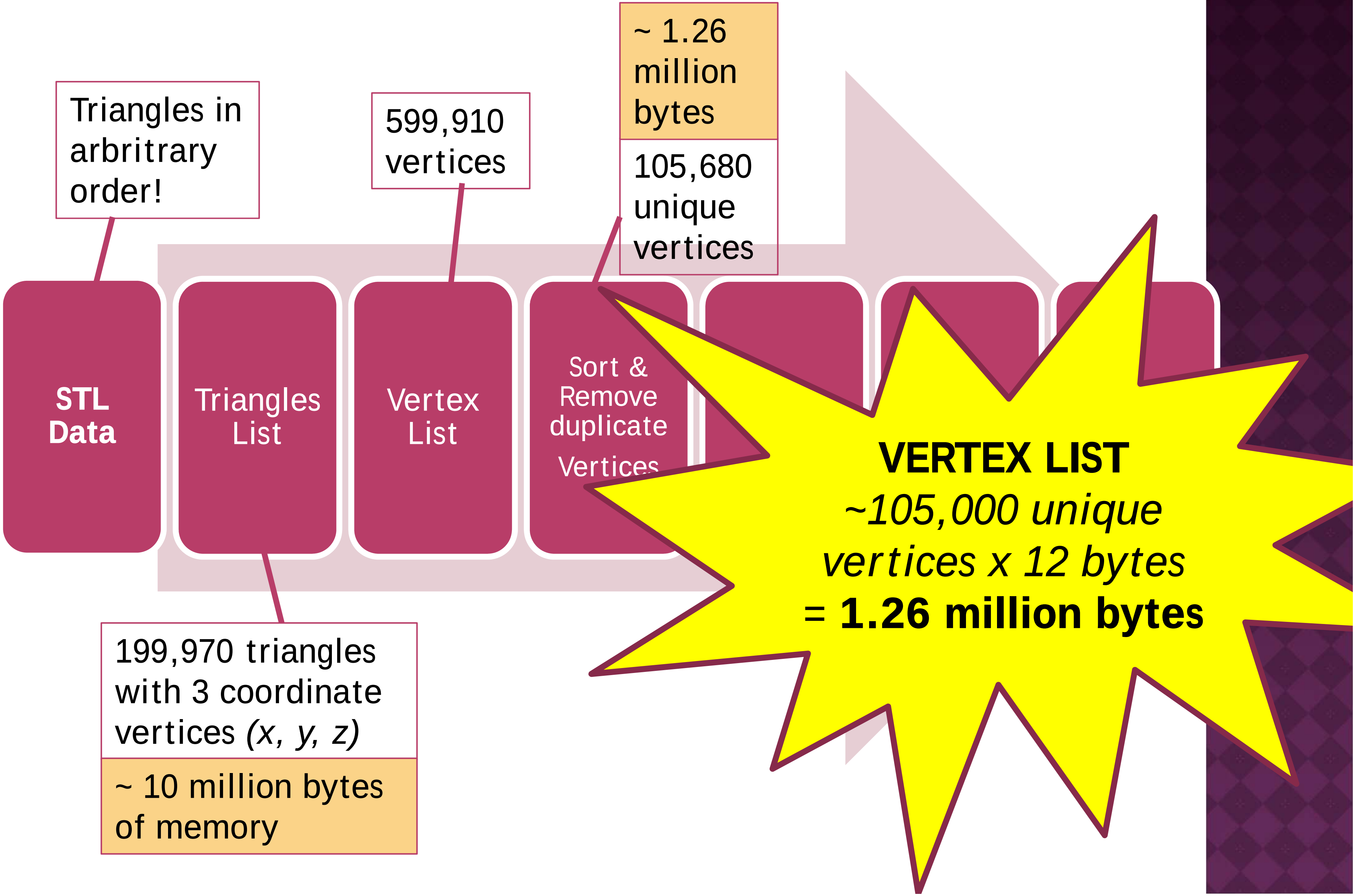
x approx 200,000 triangles

= ~ 10 MILLION BYTES

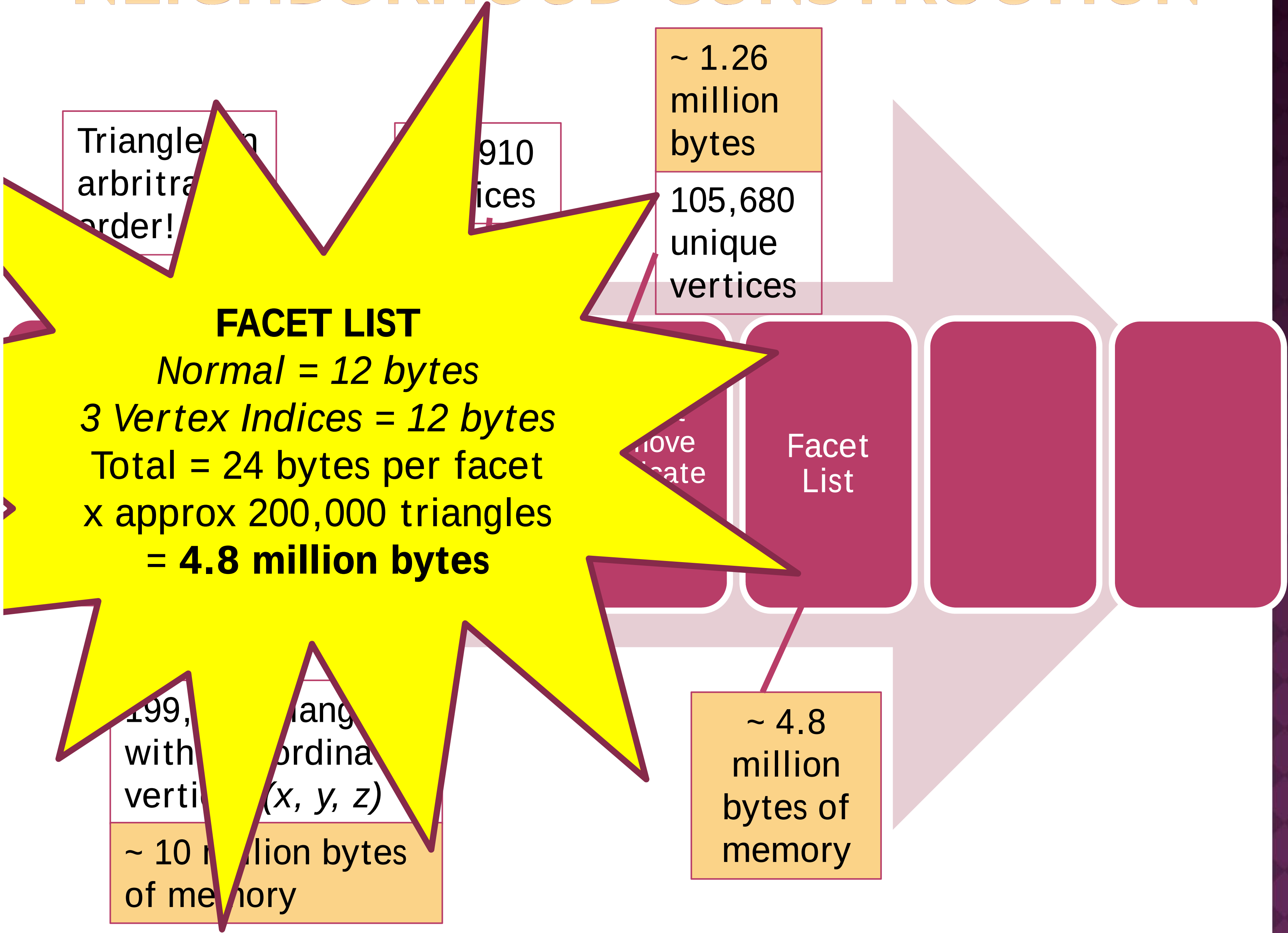
NEIGHBORHOOD CONSTRUCTION



NEIGHBORHOOD CONSTRUCTION



NEIGHBORHOOD CONSTRUCTION



NEIGH ORI OOD CONSTRUCTION

TRIANGLE LIST from STL

=10 MILLION BYTES

~ 1.26
million
...s

105,68...
...nique
...es

o...

STL Data

Triang...
List...

Ve... ...x
Li...

...t &
Re... ...ove
duplicate
Vertices

F...
Lis...

199,970 triangles with 3 coordinate vertices *(x, y, z)*

~ 10 million bytes of memory

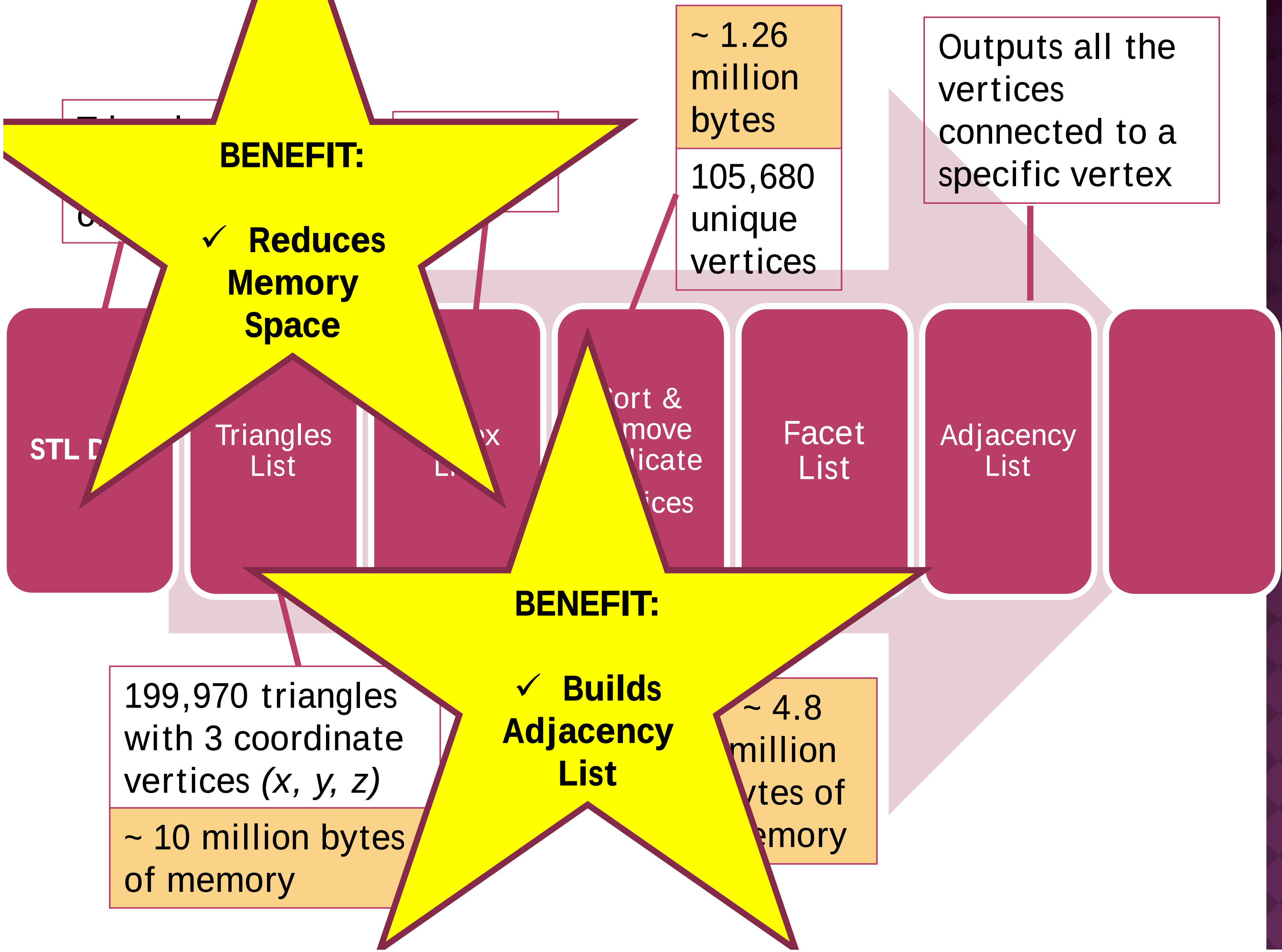
~ 4.8 million bytes of memory

VERTEX + FACET LIST

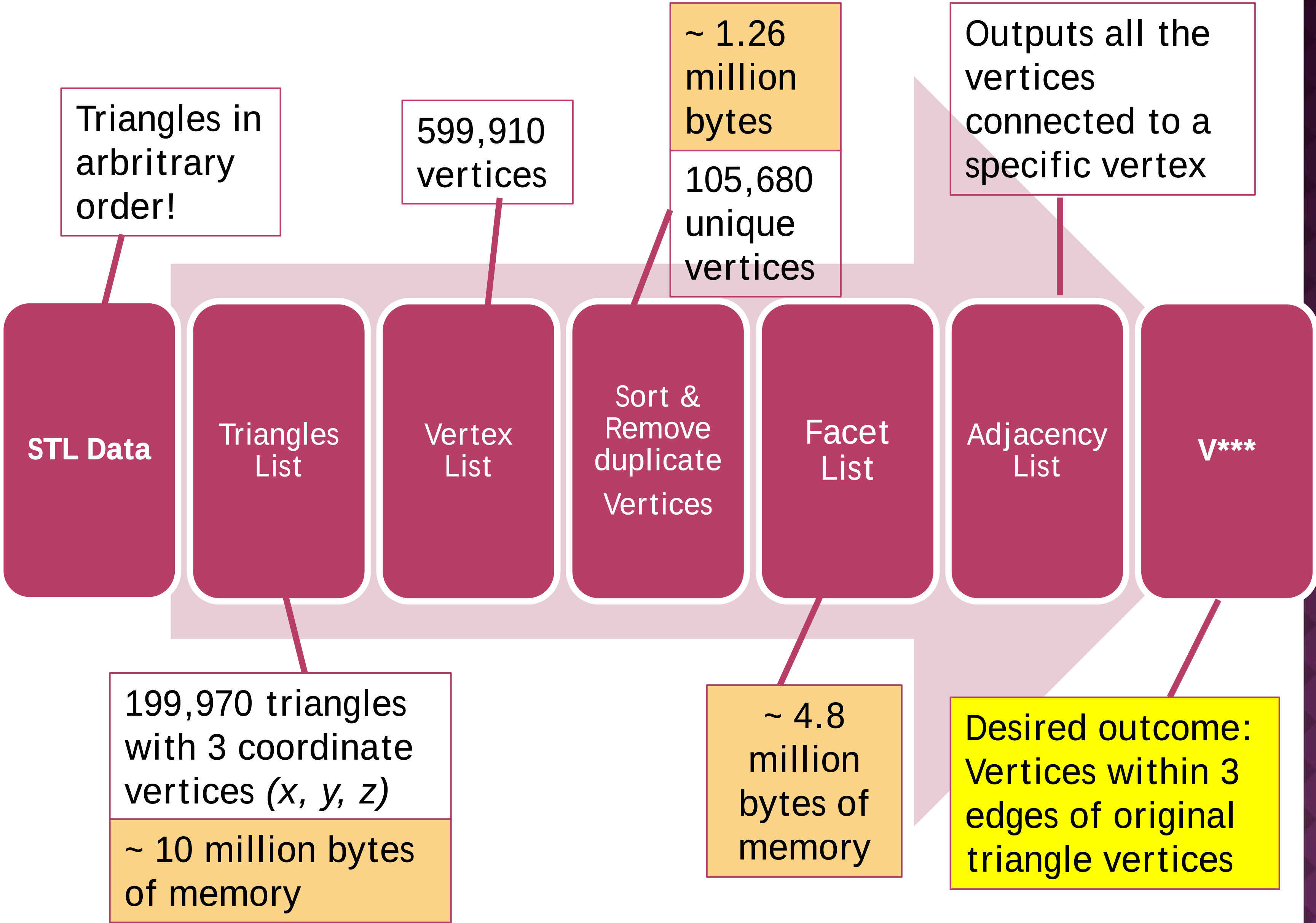
= 4.8 million + 1.26 million

= ~ 6.06 MILLION BYTES

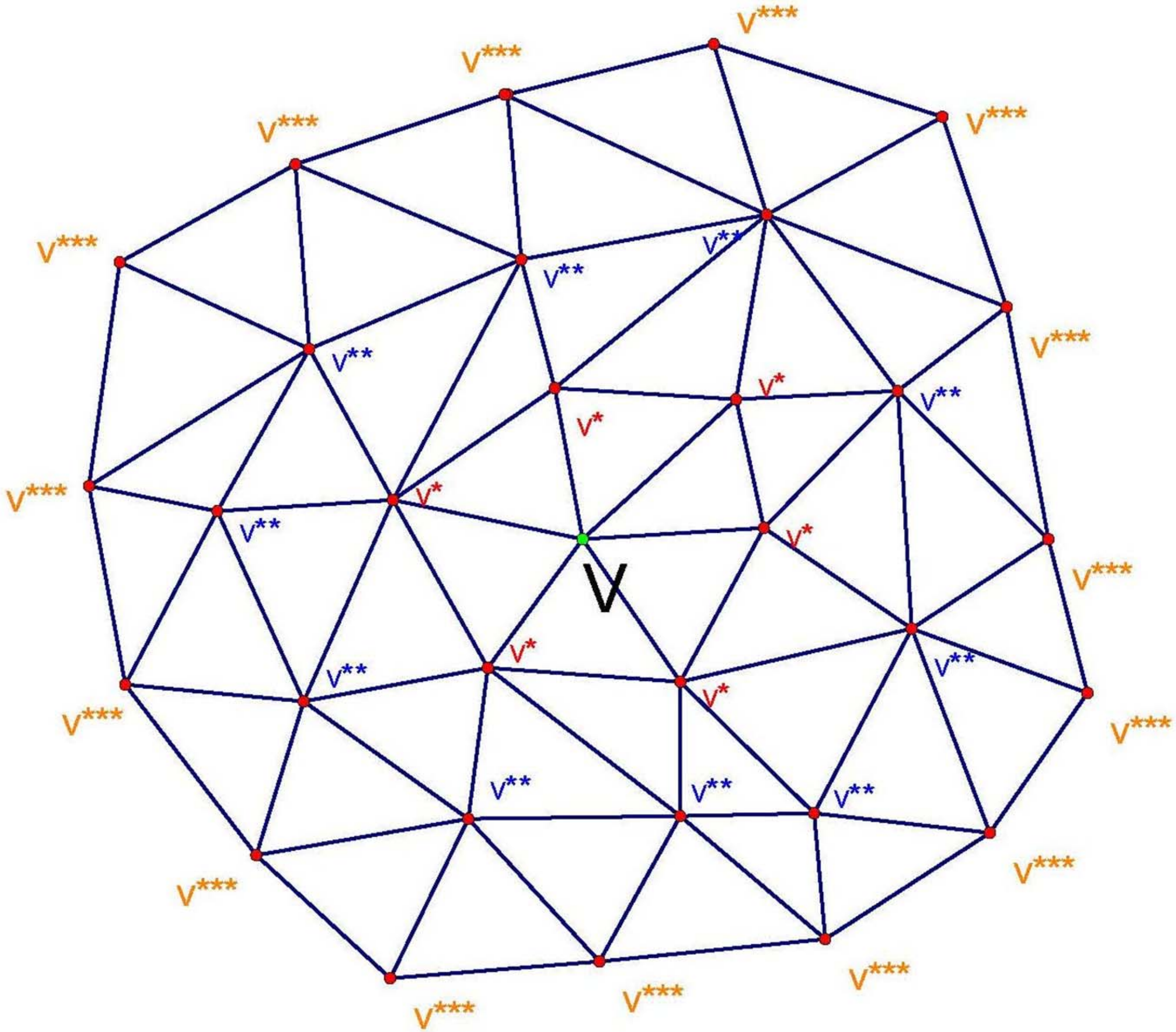
NEIGHBORHOOD CONSTRUCTION



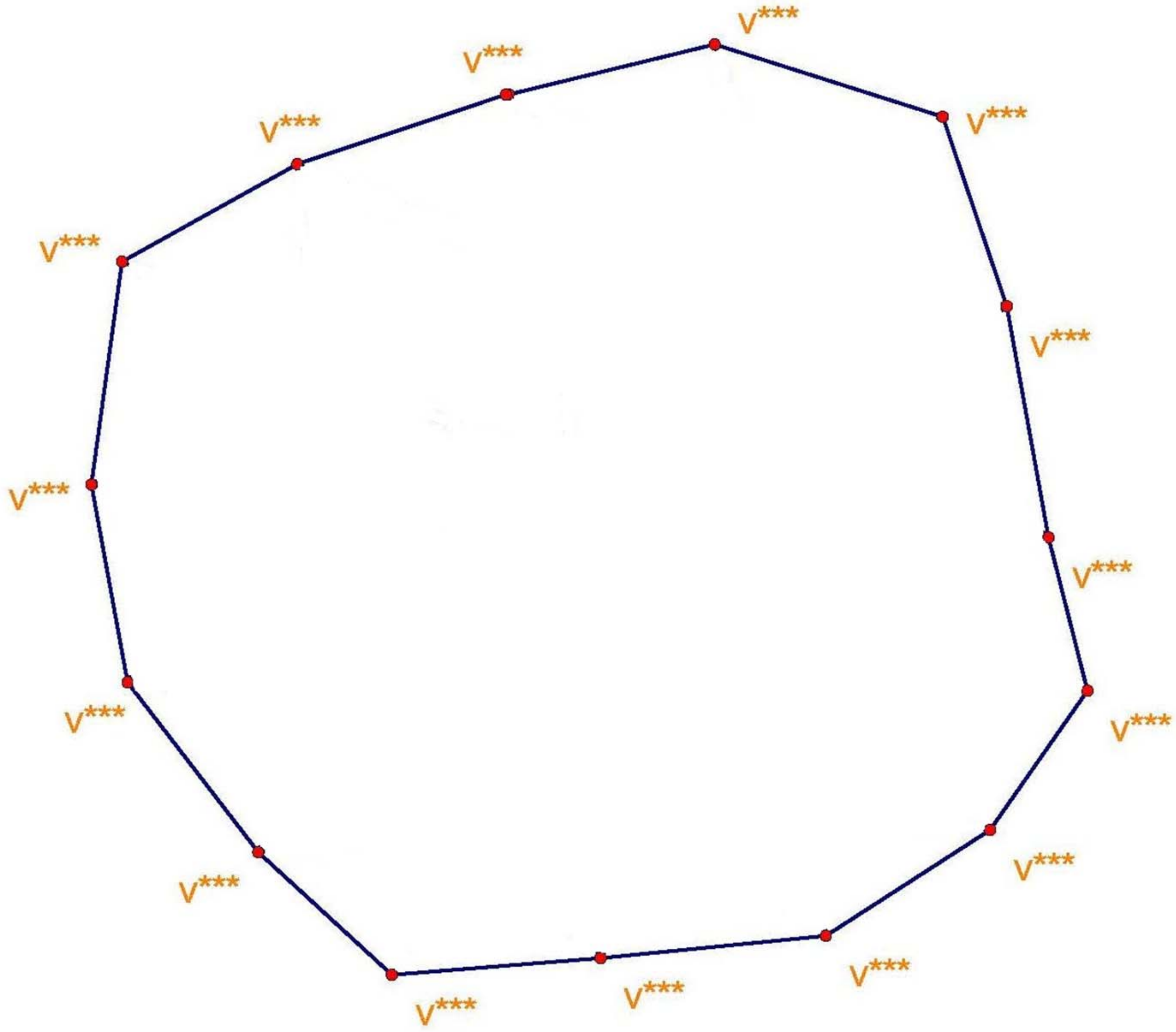
NEIGHBORHOOD CONSTRUCTION



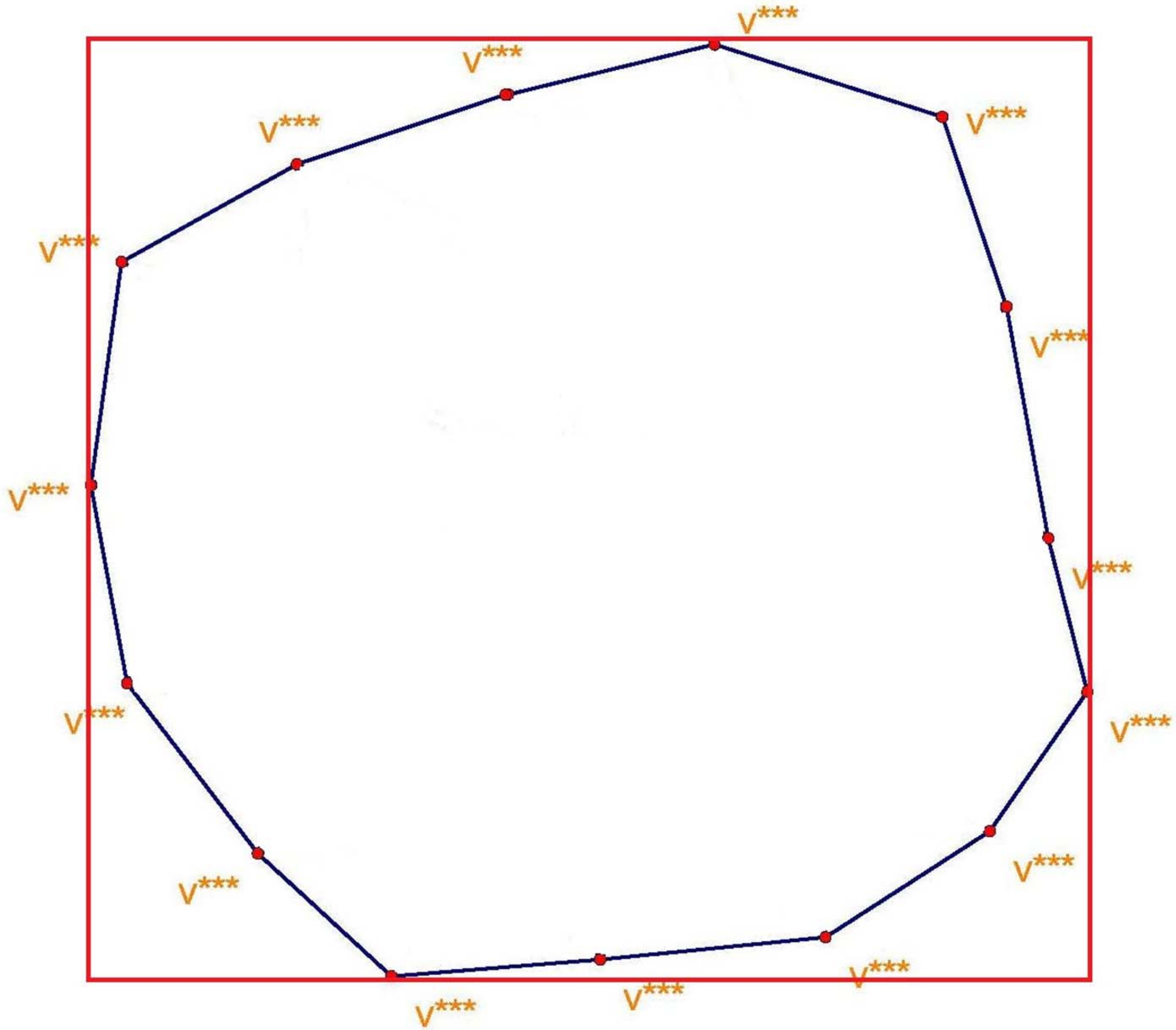
THE 3-RING NEIGHBORHOOD V***



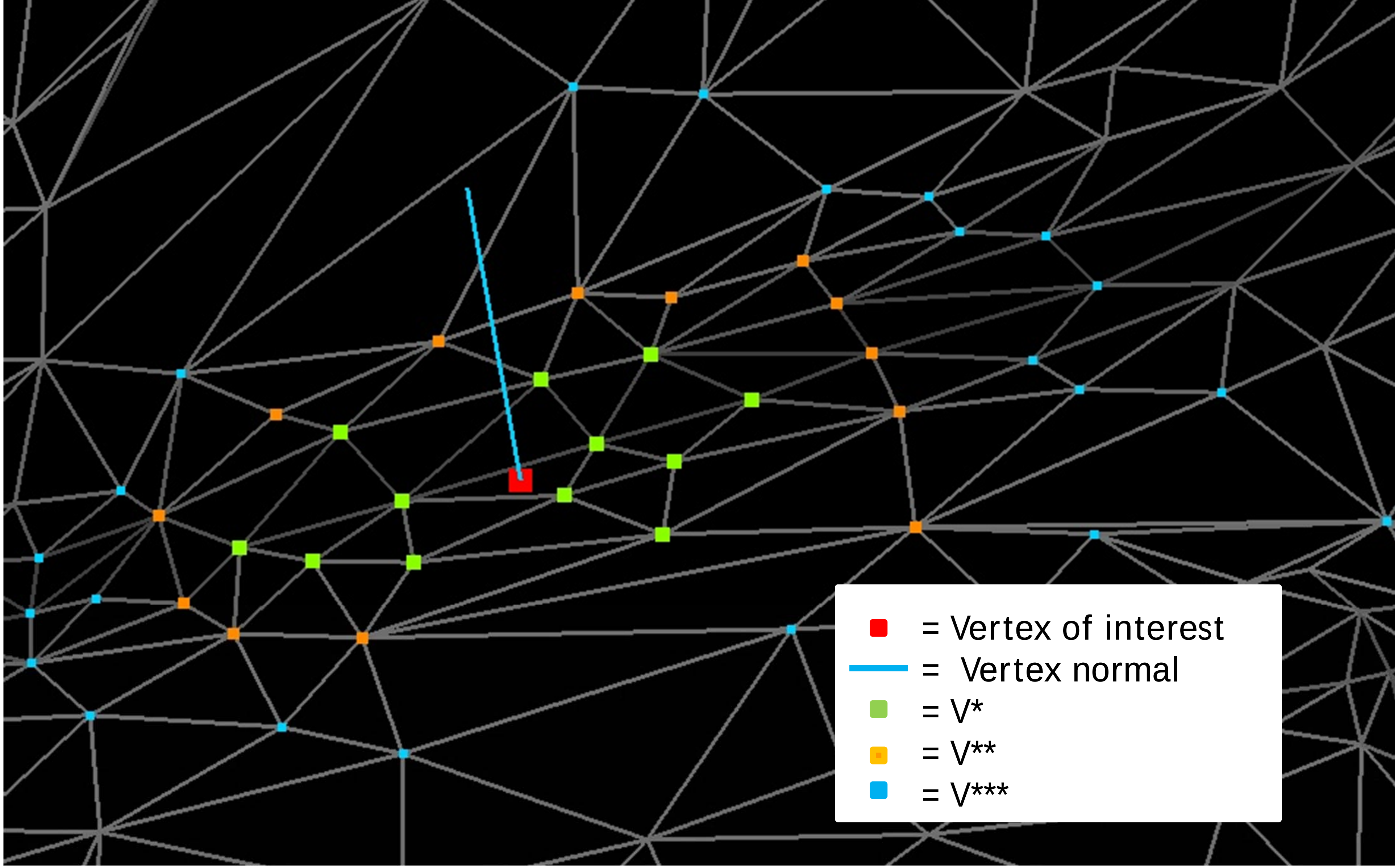
CONVEX HULL



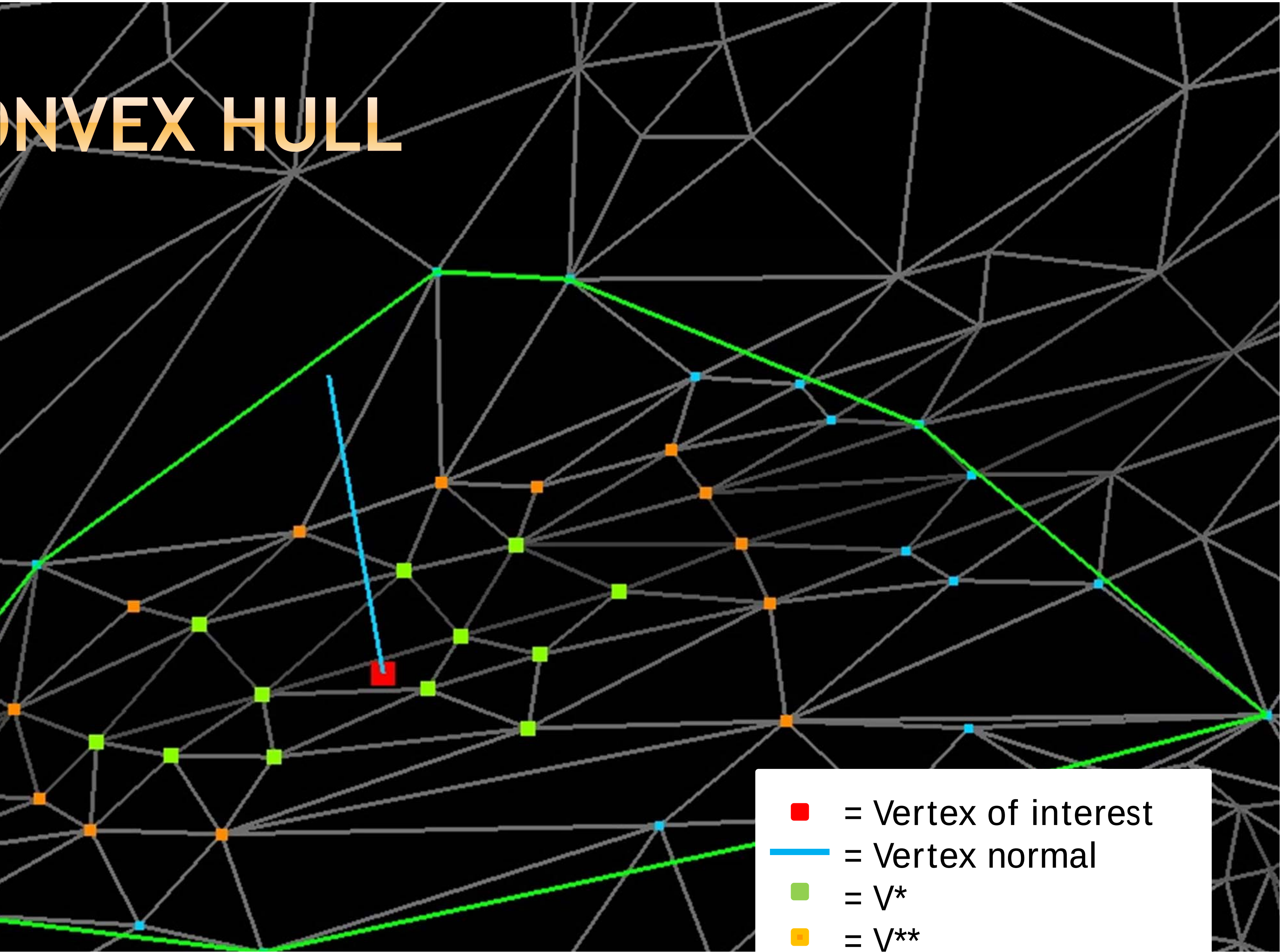
MINIMAL BOUNDING BOX



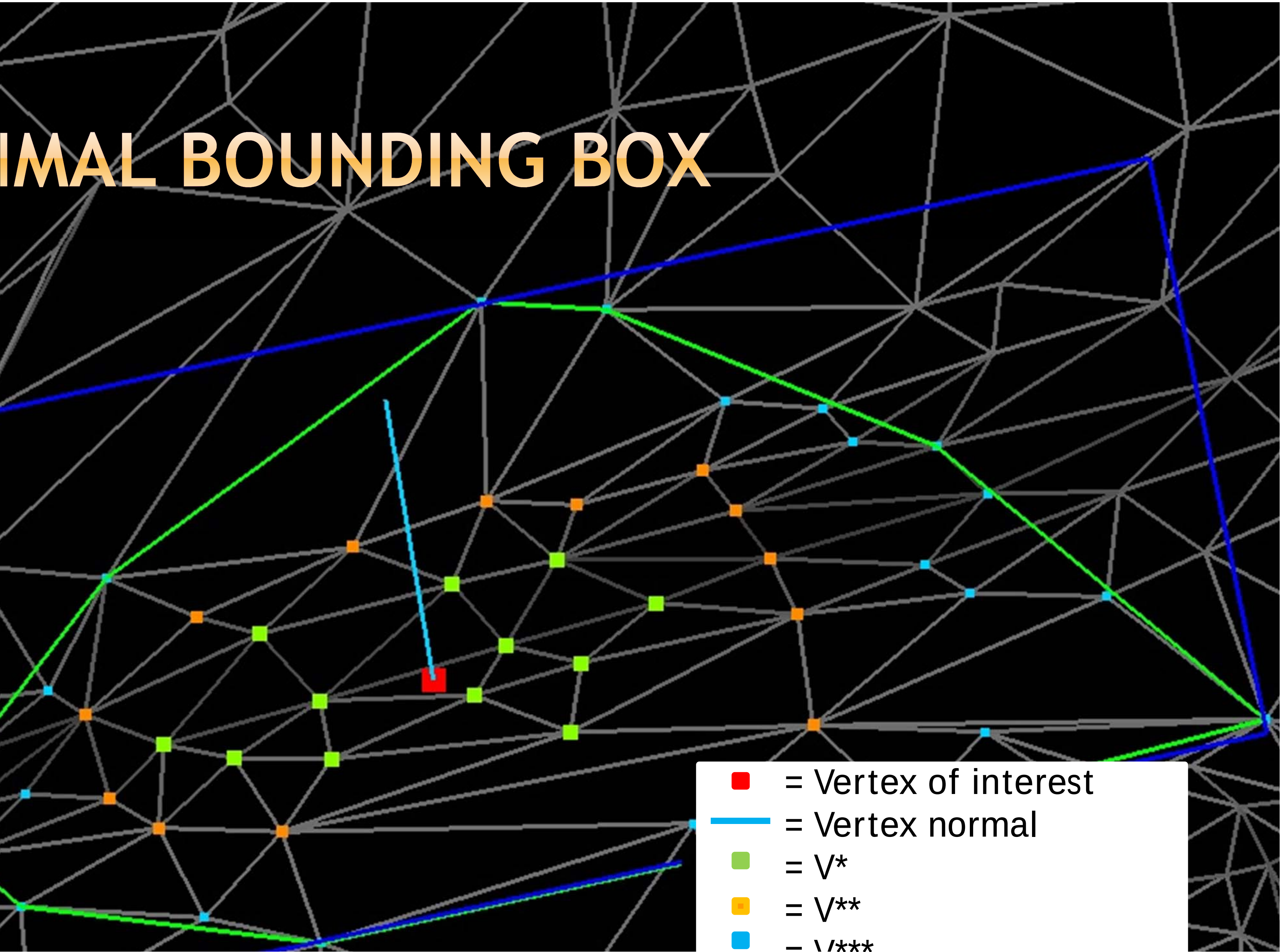
THE 3-RING NEIGHBORHOOD V***



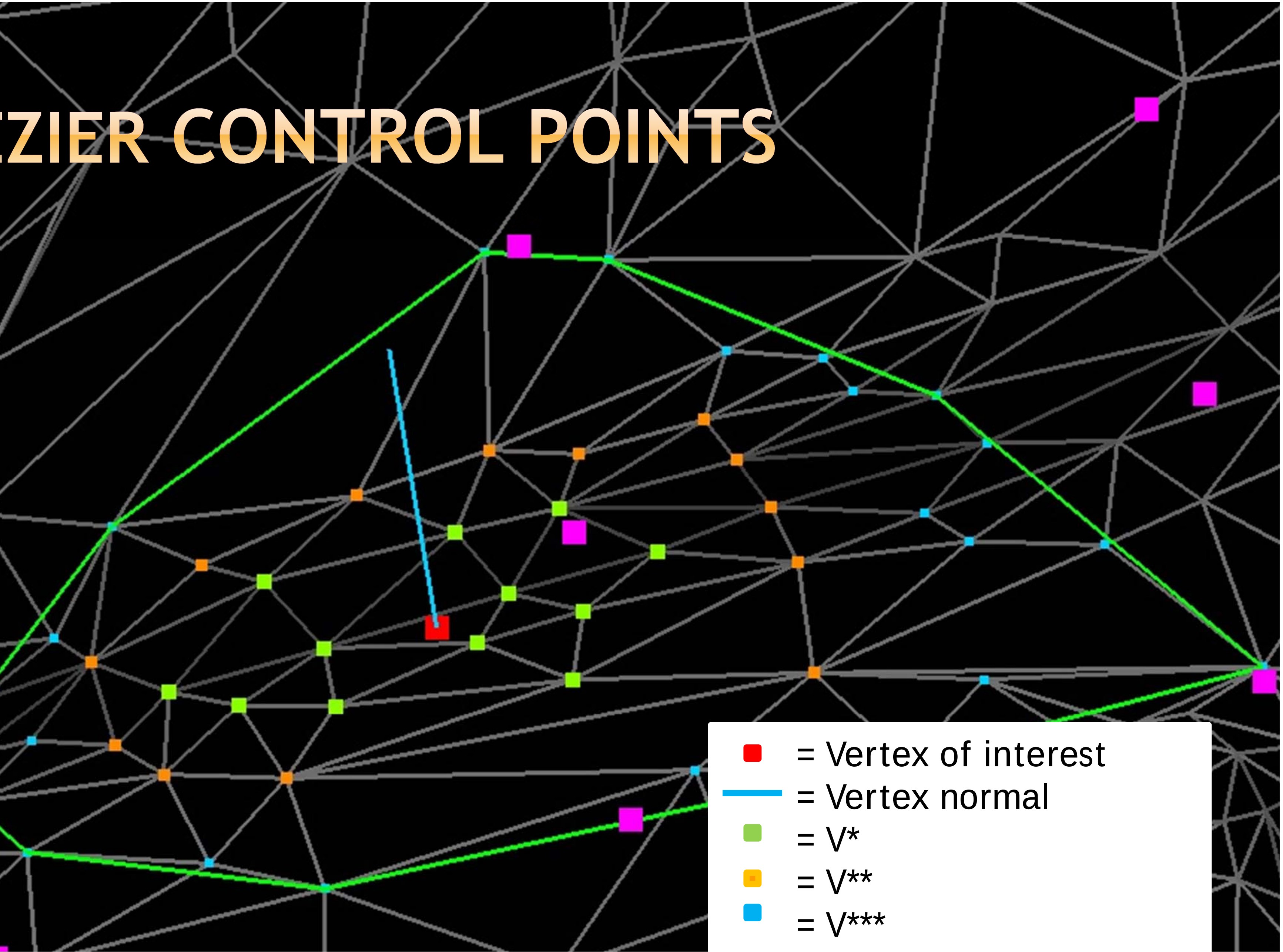
ONVEX HULL



IMAL BOUNDING BOX

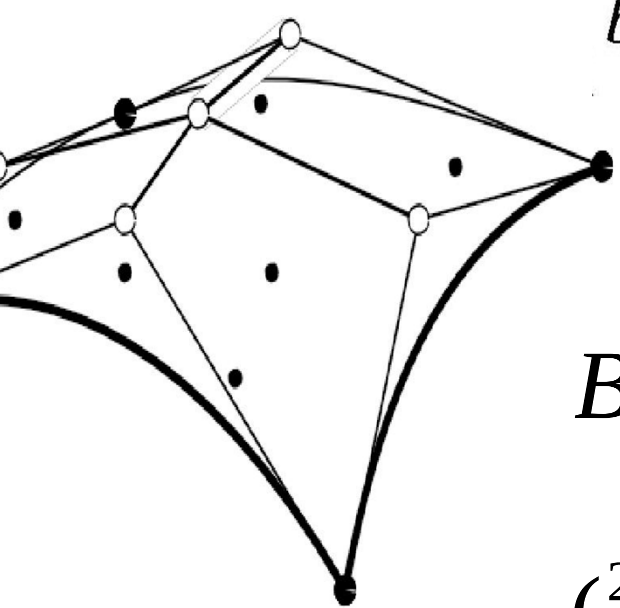


ZIER CONTROL POINTS



MPUTING CURVATURE USING ÉZIER SURFACE

$$X(u,v) = \sum_{i=0}^{2} \sum_{j=0}^{2} b_{i,j} B_i^2(u) B_j^2(v)$$

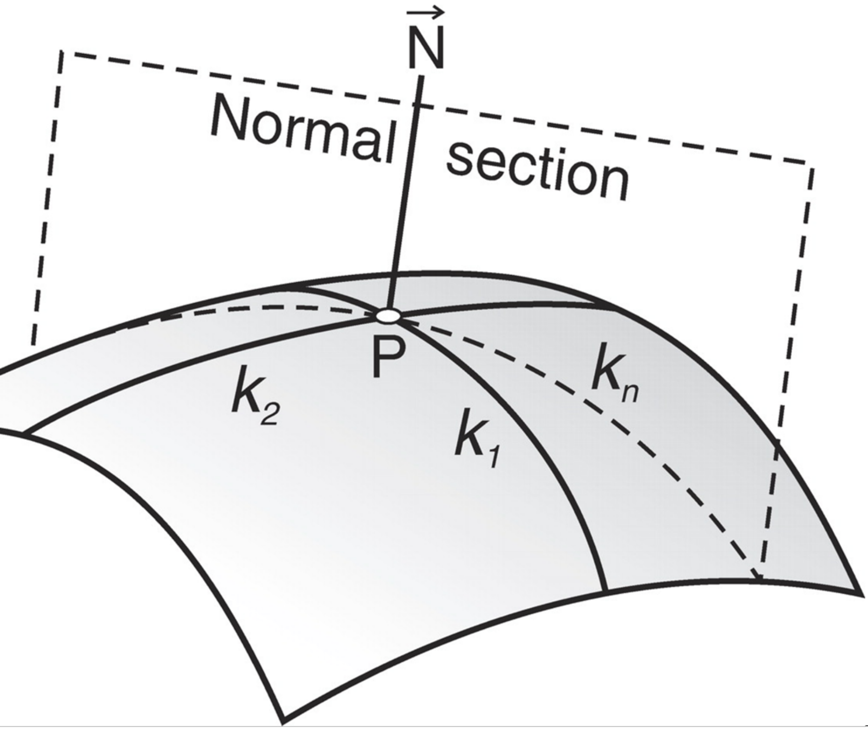


$b_{i,j}$ = Bézier Control Points, ie. the 9 vertices of the Bézier control net

$$B_i^2(u) = \binom{2}{i} u^i (1-u)^{2-i}$$

$$\binom{2}{i} = \begin{cases} \frac{2!}{i!(2-i)!} & if\ 0 \le i \le n \end{cases}$$

ATHEMATICAL BACKGROUND: AUSSIAN CURVATURE



$$M = \frac{1}{2}(K_1 + K_2)$$

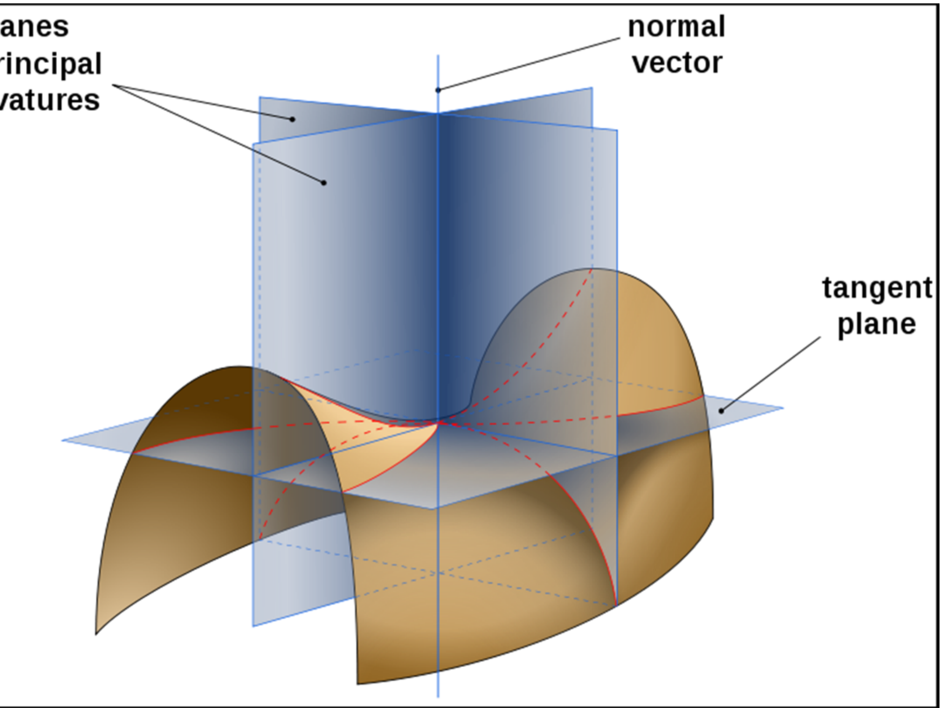
$$K = K_1 K_2$$

= the principal curvatures, i.e. the maximum & minimum curvature

Mean curvature, ie. the average of the principle curves

aussian curvature, ie. the product of the principal curvatures

ATHEMATICAL BACKGROUND: AUSSIAN CURVATURE



$$M = \frac{1}{2}(K_1 + K_2)$$

$$K = K_1 K_2$$

= the principal curvatures, i.e. the maximum & minimum curvature

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EMO

ON DAVID'S LAPTOP

REFERENCES

[1] Lili Xu and Shuqian Luo. A novel method for blood vessel detection from retinal images. BioMedical Engineering OnLine, 9(1):14, 2010.

[2] Yan Xu, Hui Zhang, Hao Li, and Guangshu Hu. An improved algorithm for vessel centerline tracking in coronary angiograms. Computer Methods and Programs in Biomedicine, 88(2):131 { 143, 2007.

[3] Zhou Shoujun, Yang Jian, Wang Yongtian, and Chen Wufan. Automatic segmentation of coronary angiograms based on fuzzy inferring and proba- bilistic tracking. BioMedical Engineering OnLine, 9(1):40, 2010.

[4] Marc Pouget and Frdric Cazals. Approximation of ridges and umbilics on triangulated surface meshes. In CGAL User and Reference Manual. CGAL Editorial Board, 3.7 edition, 2010. http\://www.cgal.org/Manual/3.7/doc_html/cgal_manual/packages.html\#Pkg\:Ridges_3.

[5] Ruben Reyes. Stl les, 2007. https://webspace.utexas.edu/reyesr/titanium/stl/stlmarch17.htm.

[6] M.I.A. Lourakis. levmar: Levenberg-marquardt nonlin-ear least squares algorithms in C/C++. [web page] http://www.ics.forth.gr/~lourakis/levmar/, Jul. 2004. [Accessed on 31 Jan. 2005.].

[7] Anshuman Razdan and MyungSoo Bae. Curvature estimation scheme for triangle meshes using biquadratic bezier patches. 9(1):21, 2005.

[8] Alejo Hausner. Graham's scan, July 1996. http://www.cs.princeton.edu/courses/archive/spr10/cos226/demo/ah/GrahamScan.html.

[9] Alejo Hausner. Convex hull, July 1996. http://www.cs.princeton.edu/courses/archive/spr10/cos226/demo/ah/ConvexHull.html.

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- QUESTIONS ???
- COMMENTS !!!