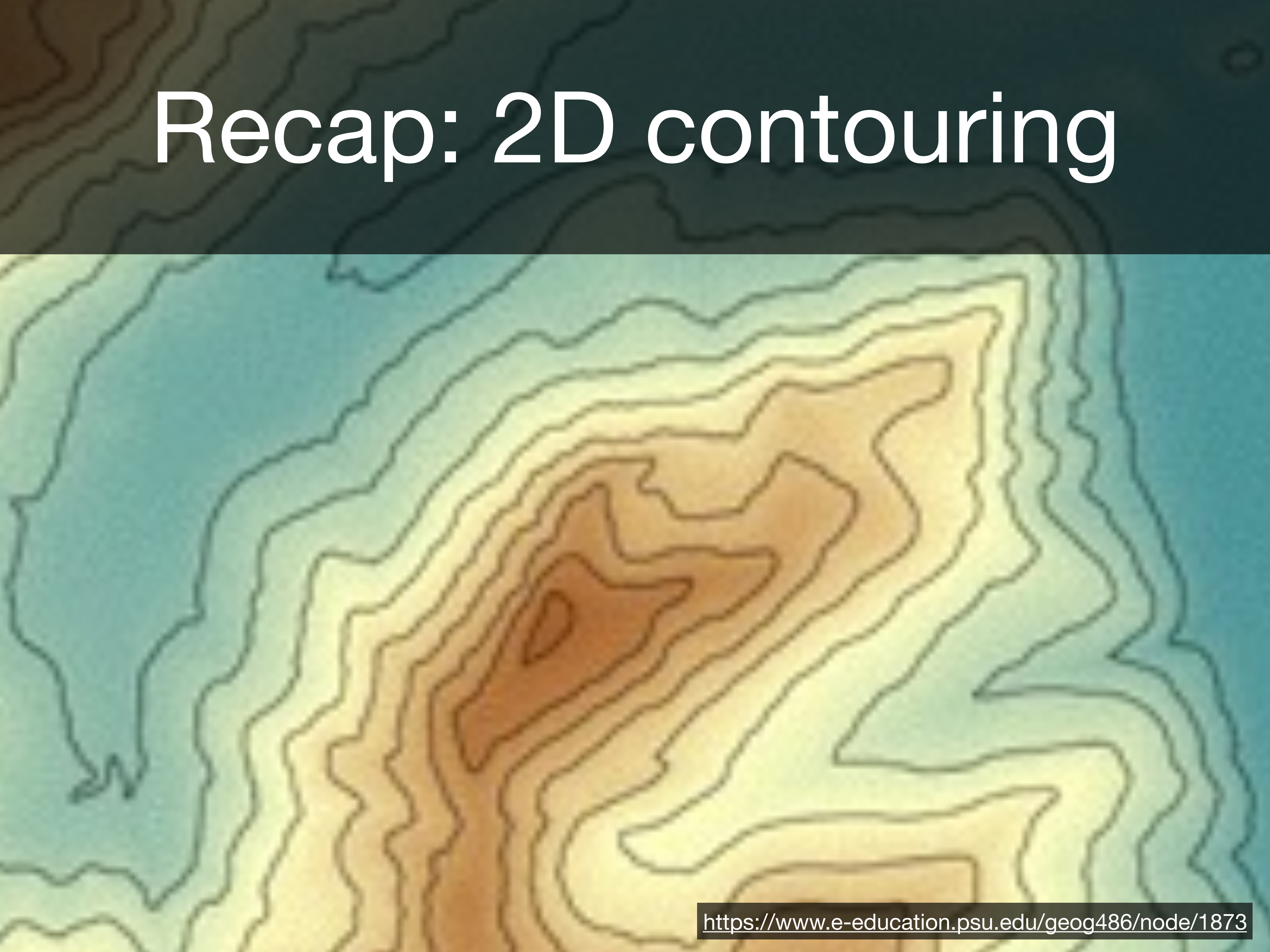
# Spatial Data: 3D Scalar Fields

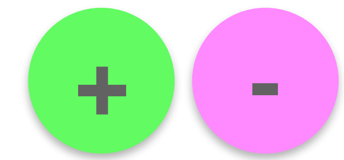
CS444

# Recap: 2D contouring

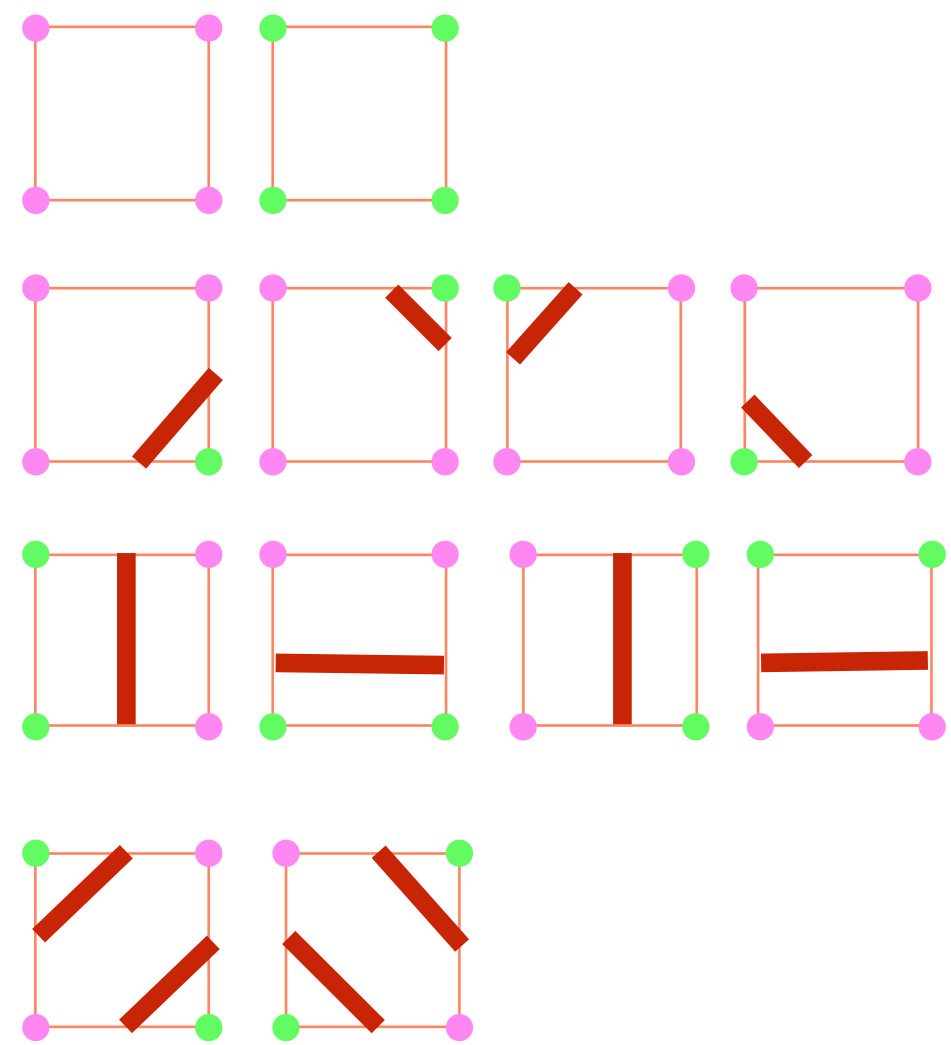


https://www.e-education.psu.edu/geog486/node/1873

# Recap: 2D contouring



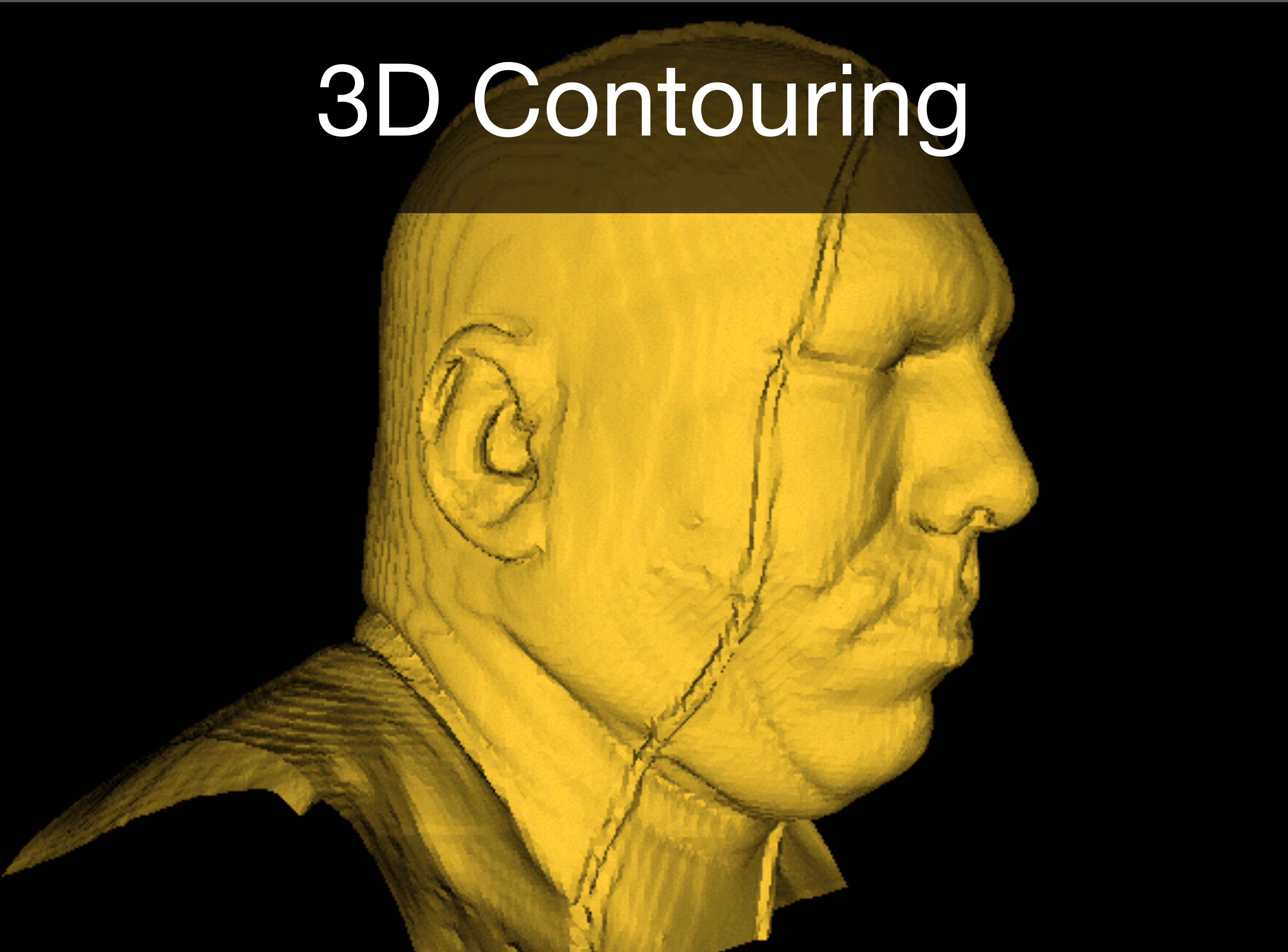

| Case | Polarity | Rotation | Total |
|---|---|---|---|
| No Crossings | x2 | | 2 |
| Singlet | x2 | x4 | 8 |
| Double adjacent | x2 | x2 (4) | 4 |
| Double Opposite | x2 | x1 (2) | 2 |
| | | | $16 = 2^4$ |



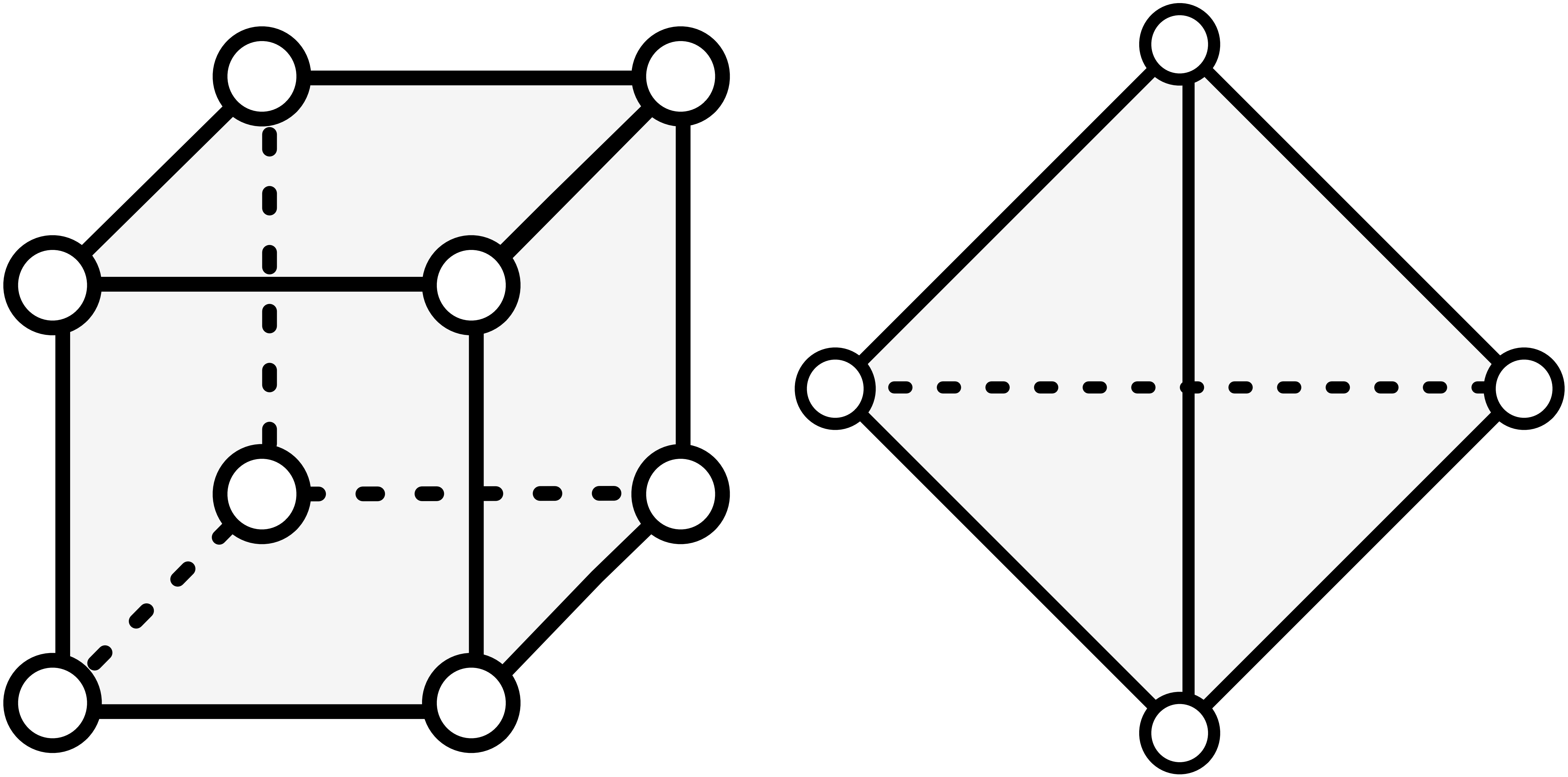
(x2 for polarity)

# 3D Contouring

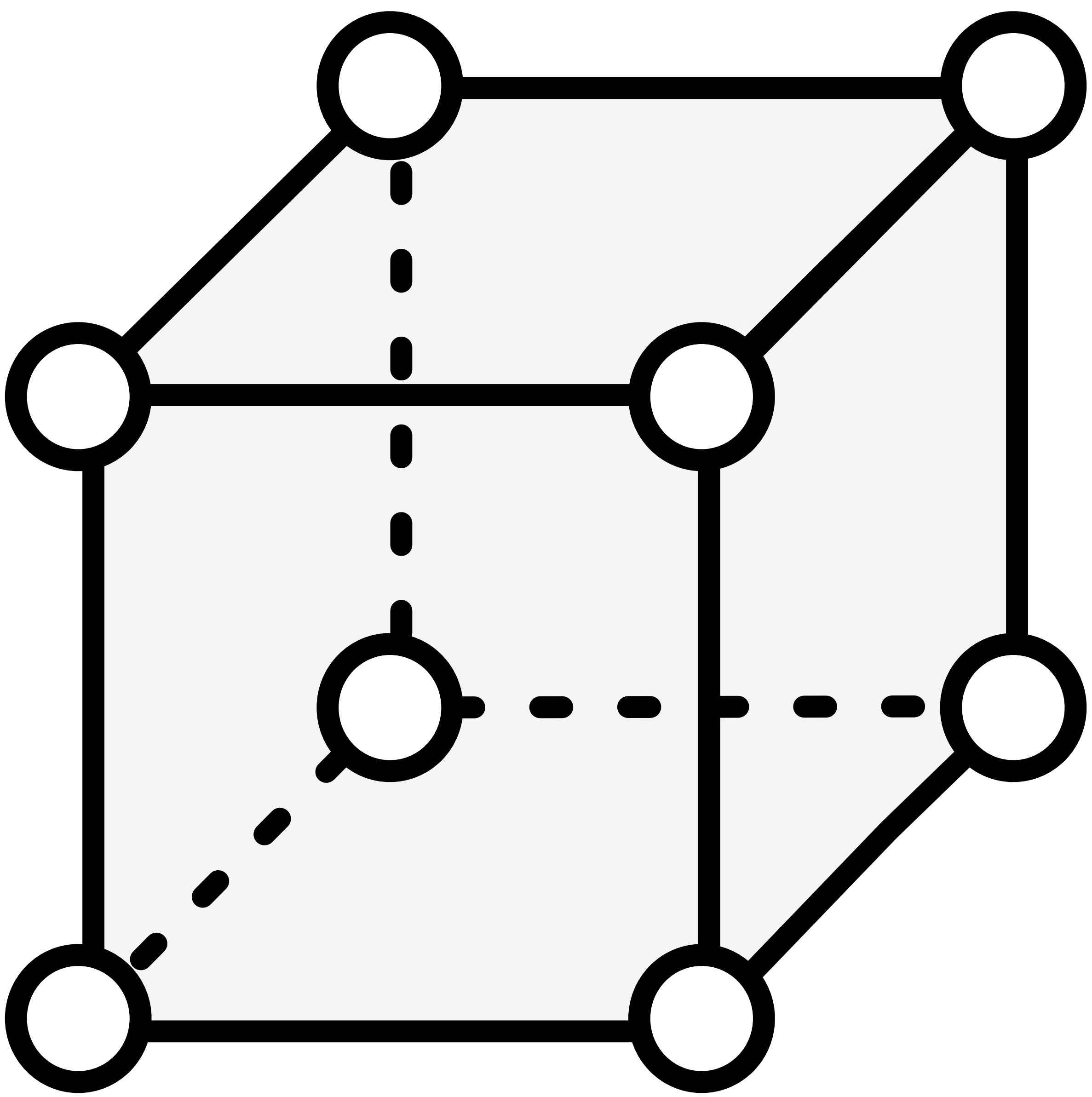
# 3D Contouring

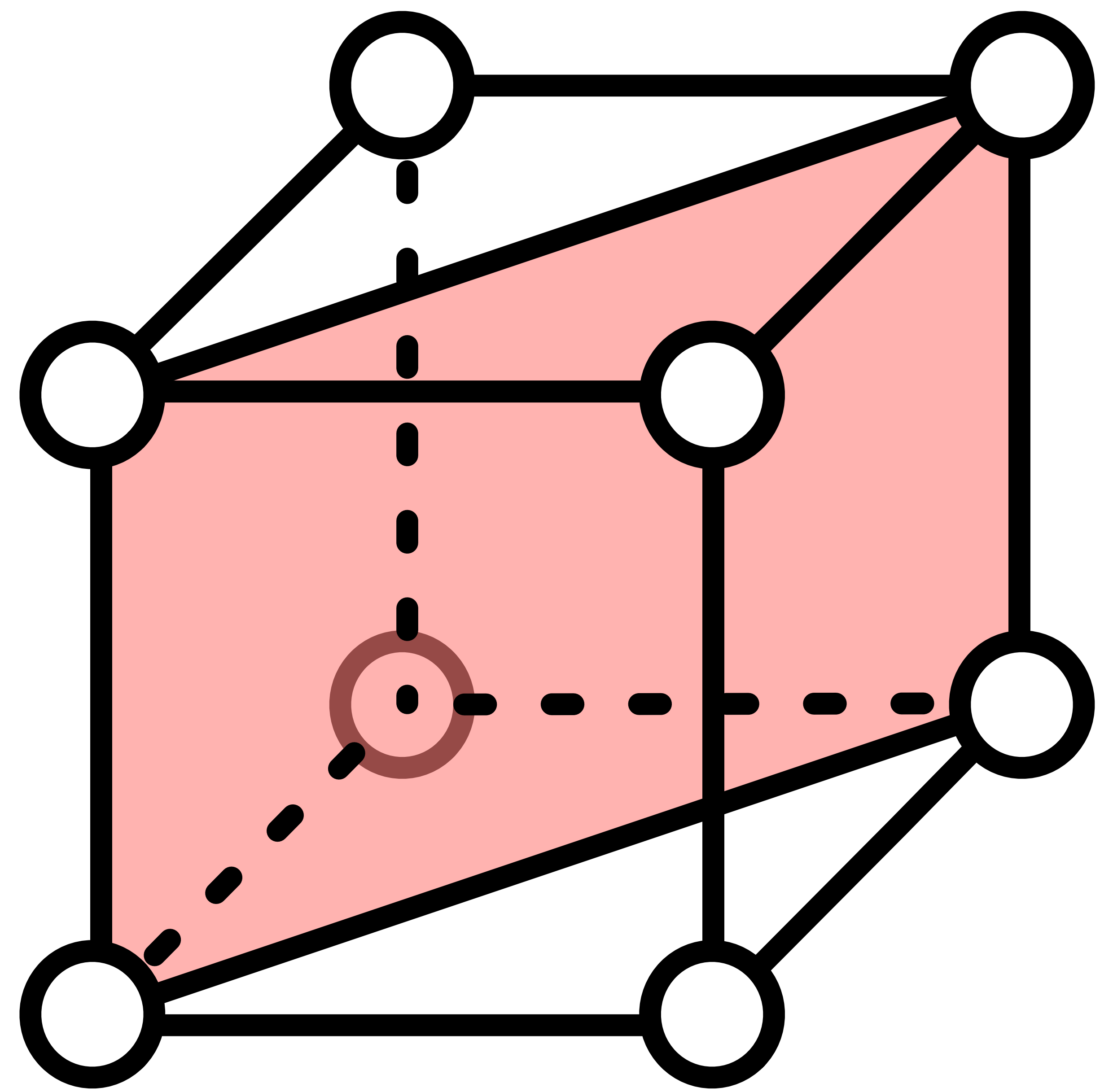


# Splitting 3D space into simple shapes

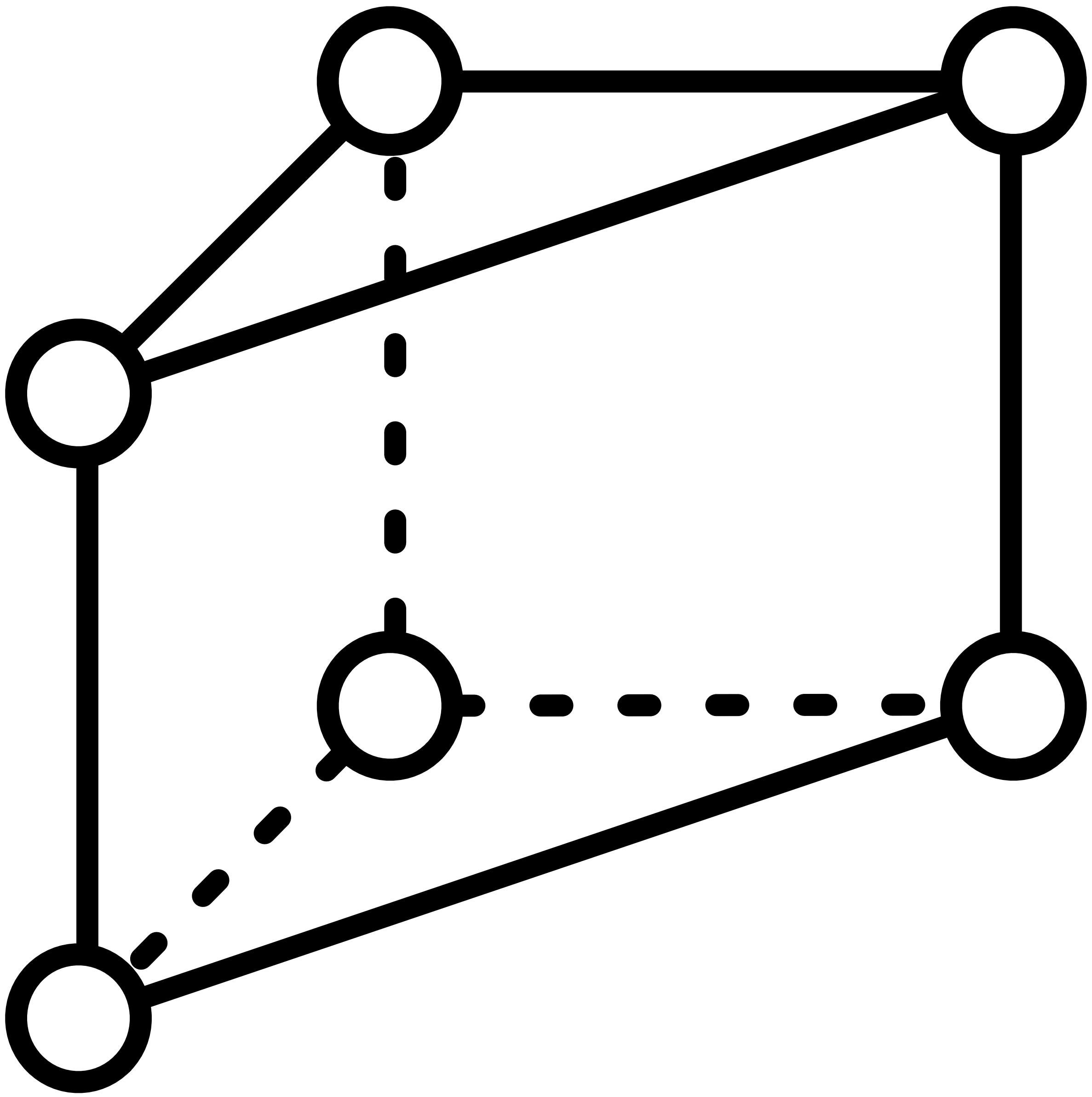


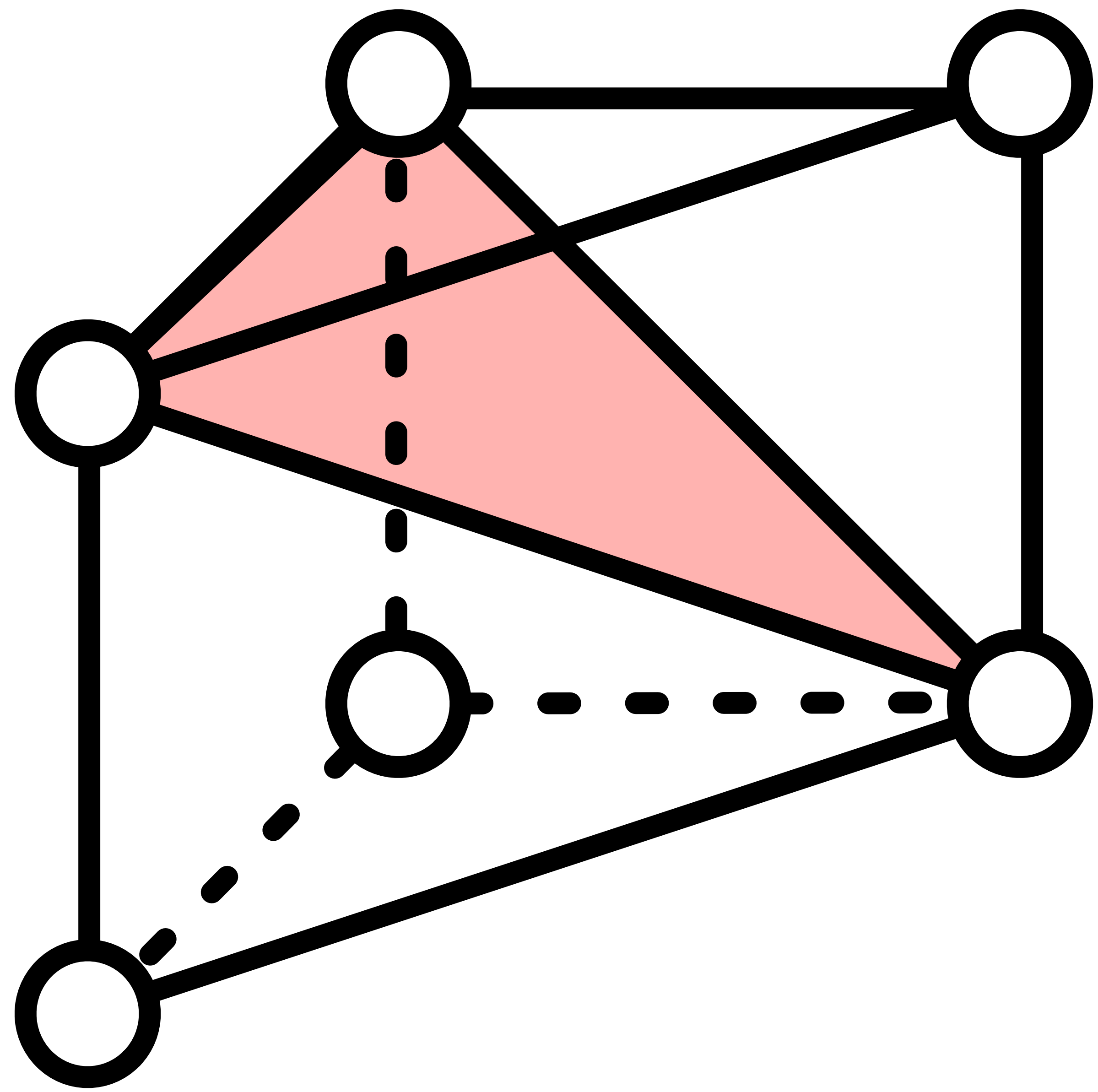
# Cube into tetrahedra



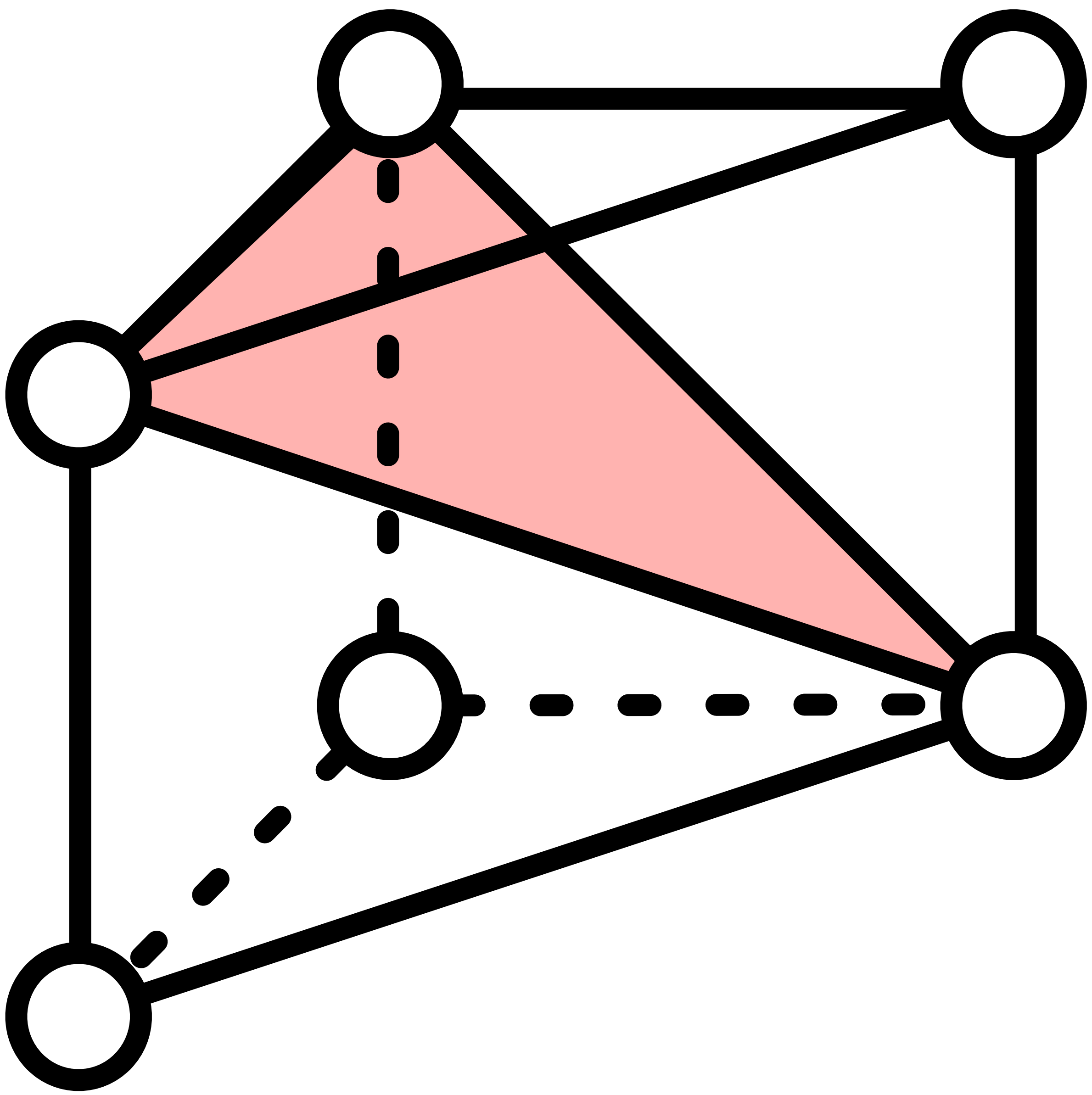


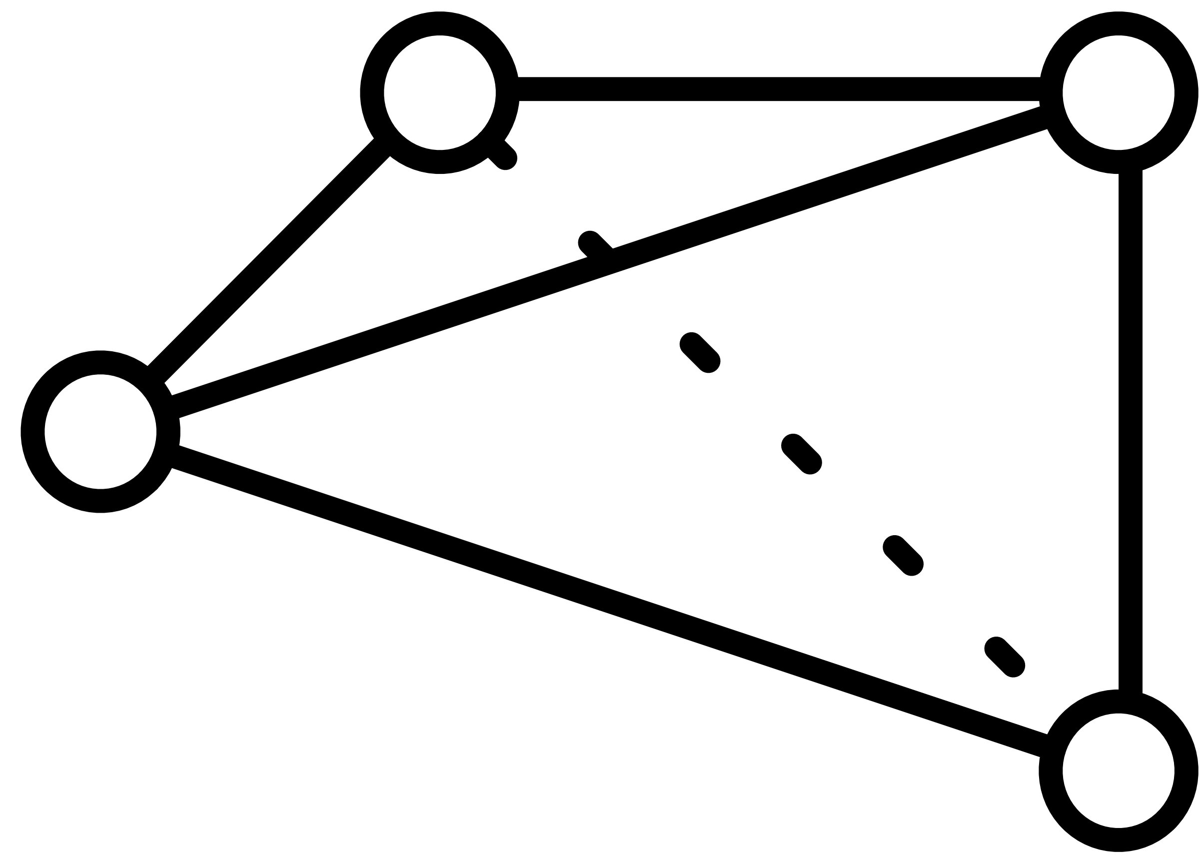
# Cube into tetrahedra





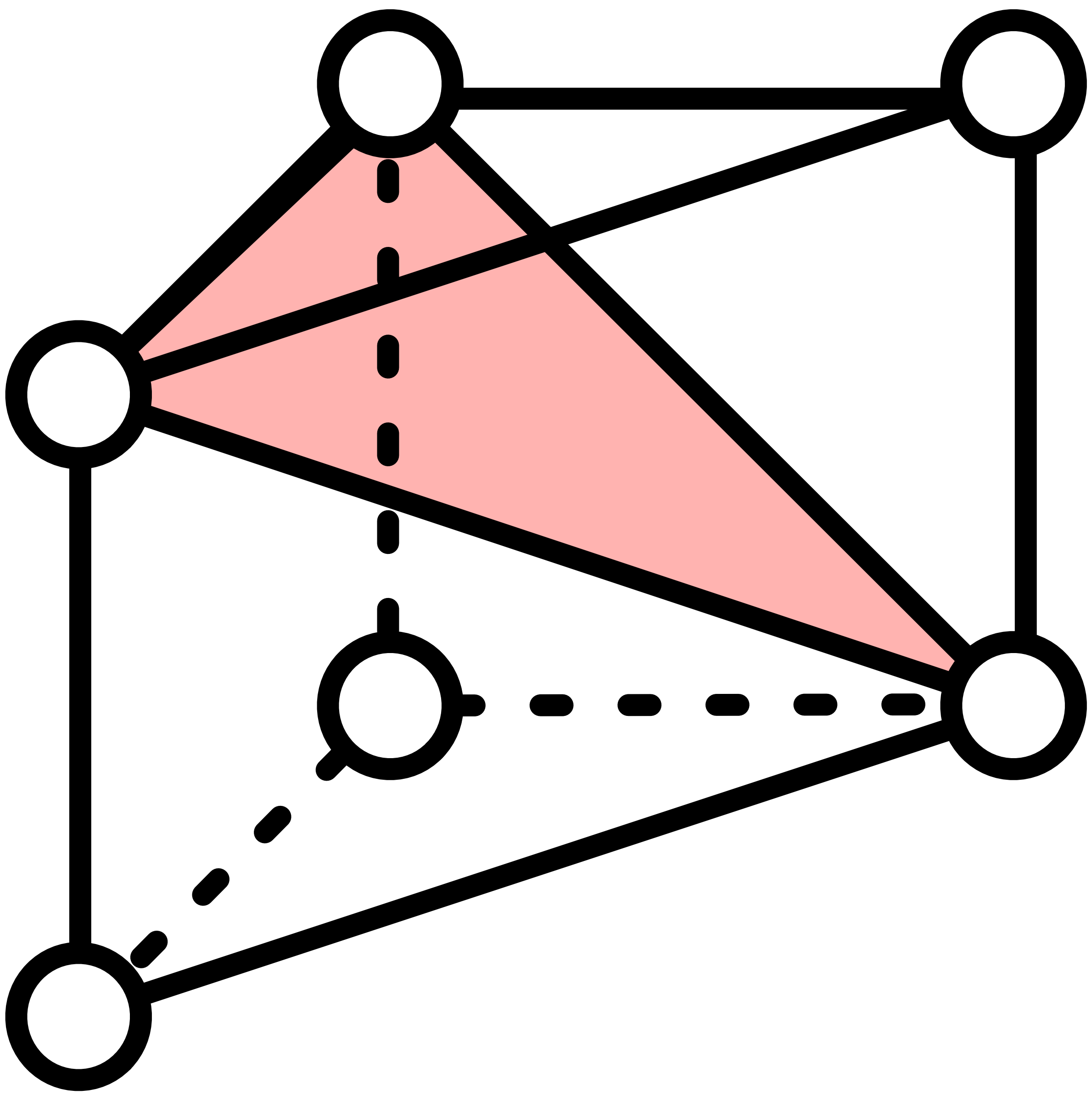
# Cube into tetrahedra

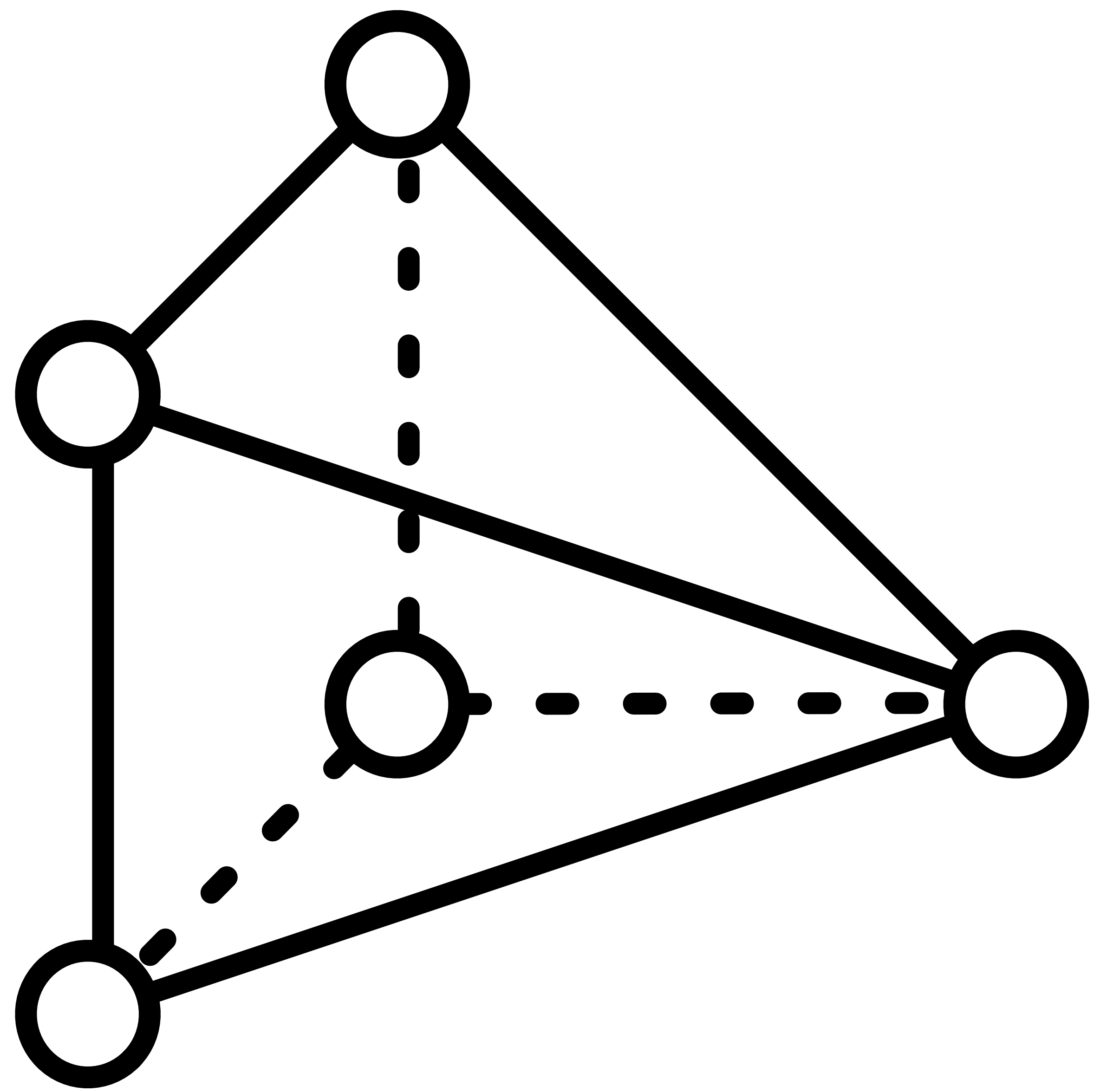




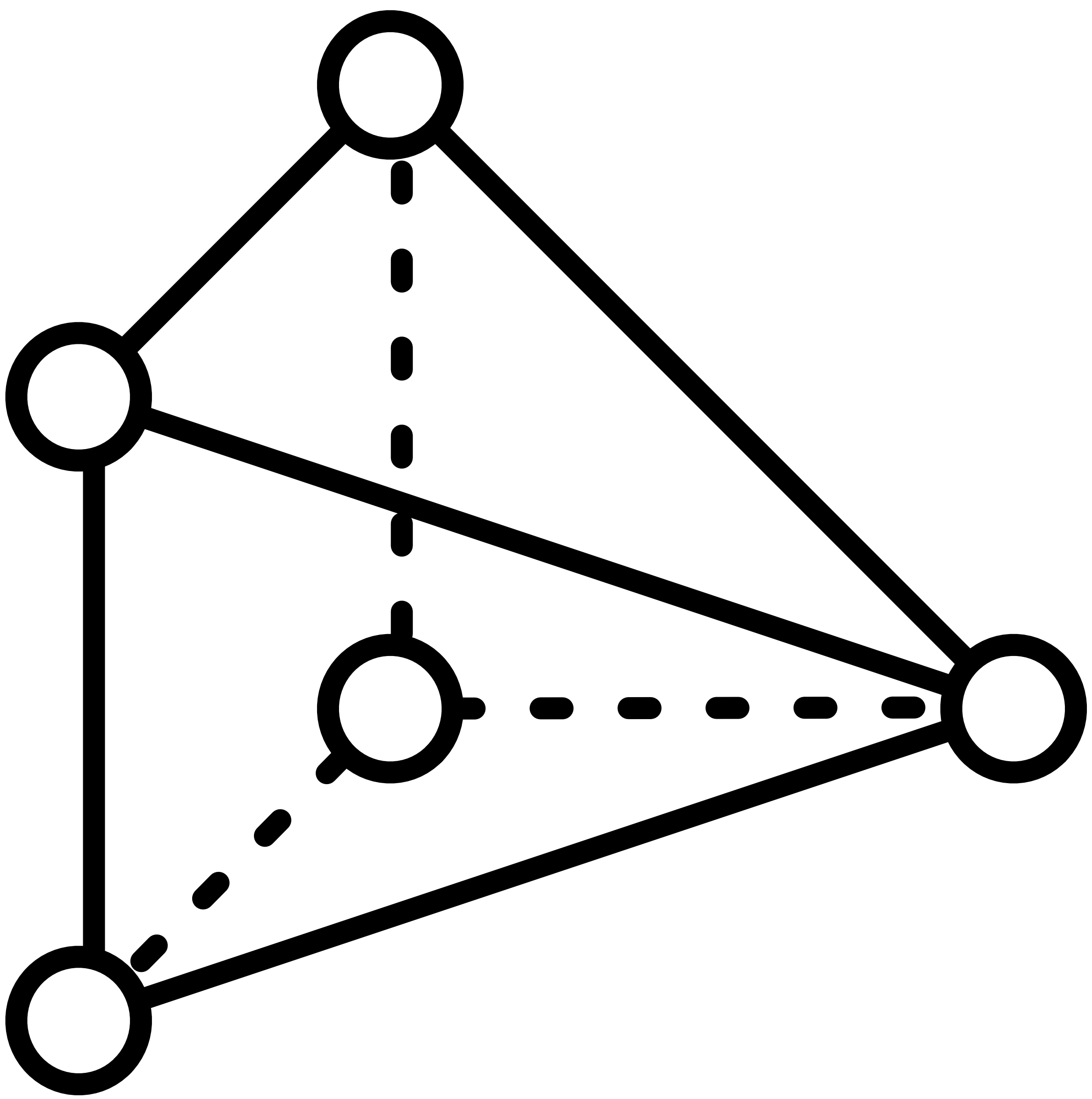
1 tetrahedron,

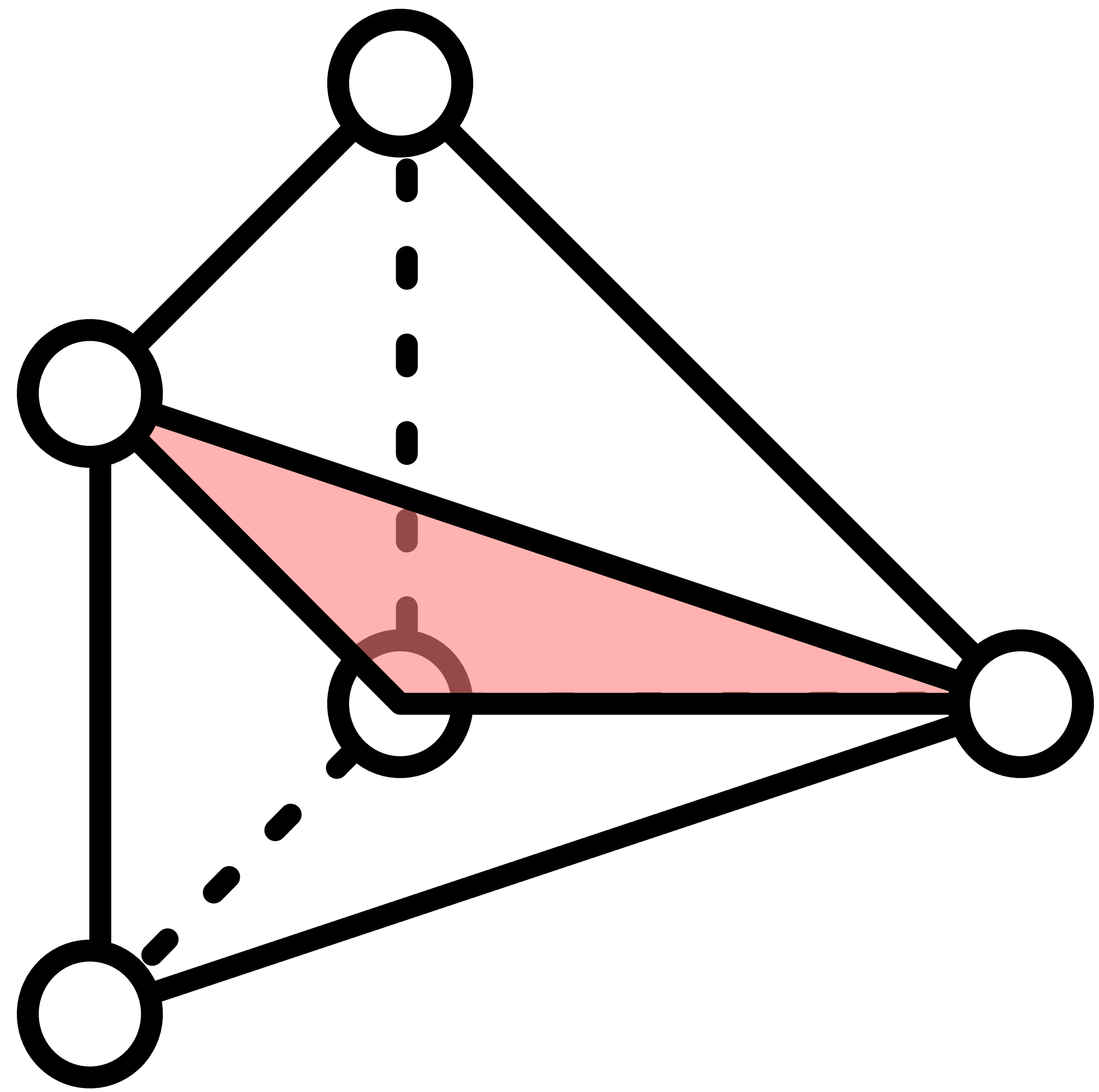
# Cube into tetrahedra





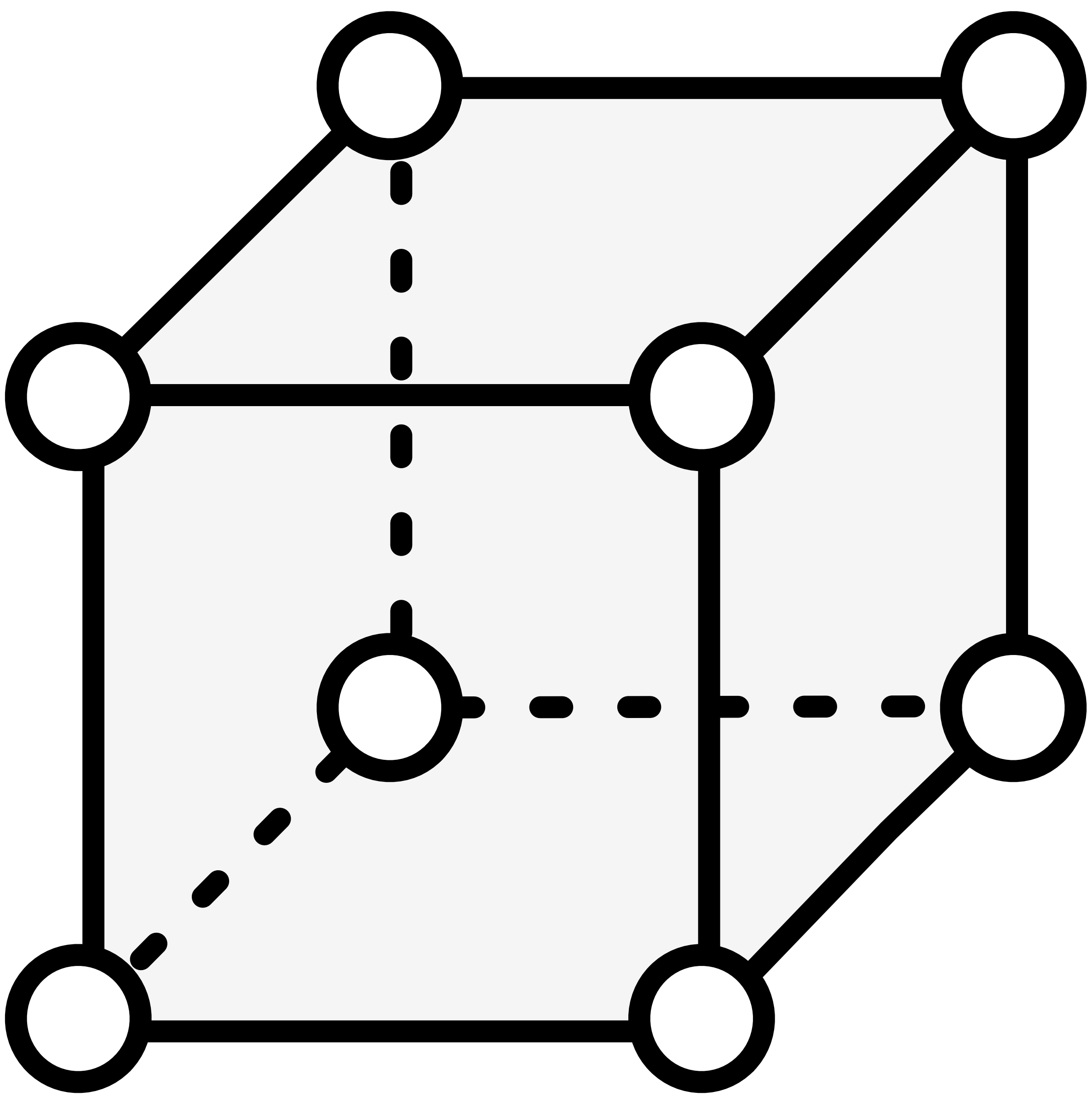
# Cube into tetrahedra





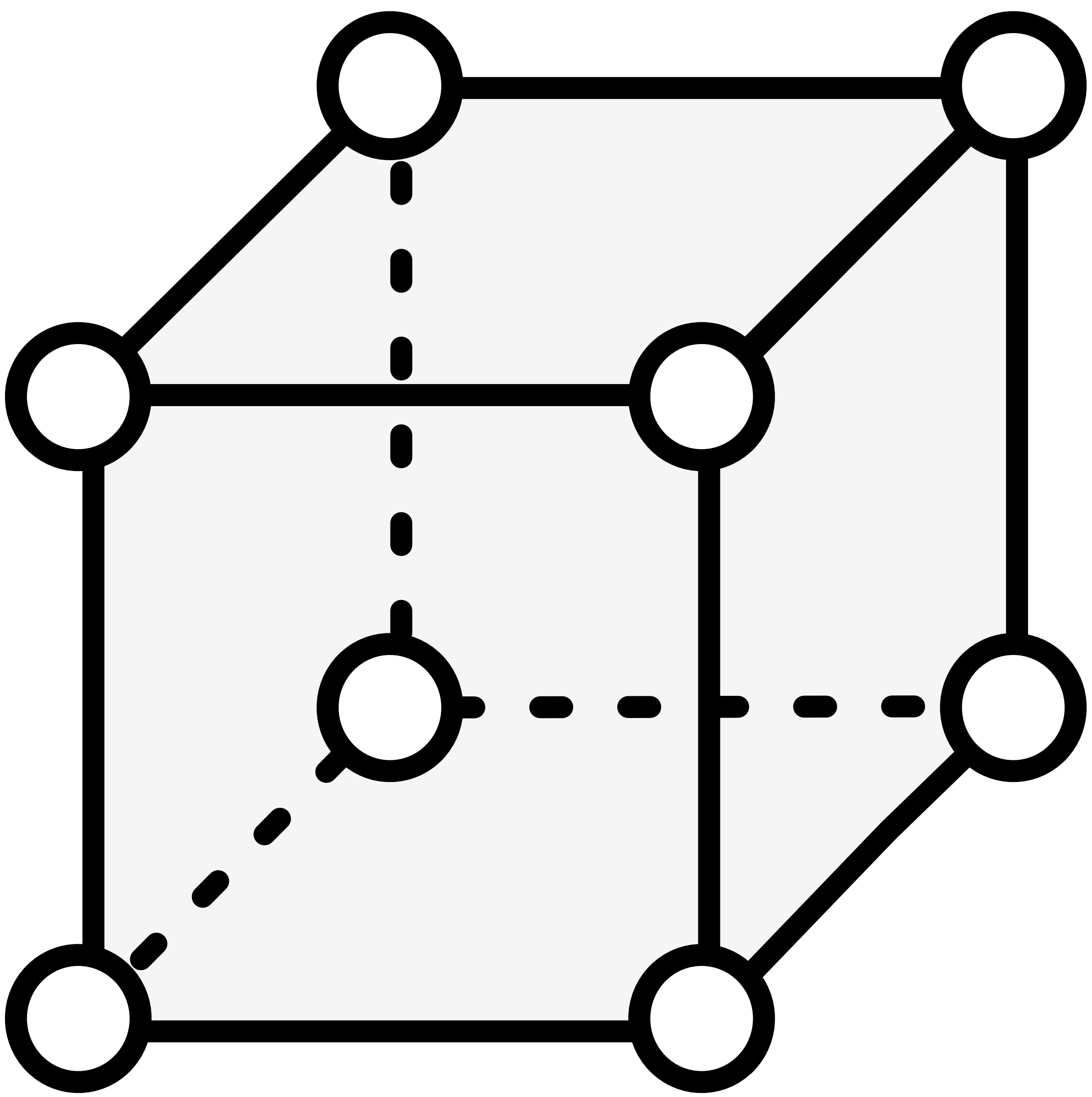
2 tetrahedra

# Cube into tetrahedra



1 cube splits into
6 tetrahedra

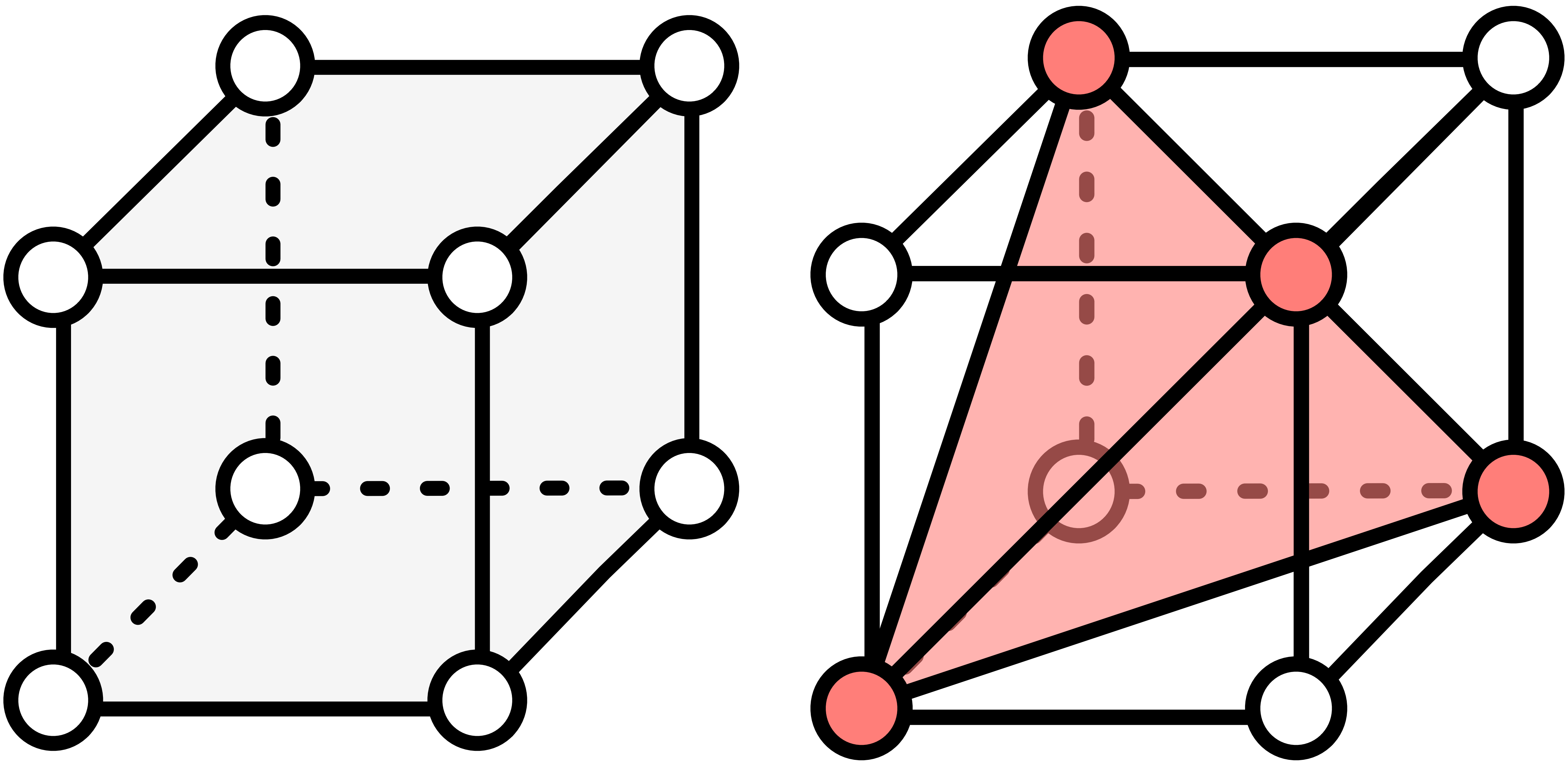
# Cube into tetrahedra



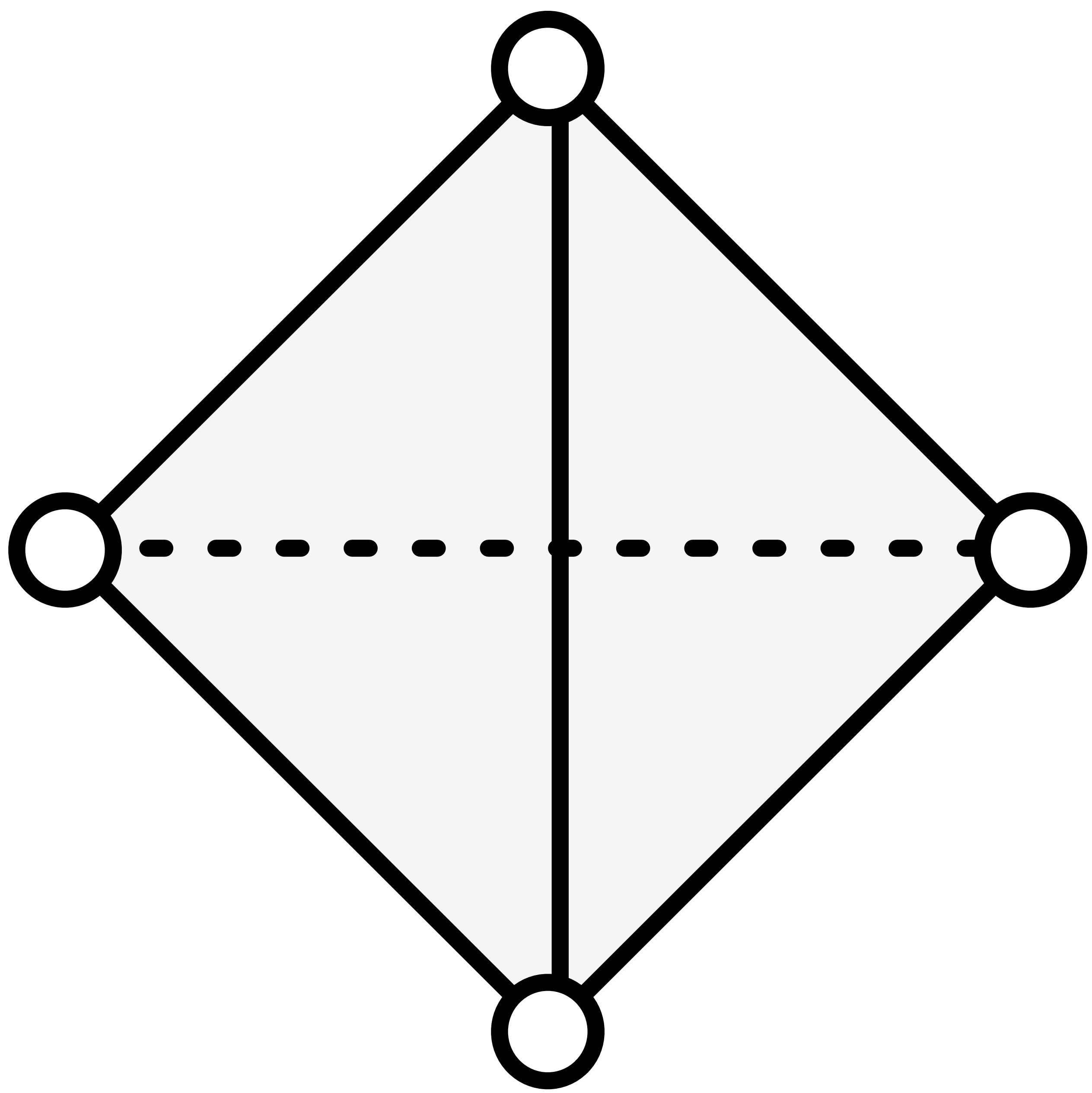
1 cube splits into
6 tetrahedra…

**but also into 5 tetrahedra!**

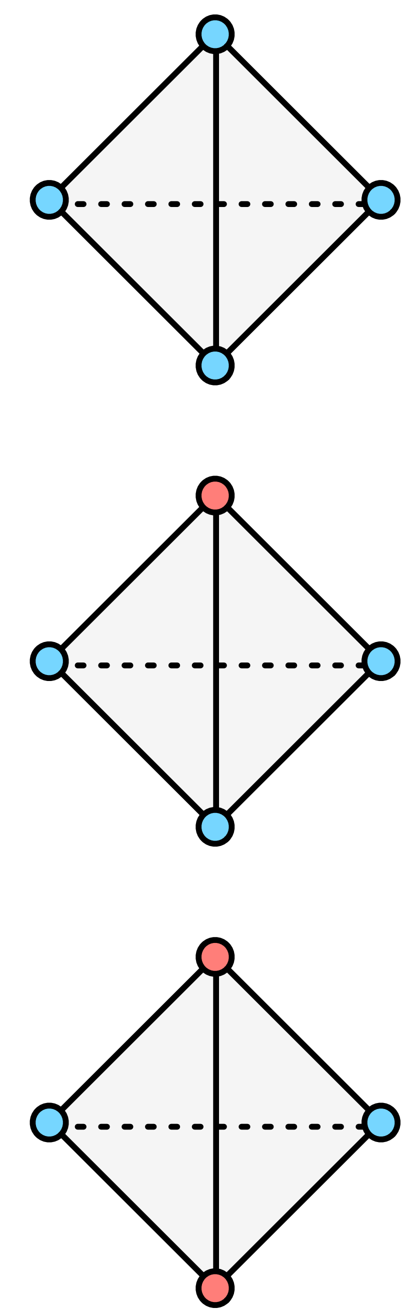
# Cube into tetrahedra



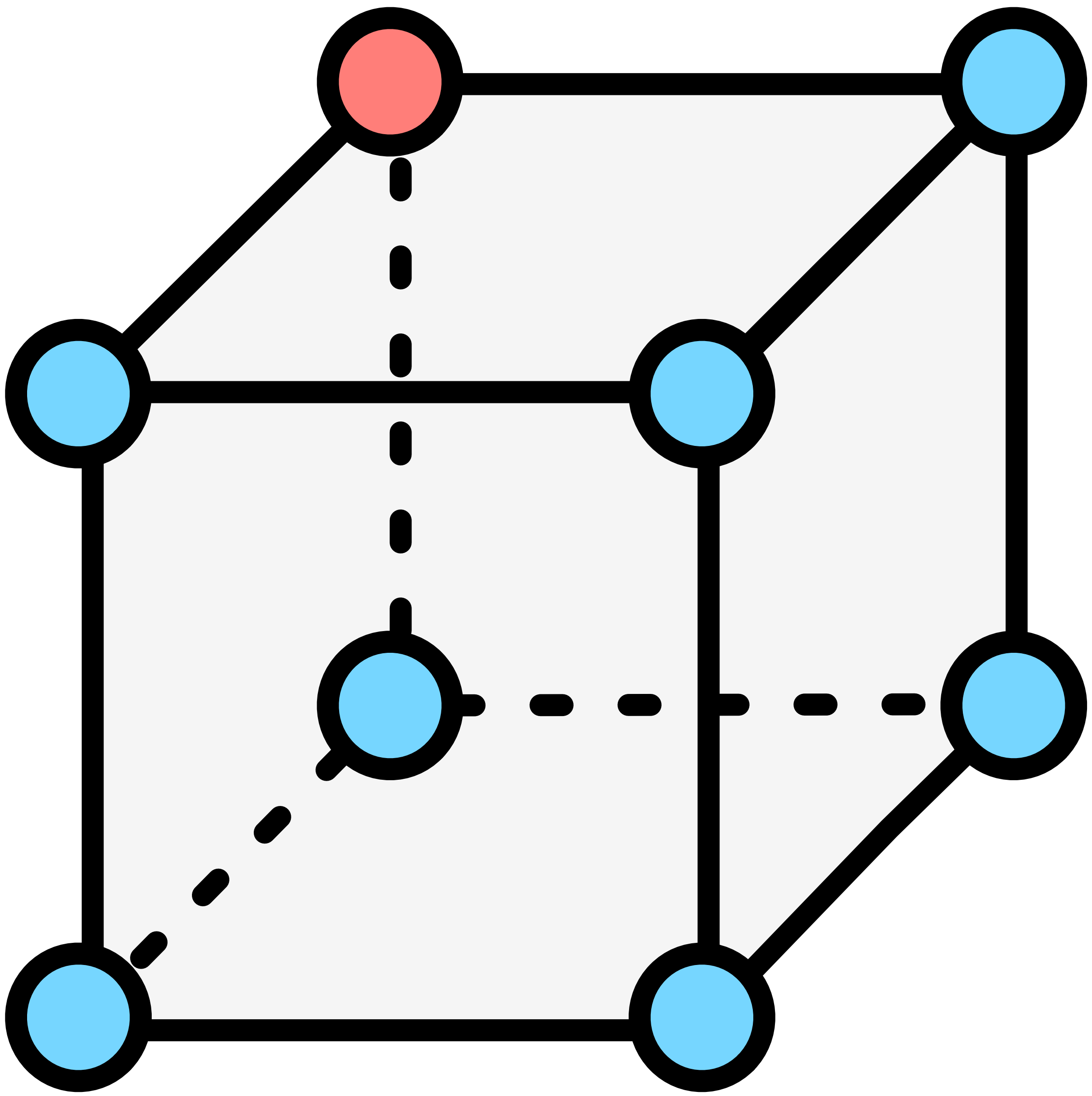
# Marching Tetrahedra

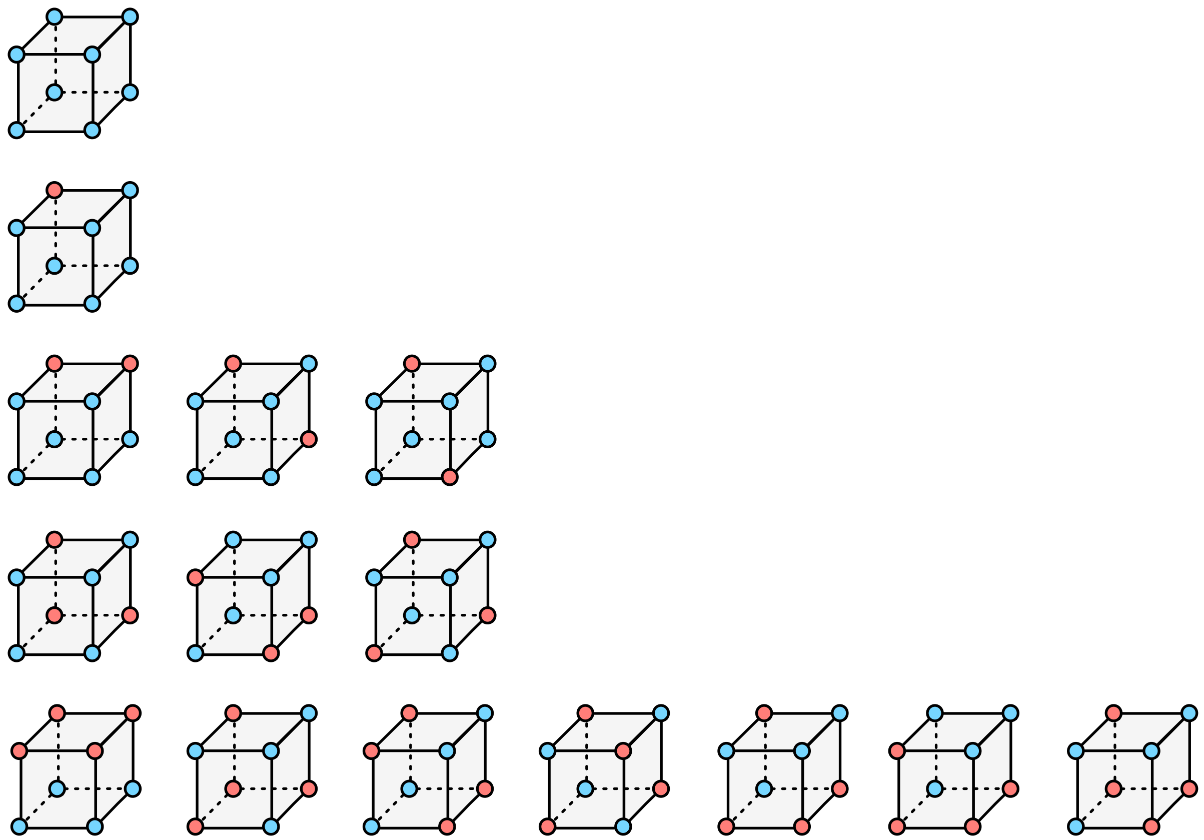


3 cases, “obvious”



# 3D Contouring





# 3D Contouring

Computer Graphics, Volume 21, Number 4, July 1987

## MARCHING CUBES: A HIGH RESOLUTION 3D SURFACE CONSTRUCTION ALGORITHM

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*Harvey E. Cline*

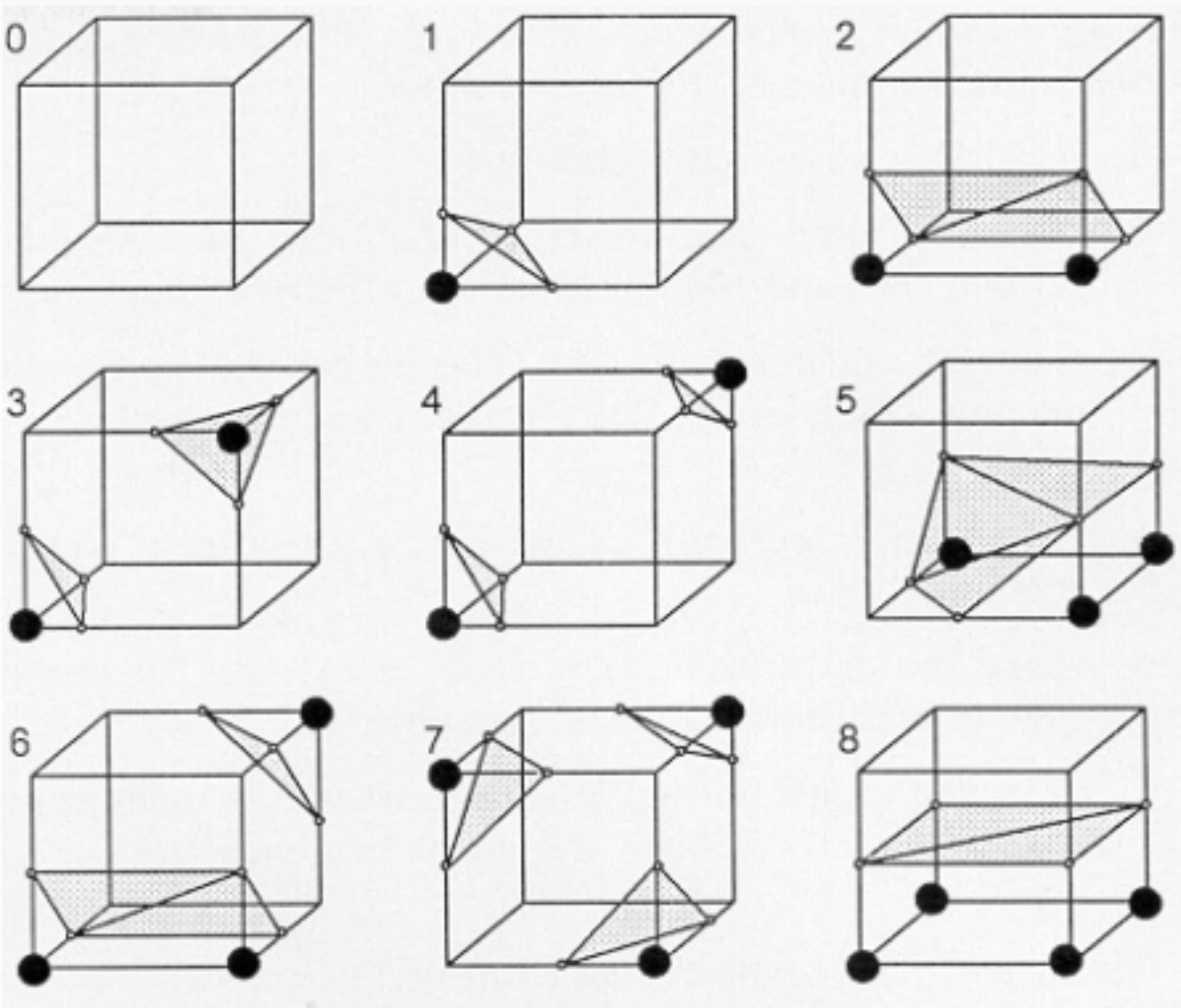
General Electric Company
Corporate Research and Development
Schenectady, New York 12301

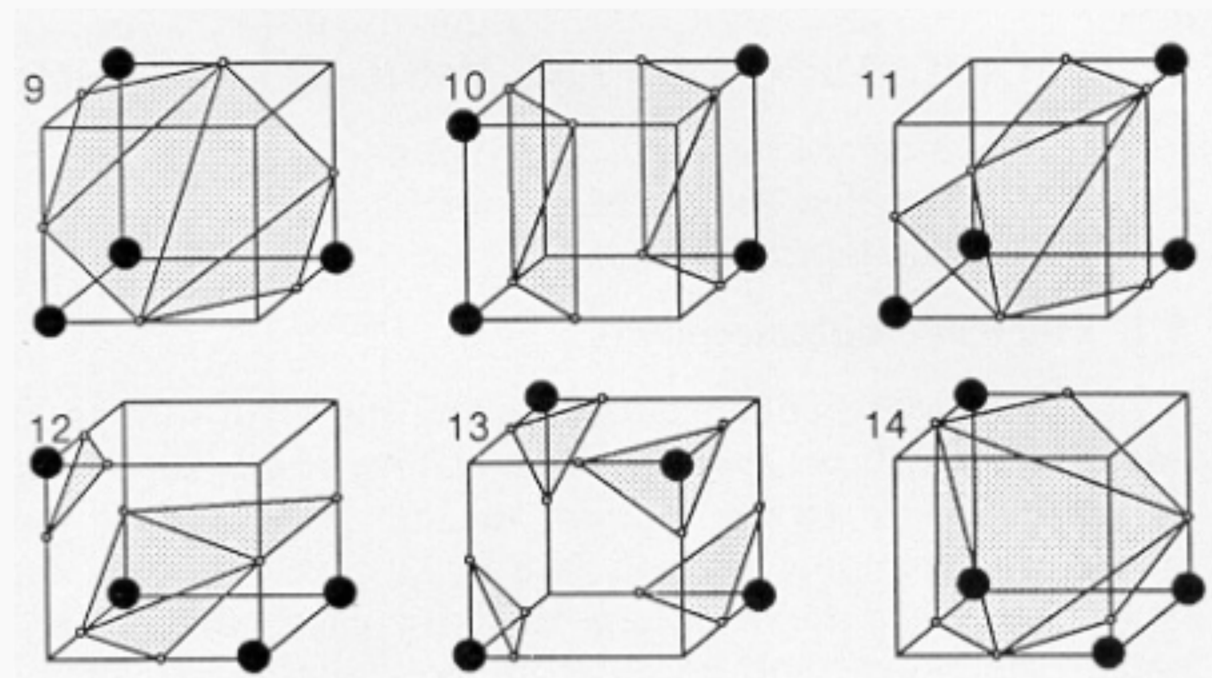
**Abstract**

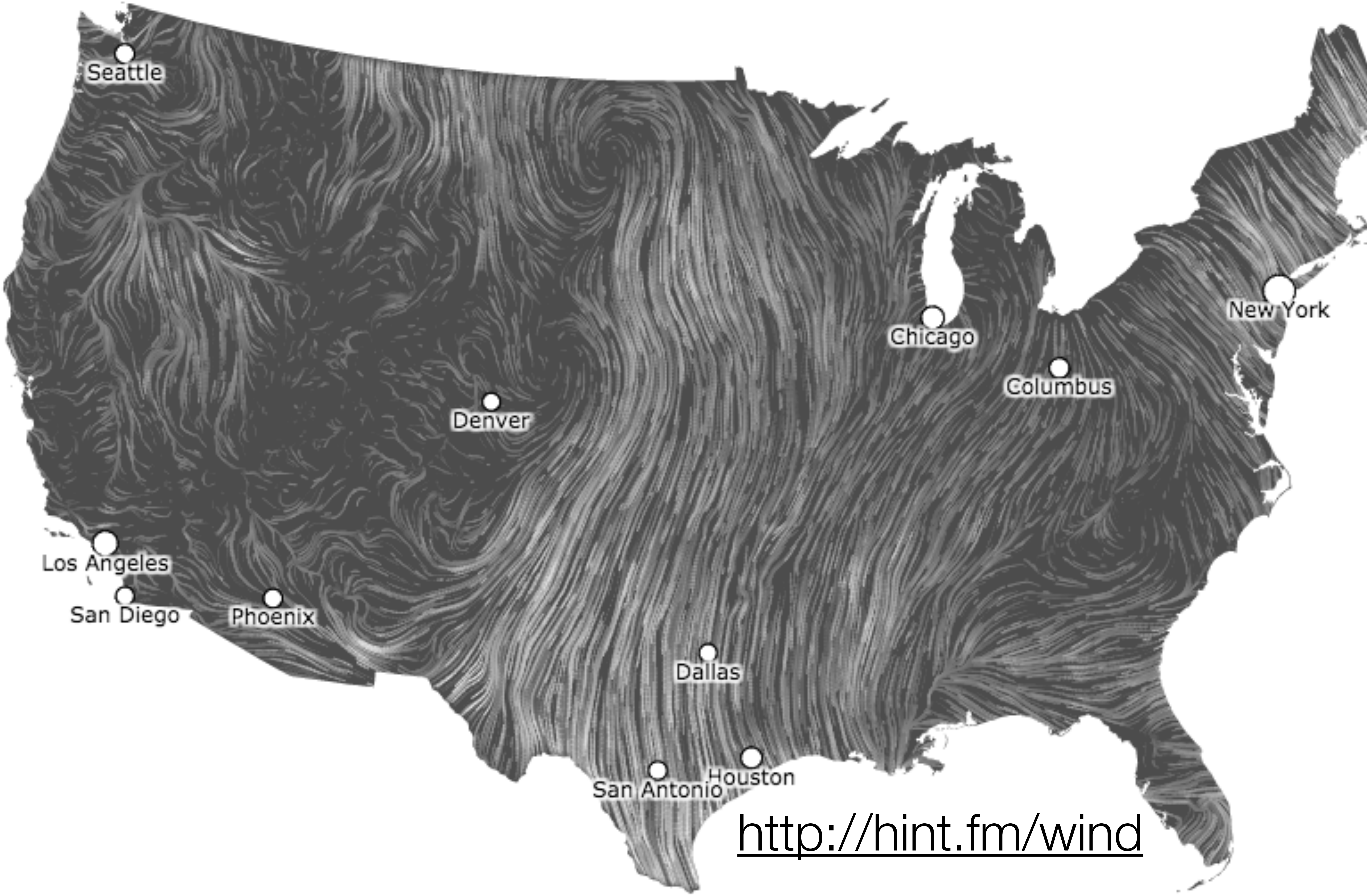
We present a new algorithm, called *marching cubes*, that creates triangle models of constant density surfaces from 3D medical data. Using a divide-and-conquer approach to generate inter-slice connectivity, we create a case table that defines triangle topology. The algorithm processes the 3D medical data in scan-line order and calculates triangle vertices using linear interpolation. We find the gradient of the origi-

acetabular fractures [6], craniofacial abnormalities [17,18], and intracranial structure [13] illustrate 3D's potential for the study of complex bone structures. Applications in radiation therapy [27,11] and surgical planning [4,5,31] show interactive 3D techniques combined with 3D surface images. Cardiac applications include artery visualization [2,16] and nongraphic modeling applications to calculate surface area and volume [21].

# 3D Contouring



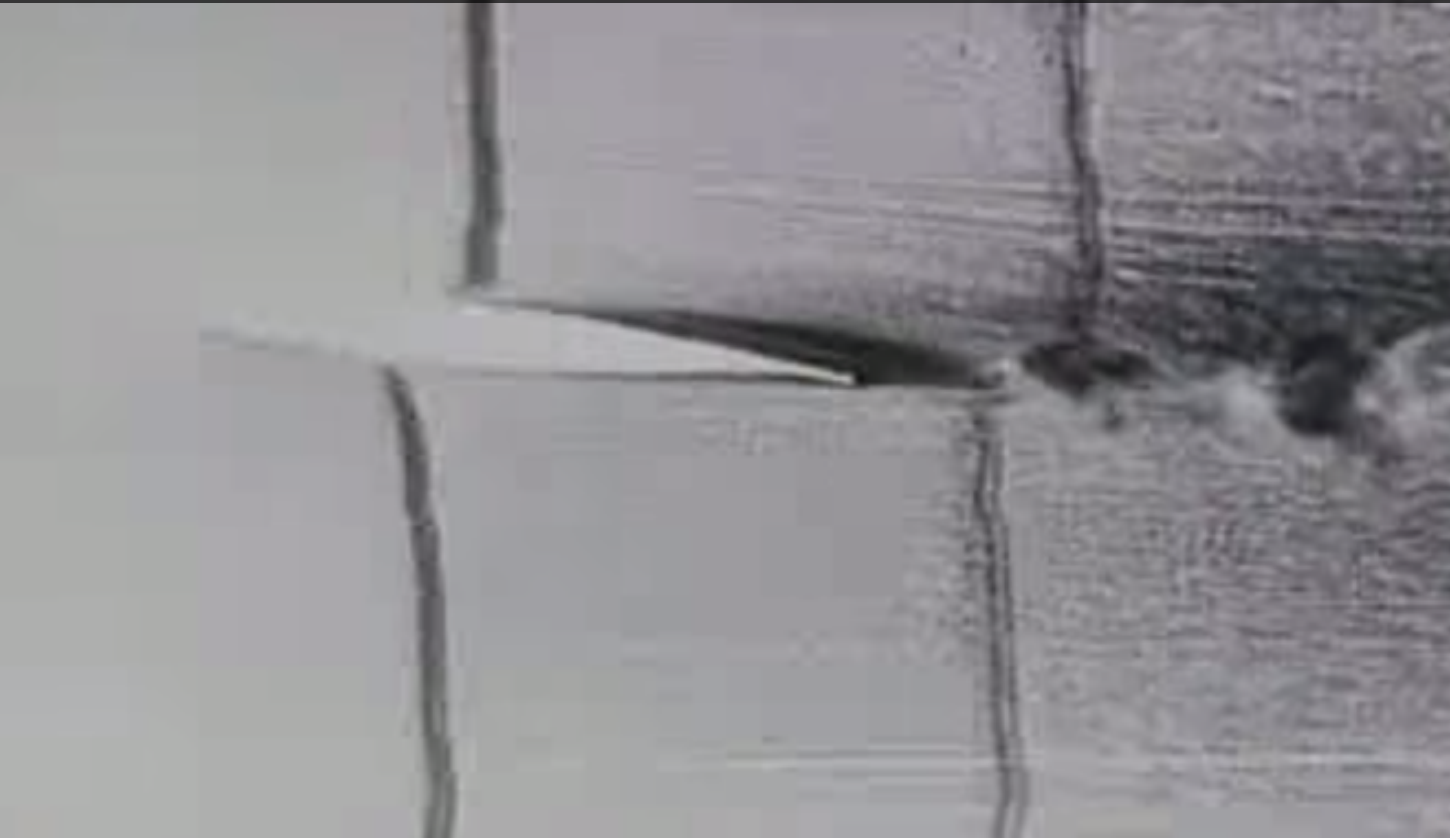






http://hint.fm/wind

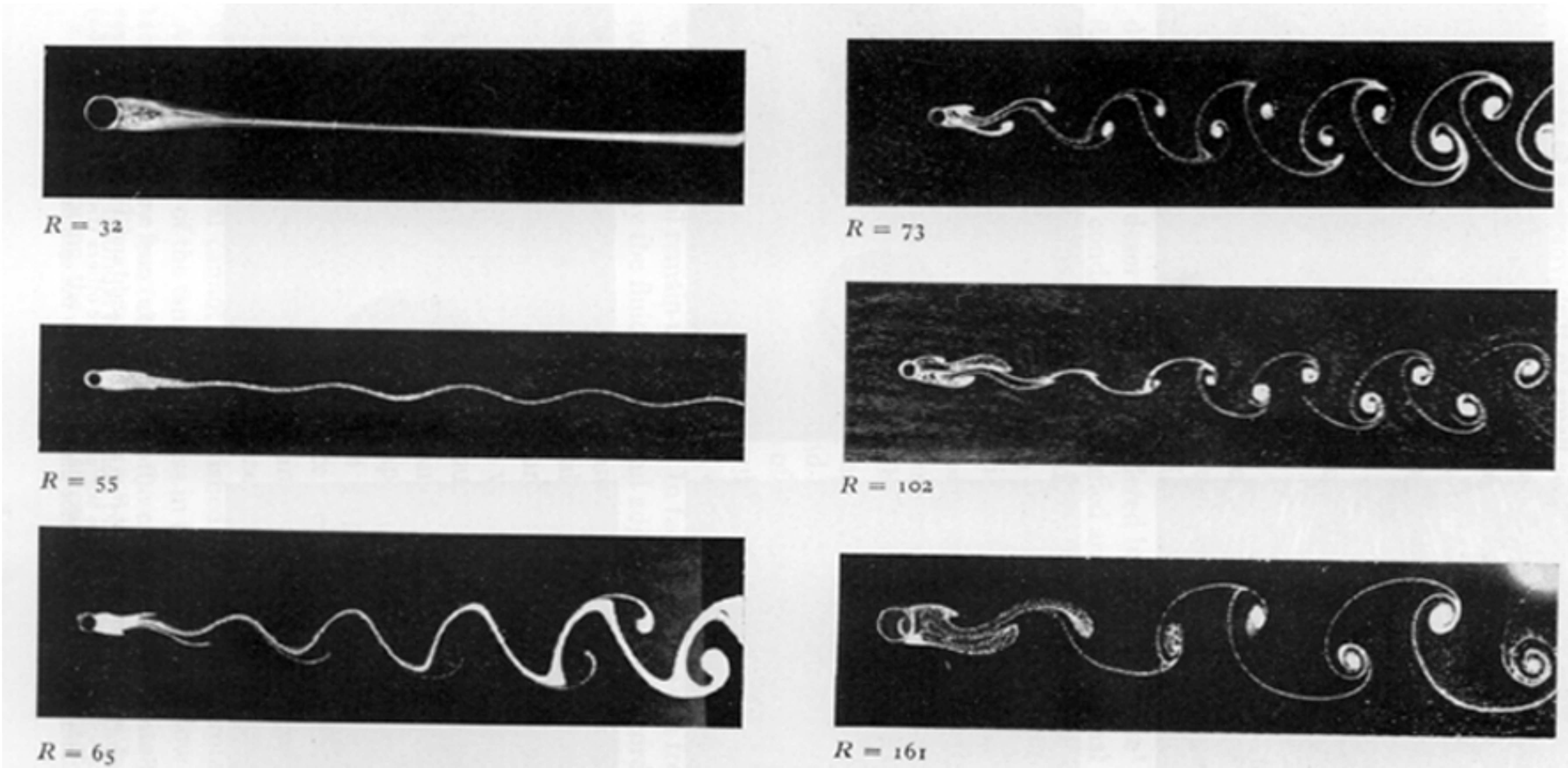
# Spatial Data: Vector Fields

https://www.youtube.com/watch?v=nuQyKGuXJOs

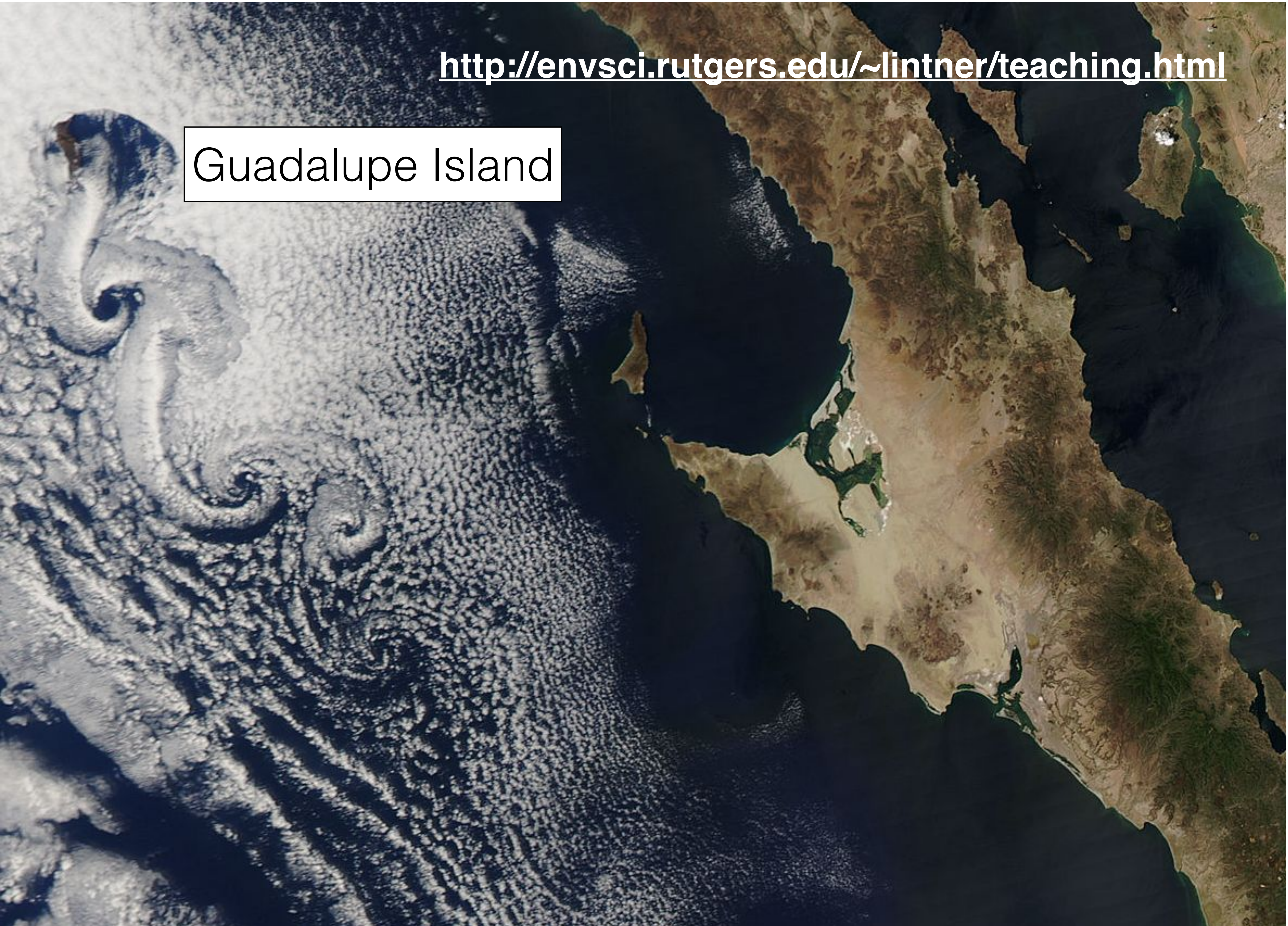


# Spatial Data: Vector Fields

# Experimental Flow Vis




von Kármán vortex street, depending on Reynolds number

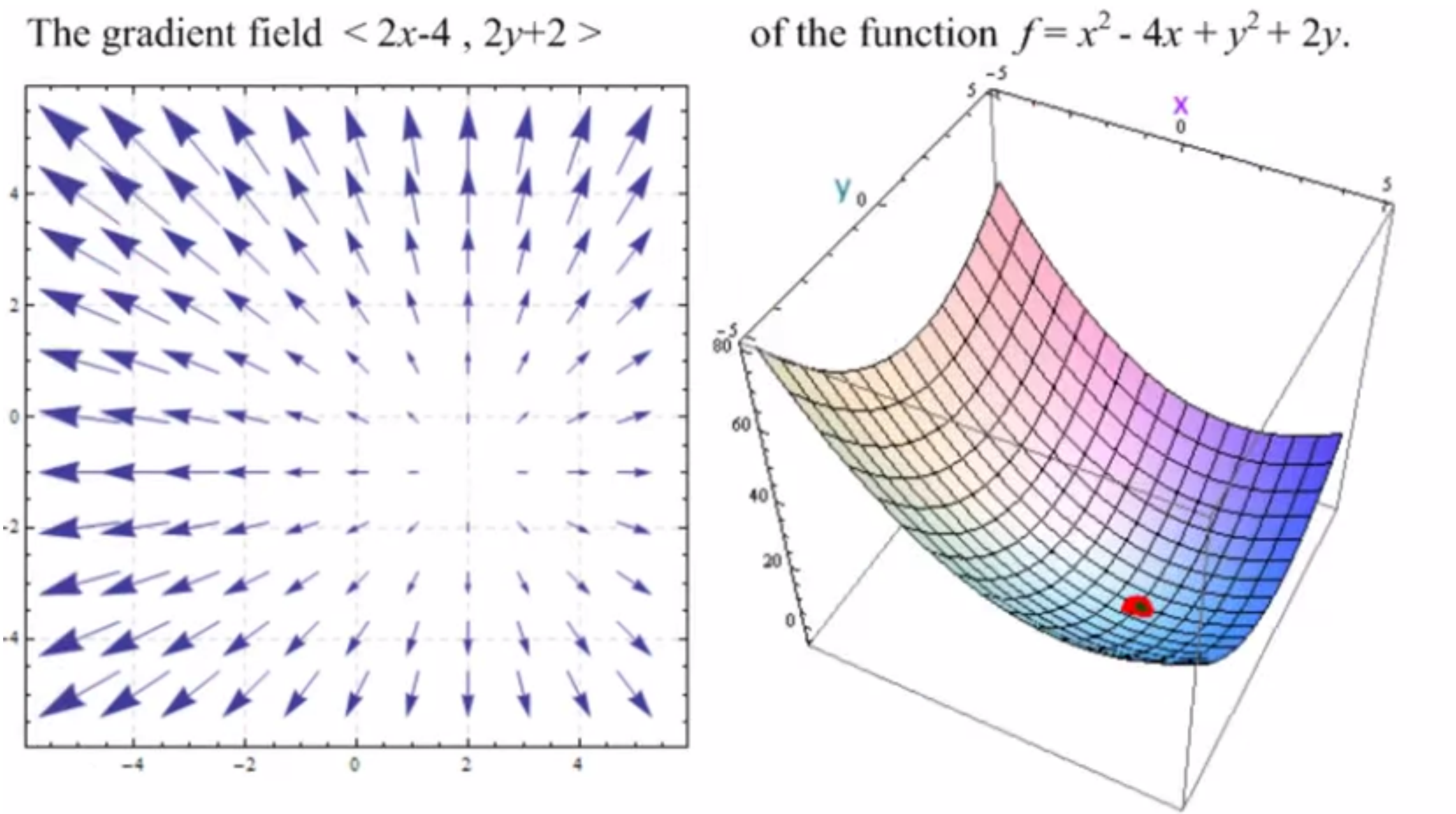

http://envsci.rutgers.edu/~lintner/teaching.html
Guadalupe Island

# Mathematics of Vector Fields

$$v : R^n \to R^n$$

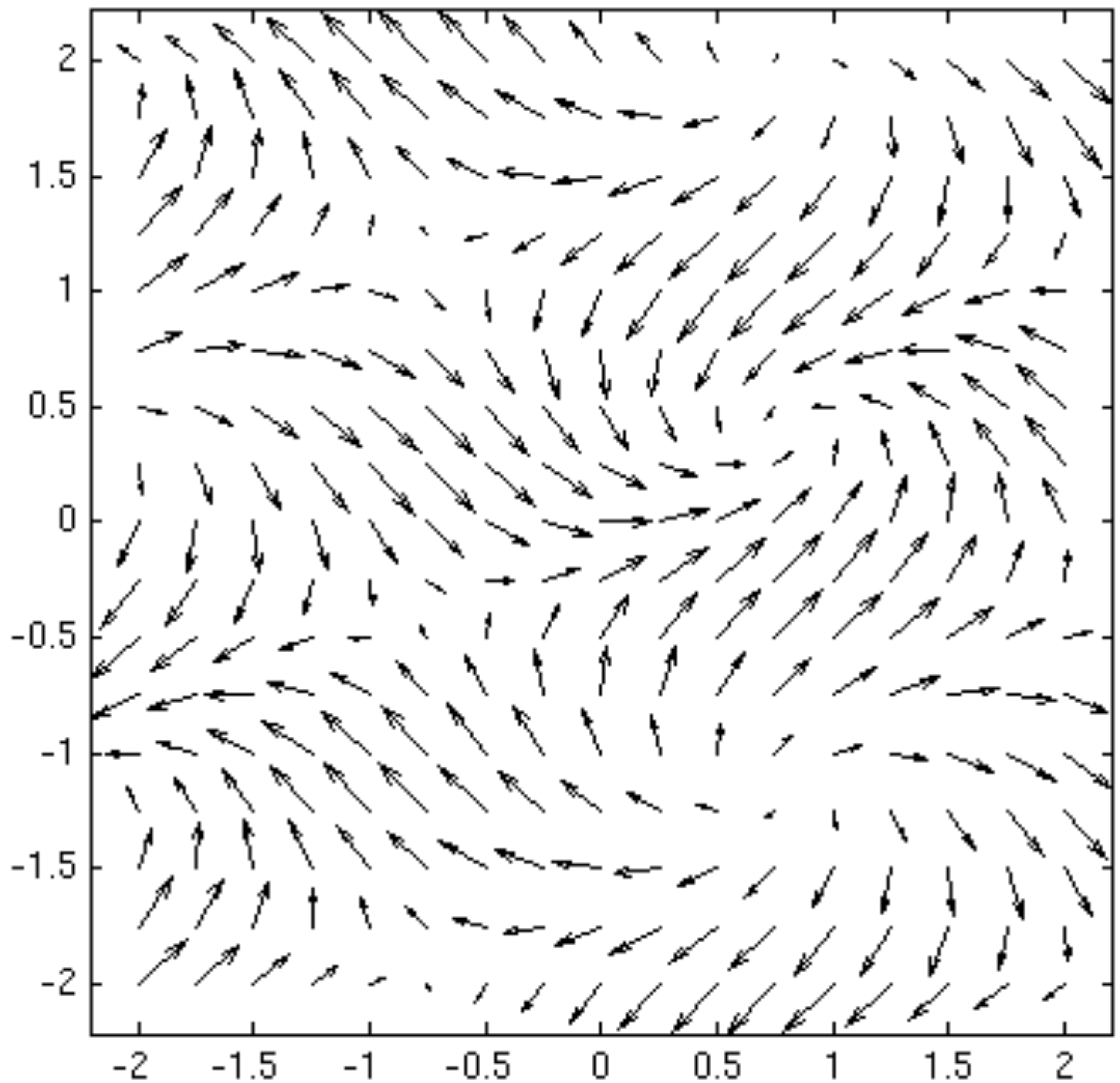
**Function from vectors to vectors**

# A simple vector field: the gradient




https://www.youtube.com/watch?v=v0_LlyVquF8

# Vector fields can be more complicated

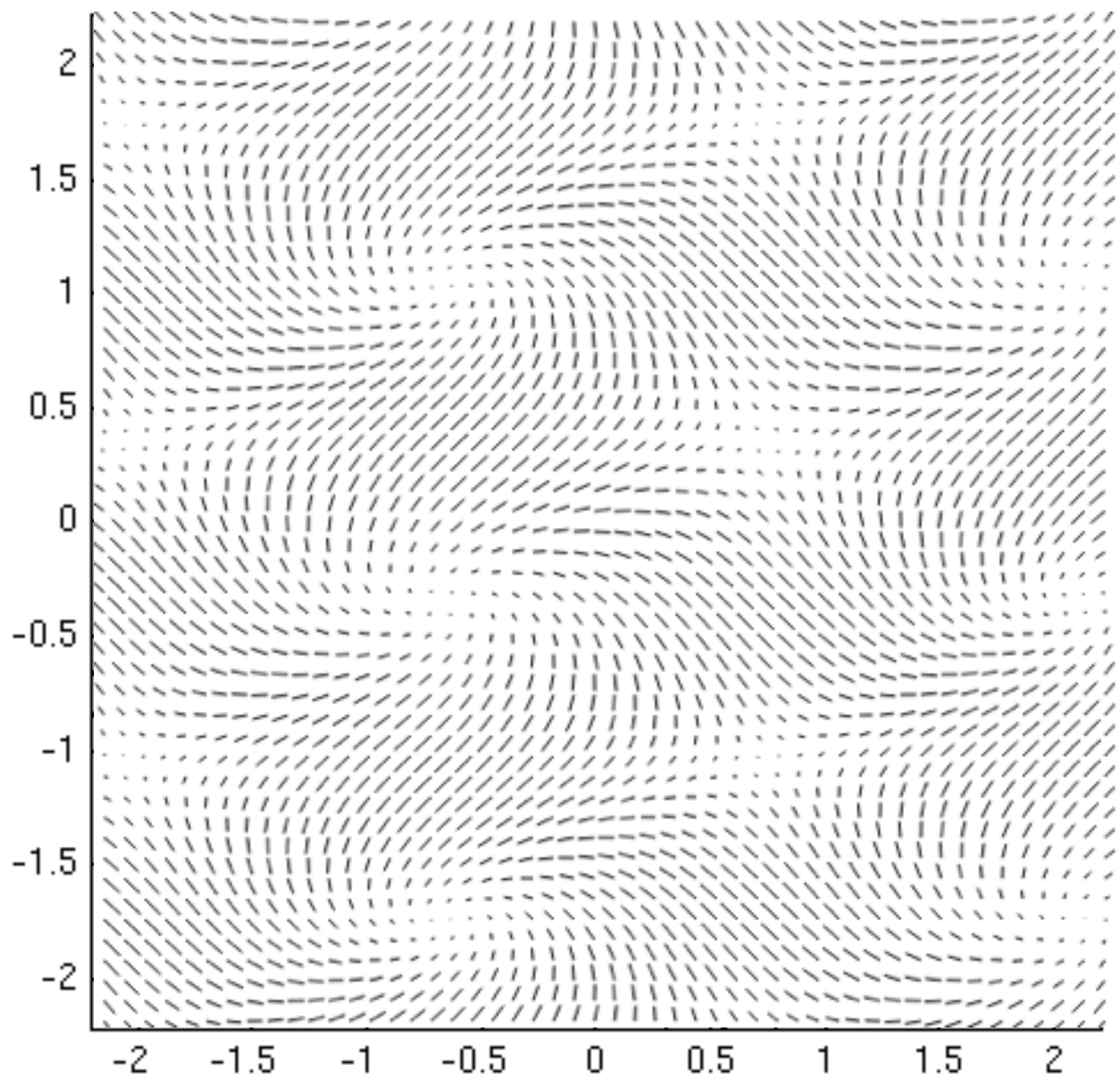



$$v(x,y) = (\cos(x+2y), \sin(x-2y))$$

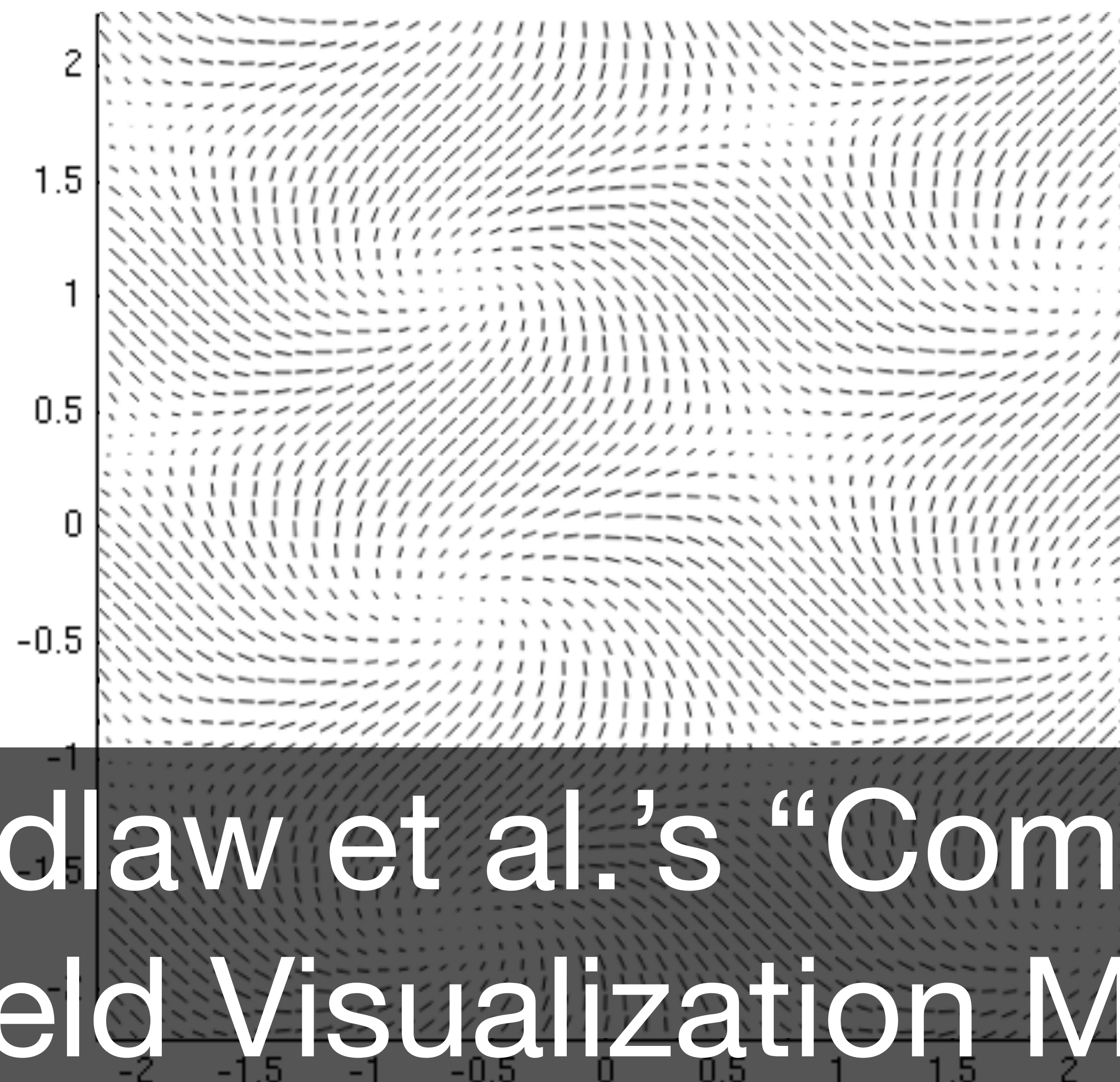
http://www.math.umd.edu/~petersd/241/html/ex27b.html

# Glyph Based Techniques

# Hedgehog Plot: Not Very Good

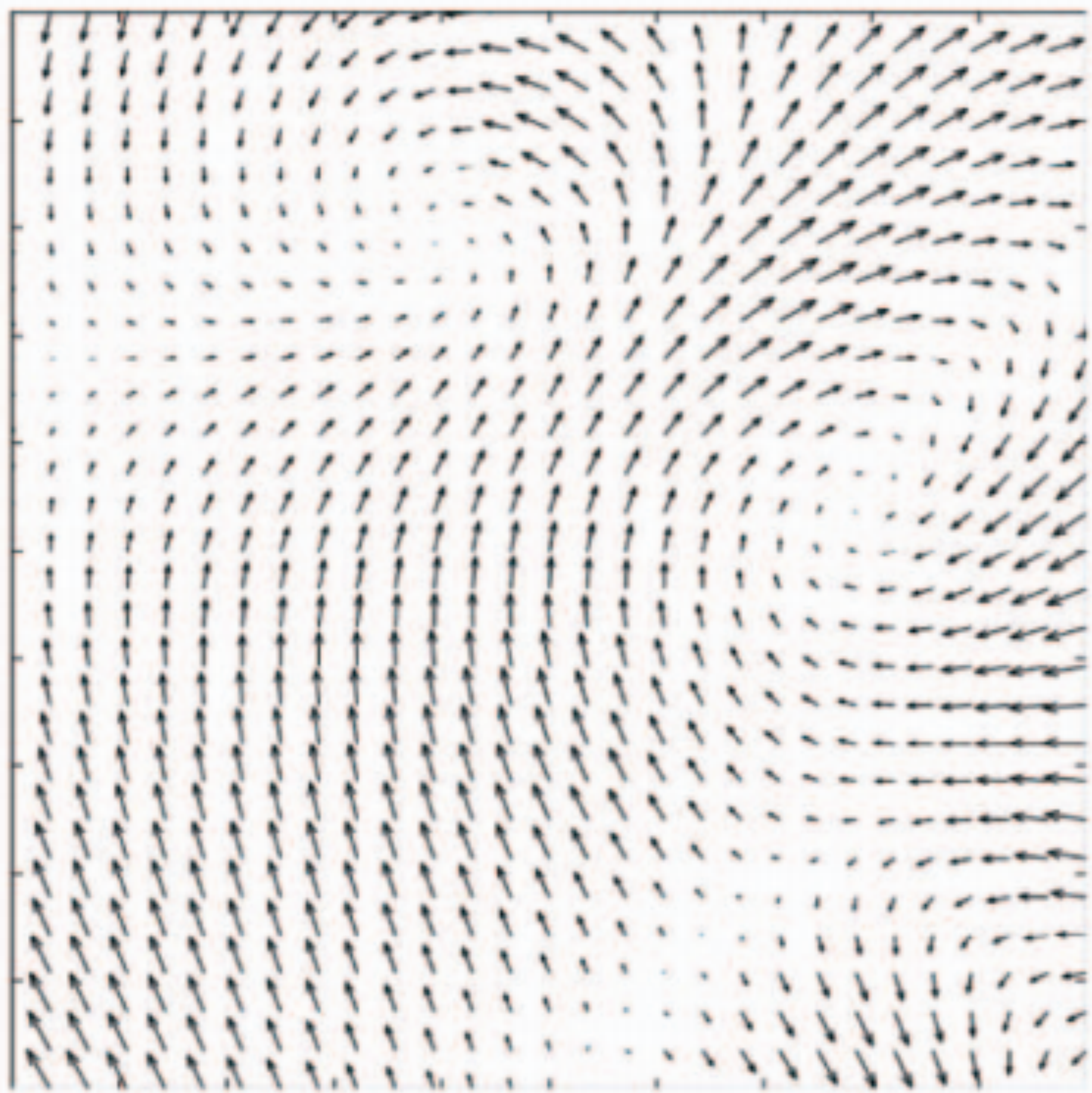


# Hedgehog Plot: Not Very Good



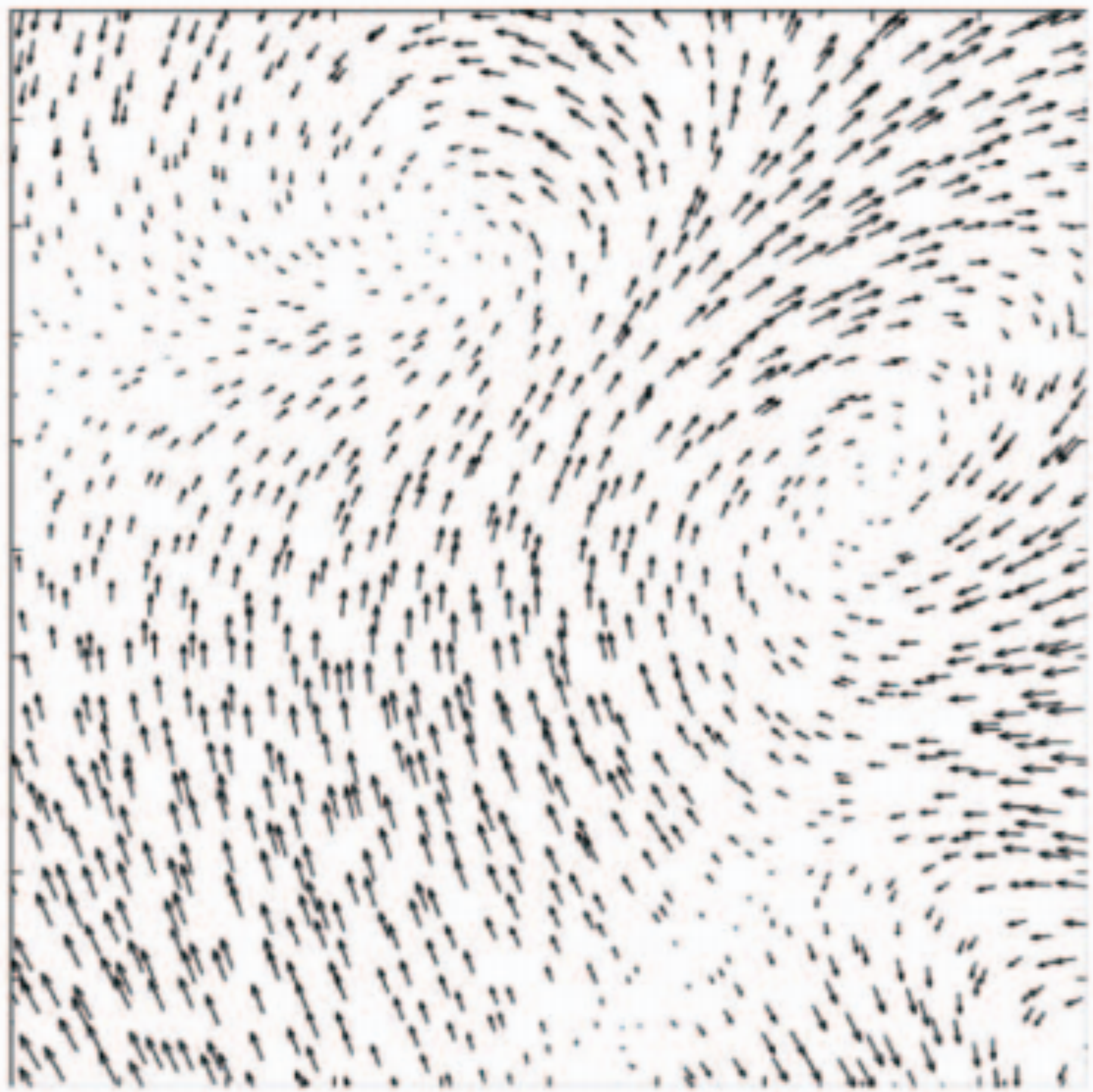

From Laidlaw et al.'s "Comparing 2D Vector Field Visualization Methods: A User Study", TVCG 2005

# Uniformly-placed arrows: Not Very Good Either



GRID

# Jittered Hedgehog Plot: Better



JIT

# Space-filling scaled glyphs

# Streamline-Guided Placement

OSTR

# **Streamline**-Guided Placement

OSTR

# Streamlines

# Streamlines

# Streamlines

# Curves everywhere tangent to the vector field

# Curves everywhere tangent to the vector field

$$\begin{aligned} x'(t) &= v_x(x(t), y(t)) \\ y'(t) &= v_y(x(t), y(t)) \end{aligned}$$

# Visualization via streamlines

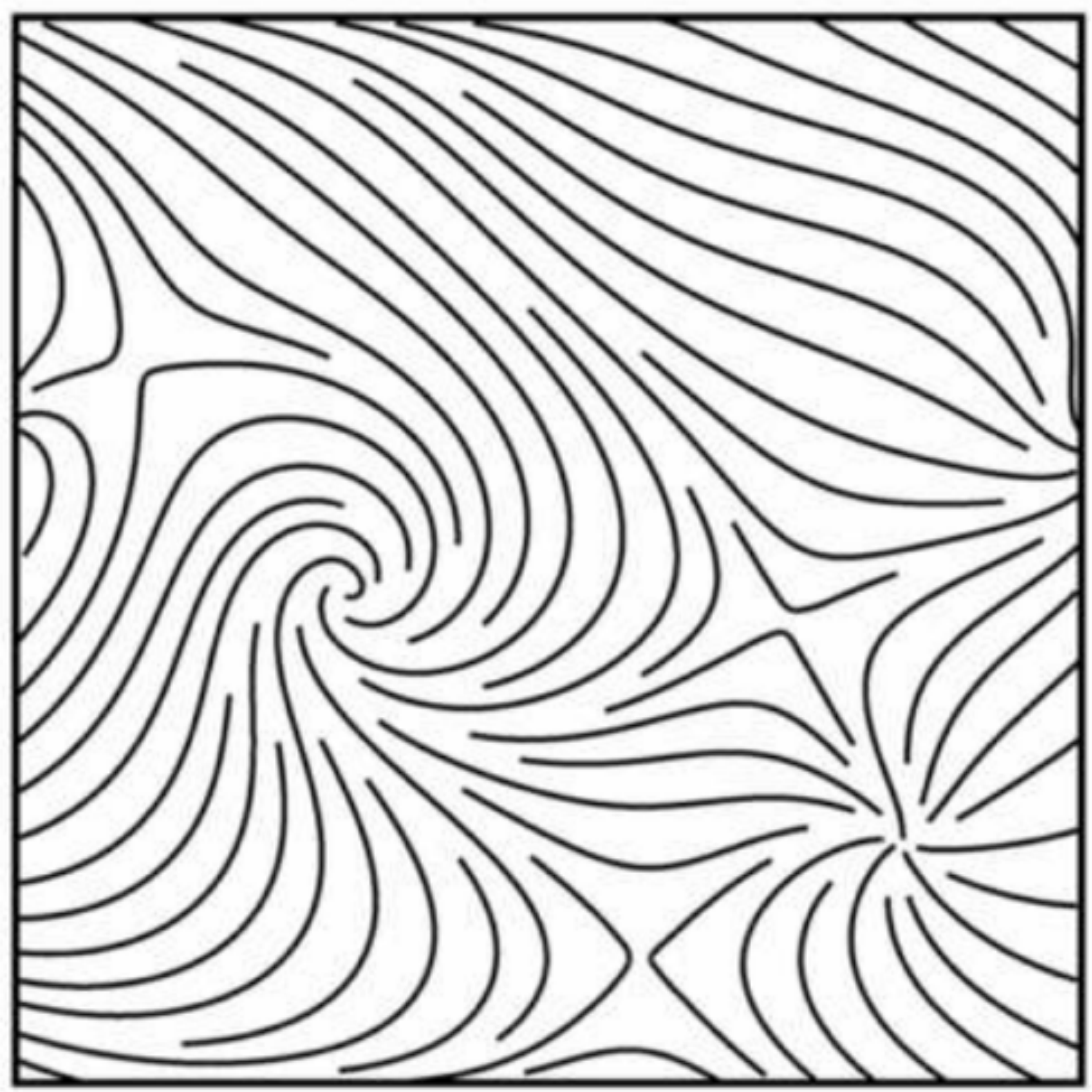
- Pick a set of seed points
- Integrate streamlines from those points

- **Which seed points?**

# Uniform placement

Turk and Banks, Image-Guided Streamline Placement
SIGGRAPH 1996

# Density-optimized placement



Turk and Banks, Image-Guided Streamline Placement
SIGGRAPH 1996

# Density-optimized placement

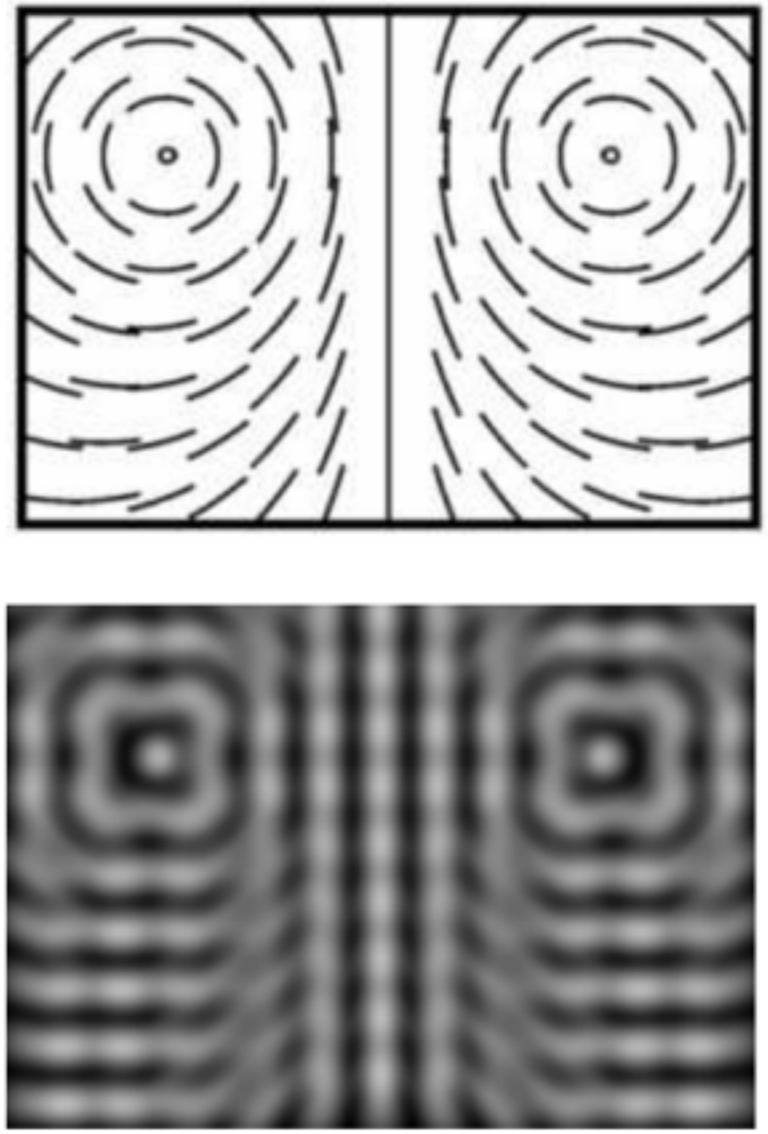


**Figure 2:** (a) Short streamlines with centers placed on a regular grid (top); (b) filtered version of same (bottom).

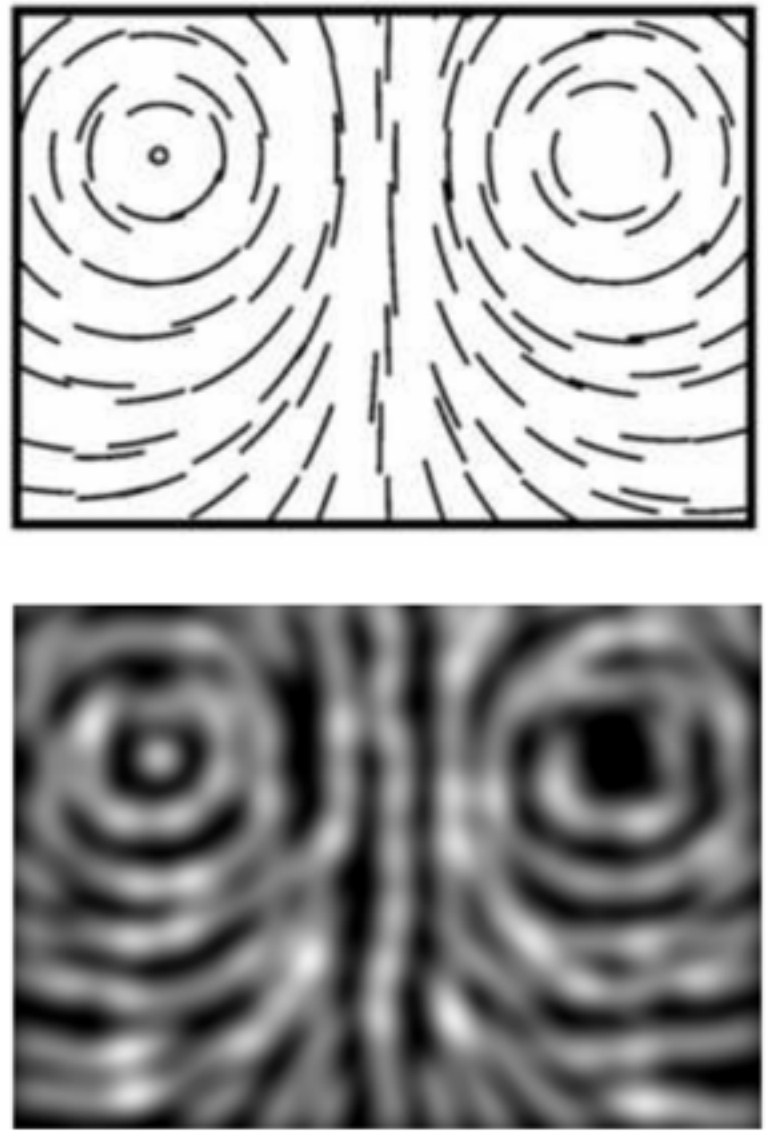


**Figure 3:** (a) Short streamlines with centers placed on a jittered grid (top); (b) filtered version showing bright and dark regions (bottom).

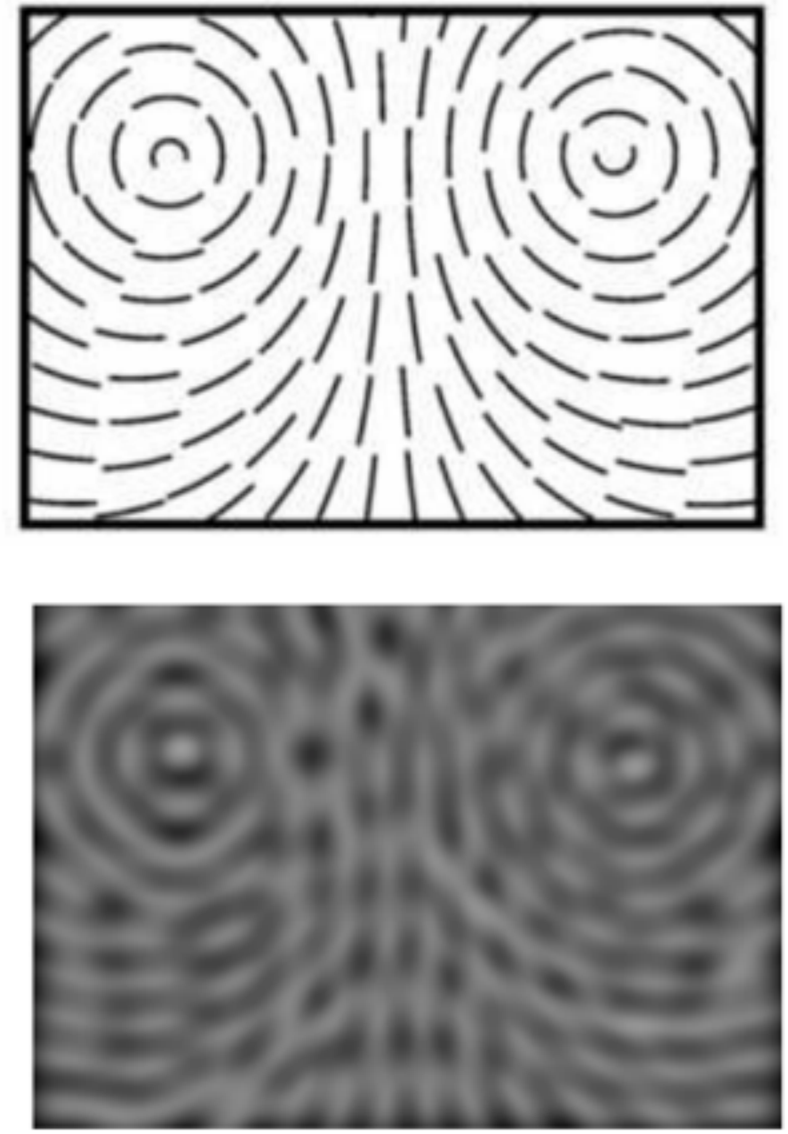
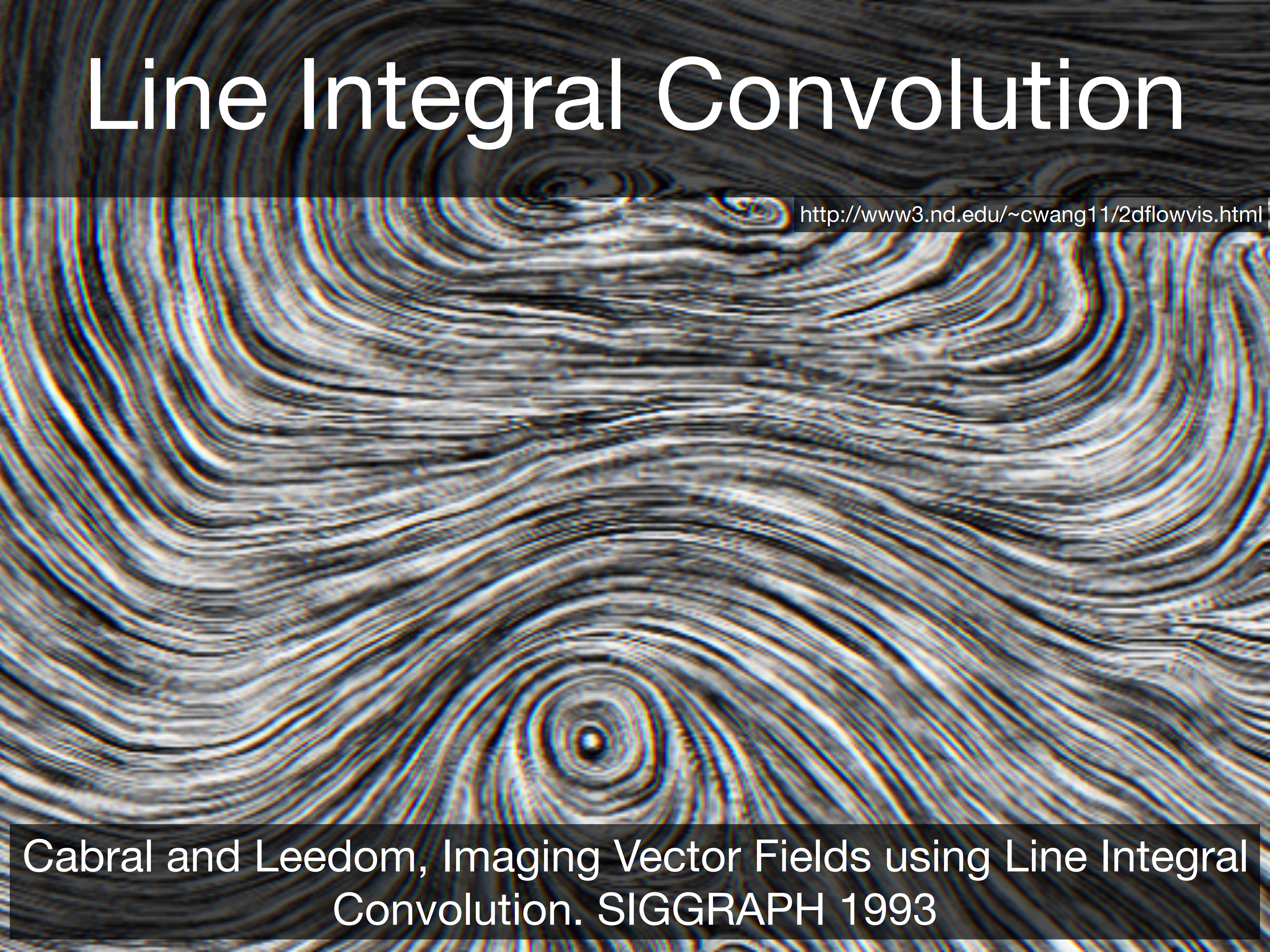


**Figure 4:** (a) Short streamlines placed by optimization (top); (b) filtered version showing fairly even gray value (bottom).

Turk and Banks, Image-Guided Streamline Placement
SIGGRAPH 1996

# Image-Based
# Vector Field Visualization

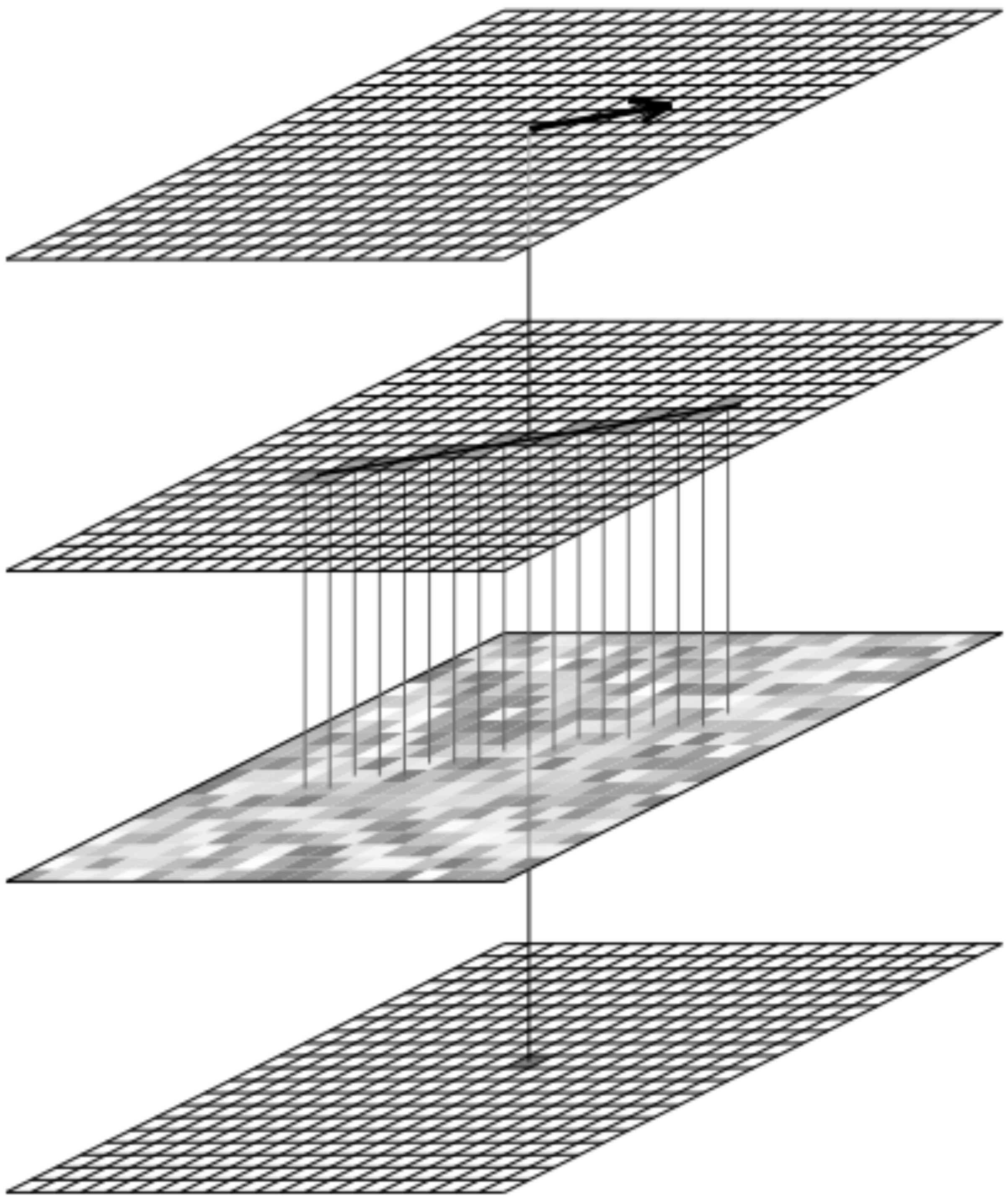
# Line Integral Convolution



http://www3.nd.edu/~cwang11/2dflowvis.html

Cabral and Leedom, Imaging Vector Fields using Line Integral Convolution. SIGGRAPH 1993

# Line Integral Convolution



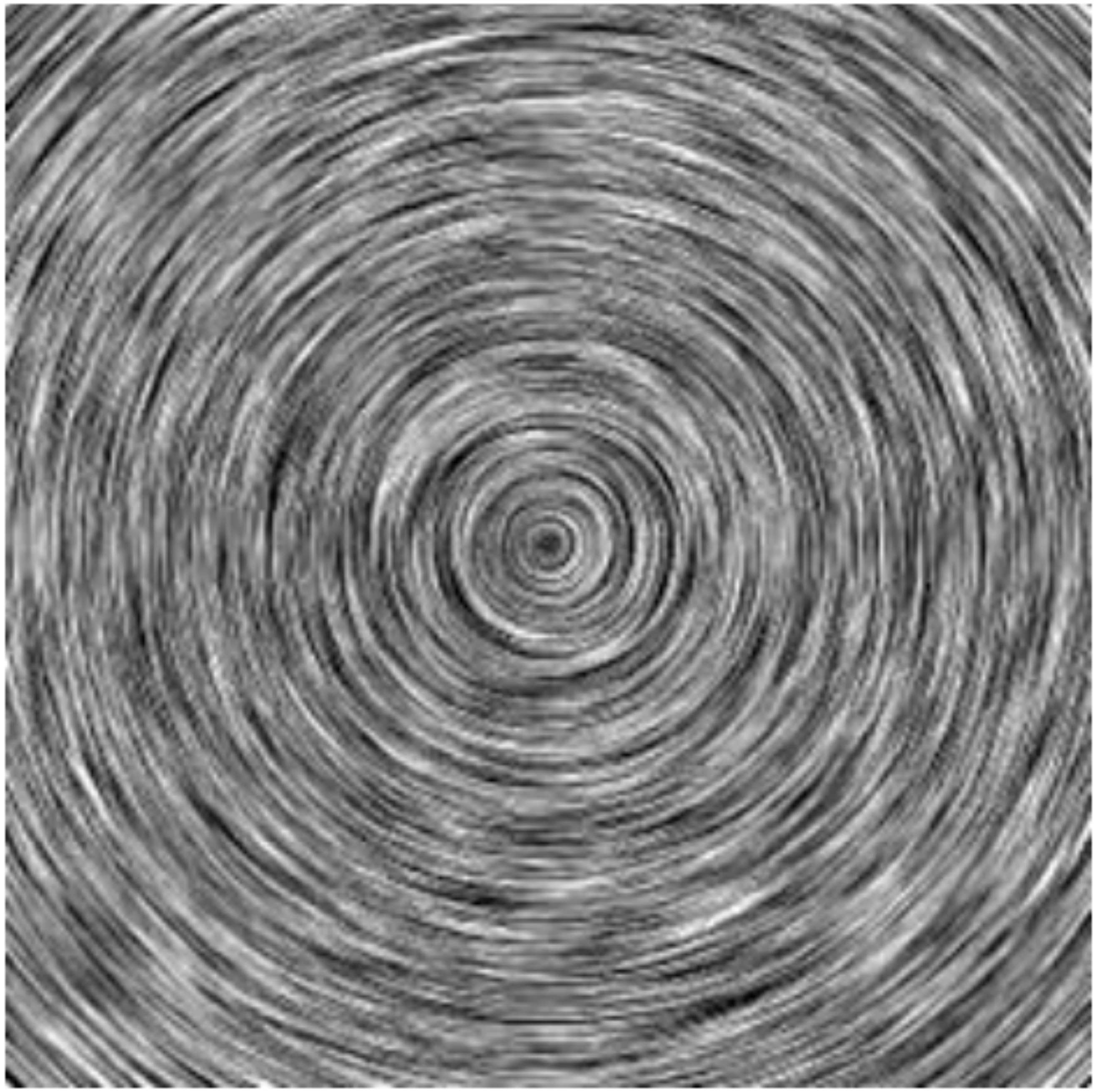
Given a
**vector field**

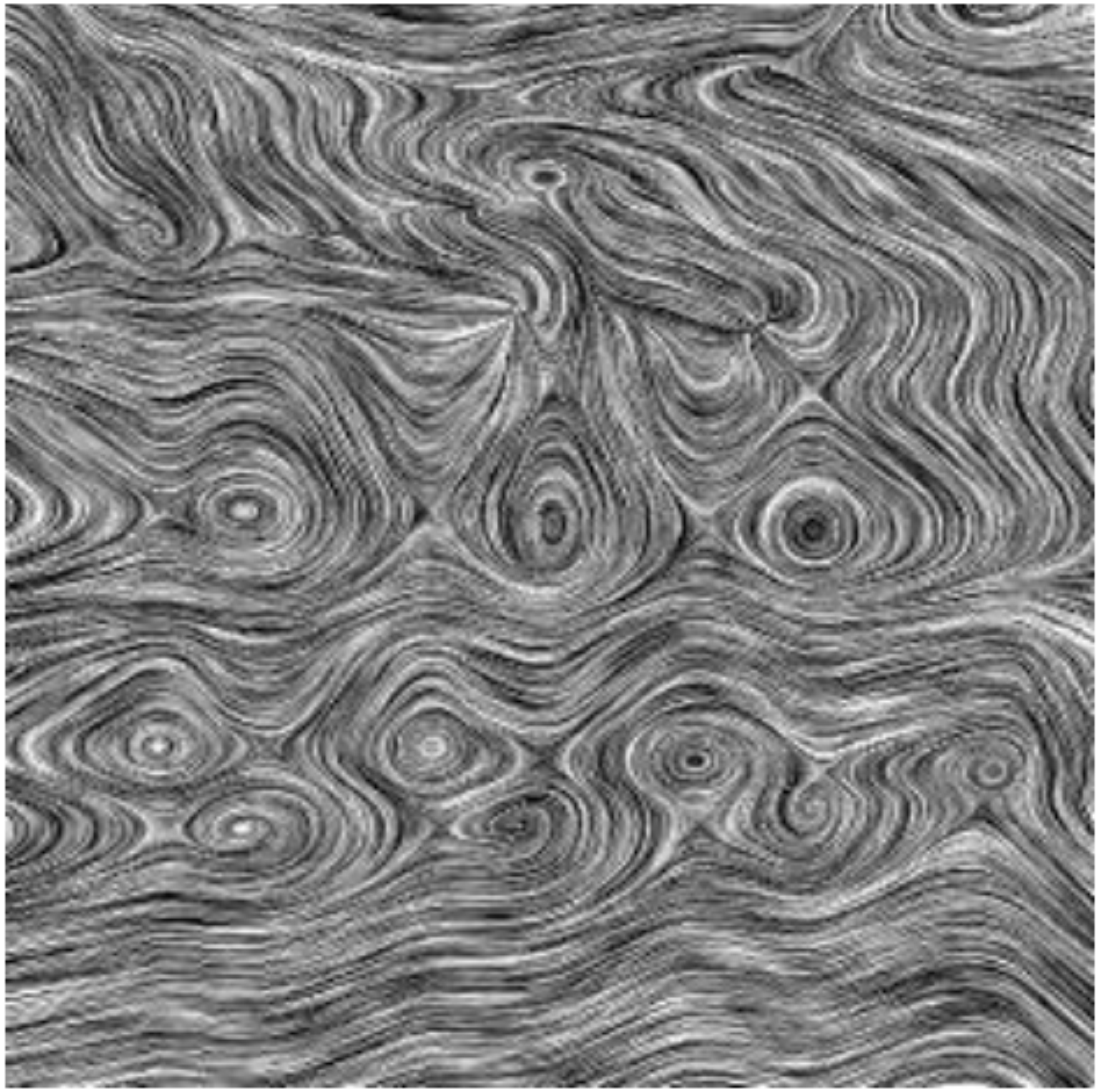
compute
**streamlines**

convolve
**source of noise**
along streamlines

**Result**

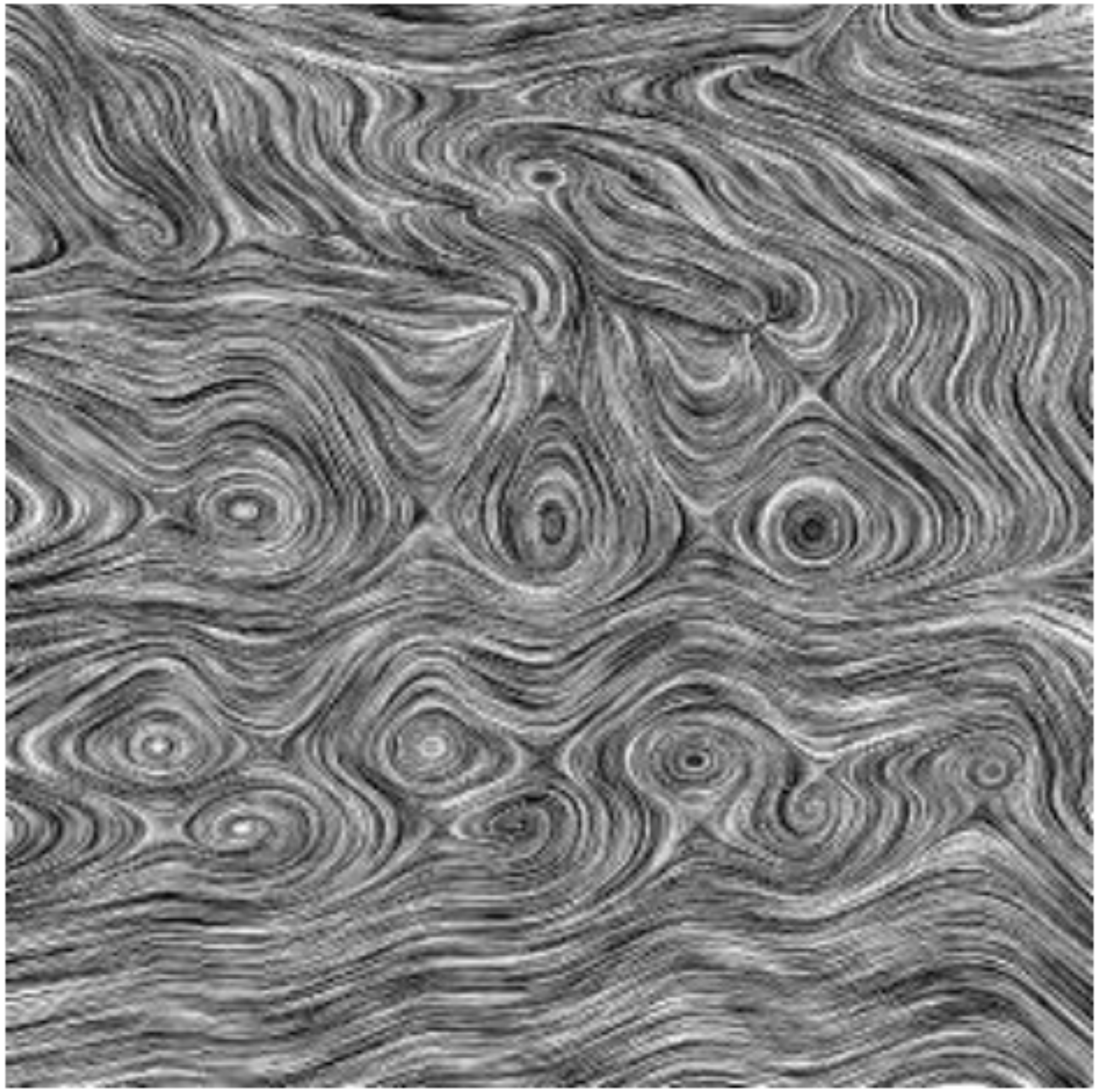
# Line Integral Convolution





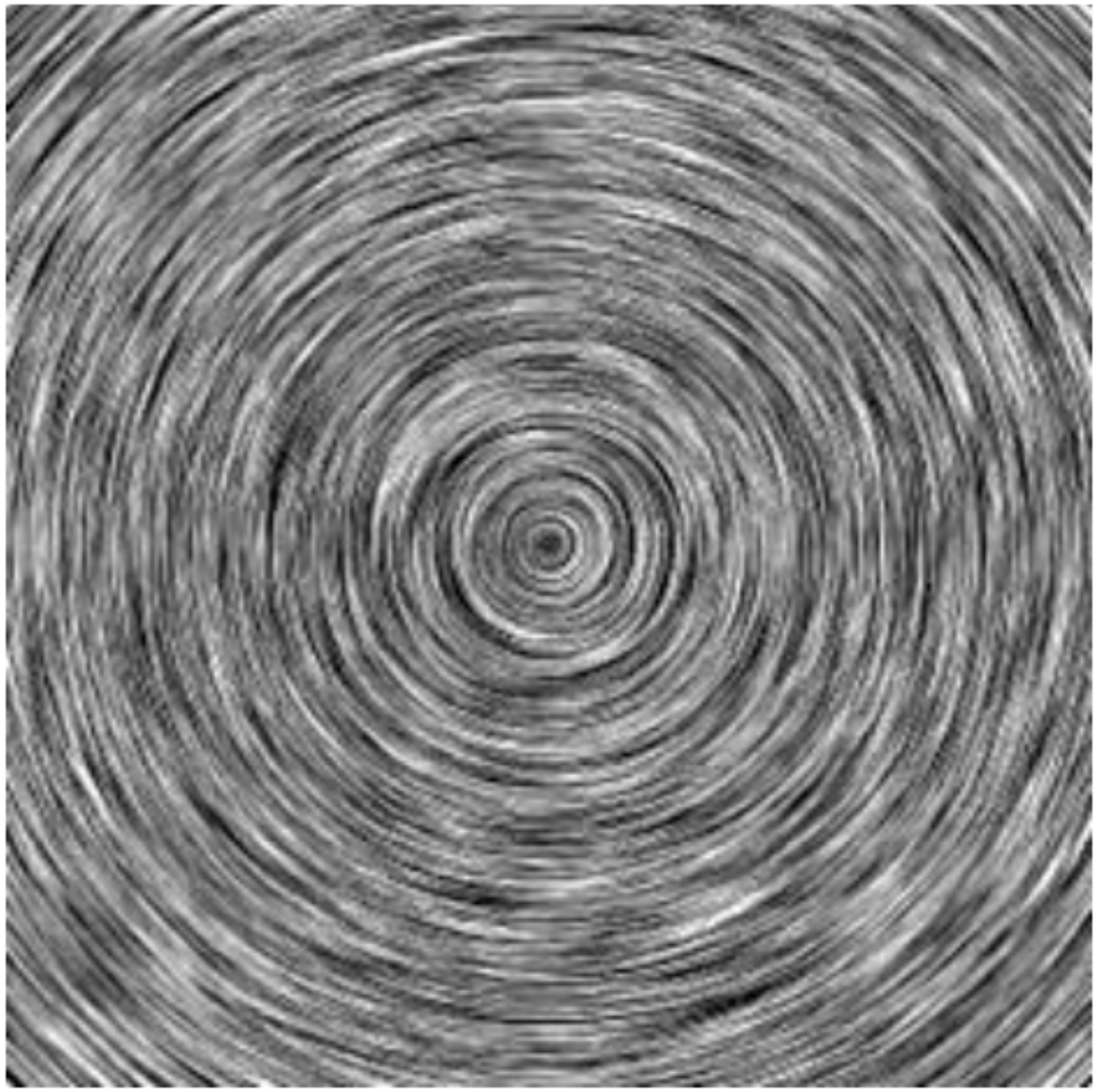
# Advantages

- “Perfect” space usage
- Flow features are very apparent



# Downsides

- No perception of velocity!
- No perception of direction!



# Image-Based Flow Visualization

- Adaptation of LIC for graphics cards
  - Extremely fast and simple to implement
  - Animation gives perception of velocity
  - (But requires knowledge of computer graphics, which we're not assuming in this course)

# Image-Based Flow Visualization

http://www.win.tue.nl/~vanwijk/ibfv/