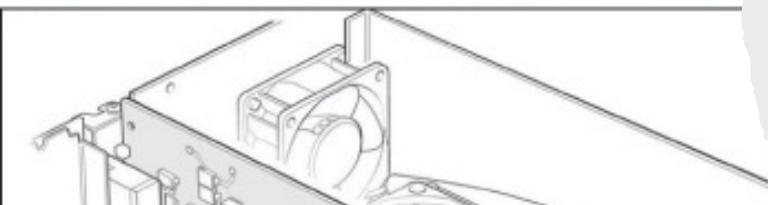
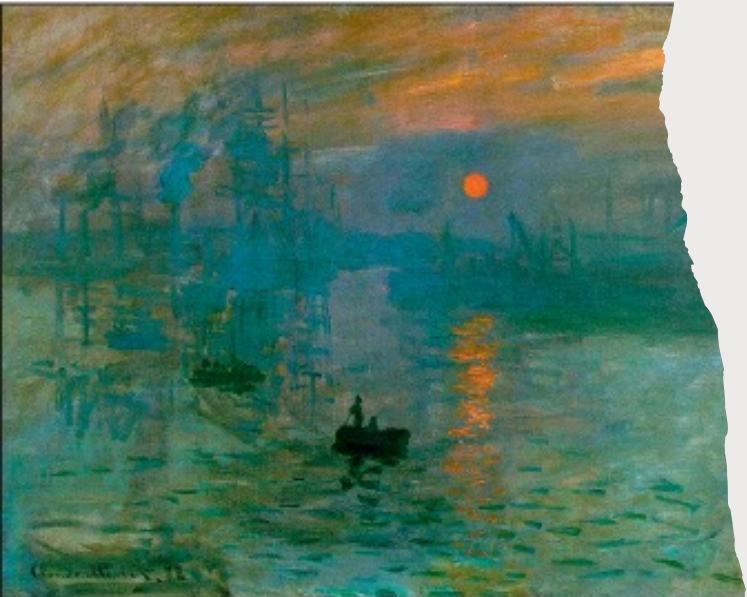


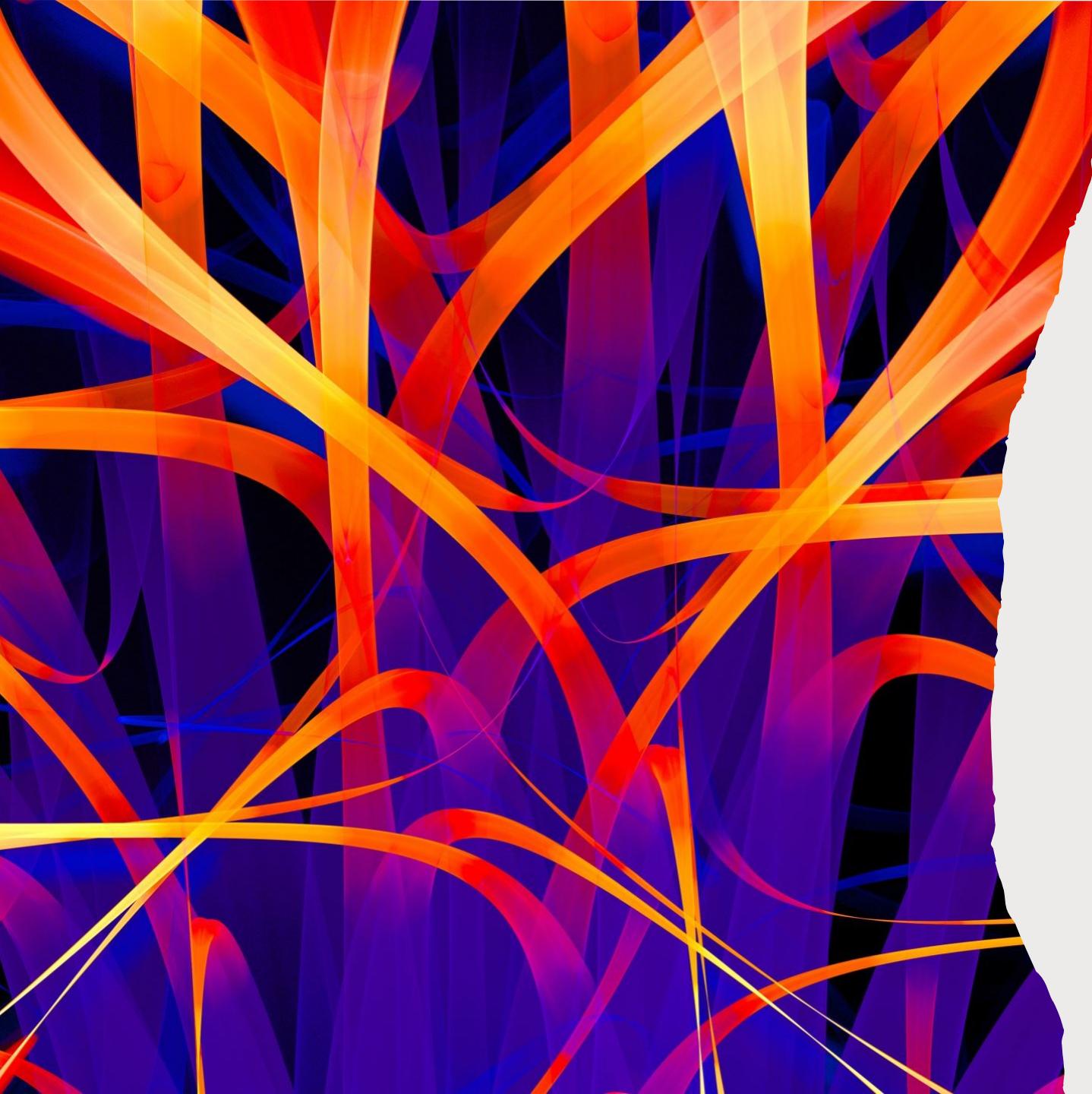
18 - Non-Photorealistic (Expressive) Rendering

Dr. Hamish Carr & Dr. Rafael Kuffner dos Anjos

Artists & Rendering

- Art isn't always realistic
- Which doesn't mean it's bad
- How do we reproduce it?
- Start by understanding it





Artistic Style & Intent

- Artists discuss their
 - style: details of technique & tools
 - intent: what they wish to achieve
 - message: what they wish to say
 - abstraction: what they wish to remove
- Illustration is generally intent + abstraction
- Fine art is generally message + style



Perceptual Issues

- Humans are *very* edge-sensitive
 - So a sketch draws only edges
 - The oldest art tools generate edges
 - Paint, carving, ink, pencils
- Humans also use shading to infer shape
 - So strokes & shadows are behind most of this

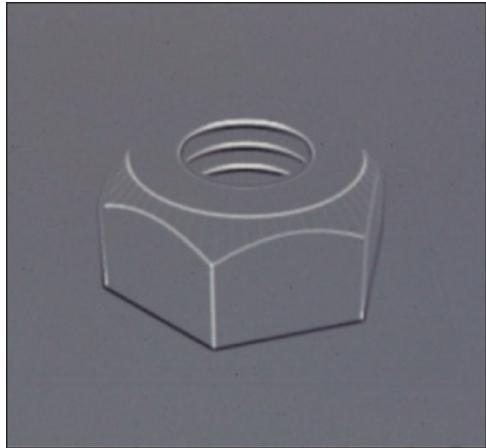


Abstraction

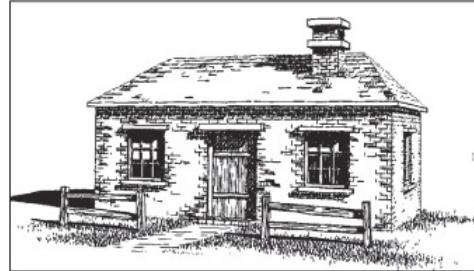
- Represents the *essence* of the object
- At the expense of detail
 - Simplify: remove redundant detail
 - Factorise: separate generic & specific
 - Schematise: substitute representations
- Stripping the image down amplifies meaning

Examples

Edge enhancement
(Edges in Z-buffer)

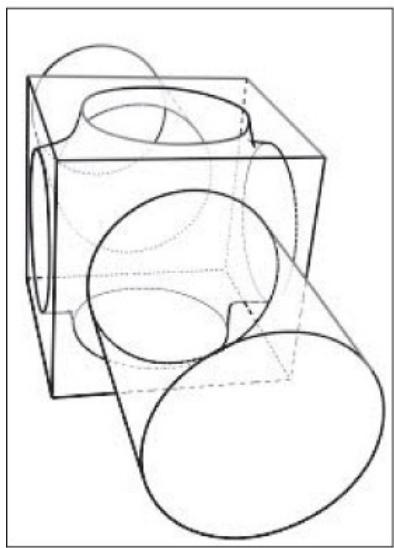


(a)



(b)

Stylised Contours
(Emphasis on edges)



(c)

Detail omission
(suppression of
redundant detail)



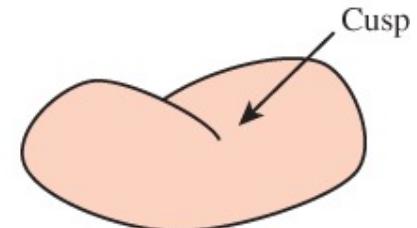
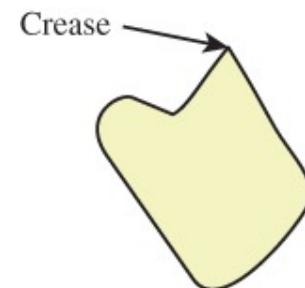
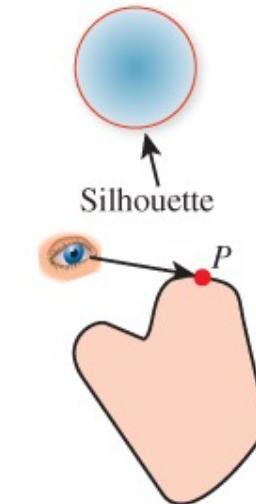
(d)

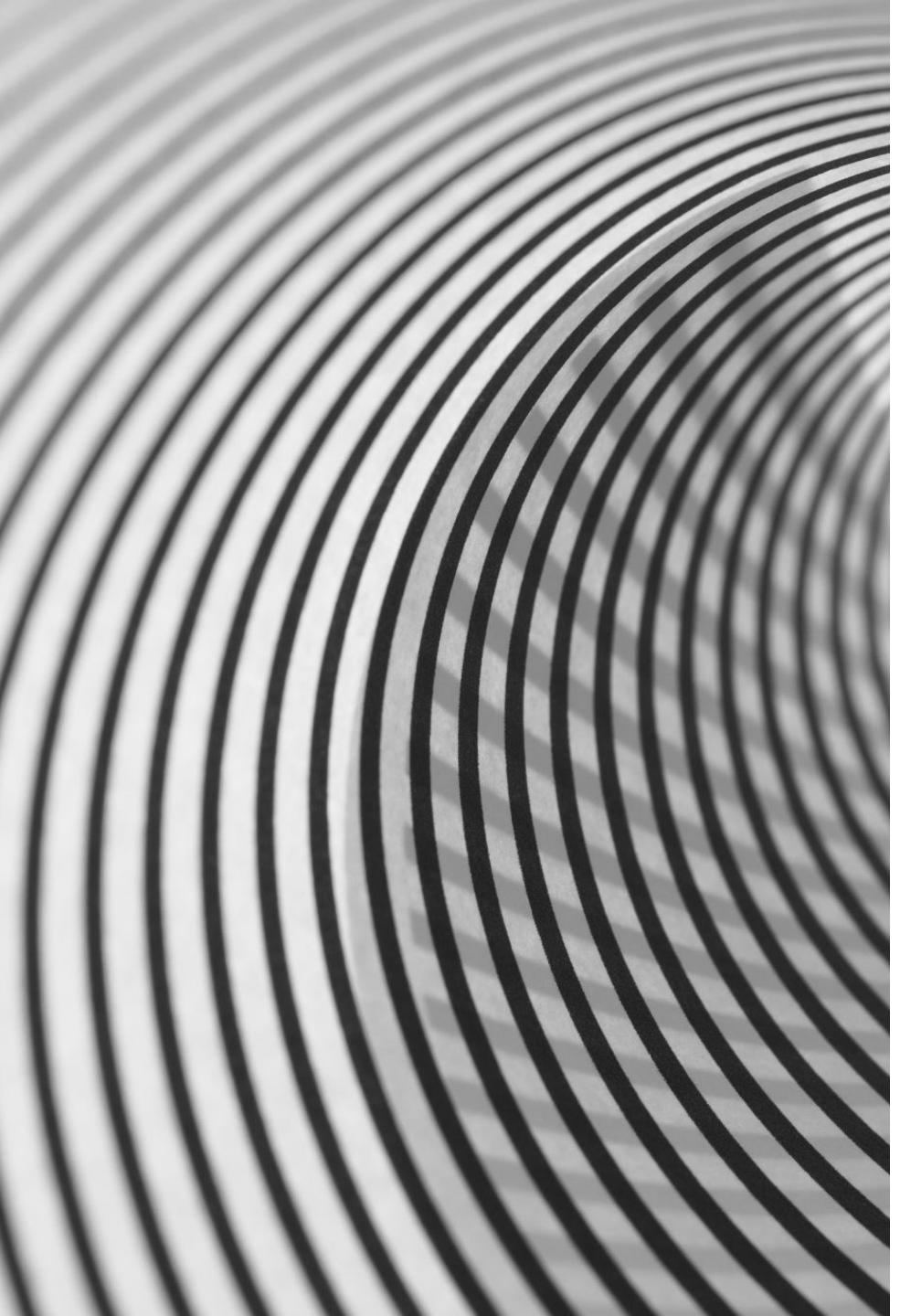
Painterly strokes
(Stylistic imitation)



Curve Extraction

- Silhouettes separate back-/fore-ground
 - Eye rays are tangent
- Creases
 - Tangent discontinuities
- Cusps
 - Eye ray tangent to curve





Contour

- Silhouette is a subset of the contour
 - Set of *all* points tangent to eye ray from C
 - $\vec{n}(P) \cdot (P - C) = 0$
- Alternate terms:
 - contour generator, visible contour, fold set



Polygonal Mesh Tangents

- Polygonal meshes are a nuisance
- Silhouette is made up of mesh edges
- But tangent planes do not exist at edges
- Most meshes derive from smooth surfaces
 - But may have *crease edges* marked
 - Edges which are intended to be sharp



Simple Silhouettes

- Any edge connects two triangles
 - One *triangle* points toward the eye
 - The other points away from the eye
- Test this with triangle normals (*not* vertex!)
- Render the surface in white
- Then render these edges in black
 - Optionally, offset slightly towards viewer



(a)



(c)



(b)



(d)



(e)

Aaron Hertzman, 1999

Cel (Toon) Shading

- Detect & draw silhouette edges
- Then simplify the shading
 - By thresholding the result
 - So only two or three colours are used
- Looks like a hand-drawn cartoon
- Relatively smooth perceptual changes
- So not too many crawlies



LordOfDragons@Deviantart

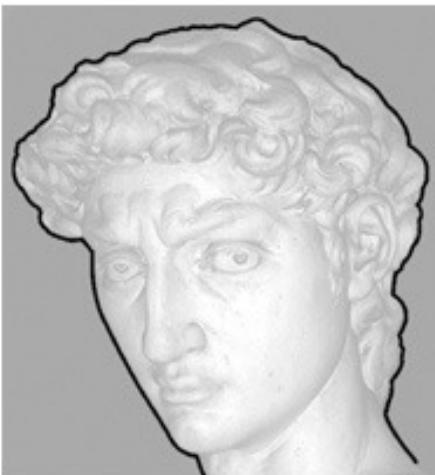


Contour Contours

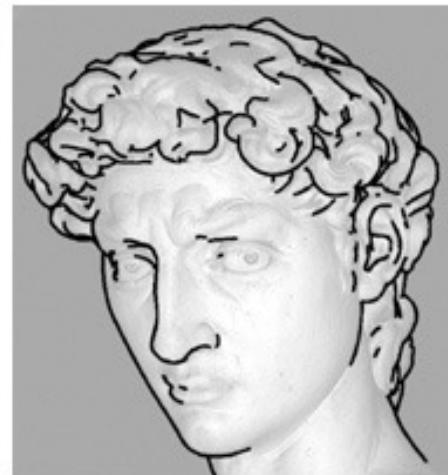
- Due to Zorin & Hertzmann
- Compute this function at each vertex:
 - $g(P) = \vec{n}(P) \cdot (P - C)$
- Interpolate over the triangles
- Then extract the zero-level set (aka contour)
- Gives clean polygonal cycles
- Can be used as the basis for hatching

Suggestive Contours

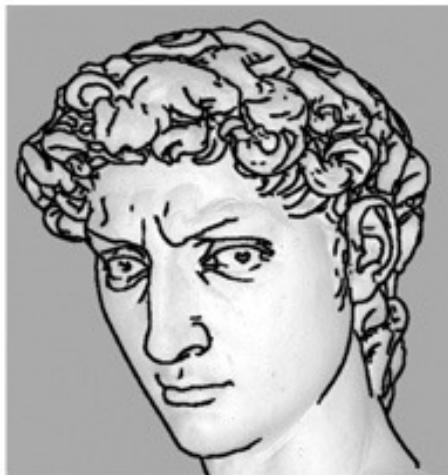
- We also want *suggestive* contours
- That suggest details of the shape
- E.g. edge of the eye (not a contour edge)
- Based on extracting curvature (L1)
 - But polygonal meshes can be a problem
- May need spline curves along the edges!



silhouette



contours



contours and suggestive contours

De Carlo et. Al 2003



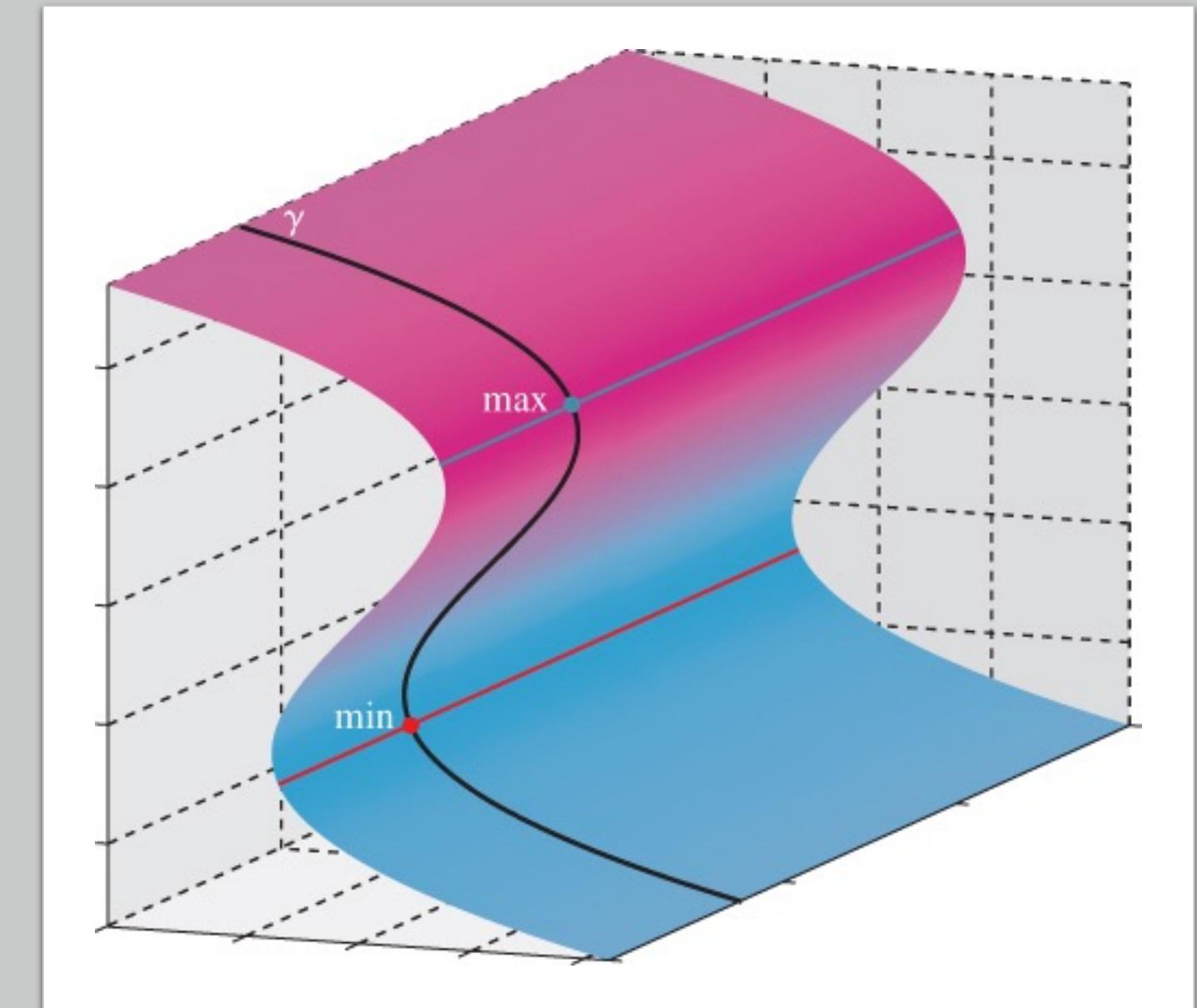


Principal & Secondary Curvature

- Principal: direction of greatest change
- Secondary: direction of least change
- Guaranteed to be perpendicular
- At least on smooth surfaces

Lines of Curvature

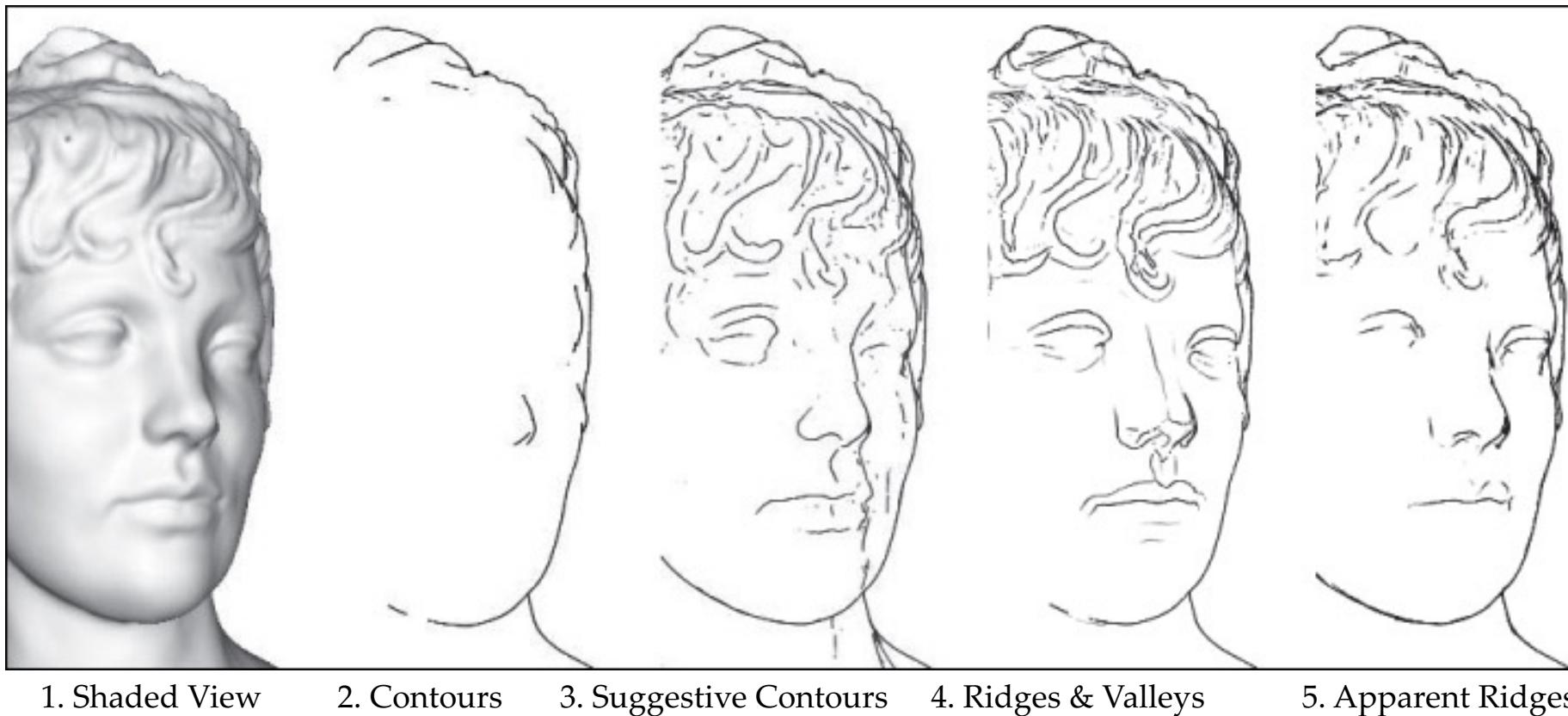
- Line of curvature follows principal direction
 - Principal curvature changes along them
 - Therefore has minima and maxima
 - Called *ridge* and *valley* points



Suggestive Contours, II

- Principal direction is a vector field on surface
- We can define other vector fields instead
- For example, we can take *radial* curvature κ_r
 - Take the view vector $\vec{v}(P) = E - P$ at point P
 - Project this onto the tangent plane at P:
 - $\vec{w} = \vec{v} - (\vec{v} \cdot \vec{n})\vec{n}$
 - Suggestive contours have $\kappa_r = 0$

Suggestive Contours, &c.



1. Shaded View

2. Contours

3. Suggestive Contours

4. Ridges & Valleys

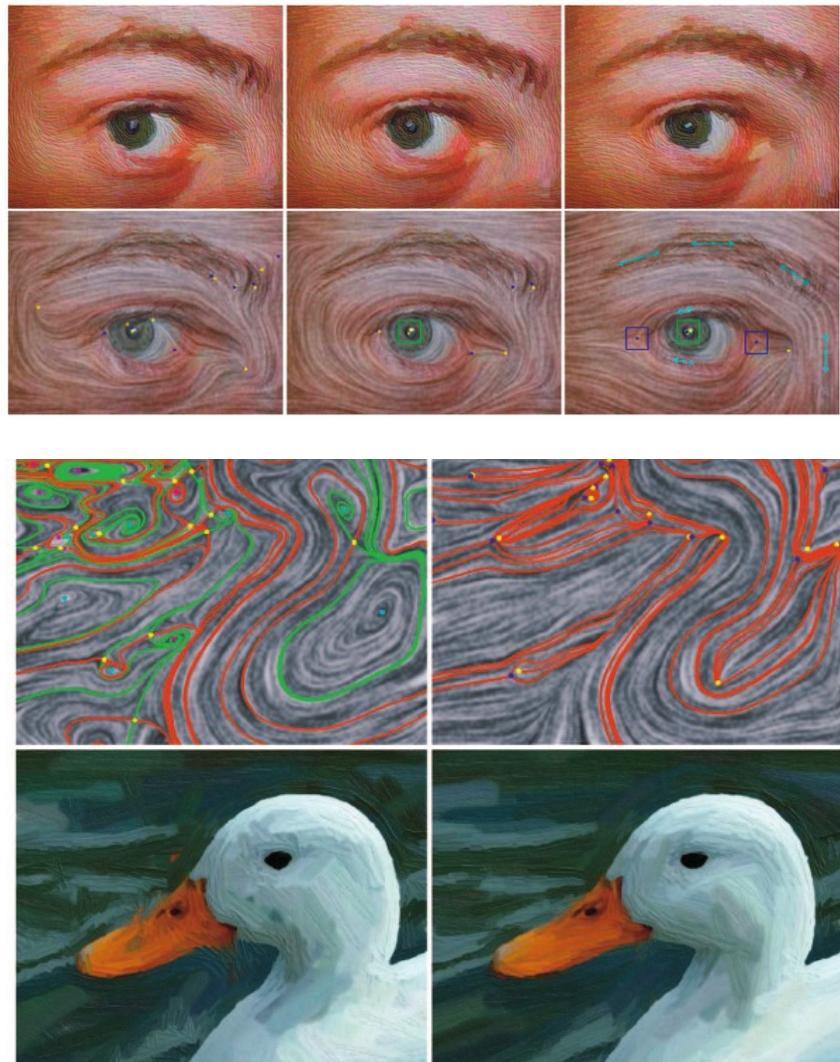
5. Apparent Ridges



Scene Abstraction

- Selection of curves / lines to *remove*
 - i.e. when too many lines in a dense area





Zhang et al. 2004

Image-space NPR

- All of this can also be done in image space with filters
- Render normally (or normals/tangents per pixel), then re-render.

Painterly rendering

- Break image down into features.
- Replace elements with brush strokes
- All image space: no mesh information used.



(a)



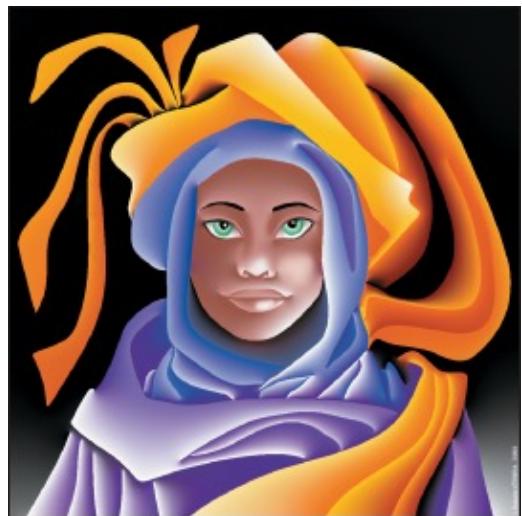
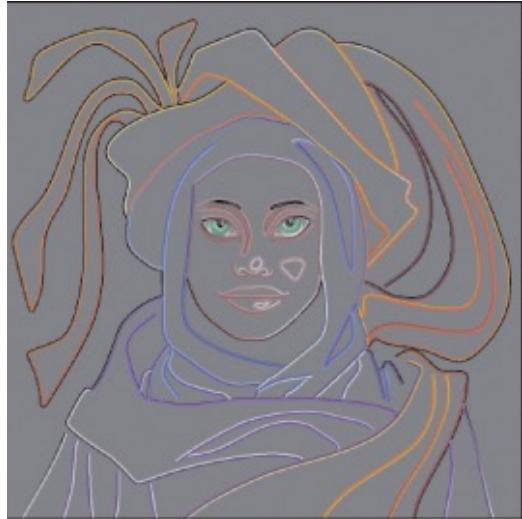
(b)



(c)



(d)



Diffusion Curves

- Paint curves with colours on each side
- Then *diffuse* the colour outwards until it meets

AI Style transfer



- Basis for several popular “art filters”
- Try to minimize perceptual loss from target image from style image.
- Works sometimes.



Summary

- Artists historically work with edges
 - Due to human eyeball, and tools available
- Edges show up in curvature calculations
- Shading is then simplified or blurred
- Artistic style is copied with stroke styles
- AI is becoming more popular in this area.

