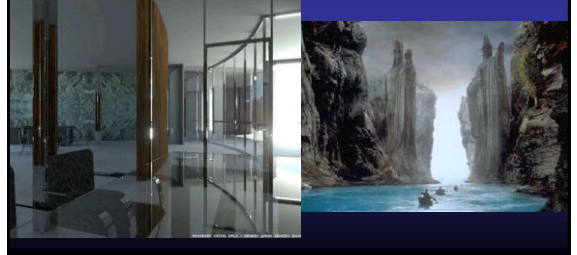


# Expressive rendering

Joëlle Thollot

# The « Quest for Realism »

$$L_o(x, \vec{w}) = L_e(x, \vec{w}) + \int_{\Omega} f_r(x, \vec{w}', \vec{w}) L_i(x, \vec{w}') (\vec{w}' \cdot \vec{n}) d\vec{w}'$$



# We don't always want photorealism

www.infovisual.info/01/024\_fr.html

www.mycocomontreal.qc.ca/milletun/Initiation\_aux\_champignons.htm

# Google image « maison »

# Portait

La jeune fille au virginal - Vermeer

La leçon de musique - Matisse

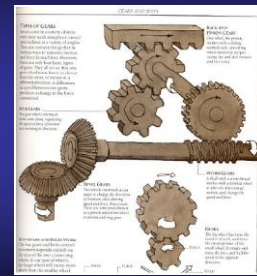
# What are images used for?

- Give a message
  - Information
  - Emotion
- Depend on the application
  - Architecture
  - Scientific visualisation,
  - Technical doc
  - Teaching
  - Art...

## A new question emerges

- How do we create tools for visual communication?
- What are the advantages of illustrations over photorealism?
- What makes an image efficient?

## Omitting extraneous detail



Macaulay: The Way Things Work, 1988

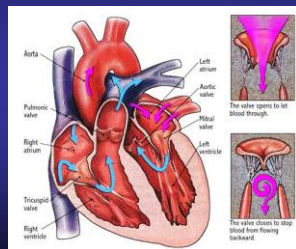
## Clarifying & simplifying shapes



<http://www.labiomed.org/cardiology/>

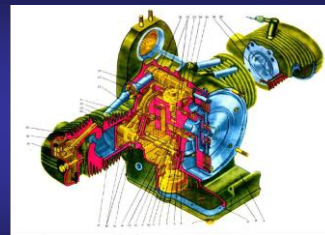


<http://www.imagencentres.com/ct.html>



[www.cts.usc.edu/hpg-heartvalvesurgery.html](http://www.cts.usc.edu/hpg-heartvalvesurgery.html)

## Exposing parts that are hidden



[dnepr.ural.free.fr/Doc\\_Avtoexport-M66.pdf](http://dnepr.ural.free.fr/Doc_Avtoexport-M66.pdf)

## Focusing attention



[static.howstuffworks.com](http://static.howstuffworks.com)



[www.lanature.fr](http://www.lanature.fr)

## Illustrating approximate ideas

School of Architecture and Landscape Architecture



[www.artsandarchitecture.psu.edu/news/building\\_updates/sala](http://www.artsandarchitecture.psu.edu/news/building_updates/sala)

## Conveying mood and emotion



How do we produce such images ?

## Actually what is an image?

- **3D scene**
  - Objects
  - Materials
  - Shapes
- **2D projection**



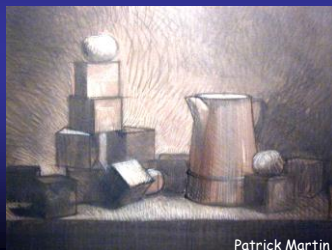
## Actually what is an image?

- **2D representation**
  - Lines
  - Junctions
  - Regions



## Actually what is an image?

- **Medium**
  - Hatching
  - Pigments
  - Strokes
- **Visual cues**
  - Light
  - Shape
  - Material



## An Invitation to Discuss Computer Depiction

Durand, Willats NPAR 02

- **Spatial**
  - 3D to 2D
- **Primitives**
  - Points, lines, regions
- **Marks**
  - Tool
- **Attributes**
  - Link everything



## An Invitation to Discuss Computer Depiction

Durand, Willats NPAR 02

- **Spatial**
  - 3D to 2D
- **Primitives**
  - Points, lines, regions
- **Marks**
  - Tool
- **Attributes**
  - Link everything

Style  
(part of)

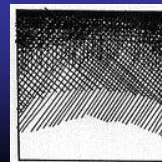
## Overview

- Filling the regions
- Lines
- Style

## I - Filling

## Marks

- **Physical representation of the medium**
  - Region filling
  - Stylisation of lines
- **Various styles**
  - Pen and ink
  - Watercolor
  - Painting



## Problems

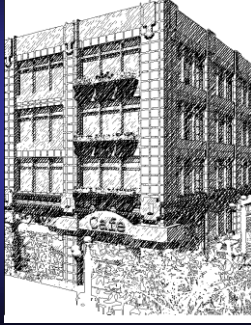
- Medium simulation
- Temporal coherence for animation
- Paper reading - discussion



- Comment modélise-t'on un médium ?
- Quel est le problème de la cohérence temporelle ?
- Quelles sont les difficultés ?
- Quelles sont les contributions de ces articles ?
- Quelles sont les limitations des solutions proposées ?
- Quelle démarche générale peut-on tirer de ces articles ?

## Illustration

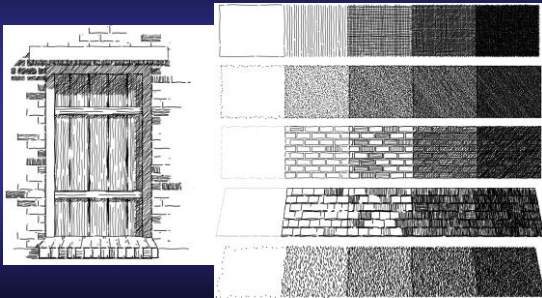
- Stylized lines
- Hatchings



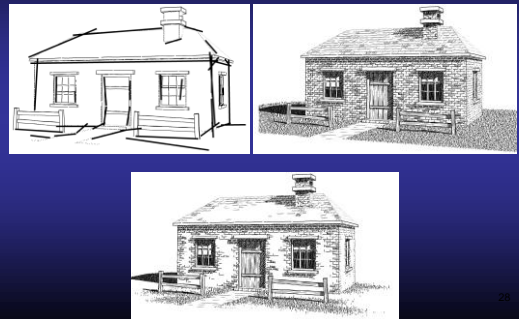
## Hatching

- Shape from shading
  - Region filling + tone mapping
- ⇒ Attributes (width, orientation) and density

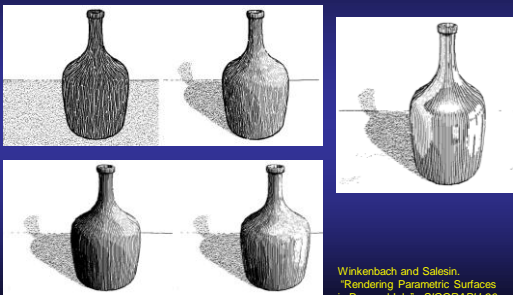
## Tone



## Indication



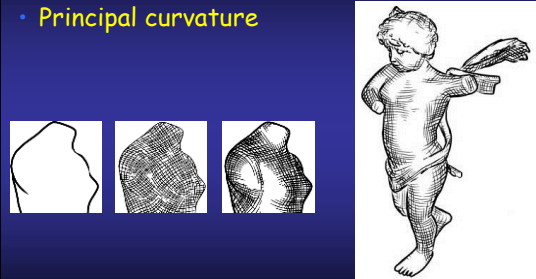
## Classic rendering + hatchings



Winkenbach and Salesin.  
"Rendering Parametric Surfaces  
in Pen and Ink." SIGGRAPH 96

## Illustration 3D

- Principal curvature



Hertzmann et Zorin - Illustrating smooth surfaces - SIGGRAPH 2000

## Real-time hatching

- Tonal arts maps + lap textures
- = mip-map
- + easy texture mapping



Emil Praun, Hugues Hoppe, Matthew Webb, and Adam Finkelstein. Real-time hatching. Siggraph 2001

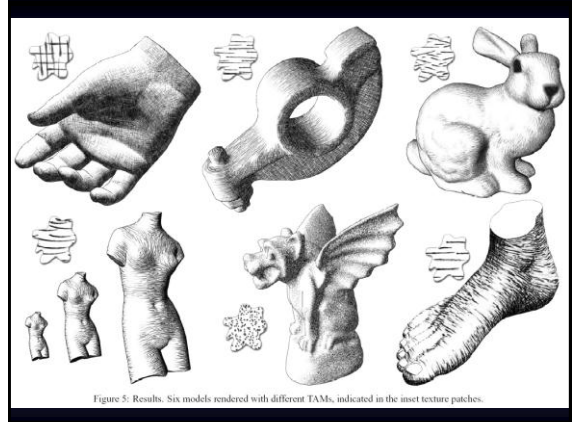


Figure 5: Results. Six models rendered with different TAMs, indicated in the inset texture patches.

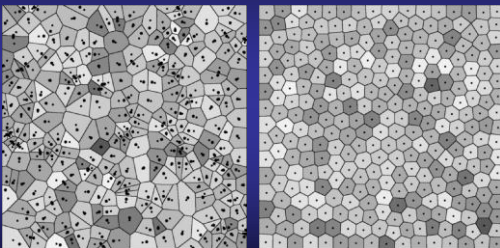


## Stippling

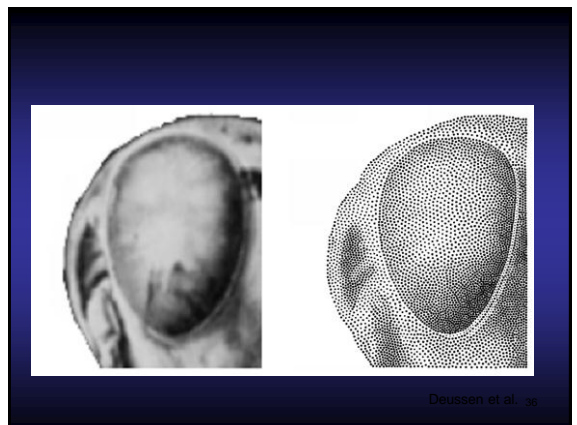
- Shape from shading
  - Tone via point distribution
- ⇒ Distribution and density

34

## Lloyd relaxation



35

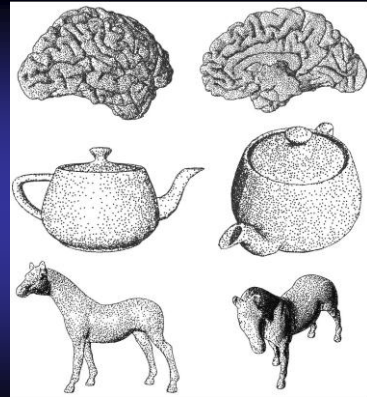
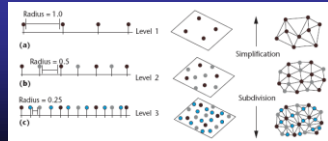


Deussen et al. 36

## Real-time stippling

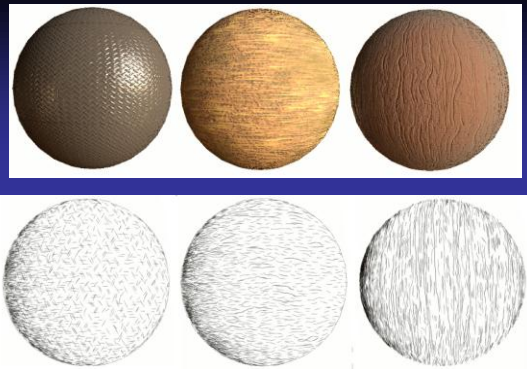
Oscar Meruvia Pastor, Bert Freudenberg, and Thomas Strothotte

- Points hierarchy on the surface
  - Simplification
  - Subdivision
- Point selection at each frame



## Illustration going further

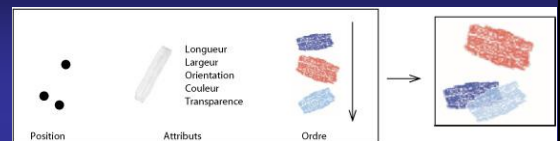
- Material perception
- Automatic extraction of parameters from a BTF or BRDF



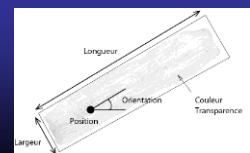
## Painting

- Color image
- Abstraction and art
- Region filling

## Stroke-based approaches



- ⇒ Position
- ⇒ Attributes

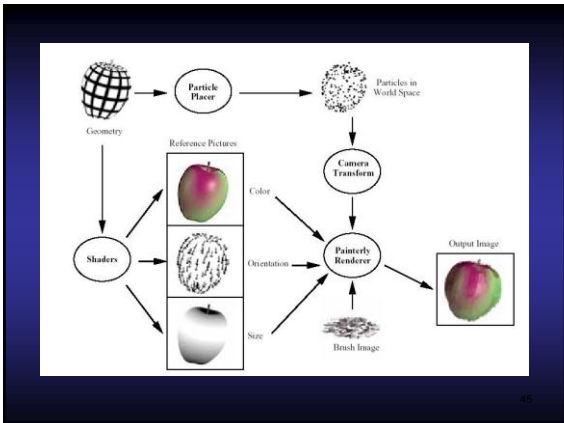




## Painterly rendering for animation [Meier]

- Temporal coherence
- Strokes attached to particles on the surface
- 2D rendering via billboards

44



## Dynamic distribution

Dynamic point distribution for stroke-based rendering  
 David Vanderhaeghe, Pascal Barla, Joëlle Thollot, François Sillion  
 Rendering Techniques 2007 (Proceedings of the Eurographics Symposium on Rendering)

46



## Texture-based approach

- Watercolor as an image processing

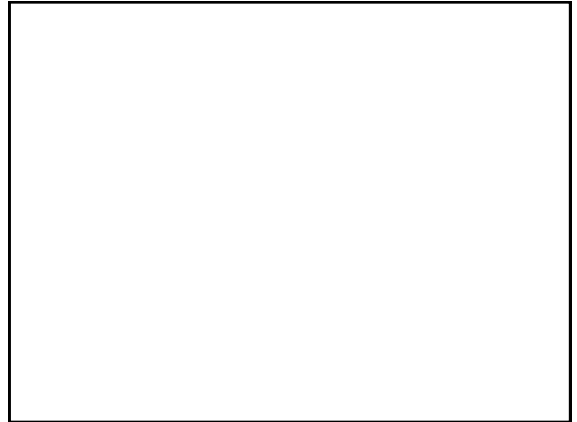
Adrien Bousseau, Matthew Kaplan, Joëlle Thollot, François Sillion  
 Interactive watercolor rendering with temporal coherence and abstraction  
 International Symposium on Non-Photorealistic Animation and Rendering (NPAR) - 2006



# 3D Object

- 3D texture mapping
- Infinite zoom mechanism

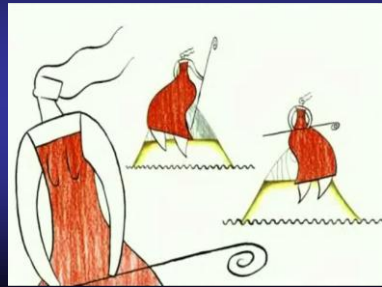
Stylizing 3D animations  
I3D 2009  
Pierre Bénard, Adrien Bousseau,  
Joëlle Thollot



Summary  
Temporal coherence

# Il pleut bergère

Jérémy Depuydt, [www.toondra.com](http://www.toondra.com)



# Naive solutions

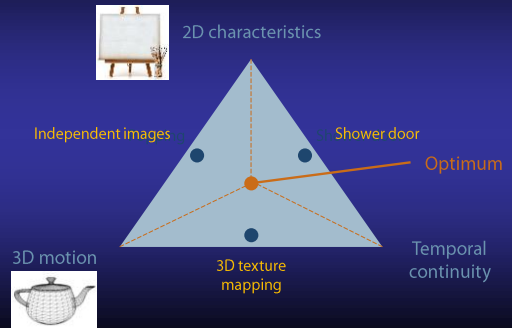


Shower door

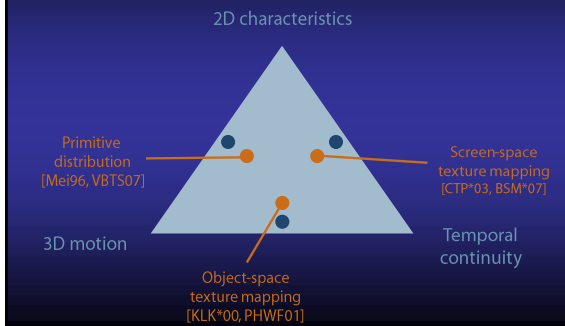


Texture mapping

# Contradictory goals

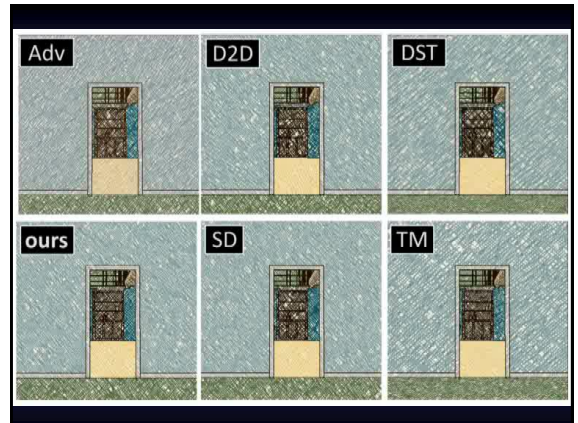


## Current solutions



## What next?

- How to evaluate the various compromises?
- Perceptual study

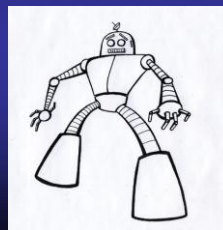


## II - Lines

### Lines

?

- What are the lines that may depict a shape?



[http://www.chrisgovias.com/blog/stompy\\_drawn1.jpg](http://www.chrisgovias.com/blog/stompy_drawn1.jpg)



©10th DDKJUT

## Lines

- Silhouettes
- Boundaries
- Ridges and valleys
  
- Depends on surface properties
  - Depth
  - Curvature
  - Normal
  - Viewpoint

## Lines detection

- How can we do that?
  - In image space
  - In object space
  
- What are the problems?

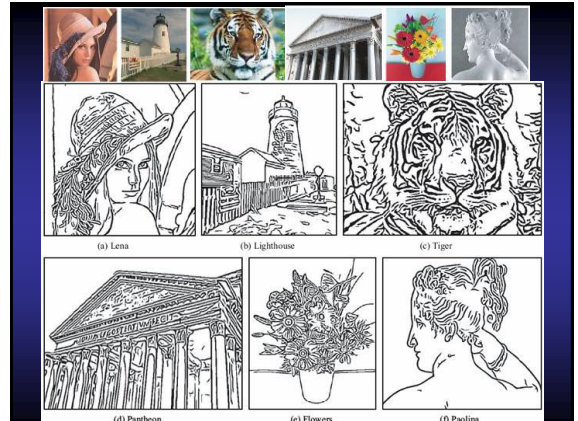


## Image space

- Edge detection
  - Numerous techniques in image processing

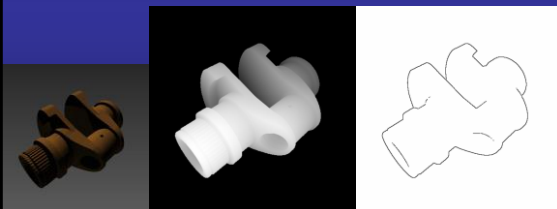


H. Kang, S. Lee, C. Chul. "Coherent Line Drawing" NPAR 07

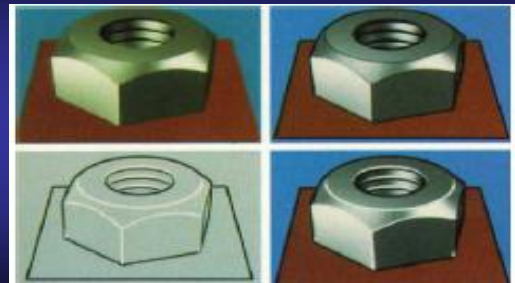


## Image space + depth

- Detect  $C_0$  surface discontinuities
- Via a Z-buffer or a computed depth map



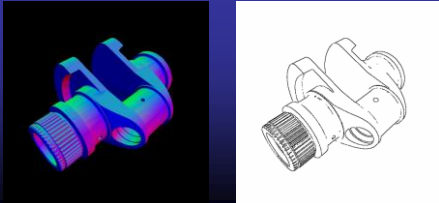
## Image space + depth



Saito and Takahashi "Comprehensible rendering of 3-D shapes" SIGGRAPH, 1990

## Image space + normals

- Detect  $C_1$  surface discontinuities
- Via normal computation
  - Maybe noisy: 2<sup>nd</sup> order differential

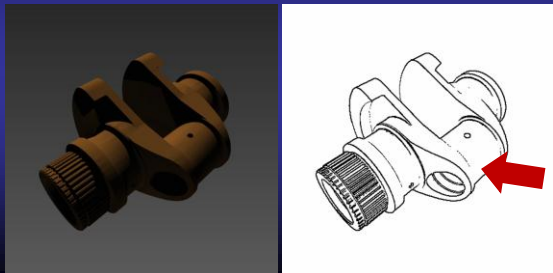


## Depth + normal map



## Image space limitations

- We loose the 3D information

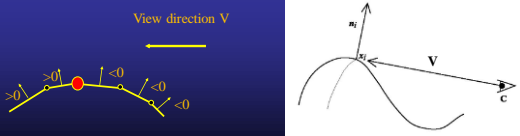


## Object space

- More complicated and costly
- Various types of lines
  - Silhouettes
  - Creases
  - Ridges and valleys

## Silhouettes - object space

- Edges that connect back and front Faces
- Surface points such that  $N \cdot V = 0$

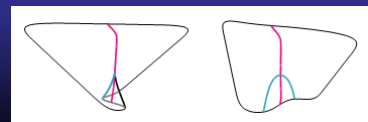


## Silhouette properties

- View dependant

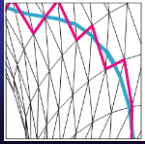


- Cusps



## Smooth silhouettes

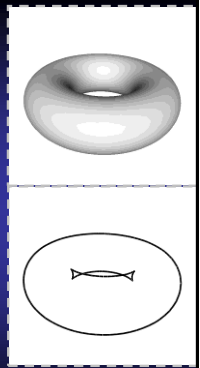
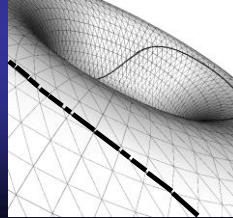
- Compute N.V for each vertex
- Interpolate to find the 0 place on the edges



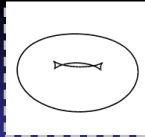
Illustrating smooth surfaces  
A. Hertzmann, D. Zorn  
SIGGRAPH 2000

## What is missing?

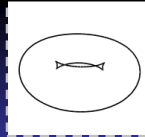
- Keep only visible edges
- Build a continuous curve



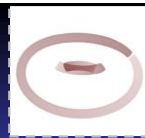
## Chosen edges



## Visible edges

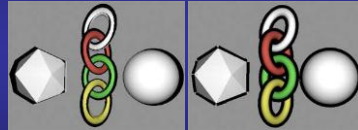


## Curve



## Silhouettes on the GPU

- Perturb the back facing polygons
  - Multiple renderings



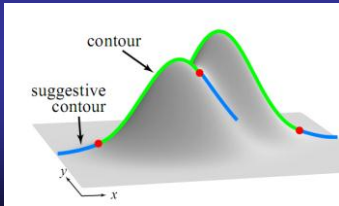
- Use an envmap



Interactive Technical Illustration, Bruce Gooch - Peter-Pike J. Sloan - Amy Gooch - Peter Shirley - Richard Riesenfeld

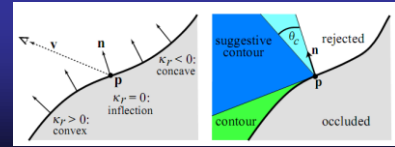
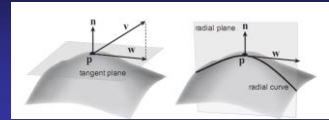
## Now what else?

- Near silhouettes



## Suggestive contours (1)

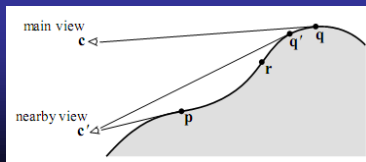
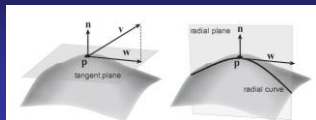
- Zeros of radial curvature



Suggestive Contours for Conveying Shape - SIGGRAPH 2003  
Doug DeCarlo, Adam Finkelstein, Szymon Rusinkiewicz, Anthony Santella

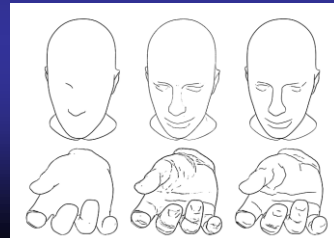
## Suggestive contour (2)

- Set of minima of N.V in the direction of W



## Two rendering algo

- in image space (min of N.V)
- in object space (zero of  $\kappa_r$ )

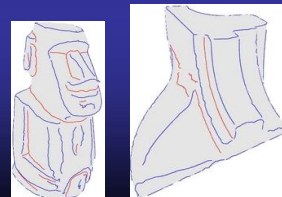


## Object space

- More complicated and costly
- Various types of lines
  - Silhouettes
  - Creases
  - Ridges and valleys

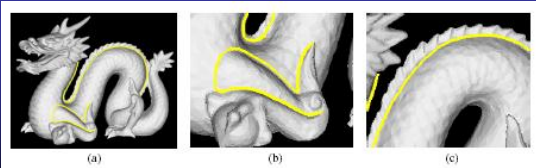
## Crease

- Sharp edges
- Threshold the normal difference between to faces



## Ridges and valleys

- Creases extension
- Curvature max in principal direction



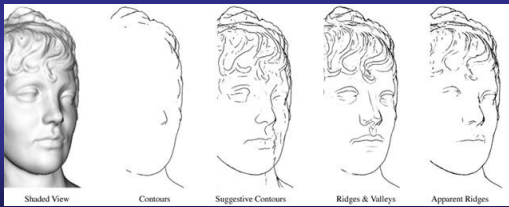
## Main problem

- Curvature computation
  - Object space: differential geometry
  - Image space: gradient



## Are ridges what we need?

- A view dependent version



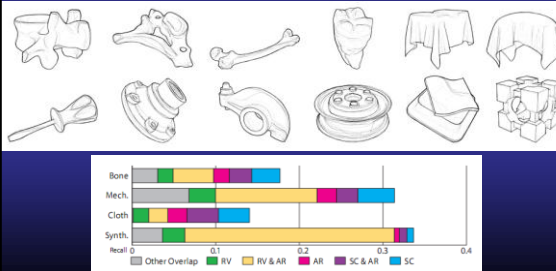
Apparent Ridges for Line Drawings  
 Tilke Judd Frédo Durand Edward Adelson

Now what?

What lines do we really need?

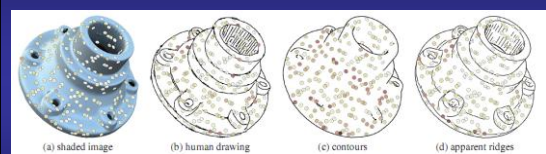
## User study

"Where Do People Draw Lines?," Forrester Cole, Aleksey Golovinskiy, Alex Limpaecher, Heather Stoddart Barros, Adam Finkelstein, Thomas Funkhouser, and Szymon Rusinkiewicz, SIGGRAPH 2008

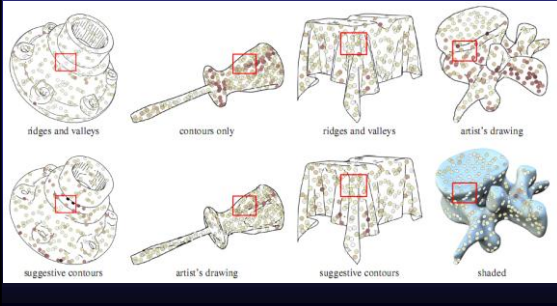


## User study

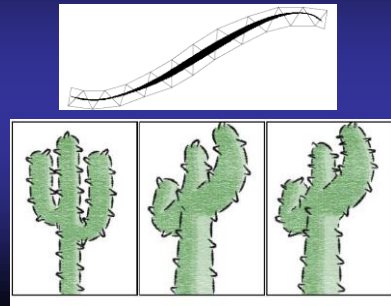
"How Well Do Line Drawings Depict Shape?," Forrester Cole, Kevin Sanik, Doug DeCarlo, Adam Finkelstein, Thomas Funkhouser, Szymon Rusinkiewicz, and Manish Singh, SIGGRAPH 2009



Results unclear yet  
To be continued...



Temporal coherence - lines



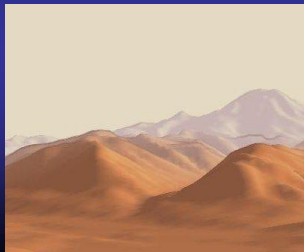
IV - Style

Attributes

- Style = transfer function
  - From scene to marks attributes
- ⇒ How to combine user choices and scene information?
- ⇒ Compromise automatic vs manual

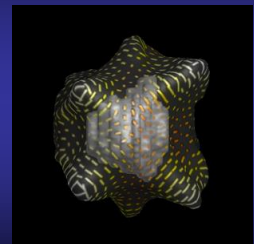
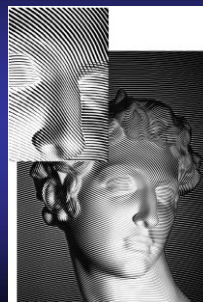
Depth to Color

- Atmospheric perspective
- $C = f(z)$



BARLA P., MARKOSIAN L., THOLLOT J.  
« X-Toon : An extended toon shader »  
NPAR 2006

Curvature to orientation

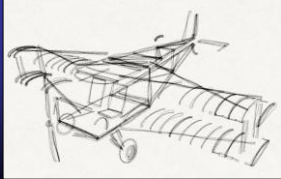
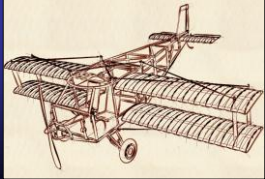


INTERRANTE V. « Illustrating surface shape in volume data via principal direction driven 3D line integral convolution » Siggraph 97

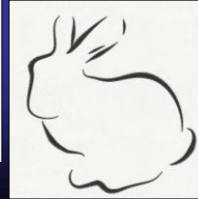


## Freestyle

- Style coding



- Independant from the 3D model



98

3D



« View Map »



+  
information

Style  
Module  
1  
2  
3

⊗

Drawing

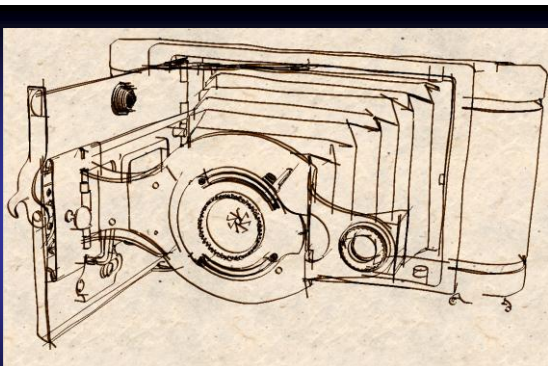


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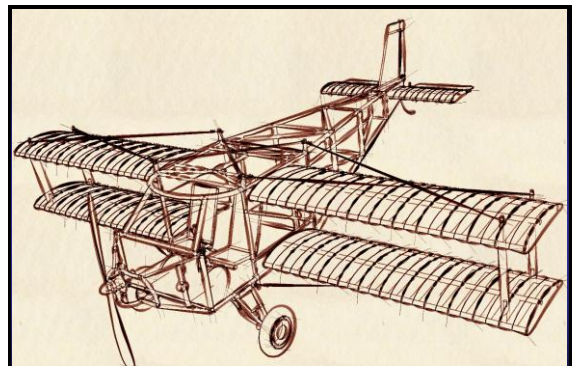
## Parameters

- Geometry (2D, 3D coord, normals...)
- Curvature
- Lines: adjacence, nature (contours, valleys...)
- Visibility, occlusion, depth discontinuity
- Material
- Density
- ...

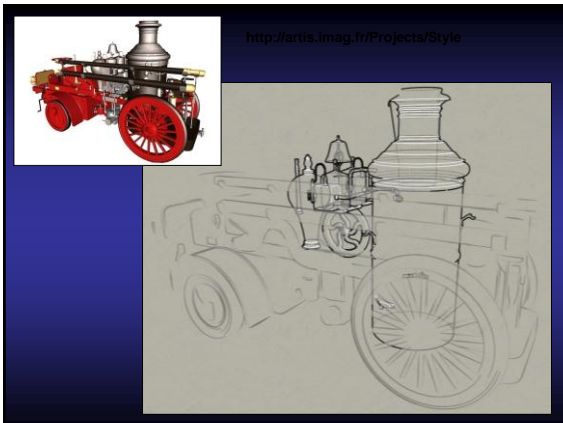
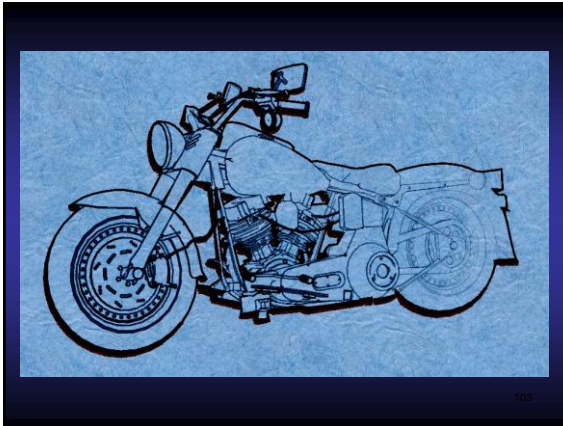
100



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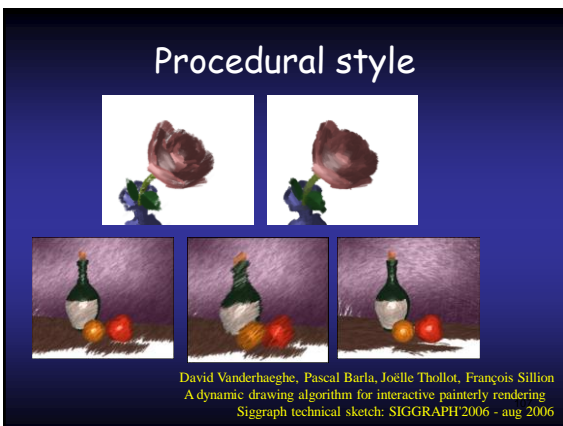


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## So what is the « style »

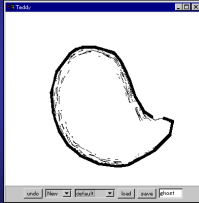
- A way for the artist to express something
- How to model that?
  - A set of parameters?
  - A set of techniques?
- Style = attributes + movement?



## Conclusions

- Tons of things to do in research
- Link with other fields
  - Cognitive sciences
  - Human vision
  - Art
- A lot of applications in industry

- Inverse problem
  - Sketch based modeling



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