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# Memorial

Luiz Velho

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# Overview

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- Education
    - B.S. Degree - ESDI
    - M.S. Degree - MIT Media Lab
    - Ph.D. Degree - U. Toronto
  - Research
    - Image Dithering
    - Multiresolution Painting
    - Modeling with Implicit Objects
    - Polygonization Methods
  - Experience
    - FAM
    - Globo
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# **B.S. Degree - ESDI**

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## **Computer Graphics and Design**

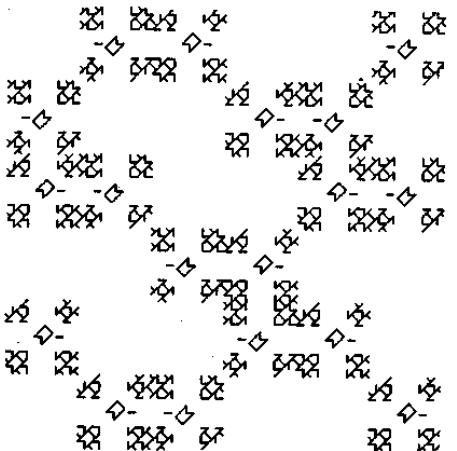
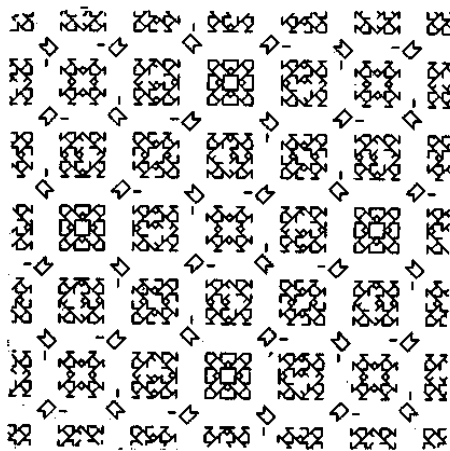
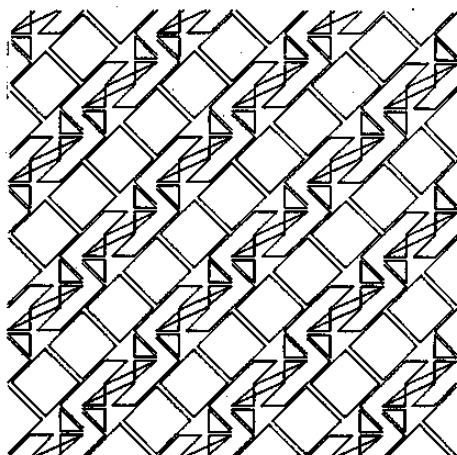
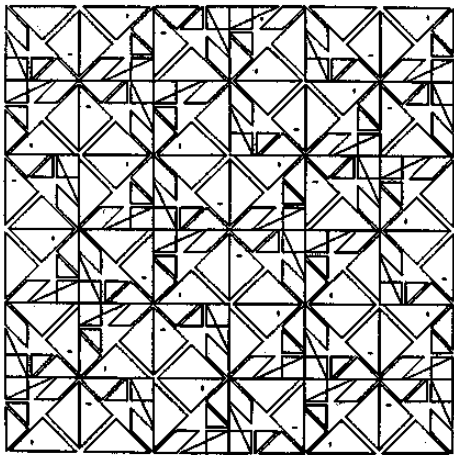
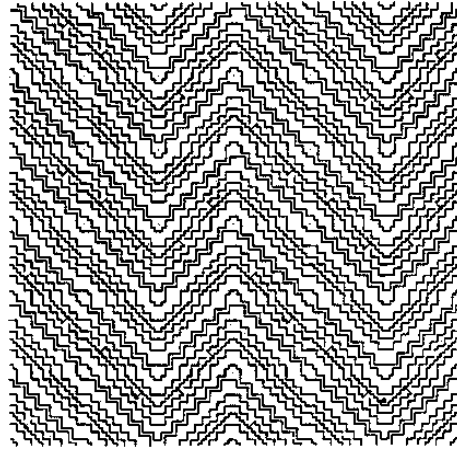
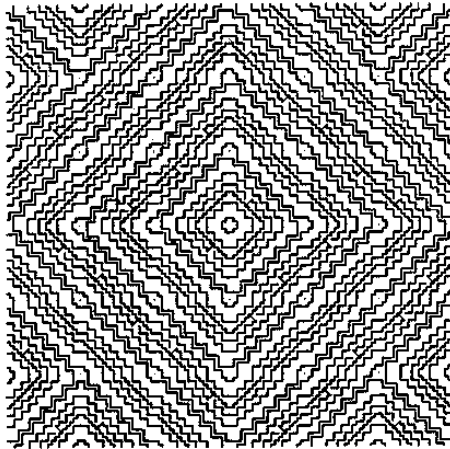
*Investigation of Technology and Applications of CG*

- Field Study
    - CAD in Brazil
  - Experiment with Designers
    - Pattern Creation  
(Symmetry Groups)
  - Computer Animation
    - Wireframe 3D System  
(Development and Production)
-

# Experiment with Graphic Designers

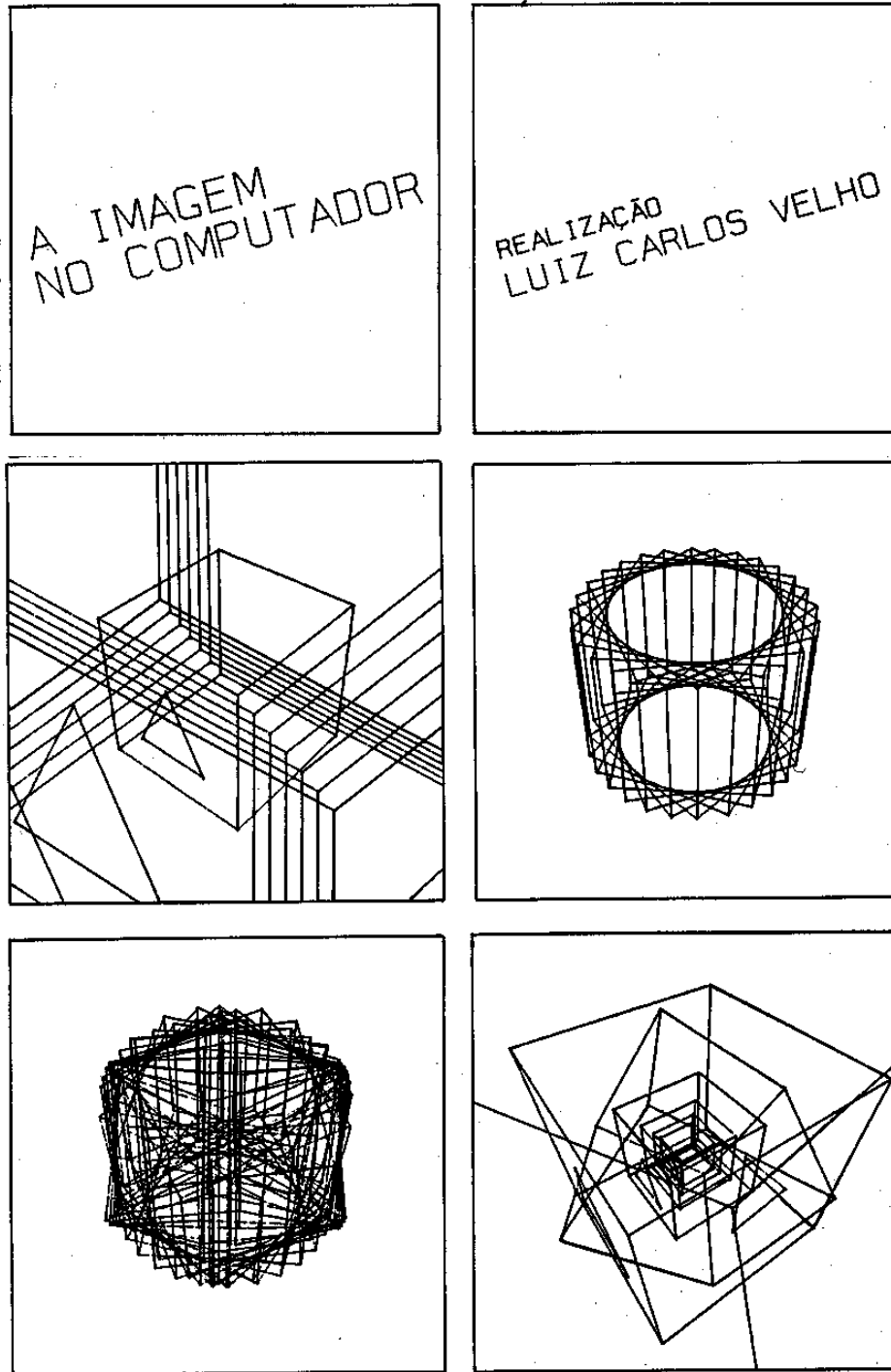
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- Symmetry Groups



# 3D Wireframe Animation

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*First Computer Generated Animation in Brazil*

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## Computer Animation

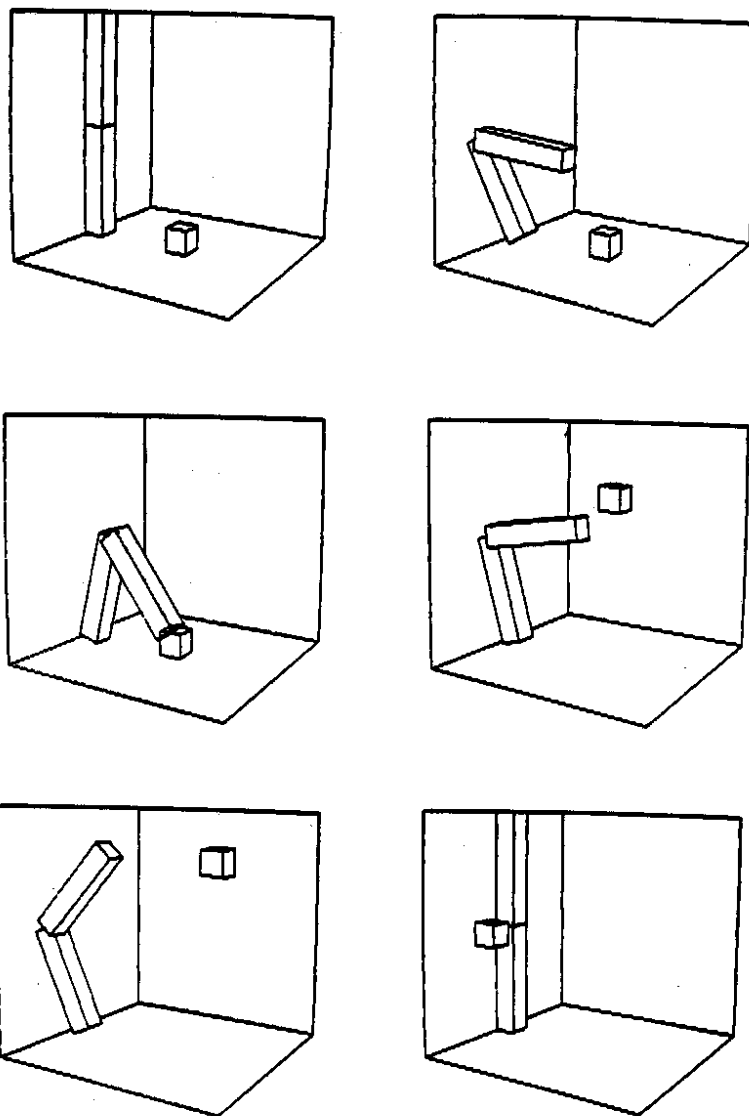
### *Procedural Animation System*

- Animation Abstractions
    - Scripts
    - Tracks
  - System Architecture
    - Extension Language
    - Distributed Computation
    - Multiple Windows (X11)
  - Different Levels
    - Authoring
    - Interaction
-



# Animation Example

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- Inverse Kinematics
  - Forward Dynamics
  - Collision Detection
-



# Ph.D. Degree - U. of Toronto

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## Geometric Modeling

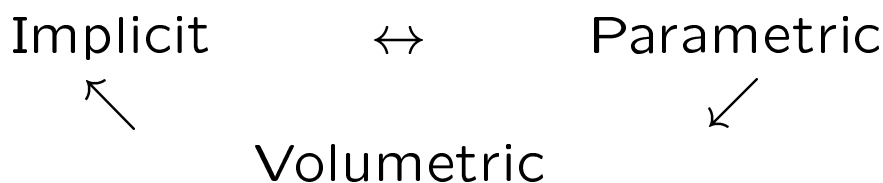
*Modeling Framework based on  
Piecewise Implicit Descriptions*

- Characterization of Implicit Models
  - Tubular Neighborhood
- Smooth Implicit Function Model
  - Multiscale Edge Analysis / Synthesis
- Hierarchical Implicit Representation
  - Multiscale B-Spline Basis
- Adapted Simplicial Decomposition
  - Physics-Based Simulation

Complete Framework

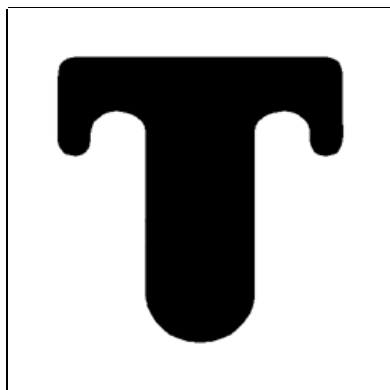
\* Decomposition + Adaptation

Conversion of Representations

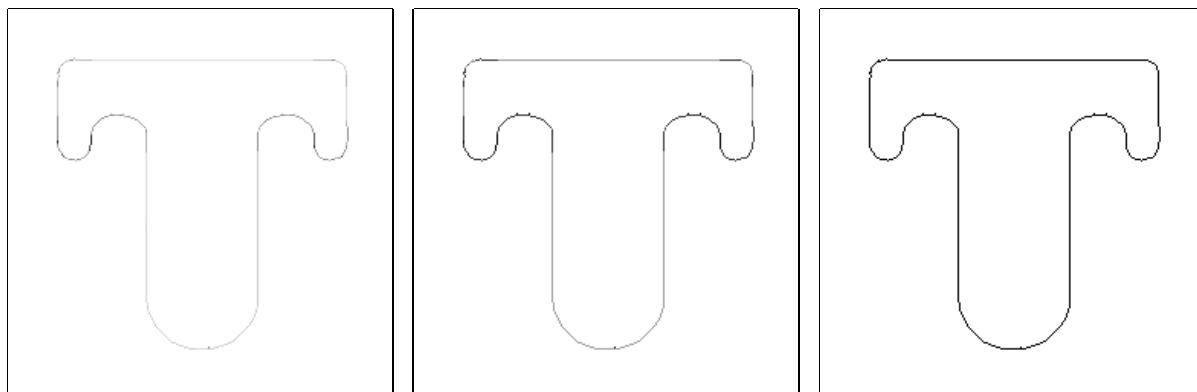


# Smooth Implicit Function

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Characteristic Function



Wavelet Maxima Values



Volumetric Implicit Function

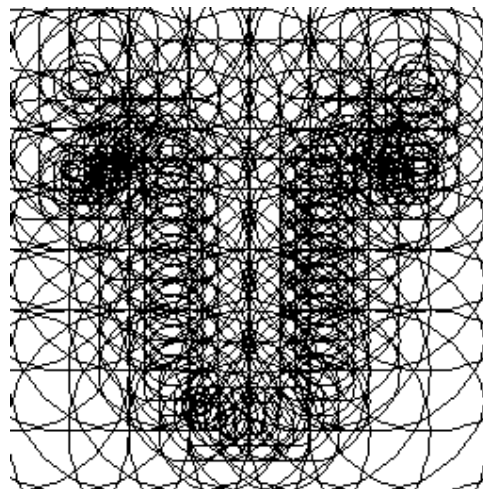
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# Hierarchical Representation

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B-spline Pyramid of the Implicit Function

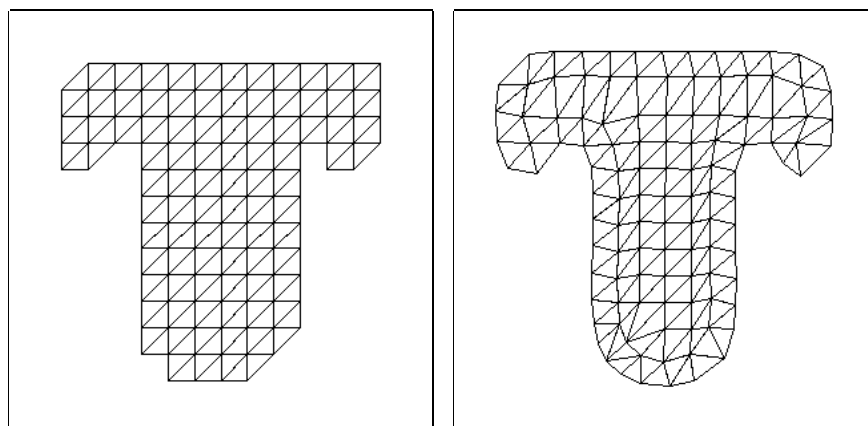


B-spline Functions

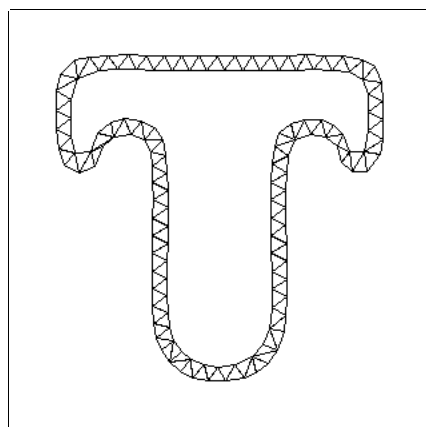
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# Approximate Conversion

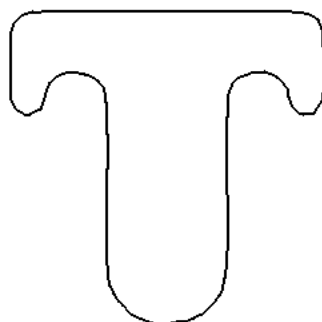
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Initial and Final Mesh for Solid Shape



Final Mesh for Hollow Shape



Boundary derived from the Mesh

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# Image Dithering

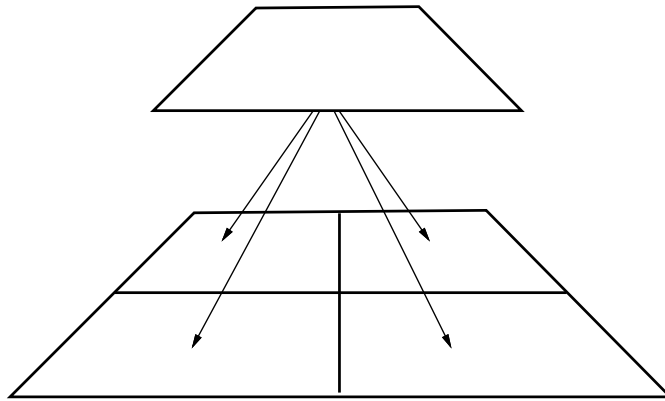
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- Pyramid Dither
- Dither with Space Filing Curves
  - Basic
  - Adaptive
  - Color
  - Graphic Effects

# Pyramid Dither

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- Image Pyramid



- Recursive Quantization

$$W = \sum w_i$$

- Distribution of Intensities

$$w_i = d_i + r_i$$

- Deterministic Component

$$d_i = \lfloor (v_i/V)W \rfloor$$

- Probabilistic Component

$$r_i = 1 \text{ with Probability } e_i$$

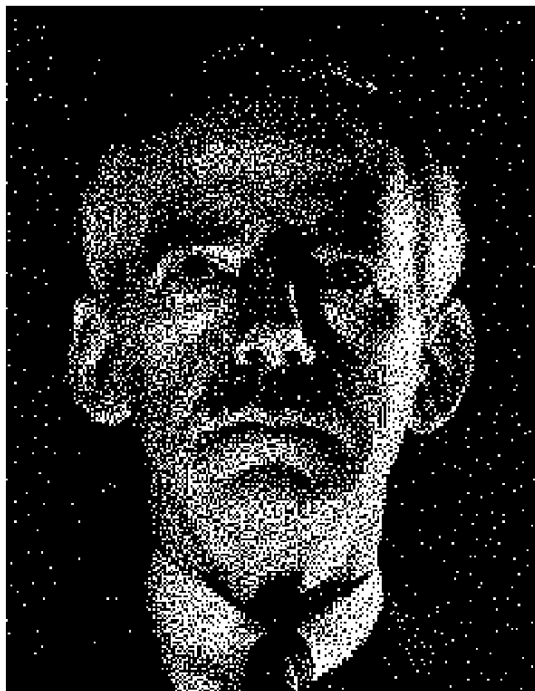
- Analysis

- Optimal Local and Global Quantization
  - Deterministic Term Dominates Globally
  - Probabilistic Term Dominates Locally
-

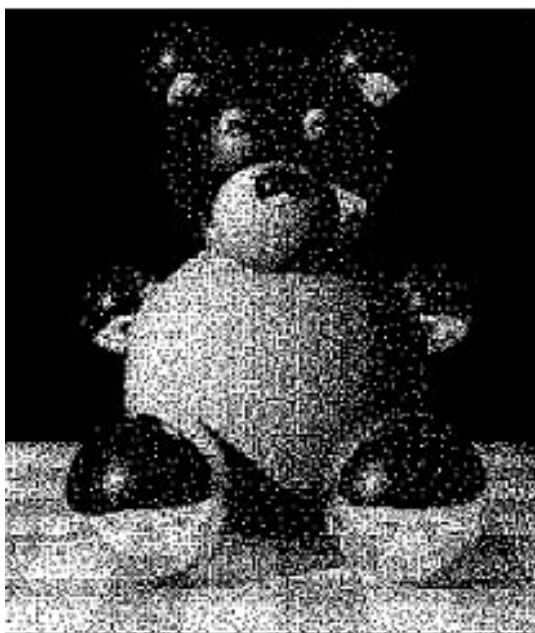
# Example

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- Photographic Image

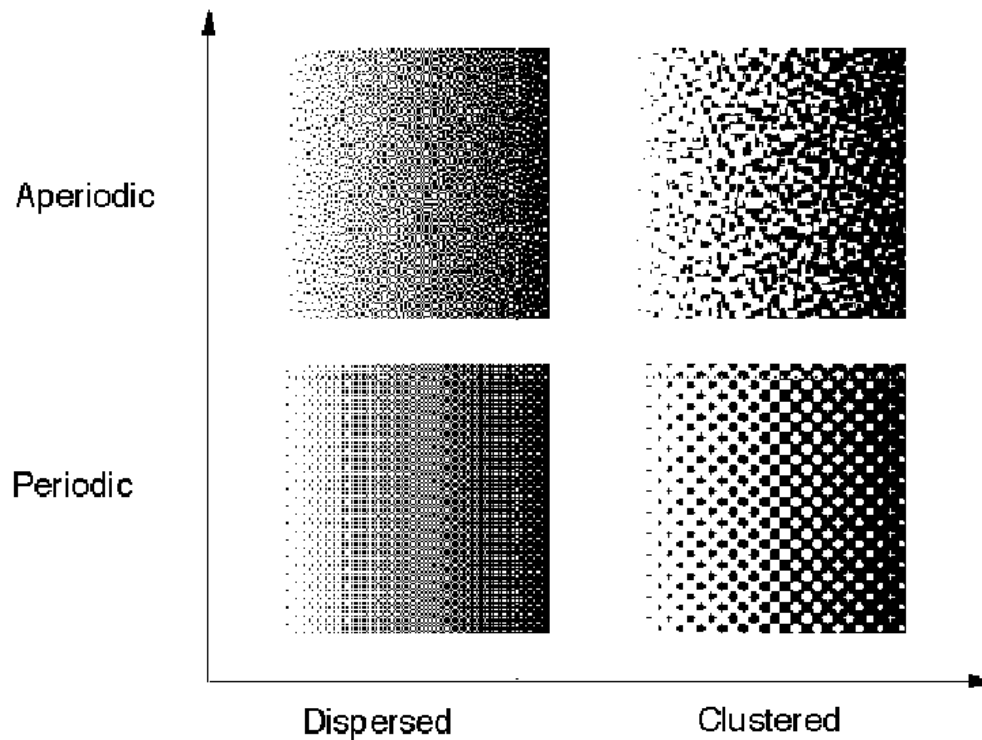


- Computer Generated Image



# Space Filling Curve Dither

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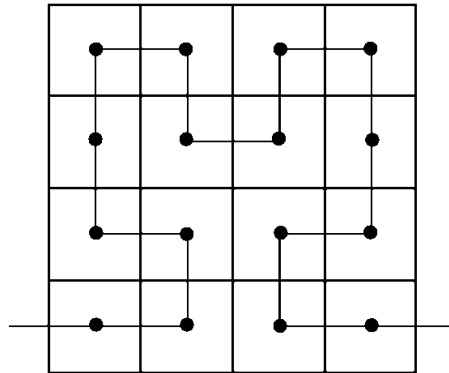
- SFC Dither
  - Aperiodic
  - Variable Cluster
  - Anisotropic
- \* *Fills Technology Gap*
- \* *Reopened the area*



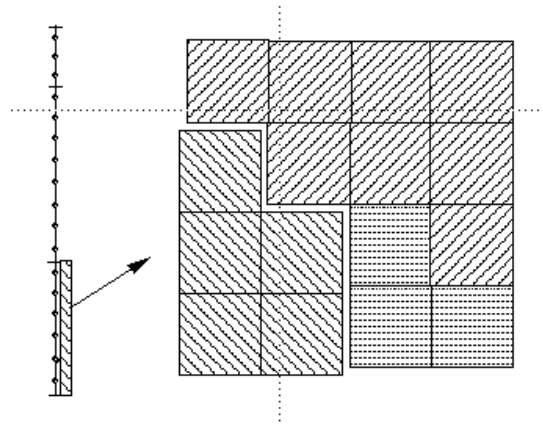
# SFC: Basic Method

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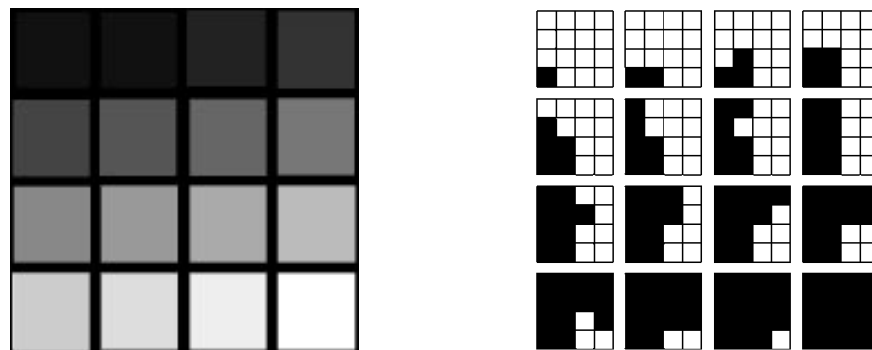
- Image Scan



- Image Partition



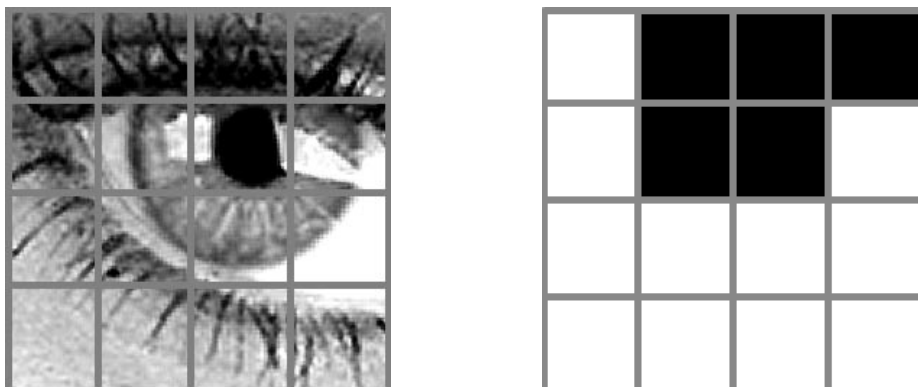
- Pattern Generation



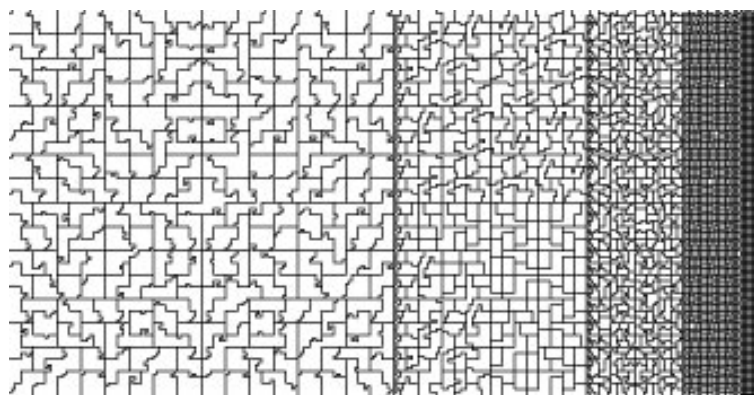
# SFC: Adaptation

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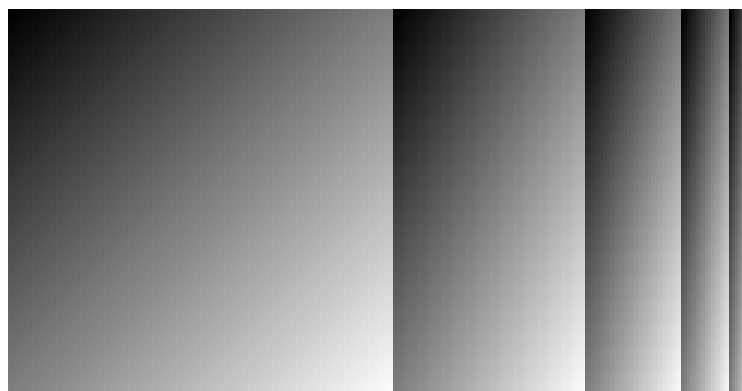
- Pixel Centering



- Variable Cluster Size



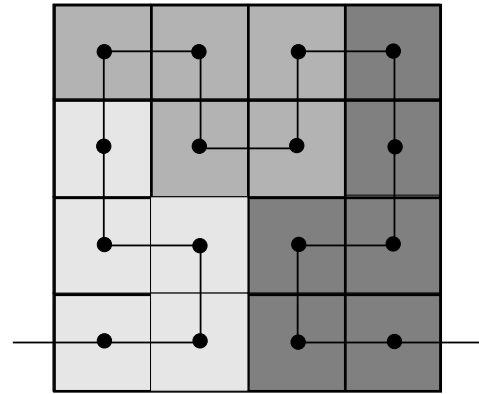
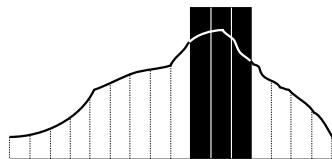
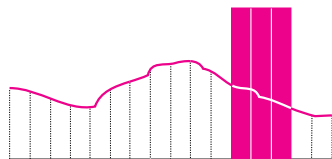
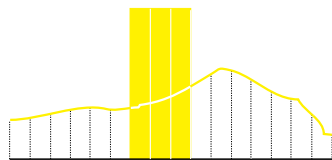
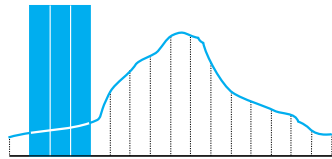
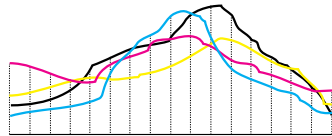
- Adaptation Function (image gradient)



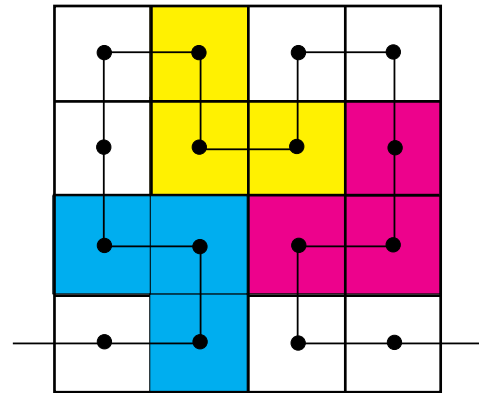
# SFC: Color

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- Correlated Cluster Positioning



(a)

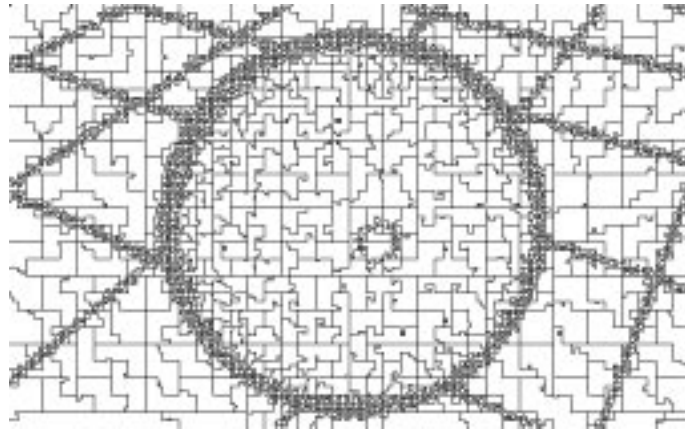


(b)

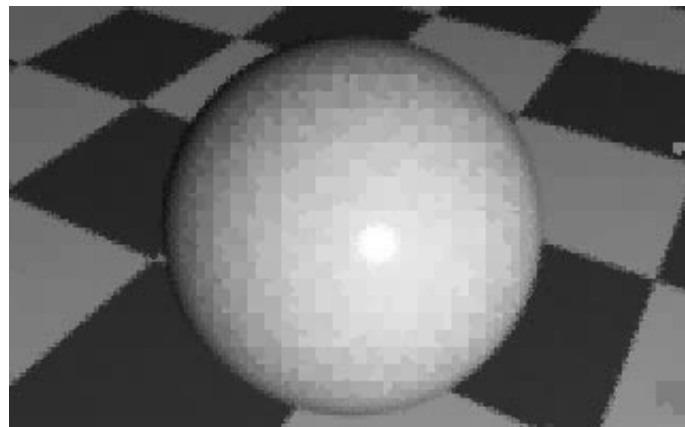
# Algorithm

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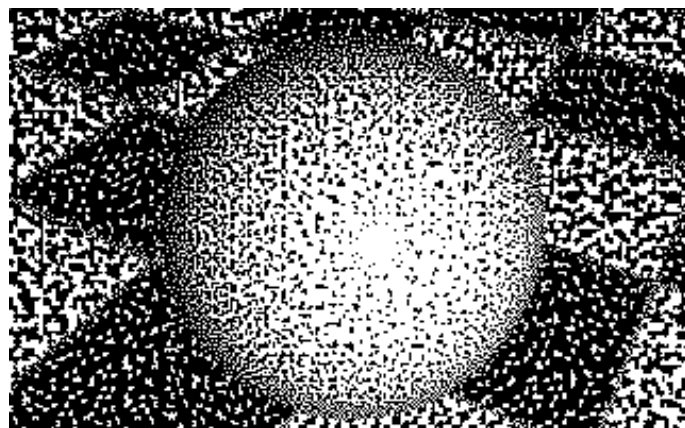
## 1. Subdivision of Image into Cells



## 2. Computation of Average Intensity



## 3. Generation of Dot Patterns



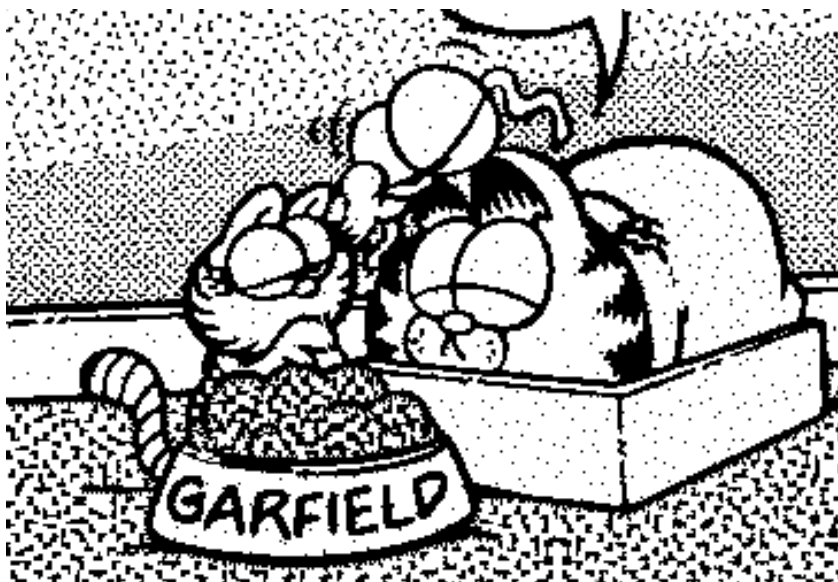
# Examples

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- Photograph



- Cartoon



# 2D Paint

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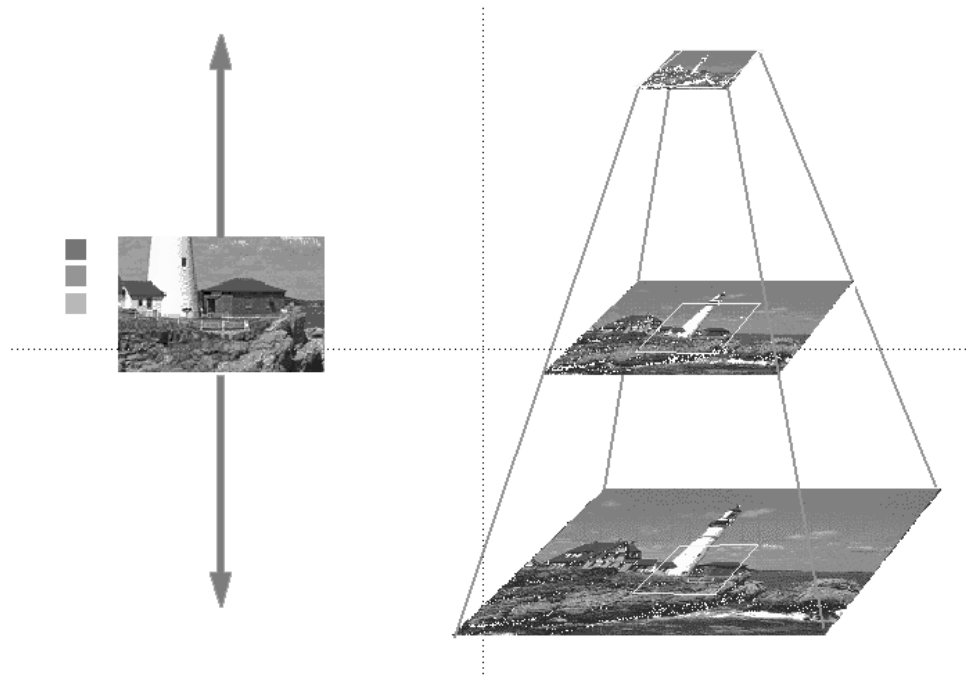
- Wavelet Paint
- Multiresolution Textures

*opened the area*

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# Wavelet Paint

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## Multiresolution Painting Process

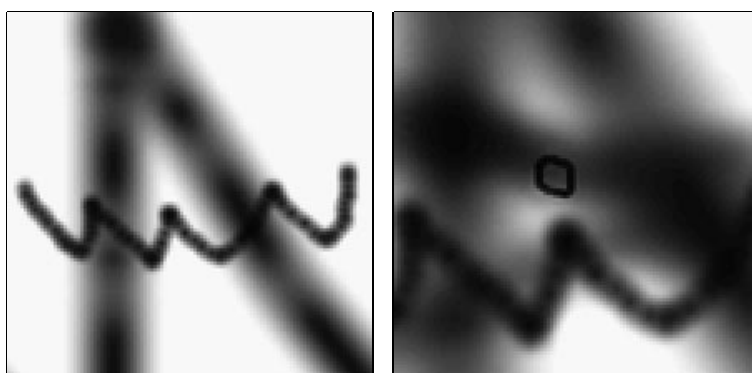
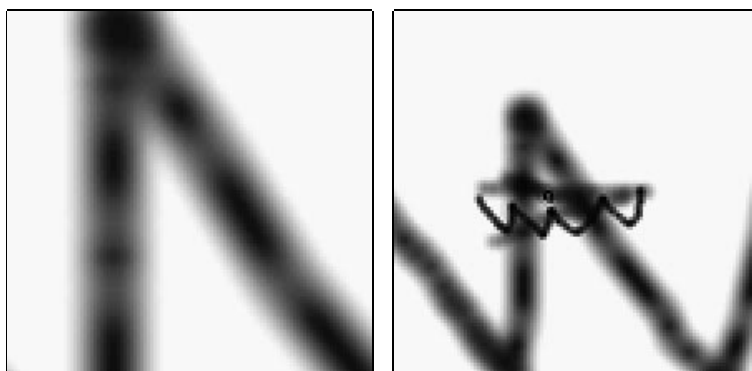
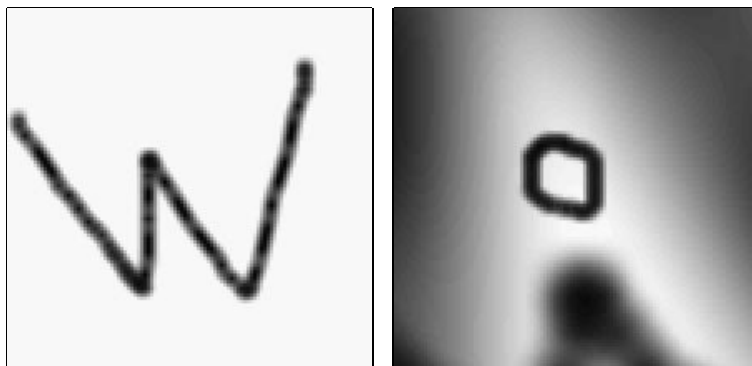
modify image at level  $x$   
↓ ↑  
move up or down a level

- Computational Support
    - Painting over Multiple Levels
    - Multiresolution Compositing
    - B-Spline Wavelets of degree  $n$
  - Advantages
    - Quick Changes (large areas)
    - Unlimited Detail
-

# Example

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- Painting and Zooming





# Multiresolution Textures

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- Procedural Paint-Brushes
- New Tool, designed for MPS
  - Complex Patterns
  - Automatic Generation of Detail

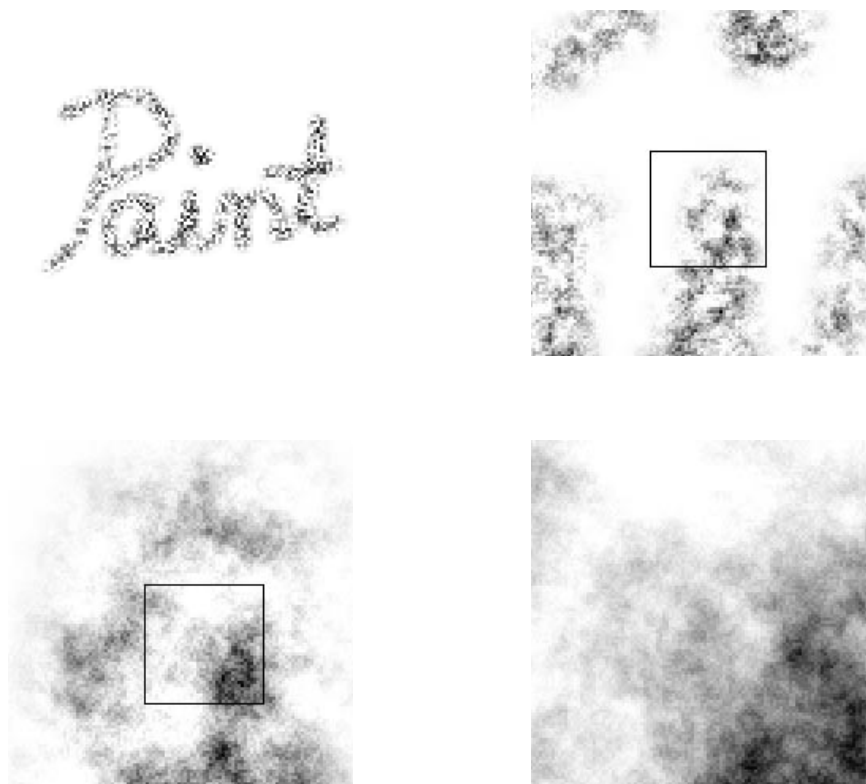
## Mechanisms

- Procedural Bandpass Pyramid:  $f(u, v, s)$ 
    - Base Procedure
      - *initil appeareance*
      - Called during Painting
    - Detail Procedure
      - *add detail*
      - Called During Magnification
  - Texture Alpha Channel:  $\alpha_f$ 
    - Texture Propagation
    - Lazy Evaluation
-

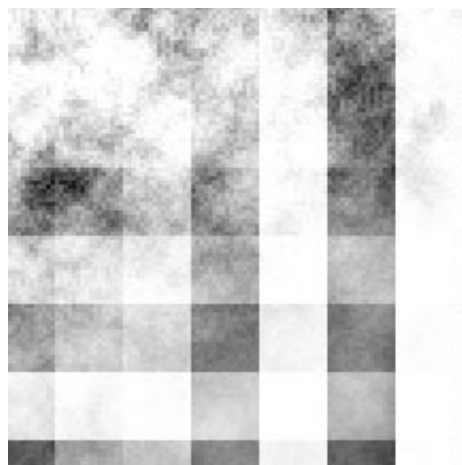
# Example

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- Rock Texture



- Mixture of Textures



# Implicit Surfaces

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- Multiscale Representation
- Surface Deformation and Animation
- Texture Mapping

# Multiscale Representation of Implicit Surfaces

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- Multiscale B-Spline Model
  - Piecewise
  - Structured
  - Hierarchical
- Representation

$$f = \sum_j g_j = \sum_j \left( \sum_i a_{i,j} \phi_{2^j, k_i}(x) \right)$$

where

$$a_{i,j} = \langle F, \tilde{\phi}_{j, k_i} \rangle$$

- Computation
    - Laplacian Decomposition
  - Data Structure
    - Spatial Hash Table
- $$H = \{a_{i,j}, \gamma_i\}$$

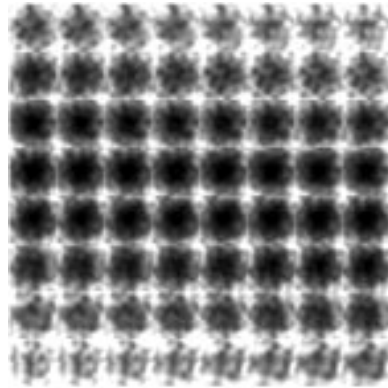
Applications

- Conversion Volumetric - Implicit
  - Variable Level of Detail Model
  - Fast Ray Tracing / Volume Rendering
-

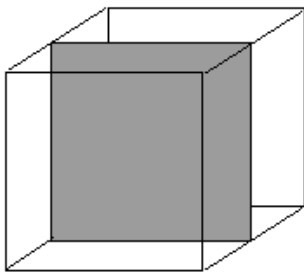
# Example: Noisy Sphere

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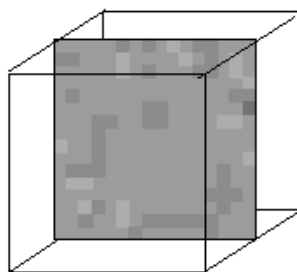
- Slices of the Density Function



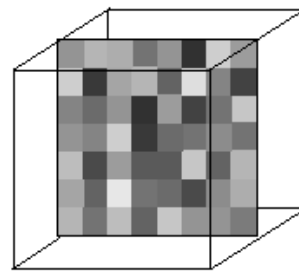
- B-Spline Pyramid



$32 \times 32$

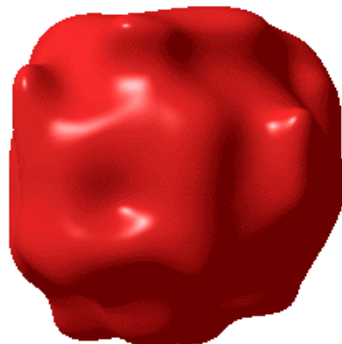


$16 \times 16$



$8 \times 8$

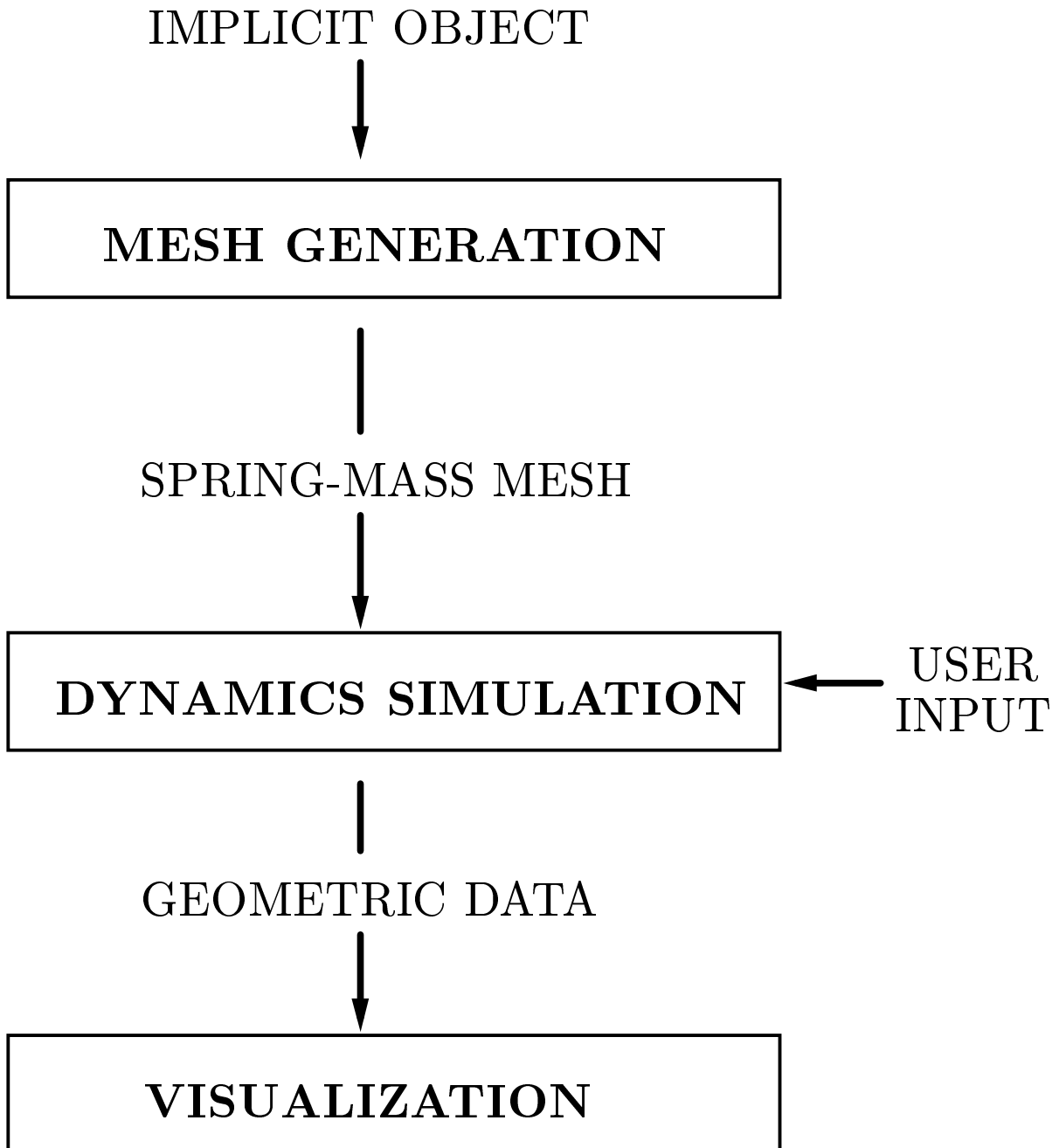
- Surface Ray-Traced



# Surface Deformation and Animation

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- System Pipeline

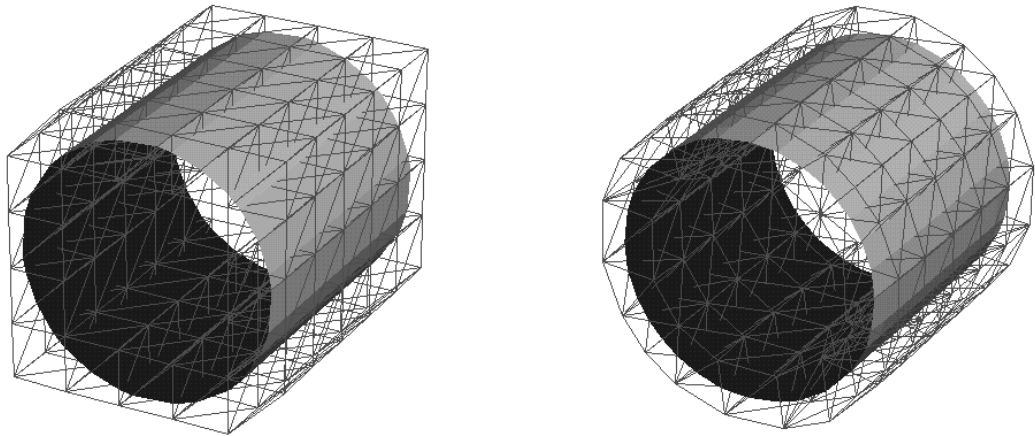


- Mesh Adaptation Algorithm
-

# Example: Cylinder

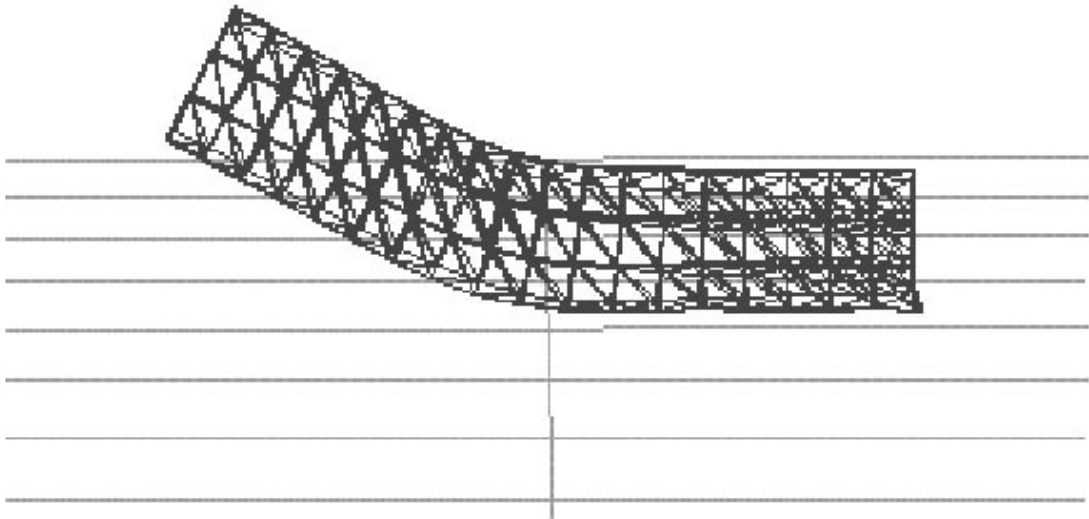
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- Mesh Adaptation



Initial and Deformed Meshes

- Dynamics Simulation



# Texture of Implicit Surfaces

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## *2D Texture Mapping with Particle Systems*

- Projection

Texture Support Object



Implicit Object

- Mapping Function
  - Force Field

$$\frac{d^2x}{dt^2} + \gamma \frac{dx}{dt} + \nabla F = 0$$

- Computation
  - Particle System
- Control
  - Global
    - Relative Positioning
    - Blending of Gradient Fields
  - Local
    - Attractors / Repulsors



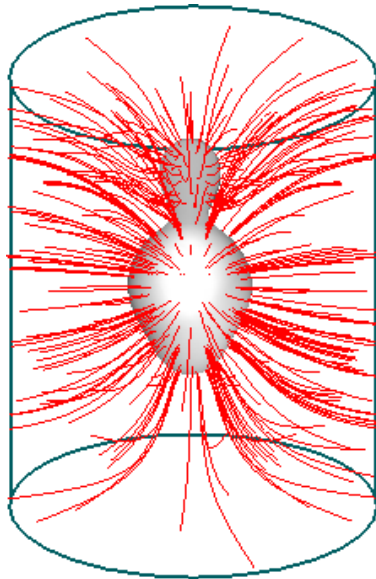
# Example: Coke Bottle

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- Source Texture



- Particle Trajectories and Textured Object



# Polygonization

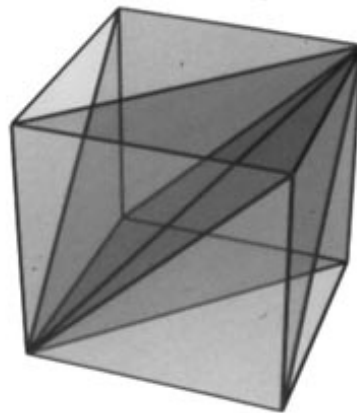
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- Polygonization of Implicit Surfaces using Simplicial Decompositions
- Physics-Based Polygonization of Implicit Surfaces
- Unified Path-Based Polygonization of Parametric and Implicit Surfaces

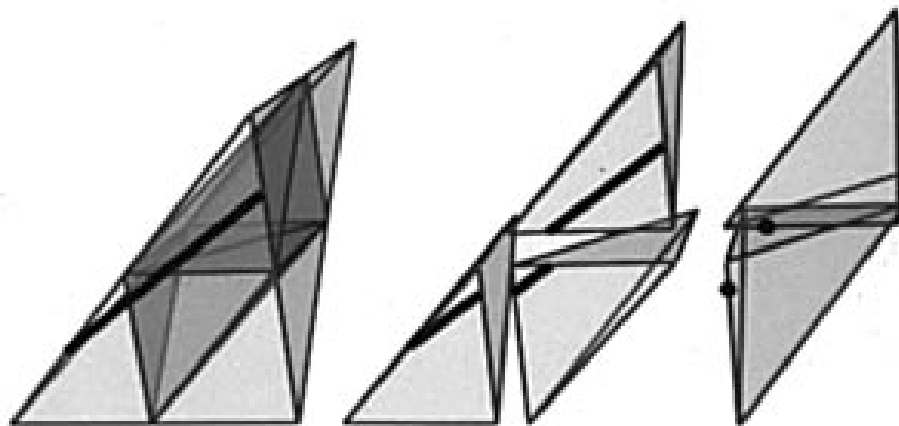
# Simplicial Polygonization

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- Adaptive Polygonization
- Method
  - Recursive Simplicial Decomposition
  - Boundary Constraints
- Subdivision of the Cube



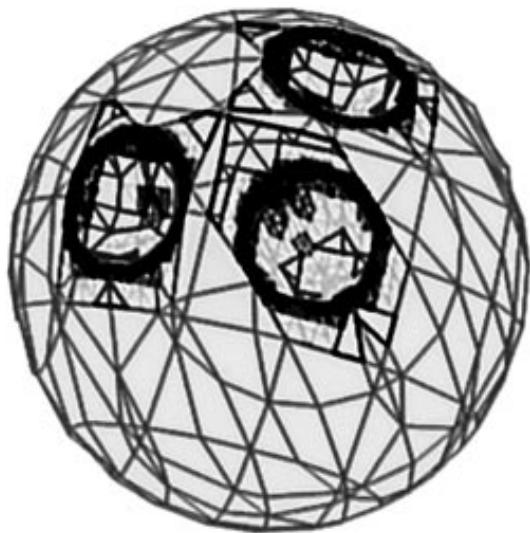
- Face and Edge Constraints



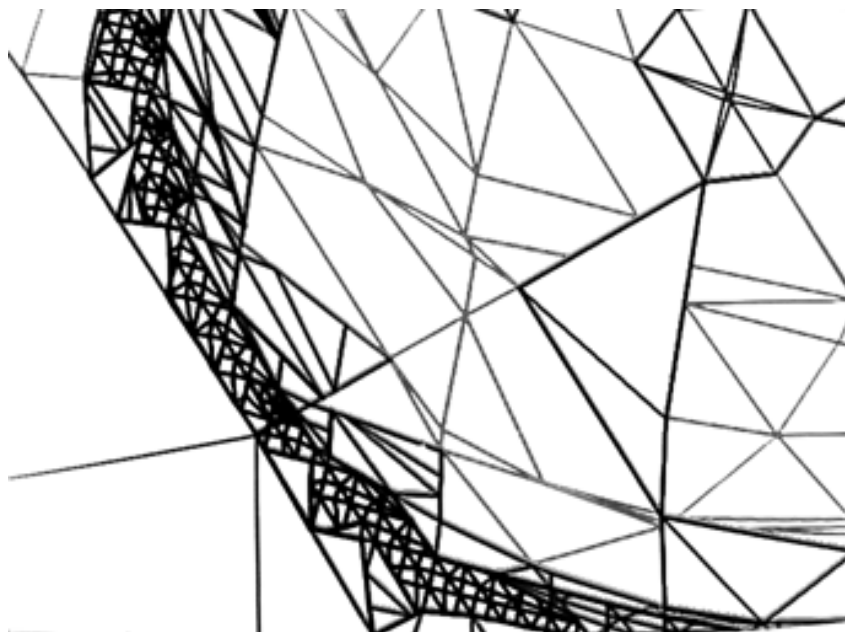
# Example: Blobby

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- Polygonization



- Detail



# Physics-Based Polygonization

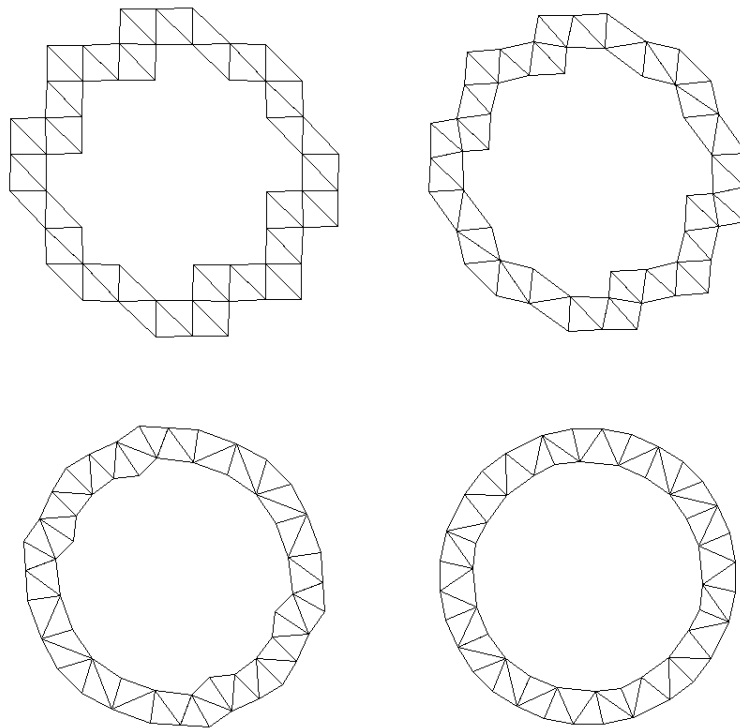
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- Quasi-Regular Triangulation
  - Fat Triangles
  - Optimal Sample Placement
- Physics-Based Method
  - Spring-Mass Meshes
  - Mesh Adaptation
    - Internal Forces (mesh)
    - External Forces (gradient field)
- Induced Polygonal Mesh
  - Dual

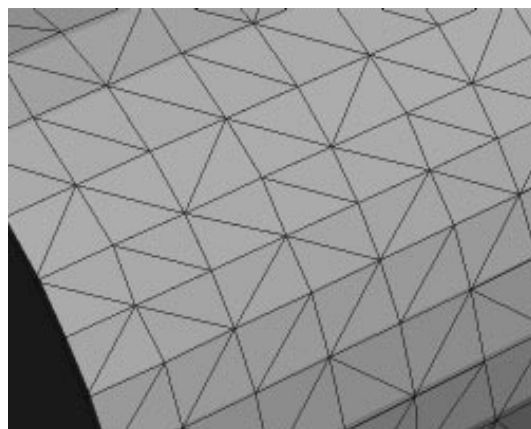
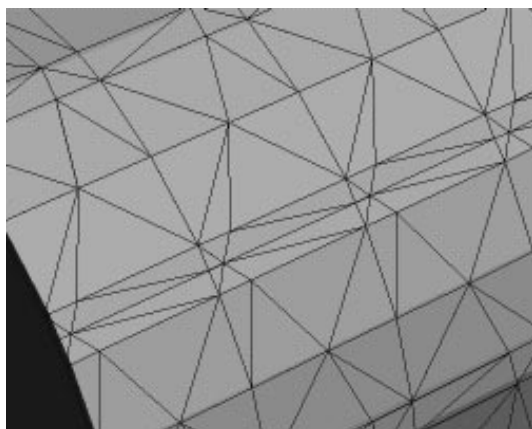
# Example: Cylinder

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- Mesh Adaptation



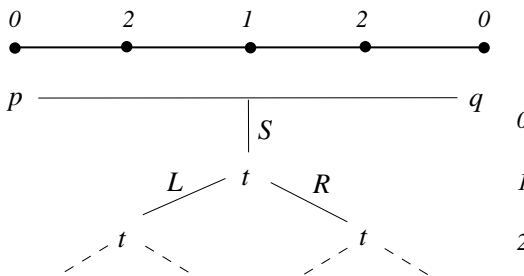
- Polygonal Mesh



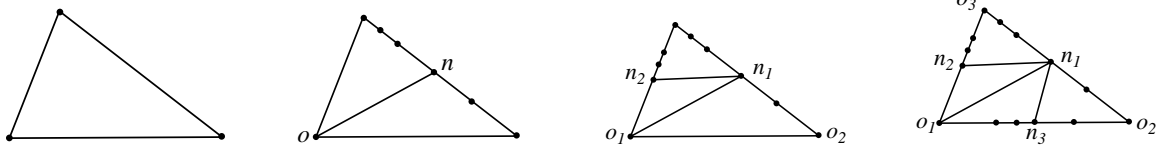
# Path-Based Polygonization

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- Unified Framework
  - Parametric
  - Implicit
- Adaptive Triangulation
  - Consistent Topology
- Hierarchical Mesh
  - Multiresolution
  - Progressive
- Operations
  - Multiresolution Path Sampling



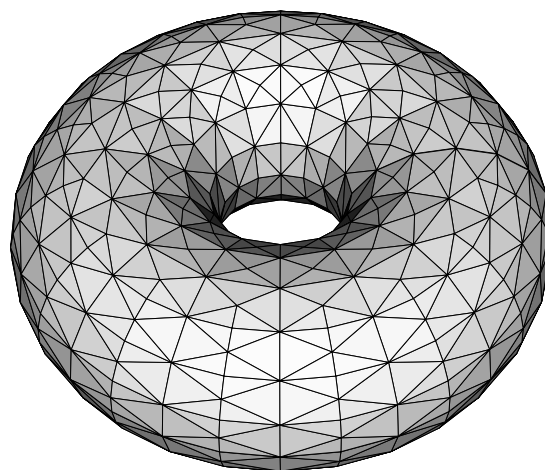
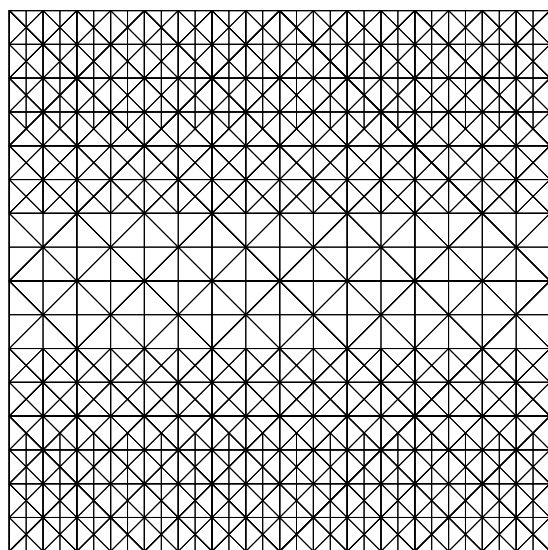
- Cell Structuring



# Example: Torus

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- Parametric



- Implicit

