Overview of Multiresolution Surface Representations

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Background Material

- Course, SIGGRAPH 97

  Multireslution Surface Modeling

  Paul Heckbert (CMU)

  Jarek Rossignac (Georgia Tech)

  Hugues Hoppe (Microsoft)

  William Schroeder (GE Labs)

  Marc Souc (InnovMetric)

  Amitabh Varshney (SUN)

- Tutorial, Eurographics 97

  Simplification, LOD and Multiresolution: Principles and Applications

  Enrico Puppo (IMA)

  Roberto Scopigno (CNUCE)

* Web Page

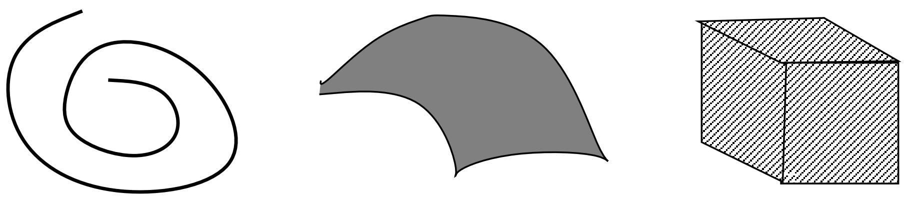
http://www.visgraf.impa.br/People/lvelho/mres98/

Structure of the Course

- Introduction
  - Motivation and Areas of Application
- Basic Concepts
  - Space Decompositions, Mesh Structures
- Multiresolution Meshes
  - MT Representation, Properties and Operations
- Simplification Methods
  - Decimation and Computational Framework
- Refinement Methods
  - Subdivision, Base Mesh Generation
- Conclusion
  - Research Groups and Companies
  - Demonstration of Software

Models and Representation

- Continuous Model: M
  - Curves, Surfaces, Volumes



- Solve Computational Problems

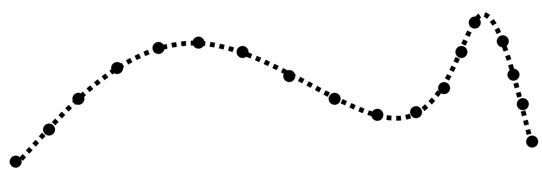
  ex: Visualization, Simulation

- Discrete Representation
  - Decompose Domain
  - Piecewise Description

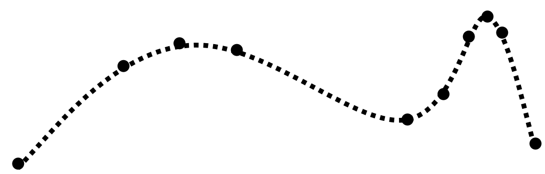
- Approximations: $\overline{M}$
  - Piecewise-Linear (PL)
  - Higher Order

Discretization and Adaptation

- Discretization

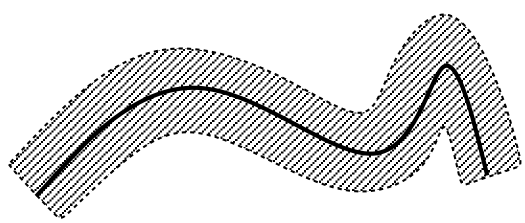


Uniform

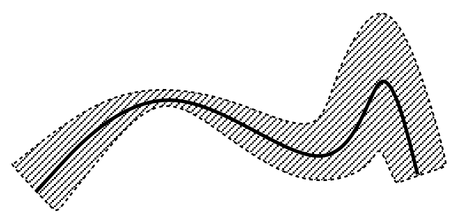


Adapted

- Adaptation Function $\epsilon(t)$

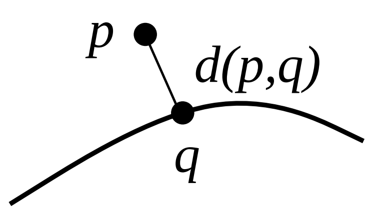


Constant



Variable

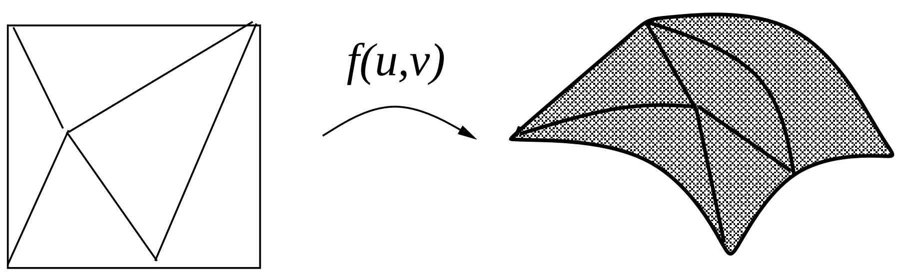
- Approximation Metric



2D Manifolds and Triangle Meshes

- 2D Manifolds
  (Most Important Case)
  - Surfaces, $(x, y, z) = f(u, v)$
  - Images, $i = g(u, v)$

- Triangle Meshes
  (Simplest Representation)
  - Simplicial Decomposition
  - Basic Graphics Primitive



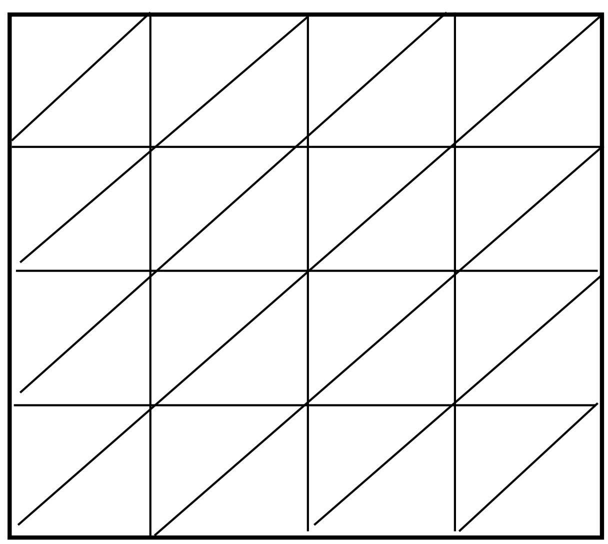
- Easy to Generalize
  - 1D (curves)
  - 3D (solids)

Discretization and Meshes

- Uniform Discretization
- Adaptive Discretization
- Multiresolution Discretization

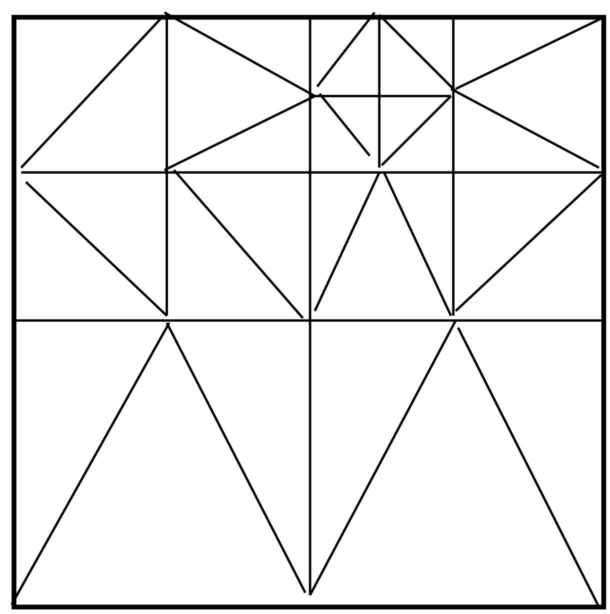
Uniform Mesh Discretization

- Easy to Compute
- Too many elements, in general
- May be impractical



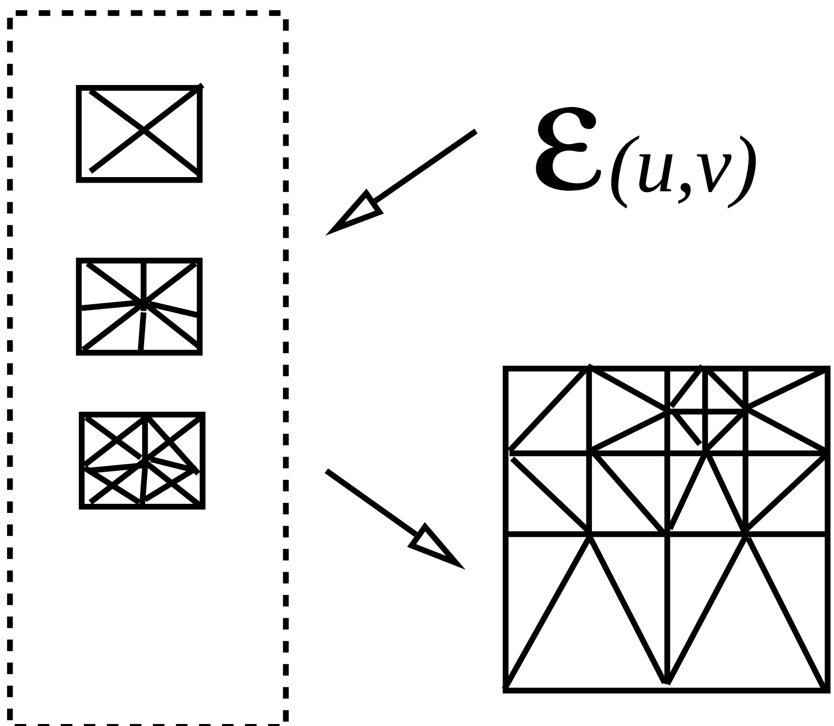
Adaptive Mesh Discretization

- Right Number of Elements
- More Difficult to Compute
- Depend on the Problem



Multiresolution Mesh Discretization

- Can be Pre-Computed
- Adaptation On-The-Fly



Properties of Multiresolution Representations

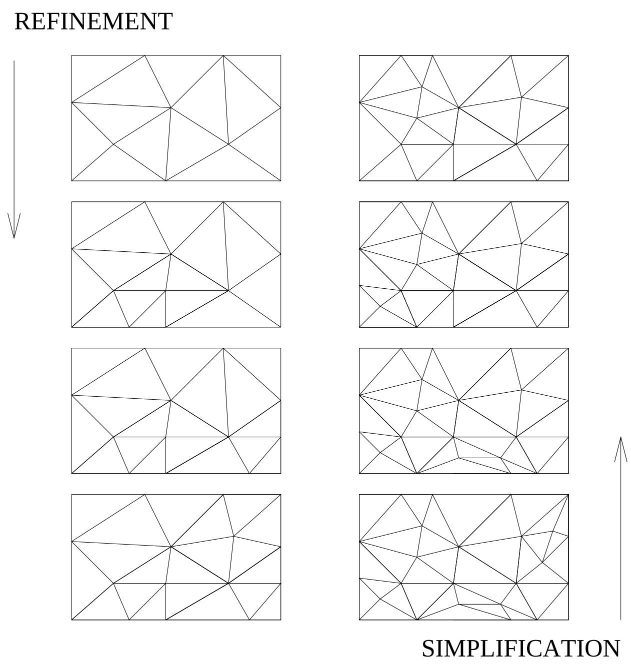
- Compacteness
  - Size of Representation vs. Size of Mesh
- Consistency
  - Simplicial Complex
- Efficiency
  - Polynomial Complexity of Operations
- Flexibility
  - Spatially Variable Adaptation
- Monotonicity
  - Sequence of Approximations

Building Multiresolution Representations

- Construction Schemes
  - Local Mesh Modifications

- Mesh Refinement
  - Add Elements

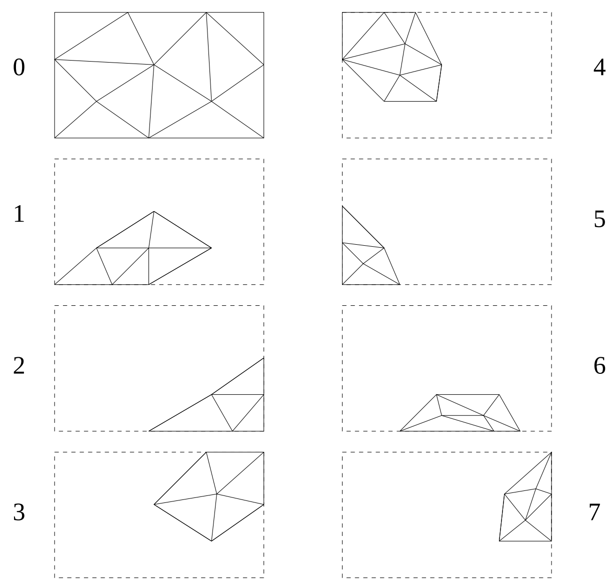
- Mesh Simplification
  - Remove Elements



Computational Framework

- Basic Method
  1. Generate an Initial Mesh
  2. Repeat until done
     - Apply Scheme
     - Record Changes

- Representation
  - Initial Mesh + Changes



Graphics Problems

- Visualization
  - Adapted Rendering
    (Display Resolution)
  - Progressive Rendering
    Interaction (Low Res) - Idle (High Res)

- Representation
  - Geometry Compression
    (Exploit Smoothness)
  - Progressive Transmission
    (Low Res + Differences)

Graphics Problems (cont.)

- Computation
  - Surface Properties
    (Domain Decomposition)
    ex: FEA
  - Geometry Design
    (Shape Optimization)

- Modeling
  - Multiscale Editing
    (Changes at LOD)
  - Data Base Integration
    (Objects at Different Res)

Video

- Levels of Detail
- Variable Resolution Meshes
  - Single Surfaces
  - Clustering
- Adapted Rendering
  - Terrain
  - 3D Environments
- Progressive Rendering
- Adaptation Function
  - Geometry
  - Texture

Areas of Application

- GIS / Cartography
  - Data:
    - Terrain Elevation
    - Satelite Images and Derivations
  - Problems
    - Visualization
    - Database Operations

- Virtual Reality / Simulation
  - Data:
    - 3D Environments
  - Problems
    - Real-Time Display
    - Transmission
    - Interference Tests

Areas of Applications (cont.)

- Graphics / Scientific Visualization
  - Data
    - Parametric and Implicit Surfaces
    - Volume Data
  - Problems
    - Geometry Compression
    - Mesh Adaptation

- Vision / Image Processing
  - Data
    - Image
    - Range Data
  - Problems
    - Reconstruction
    - Segmentation

Areas of Application (cont.)

- CAD / Enginnering
  - Data
    - Free-Form Surfaces
    - Subdivision Surfaces
  - Problems
    - Design
    - Analysis (FEA)

Surface Descritption

- Height Fields (Monge Surfaces)
  - Terrain
  - Range Data
  - Images
- Parametric Surfaces
  - Global Parametrizations
  - Patches
- Implicit Surfaces
  - Primitives
  - Composite
  - Volumetric

Mesh Generation

- PL Approximation
  - Analytic Description

    $(x, y, z) = f(u, v)$

- Sparse Interpolation
  - Data Samples

    $\{p_0, p_1, \ldots p_k\}, \quad p_i \in \mathbf{R}^3$

Products

- Graphics Libraries and Formats
  - Open Inventor
  - VRML
  - Direct 3D

- Tools
  - IM Compress
  - Cosmo Worlds
  - HP Direct Model

- Graphics Systems
  - IBM Interaction Accelerator
  - OpenGL Optimizer/ Fahrenheit project (SGI/IBM)

Libraries and Formats

- Inventor / VRML
  - Support Only for LOD

```
LOD {
  exposedField MFNode  level    []
  field        SFVec3f center   0 0 0
  field        MFFloat range    []
}
```

- Parameters
  - level$_i$: Models at level of detail i
  - range$_i$: Ranges of distances

    $i = 1, \ldots, n$M
  - center: Centroid of the model

- Selection based on Distance from the Viewer

Tools

- IM Compress

  Polygon reduction tool
  - Adapted Mesh Simplification
  - Combines Geometry with Texture
  - *outputs a final mesh + texture*

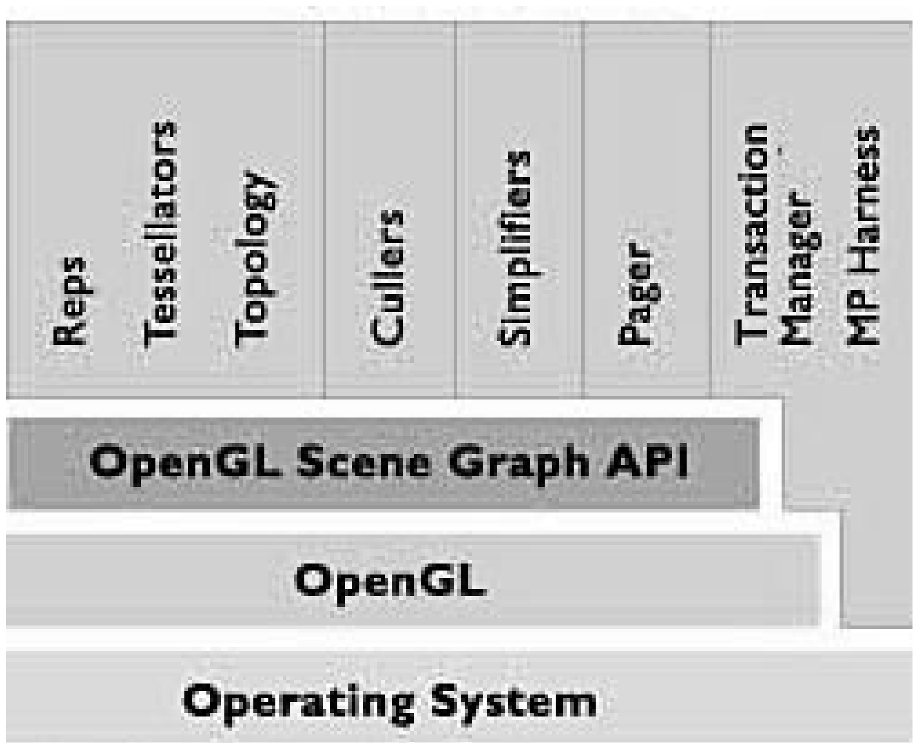
- Cosmo
  - Polygon Reduction Editor

- HP Direct Model
  - Mesh Simplification and LOD
  - Integrated in the Graphics Pipeline

- IBM 3D Interaction Accelerator
  - Polyhedral Simplification

Graphics Systems

- OpenGL Optimizer



- Fahrenheit
  - Large Model Visualization API (new) - 2000
  - Scene Graph API (Inventor) - 1999
  - Low-Level API (OpenGL / DirectX) - 1999