Luiz Henrique de Figueiredo

A Personal Portrait

by

Luiz Velho

Inspiration

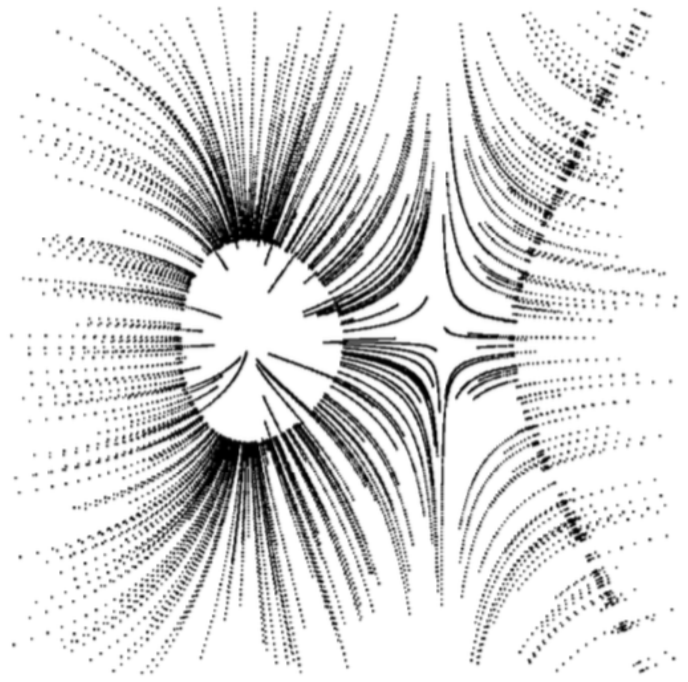
"É da natureza íntima da Matemática
a busca do entendimento das coisas simples e fundamentais
naquela faixa de idéias onde, segundo os gregos antigos,
Verdade e Beleza se misturam de maneira indistinguível."

Manfredo do Carmo, 28 de Agosto de 1984 (*)

(*) Parte do discurso ao receber o Prêmio Nacional de Ciência e Tecnologia

The Big Picture

Mathematics

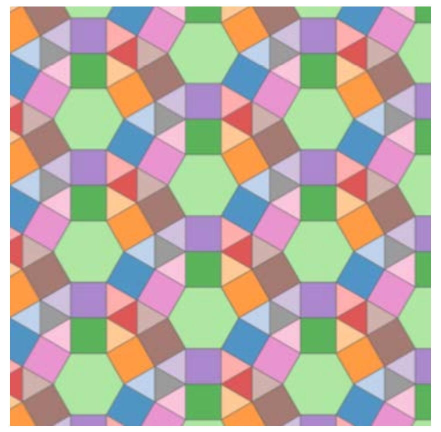


$$\frac{d^2x}{dt^2} + \gamma\frac{dx}{dt} + \text{sign}(h)\nabla h = 0$$

Computing

```
function add (a)
  local sum = 0
  for i = 1, #a do sum = sum + a[i] end
  return sum
end
```

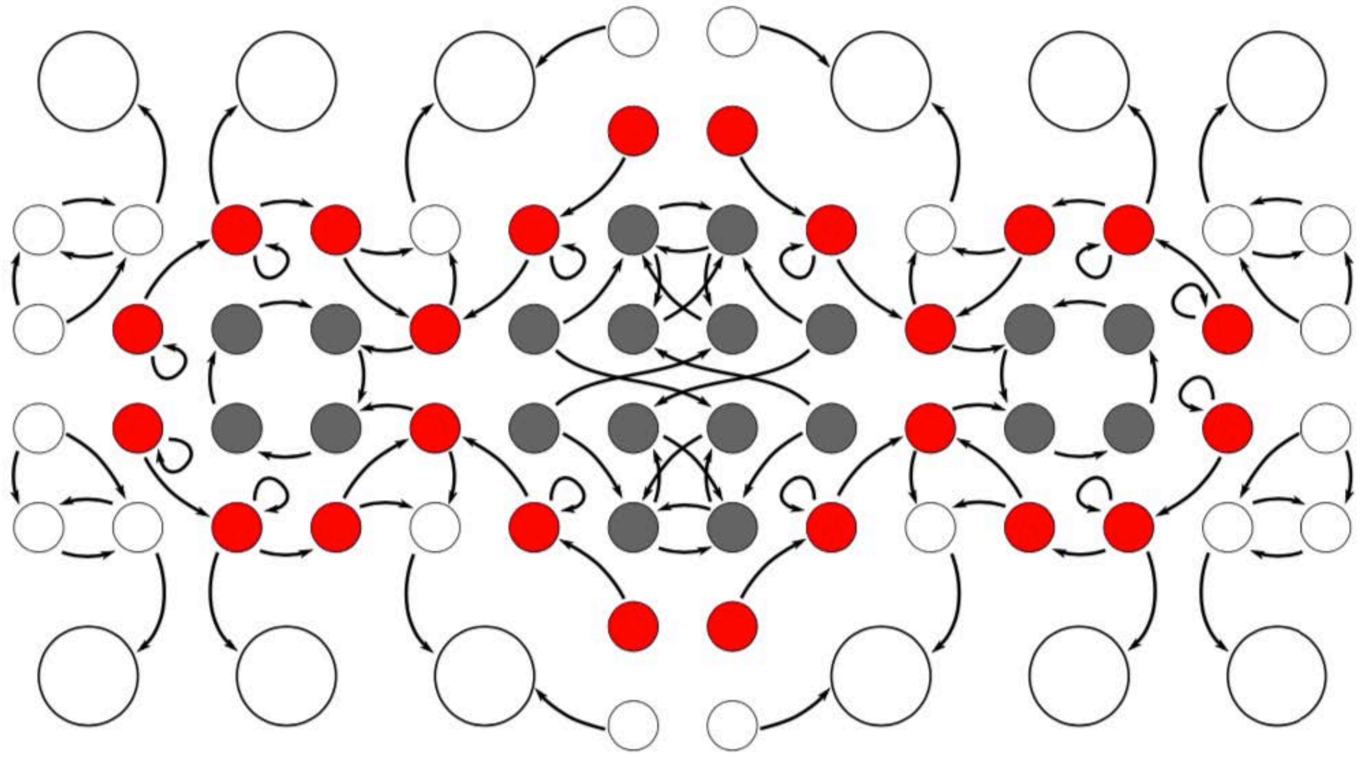
Art

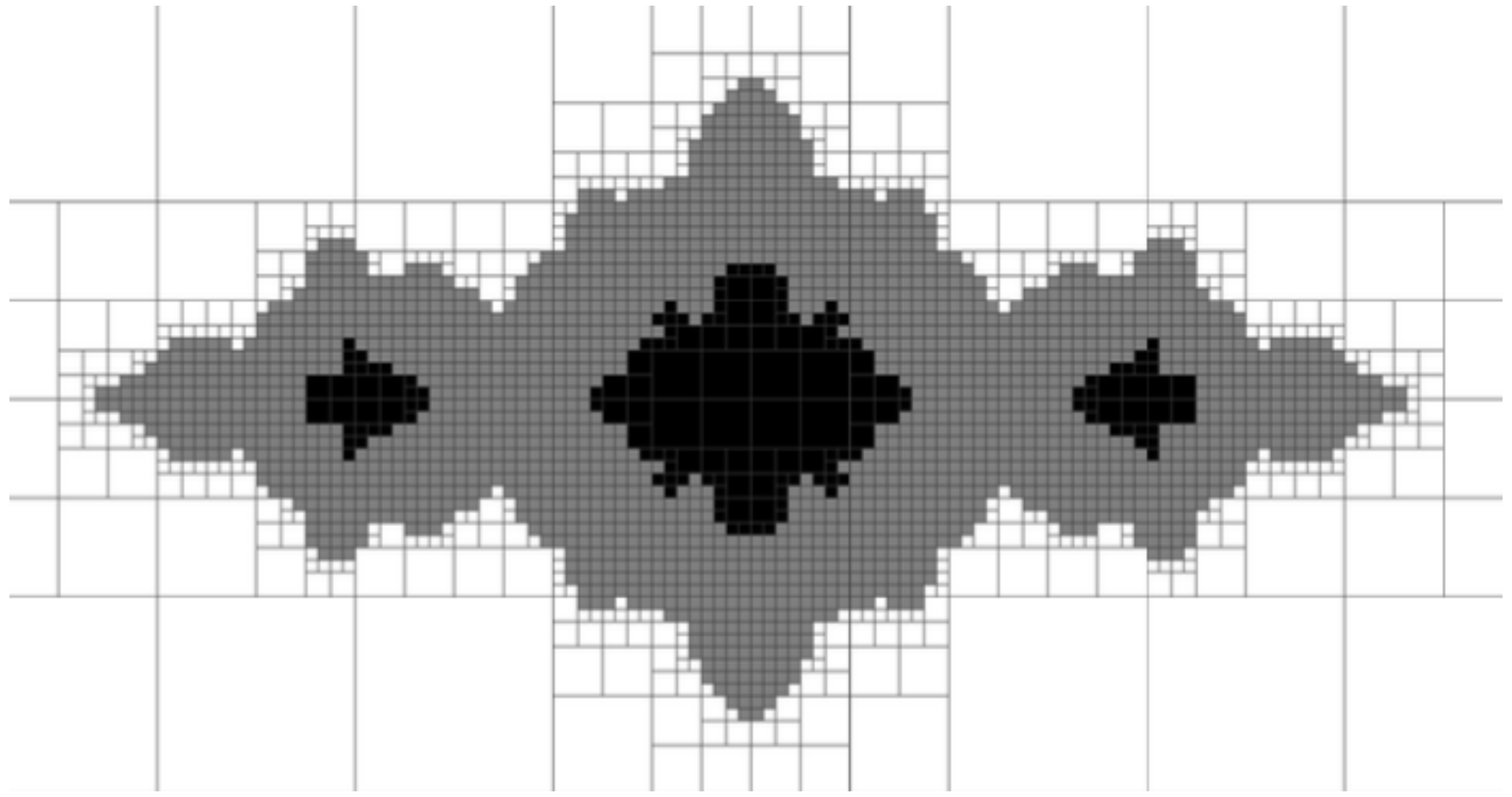


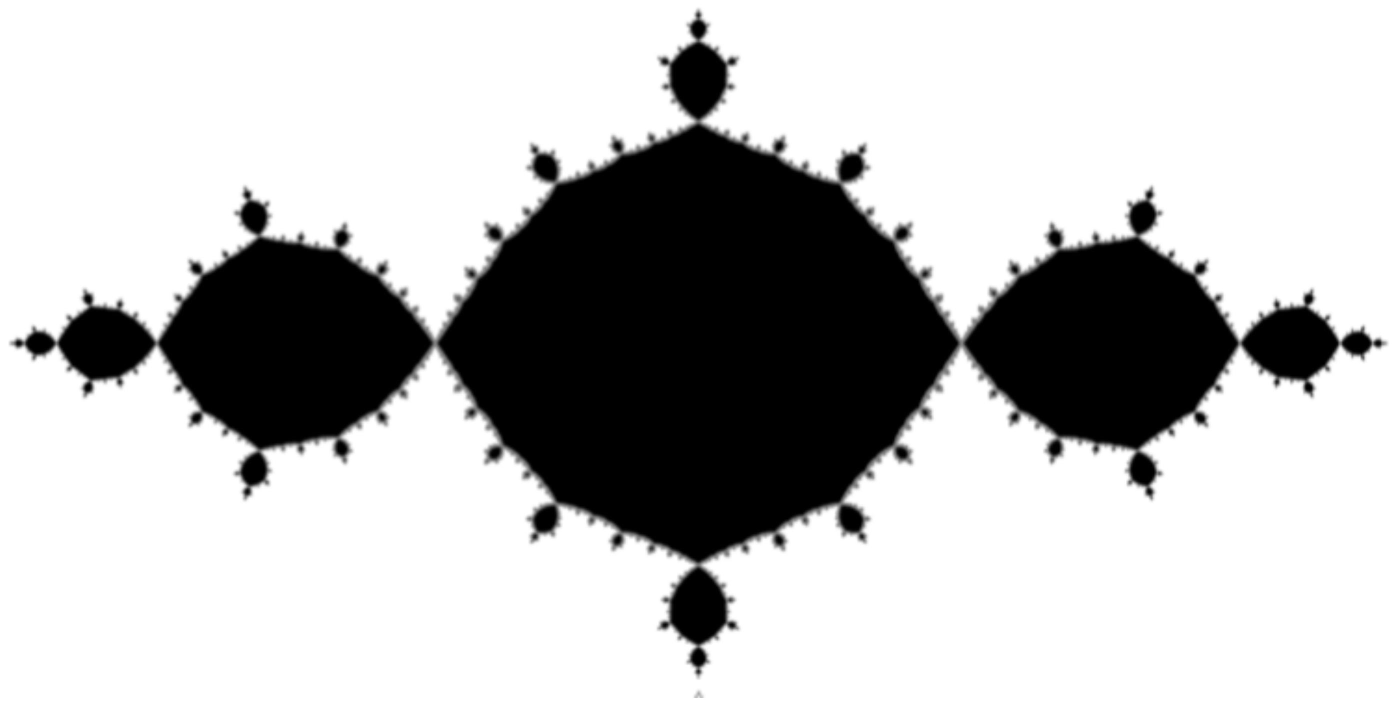
basic directions:	$1, \omega, \omega^2, \omega^3$
translation vectors:	$[1,0,0,0], [0,0,1,1]$
seeds:	$[0,0,0,0], [1,0,0,1]$

Three Pillars

Analysis	Adaptation	Depiction







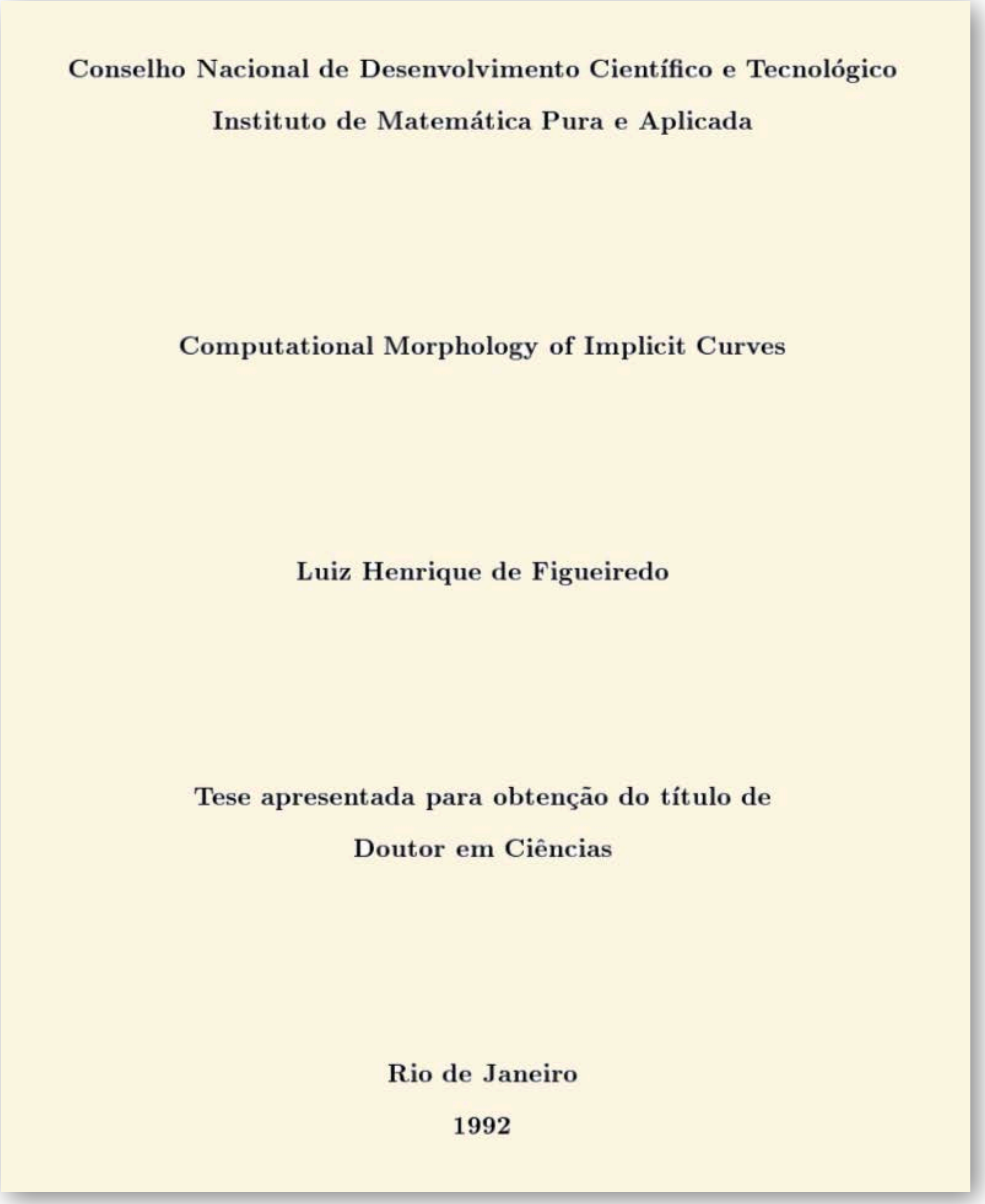
Images of Julia sets that you can trust

with Diego Nehab, Jorge Stolfi, and João Batista Oliveira

Rigorous Bounds for Polynomial Julia Sets, Journal of Computational Dynamics (2016)

The Beginning

- PhD thesis @ IMPA



Conselho Nacional de Desenvolvimento Científico e Tecnológico
Instituto de Matemática Pura e Aplicada

Computational Morphology of Implicit Curves

Luiz Henrique de Figueiredo

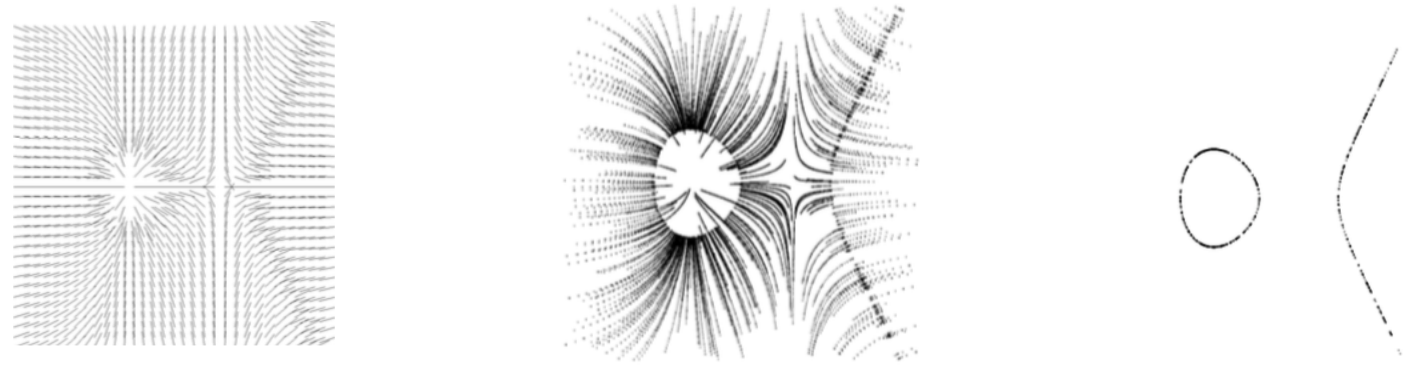
Tese apresentada para obtenção do título de
Doutor em Ciências

Rio de Janeiro
1992

Start of IMPA's
Academic Program
in Computer Graphics

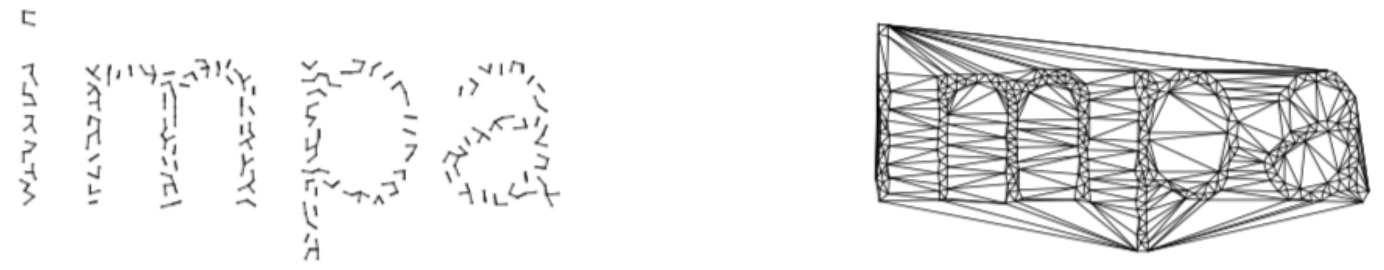
Main Contributions

- Physically-Based Sampling for Implicit Objects



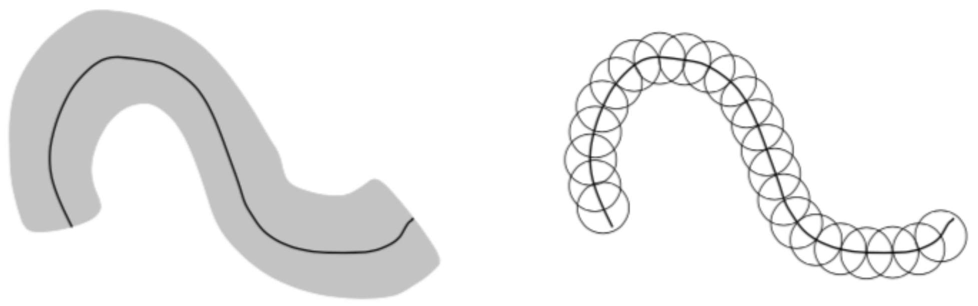
Gradient Field *Dynamical Systems*

- Taxonomy of Structuring Problems



Spanning Trees *Computational Geometry*

- New Ideas for Modeling Implicit Geometry



Tubular Neighborhood *Differential Topology*

Our First Joint Paper

- Graphics Interface'92

Physically-Based Methods
for Polygonization of Implicit Surfaces

Luiz Henrique de Figueiredo[†]
Jonas de Miranda Gomes[†]
Demetri Terzopoulos[‡]
Luiz Velho[†‡]

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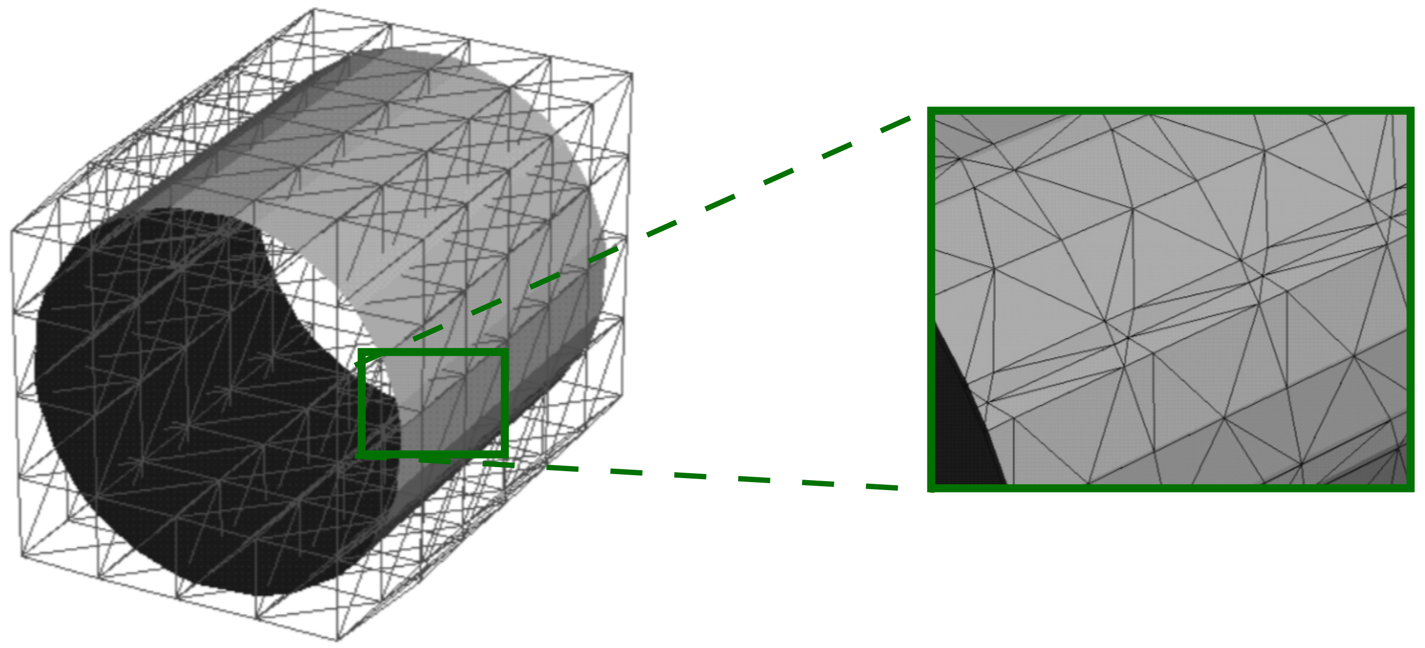
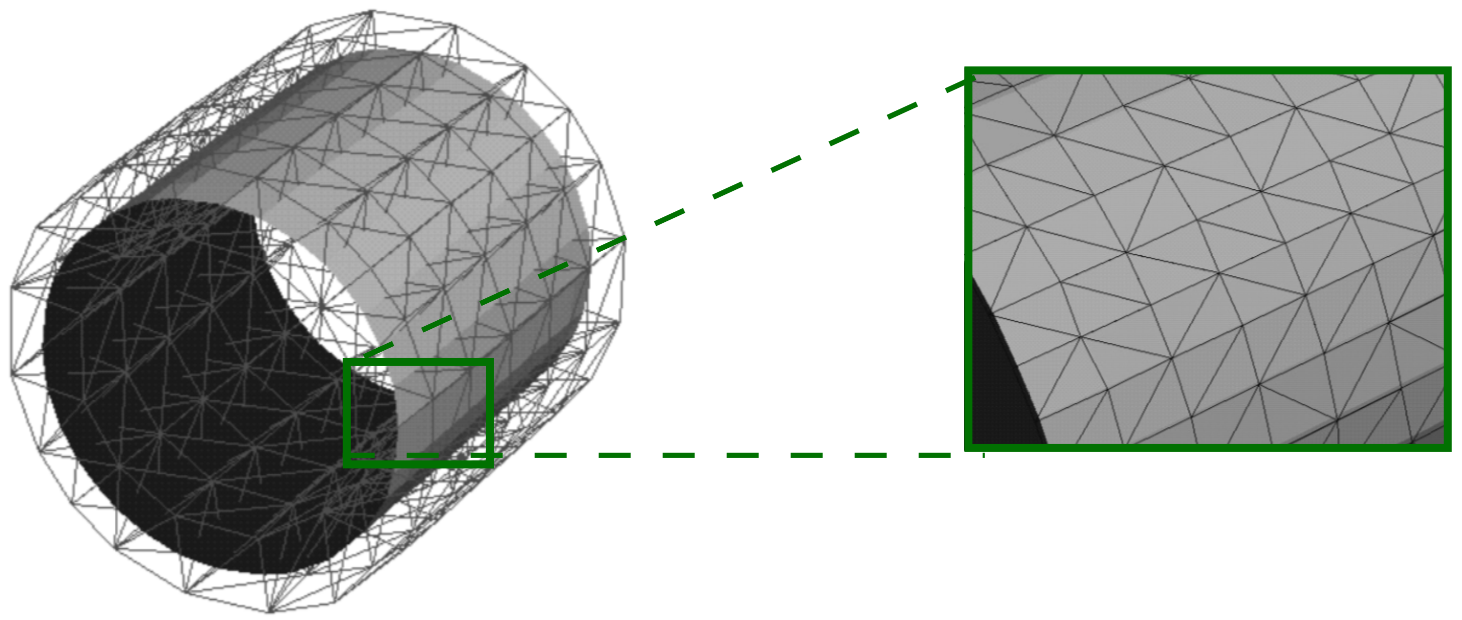
Toronto, Ontario, M5S-1A4

  - *Results*





Expanding the Collaboration

- *Texture, Implicit Objects and Particle Systems*

Basic

Textura de superfícies implícitas com sistemas de partículas
Proceedings of SIBGRAPI'95, 305–306 (with Ruben Zonenschein, Jonas Gomes, Luiz Velho)

Texturing implicit surfaces with particle systems
SIGGRAPH'97 Visual Proceedings 172 (with Ruben Zonenschein, Jonas Gomes, and Luiz Velho)

Extensions

Controlling texture mapping onto implicit surfaces with particle systems
Proceedings of Implicit Surfaces'98, 131–138 (with Ruben Zonenschein, Jonas Gomes, and Luiz Velho)

Texturing composite deformable implicit objects
Proceedings of SIBGRAPI'98, 346–353 (with Ruben Zonenschein, Jonas Gomes, Luiz Velho, Mark Tigges, and Brian Wyvill)

(Part 1) With IMPA's Crowd …

- Papers and Films

Textura de superfícies implícitas com sistemas de partículas

Ruben Zonenschein[1] Jonas Gomes[1] Luiz Velho[1] Luiz Henrique de Figueiredo[2]

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Abstract. We present a new method for applying texture onto implicit surfaces. The method tracks particles associated with the gradient vector field of the implicit function. Unlike others methods, this approach gives effective tools for controlling the placement of the applied texture.

1 Introdução

O problema de se aplicar uma textura plana a uma superfície é essencialmente um problema de associação entre os pontos do objeto e os atributos de um espaço de textura. Tal problema implica em uma mudança de sistemas de coordenadas.

Quando a superfície a ser texturizada é descrita parametricamente, essa correspondência é dada pela própria função de parametrização. Nesse caso, o mapeamento pode ser controlado manualmente. Em geral, não temos uma parametrização global do objeto, mas sim um conjunto de parametrizações definidas em uma partição do objeto. Portanto, o controle das coordenadas de textura é extremamente trabalhoso para o usuário. Seria desejável um mecanismo mais poderoso e interativo.

Uma superfície implícita é o conjunto de pontos que satisfazem uma equação $F(x, y, z) = c$. Neste caso, não temos um sistema global de coordenadas na superfície que possa ser associado ao sistema de coordenadas da textura. Uma solução é utilizar uma textura tridimensional [1]. A correspondência entre os pontos da superfície e a textura é geralmente a identidade e poucas formas de controle são possíveis no mapeamento. Um segundo método baseia-se em uma projeção (ortogonal, cilíndrica, esférica, etc.) a partir de uma textura bidimensional [2]. Como num projetor de *slides*, os atributos de textura são obtidos pela interseção dos raios com a superfície. Dependendo da superfície e do tipo de projeção, este mapeamento pode associar o mesmo atributo de textura a todos os pontos que interceptam um mesmo raio, o que muitas vezes é indesejável. Vamos descrever um método eficaz para aplicar uma textura bidimensional a uma superfície implícita, permitindo ao usuário um bom grau de controle do mapeamento.

2 O Método

Em nosso método, estabelecemos a correspondência entre os pontos da superfície implícita e os atributos de textura com auxílio de um sistema dinâmico gerado a partir do modelo implícito.

Os pontos da superfície são tratados como partículas que se movimentam em direção a um objeto auxiliar, utilizado como suporte para a textura bidimensional. Simulando este sistema físico, obtemos coordenadas de textura para um ponto da superfície pela interseção da trajetória da partícula correspondente com a superfície de suporte da textura.

O método é composto dos seguintes passos:

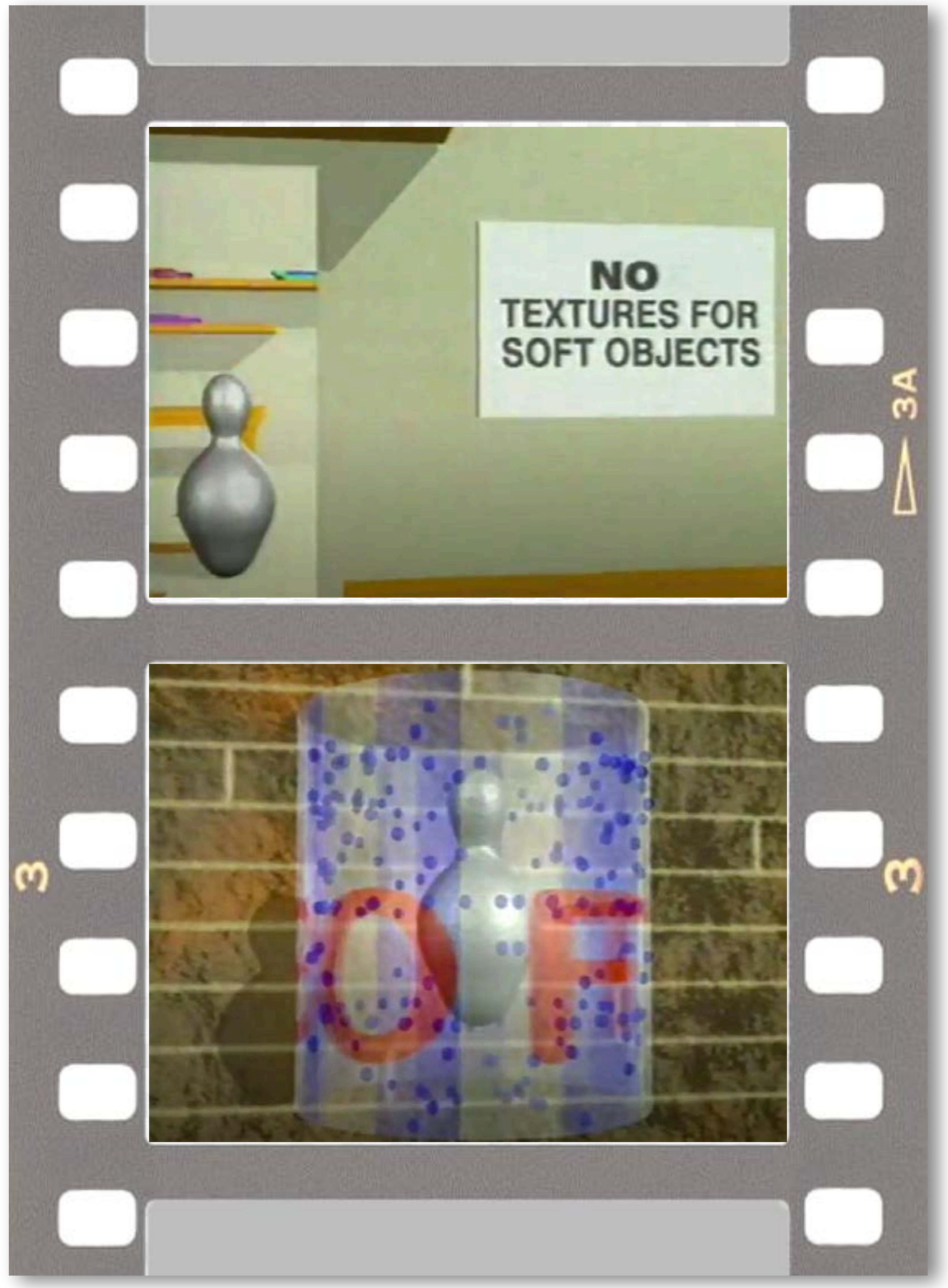
1. Um sistema dinâmico de partículas é gerado a partir do modelo implícito.
2. Pontos da superfície implícita são escolhidos como posição inicial de partículas introduzidas no sistema dinâmico.
3. O atributo de textura de cada ponto na superfície é "lido" na interseção da trajetória da partícula correspondente com a superfície de suporte da textura.

3 Modelo Implícito e Sistemas Físicos

O campo gradiente da função que define a superfície implícita, $\nabla F(x, y, z) = (\frac{\partial f}{\partial x}, \frac{\partial f}{\partial y}, \frac{\partial f}{\partial x})$, pode ser interpretado como um campo de forças que irá governar o comportamento de um sistema físico de partículas. O movimento de uma partícula é dado pela equação diferencial

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

onde γ é uma constante de "viscosidade" [3].

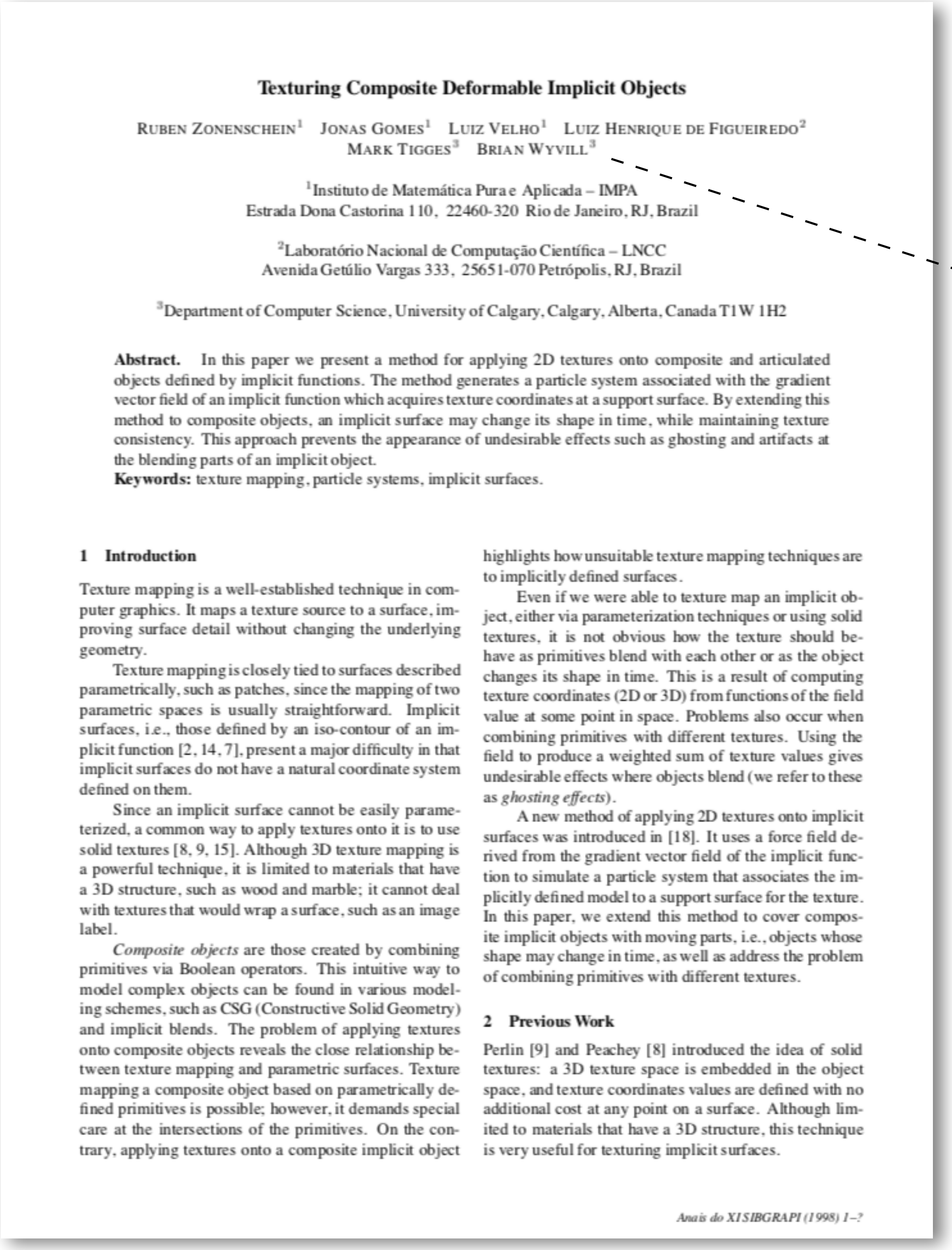


SIBGRAPI'95 - Main Track

SIGGRAPH'97 - Video Show

… and With the Man Himself (Part 2)

- Canada Connection



Texturing Composite Deformable Implicit Objects

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Abstract. In this paper we present a method for applying 2D textures onto composite and articulated objects defined by implicit functions. The method generates a particle system associated with the gradient vector field of an implicit function which acquires texture coordinates at a support surface. By extending this method to composite objects, an implicit surface may change its shape in time, while maintaining texture consistency. This approach prevents the appearance of undesirable effects such as ghosting and artifacts at the blending parts of an implicit object.
Keywords: texture mapping, particle systems, implicit surfaces.

1 Introduction

Texture mapping is a well-established technique in computer graphics. It maps a texture source to a surface, improving surface detail without changing the underlying geometry.

Texture mapping is closely tied to surfaces described parametrically, such as patches, since the mapping of two parametric spaces is usually straightforward. Implicit surfaces, i.e., those defined by an iso-contour of an implicit function [2, 14, 7], present a major difficulty in that implicit surfaces do not have a natural coordinate system defined on them.

Since an implicit surface cannot be easily parameterized, a common way to apply textures onto it is to use solid textures [8, 9, 15]. Although 3D texture mapping is a powerful technique, it is limited to materials that have a 3D structure, such as wood and marble; it cannot deal with textures that would wrap a surface, such as an image label.

Composite objects are those created by combining primitives via Boolean operators. This intuitive way to model complex objects can be found in various modeling schemes, such as CSG (Constructive Solid Geometry) and implicit blends. The problem of applying textures onto composite objects reveals the close relationship between texture mapping and parametric surfaces. Texture mapping a composite object based on parametrically defined primitives is possible; however, it demands special care at the intersections of the primitives. On the contrary, applying textures onto a composite implicit object highlights how unsuitable texture mapping techniques are to implicitly defined surfaces.

Even if we were able to texture map an implicit object, either via parameterization techniques or using solid textures, it is not obvious how the texture should behave as primitives blend with each other or as the object changes its shape in time. This is a result of computing texture coordinates (2D or 3D) from functions of the field value at some point in space. Problems also occur when combining primitives with different textures. Using the field to produce a weighted sum of texture values gives undesirable effects where objects blend (we refer to these as *ghosting effects*).

A new method of applying 2D textures onto implicit surfaces was introduced in [18]. It uses a force field derived from the gradient vector field of the implicit function to simulate a particle system that associates the implicitly defined model to a support surface for the texture. In this paper, we extend this method to cover composite implicit objects with moving parts, i.e., objects whose shape may change in time, as well as address the problem of combining primitives with different textures.

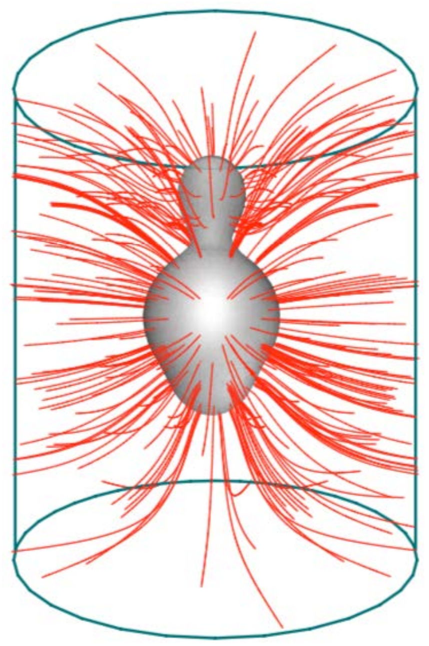
2 Previous Work

Perlin [9] and Peachey [8] introduced the idea of solid textures: a 3D texture space is embedded in the object space, and texture coordinates values are defined with no additional cost at any point on a surface. Although limited to materials that have a 3D structure, this technique is very useful for texturing implicit surfaces.

SIBGRAPI 1998

The Basic Method

- Compatible Surfaces
  - Source / Destination



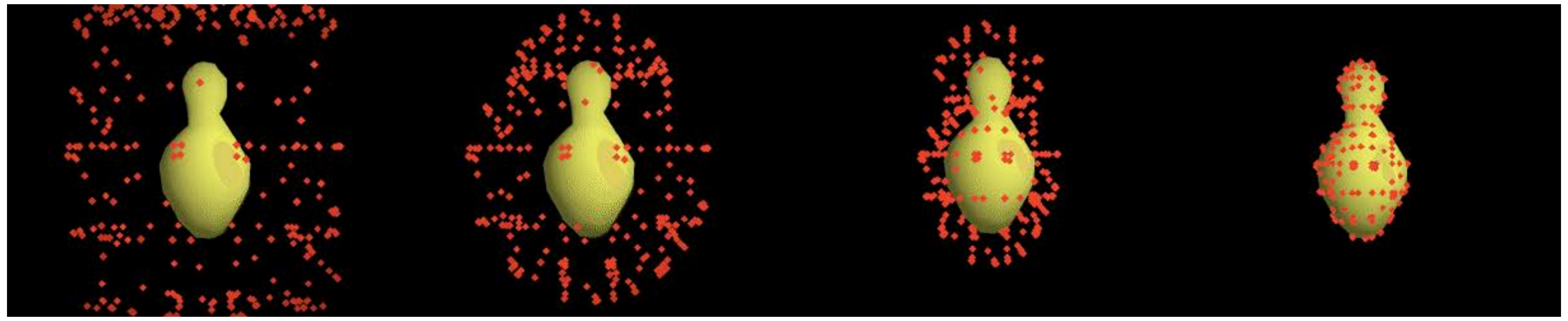
support surface

texture

implicit surface

1. Projection Step

$$\frac{d^2x}{dt^2} + \gamma\frac{dx}{dt} + \alpha(t)\nabla F - (1 - \alpha(t))\nabla G = 0.$$



particle advection by gradient flow

2. Mapping Step

- Implicit Surface Points

$\updownarrow$

- Texture Coordinates

texture coordinate transfer

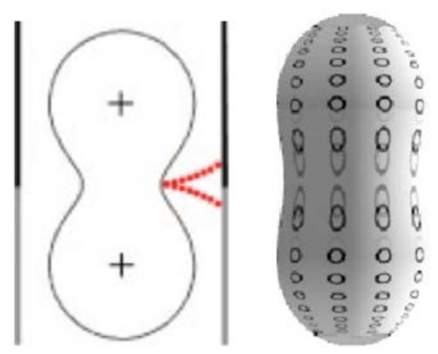
Extensions

- Blob Trees
  - Composite Implicit Objects

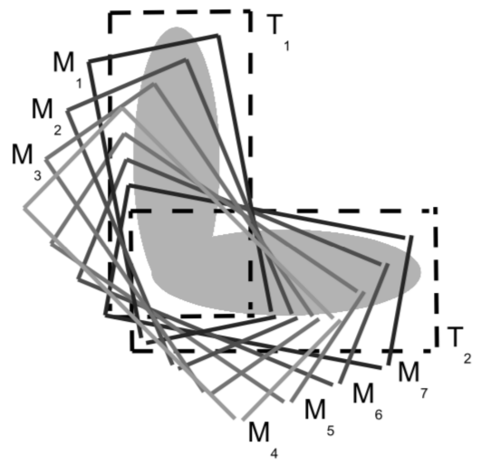
$$F_c = C(F_1, F_2, \ldots, F_n).$$

1. Color Blending

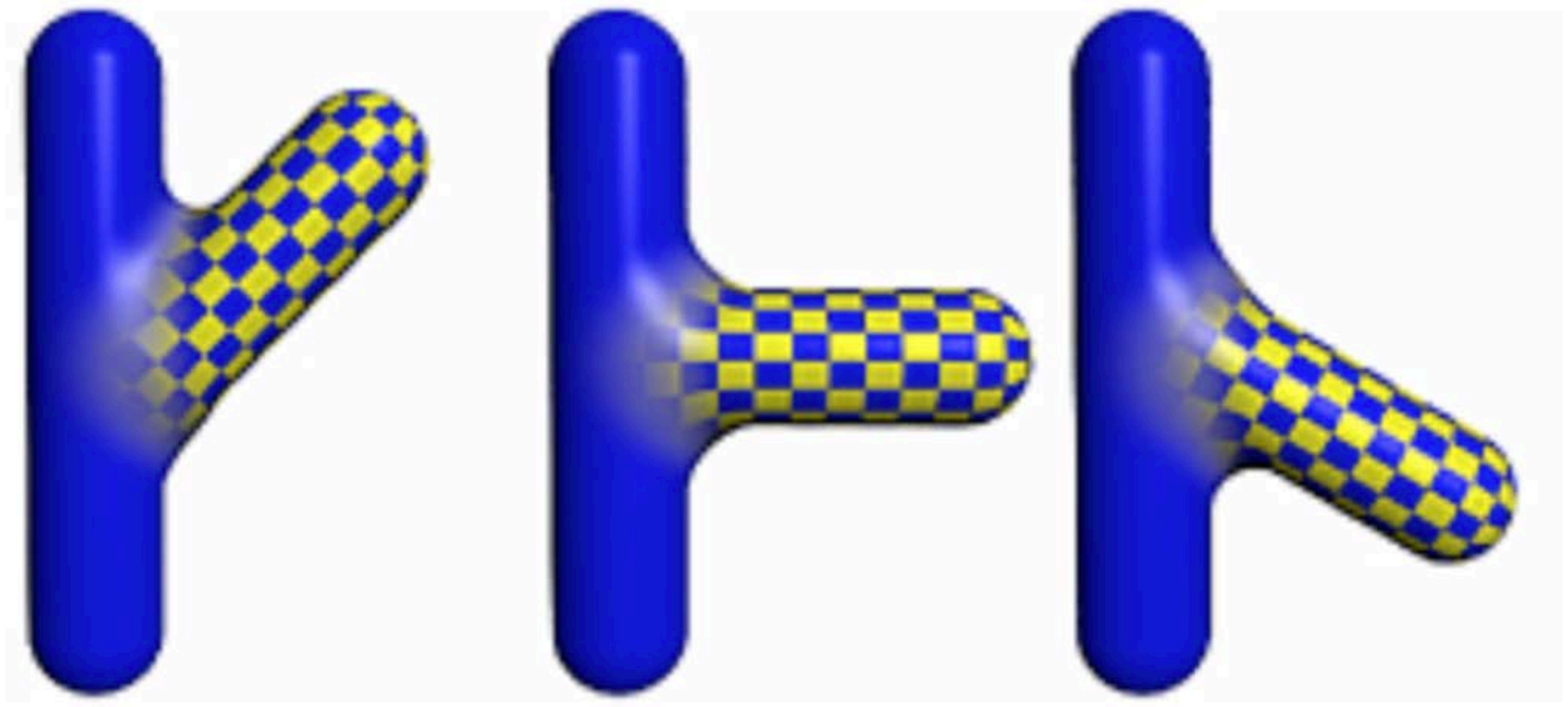
$$F_c\colon\ c_p = \alpha_1 * c_1 + \alpha_2 * c_2 + \ldots + \alpha_n * c_n.$$



2. Transformation Blending



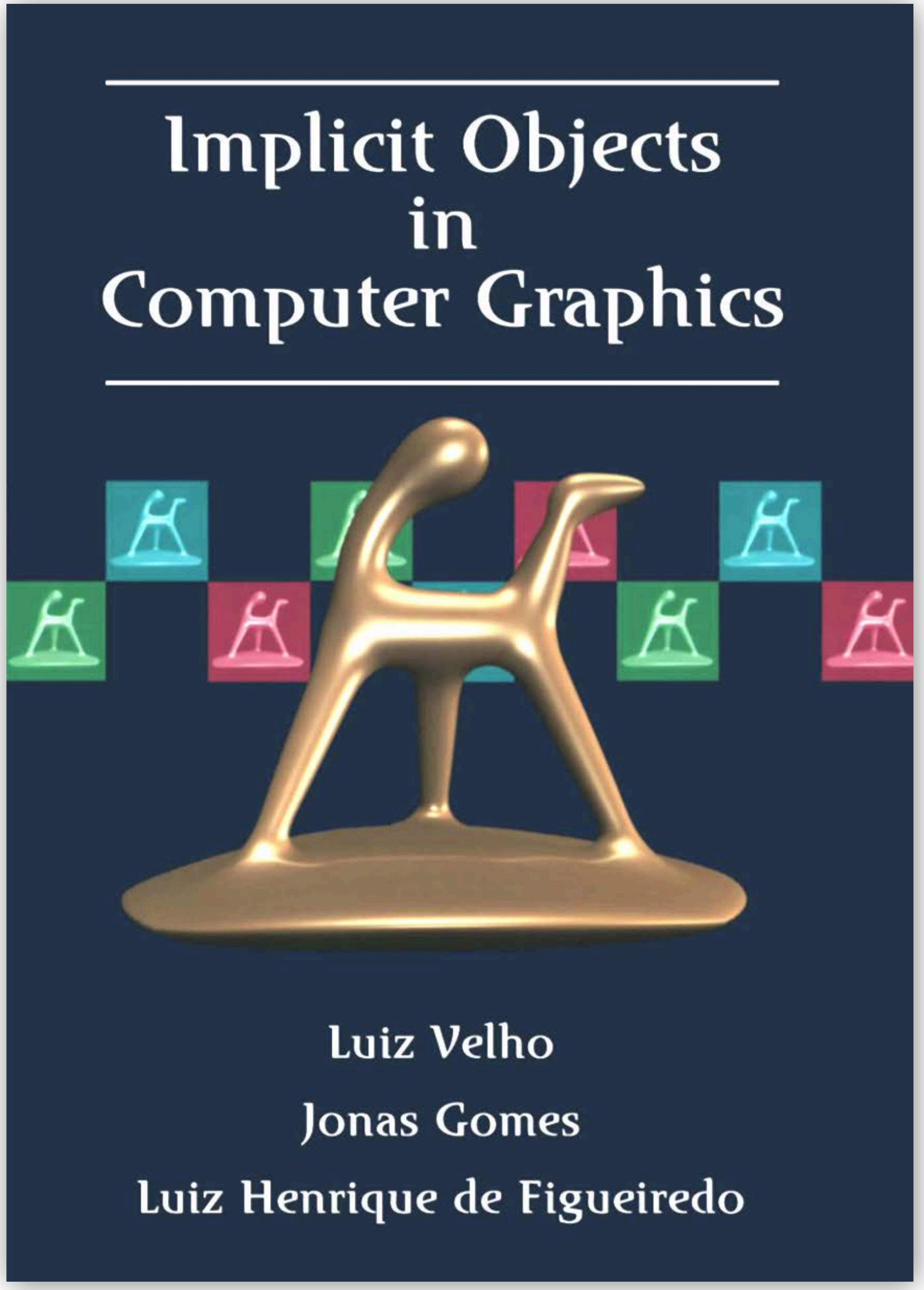
Metaballs



Articulated Objects

We Wrote the Book

- Main Research Topic

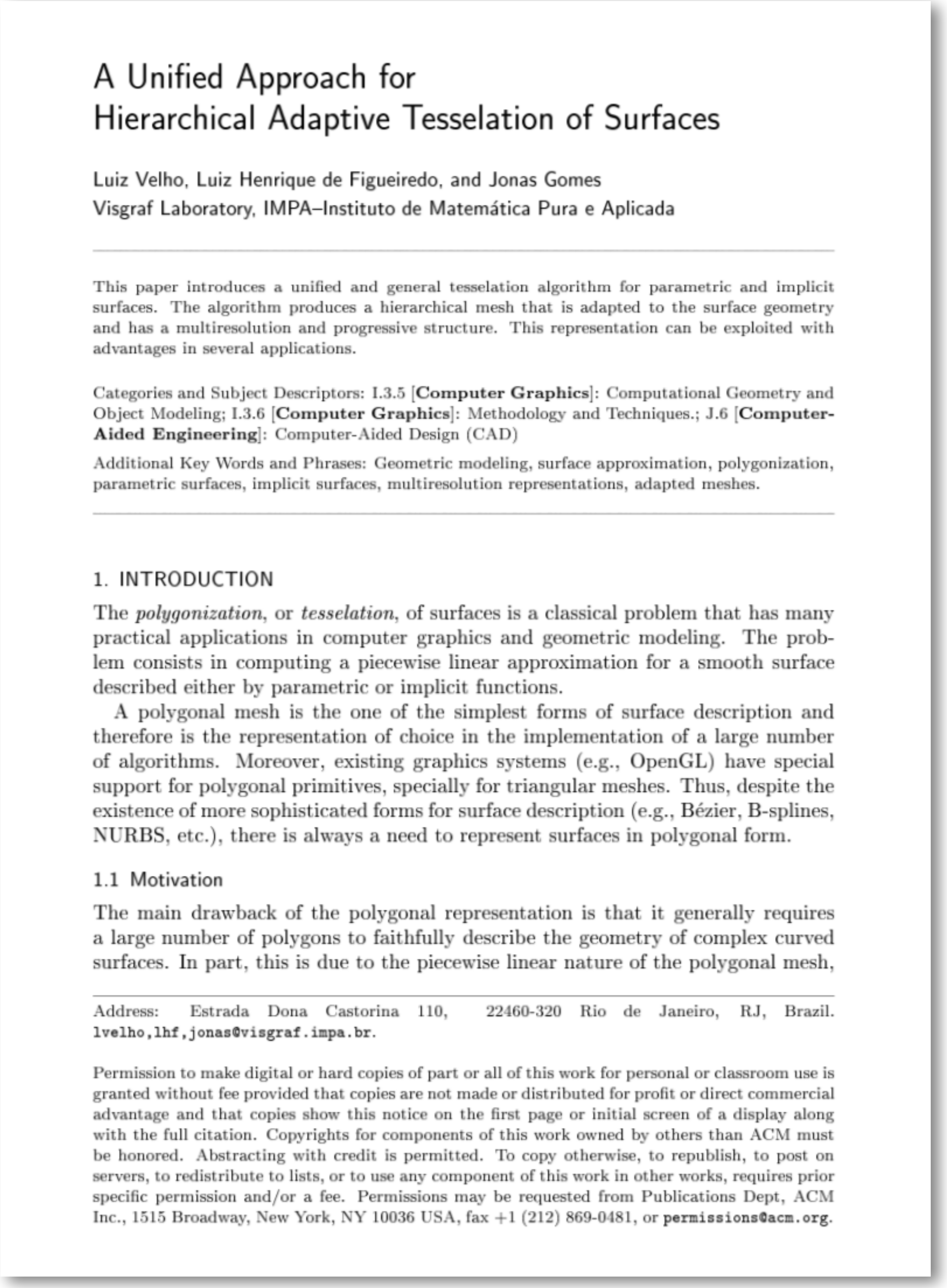


Visgraf Vision and Graphics Laboratory

Springer

TOG!

- ACM Transactions on Graphics, 1999



A Unified Approach for Hierarchical Adaptive Tesselation of Surfaces

Luiz Velho, Luiz Henrique de Figueiredo, and Jonas Gomes
Visgraf Laboratory, IMPA–Instituto de Matemática Pura e Aplicada

This paper introduces a unified and general tesselation algorithm for parametric and implicit surfaces. The algorithm produces a hierarchical mesh that is adapted to the surface geometry and has a multiresolution and progressive structure. This representation can be exploited with advantages in several applications.

Categories and Subject Descriptors: I.3.5 [**Computer Graphics**]: Computational Geometry and Object Modeling; I.3.6 [**Computer Graphics**]: Methodology and Techniques.; J.6 [**Computer-Aided Engineering**]: Computer-Aided Design (CAD)

Additional Key Words and Phrases: Geometric modeling, surface approximation, polygonization, parametric surfaces, implicit surfaces, multiresolution representations, adapted meshes.

1. INTRODUCTION

The *polygonization*, or *tesselation*, of surfaces is a classical problem that has many practical applications in computer graphics and geometric modeling. The problem consists in computing a piecewise linear approximation for a smooth surface described either by parametric or implicit functions.

A polygonal mesh is the one of the simplest forms of surface description and therefore is the representation of choice in the implementation of a large number of algorithms. Moreover, existing graphics systems (e.g., OpenGL) have special support for polygonal primitives, specially for triangular meshes. Thus, despite the existence of more sophisticated forms for surface description (e.g., Bézier, B-splines, NURBS, etc.), there is always a need to represent surfaces in polygonal form.

1.1 Motivation

The main drawback of the polygonal representation is that it generally requires a large number of polygons to faithfully describe the geometry of complex curved surfaces. In part, this is due to the piecewise linear nature of the polygonal mesh,

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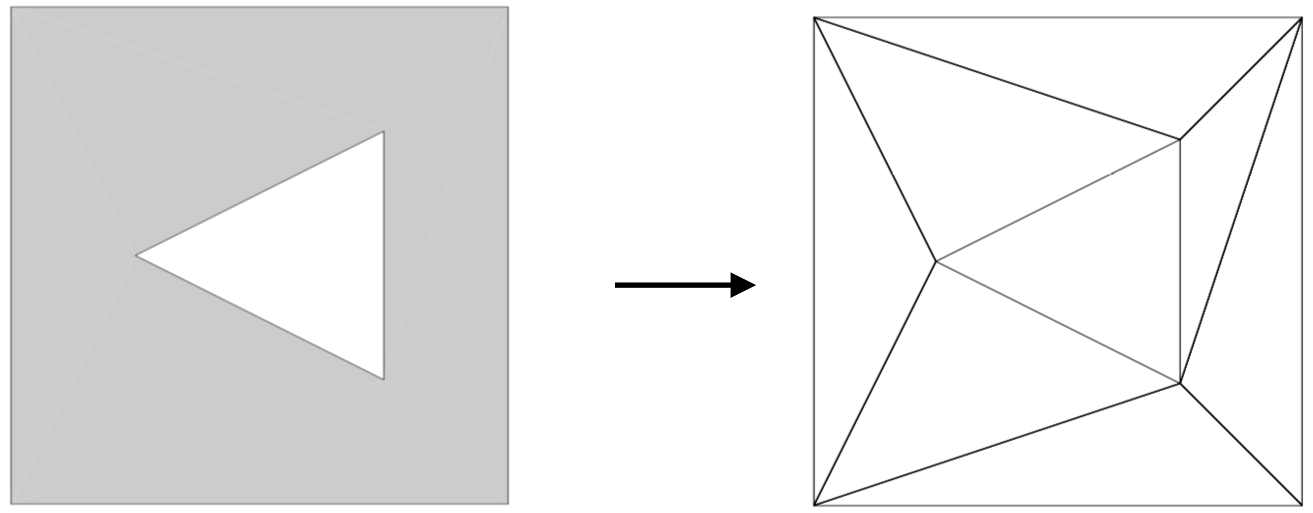
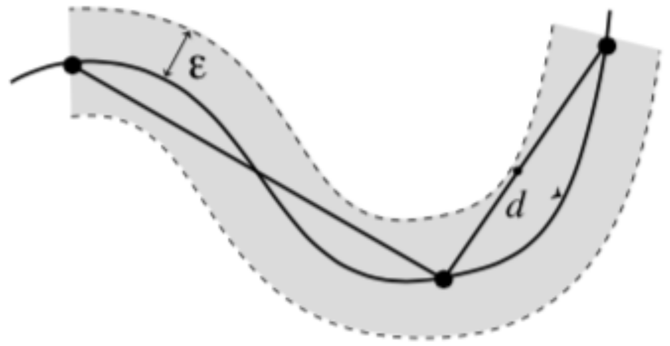
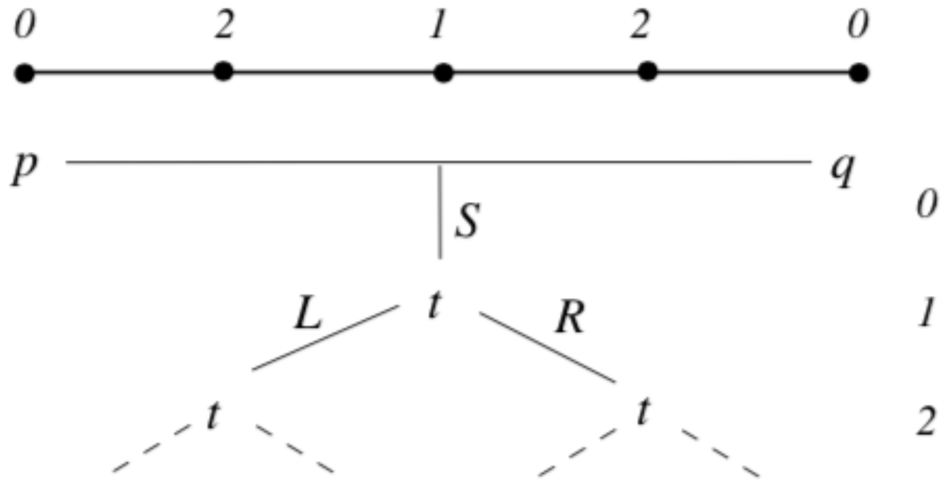
The Method

- Base Mesh Generation
  - Input: *Surface Description*
  - Output: *Triangular Mesh*

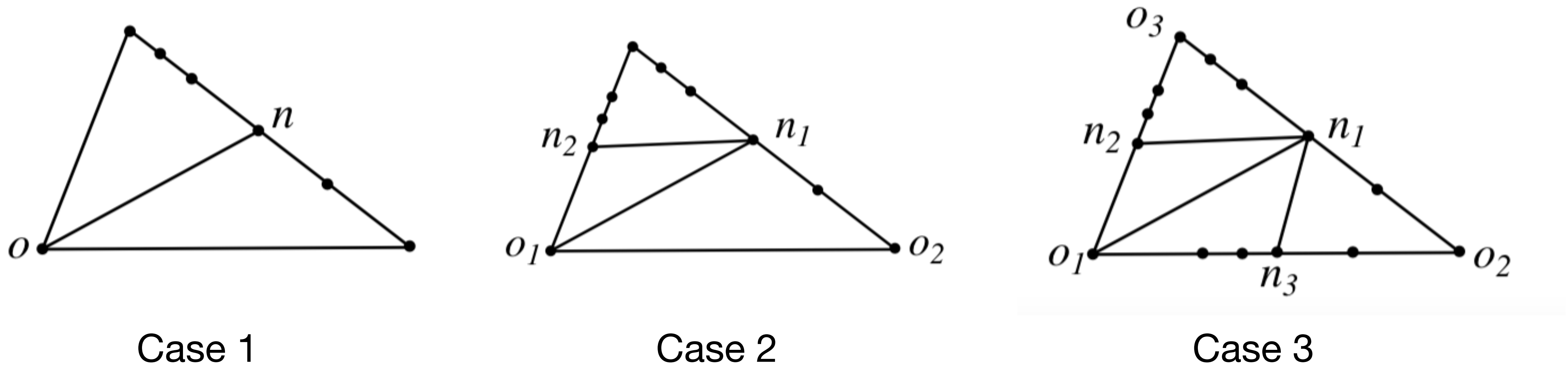


- Edge Sampling
  - Input: *Edge Endpoints*
  - Output: *Multiresolution Curve*





- Cell Structuring
  - Input: *Triangular Cell*
  - Output: *List of Sub-Cells*



Algorithm

1 [Initialization]

Start with a coarse decomposition of the surface:

1.1 Generate the base mesh;

1.2 Sample the edges of all cells in the base mesh.

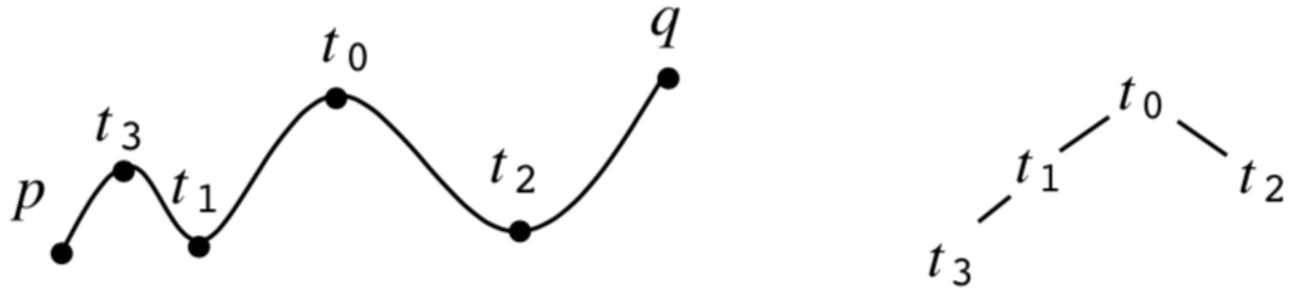
2 [Refinement]

For each cell, test the corresponding surface patch for flatness.

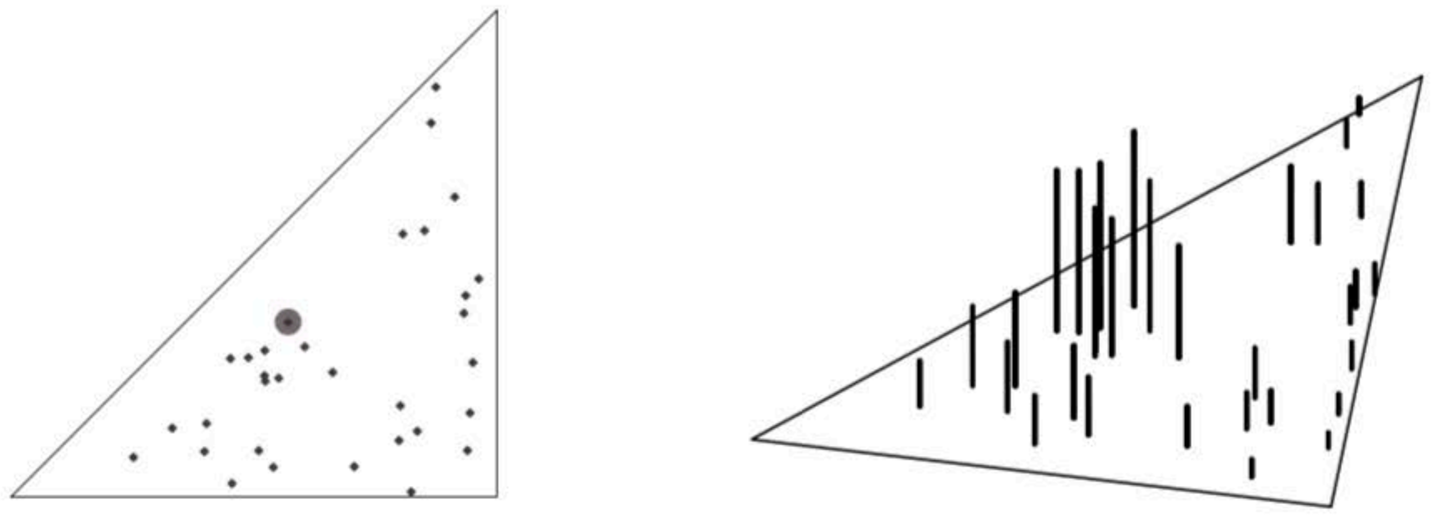
If the patch is not flat, then recursively subdivide the cell:

2.1 Structure new cells by constructing internal edges;

2.2 Sample all internal edges.



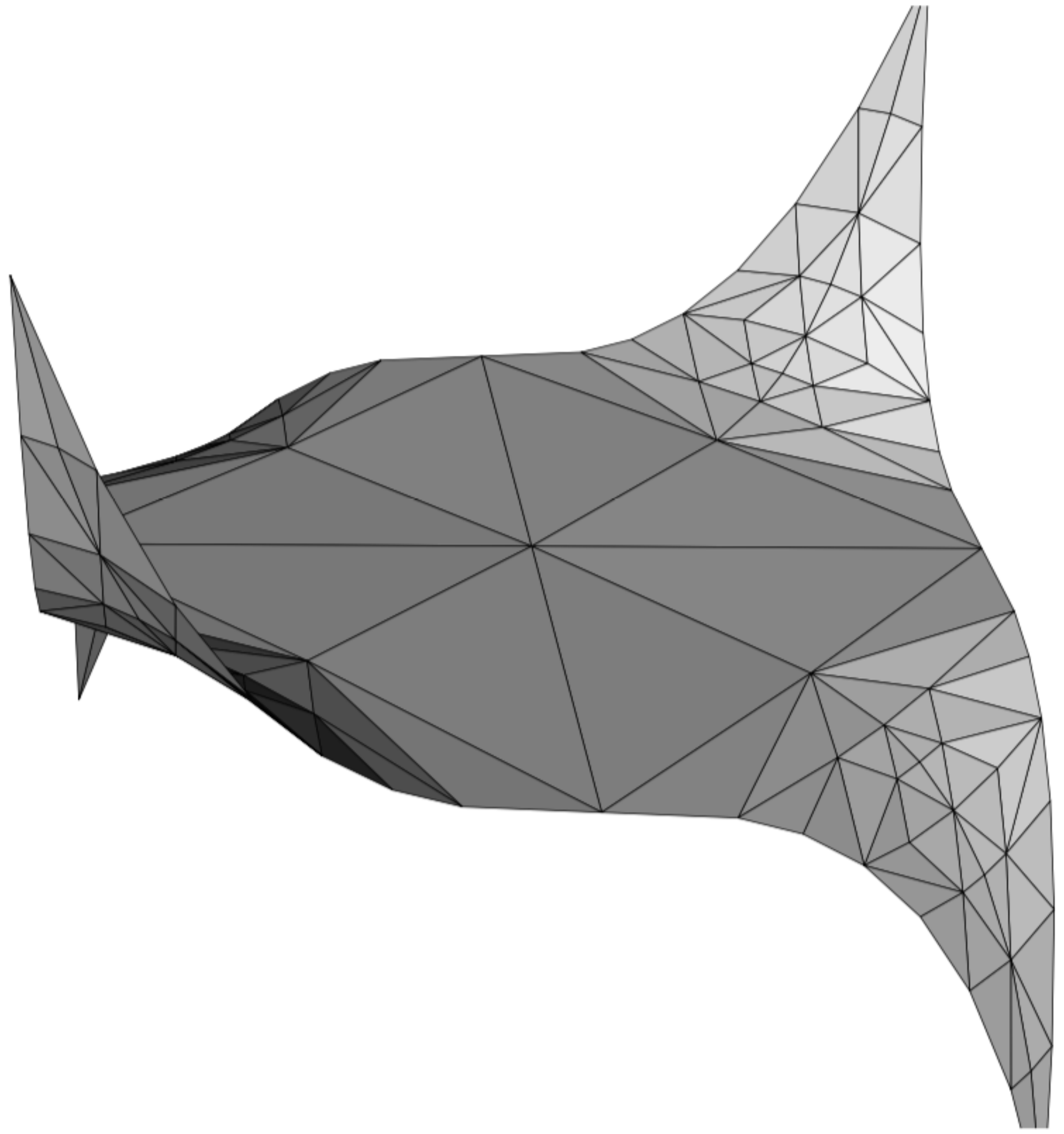
edge sampling



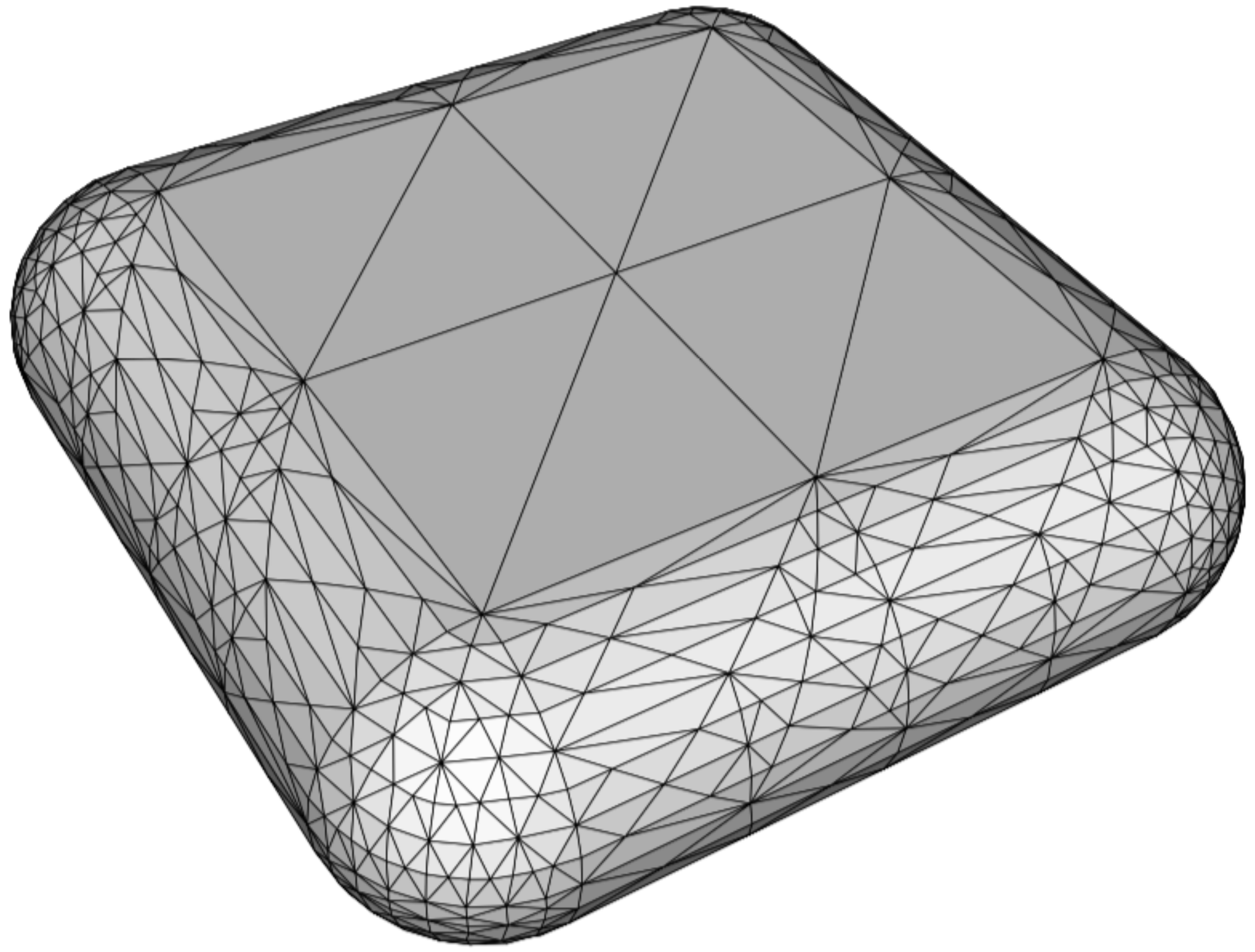
flatness test

Agnostic to Representation

- Parametric and Implicit Surfaces



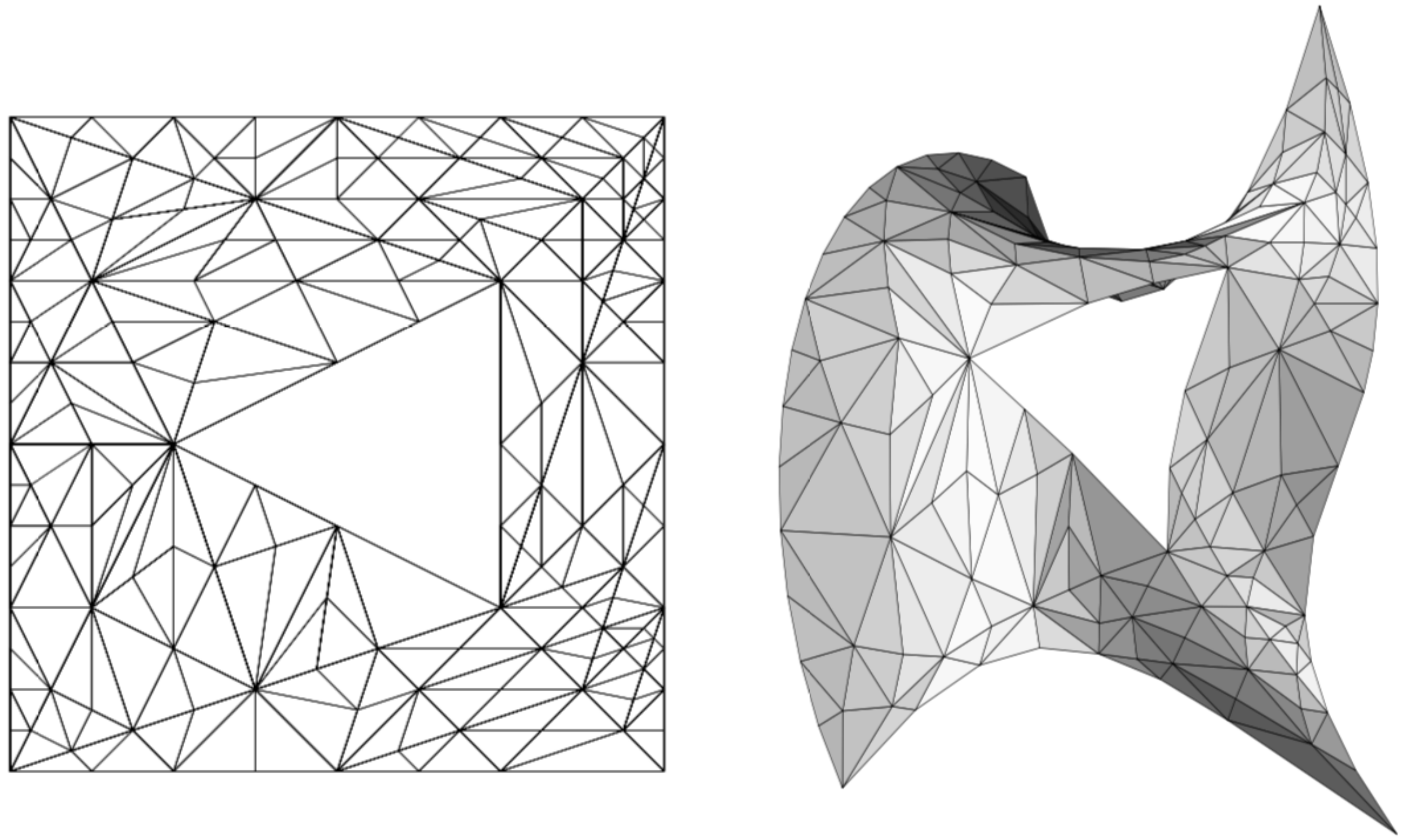
saddle patch



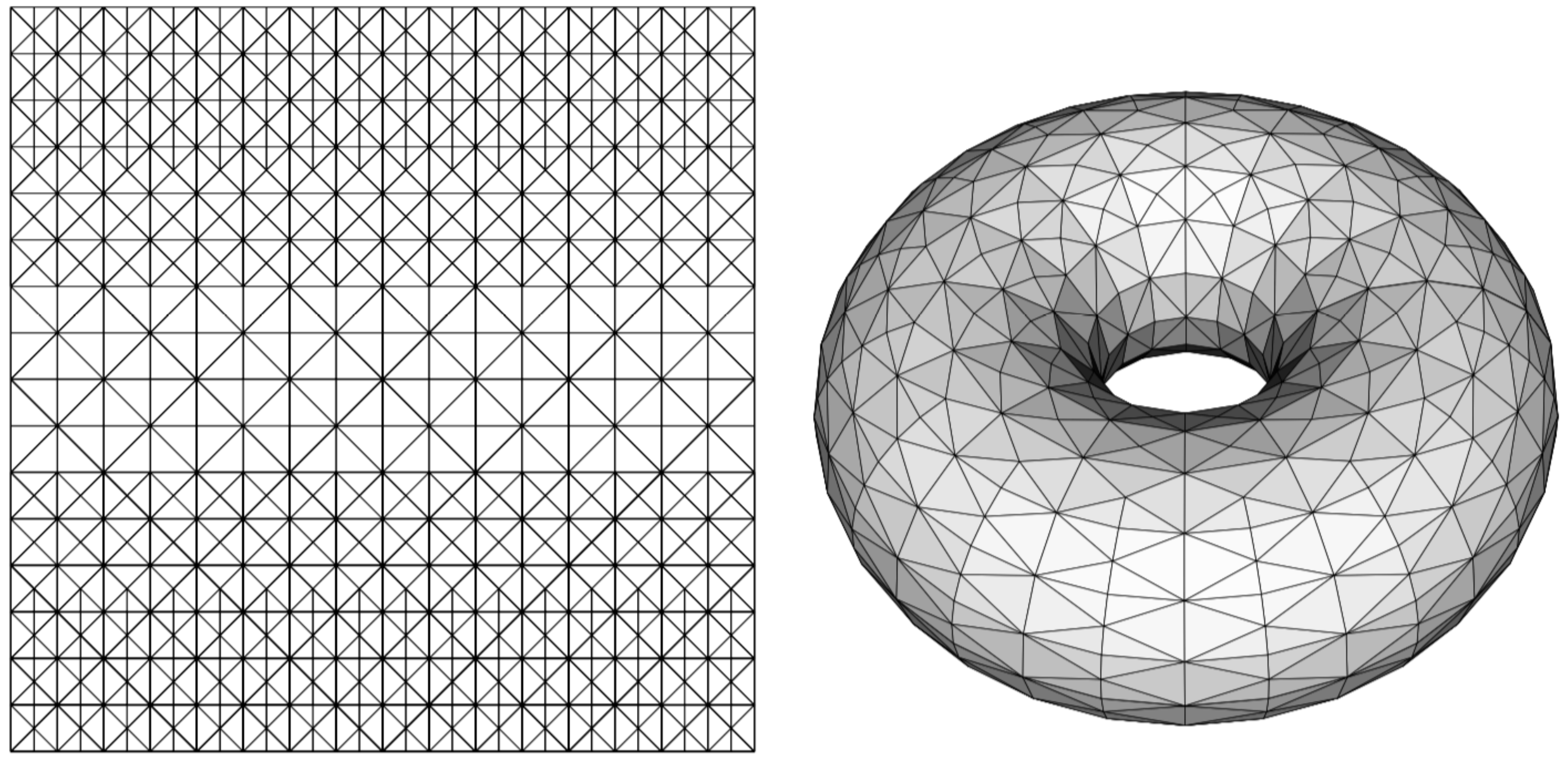
offset surface

Adaptation

- Boundary, Curvature, etc…



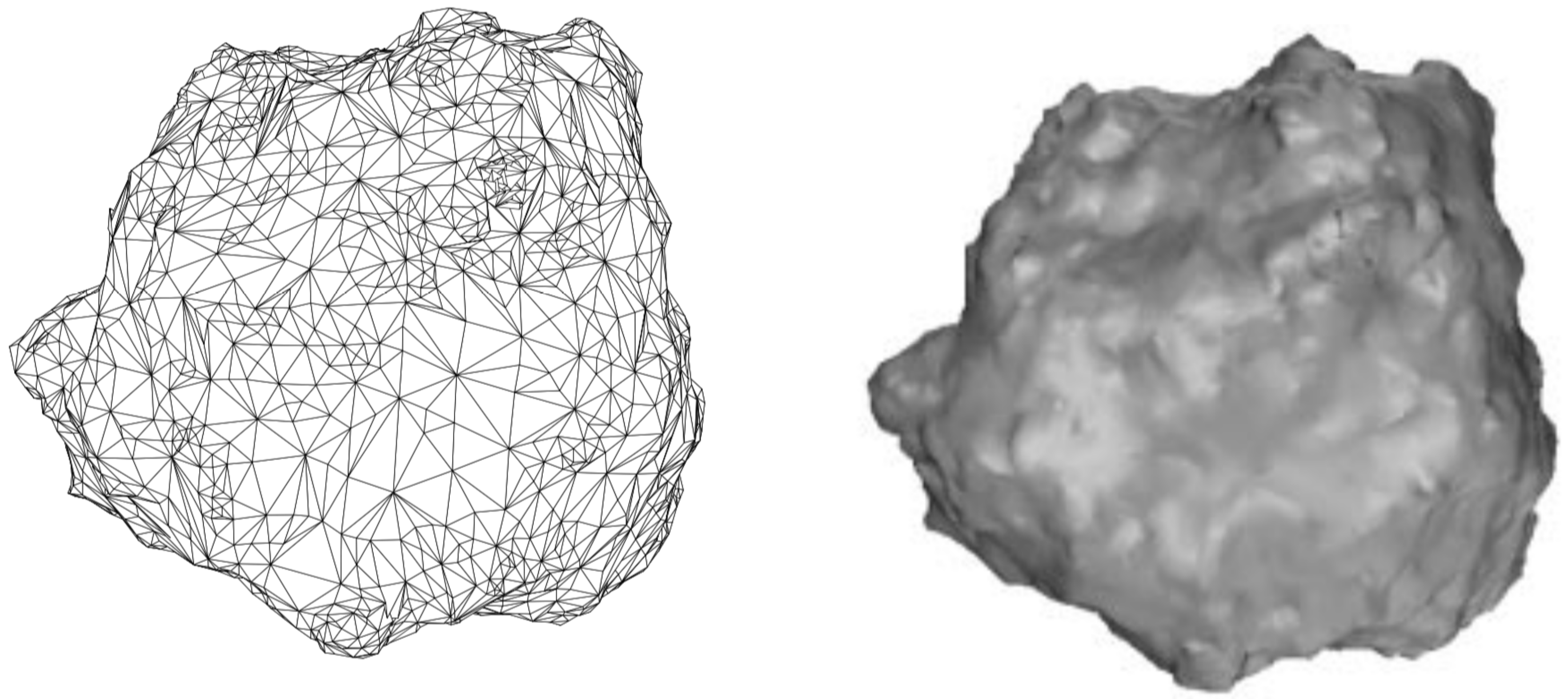
trimmed Bezier patch



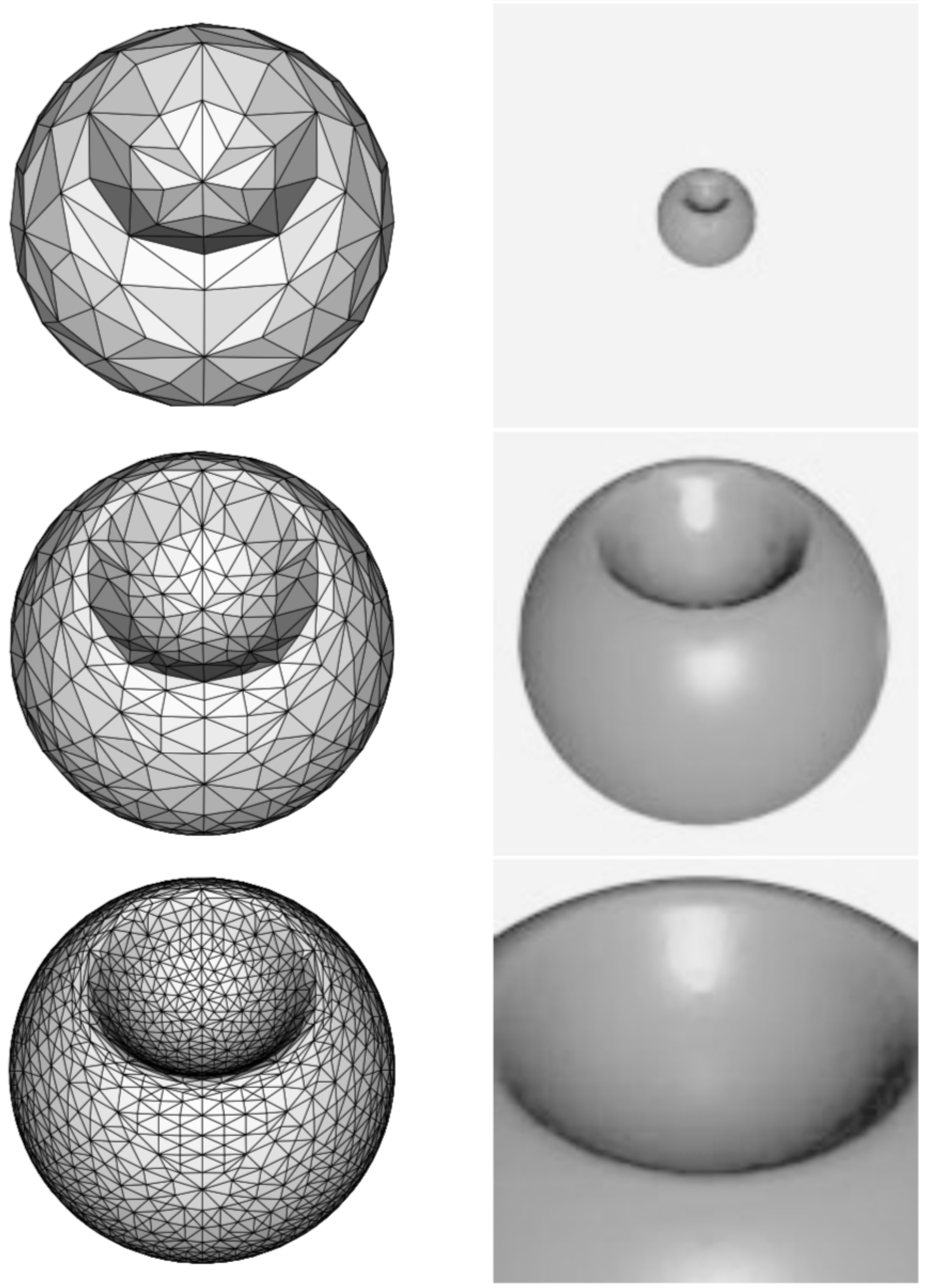
parametric torus

Multi-Resolution

- Level-of-Detail and Visualization



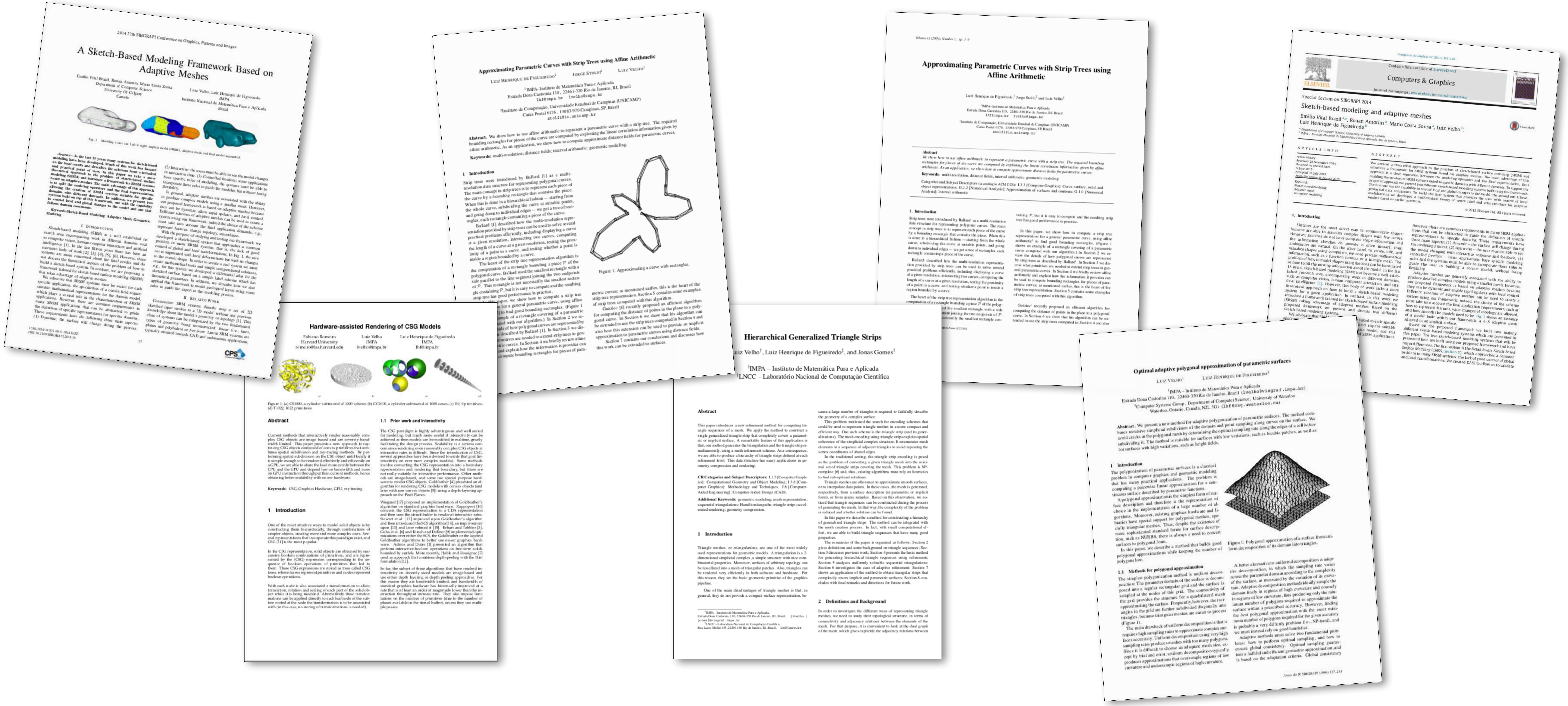
polygonal approximation of fractal rock



multi-resolution sequence / camera zoom

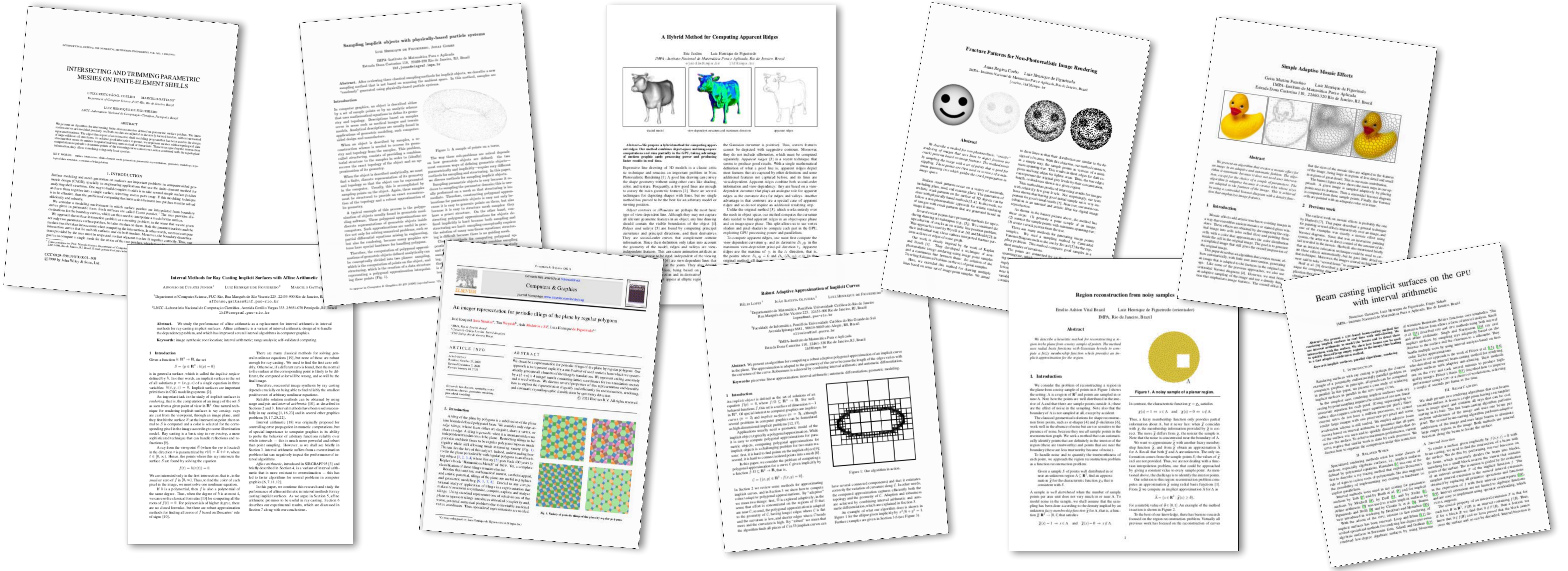
Other Works

- With Me…



… and Many More

- With Students and Collaborators



Stay Tuned for the Next Episodes..

- 14:30 - 15:00
  Ladrilhamentos com triângulos e quadrados: origami e métodos de inflação
  José Ezequiel Soto Sánchez (ITAM)
- 15:00 - 15:30
  Coffee Break
- 15:30 - 16:00
  Lua: a história de uma "little language"
  Roberto Ierusalimschy (PUC-Rio)
- 16:00 - 16:30
  TBA
  Special Guest
- 16:30 - 17:30
  Mesa Redonda Visgraf
- 17:30 - 17:40
  Closing

“There is one more thing.”

– Steve Jobs

Thank You!

- The Organizers

Afonso Paiva
ICMC-USP

Emilio Vital Brazil
IBM Research

Waldemar Celes
PUC-Rio

LHF60: Celebrating the 60th Birthday of Luiz Henrique de Figueiredo

SIBGRAPI 2022, Natal, October 24th, 2022

This event commemorates the 60th anniversary of **Luiz Henrique de Figueiredo (IMPA)** and includes guest lectures according to the schedule below.

LHF60++: Celebrating *again* the 60th Birthday of Luiz Henrique de Figueiredo

IMPA, Rio de Janeiro, January 25th, 2023

This event commemorates the 61st anniversary of Luiz Henrique de Figueiredo (IMPA) and includes guest lectures according to the schedule below. This meeting is a continuation of the event held on SIBGRAPI 2022.