

Procedural and Multiscale Models in Computer Graphics: *a Personal Perspective*

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- ## Contents
- Overview of Research Career
Past 25 years (1978 – 2002)
 - ESDI, PUC
 - MIT Media Lab, University of Toronto
 - NFB, FAM, TV Globo, HP, NYU, IMPA
 - Personal Account of SIBGRAPI
 - Participated from the very beginning!
 - Significant part of the work presented there

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Foreword

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(b.s.) Before SIBGRAPI

São Paulo, Nov 1978

- 1° SIACG
 - Organized by Industry
 - ACM / SIGGRAPH Local Group
- Bourne and Died!
 - Too early
 - Lack of Critical Mass



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SIBGRAPI (10 years later)

Petrópolis, April 1988

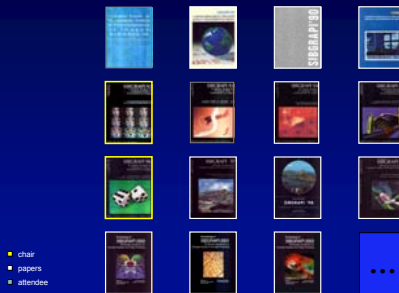
- SIBGRAPI
 - Organized by Academy
 - SBC Special Interest Group
- Here to stay...
 - Right Time / Right Place
 - Demand of CG+IP Community

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My SIBGRAPI 4x4 Matrix



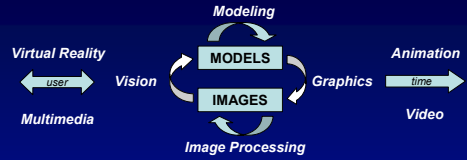
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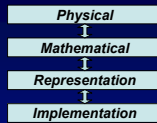
Methodology

Integrated View



- Different Aspects of an Encompassing Field
 - (Model / Image) Synthesis / Analysis
 - (Model / Image) Creation / Manipulation
- *Consonant with SIBGRAPI !*

Conceptual Approach



- Computational Applied Mathematics
 - Four Universes Paradigm, (*Visual Computer*, 1995)
 - Graphical Objects, (*Visual Computer*, 1996)
- * *Joint Work with Jonas Gomes*
 - VISGRAF Laboratory

Research Perspective

- Procedural Methods
 - Computer Graphics*
 - Expression Power
 - Effective Control
- Multiscale Models
 - Computer Graphics*
 - Visual Perception
 - Efficient Approximation

Broad Interest

- Many Areas
 - Animation and Video
 - Visualization and Rendering
 - Image Processing and Vision
 - Geometric Modeling
 - Interaction Techniques
- Intersection of Areas
 - IBR, 3D Photography
- Applications
 - Entertainment, Medical

Animation

Wireframe Animation

- My First Steps (1976-1979)
Newman and Sproull, 1973
"Principles of Interactive Computer Graphics"
 - Plotter
 - IBM 1130
 - Fortran
- Undergraduate Final Project - ESDI, 1979
First Computer Generated Film "made in Brazil"
 - Simple Graphics Package
 - Plotted Frame-by-Frame
 - Filmed on Animation Stand

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"A Imagem no Computador"



* SIBGRAPI Video Show, 1992 (produced in 1979)

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Motion Control

Montreal, 1981-1982

- National Film Board
 - Visiting Filmmaker (Brazil / Canada cooperation)
 - French Animation Group (*La Faim*)
- Computer Controlled Animation
 - Oxberry 35 mm Animation Stand
 - Motion Control Computer

➤ *Graphics Experiments*

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"Graphisms"



• N.F.B., 1982

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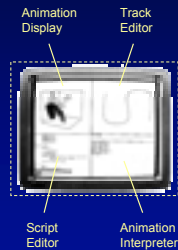
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Procedural Animation System

MS. MIT Media Lab, 1983-1985
(advisor: David Zelter)

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



* paper - SIBGRAPI, 1989

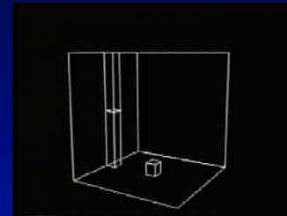
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"Scripts"

- inverse kinematics, forward dynamics, collision detection



• MIT Media Lab, 1984

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Motion Capture

MS. UFRJ, 1998
(supervisor of Fernando Wagner)

- MOCAP Animation System
 - Intuitive Interface
 - Signal Processing Approach
- Thesis Award
 - XII CTD - SBC, 1999
 - VI CLEI - UNESCO, 1999

* paper SIBGRAPI, 1997

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"Animação por Movimento Capturado"



* SIBGRAPI Video Show, 1997

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Facial Animation

MS. PUC-Rio, 2002
(supervisor of Paula Lucena)

✓ Collaboration with Ken Perlin

- Real -Time Facial Animation
 - Lip Synch + Facial Expressions
 - Annotated Text Input
 - Client / Server JAVA Implementation
- Potential Applications
 - Internet, Entertainment
 - Education, Tele-Collaboration

* paper WTDCGPI, 2002

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"Expressive Talking Heads"



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"Expressive Talking Heads"



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Visualization

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The Ultimate Renderer

Fantastic Animation Machine, 1985

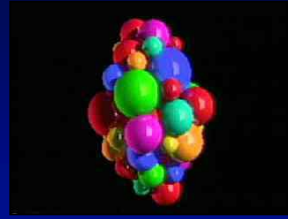
- Designed the “in-house” 3D System
 - Modeler
 - **Renderer** (*its all about the looks...*)
 - Animation
- Multi-modal Visualization
 - Wire / Hidden Line
 - A-Buffer, *Phong* Shading
 - Distributed Ray Tracing
 - Texturing, Special Effects

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“F.A.M. Demo”



★ *ACM-SIGGRAPH Electronic Theater, 1986*

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2D Texturing Implicit Objects

IMPA, 1995

(joint work with R. Zonenschein, L.H. Figueiredo, B. Wyvill)

- Texture Mapping Implicit Surfaces
 - 3D textures: *Trivial*, (Embedding Space)
 - 2D textures: *Hard*, (Lack of Natural Parameterization)
- Extrinsic Projection Method
 - Transfer Texture from a Canonical Space
 - “Natural” Projection, i.e. Blended Gradient Field
 - Physically-Inspired: ODE, Particle System

★ Tech Sketch ACM-SIGGRAPH, 1997 - paper SIBGRAPI, 1998

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“Textura com Sistema de Partículas”



★ *SIBGRAPI Video Show, 1997*

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Direct Volume Rendering

D.Sc. IMPA, 2003

(supervisor of Vinicius Mello)

✓ Collaboration with Claudio Silva

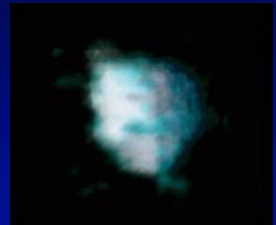
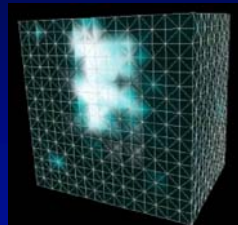
- Hierarchical Space Decomposition (*Binary Multi-Triangulations*)
 - Stellar Operations
 - Conforming 3D Meshes
- Interactive Progressive Visualization
 - Cell Visibility Ordering
 - Simplicial Splatting
 - View Dependent / Independent Adaptation

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Adapted BMT's



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Imaging

Digital Halftoning

IMPA, 1991

- Dithering with Space Filling Curves
 - Aperiodic Patterns (*photography look*)
 - Variable-Size Dots (*device dependent*)
 - Anisotropic Clusters (*image adaptive*)

➤ Key Research Contribution

- Filled Technology Gap
- Reopened the Area

* papers ACM-SIGGRAPH, 1991 / 1995 - paper SIBGRAPI, 1992

Dithering with Space Filling Curves



Dithering with Space Filling Curves



Wavelet Paint

IMPA, 1993-1995
(joint work with Ken Perlin)

- Painting over Multiple Levels

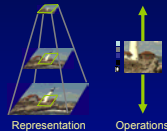
Modify image at level X
Move up / down a level

- Features

- Multiresolution Compositing
- Procedural Brushes

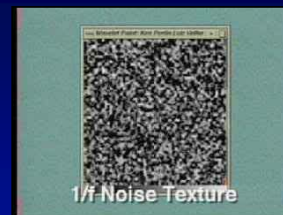
- Advantages

- Quick Changes
- Unlimited and Automatic Detail



* Tech Sketch ACM-SIGGRAPH, 1994 - paper ACM-SIGGRAPH, 1995

"Procedural Multiscale Textures"



* SIBGRAPI Video Show, 1994

Image Effects with Contractive Mappings

IMPA, 1996
(joint work Cícero Mota, Romildo Silva)

❖ Fractal Image Compression

- Model
 - Iterated Function System, $F_k : I \rightarrow I$
 - Fractal Interpolation
- Image
 - Fixed Point of a Contractive Mapping
 - Image Generation, $i_0 \xrightarrow{F} i_1 \rightarrow \dots \rightarrow i_\infty$
- Visual Effects
 - Control Parameters, (i_0, n, \dots)



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"Diamond House"



* Title Image - SIBGRAPI Proceedings, 1996

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"Tropical Birds"



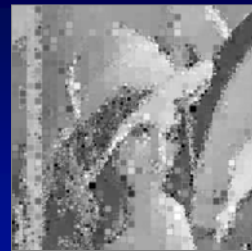
* Back Cover - SIBGRAPI Proceedings, 1996

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"Lena"



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Image Quantization

MS. PUC-Rio, 1997
(Marcos Rayol, supervised by Jonas Gomes)

- Strategy
 - Minimization of the Quantization Error
 - Iterative Pairwise Clustering
- Algorithm and Data Structure
 - Bottom-Up Divide and Conquer
 - Binary Tree

❖ Multiresolution Quantization

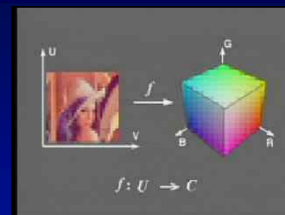
* paper SIBGRAPI, 1997

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"Quantização por Aglomeração Binária"



* SIBGRAPI Video Show, 1997 - (Best Technical Video)

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Virtual Memory for 2D Objects

MS. PUC-Rio, 1998 - D.Sc. PUC-Rio, 2002
(supervisor of André Matos and Sergio Pinheiro)

- **Trend:** Large Datasets + Real-Time
 - More Complexity and Detail
 - Faster Graphics Hardware and Networking
- Need for Scalability
- Generic Solution → *Structured 2D Graphics Objects*
- System Characteristics
 - Predictive Cache (*Spatial Coherence*)
 - Multiresolution Structure (*Time-Critical Visualization*)

* Related Paper SIBGRABI, 1998

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"Multiresolution Panoramas"



* SIBGRABI Video Show, 1998

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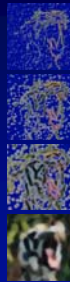
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Multiscale Painterly Rendering

IMPA / PUC-Rio, 2001
(joint work with Diego Nehab)

- ❖ Started as a Course Project on NPR
(*Image Moment Stroke Placement*)
 - Extensions
 - More Efficiency and Control
 - Techniques:
 - Multiscale Analysis
 - Parameterized Dithering
 - "Lua" Implementation
 - Optimized Image Abstraction
- * Paper SIBGRABI, 2002



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"Parrot"



* Cover Image - SIBGRABI Proceedings, 2002

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"Canoe"



* Back Cover - SIBGRABI Proceedings, 2002

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"Train"



* Back Cover - SIBGRABI Proceedings, 2002

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"Old Man"



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Interactive Techniques

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Warping and Morphing

IMPA, 1998

(joint work with Jonas Gomes, Lucia Darsa, Bruno Silva)

❖ "Morphos": A Test Bed System

- Graphical Objects
 - Curves, Images, Surfaces, Volumes
- Computational Methods (*Representation*)
 - Forward / Inverse Mapping, Single / Multi Pass
- Interaction Techniques (*Specification*)
 - Parametric, Features, Partition-Based

➤ Book / CD, published by Morgan-Kaufmann
"Warping and Morphing of Graphical Objects"

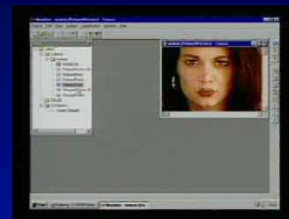
* Paper SIBGRAPI, 1998

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"Morphos"



- IMPA, 1998

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Interaction using the Arcball

IMPA, 1998

(joint work with Jonas Gomes, Sergio Estevão)

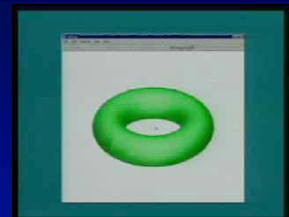
- Quaternion-Based Specification of Rotations
 - "Arcball": Natural One-Window Interface, (Shoemake, 1992)
- Extending Arcball
 - Interactive Specification of 3D Vectors
- Many Important Applications
 - Warping and Morphing (*Displacement Vectors, Features*)
 - Geometric Modeling (*Normal Vectors*)
- Implementation
 - OpenGL
 - FLTK

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"3D Widget for Rotations and Displacements"

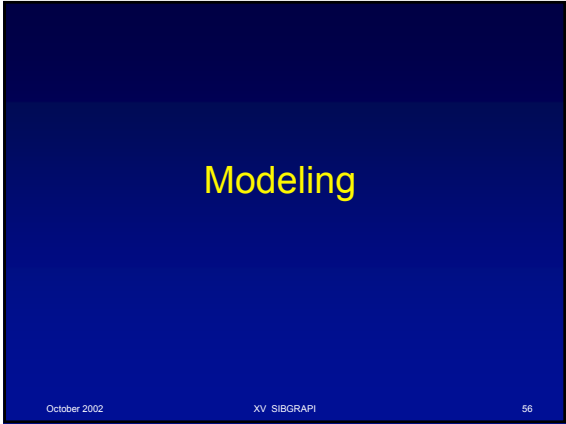


- IMPA, 1999

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Modeling

Piecewise Implicit Objects

*PhD. University of Toronto, 1994
(advisor: Demetri Terzopoulos)*

Complete Modeling Framework (*Decomposition + Adaptation*)

- Smooth Implicit Model
 - Multiscale Edge Analysis / Synthesis
- Hierarchical Implicit Representation
 - Multiscale B-Spline Basis
- Adapted Simplicial Decomposition
 - Physics-Based Simulation

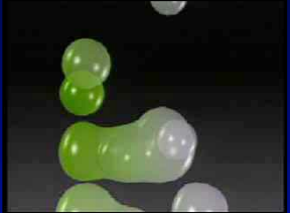
Conversion of Representations

```

  graph LR
    Implicit --> Parametric
    Parametric --> Volumetric
    Parametric --> Implicit
  
```

* Paper SIBGRAPI, 1998

"Bobby Bubbles"



* SIBGRAPI Video Show, 1997

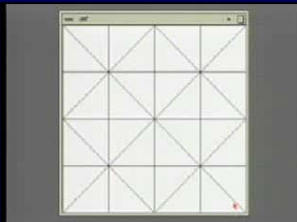
Variable Resolution Structures

*IMPA, 1998-2000
joint work with Luiz Henrique Figueiredo*

- Binary Multi-Triangulations (*BMT*)
 - Based on Stellar Operators
 - Best Properties (Expression Power)
- Construction Methods
 - Refinement
 - Simplification
- Operations
 - Adaptive Query and Extraction

* Paper SIBGRAPI, 2000

"Hierarchical 4-K Meshes"



- SIBGRAPI Video Show, 2000

4-8 Subdivision Surfaces

NYU, 2000-2001
joint work with Denis Zorin

- Extends Four Direction Box Splines to Arbitrary Meshes
- Bisection Interleaved Refinement
 - Adaptive Tilings
 - Factor Subdivision Rules
- Dual and Primal Schemes for Quads
 - Simplest, Doo-Sabin, Catmull-Clark
- C4 Smooth Four-Direction Subdivision Surface

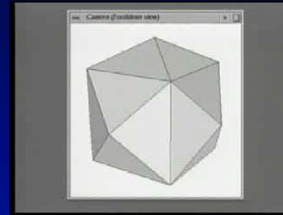
* Paper SIGGRAPH, 2000

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"Semi-Regular 4-8 Meshes"



- SIGGRAPH Video Show, 2000

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Procedural Shape Synthesis

NYU, 2001 -
joint work with Ken Perlin, Henning Biermann

- Procedural Subdivision Surfaces
 - Base Shape
 - Detail Function
- Multiscale Shape Features
- Multiscale Shape Operations
 - Global Covering (*automatic*)
 - Local Placement (*manual*)
 - Detail Processing (*interactive*)
 - Shape Blending (*morphing*)

* Paper SIGGRAPH, 2001

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"Synthesis on Surfaces"



- * SIGGRAPH Video Show, 2001 - (Best Technical Video)

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Acknowledgments

- SIGGRAPH 2002 Organizers
 - Soraia Raupp Musse
 - Luiz Marcos Gonçalves
- Jonas Gomes
- Research Collaborators
- Former and Current Students
- VISGRAF Laboratory at IMPA
- SIGGRAPH Community

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Thanks!!!