Fulldome …and beyond!

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Outline

- Basic Concepts
  - Mathematical Fundamentals
  - Computational Framework
- Omnidirectional Video Production
  - Augmented 360 Panoramas
- Immersive Interactive Visualization
  - IMPA’s Dome

Math Fundamentals

- Plenoptic Function
- Light Fields
- Parametrization and Projections
- Omindirectional Images
**Plenoptic Function**

*Complete description of Visual Information in a 3D environment*

- $I_x = P(x, y, z, \theta, \phi, t)$
  - Holographic Image
- $P : \mathbb{R}^3 \times S^2 \times \mathbb{R} \rightarrow \mathcal{E}$
  - 6D Phase Space

**Light Field**

*A Slice of the Plenoptic Function*

- Structured Sampling of $P$
  - example: Camera

**Panoramic Surfaces**

*Generalized Support for Visual Information*

- Data Representation
  - example: Cylindrical Panorama
Parametrizations
Maps 2D Surface to Planar Domain

- Coordinate Systems
  - example: Cylindrical Mapping

Omnidirectional Image
The Set of All Rays incident at a point (x,y,z)

- Spherical Light Field = 360 degrees

360° Image Formats

- Parametrizations of the Sphere
  - Stereographic
  - Lat-Long
  - Cube Map
  - Azimuthal
Stereographic Projection

- Conformal Mapping (preserves angles)

![Image of Stereographic Projection](image1)

singularity  infinite plane

Equirectangular Projection

- Latitude-Longitude Mapping (e.g., Flickr)

![Image of Equirectangular Projection](image2)
natural coordinate system  distortion toward poles

Most Convenient Format

Cube Mapping

- 6 Perspective Projections

![Image of Cube Mapping](image3)
suitable for CG rendering
Azimuthal Projection

- Hemispherical Mapping

Dome Master standard

Omnidirectional Cameras

- Catadioptric
- Dioptric
- Multi-Camera

Catadioptric Cameras

- Mirror-Based (parabolic or hyperbolic)
Dioptric Cameras

- Fish Eye Lenses

Multi-Camera Systems

- Point Grey's Ladybug (6 Perspective Cameras)

Production

- Assuming
  - Equirectangular Representation
  - Multi-Camera System

- Pipelines
  - Live Action
  - Computer Graphics
Live Action Production

• Pipeline

Capture + Stitch → Process

Editing → Convert + Display

Data

• Tools
  - After Effects, ...
  - Premiere / Final Cut / ...
  - xRes / Digital Sky / ...

(Interactive) CG Production

• Pipeline

Model → Render or Simulate → Data

Convert + Display → Sense

• Tools
  - Blender
  - LuxRender
  - etc...

Augmented 360° Panoramas

Photorealistic Rendering of Omnidirectional Images, combining Real and Synthetic Scenes

• Current Research at VISGRAF Lab
• Collaboration with
  - Aldo Zang
  - Dalai Felinto
HDR RGB-D Panorama

- Radiance

- Depth

Environment Model

- Derived Data:

  Scene Geometry

  Light Map

CG Integration

- Blender Plugin
**Synthetic Objects**

- Insertion into the Scene

**Augmented Reality**

- Full Simulation of Real-Virtual Interaction

**Photorealistic Rendering**

- Blender to LuxRender
ARLuxRender
- Lux Render Plugin

Fish Eye Output
- Cycles

Final Results
- Equirectangular
- Dome Master
Technique pipeline

- Environment capture
- Scene modeling
- Depth map
- Illumination setup
- Synthetic elements
- Integration and rendering

Applications

- What can we do with this technology?
  - Special Effects for FullDome
  - Realistic Lighting Simulation
  - Real-Time Augmented Reality

Authoring Issues

- Passive
  - Movies
- Interactive
  - Google Street View
- Immersive
  - AR Cinema
Film Language

- Conventional Cinema
  - HD Television
  - Theater Panavision
- 360 Degrees Dome
  - Omnimax
  - Dome Master

Conventional Cinema

- Camera Moves

  Track  |  Pan / Tilt  |  Zoom

  ![Diagram](image1)

Full Dome

- Camera Moves

  Track  |  Pan / Tilt  |  Zoom

  yes  |  no  |  ?

  ![Diagram](image2)
360° Image Transforms

Complex Plane Transformations for Manipulation and Visualization of Spherical Panoramas

- Current Research at VISGRAF Lab
- Collaboration with
  - Leonardo Koller Sacht

Möbius Transformations

- Complex Map
  \[ M : \mathbb{C} \mapsto \mathbb{C} \]

Transformation Pipeline

- Hyperbolic Möbius Mapping (i.e., scaling)
Example

- Extreme Zoom

Comparison

- Alternative Projections

  input panorama

  equirectangular  projective  mercator  möbius

Video 1

Different scales applied to an equi-rectangular image
More than Meets the Eye

- Beyond Full Dome Theater!
- Active / Dynamic / Reconfigurable..

IMPA's Dome

Immersive Visualization of Spherical Interactive Panoramic Content for Augmented Reality

- Experimental 360° Playground
- Complete I/O Setup
- Real-Time Rendering

★ Planned for 2014

Location

Horta, RJ

Est. Dona Castorina, 110
Environment

- Integrated with IMPA's building and Nature

Mockup

Floor Plan
Specifications

- Size: 8 meters diameter
- Projection: 360° x 140°
- Sound: 7.2 Surround
- Reconfigurable Viewing Space
- Tracking: Head and Full Body
- Depth Cameras: RGBD

Projection

- Hemispherical Mirror + 4 Projectors

Simulation

- Projector Coverage
Reconfigurable Floor

- Two-Level Base

![Level 1](image1)

Level 2 - FOV

- Center View (~140° Vertical Field of View)

![Level 2 - FOV Center View](image2)

Level 2 - FOV

- Border View

![Level 2 - FOV Border View](image3)
Envisioned Applications

- 360° Cinema
- Full Scale Games
- Immersive Visualization
- Parallel Reality
- Interactive Exploration

Future Research

- Authoring Systems
  - Integrated Media
  - Natural Interfaces
- Production Techniques
  - Live Action + CG
  - Real Time Simulations

Some Examples

- Relativistic Visualization
  - 2007
  - collaboration with: Marcelo Cicconet
- Exploring 3D Manifolds
  - current work
  - collaboration with: Pierre Berger, Pierre-Yves Fave, Alex Bordignon, Sergio Krakowski
Hyperbolic 3D Orbifold

Questions?