Fourth Generation Video:

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Outline

• Context and Background
• Project Overview
• Technical Details
• Preliminary Results
• Impacts and Publications
• Future Perspectives

What is the Project about?

Investigate and Develop a Platform for the Next Generation Digital Video

• Complete system
  – Hardware
  – Software
• Entire Process
  – Capturing
  – Processing
  – Transmission
  – Exhibition

Motivation

• Digital Video is at the Core of the Information Technology Revolution
• Brazil is already taking the first steps towards a standard for Digital TV
• Advanced Research has Strategic Importance to Leadership in the Area

Evolution of Digital Video

• 1st Generation
  Analog to Digital Conversion (Raw Formats)
  – Capture and Exhibition
• 2nd Generation
  Compression Techniques (DCT, Wavelets)
  – Non-Linear Editing
• 3rd Generation
  Format Standards (MPEG)
  – Distribution
• 4th Generation
  Content-Based (Objects)
  – Advanced Applications

Next Generation Digital Video

3D Video

\[ f(x, y, t) = ((r, g, b), z) \]

– Color: \((r, g, b)\)
– Geometry: \(z\)

• New Kind of Information
  – Higher Dimensionality (3D world - more than stereo)
• Structure
  – Segmentation (surfaces and texture)
• Objects
  – Foreground / Background (human perception)
Novel Possibilities

- Enhanced Techniques
  - Compression
  - Special Effects
  - Shape Reconstruction

- Advanced Applications
  - Digital Television (Stereo) and Cinema
  - Virtual Reality and Tele-presence
  - Games and Theme Parks
  - Art and Education

Technological Paths to 3D Video

- Range Sensors (Video + Depth Cameras)
  - Low Resolution / Registration Problems
  - Feasible, but Expensive

- Passive Stereo (Pair of Video Cameras)
  - Not Robust
  - Ideal, but not Real-Time yet

- Active Stereo (Video Camera + Projector)
  - Interfering Pattern
  - Robust and Inexpensive

Structured Light Stereo

- \((b,s)\)-BCSL code
  - The \((b,s)\)-BCSL method defines a coding / decoding procedure for unambiguously finding the id of a stripe transition using \(s\) slides and \(b\) colors.
  - In our case, \(b=6\) colors (R,G,B,Y,M,C) and \(s=2\) slides which gives a code of length 900 as illustrated below:

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Slide 2 color sequence: R G C G ...
Slide 1 color sequence: R G C G ...
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- The color transitions \(R,G\) in slide 1 and \(G,C\) in slide 2 uniquely map to the transition id \(p\) in \(O(1)\) decoding procedure.

Overview of 3D Capture Process

1. Projecting and capturing color patterns
   - Two slides \((S1, S2)\) having vertical color stripes specially coded are projected on the object. Each slide is followed by the projection of its color complement.
   - A camera captures the four projected patterns on scene.

2. Detecting Stripe Boundaries and Colors
   - Zero crossings and projected color stripes are robustly identified in camera images using complementary slides.
Step 3: Camera / projector correspondence

- Projected color sequences are decoded for each zero crossing giving camera/projector correspondence.

Step 4: Photometry and geometry reconstruction

- Geometry is computed using camera/projector correspondence images and calibration matrices.
- Texture image is obtained by a simple combination of each complementary slide pair. For example, the maximum of each channel gives an image that approximates the full white projector light.

Video + (b,s)-BCSL code

- The key for real-time 3D video is the combination of the (b,s)-BCSL code with video stream.

- Our scheme has the following features:
  - Each frame contains a slide in the even field and its complement in the odd field. Frames (S1,S1') and (S2,S2) are interleaved in time.
  - Projector and camera are synchronized through a genlock signal.
  - Camera output is grabbed and pushed into the reconstruction pipeline.

Reconstruction pipeline: How it Works?

- Our reconstruction pipeline is as simple as possible, achieving real-time 3D video with high quality geometry and photometry at 30Hz. This is possible because:
  - Every input frame captured gives a new texture image (by combining both fields).
  - New zero crossings and projected color map are computed for every input frame and correlated to the previous frame zero crossings and projected color map. The (b,s)-BCSL decoded transitions give a new geometry set.
  - The following diagram illustrates the reconstruction pipeline. The frame arrived at time t gives texture pi from its fields and geometry gi by correlation with the frame arrived at time t-1.

First Example

- The bunny-cube 3D video:

Visualization Styles

- Computed surface normals

- Moving hand (rendered with lines)
Deformable Shapes
- Face and mouth movement

Articulated Objects
- Background / Foreground

Video - SIGGRAPH 2004
Real-Time 3D Video
VISGRAF Laboratory
IMPA

Why It works?
- Complementary slides projection is suitable for both photometry and geometry detection.
- Projected stripe colors are robustly recovered through camera / projector color calibration.
- Stripe transitions are robustly detected by zero-crossings.
- Slides are captured at 60Hz. This is fast enough for capturing "reasonably normal" motion between consecutive frames.
- Transition decoding is performed in $O(1)$.
- While objects move the stripes projected over their surface remain practically stationary.

Discussion
Current System Embodiment uses NTSC video

Pros and Cons
- Standard off-the-shelf equipment
  - Widely Available and Good Cost-Benefit
- Small resolution
  - 640x240 per field. (It reduces the maximum number of stripes around 75.)
  - Composite video signal has poor color fidelity. (It reduces the transition detection precision at stripe boundaries).

Next Step: High Definition Digital Video.

Planning
- Fourth Generation Video Platform
  - Acquisition Device
  - 3D Video Processing
  - Visualization
  - Structuring and Encoding
  - Transmission
  - Applications

Phase One (2003-2004)
Phase Two (2005-2006)
Conclusions

• Platform for Next Generation Digital Video
• Advanced the State-of-the-Art
• First Results are Very Encouraging
• Promising Future Developments
• Many Applications
• Technology Transfer