3DTV: Technical Challenges for Realistic Experiences

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Yo-Sung Ho: Biographical Sketch
- 1977~1983 Seoul National University [BS, MS]
- 1984~1989 University of California, SB [Ph.D.]
- 1990~1993 North America Philips Labs, NY, USA (NAPL)
- 1995~Now Gwangju Institute of Science & Technology (GIST)
- 1981~Now Senior Member of IEEE, SPIE, IEEK, KICS, KSBE
- 1990~1993 Delegate to MPEG/JVT Meetings
- 1999~Now Tutorial Lecturer at Various International Conferences
- 2003~Now Director of Realistic Broadcasting Research Center
- 2004~Now Associate Editor of IEEE Trans. on CSVT

Gwangju Institute of Science and Technology
- Research-oriented Graduate School
  - Funded by the Korean Government
  - Founded in 1993 (16 years old)
- M.S. and Ph.D. Degree Programs
  - Five Departments in Applied Science and Engineering
    - Information and Communications, Material Science and Engineering
    - Mechatronics, Environmental Science and Engineering, Life Science
  - 800 Graduate Students (10% Foreigners), 105 Faculty Members
  - All lectures are delivered in English
  - Top-ranked in terms of SCI paper publication and research fund
- Financial Support
  - Tuition waved, Dormitory and living expenses are provided
  - For more information, please visit www.gist.ac.kr

Outline
- Trend of Broadcasting Technologies
- History of 3D Technologies
- 3DTV System: Cameras and Displays
- Current MPEG Activities for 3DTV
- Multi-view Video Coding
- 3D Video Processing Techniques
- Conclusions

Trend of Broadcasting Technologies

Evolution of TV Technologies
Hit of 3D Movies

History of 3D Technologies

1838
1891
1908
1915
2006

ANALOG Technology Era

DIGITAL Technology Era

1844
1903
1950s

1989

1990s

2000s

1910s

Multi-view Cameras

3D Display Monitors
Anaglyph

Polarization

Polarized Glasses

Shutter Glasses

3D Display without Glasses

Parallax Barrier
Lenticular Sheet

Auto-stereoscopic 3D Display

History of 3DAV

First Proposal on 3D Video
EEs on 3DAV
3DAV Seminar
CIC on 3DAV
CIE on MVC

<table>
<thead>
<tr>
<th>Year</th>
<th>3DAV activities</th>
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<tr>
<td>2001</td>
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Applications and requirements
Representation format and camera parameters
EEs on 3DAV

History of MVC

2005/01 - 2005/04
2005/07
2006/01 - 2006/07

First Draft CIP
Second Draft CIP
CIP on MVC
Evaluation of Proposals
Core Experiments
MVC Work in JVT

MVC works in MPEG
Fix Test Conditions
MVC Work in JVT

Multi-view Video Coding

Multi-view Camera System
Multi-view Video Acquisition

Data acquisition
- N cameras (N=2-128 or more)
- How to calibrate multiple cameras?
- How to translate and rotate each camera?
- Elaborate camera control system is required (hardware)
- All the camera parameters should be stored

Data size
- A huge amount of data
- Raw data rate with no compression (example)
  - VGA color video, 8 views, 30 fps, 10 sec.
  - 1024 x 768 x 3 bytes (R, G, and B) x 8 views x 30 fps x 10 sec. = 5,662 Gbytes
  - For 1 multi-view video, 8 CDs are required
  - If the image resolution is HD (1920 x 1080)
    - Over 14 Gbytes for a single 10 sec. multi-view video
    - More than 3 DVDs for storage only

Technical Problems

Display of Multi-view Video

Technical Problems

- Color/luminance inconsistency among multiple views
- Synchronization among multiple cameras (capture, display)
- Transmission of a huge amount of data
  - Is it possible to transmit raw multi-view videos in the current network?
  - Real-time rendering
  - Is it possible to render multi-views/free-views in real-time?
- Multi-view 3-D display devices
  - No-glasses, simultaneous multiple view displays

History of 3DV/FTV

Vision on 3D Video

- Vision on 3D Video
  - To develop a new 3D video format
  - To support stereo or auto-stereoscopic displays
  - To make a standard for a new 3D video codec within next two years.
Free-viewpoint TV

- FTV
  - Free viewpoint functionality
  - View generation for auto-stereoscopic displays

FTV System

Ray-Space Representation

N Video + Depth

- Depth/Disparity Estimation
  - Sub-pixel accuracy
  - Temporal enhancement to reduce flickering effects
  - Depth map refinement for distorted depth map

- Coding of Multi-view Video + Depth Map
  - Coding structure
  - Depth map coding scheme
  - Bit allocation for depth map coding

- Intermediate View Synthesis
  - View synthesis method for depth map distortion
  - Filtering along object boundaries

Challenging Issues

- Finding out camera parameters
  - Relationship between 3-D object point and its 2-D image projection
  - Form a 3x4 projection matrix \( P \)
  - Homogeneous coordinate representation of points
  - Camera parameters
    - Intrinsic parameters: matrix \( A \)
    - Extrinsic parameters: matrix \( R \) and vector \( t \)

\[
\tilde{m} = PM = A[R | t]M
\]

Camera Calibration

- Why Multi-view Image Rectification?
  - To compensate for non-ideal conditions
  - Non-ideal conditions are due to
    - Manual adjustment of multiple cameras
    - Hard to use mechanical instruments for camera alignment
  - Non-ideal conditions cause
    - High complexity in finding pixel correspondence or matching
    - Unclear viewpoints and viewpoint change

Multi-view Image Rectification
Before Multi-view Image Rectification

- Overlapped image by nine original images

After Multi-view Image Rectification

- Overlapped image by nine rectified images

Color Consistency

- Single Camera System
- Multi-view Camera System

Examples

- Race
- 181

Global and Local Properties

- Global Property: Average brightness, histogram
- Local Property: Color Chart, Correspondence

Histogram Matching

\[ M_P = u + \alpha \cdot e_P(u) \leq u + \alpha \]
**View Synthesis by 3-D Warping**

- Key idea of intermediate view synthesis using depth map
  - Project the pixels of the reference view into world coordinates
  - Reproject the scene in the world coordinates into the desired view

**3-D Scene Rendering**

**Generated Intermediate Views**

**Conclusions**

- History of 3D Technologies
- 3DTV System: Cameras and Displays
- MPEG Activities on 3D Video Coding
  - 3D Audio Visual (3DAV)
  - Multi-view Video Coding (MVC)
  - 3D Video Coding (3DV/FTV)
- Challenging Issues for 3D Video
  - Capturing of Multi-view Images
  - Depth/Disparity Estimation
  - Coding of Multi-view Video + Depth Map
  - Intermediate Virtual View Synthesis

**Acknowledgments**

- MPEG/JVT Contributions
- GIST RBRC Members
- GIST VCL Members

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