3D Light Field Displays and Rendering

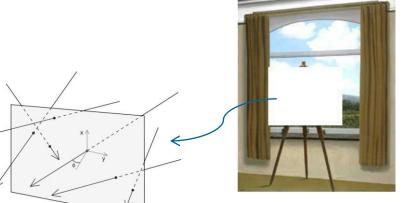
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NEM Summit New Immersive Media Formats 24, 11, 2021

3D Light Field

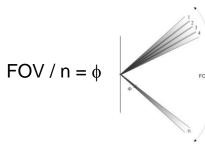
- General representation of 3D information that considers a 3D scene as the collection of light rays that are emitted or reflected from 3D scene points
- Perfect 3D displaying reconstructing the light field as present in the natural view
 - producing light beams with the same parameters: direction, position, intensity, color (but polarization, phase)
 - the visible light beams are described with respect to a reference surface (screen) using the light beams' intersection with the surface and angle, or positions on two planes
 - the LF is defined as a function of position (2 parameters) and direction (2 parameters):
 (L(x,y,[z],Θ,Φ) Plenoptic function)

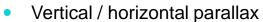




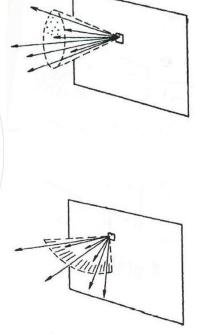
3D Light Field

- Additional independent variant to x, y : φ
 - emission range FOV
 - number of independent beams in the range Angular resolution (φ) determining FOD





- reducing the number of beams by omitting the vertical parallax
- HOP systems



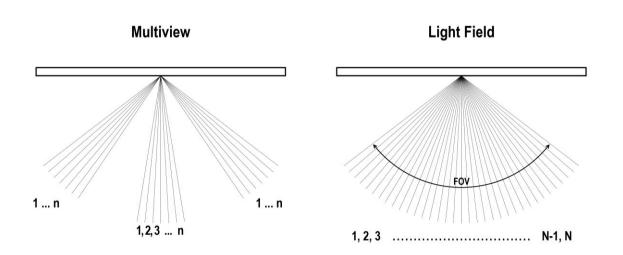
3D Light Field

- 3D Light Field formats
 - Similar to variety of resolutions and aspects today, generalized approach on the angular domain: narrow angle, wide angle content, up to 180/360 degrees, continuous parallax, open to full parallax

Scalability

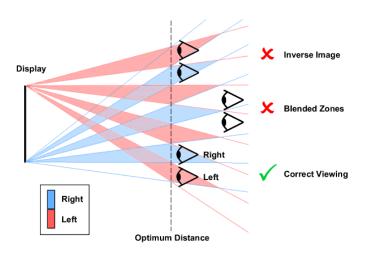
3D Light Field Displaying

Multiview vs. 3D light field display screen



Multiview vs. Light Field

- Multiview not the number of views that counts:
- Repeated views altogether more areas in the FOV, where the 3D is collapsed, than correct



Leia Lume Pad "3D Light Field" technology: 4 views



Number and size of pixels

- 3D image contains more information than a corresponding 2D
 - more pixels or higher speed components, or combination of both ...
- For a good-enough 3D display the game is about the **pixel count and pixel size** (density)
 - time-multiplex: no fast light-valve technology available, plus structural problems
 - spatial multiplexing: pixels became cheaper and small enough (a few microns)
- Solutions based on commercially available panels are stuck by the pixel count and pixel arrangement
 - using even a 8K panel (7680 x 4320) at a 36 view LF system the final image resolution comes to 1280 x 720 (Looking Glass, FOV 45-50 degrees 45 views with counting color subpixels they claim more)

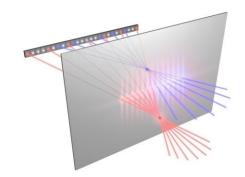
What is the way ahead?

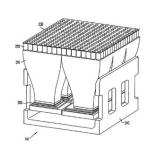


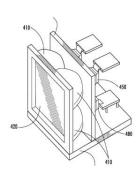
Future: Modularity

Modular 3D Light Field Displays

- HoloVizio System
 - Distributed projection by nature modular prinicple
 - Systems in the range of 100 Mpixels, exploiting microdisplays
 - HOP
- Light Field Labs, FOVI (ex Zebra Imaging)
 - Using array of OLED microdisplays inactive area (bezel) problem
 - Full-parallax
 - Commercial viability (?)







LED Displays

- LED technology will dominate future displays
 - Emissive displays offer very efficient operation,
 - high-brightnes, excellent contrast with real black levels, when off, vivid colors
 - microLEDs
- LED walls
 - modular any size, any aspect, any shape displays, any surfaces
 - creative platform
 - large-scale displaying, but with pixel pitch under 1 mm –
 in the size range of TV sets in the living room



LED Wall Displays

We have

LED walls, with scalable resolutions, 4K, 8K and beyond, bright, wide color gamut, contrast of super blacks, HDR, any-aspect, any-curved-surface, configurations for various appliactions, incl. indoor-outdoor, transparent, etc., limited only by creative imagination





Something is missing: 3D

3D Light Field LED Wall Display

Pixels, pixels and pixels

- for the 2D resolution we need small pixel pitches, close to usual LED walls
- for 3D we would need much larger number of LEDs in the same pixel area

Contradiction or challenge?

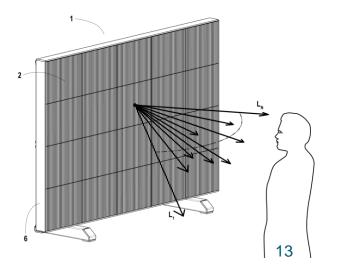
How to arrange large number of emitters in the pixels, even with state-of-the-art LED components, to build 3D light field LED walls?

3D Light Field LED Wall

- Specific LED lay-outs, up to the theoretical limits (chip active area)
- Novel optics for wide angle and high angular resolution
- High-density LED backplane PCB
- Seamlessly tile-able LED panels

... and other challenges solved





Close-up of a 5mm pitch 120mm x 120mm panel (24x24 3D pixels)



3D Light Field LED Wall

Specifications:

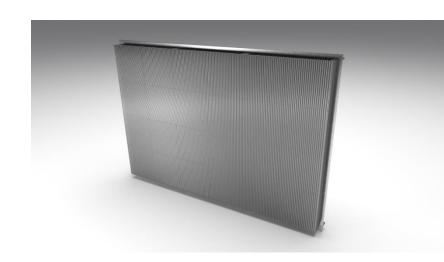
FOV: 70°
 Pitch (3D): 5 mm
 Angular resolution 1,9°

Brightness: 1800 cd/m²
 Brightness (ECO): 1000 cd/m²
 Black level: < 0.03 cd/m²
 Color gamut: 137% of sRGB

- Cabinet size: 240 x 240 x 35 mm

Demonstrator size:
 720 x 480 x 35 mm (24 panels – 3 x 2 cabinets)

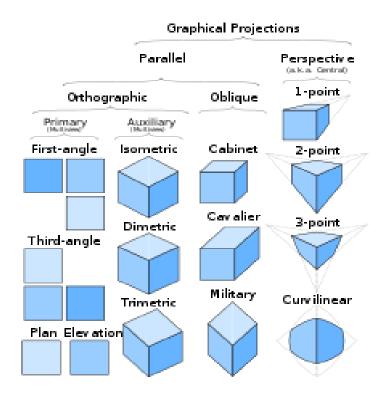
- Cooling: Passive



Software for 3D Light Field Rendering

- HoloVizio SDK for light field displays
 - Mathematical representation of light field geometries
 - Multi GPU and Beowulf clustering support
 - Descriptors for display input and pixel layout arrangements
- ClusteredRenderer SDK for light field rendering
 - Rendering engine with support for rasterized and ray traced rendering for various types of light field displays

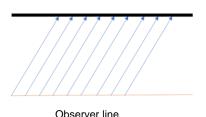
3D Rendering – Grahical Projections



Rasterized Rendering with Mixed Perspective

- Ray directions emitted from display towards the same angle form an orthographic projection horizontally
- From any point on the observer line, every column of pixels on the display is visible under a symmetrical angle vertically
- By selecting the largest angle, the whole display surface can be projected onto an image
- Overall resolution so that the resolution of the smallest visible pixel column on the image matches the resolution of the physical pixel column
- Texture is fitted to image during post rendering pixel rearrangement
- As the front and back cut planes are not parallel to the display surface, additional cut planes, parallel to the screen
 can be used to avoid objects with different depth being visible from various angles.

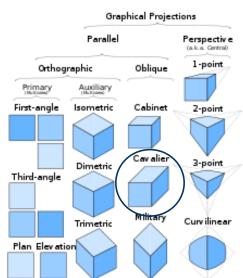






Rendering with Oblique Projection

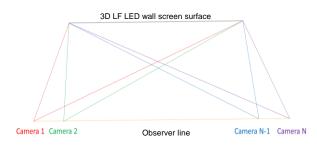
- Use previous ideas to separate image generation by emission angle.
- Use a shear matrix during projection which skews the view space horizontally with the emission angle to calculate oblique projection.
- Keeps the near and the far cut planes the same on all cameras.
- Vertical perspective is the same for all cameras.
- Avoids vertical perspective sampling errors.
- Perspective cut problems can be dealt with during geometry shader phase. (computationally expensive)



Rendering with Pinhole Cameras and Light Field Conversion

- Due to the relatively constrained emission angle traditional asymmetric perspective rendering will also capture most rays in the light field with small error
- To determine the cameras:
 - Eye positions are determined on the observer line
 - Forward direction is set to the back normal of the display cabinet
 - An asymmetric perspective is created by connecting the corners of the screen to the selected eye position

Conversion is using pre-calculated conversion tables

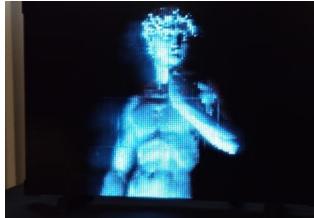


Ray-traced Rendering

- Most natural for ray arrangement
- Supports light field real-time ray tracing via
 - Compute shaders
 - RTX hardware (via NVIDIA OptiX)
- No need to rearrange pixels post rendering



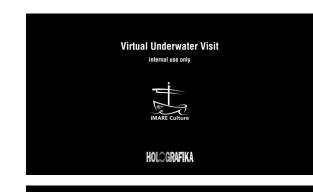






Enhancements for interactive applications

- Display blur is enhanced with three layered rendering to provide depth of field effect (implemented for underwater rendering).
- Realistic camera movement for light field rendering.
 (restricted to avoid uncomfortable camera speeds and motion)
- Support for large model rendering with enhanced culling.
- Light field particle effects using instanced, low resolution spherical particles.



Thank you - Questions?



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