FTV Seminar
- A Viewing Revolution in the Making –

Integral three-dimensional television

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1. Introduction

2. Integral three-dimensional television

3. Characteristics of reconstructed image

4. Experimental setup

5. Requirements

6. Conclusion

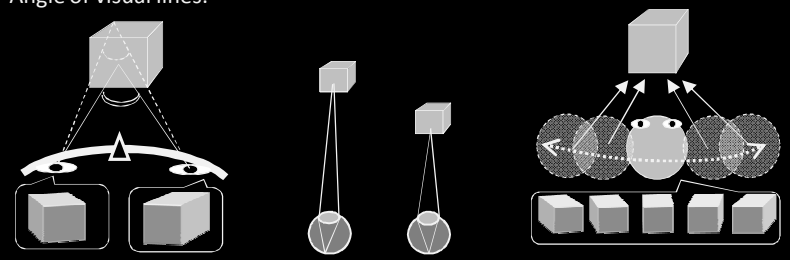
Motivation

- Free-viewpoint television (FTV) AhG [1]
  - "Super multi-view" and "Free navigation"
- Integral 3D television prospective candidate technology for super multi-view systems
  - Developments at NHK
  - Possible requirements

[1] M. Tanimoto et al., "Proposal on a New Activity for the Third Phase of FTV," ISO/IEC JTC1/SC29/WG11/M30229, Vienna, Austria, July 2013.

Major factors in depth perception

Vergence:
Angle of visual lines.

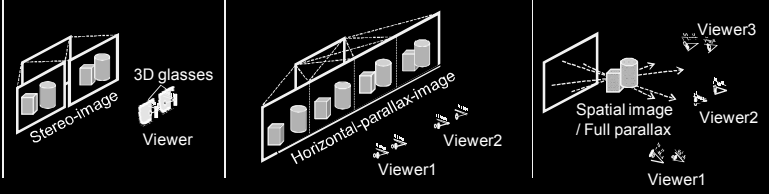


Binocular Disparity:
Image difference caused by viewpoint difference.

Accommodation:
Focusing of the lens
Reflects distance to object.

Motion Parallax:
Image difference according to the change of a viewpoint.

	Stereogram	Parallax panoramagram	Spatial imaging (Integral 3-D display)
Vergence	✓	✓	✓
Binocular disparity	✓	✓	✓
Motion parallax		(Horizontal parallax only)	✓ (Full parallax)



Three-dimensional display technology

Integral 3D television

- Based on integral photography [2]
- No special viewing glasses required
- No special light source, e.g., coherent illumination, required
- Viewable without restricting viewer's posture
- Applicable to live broadcasting services

[2] M. G. Lippmann, "Épreuves, réversibles donnant la sensation du relief," J. de Phys, vol. 4, pp. 821–825, 1908.

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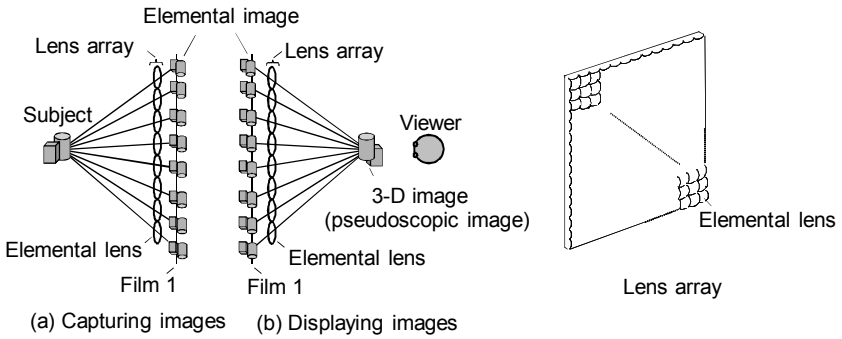
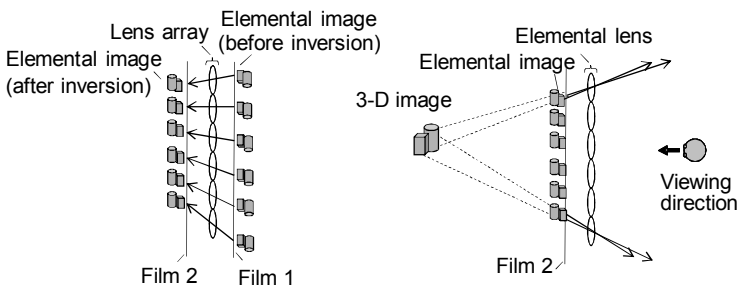
2. Integral three-dimensional television



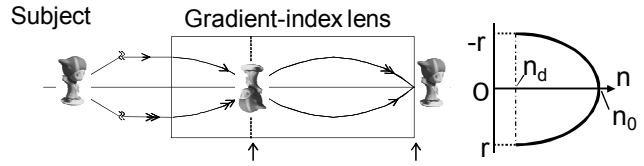
Principle of integral photography M. G. Lippmann (1908)

Display of orthoscopic image



(a) Inversion of elemental image (b) Display (orthoscopic image)

・Gradient-index lens array



Elemental image equivalent to an image generated by a convex lens

Elemental image equivalent to an image generated by two-step capture

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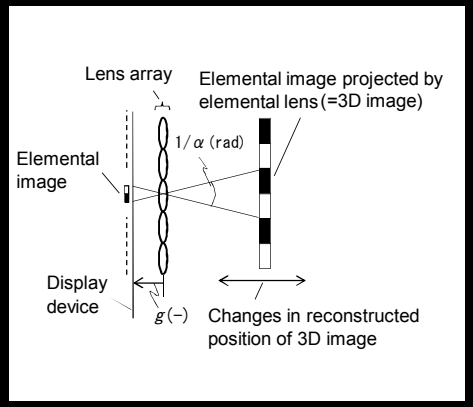
3. Characteristics of reconstructed image

Resolution characteristics

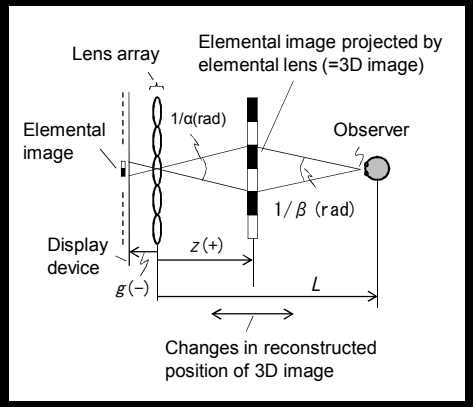
Projected spatial frequency: α(cycle/rad.)



Smaller pixel pitch of display device

Elemental image can be projected at higher spatial frequency

Resolution characteristics



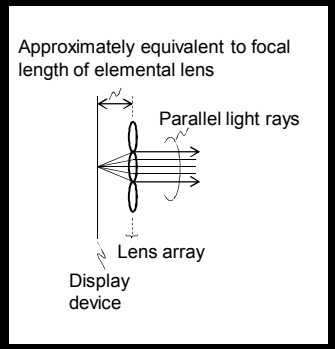
Viewing spatial frequency : β(cycle/rad.)

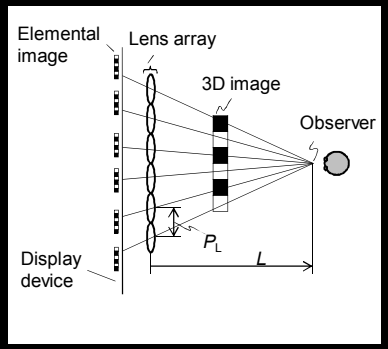
$$\beta = \alpha(L-z) / |z|$$

Smaller pixel pitch of display device

3D image with higher spatial frequency can be viewed

Maximum spatial frequency : β_n(cycle/rad.)





Output of parallel light rays → 3D image sampled at pitch of the elemental lenses

Nyquist frequency → Maximum spatial frequency $\beta_n = L/2p_L$

Resolution characteristics : 3D image

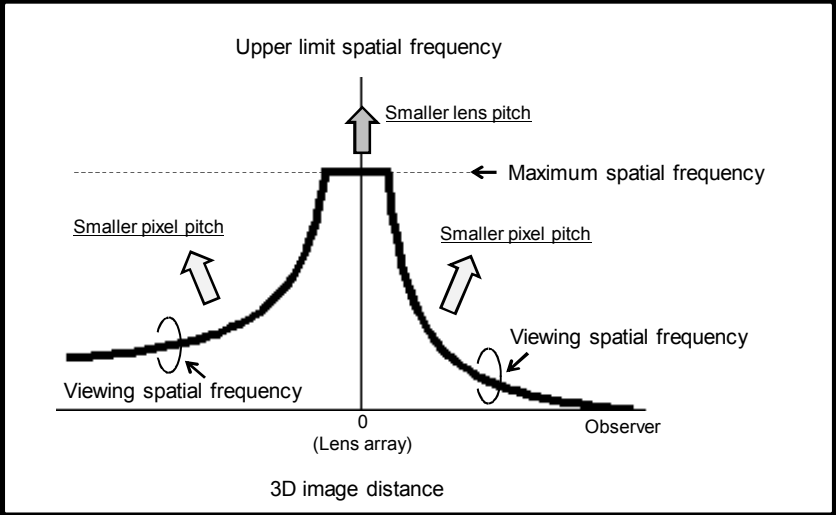
- Upper limit spatial frequency : γ(cycle/rad.)

  $\gamma = \min[\beta, \beta_n]$

  - Viewing spatial frequency : β(cycle/rad.) = α(*L*-*z*) / |*z*|
    - Smaller pixel pitch of display device

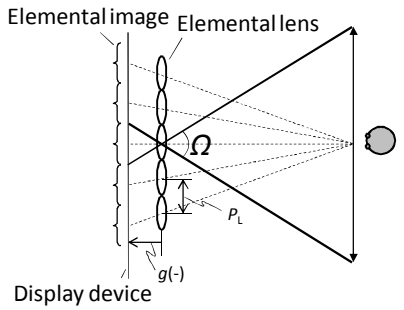
      3D image with higher spatial frequency can be viewed
  - Maximum spatial frequency : β_n(cycle/rad.) = $L/2p_L$

    Nyquist frequency determined by elemental lens pitch



Viewing area:

Range in which the observer of the 3-D image can move about



Viewing angle : Ω (rad.)

$\Omega \fallingdotseq 2\tan^{-1}(p_L / 2|g|)$

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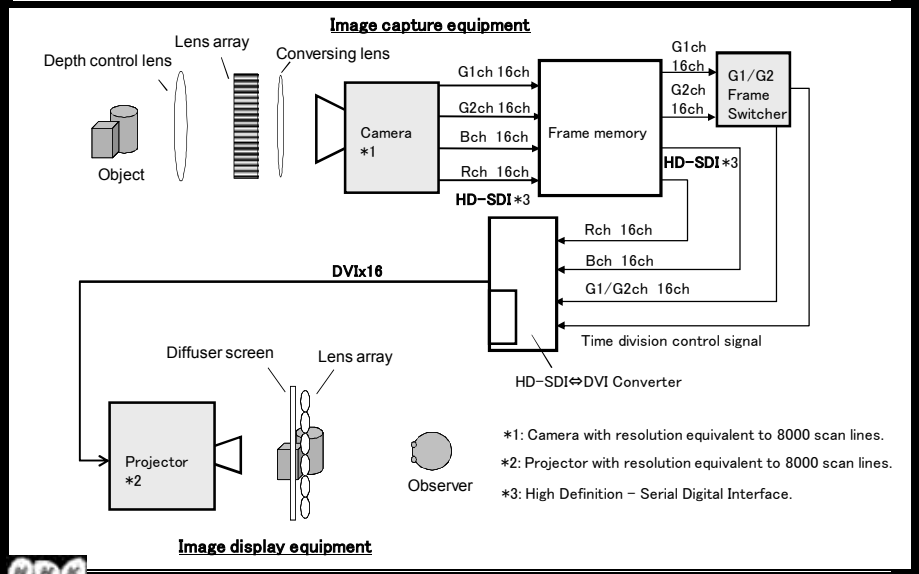
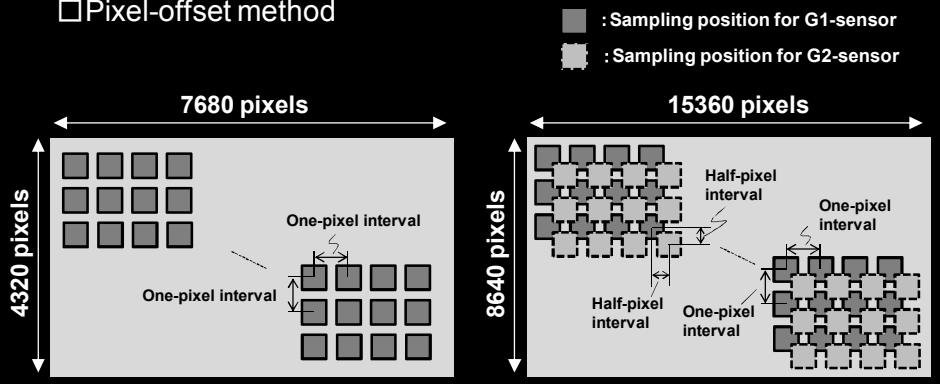


Specifications of integral 3-D television

Image capture equipment			Image display equipment		
Television camera	Pixel count (active)	7680(H)x 4320(V)x 4 One each for red, blue, green 1, and green 2.	Projector	Pixel count (active)	7680(H)x 4320(V)x 4 One each for red, blue, and green .
	Capture lens	Focal length 61.59mm		Time-division multiplexing	Complementary field-offset method
Lens array	Type	Gradient-index lens / Concave lens		Projection lens	Focal length: approx. 59.31 mm
	Number of lenses	400(H)x259(V)		Projection size	Diagonal angle: approx. 26 in.
	Lens pitch	1.14mm / 1.35mm (horizontal direction)	Lens array	Type	Convex lens
	Focal length	-2.65mm / - 2.745mm		Number of lenses	400(H)x250(V)
	Arrangement	Delta array		Lens pitch	1.44mm (horizontal direction)
Converging lens	Focal length	800mm		Focal length	2.745mm
				Arrangement	Delta array
			Viewing angle		28 degrees (design value)

☐Pixel-offset method



Single-chip imaging (Green)

Pixel-offset method (G1/G2) (Four-chip imaging)

Sampling structure of green channel

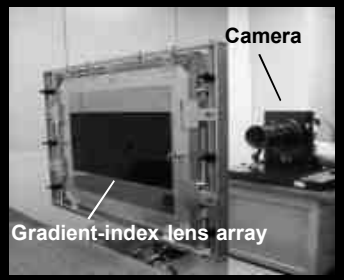


Image capture equipment

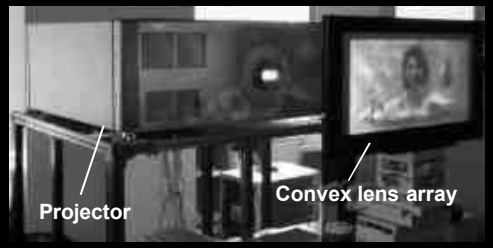


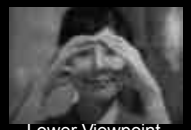
Image display equipment

Reconstructed 3D image

Upper Viewpoint

Left Viewpoint

Right Viewpoint

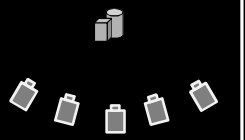


Lower Viewpoint

Conversion from 3D model to elemental images

① Scene capture

Scene



Multiple cameras

➡

② Initial depth estimation

Initial depth estimated by using belief propagation method with three neighboring camera images

⬇

③ 3D model generation

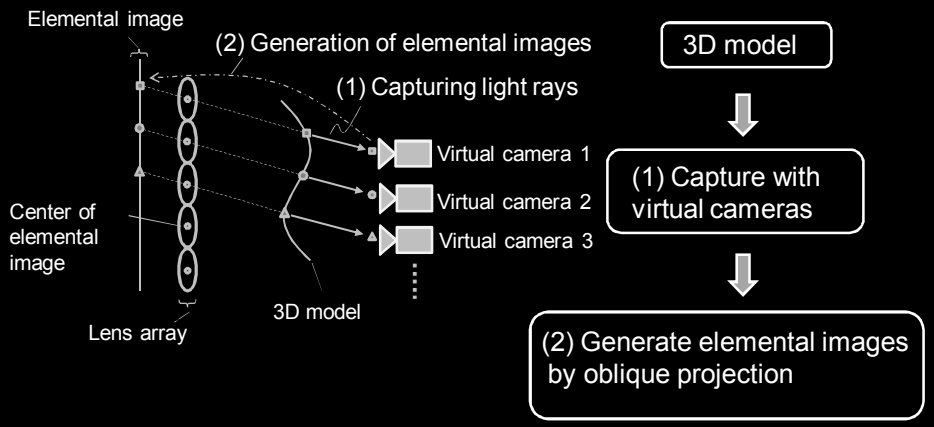
3D model data generated from depth map

⬇

④ Converting 3D model to elemental image

Merging elemental images converted from 3D model

Fast generation of elemental images from 3D model



Fast generation of elemental images from 3D model

Number of elemental images	144 (H) x 124 (V)
3D model	90,000 polygons
Frame rate	10 fps

Reconstructed 3D image

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- Requirements (FTV)
  - Lens-array arrangements: planar
  - Light ray density: ultra-dense (ray space or light-field)
  - View synthesis: rendering from planar lens-array setup
  - Data format: enables generation of additional views from ultra-dense representation of 3D scene
  - Coding: efficient real-time coding of hundreds of views

- Prior stereo and multi-view image coding
  - Assumes linear arrangement of camera inputs
  - Supports narrow, not an ultra-dense, baseline

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Integral 3D television

- Glasses-free
- Full-parallax
- No special light source required
- Motion picture in real time

MPEG's activity on FTV

- FTV technologies
  - Super multi-view
    Ray Emergent Imaging, Holo Vizio, Integral 3D television, and others
  - Free navigation
- Toward future standardization