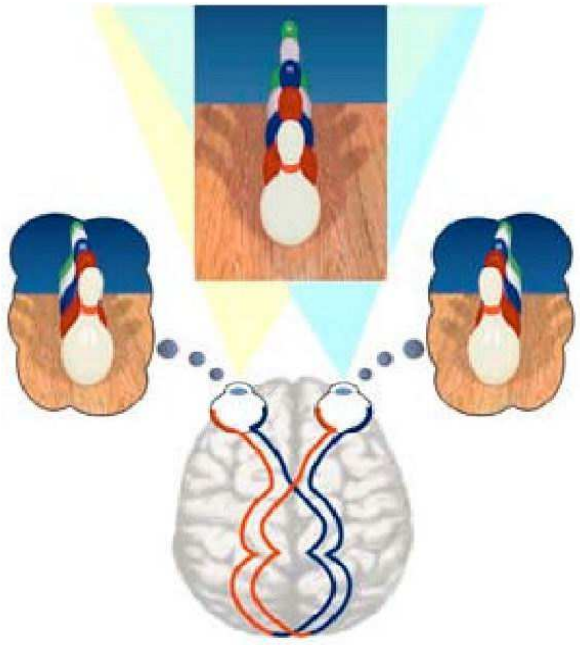
3D Display System

lbg@dongseo.ac.kr

3D Display

Human Visual System

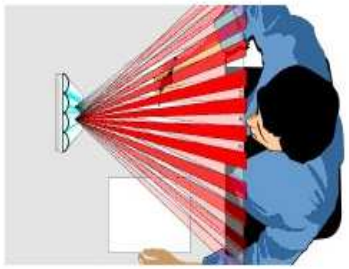
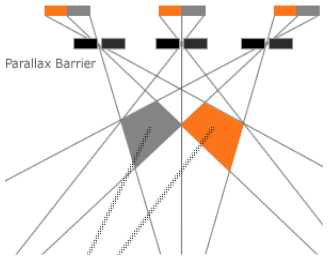


Stereo Disparity

3D Display Systems

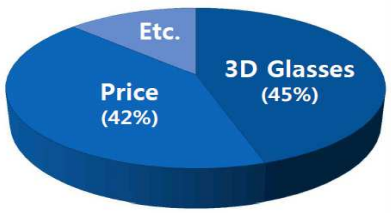
- Stereoscopic display
- Autostereoscopic display
- Holographic display

Classification of 3D Display

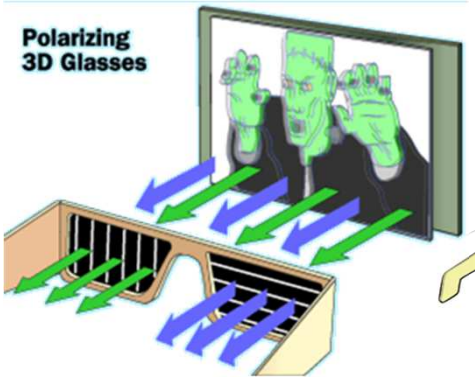
	Glasses	Non-glasses
	Stereoscopic display **- Polarization method** **- Sutter glasses method**	**Autostereoscopic display** **- Lenticular-type**  **- Barrier-type** 
Real 3D		**Floating** **Integral imaging** **Holography**  

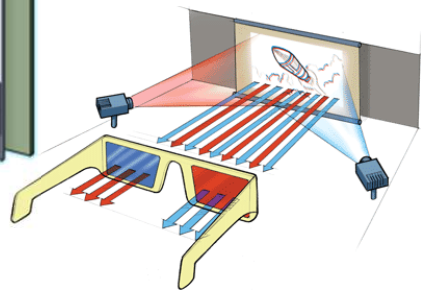
3D Display

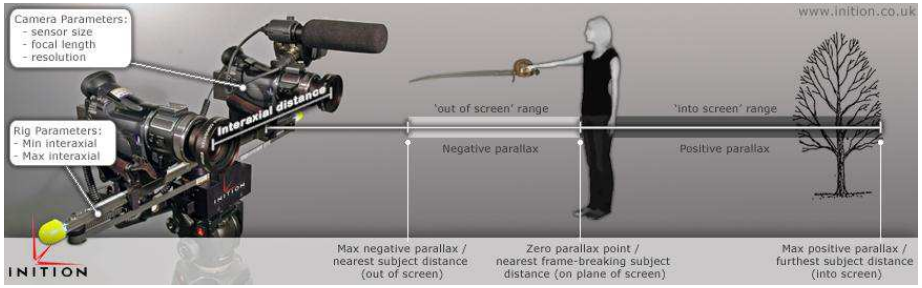
- **Stereoscopic display**
- Multiview display
- Integral Image display
- Holographic display



Reasons for not buying 3D TV
(NPD Group, 2011)





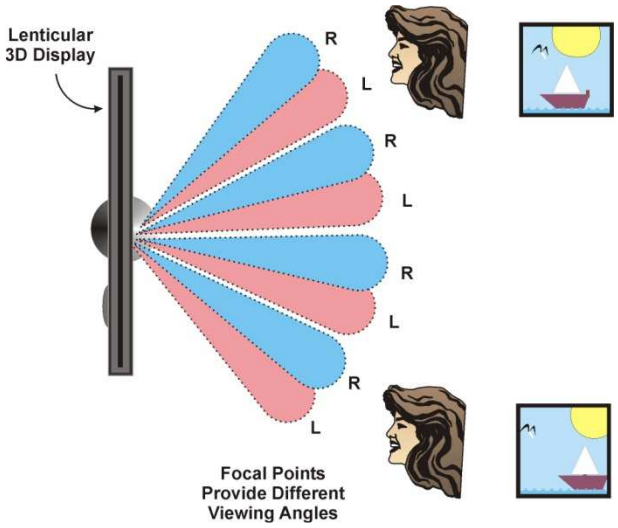


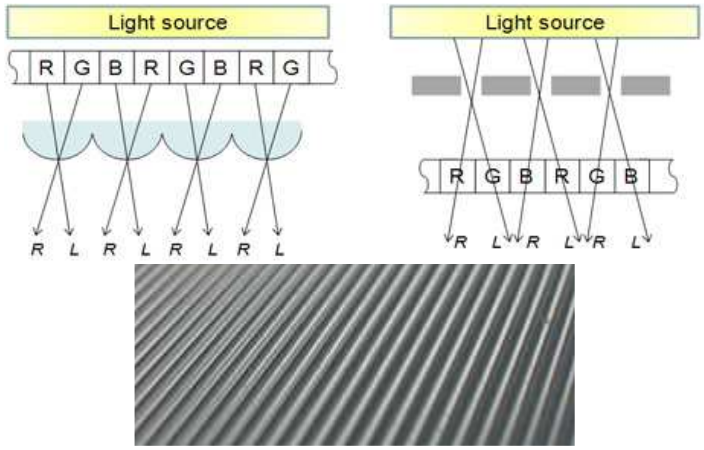
3D Display

- Stereoscopic display
- **Multiview display**
- Integral Image display
- Holographic display

15 views 50" 1999

Cambridge Univ.

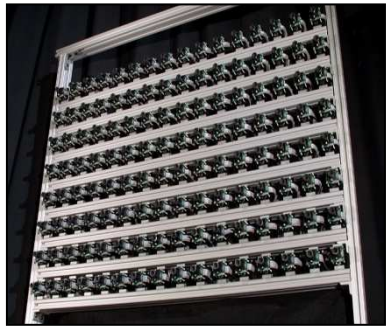


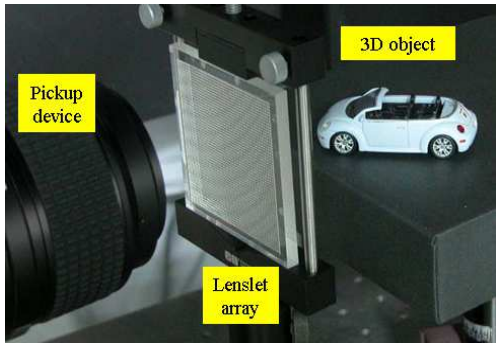


http://www.uv.es/imaging3/Structure.htm

3D Display

- Stereoscopic display
- Multiview display
- **Integral Image display**
- Holographic display

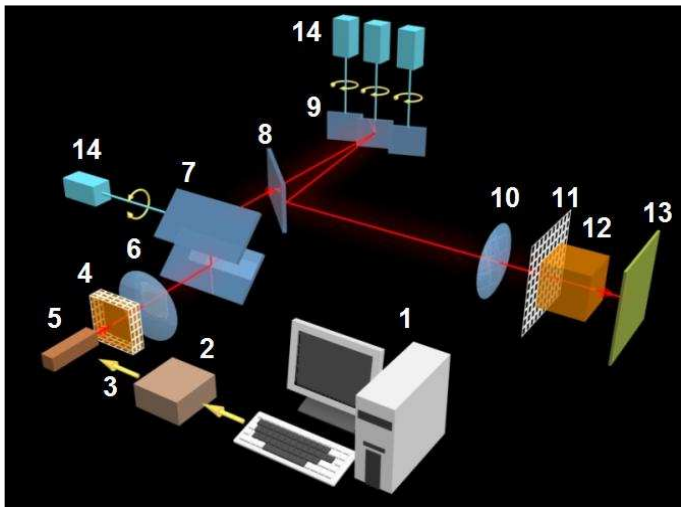


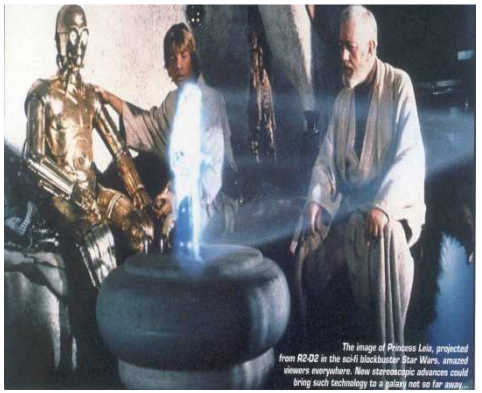


Super multi-view camera system
M x N CCD Camera [1024X768]
Resolution : 1024 x 768 x M x N

3D Display

- Stereoscopic display
- Multiview display
- Integral Image display
- **Holographic display**





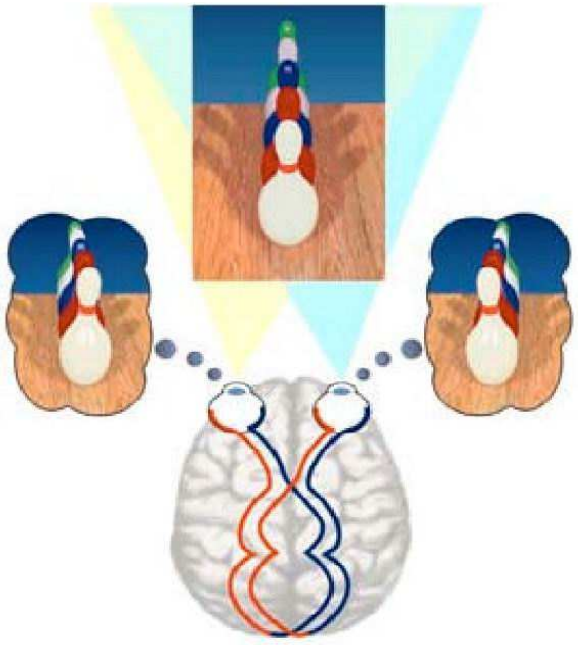
Ideal 3D Display Technique

- Based on Wave Optics
- Real images in space
- Full parallax
- Continuous viewing points
- Coherent illumination
- Color images

Fig. 4–1 Chart of the principle of holographic display operation
1 – computer, 2 – RF processor, 3 – RF signal, 4 – acoustic-optical modulator, 5 – laser, 6 – lens, 7 – vertical scanner, 8 – beam splitter, 9 – horizontally connected scanners, 10 – output lens, 11 – dispersion window (ground-glass), 12 – display area, 13 – display plane, 14 – drive

3D Display

Human Visual System



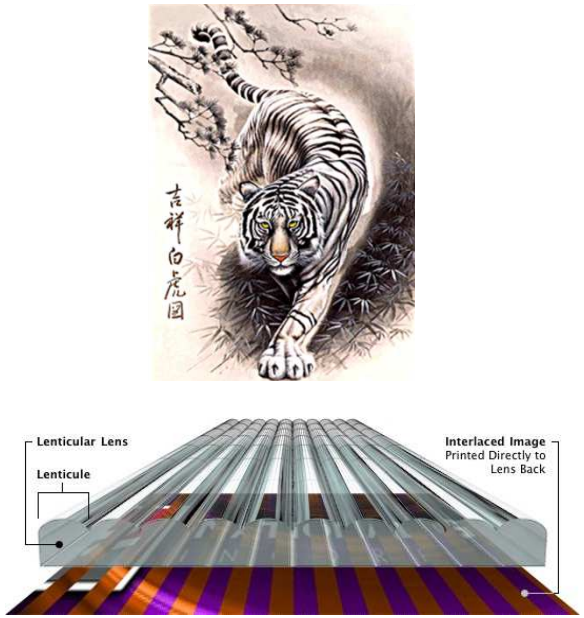
Stereo Disparity

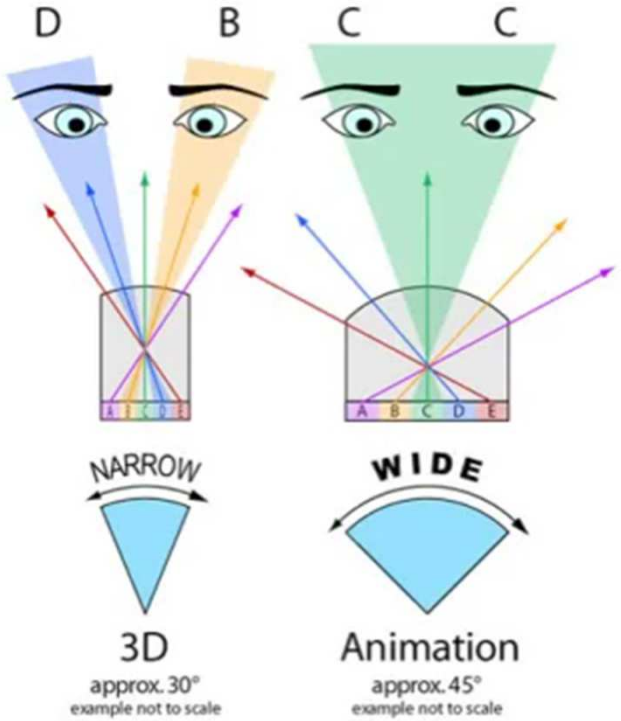
3D Display Systems

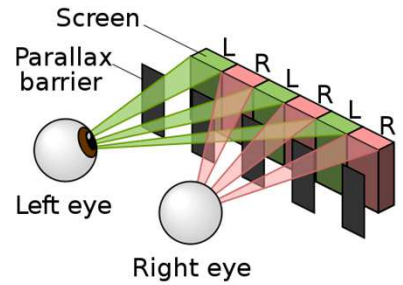
- Stereoscopic display
- **Autostereoscopic display**
- Holographic display

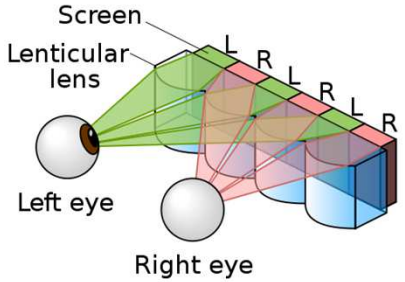
http://blog.naver.com/PostView.nhn?blogId=intel007&logNo=50144775536

Lenticular lens





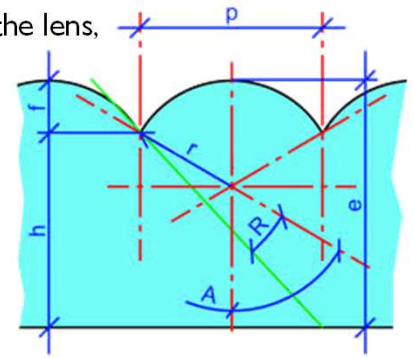


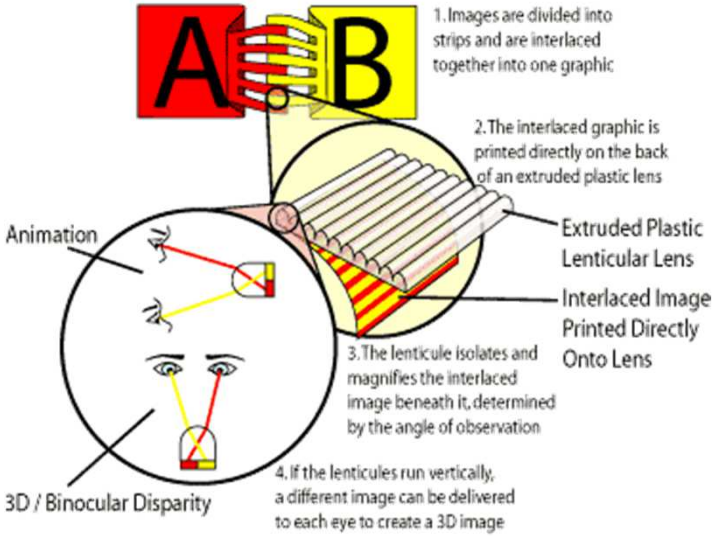


http://en.wikipedia.org/wiki/Lenticular_lens

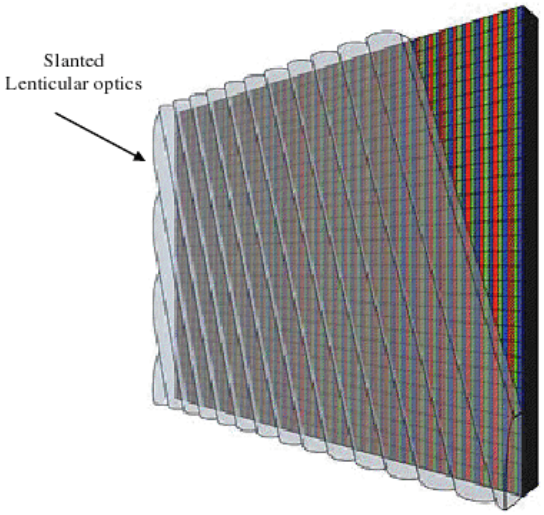
Lenticular Lens

- R is the angle between the extreme ray and the normal at the point where it exits the lens,
- p is the pitch, or width of each lenticular cell,
- r is the radius of curvature of the lenticule,
- e is the thickness of the lenticular lens
- h is the thickness of the substrate below the curved surface of the lens, and
- n is the lens's index of refraction.





Slanted Lenses



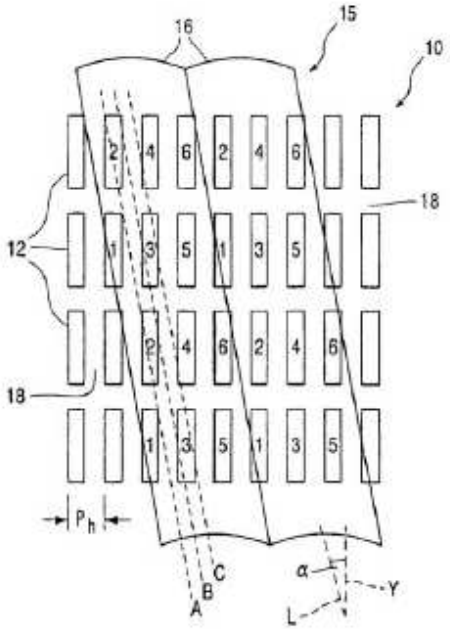
slanted lenses

more views

7 views (Philips)

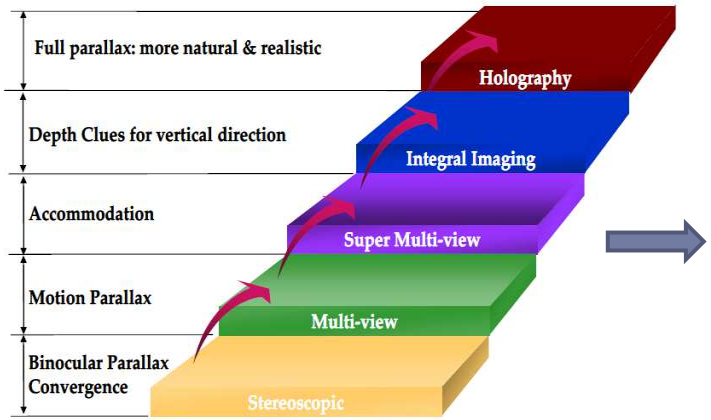
9 views (Stereographics)

no visible dark bands



This all changed in the mid 1990s, when Cees van Berkel, at Philips research lab in the UK, discovered that slanting the lenticular array solved both problems. The slanted configuration meant that both horizontal and vertical resolution are divided amongst the multiple horizontally-spaced views. We thus get a reasonable resolution in both dimensions In all views. The slanted lenslets also smear out the dark bands so that they are no longer visible.

Real 3D Display

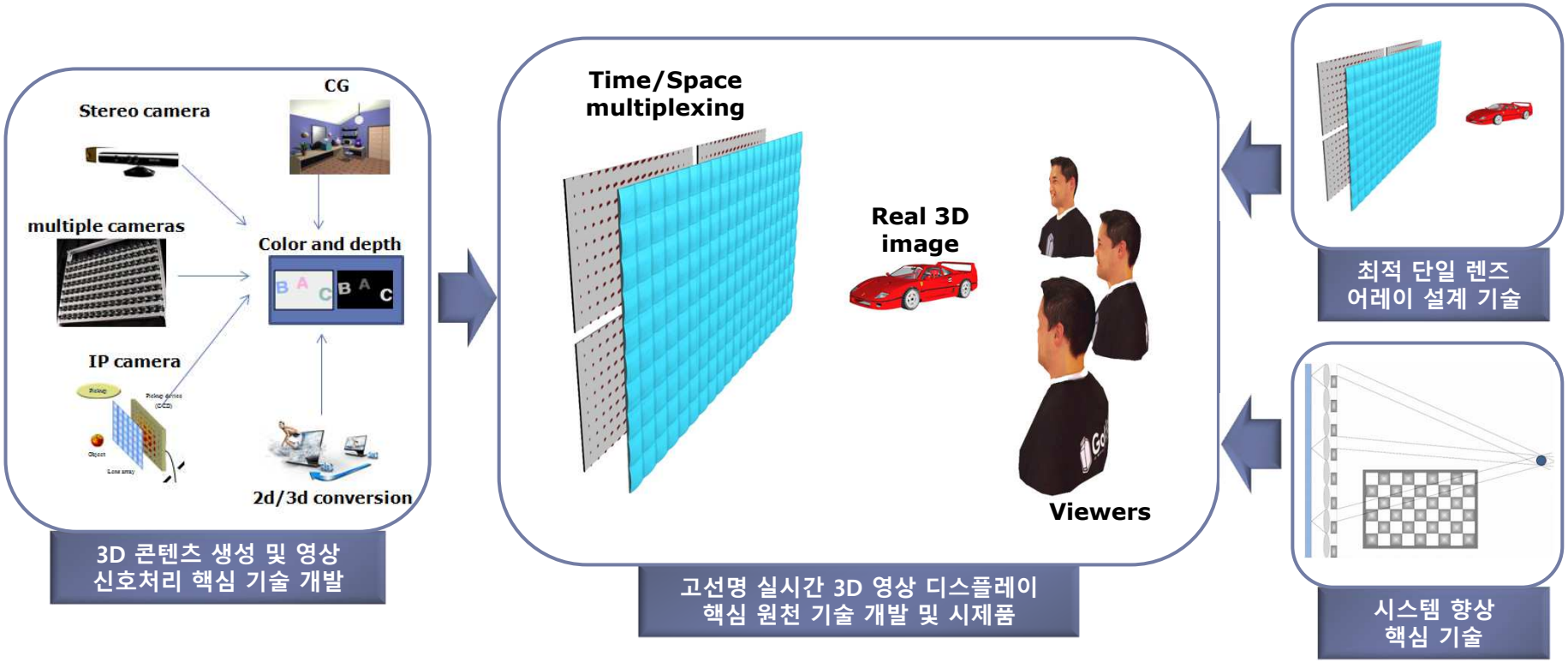


2010 방송통신 산업전망 컨퍼런스

- 완전시차 연속시점 제공
- 저 피로도 구현
- 간단한 시스템 구조
- 칼러 Real 3D 영상 구현 용이
- 공간 영상 재생 기술

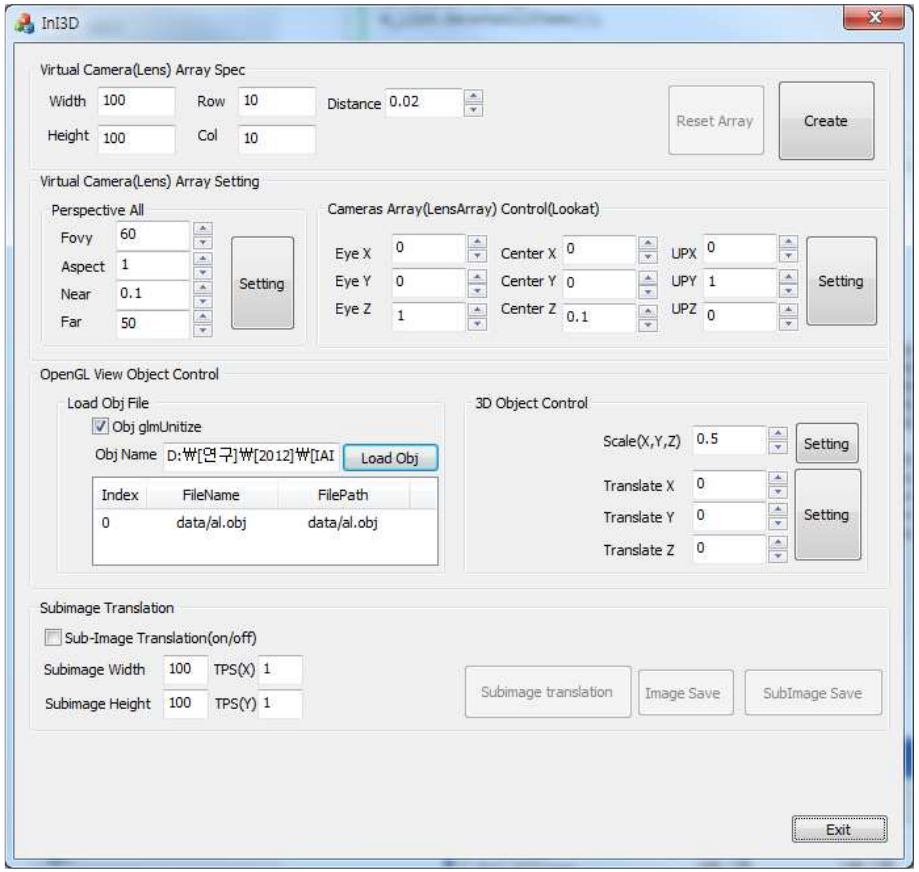
집적영상 고선명 실시간 3D 디스플레이 시스템

최종 목표	■ 단일 렌즈어레이를 이용하는 집적 영상 기반의 고선명 실시간 3D 영상 디스플레이 시스템 핵심 원천 기술 개발 및 시제품 제작 ■ 집적 영상용 실시간급 3D 콘텐츠 생성 및 영상 신호 처리 핵심 원천 기술 개발

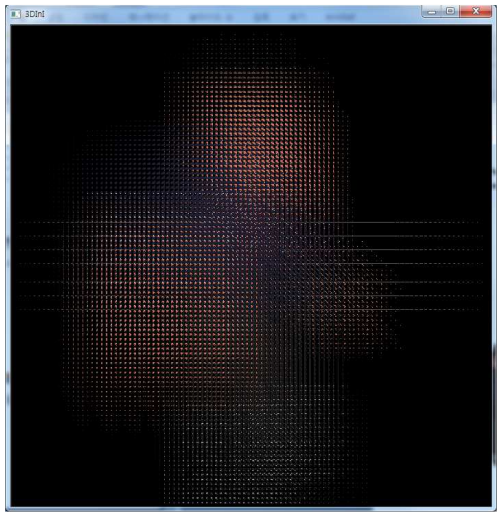


2012년 산업융합원천기술개발사업 홈/정보가전분야
집적영상(IP) 깊이 표현 범위를 개선한 고선명 3D 영상 처리 기술 개발

Camera Array Simulation using OpenGL



SubImage



ElementImage

Dong-Hak Shin, Byung-Gook Lee and Joon-Jae Lee, "Occlusion removal method of partially occluded 3D object using sub-image block matching in computational integral imaging", Optics Express, Vol. 16, Issue 21, pp. 16294-16304, Oct. 2008.

Sub Image Transformation

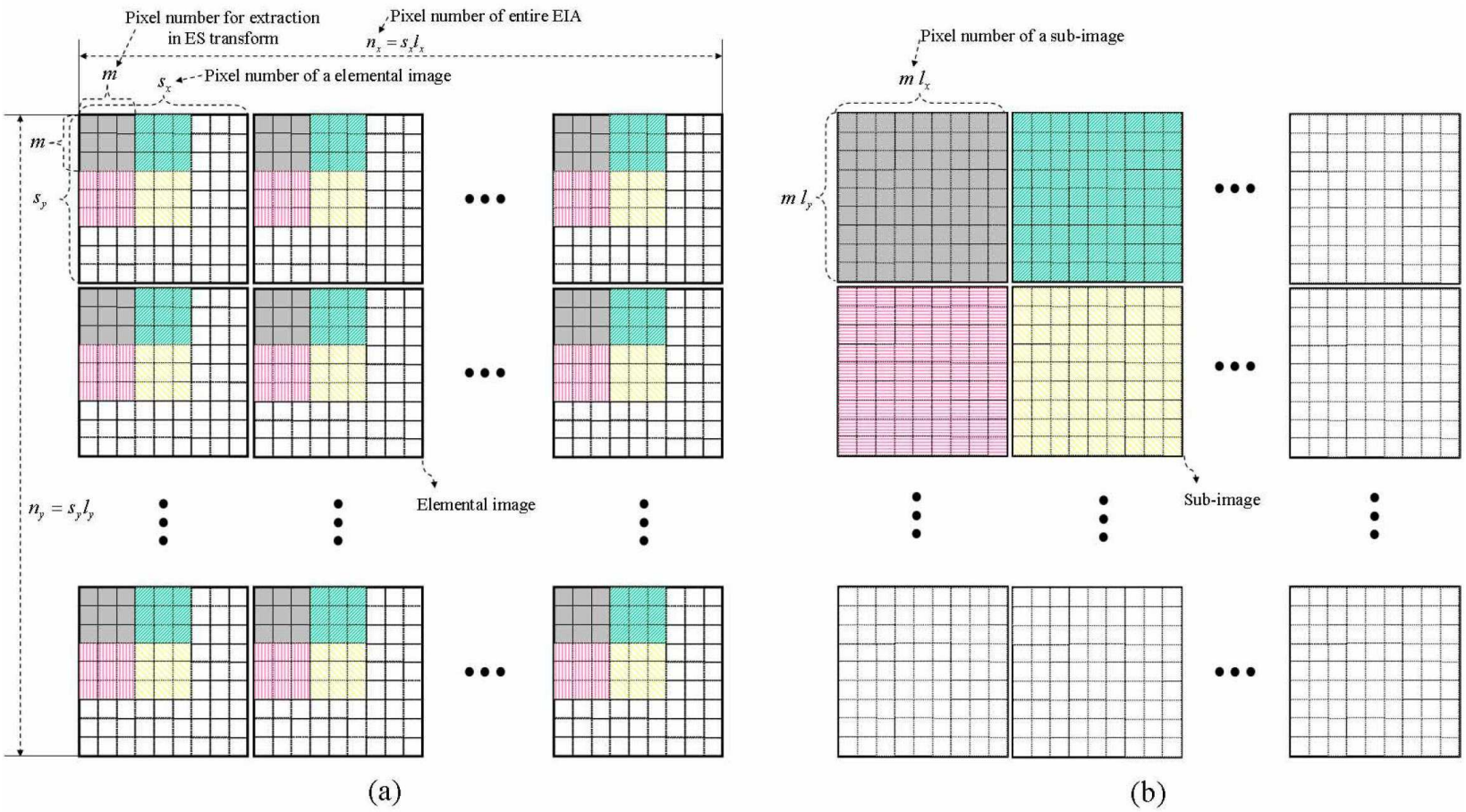
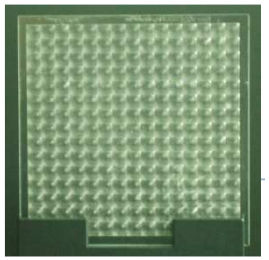


Fig. 6. ES transform based on multiple pixel extraction (a) EIA (b) Sub-image array.

Optical System Setup



Specifications of Lenslet Array	
Type	Fresnel, Square
Lenslet pitch	5mm
No. of Lenslet	15 × 15
Focal length	10mm

InI 카메라 및 프로젝션형 디스플레이 시스템

IP 카메라 및 9 인치 프로젝션형 3D 디스플레이 시스템

▶ 국내특허: 중간 요소 영상을 이용한 입체 영상 표시 장치, 등록번호 100730406, 2007.06.13
국제특허: US Patent Pending, Appl No. 12/004309, 2007.12.19

기술 개요

- ❖ 고해상도 IP 카메라 제작
- ❖ 집적영상 기술의 콘텐츠 제작전용 S/W 개발
- ❖ 집적영상 전용 소프트웨어로서 최적화

- ❖ 고해상도 영상 디스플레이 장치
- ❖ 3D 영상표시를 위한 렌즈 어레이부 포함
- ❖ Real/Virtual 영역 구동이 가능한 동영상 콘텐츠 제공

IP 카메라 사양

유효화소수	렌즈 배열스펙
610만 (3000*2000)	폭:1.08mm 초점:3.0mm

Display 시스템 사양

렌즈릿 배열개수	렌즈릿 초점거리	요소영상 해상도	프로젝터 모델
150x150 (9인치)	5.02mm	1600x1200	EPSON EMP-820

iPhone4 깊이우선방식 3D Display System

iPhone4를 이용한 깊이우선 IP 기반의 3D 영상 디스플레이 시제품

▶ 국내외 특허 출원 진행 중 : 탈착식 렌즈어레이 기반의 3D 영상 디스플레이 방법 및 시스템

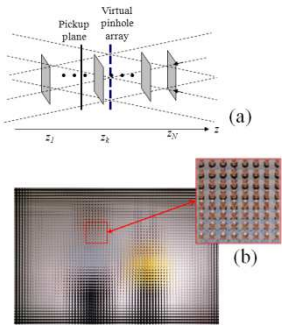
기술 개요

- ❖ 깊이우선 IP 기술을 이용한 무안경 3D 영상 표시
- ❖ Retina Display를 이용한 컬러모아레 제거
- ❖ 탈착식 구조의 렌즈어레이 사용

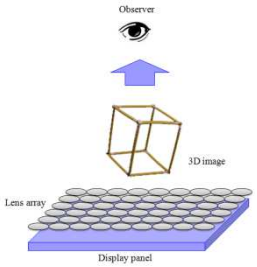
기술 특징

(1) Pickup

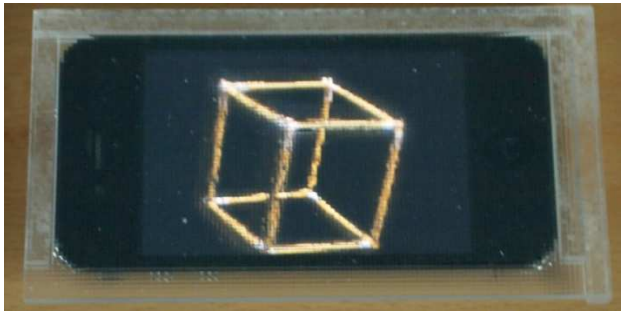
(2) IP 콘텐츠생성



(3) 3D display

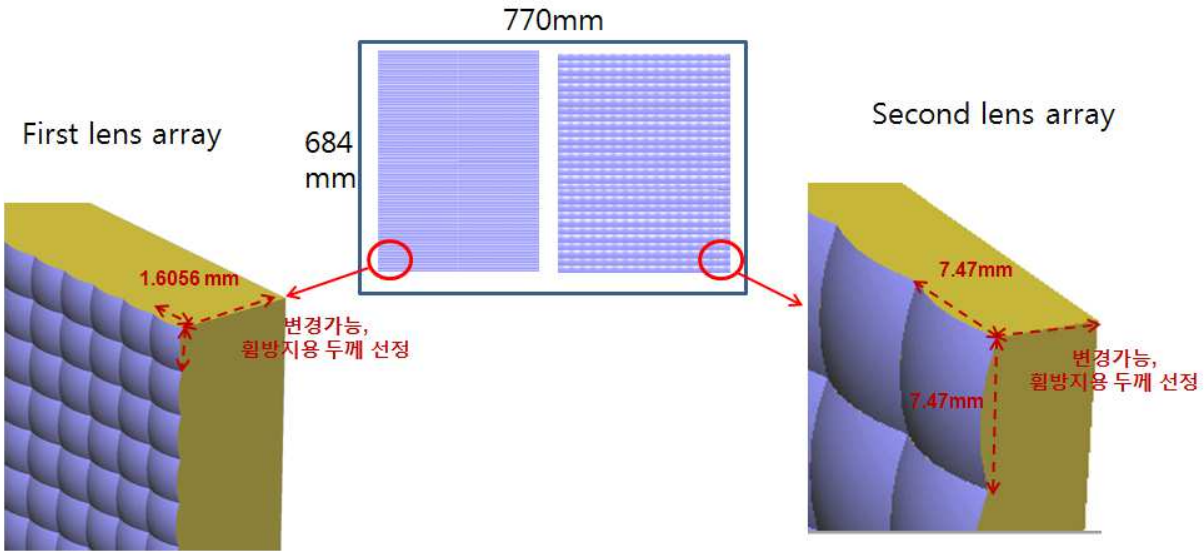


시제품 제작



렌즈릿 배열개수	렌즈릿 초점거리	요소영상 해상도	Display 모델
75x50 (4인치)	5.02mm	960*640	iPhone 4

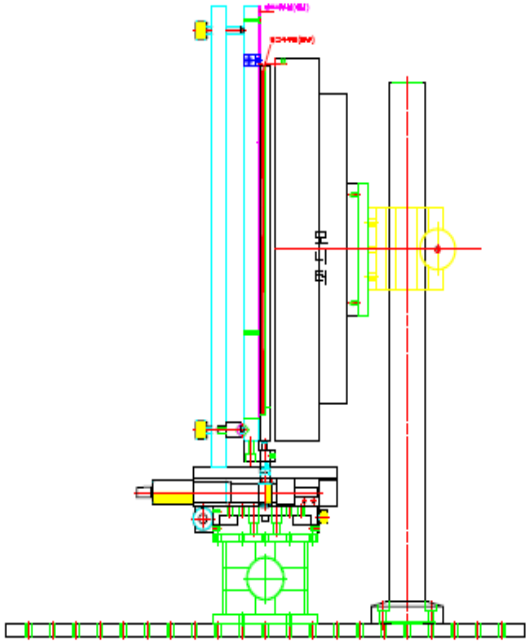
Lens Array



- 디스플레이 장치 : Barco3420
- 2048 x 1536 화소크기 : 0.207 mm
- 렌즈어레이 사양
- 전체크기 : 684mm x 385.3440 mm
- 전체렌즈개수 : 426x240 개
- 기초렌즈 사양
- 초점거리 : 8.028 mm
- 직경 : 1.6056 mm

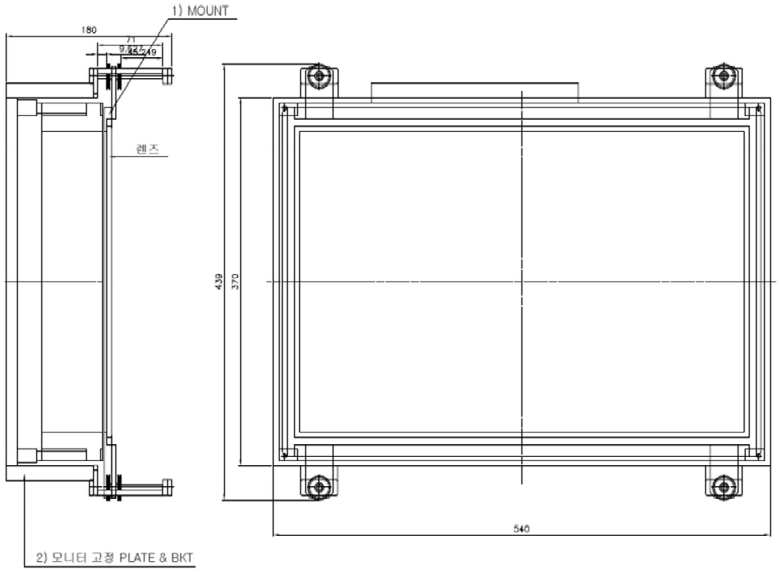
- 디스플레이 장치 : IBM t221
- 3840 x 2400 화소크기 : 0.1245 mm
- 렌즈어레이 사양
- 전체크기 : 679.77 x 380.97 mm
- 렌즈개수 : 91x51 개
- 기초렌즈사양
- 초점거리 : 29.88mm
- 직경 : 7.47 mm

DPII 3D Display System



- Time Multiplexing Display Device Panel BenQ XL-2411T 24” 1920x1080 pixel pitch 0.276 mm
- Lens array 330x186 24" focal length 8.028 mm radius 1.6056 mm
- DPII System : Viewing Angle 1.974 Depth Range 50 cm

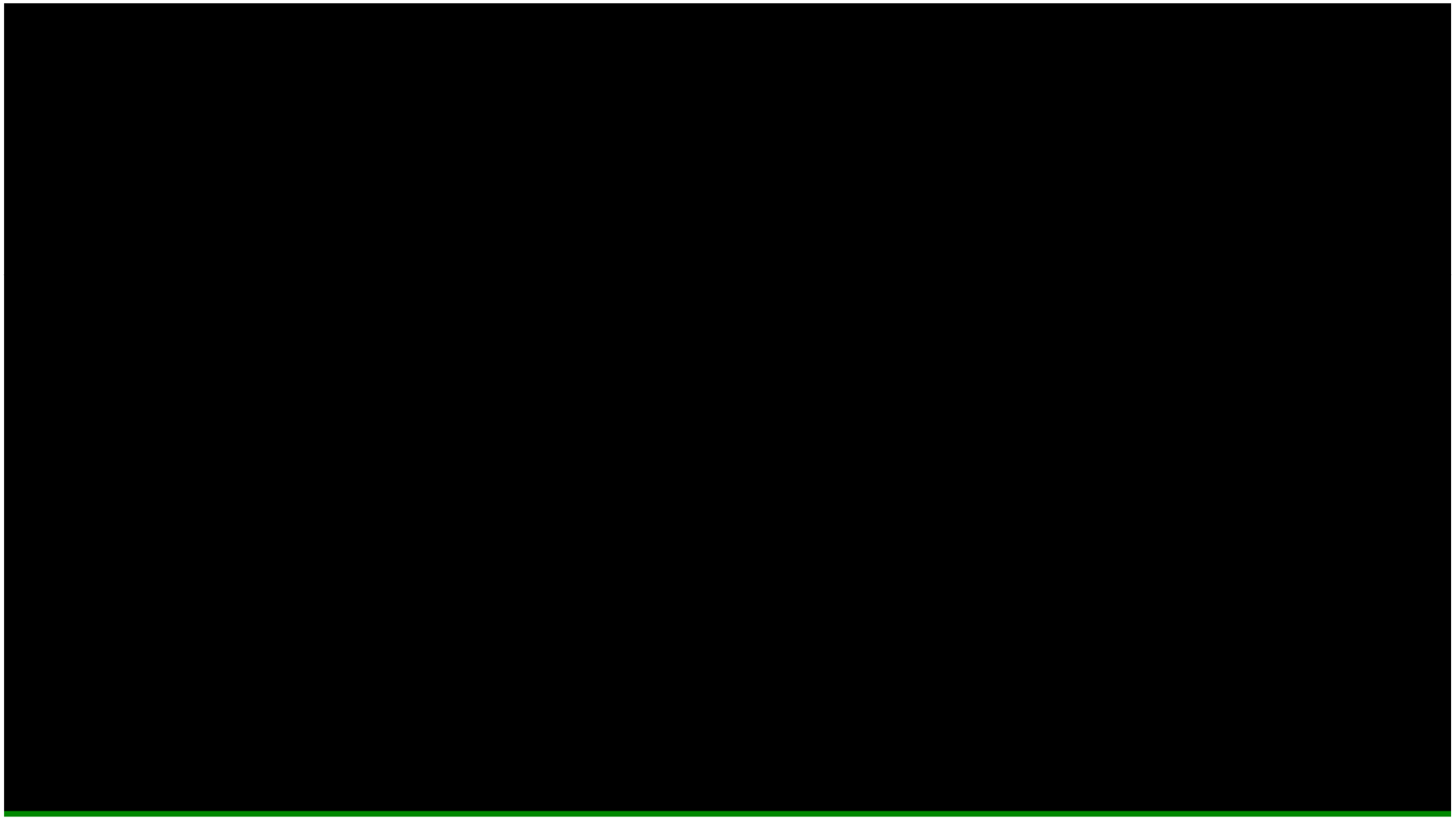
RPII 3D Display System



- IBM T221 22" 3840x2400 Pixel Pitch 0.1245 mm
- Lens Array 69x39 22” Focal Length 29.88 mm Radius 7.47 mm

Eye Tracking with Kinect Calibration

DPII 3D Display System



DPII 3D Display System

- Display Panel : Dell UP2414Q 24” 3840x2160 Pixel Pitch 0.137mm
- Lens Array 330x186 24” Focal Length 8.028 mm Radius 1.6056mm

Light Field Camera

lbg@dongseo.ac.kr

http://graphics.stanford.edu/projects/array/

Stanford Multi-Camera Array

- 640 × 480 pixels × 30 fps × 128 cameras
- synchronized timing
- continuous streaming
- flexible arrangement

http://lightfield.stanford.edu/lfs.html

Stanford Light Field Archive

The (New) Stanford Light Field Archive

Computer Graphics Laboratory, Stanford University

Home | Light Fields | Calibration | Acquisition | Software | Publications

Listed below are the light fields in our archive. For each light field, there is a link to the imagery - sometimes in several forms, and sometimes accompanied by calibration information. Following this is a link that allows you to view the light field in your browser using our Flash-based light field viewer.

Notes about the light field viewer

In most cases you shouldn't need to download any software to use our viewer; just click on the indicated links below. Be warned though, this involves loading the entire light field (usually at slightly reduced spatial resolution) into memory. For the largest light fields, this involves downloading about 30MB of data, and will cause your browser to use up to a gigabyte of RAM. Firefox 3 uses notably less RAM than Firefox 2 when viewing these light fields, as does Internet Explorer 7. Safari and Opera should also work, with the appropriate flash player plugin.

You're free to take the viewer and use it for your own light fields. The source code and instructions for the using or modifying viewer are available.

Light Fields from the Lego Gantry

The light fields in this section were acquired by Andrew Adams.

Chess

289 views on a 17x17 grid, image resolution 1400x800
Original camera images, Rectified and cropped images

A chess board with pieces. Chess boards are great for demonstrating refocusing.

View light field online

Lego Bulldozer

289 views on a 17x17 grid, image resolution 1536x1152
Original camera images, Rectified and cropped images

A Lego Technic bulldozer. Very complex geometry.

View light field online

Lego Truck

289 views on a 17x17 grid, image resolution 1280x960
Original camera images, Rectified and cropped images

A Lego Technic truck. Very complex geometry.

View light field online

Eucalyptus Flowers

289 views on a 17x17 grid, image resolution 1280x1536
Original camera images, Rectified and cropped images

Some traditional Australian flowers. Lots of fine geometry.

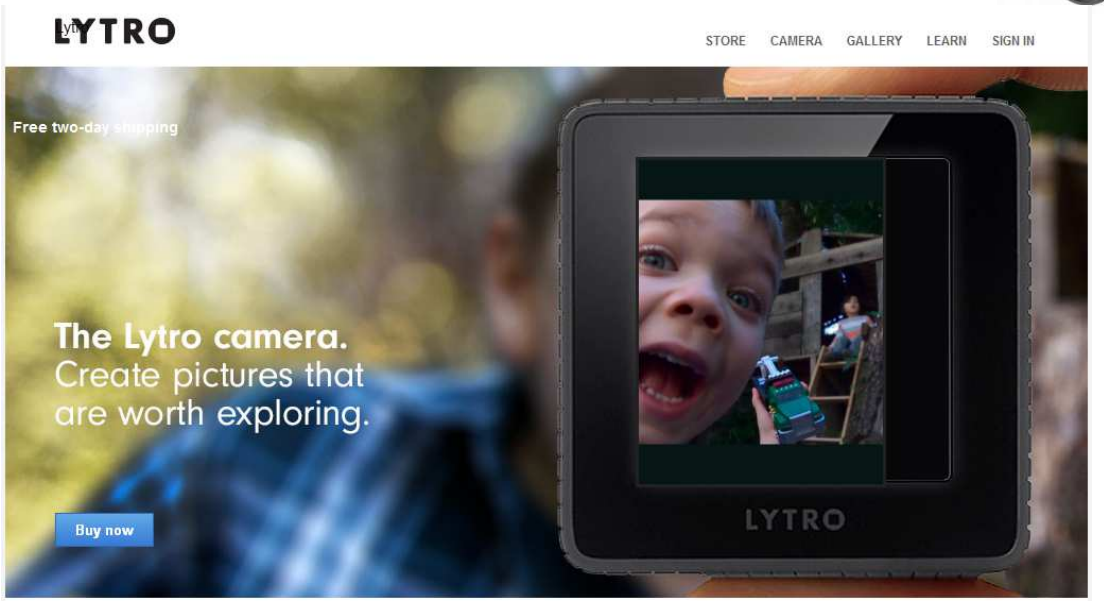
View light field online

http://lightfield.stanford.edu/lfs.html

Stanford Light Field Archive

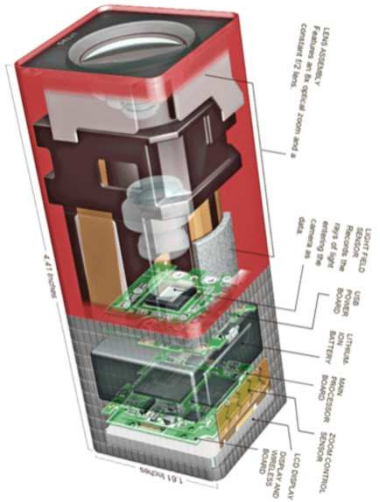
https://www.lytro.com/
https://www.youtube.com/watch?v=OfScn-YIQ0U

Lytro Camera



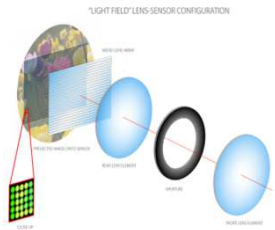
Fred R. Conrad/The New York Times

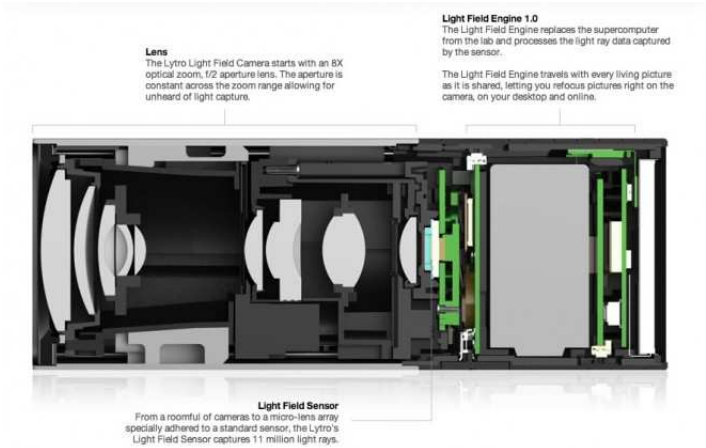
Ren Ng, chief executive of Lytro, a start-up company in Silicon Valley.



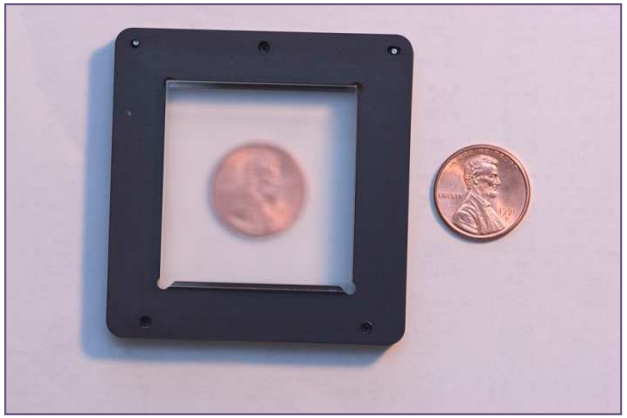
Red Hot
16GB
750 Pictures
$499.00

Electric Blue
8GB
350 Pictures
$399.00

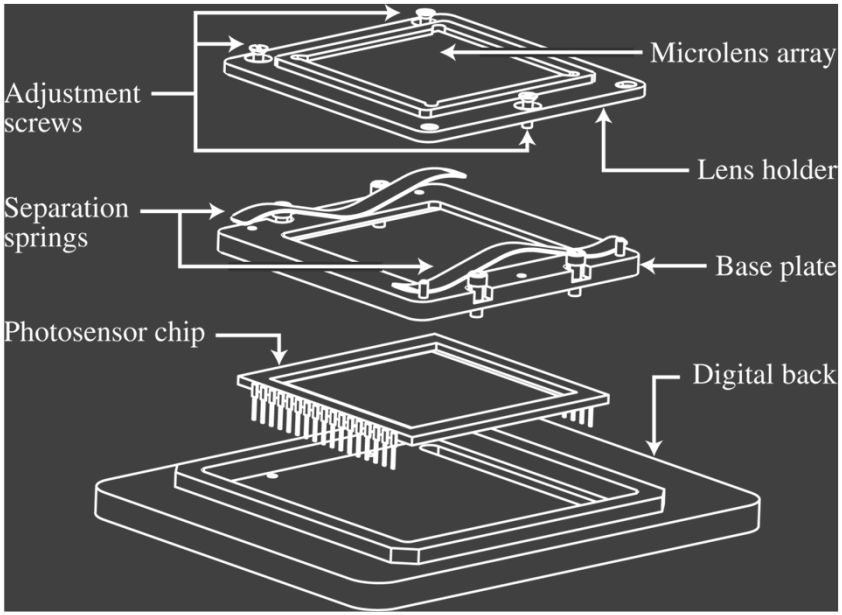


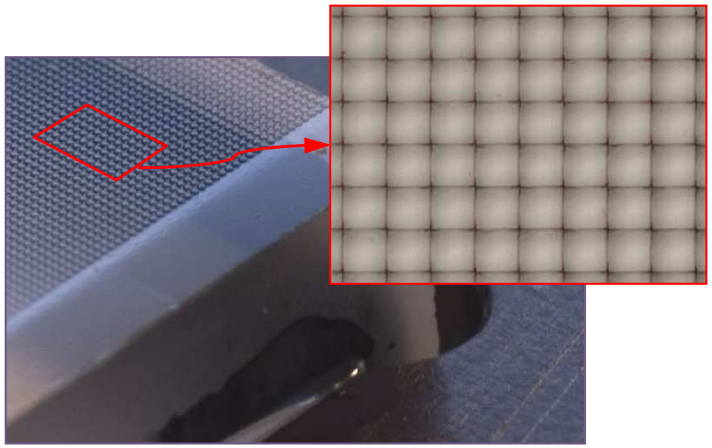


Adaptive Optics Microlens Array



Adaptive Optics microlens array





125µ square-sided microlenses

4000 × 4000 pixels ÷ 292 × 292 lenses = 14 × 14 pixels per lens

http://lightfield-forum.com/light-field-camera-prototypes/adobe-lightfield-camera-protypes/
https://www.youtube.com/watch?v=jS7usnHmNZ0

Adobe LightField Camera

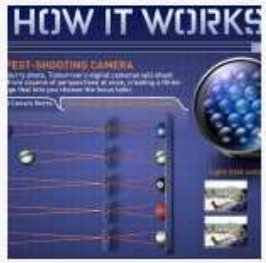
Adobe LightField Camera Protypes

Adobe Systems, the leading specialist of image manipulation, multimedia and creativity software products, has long been investigating the possibilities of LightField photography and computational imaging. Known prototypes date back to 2004, and have evolved from compound lenses with only a few sub-images to microlense arrays.
Here's an overview of Adobe's (publicly shown) LightField camera prototypes.

1. Generation Prototype: Magic Lens

Adobe's first LightField camera prototype was tested and developed in 2004-2006, and publicly demoed in 2006/2007. It consisted of a 100 megapixel camera with a special compound lens (dubbed "Magic Lens") made of 19 sub-lenses in a hexagonal array. Each of these is facing an individually configured prism set at a unique angle, resulting in 19 different focal points.
This setup created 19 subpictures of the entire scene, with a resolution of 5.2 megapixels per subpicture.



Depth Camera

lbg@dongseo.ac.kr

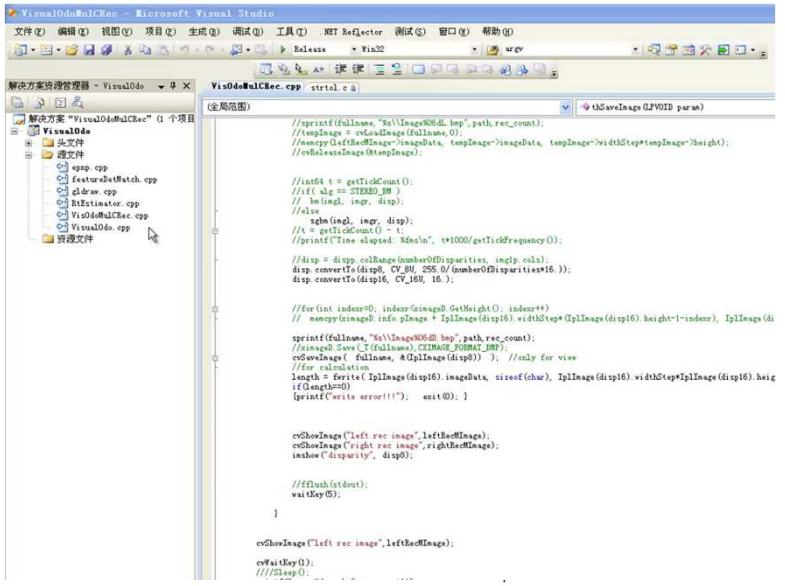
Bumblebee

- http://www.ptgrey.com/products/stereo.asp

Specifications:

- 640x480 Option: two Sony ICX084 Color or BW CCDs
- 1024x768 Option: two Sony ICX204 Color or BW CCDs
- 1/3 inch, progressive scan CCDs
- 640x480 square pixels at 30 Hz frame rate
- 1024x768 square pixels at 15 Hz frame rate
- 10 bit A/D
- Shutter speed: 1/16000 to 1/30 second
- Baseline: 12cm
- Choice of 2mm, 4mm or 6mm focal length lenses (100°, 70°, and 50° HFOV respectively)

Sony Bumblebee Stereo Camera



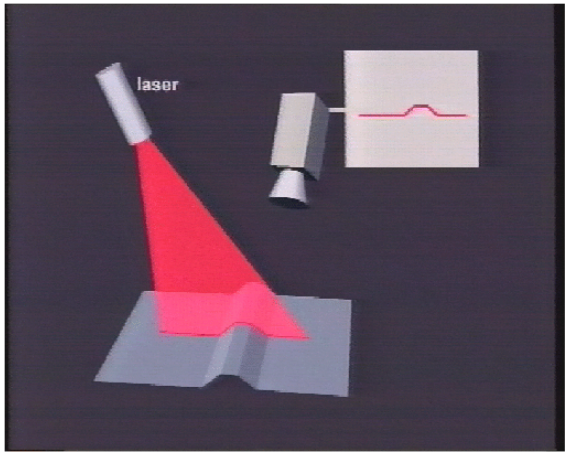
Revised February 14, 2005

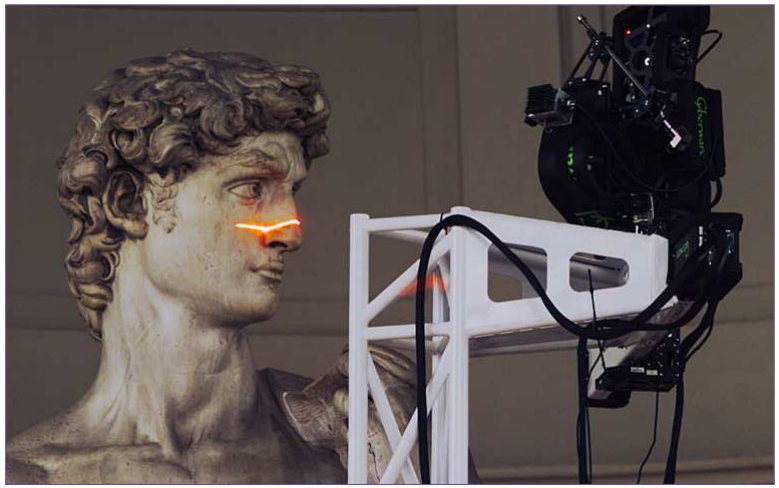
www.ptgrey.com

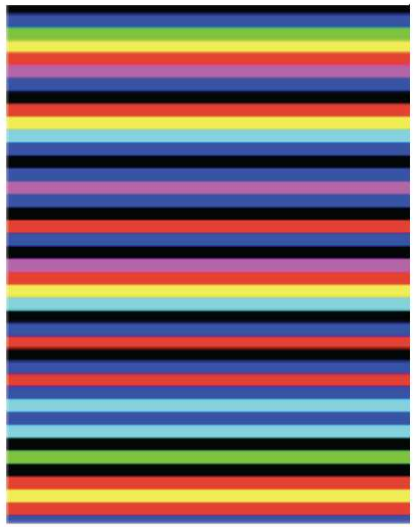
305-1847 West Broadway, Vancouver, B.C., Canada V6J 1Y6 T: +604-730-9937 F: +604-732-8231

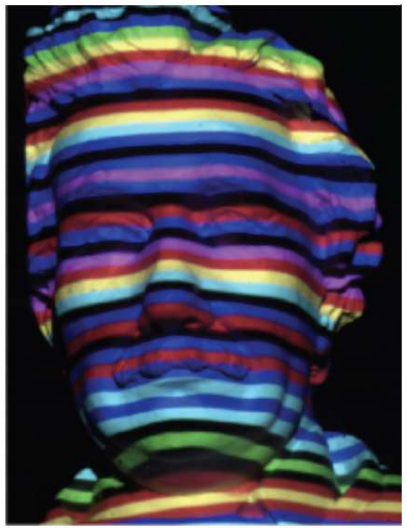
Point Grey Research (PGR) is a worldwide leader in the development of advanced digital camera technology products. Based in Vancouver, British Columbia, PGR designs, manufactures and distributes IEEE-1394 cameras, stereo vision cameras and spherical digital video cameras to a broad spectrum of industries. Through a close working relationship wtih its customers, PGR continues to be at the forefront of innovation.

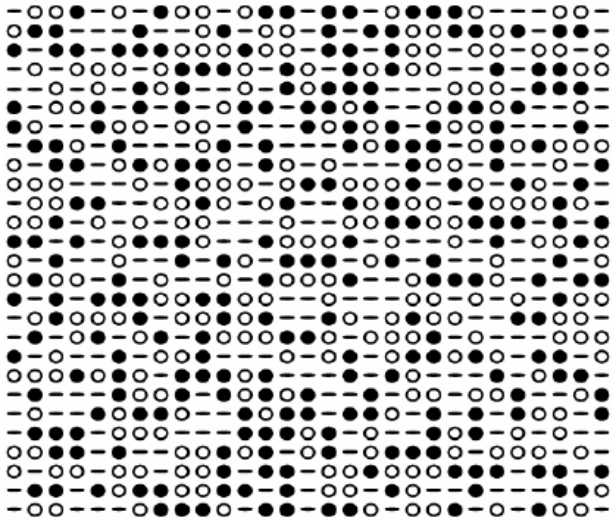
Structured Light 3D Surface Imaging

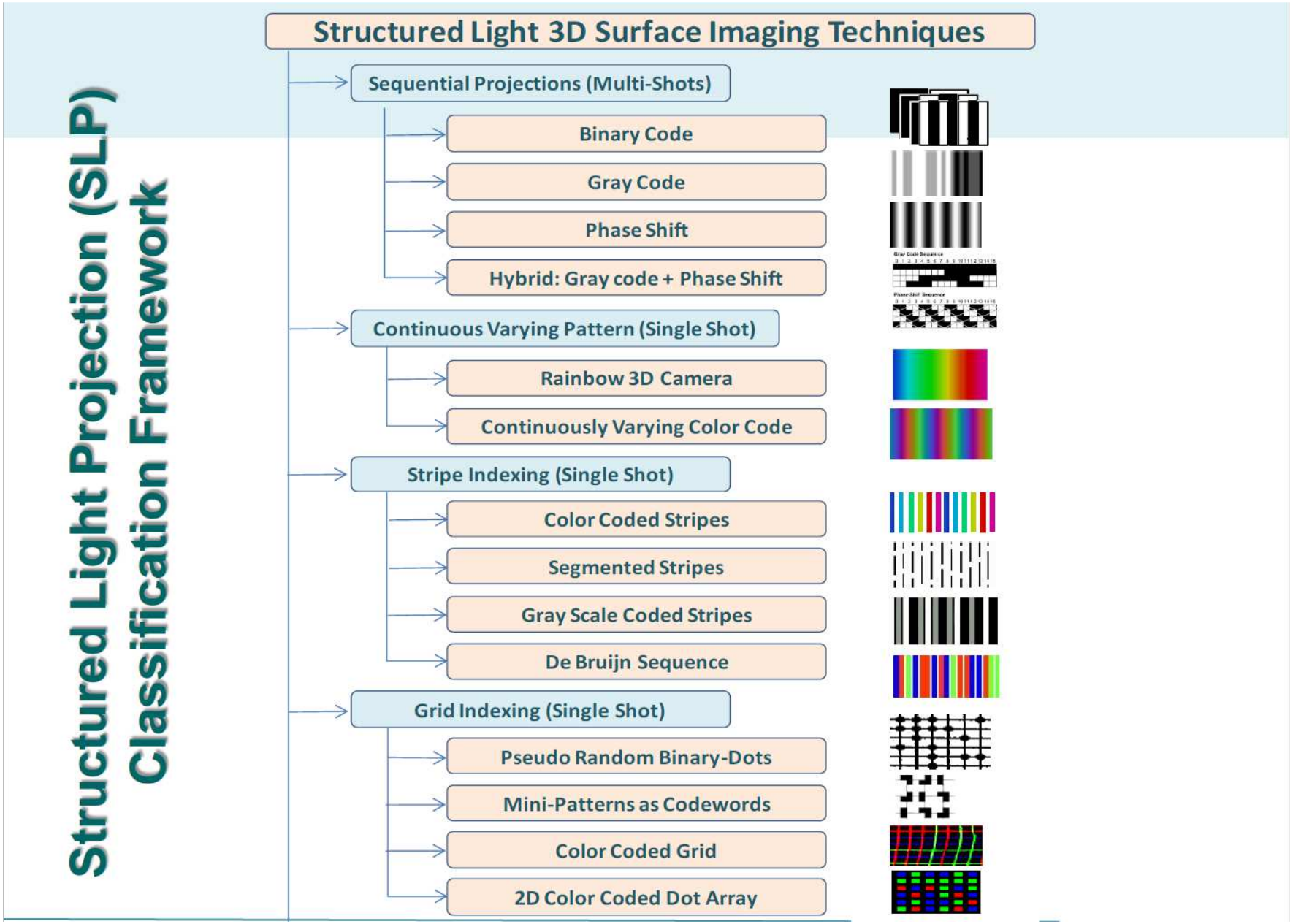











Structured Light 3D Surface Imaging Techniques
Structured Light Projection (SLP) Classification Framework
Sequential Projections (Multi-Shots)
Binary Code
Gray Code
Phase Shift
Hybrid: Gray code + Phase Shift
Continuous Varying Pattern (Single Shot)
Rainbow 3D Camera
Continuously Varying Color Code
Stripe Indexing (Single Shot)
Color Coded Stripes
Segmented Stripes
Gray Scale Coded Stripes
De Bruijn Sequence
Grid Indexing (Single Shot)
Pseudo Random Binary-Dots
Mini-Patterns as Codewords
Color Coded Grid
2D Color Coded Dot Array

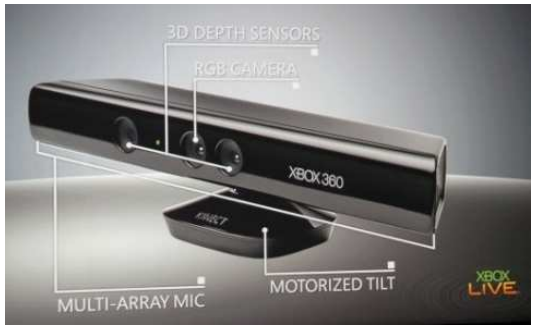
Kinect for XBox

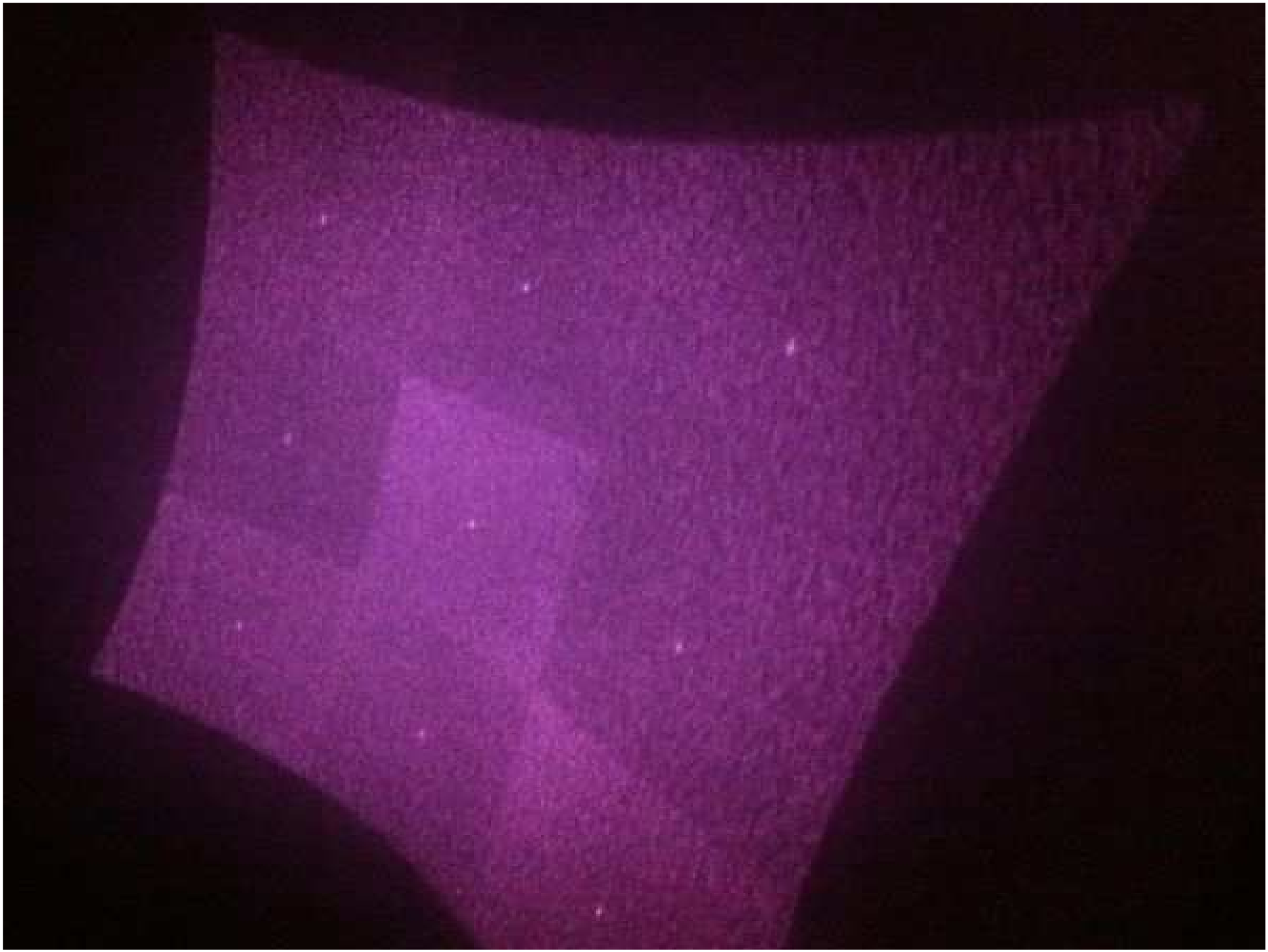
http://www.microsoft.com/en-us/kinectforwindows/discover/features.aspx

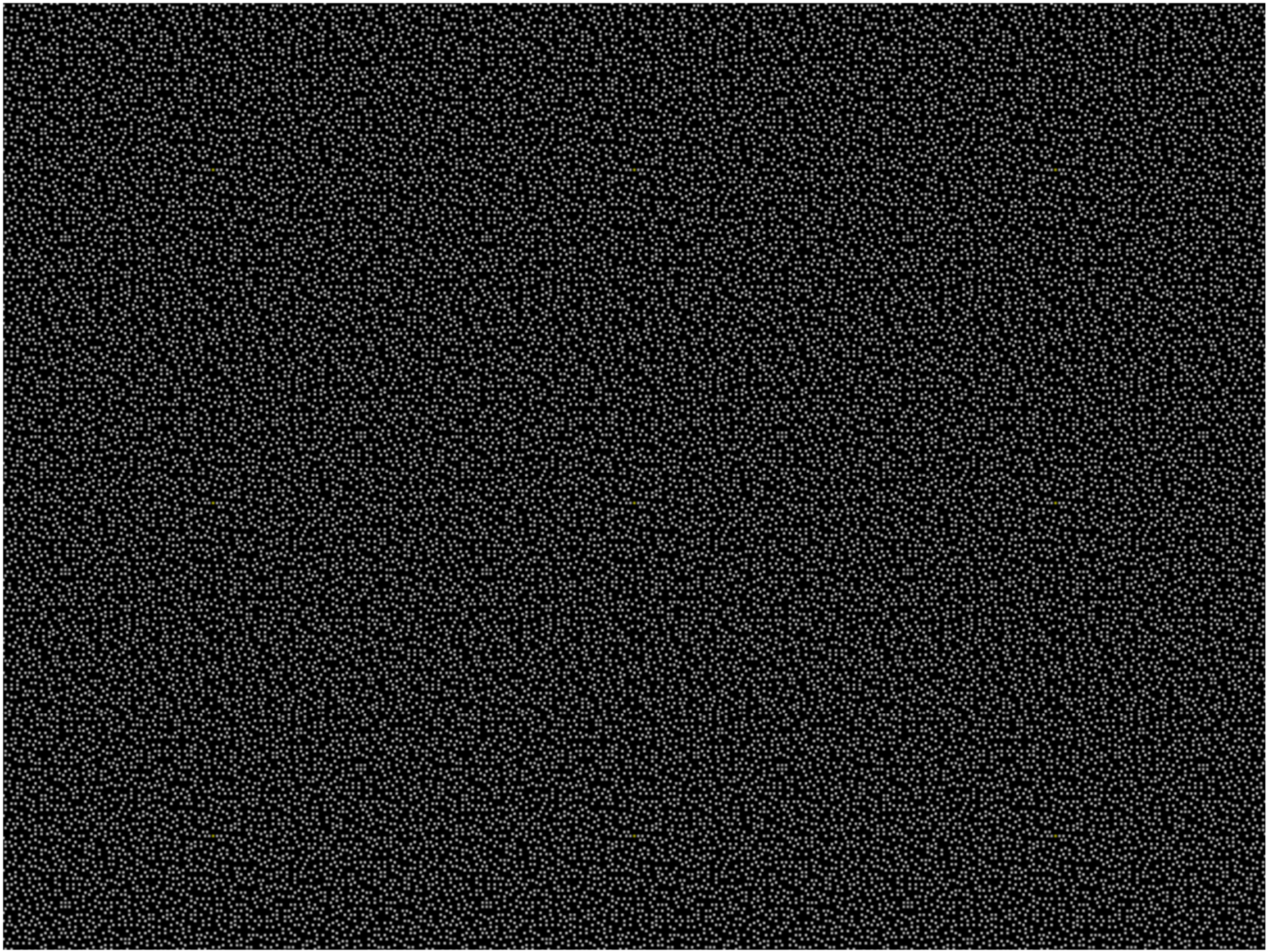
What is Kinect?

- Motion sensing input device by Microsoft
- Depth camera tech. developed by PrimeSense Invented in 2005
- Software tech. developed by Rare
- First announced at E3 2009 as "Project Natal"
- Windows SDK Releases

Rare



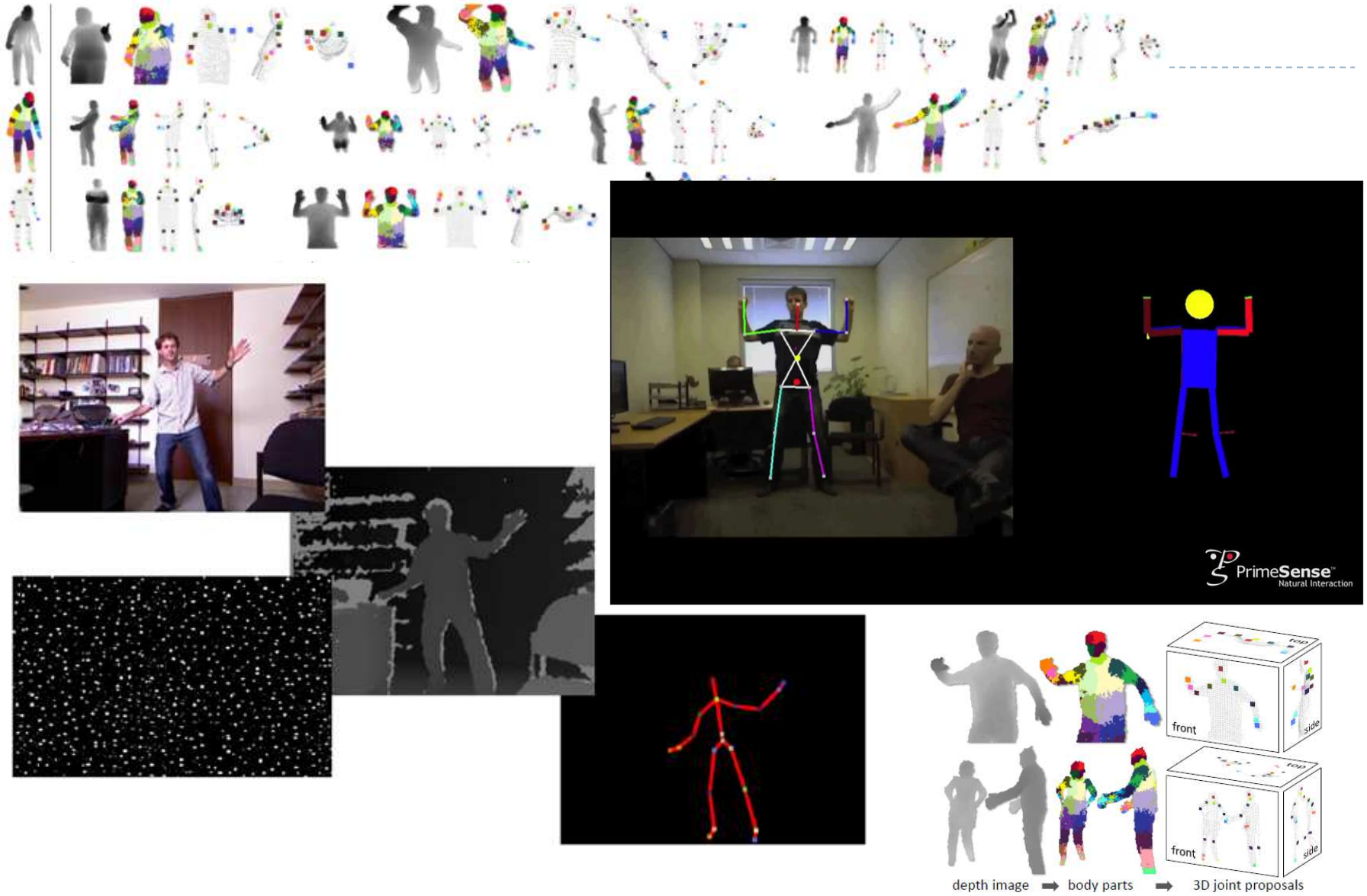




Kinect for XBox

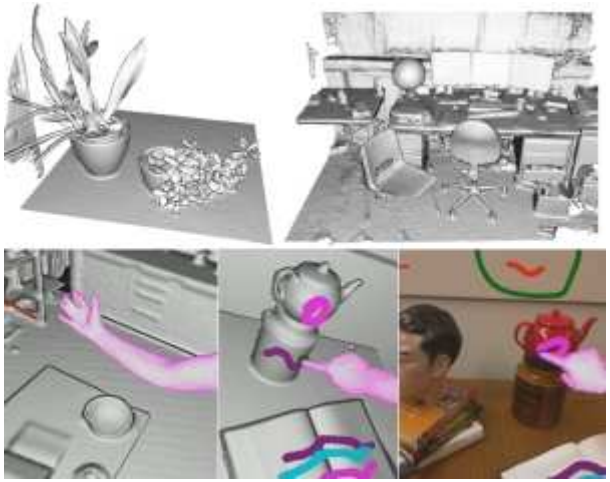
- The subpattern is 211 x 165, totalling to 633 x 495 spots, sensor chip with SXGA resolution (1280 x 1024)
- Both dimensions are odd numbers, so that there can be a central bright spot.
- The number of (bright or dark) spots inside the subpattern region is 34,815.
- 3,861 of them are bright 0.1109 = 1 / 9.017094. Therefore, on average every 3×3 region there is one bright spot.
- No bright spots are 9-connected.
- No repetitive structures.
- Always 4 bright spots per 6×6 spots
- Each bright spot is surrounded by dark spots. the number of spots per pixel is constant, a local thresholding operation could be implemented, that quickly filters out the spots in the sensor image, and converts it in a binary image for easy neighbor extraction and ID computation.
- The average brightness looks quite constant.
- A small region of spots, that is unique within the whole pattern
- Depth or disparity is finding the ID in a reference image.

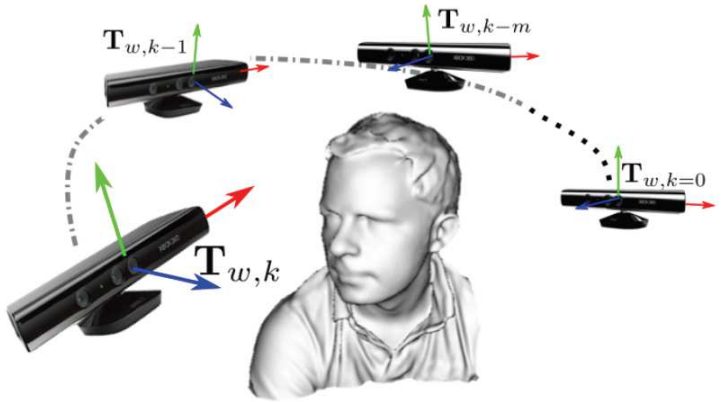
Real-Time Human Pose Recognition in Parts from Single Depth Images, Jamie Shotton Andrew Fitzgibbon Mat Cook Toby Sharp Mark Finocchio, Richard Moore Alex Kipman Andrew Blake, Microsoft Research Cambridge & Xbox Incubation

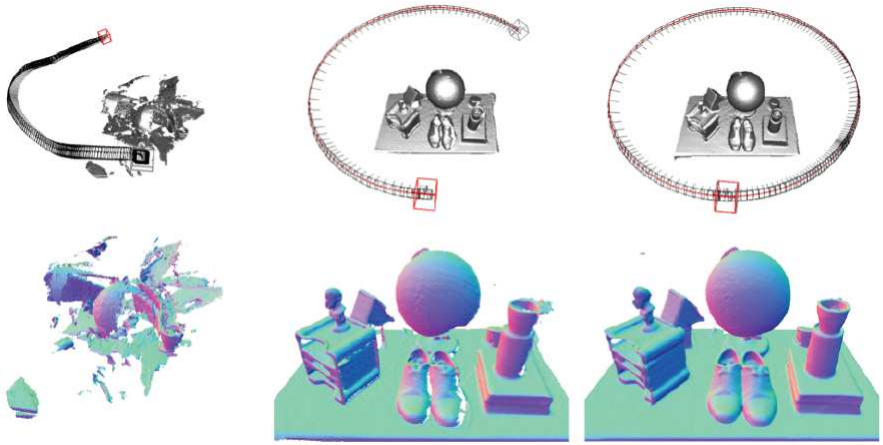


http://research.microsoft.com/en-us/projects/surfacerecon/

KinectFusion







(a) Frame to frame tracking (b) Partial loop (c) Full loop

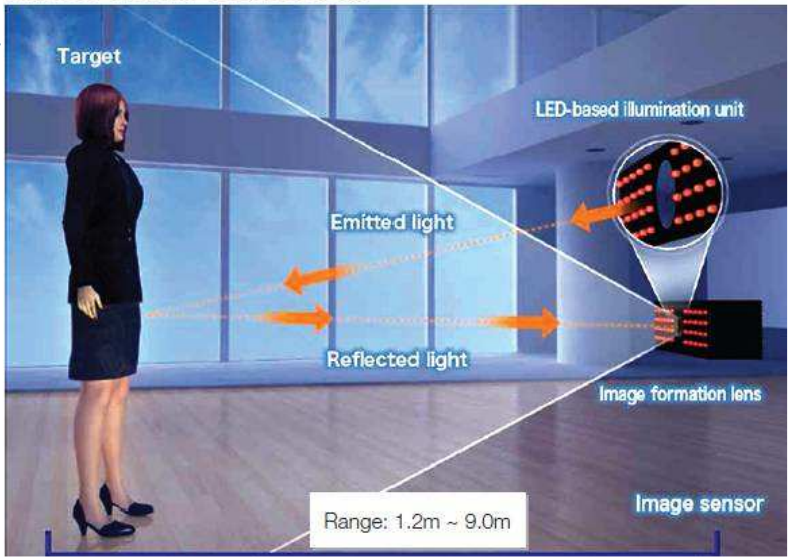
ToF 3D Camera

Time of flight cameras

3DV ZSense

3DV, Canesta (no-longer public)
PMD Technologies http://www.PMDTec.com
Mesa Technologies http://www.mesa-imaging.ch

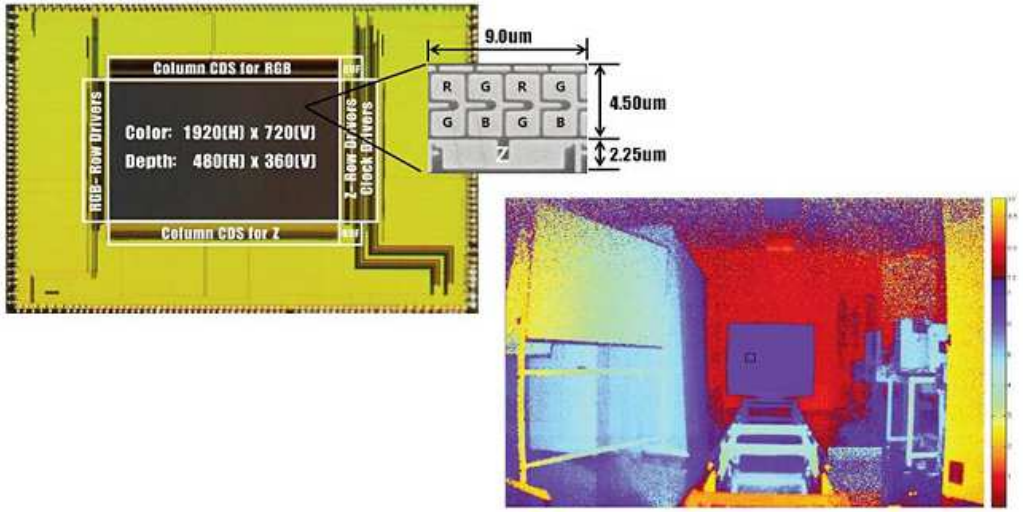
TIME-OF-FLIGHT TECHNOLOGY



The Mesa Imaging SwissRanger 4000 (SR4000) is probably the most well-known ToF depth camera. It has a range of 5-8 meters, 176 x 144 pixel resolution over 43.6° x 34.6° field of view. It operates at up to 54 fps, and costs about $9,000. I've seen these used in a number of academic laboratories.

The PMD Technologies CamCube 2.0 is a lesser-known, but equally impressive ToF depth camera. It has a range of 7 meters, 204 x 204 pixel resolution with 40.0° x 40.0° field of view. It operates at 25 fps, and last time I checked, it costs around $12,000.

DepthCamera@Samsung



GUTS

New Camera Sensor Captures Images and Depth Data At the Same Time

BY ANDREW LISZEWSKI FEB 29, 2012 4:00 PM

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Samsung has developed what they're touting as the world's first sensor that can capture both an RGB and range (or depth) image at the same time, granting Kinect-like gesture recognition capabilities to a host of devices.

The new CMOS sensor uses an array of red, blue, and green pixels that sit alongside the depth-recording z-pixels, which are four times as large. As a result, the sensor can only capture images with a resolution of 1,920 x 720, while the depth map is limited to just 480 x 360.