Visualization Technologies

IGS HT 2003

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Displays

Additional Reading

Roy S. Kalawsky: The Science of Virtual Reality and Virtual Environments
Addison-Wesley Publishing Company, 1993, ISBN 0-201-63171-7

Perception: pages 50-59

Displays techniques: pages 98-107

Physiological Aspects

Spatial Retinal Resolution : 1´

Visual Field : approx. 200°, with 120° binocular overlap

Limits of depth perception from lateral disparity

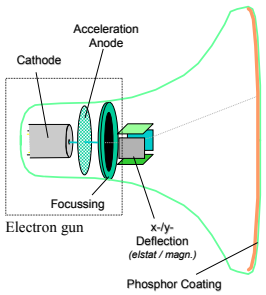
Temporal Resolution : approx. 50 Hz, increasing with luminance

Visual Displays - Basic Technologies

- Cathode Ray Tubes
- Flat Panel Displays
  - Electroluminiscence Displays
  - LCD Displays
  - Active Matrix TFT
- Light Valves
- Laser Scanners
- Micro Mirror Devices

Basic Technologies - Cathode Ray Tubes (CRT)

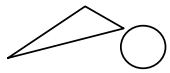
Advantages:
- high resolution
- easy to control
- reliable technology
- low cost



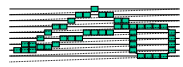
Basic Technologies - Cathode Ray Tubes (CRT)

Operation modes of CRTs:

Random scan mode



Raster scan mode

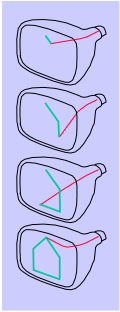


Basic Technologies - Random Scan CRT

How it works:

Display *primitives* are stored in a display list (ellipses, circles, lines...)

Electron beam is controlled continuously between vertice -> analog line drawing



+ no aliasing, smoth lines
+ transformation in hardware possible
+ little memory required

- only line drawing possible
- complex control hardware for the beam
- flickers if scene becomes complex

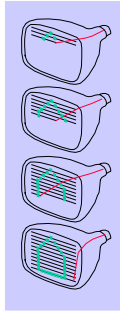
Basic Technologies - Raster Scan CRT

How it works:

Display is rasterized into pixels which are stored in a two-dimensional memory array (raster memory)

Electron beam is traversing the screen line by line in a regular time frame and scheme

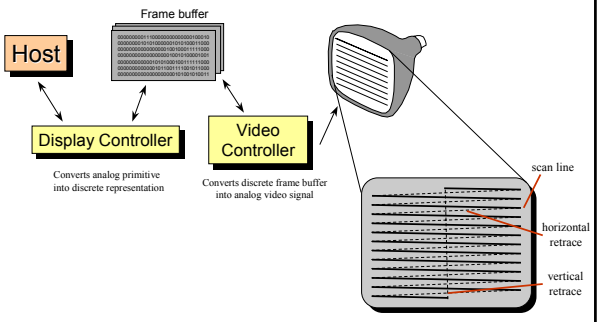
Content of the raster memory controls beam intensity



+ uses old TV technology (simple approach)
+ filled and shaded surfaces are possible
+ guaranteed screen refresh rate

- aliasing problems “staircase effect”
- electronics required for raster memory readout
- drawing algorithms more complex

Basic Technologies - Raster Scan CRT



Basic Technologies - Cathode Ray Tubes (CRT)

The role of the phosphor coating :

- **Fluorescence** (glowing when hit by electron beam)
- **Phosphorescence** (after glowing while being activated)
- **Persistency** (time until glowing phosphorescence decreases below 10%) typically 5-60 milliseconds.

- Persistency is important. Short persistency requires high update rates otherwise flicker. Long persistency causes stabile but smeary images.

- **Granularity** of the phosphor -> spot size, image resolution

- **Type of phosphor** defines color:
  p1 : green, average persistency
  p4 : white, short persistency
  p12 : orange, average persistency
  p31 : green, short persistency

Basic Technologies - Cathode Ray Tubes (CRT)

How is color accomplished in displays ?

Most usually, colors are mixed by additive composition of base colors

1. Spatially modulated color composition

see also page 99, in Kalawsky

2. Temporally modulated color composition

see next slide

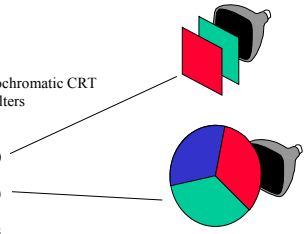
Basic Technologies - Cathode Ray Tubes (CRT)

How is color accomplished ?

Color shutter technology.

- Sequential display of color fields on monochromatic CRT
- Synchronization of the fields with color filters

- Filters can be :
  a) LCD filters (electronically controlled)
  b) Optical filters (mechanically coupled)

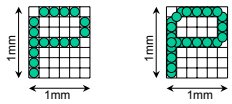


- Advantages : No color convergence errors

- Disadvantages : High frequent oscillations in the visual field decompose colors

Parameters for display assessment

- dot size (mm)
- dot pitch (mm)
- resolution (lp/mm)
- brightness (cd/m^2)
- contrast ratio
- display size
- addressability
- refresh rate
- color range
- convergence
- weight / power consumption



dot size ?
dot pitch?
resolution?

Basic Technologies - Typical parameters for CRTs

Screen Diagonal Size (14"-26")

Shadow masks (Triple holes, Strips)

Dot pitch (0.24 - 0.30 mm)

Video bandwidth (50 -250 MHz)

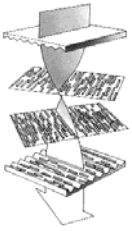
Horizontal Sync. Frequency (30 - 170 kHz)

Vertical Sync. Frequency (48 - 170 Hz)

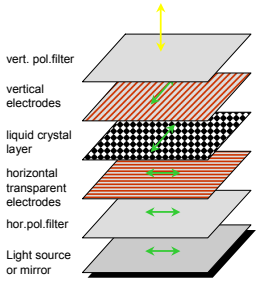
max. Resolution (1280x1024 - 4800 x 4000)

Basic Technologies - Flat Panel Display - LCD

Liquid Crystal Displays



No electric field = light passes through



Basic Technologies - Flat Panel Display - LCD

Addressing of Pixels:

Deposit an electronic charge on intersections between horizontal and vertical electrodes sequentially row by row.

Limited speed, since certain minimum time is required to is deposited (depending on the capacity of the intersections)

When last row has been addressed, first rows have already lost their electric charge

Poor contrast image

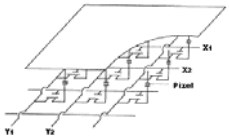
Basic Technologies - Flat Panel Display

Thin Film Transistor Matrix (TFT):

An array of transparent transistors is deposited on the LCD

Pixels can be switched on and off

Pixel keep their electrical state and optical properties



=> Significant contrast and intensity enhancements

Basic Technologies - Flat Panel Display

Color reproduction / Optical Efficiency:

Groups of adjacent pixels are forming one effective color pixel

Sub-pixels are covered with color filters

Common sub-pixels configuration are RGB stripes, triads or quads

Efficient resolution is reduced

Light intensity is diminished significantly when passing through polarizes, liquid crystals, and color filters (poor optical efficiency)

(see also page 96)

Basic Technologies - Flat Panel Display

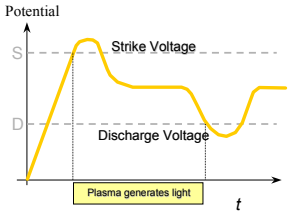
Electro Luminescence Displays (plasma panel displays):

Gas is encapsulated between electrodes

When a certain amount of voltage is applied (striking voltage) the plasma discharges and glows until the potential drops below the discharge voltage.

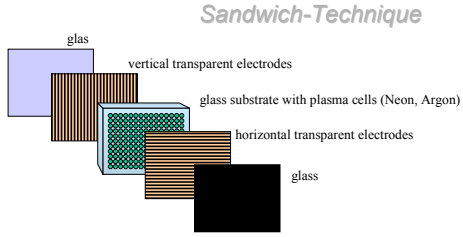
Plasma cell keeps “glowing” for a while without being refreshed.

Active luminance, high intensity display



Basic Technologies - Flat Panel Display

Electro Luminescence Displays (plasma panel displays):



Basic Technologies - Light Valves

Application : Projection Displays

High resolution light modulation (>1600 x 1200)

High refresh rates possible (>130 Hz)

Usable for high light output projection displays

The **first choice** for stereo projection systems

Tricky problems : Ghost images with slow phosphor

see page 103 in Kalawsky

Basic Technologies - Laser Scanner

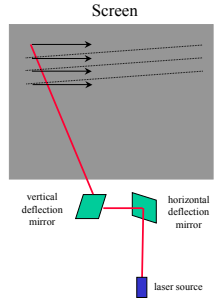
Used for:

large screen projection displays

direct retinal displays

(very high resolution)

for color displays, several lasers required (convergence ?)



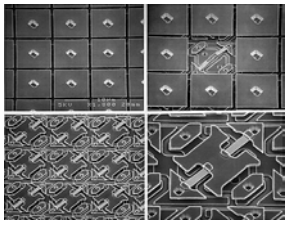
Basic Technologies - Micromirror Devices (MMD)

Matrix of micro mirrors

Addressable and electronically controllable

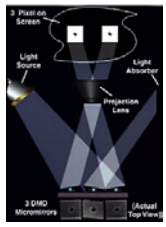
Used for Light Reflection and Projection Display Systems

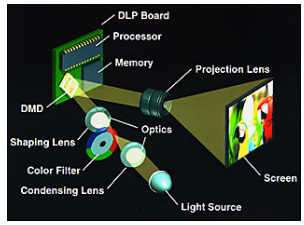
Extremely high ***optical efficiency***



Basic Technologies - Micro Mirror Devices (MMD)

MMD System Working Principle

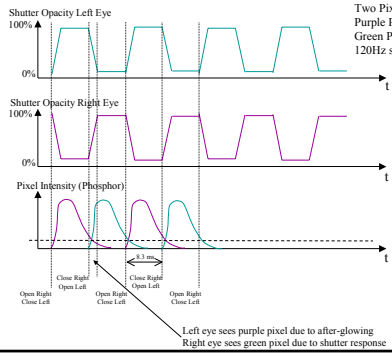




3D Display Categoriess

- Stereographic Displays (2 projected planar views)
  - Dual Display Immediate Mode
  - Single Display Plane Multiplexed
    - Temporal MUX
    - Spatial MUX
    - Chromatic MUX
    - Polarization MUX
- True Volumetric Displays

Temporal Multiplexing and "Ghosting"



Two Pixels are Drawn On-Screen:
Purple Pixel for the Right Eye
Green Pixel for the Left Eye
120Hz screen refresh rate

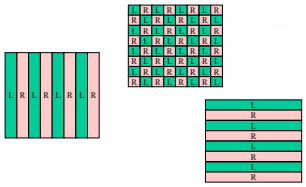
Spatial Multiplexing

The stereo image pair is imaged on alternating pixels, pixel columns, or scan-lines.

Optical arrangements are used to block-out the the wrong image for the corresponding eye.

Effective resolution is reduced.

Simply clip on your micropol glass over your LCD screen and have instant 3D stereo viewing!



VR-3100

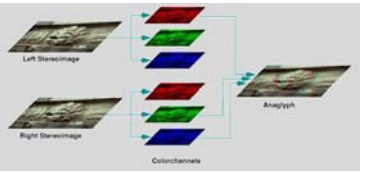
Chromatic Multiplexing

Encoding:

A stereo image pair is combined into one so called anaglyph.

The left eyes view is encoded with the red colour component.

The right eye view is encoded with the complementary colour i.e. green And blue colour components.

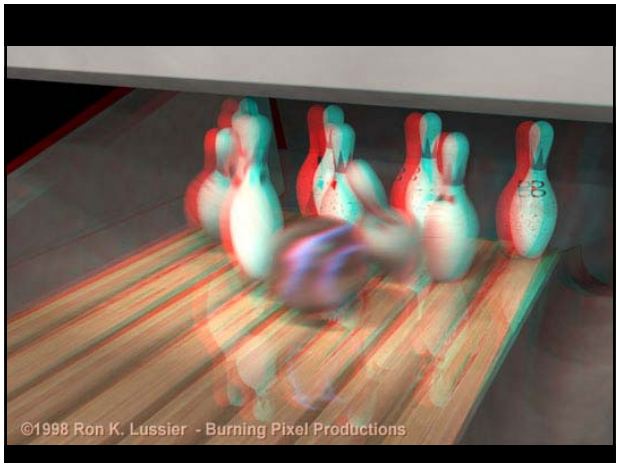


Decoding:

The left eye uses a red colour filter that passes through dominant red components.

The right eye uses a cyan colour filter that passes through dominant blue And green components.

Images curtsey: http://axon.physik.uni-bremen.de/research/stereo/color_anaglyph/index.html#ana



Light Polarization Multiplexing

Tavla

Combined Temporal and Filter Multiplexing

The stereo image pair is displayed on-screen using a time multiplexing scheme.

The Z-Screen is an active optical polarizer, that alternates the direction of the transmitted light.

The user wears passive glasses that do not need synchronization.

Monitor ZScreen 2000i
with integrated electronics:
- **Light Transmission:** 32% ← Observe: Loss of luminance
- **Field Rate:** 40Hz to 200Hz
- **Height:** 17.25"
- **Width:** 20.125"
- **Depth:** 3.25"
- **Viewing Area:** 15.5" x 11.75"
- **Weight:** 4.2 lbs. (without cables)
- **Frame Material:** Extruded Box Section Aluminum in plastic bezel
- **Operating Temperature:** 0°C to +70° C
- **Storage Temperature:** -50°C to +125°C
- **Power Supply:** 18 VAC, 2VA

3D Displays and Optical Systems - Projection Systems

3D Projection Display Systems require:

Very high intensity image source
- Transmission LCD/TFT Panel + Light Source
- Reflection LCD/TFT Panel + Light Source
- Projection CRT (specialized high intensity CRT tube)
- MMD
- Light Valve
- (Laser)

Focusing optics/color splitter
- Wide / narrow angle optics, fixed or variable

Projection screen
- Transparency / Diffusion / Specular Properties

Means of splitting left/right channel
- Time Multiplexing / Chromatic Separation / Light Polarization

3D Displays and Optical Systems - Projection Systems

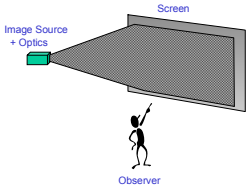
3D Front Projection Systems:

Image source and observer are located on the same side of the projection surface (- user may interfere with projection beam)

Stereo 3D with *active shutter* glasses
- requires very fast image source (>120 Hz)
- light valve / projection CRT
- extremely expensive
- single graphics pipeline
- screen with good diffuser properties

Stereo 3D with *passive polarizing* glasses
- requires two image sources
- image alignment problems
- dual graphics pipeline required
- requires *special silver* screen which preserves polarization

Stereo 3D with color field separation (red/green)
- one color capable projector (cheap)
- poor image result
- screen with good diffuser properties



3D Displays and Optical Systems - Projection Systems

3D Rear / Retro Projection Systems:

Image source is positioned behind the projection screen

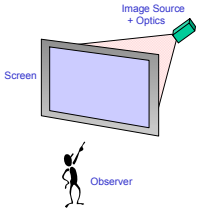
No interference between user and image source

Requires transparent screen material

No polarized 3D stereo possible since polarization is disturbed in transmission

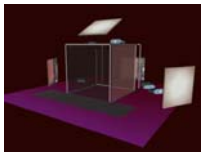
Stereo 3D with active shutter glasses
- requires very fast image source
- light valve / projection CRT
- expensive
- single graphics pipeline

Attention must be paid to mirror effects (nowadays in HW)



3D Displays and Optical Systems - Projection Systems

3D Rear / Retro Projection Systems: Examples



Caves

Virtual Planes

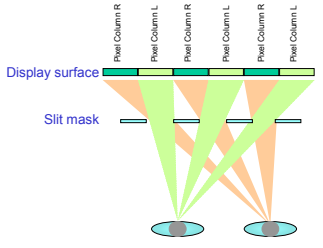
Viewing wands

3D Displays / Optical Systems - Autostereoscopic Displays

Autostereoscopy - stereoscopic perception with the "naked" eye

Image Splitter (e.g. Sanyo)

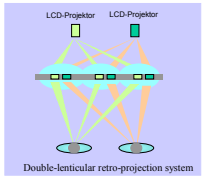
- Display divided in vertical stripes
- Alternate stripes display left and right image
- Slit-mask is blocking out the view of the left eye onto the right picture and vice versa
- Only a single user
- Dedicated observer position
- Horizontal resolution decreased



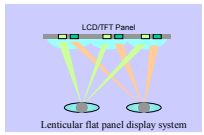
3D Displays / Optical Systems - Autostereoscopic Displays

(Double) Lenticular Lens Arrays

- Display divided in vertical stripes
- Alternate stripes display left and right image
- Half-Cylinder shaped lenses project the stripes to the corresponding eye
- Several viewing zones
- Dedicated observer distance
- Horizontal resolution decreased



Double-lenticular retro-projection system



Lenticular flat panel display system

3D Displays / Optical Systems - Autostereoscopic Displays

Examples (Heinrich-Hertz Institute, Berlin)

- Allows for user movements
- Uses head-tracking
- Screen is automatically positioned correctly with a robot arm

- Allows for user movements
- Uses head-tracking
- Lenticular array is shifted

3D Displays / Optical Systems - Volumetric Displays

The display creates a real volumetric representation which is perceived as a 3D structure without the need for glasses or other aids.

The idea is to project dynamic images onto oscillating or rotating surfaces in order to create the sensation of a volumetric object.

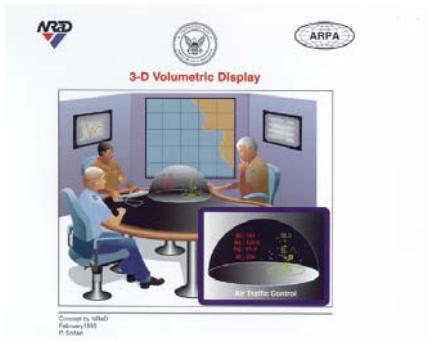
Prototypes have been build using:
- rotating LED matrices
- rotating helical projection surfaces with laser projection laser
- lasers projecting into fog
- experiments are underway to bring a solid crystal to illumination on addressable positions

All these systems can only show transparent/monochrome objects

Mechanical problems and limits, dead viewing areas

Commercial systems are far ahead

3D Displays / Optical Systems - Volumetric Displays



Choice of VR Displays - Evaluation of Requirements

How many observers are watching at the same time ?

What resolution and color fidelity requirements are there ? -> basic display technology

Is wide field of view desirable ?

Is immersion an important issue for the application ?

Is stereoscopic 3D rendering required ?

If yes, decide which type
- one screen polarized -> take care for optical properties of the system
- one screen time multiplexed -> display must tolerate high refresh rates
- dual screen (HMD) -> check for resolution
- autostereoscopic ?

Does the application require interaction with haptic stimuli ?

Displays Technologies - Features

	CRT	LCD	TFT	MMD	Lightwalv
Addressability	4 kPixel	2 kPixel	2 kPixel	1.3 kPixel	4 kPixel
Contrast	high	low	high	high	high
Colors	very good	medium	good	very good	very good
Dimensions	huge	small/medium	small/medium	small	medium
Refresh	<180 Hz	60 Hz	60 Hz	60 (180Hz)	140 Hz
Costs	low	average	high	high	very high

3D Displays and Optical Systems - Projection Systems

Considerations with regard to stereo image projection

Time-multiplexing with active shutters:

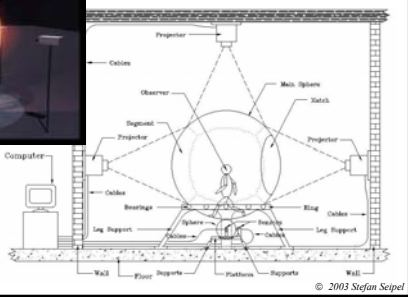
- both front and retro projection possible
- active glasses are quite expensive (if many are required)
- very high speed projector is required (light valve technology, expensive)

Polarized filtered images:

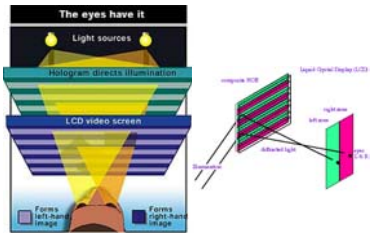
- projection screen must preserve polarization (aluminized silver screen)
- retro projection not yet possible (no suitable screen material available)
- glasses are very cheap
- two projectors are required (can cause image alignment problems)

FULLY IMMERSIVE SPHERICAL PROJECTION SYSTEM
(THE CYBERSPHERE)

http://www.ndirect.co.uk/~vr-systems/sphere1.htm



RealityVision´s autostereoscopic display
using holographic optical elements



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