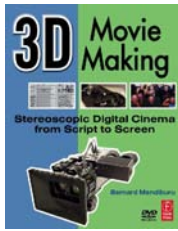


Introduction to 3D Cinematography



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Note to the reader

This set of slides are the backbone of the 3D lectures I have been giving around the world since I started speaking about 3D at Insight Media's 3D BizEx on October 2008. Since then I had the pleasure to present at NAB, IBC, SD&A, D3C, in Tokyo, Seoul, Paris, Roma, Portland, San Diego and Capetown.

If you want me to come give a lecture on 3D, I'll be happy to hear from you. I love traveling, educating and learning about 3D. So far, there have been no 3D lecture where I did not learn from the audience or from my hosts.

If you want to use this material as a starting point to build your own 3D lecture, please source it, please include a mention of my book, my publisher really appreciate this.

Talking about him, I have not yet achieved to convert them to the concept of Creative Commons, and as a result, most of the illustrations in the slides are © to focal Press. Note that some images are owned by their artist.

If you are lazy, or just don't have time, and want to use this presentation in a lecture on 3D, please contact me, I may provide you with an updated PDF or PPT.

Bernard Mendiburu, August 2010

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Plan

- [1] Human perception of depth
- [2] Stereoscopic Imaging
- [3] Filming 3D
- [4] 3D Camera Rigs
- [5] Editing 3
- [6] 3D Cinematography
- [7] Thinking 3D

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Human Perception of Depth

1

- What are the **Monoscopic** and **Stereoscopic** **Depth Cues**
- How our brain uses our **Binocular Vision** to **Fuse** images in 3D

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Depth Perception





Our Perception of Depth rely on:

- **Monoscopic Depth Cues**
 - Depth information extracted from a single image
 - Simple visual clues set the depth
- **Motion Depth Cues**
 - Depth information extracted from a single view point
 - Evolution in time is used to infer depth position
- **Stereoscopic Depth Cues**
 - Depth information extracted from comparing two view points
 - The visual cortex fuses the 2D images into 3D

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Monoscopic Depth Cues

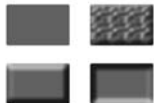
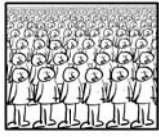
- **Occlusion**
- **Position relative to the horizon**
- **Relative Size**
- **Atmosphere Blur and Desaturation**

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Monoscopic Depth Cues

- Texture Gradient



- Cast Shadows, Specular Highlights



- Previous Knowledge of Shapes



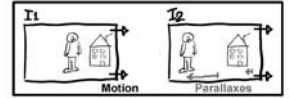
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Motion Depth Cues

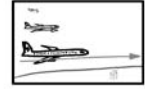
- Point of View Motion Parallax

- In many cases, the only reason why the camera is moving



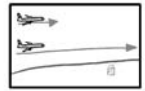
- Objects' Relative Speed

- The further away, the slower it seems to move



- Relative Speed 2

- That plane is a close-up scale model



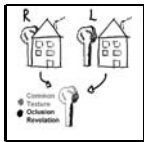
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Stereoscopic Depth Cues

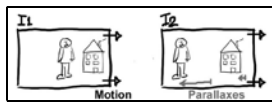
- Occlusion Revelation

- What only one eye sees



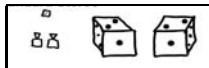
- Stereoscopic Parallax

- Position of images on retinas



- Shape Change

- Fine Depth Structure of objects



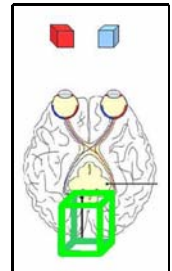
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Binocular Stereopsis

The Visual Cortex processes both images in both hemispheres

- 3D effect is generated by the differences between the two images
- Also called **Retinal Disparities**
- Our Brain creates the 3D
- **3D is a feeling, not a perception**



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Stereoscopic Imaging

2

- The **Convergence** and **Accommodation** reflexes
- What is a **Parallax** and a **Depth Budget**
- How **Inter-Ocular** and **Convergence** affects **Depth Bracket** and **Depth Position**

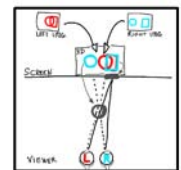
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Stereoscopic Photography

- 3D is made with two 2D images

- One picture per Eye
- Mixed Together to generate 3D
- Assets named "Left Eye" and "Right Eye".



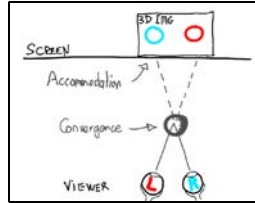
Left Eye + Right Eye = 3D Picture

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Convergence and Accommodation

- Reflex link between:
 - Eyes Sight Crossing on the object
 - Eyes Lenses Focusing on that object
- That reflex is countered in 3D
 - Focus on Screen (real image)
 - Converge on Virtual Object
 - Can't go too far, too long
 - How to assess it ?
- Theater screens are far away
 - Audience in "Hyperfocal" condition



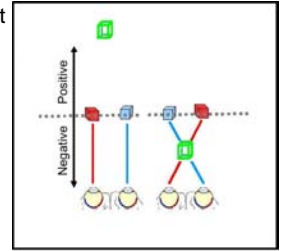
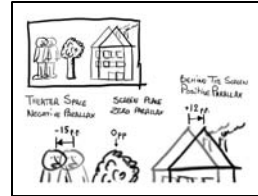
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The Stereoscopic Parallax

Distance *on the screen* between left and right images of an object

- Positive : Far Away
- Negative : "In your face" 3D

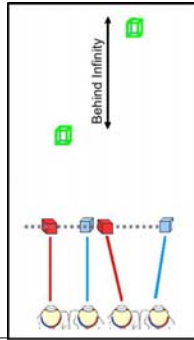


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Positive Parallax

- **Infinity Positive Parallax**
 - Equal to Eye Width, inter-pupillar distance
 - Eyes Sight is Parallel
 - Objects are perceived at approx 10m
- **Maximum Positive Parallax**
 - Objects are seen even further away
 - Eyes are Diverging, and divergence is painful
- **Effect of Positive Parallax**
 - Effect is function of screen size
 - Is slightly affected by viewing distance

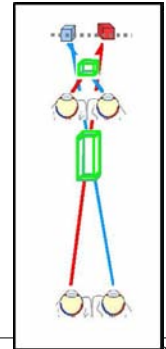


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Negative Parallax

- **Mid-Distance Parallax**
 - Equal to Eye width
 - Eyes Sight is Crossed
 - Object is seen "half way to the screen"
- **Maximum Negative Parallax**
 - Is time-sensitive
 - Objects can stay at 1x to 2x MDP
 - Move, 3x MDP
 - Fly by, 3x to 5x MDP
- **Effect of Negative Parallax**
 - Is function of the screen size
 - Is function of viewing distance

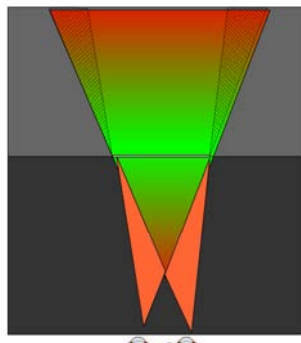


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Stereoscopic Comfort Zone

- Gray: Invisible to the audience
- Red: **Danger Zones**
 - Strong muscular activity
 - Convergence vs Accommodation
 - Do not stay too long
- Orange: **No Parking**
 - Retinal Rivalry Area
 - Move in, out and fast
- Green: **Rest Areas**
 - Close to the screen plane
 - Stripped: natural **retinal rivalry zones**



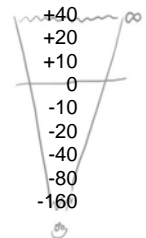
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The Depth Budget

The amount of depth available to tell your story
= (Max. Neg. Px. + Max. Pos. Px.)

- Counted in pixels
- MNP and MPP +/- 30pxls at 2K on 30'
- Actually -45 to +100 for strong 3D effect:



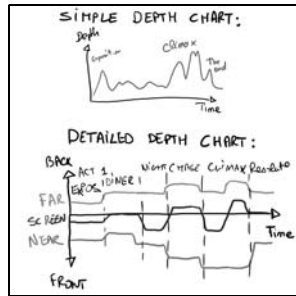
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The Depth Sript

The modulation of the depth used to tell your story

- Sets the Sequences' Depth Budget
- Needed for visual comfort
 - Alternate **Strong 3D**, **Violent 3D** with **Smooth 3D**



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Filming 3D

3

- Inter-Ocular distance and Depth Bracket
- Convergence and Depth Position

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The 3D Camera Rig

Pair of Camera on an apparatus that replicates human vision

- Matching Geometry
 - Same Camera
 - Same Lens
 - Optical Axis forming an horizontal plane
- Matching Photography
 - Same speed, shutter, color, everything
 - Pixel Accurate Genlock



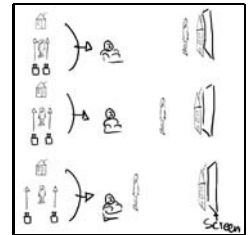
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The Inter-Ocular

The distance between the left and right camera

- Sets the Depth Bracket
 - The overall depth of 3D scene
 - Foreground to Background distance
 - Has to fit in the Depth budget
- Created on set
 - Almost impossible to change later on



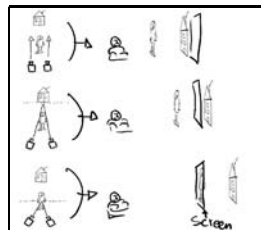
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The Convergence

Angle formed by the cameras' optical axis

- Sets the Depth Position
 - Moves the scene along Z axis
 - Does not affect Depth Bracket
 - Should keep Bracket in Budget
- Created
 - On Set: Toe-in, creates Keystone issues
 - On Set: Shifting camera's backs or lenses
 - On Post: Re-convergence, H.I.T



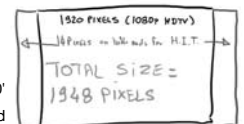
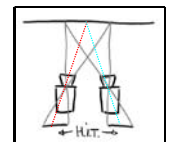
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Post Convergence

Resetting the Depth Position of a scene by shifting images

- Also called H.I.T.
 - Horizontal Image Translation
 - Set 3D to perfect depth position
- Generates NO KEYSTONE
 - It is advised to "Shoot Parallel"
 - And "Post Converge"
- Requires "Overshooting"
 - Approximately Max. Pos. Px., 30pxl @2K/30'
 - Otherwise the image is zoomed and cropped



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3D Camera Rigs

4

- Side-by-Side
- Beam Splitter
- Dynamic Rigs
- Computerized Rigs

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Side-by-side 3D Camera Rig

- Easiest to produce.
 - Make your own with two palm camera.
 - Lowest price, Limited quality.
- Wide Inter-Ocular
 - Minimum at camera width
 - Large Optics, Long focal, poor 3D



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Beam-Splitter 3D Camera Rig

- Using a half-mirror
- Camera mounted at a 90 deg. angle
- Camera shoot though a Half Mirror at 45deg.
- Inter-ocular distance down to 0mm
- Must use for close-up shots
- One to two f-stop are lost
- The mirror generates asymmetric Colorimetry
- Expensive, almost none for sale



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Using Zoom lenses

- Why in hell would we use zoom lenses ?
 - No DP like to have to change two lenses at once in a complex and fragile mechanical camera assembly.
 - BUT, no pair of zoom lenses are matched in:
 - Optical Axis (Shifts, including vertically, with zoom power)
 - Progressivity (Zoom power is not linear to ring rotation)
 - Solutions
 - Find matched lenses
 - Electro-mechanical compensations (3-axis control)

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Progress in 3D camera rigs

- 1990's
 - Electronic Camera Heads (HD)
 - Dynamic I.O and Convergence (Motion Ctrl)
- 2000's
 - Computerized Motion Control
 - Zoom L.U.T for Tele-centrism and Progressivity
- 2010's
 - Computerized Image Analysis
 - Real-Time Disparity Tracking
 - Automatic Depth Settings and Correction

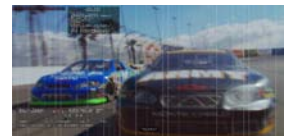


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Automatic Stereo Correction

- Real Time Image Analysis
- Detect vertical disparities
 - Motion Control Feed Back
 - Correct Rotations, Keystones
- Assess horizontal disparities
 - Compare with assigned depth budget
 - Issue Warnings to operator
 - Corrects Inter-Ocular Distance
 - Corrects Convergence, H.I.T.



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High-end 3D rigs for live 3D

- Integrated 2D/3D Camera GUI
 - Slave/Master or single camera models
 - Automatic matching of photography (Focus, Iris, Zoom...)
 - Unified Time Code, XML and Metadata records
 - Synchronous Start and Stop on Left and Right recorders on DTR
 - 3D File Naming enforcement on DDR
 - Integrated 3D monitoring
- Camera experienced as a single 3D camera
 - Productivity gains on set
 - Productivity gains on post

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3D monitoring on set

- Director
 - Anaglyph, Active and Passive 3D
- DP, camera operator
 - 50% Mix
- Convergence Puller
 - L/R Difference
 - Shows parallax and optical alignment
- Theater Screen on lot
 - Validate shots on large screen
 - Keeps VIP and stalkers away from set

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Editing 3D

5

- Editing 3D requires to manage **Depth Continuity**, and **Depth Velocity**
- Waiting for 3D editing tools we use **2D-compatible formats**, and **3D video codec**

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Edit a 3D Movie: special needs

3D movies need to be edited in 3D

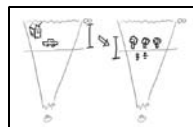
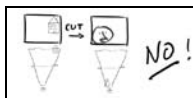
- 3D Continuity:
 - Avoid 3D "jump cuts"
 - Use of "active cuts" with dynamic re-convergence
- 3D Rhythm:
 - 3D image takes longer to read
 - 3D edit are felt being faster than 2D

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Depth Continuity

- Can't cut 3D to/from anywhere
 - Depth bracket of in/out shots should overlap
 - Otherwise
 - Stereopsis is discontinued
 - Audience suffers "double vision"
 - Suspension of disbelief is interrupted
- Active Depth Cut
 - Re-converge the in shot to the screen (H.I.T.)
 - Cut to the out shot, placed in screen depth
 - Re-converge the of shot to its original depth position
 - Keep a Constant Depth Velocity



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Depth Velocity

- In-shot Depth Velocity
 - I.O. animation for camera effects
 - Action on screen, flying objects...
- Across-Shots Depth Velocity
 - Depth Jump cuts
 - Active Jump Cuts
 - Dynamic Stereo Window Velocity
- Effect on Story Telling
 - Changes in depth position increase reading time
 - Audience can not ingest too much "depth per second"

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Edit a 3D Movie: Methods

- Previs and rough cut:
 - Use 2D-compatible assets (anaglyph, row-interleaved)
- Fine cut, FX prepping:
 - Use real 3D assets
 - If needed, uses proxies: Compressed, Side-by-side
- Final cut:
 - Edit both eyes at full resolution (two passes)
 - Third pass to generate 3D (this era is ending soon, hopefully)

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Edit a 3D Movie: New Tools

- DI and Color Grading solutions
 - Iridas, Assimilate, Da Vinci
 - Quantel Pablo, IQ...
- Avid Media Composer
 - Use 2D-compatible assets
 - Off-line rendering of left and right eyes
- Cineform's Neo3D
 - Hides second eye in Metadata,
 - Shows and 2D-compatible format
 - Retrofit any 2D app into a 3D app
 - Online Database for stereoscopic correction of shots

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3D Cinematography

6

- The 3D screen is a **Window**, and windows breaks...
- A 3D object has a **Size**, a **Volume**.
- What are **Multiple Rigs** and **Non-Realistic Depth**?

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The Stereoscopic Window

- In 3D, the screen is a **Window**
 - Defines a "Screen Space" and a "Theater Space"
 - Or "World Space" and "Personal Space"
- The frame "cut out" what is behind
 - One eye sees more than the other
 - And this is the way we see naturally
- The frame "cut out" what is in front
 - Not symmetrically on both eyes
 - AND THIS NOT NATURAL



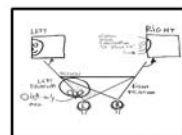
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Stereoscopic Window Violation

Occurs when an object hits the frame, in front of the screen

- The visual cortex face a dilemma:
 - Occlusion Depth Cue says "Behind the screen"
 - Parallax says "In front of the screen"
- In mild SWV, Occlusion supersedes Parallax
 - The visual cortex "Pushes" the violator behind the screen
- In strong SWV, Stereopsis is impossible
 - Fusion is interrupted
 - Audience see the double image
 - Suspension of disbelief is compromised



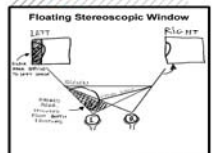
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Floating Stereoscopic Window

Virtual screen that seems to float in the theater room

- Created by masking the side of the pictures
 - Simple Black Mask
 - Asymmetrically applied on Left and Right Eyes
- That virtual screen
 - Can be set floating in the room
 - Can be pushed behind the screen
 - Can be Twisted, Bended, Rotated



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Dynamic Floating Window

- Floating Windows can be animated

- Moves the screen to follow the action
 - Remains unnoticed, even across cuts
- Moves the audience against action
 - Can be used to generate camera motion
- No continuity is needed
 - DFW jumps are unnoticed



- Metadata until the very last minute

- The director can "tune up" the 3D effects
- Powerful Depth Touch-up Tool



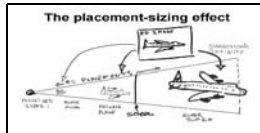
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The 3D Size Effect

- New Constraint

- A 2D image has a **Scale**
- A 3D object has a **Size**



- H.I.T. Changes the objects' sizes

- Far Away, it's a Jumbo Jet
- Inside the room, it's a Scale Model

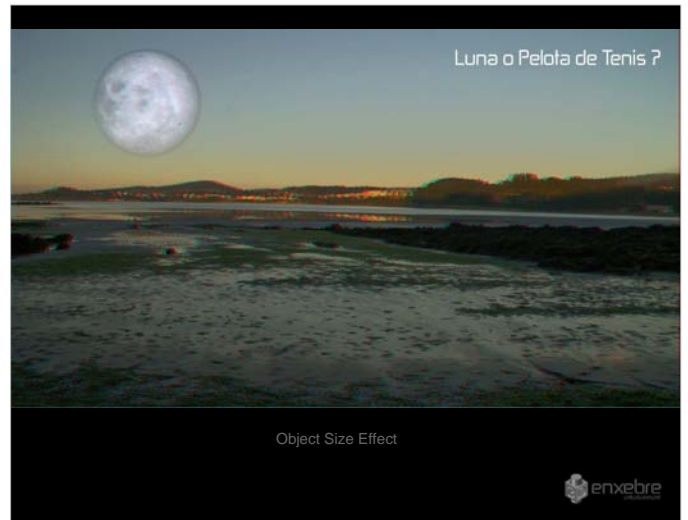
- Can be used for storytelling

- Push the Trolls
- Pull the Hobbits



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The Audience Sizing

- New Constraint

- A 2D camera has a focal length
- A 3D camera rig has a **Size**
- The audience identifies with camera size

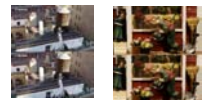
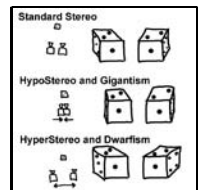
- Hyper Stereo: Audience Giantism

- Inter-Ocular set to more than Human I.O.

- Hypo Stereo: Audience Shrink

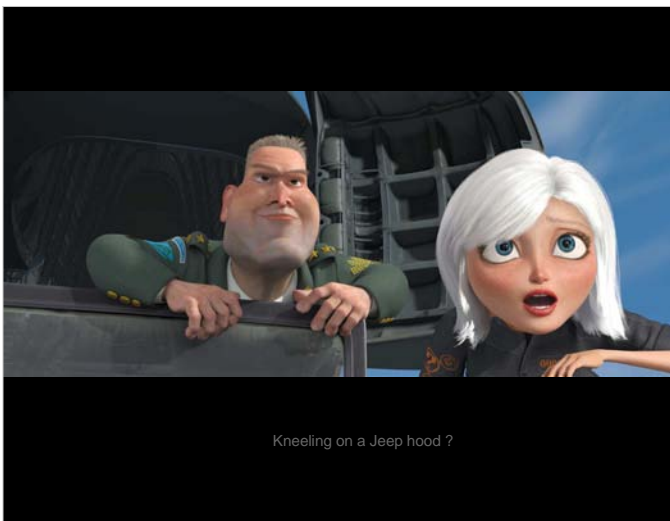
- Inter-Ocular set to less than Human I.O.

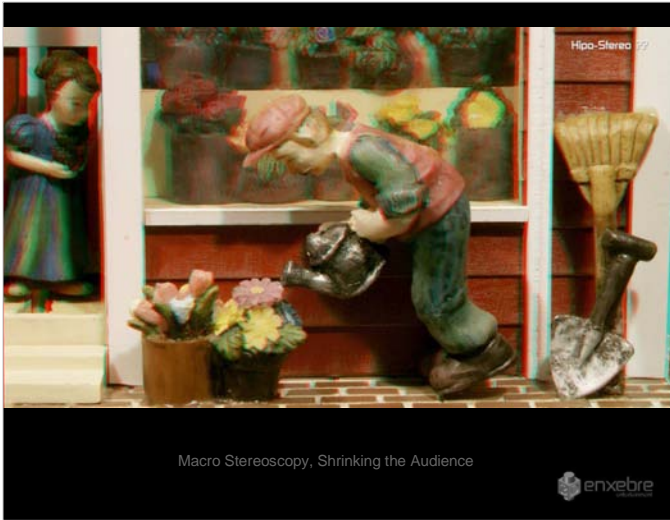
- Can be used for storytelling



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Macro Stereoscropy, Shrinking the Audience



HyperStereo, Audience Gigantism



The 3D volume

New Constraint

- A 3D object has a **Volume**
- 3D Volume** is Relative to Natural



How to assess volume ?

- Close one eye, imagine a good depth
- Open it, to compare with expectation



Effect on Lens Choice

- With Long Lenses, 3D Look Flat
 - "Card-Boarding Effect"
 - 35mm makes poor 3D, 50mm make bad 3D
- With Short Lenses, 3D Look Round
 - 25mm is good, 15mm is great

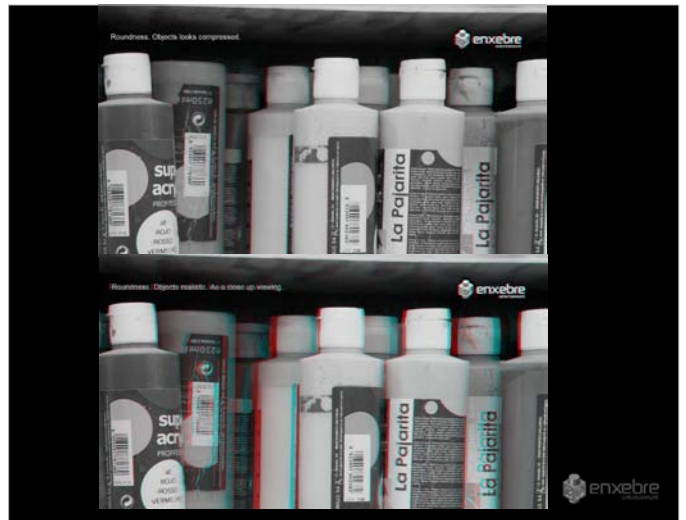


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What if you have reach the limits?

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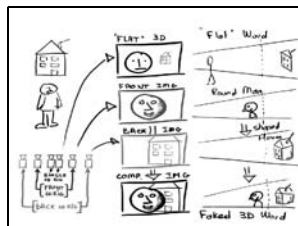


Multiple Rigs

Sets of 3D rigs of a single shot, composited together

One rig per depth setting

- Rig A for foreground
- Rig B for background
- Composited in a single 3D image
- Requires Alpha Channel



Used in

- CGI Animation: Virtual Rigs
- Live Action: Green Screen

What if you have reach the limit?

- And your image is still flat...

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2D to 3D Conversion

"We'll make it 3D for less than the cost of shooting it"

Methods

- Cut and Nudge
- Depth Maps used as Horizontal Displacement Maps
- Motion Parallax turned into Stereoscopic Parallax
- Projection Mapping on Reconstructed 3D Geometries

As simple as 2D and a Purchase Order

- "How much 3D in your coffee this morning?"

We warranty;

- NO Camera rig issues
- NO 3D settings issues

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Future: Space Warping

- Space Warping is to Depth what HDR is to Saturation
 - Depth does not have to be realistic
 - Depth has to be entertaining and enjoyable
- Short Term: View Synthesis
 - Dual Rigs = Multiple Depth Brackets
 - 2D+Depth Map = 3D (3D conversion method)
- Mid-Term: Non-Linear Depth Function
 - Integral Imaging Cameras
 - Full-Scene Photo Modelization
 - Virtualization of Camera and Optics
- "Per Pixel Inter Ocular"



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3D Movie Design

7

- Why Go 3D
- How to go 3D
- Think 3D

Take a deep breath...

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Why Go 3D ?

- Because it will serve your story
 - Otherwise, you'd better make a 2D movie
- Because it will boost the box office
 - Average 3x on per-screen revenue
 - Beware that you will soon have to fight for 3D screens
 - Cheesy 3D will not magically make money starting fall 2009
- Eventually, what sort of movie is a 3D movie ?
 - REMEMBER: **A 3D movie is NOT two 2D movies.**
 - The 2D version of Beowulf is not a single-eye flat version of Beowulf 3D. 99% of shots are different

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What does 3D add to movies?

- 3D is the natural way of seeing
 - 3D brings realism
 - 3D reduces the effort to sustain suspension of disbelief
- Presence
 - Actors are in the room
 - Unless they were "cardboarded"
- Immersion
 - There's a whole world behind the window
 - Unless it's inappropriately scaled
- New pace
 - 3D reads differently, tells your story in an appropriate way

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Depth Treatment

Integrate the 3D into the artistic development

- Decide on a treatment for the whole movie.
 - gimmicky, realist, unnoticeable, and so on
- Specify depth stamina for various acts and chapters.
 - strong, intrusive, smooth, flat, disturbing, and so on
- Think about depth placements and effects for special scenes and shots.
 - gigantism, dwarfism, close-up, far away, window breaking, and so on
- 3D script, 3D composition, 3D edit rhythm
 - Modulate 3D along the story, like music: Depth Script
 - Alternate "eye popping" and "rest areas" sequences

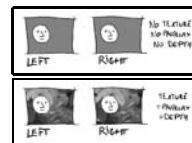
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Visual Development for 3D

Create a visual world that support 3D

- Populate it with density
 - Scarce universes feels... empty !
 - Cluttered universes reads better in 3D
- Paint it with complexity
 - Flat colors generates flat objects
 - Textured universes reads better in 3D
- Texture it with grain and bumps
 - And the light will take care of the 3D cues
- Get a nice soft ambient light
 - Flat black or white feels... flat, and settle in the screen's plane



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Think 3D

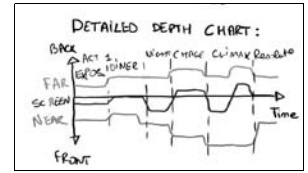
- 3D is changing the workflows
 - New Objectives, New Processes, New Tools
- 3D is changing the Cinematography
 - New Visual Grammar
- Objective : write with depth like with color, sound
 - Space : Depth Warping (non-linear depth function)
 - Time : Depth Grading (controlling depth velocity)

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Artistic Dimension of Depth

- Depth Treatment
 - Depth Strength
 - Depth Realism
 - Depth and Window Placement
- Depth Rhythm
 - Scenes' Depth Budget modulation
 - Depth Script, Scenes' Depth Budget modulation
 - Depth Distance to Action, Distance to Screen



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New Cinematographic Language

- Multiple Rigs, Non-Realistic Optics
 - Freedom from Camera and Lenses Constraints
- Stereoscopic Floating Window
 - Freedom from Screen Constraint
- Space Warping
 - Non-linear Depth Functions, Non-Realistic Geometry
- Depth Grading, Depth Continuity, Depth Scripting
 - Depth as an Artistic Tool, not a Technical Constraint
- Another 90' Lecture...

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A rare opportunity...

We are at a **rare moment** when...
The cinematographic story telling rules are revisited.

Even more;
We are escaping millenniums of flat art
... since we leaved caves to paint on walls and paper.

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How to Learn more about 3D

- Practice
 - Get a 3D Camera
 - Get Stereo Photo Maker
 - Join a stereo club, NSA, ISU
- Read,
 - 3D Movie Making Book
 - CML3D, 3DTV@yahoo, forums
- Watch
 - SMPTE PDAs
 - 3D Movies !



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The End

Questions ?

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