



Fundamentals of Stereoscopic Imaging

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PLAN



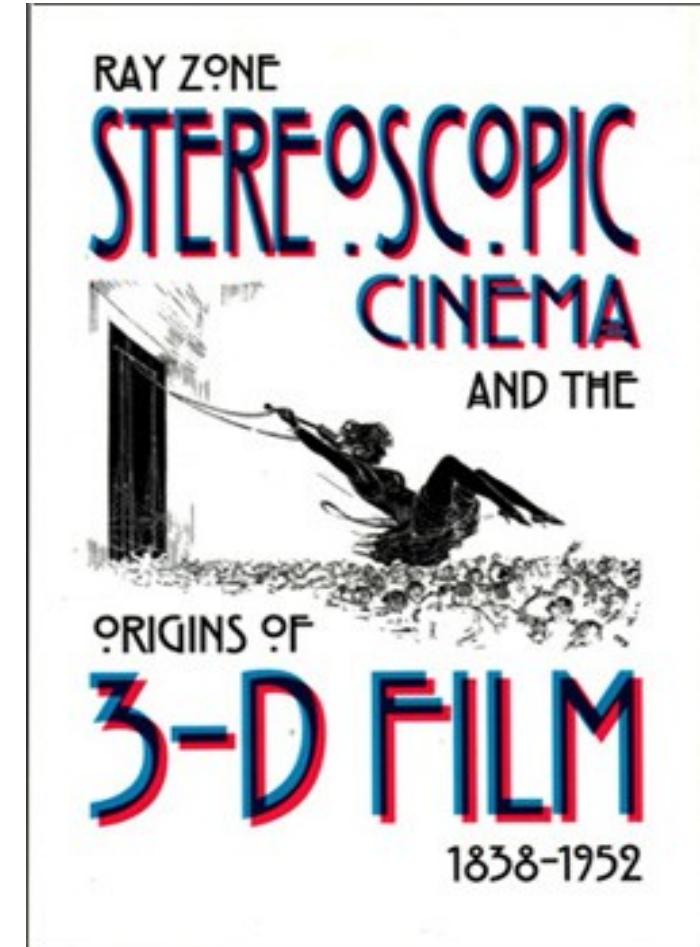
- A Few Prerequisites
- Stereoscopic Imaging:
Inter-Axial and Convergence
- Stereoscopic Cinematography:
Depth Quality and Storytelling
- Conclusion

Some 3D History

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- 3D is quite ancient
 - Wheatstone's Stereoscope, 1830's
 - 3D photography 1840's
 - 3D motion picture patent 1850's
- 50's "3D Golden Age" had;
 - Full colors, not in anaglyph (Polaroid)
 - A-list directors (Hitchcock...)
 - Big Success (Hondo)
- History of talented stereographers
 - hampered by technical complexity of 3D

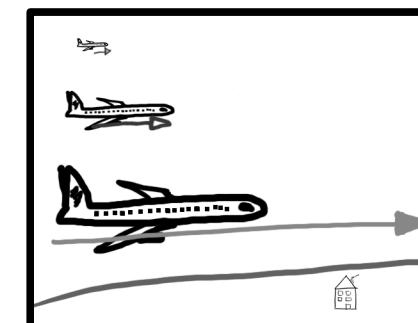
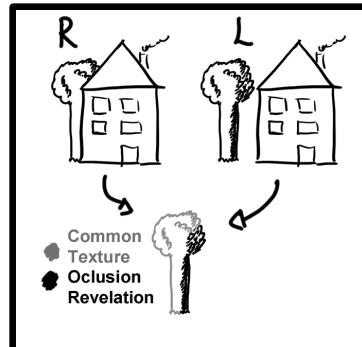
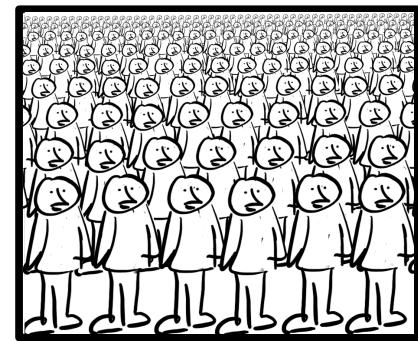
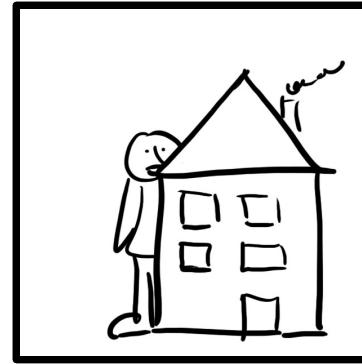


Depth Cues

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- Visual cues allowing to sort objects in relative depth
- Monoscopic Depth Cues
 - Overlap, Size, Hue...
- Motion-Based Depth cues
 - Subject Movement
 - Relative speed
 - Viewer Movement
 - Traveling and Pan
- More Powerful than Stereoscopy
 - Very efficiently used in 2D cinema

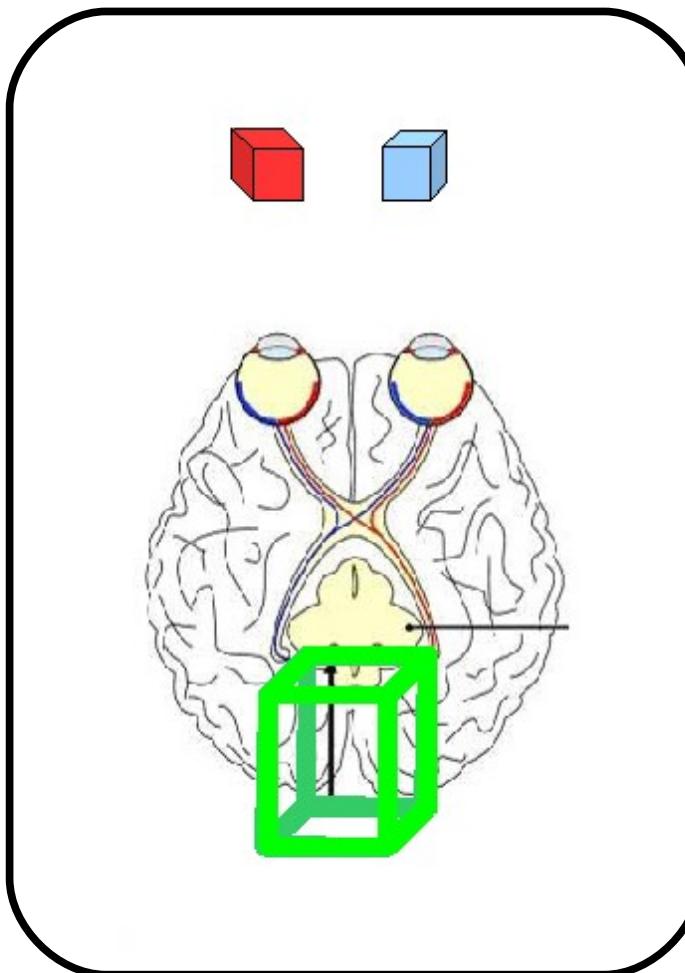


Binocular Stereopsis

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- Binocular Vision
 - Eyes see in 2D
 - Accommodation, Focus
 - Visual fields can overlap
 - Convergence, Coordination
- Stereopsis
 - The Visual Cortex...
 - Analyze the retinal disparities
 - Fuse the 2D images into 3D
 - 3D is not a perception, it's a feeling
 - Like harmony, not like color



PART 1: Basics of stereoscopic imaging

- What is a **Parallax** and a **Depth Budget**
- How **Inter-Axial** and **Convergence** affects **Depth Bracket** and **Depth Position**

Stereoscopic Projection

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- Two Images at once
 - One or two projectors
- Encoded in
 - Time
 - Polarization
 - Color
- Seen with 3D glasses

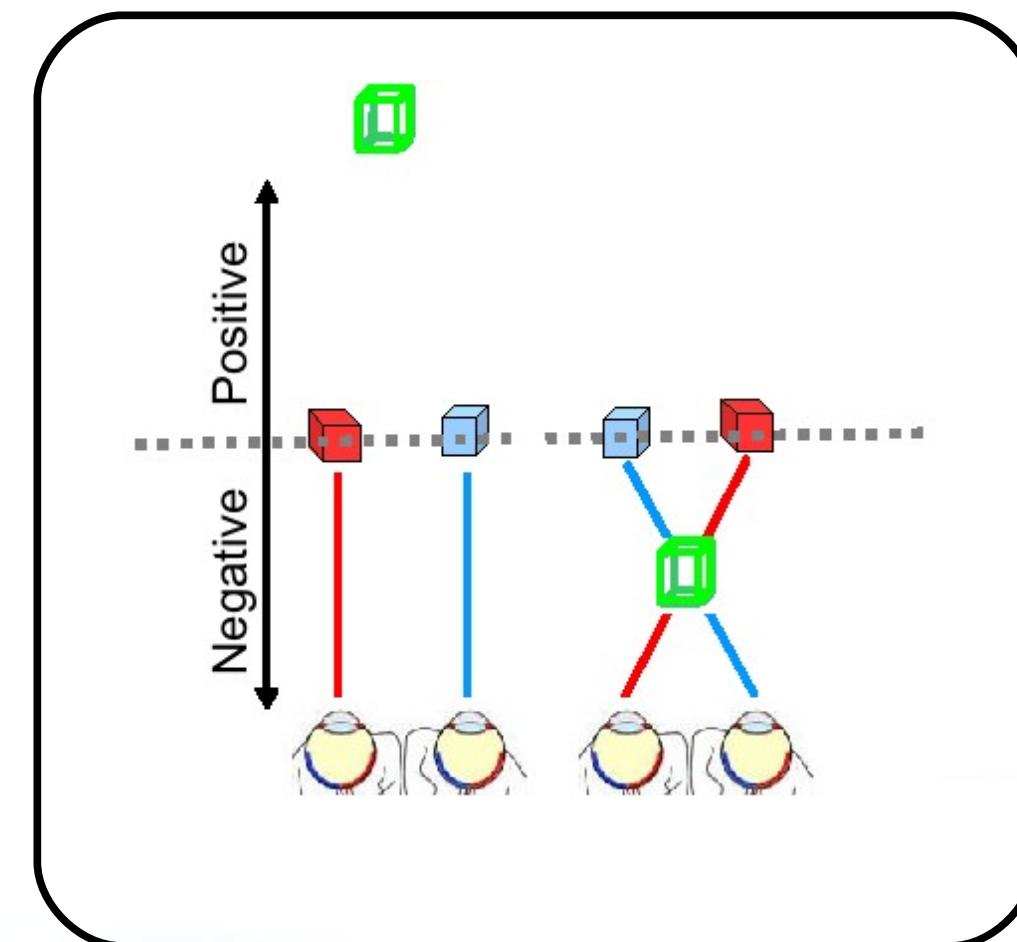


The Stereoscopic Parallax

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- Distance on the screen between left and right images of an object
 - Positive : Far Away
 - Negative : “In your face”

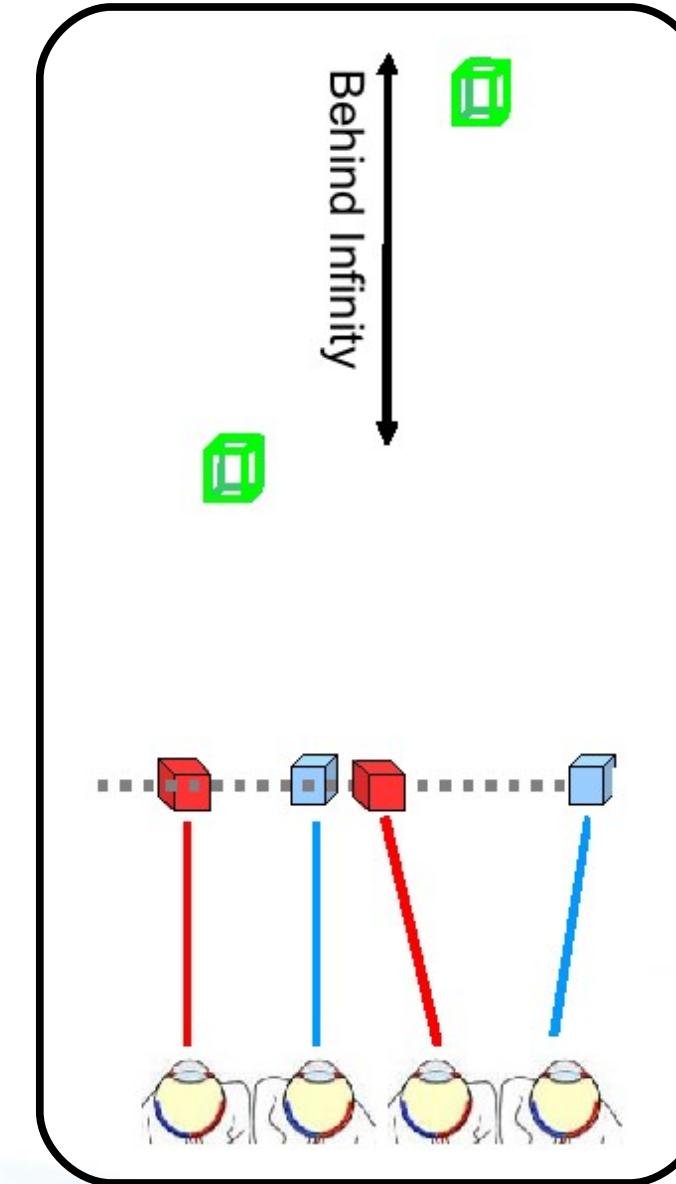


Maximum Positive Parallax

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- MPP is Equal to Eye Width
 - Eyes Sight is Parallel
 - Objects are perceived at “Stereoscopic Infinity”
- What happens beyond MPP ?
 - Objects are seen even further away
 - Eyes are Diverging, and **divergence is painful**
 - Actually we go up to twice infinity for short period of time
- MPP is function of the screen size
 - Current reference is 30 to 40 feet screens
 - What if the screen gets bigger?
 - What if you get closer to the screen?

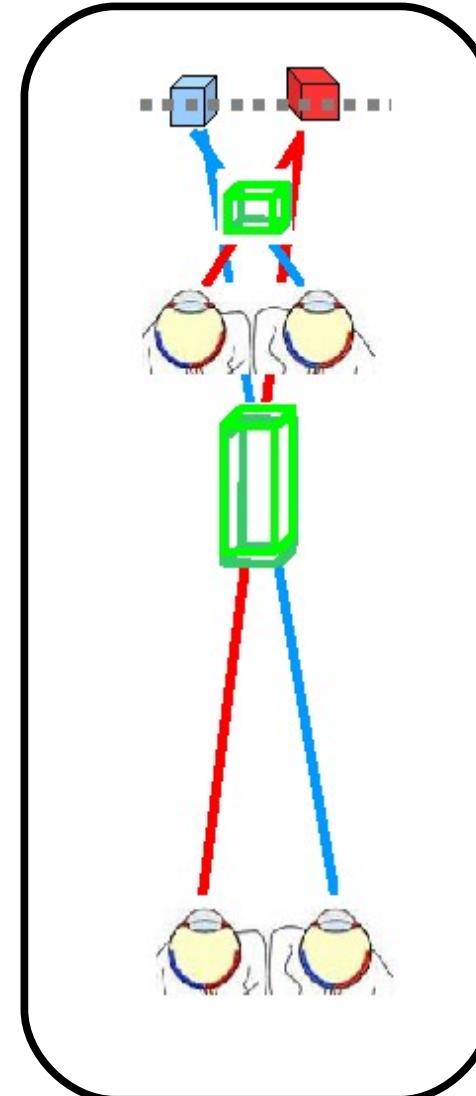


Negative Parallax

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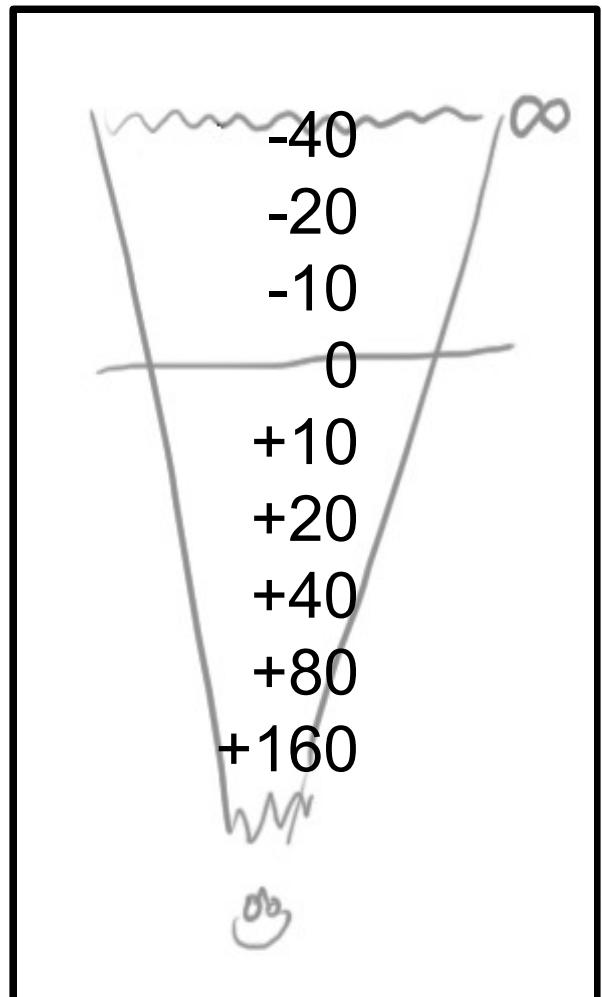
- Medium Negative Parallax (MNP)
 - Equal to Maximum Positive Parallax
 - Object seen “half way to the screen”
- Negative Parallax
 - sets a **relative distance to the screen**
 - is time-sensitive
 - Objects can stay at 1x to 2x MNP
 - Objects can move up to 3x MNP
 - Objects can be flashed up to 3x to 5x MNP
 - is function of the screen size



The Depth Budget



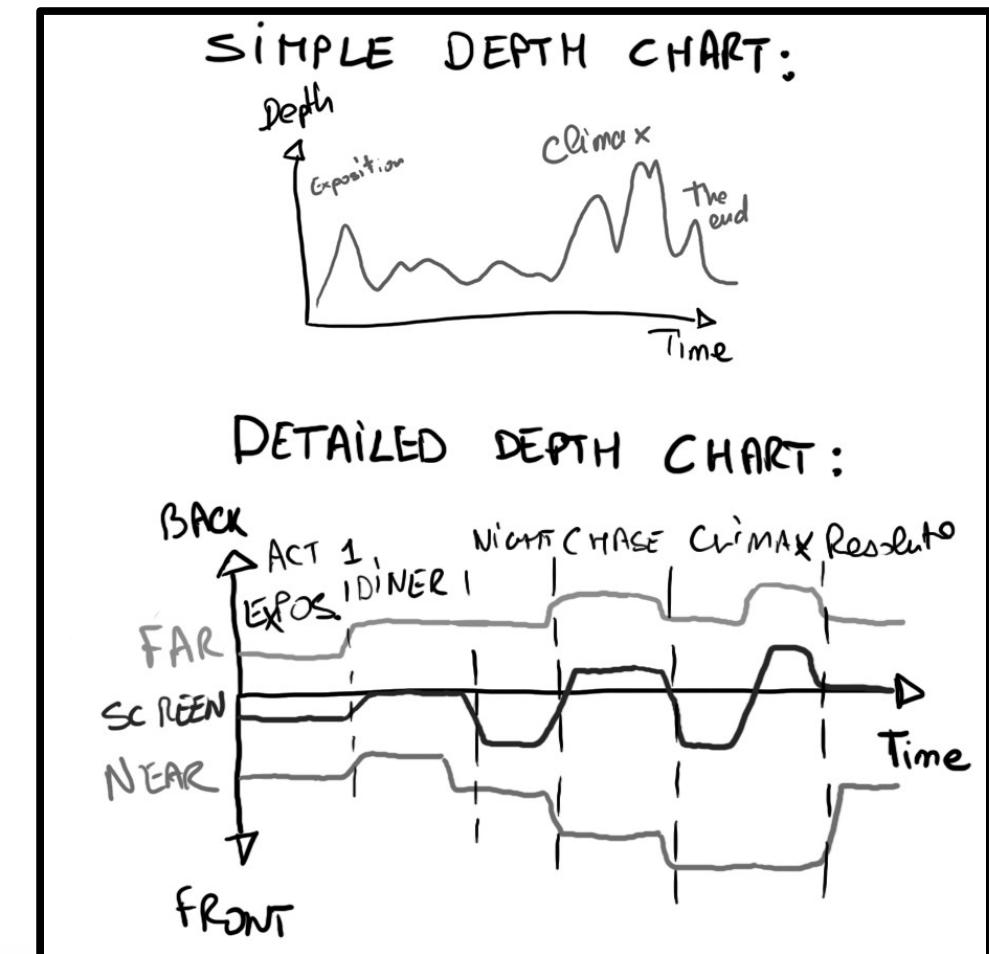
- The amount of depth available to tell your story
 $= (\text{Max. Neg. Px.} + \text{Max. Pos. Px.})$
- Counted in pixels
 - MNP and +/- 30pxls at 2K on 30'
 - Actually -50 to +150 for strong 3D effects



The Depth Script



- The modulation of the depth used to tell your story
- Ranging from 0 to 10
 - Zero is flat, 10 is full range, 11 is grand finale
- Sets the Sequences' Depth Budget
 - According to the ongoing story, challenges and drama
- Needed for visual comfort
 - Alternate **Strong 3D**, **Violent 3D** with **Smooth 3D**

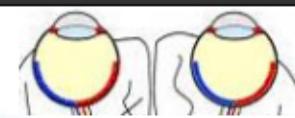
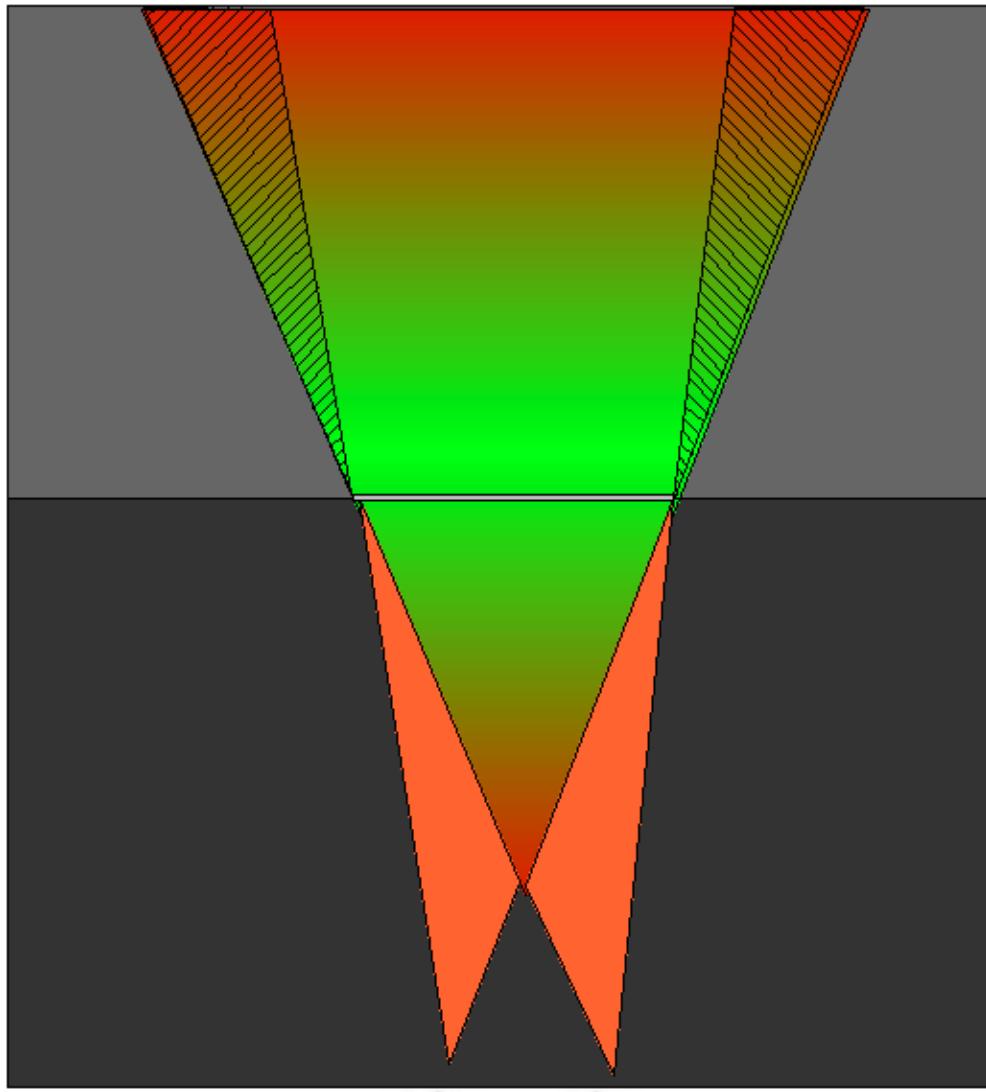


Stereoscopic Comfort Zone

- 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 3D Camera Rig

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- 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

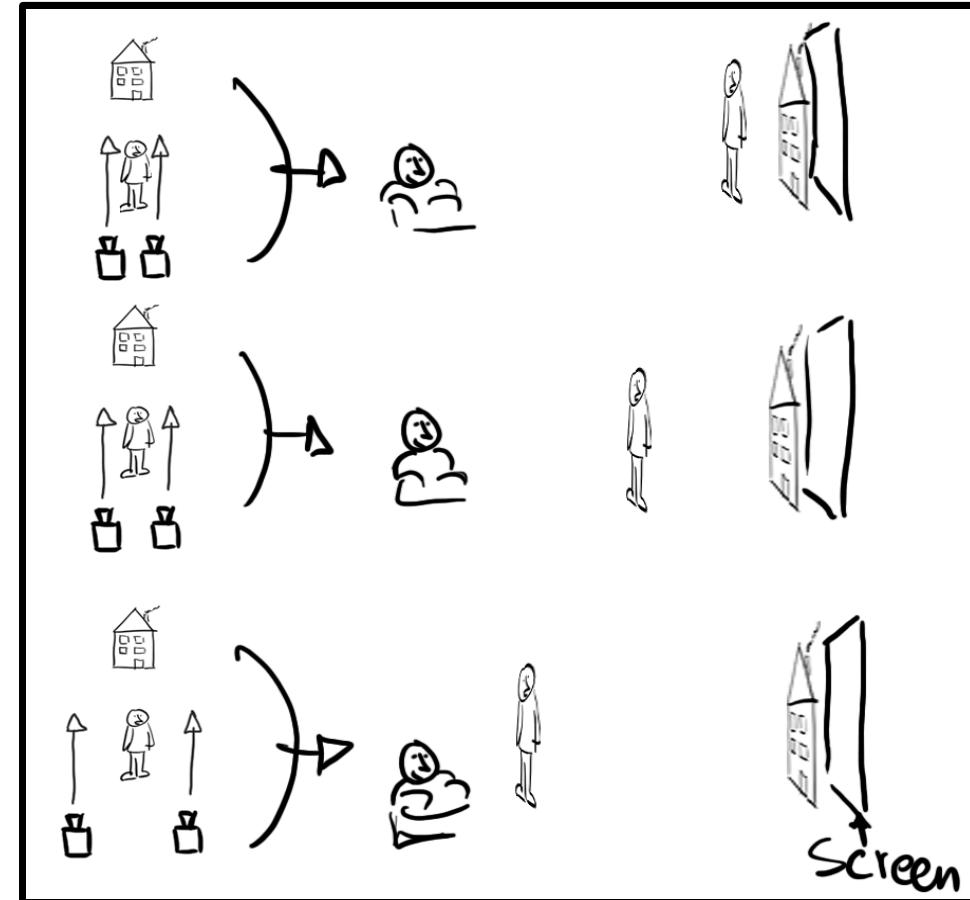


The Inter-Occular

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- 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



The Convergence



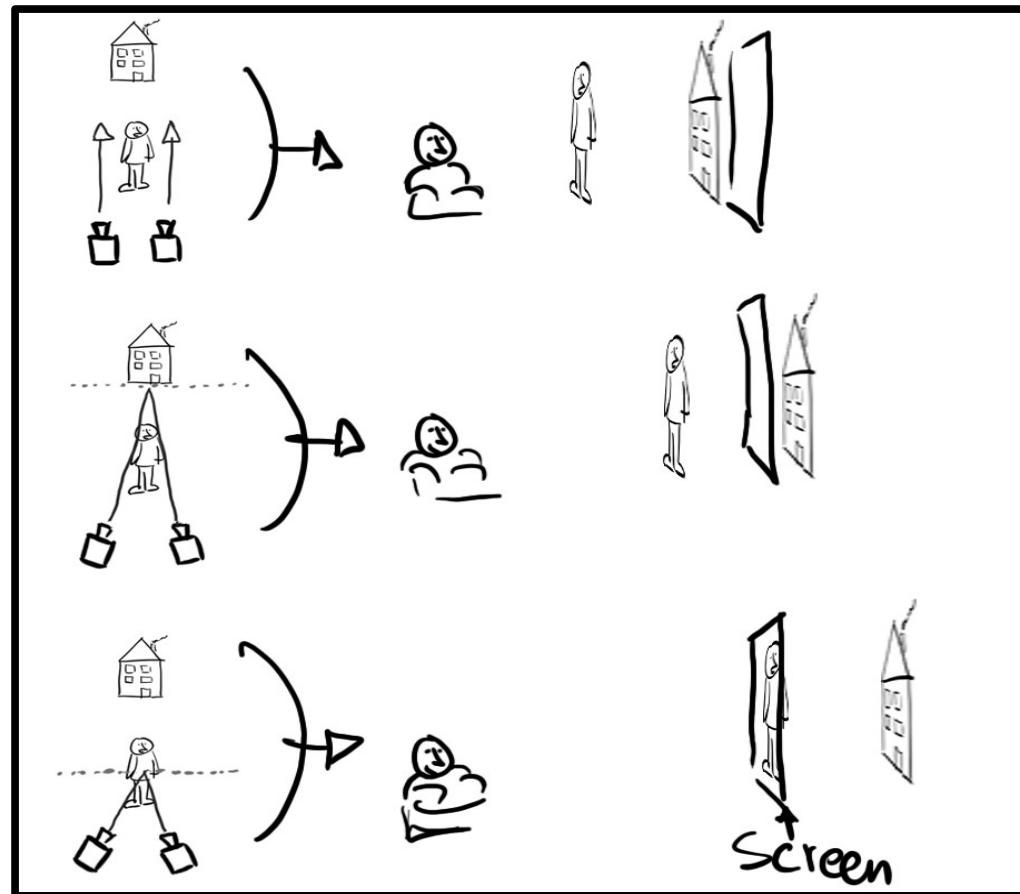
- Angle formed by the cameras' optical axis

- **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

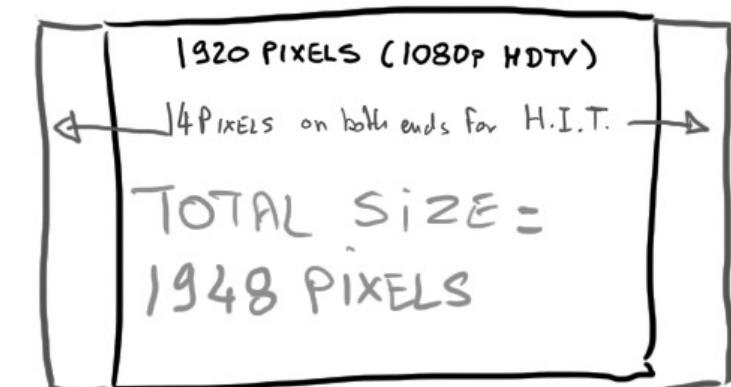
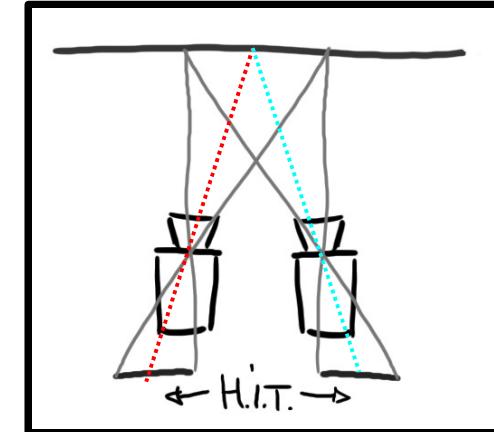


Post Convergence

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- Resetting the Depth Position of a scene by shifting images
- Also called H.I.T.
 - Horizontal Image Translation
 - Set 3D to perfect depth position
- Requires “Overshooting”
 - Approximately Max. Pos. Px., 30pxl @2K/30'
 - Otherwise the image is zoomed and cropped
- Generates NO KEYSTONE
 - It is advised to “Shoot Parallel” and “Post Converge”



Progress in 3D camera rigs

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- 1990's
 - Digital Camera Heads
 - Dynamic I.O and Convergence
- 2000's
 - Computerized Motion Control
 - Zoom L.U.T for Tele-centrism and Progression
- 2010's (starting Monday 9:00am)
 - Computerized Image Analysis
 - Real-Time Disparity Tracking
 - Automatic Depth Settings and Correction



Automatic Stereo Correction

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- 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-Axial Distance
 - Corrects Convergence, H.I.T.



Images courtesy of
3Ality Digital and Binocle

PART 2: Advanced Stereoscopy

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

The Stereoscopic Window

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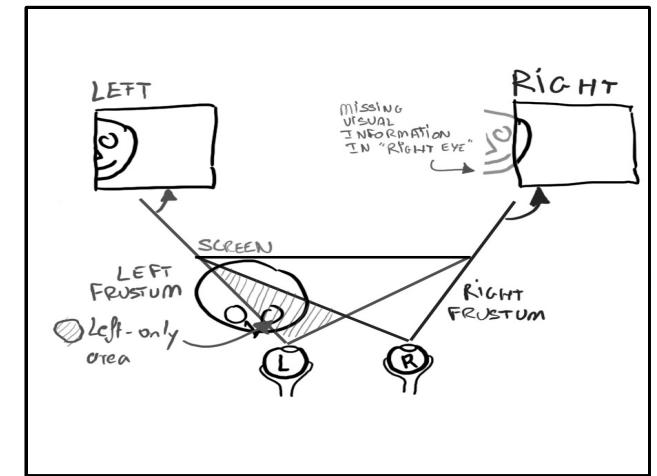
- In 3D, the screen is a Window
 - Defines a “Screen Space” and a “Theater Space”
 - Or “World Space” and “Personal Space”
- The frame “cut out” what is behind
 - And this is the way we see naturally
- The frame “cut out” what is in front
 - AND THIS NOT NATURAL



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

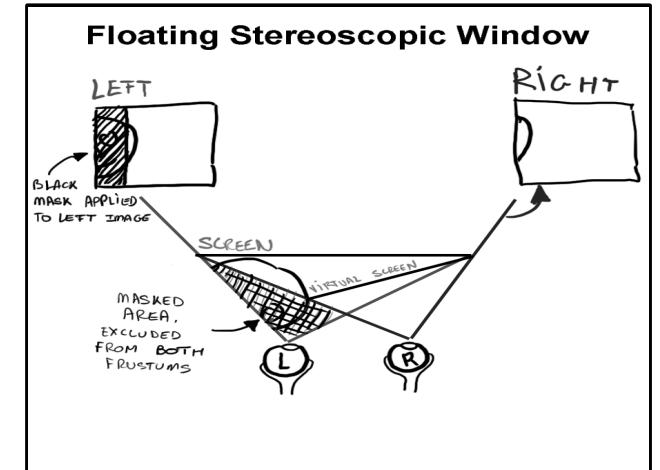
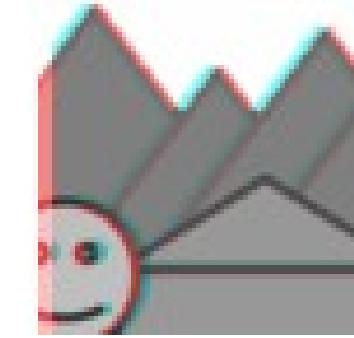


Floating Stereoscopic Window

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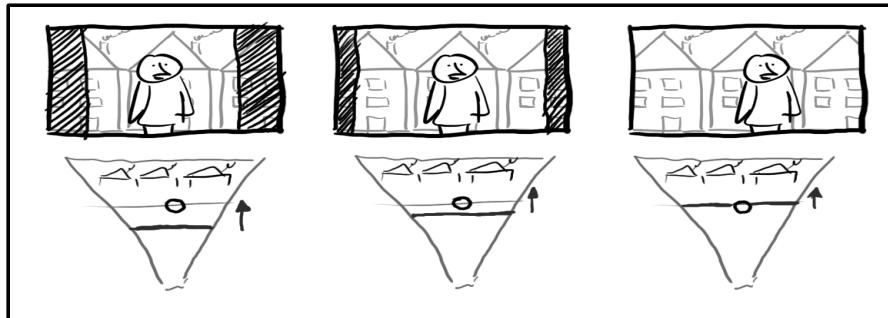
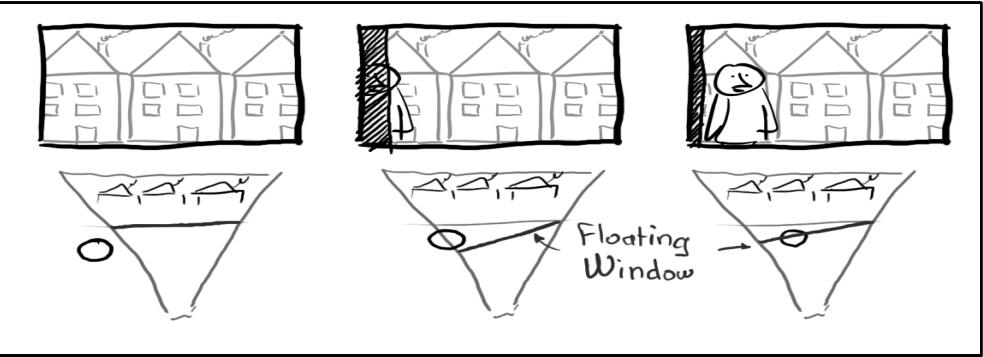
- Virtual screen that seems to float in the theater room
- Created Masking the side of the pictures
 - Simple Black Mask
 - Asymmetrically applied on Left and Right Eyes
- That virtual screen
 - Can be set floating in the room
 - Can be pushed behind the screen
 - Can be Twisted, Bended, Rotated



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

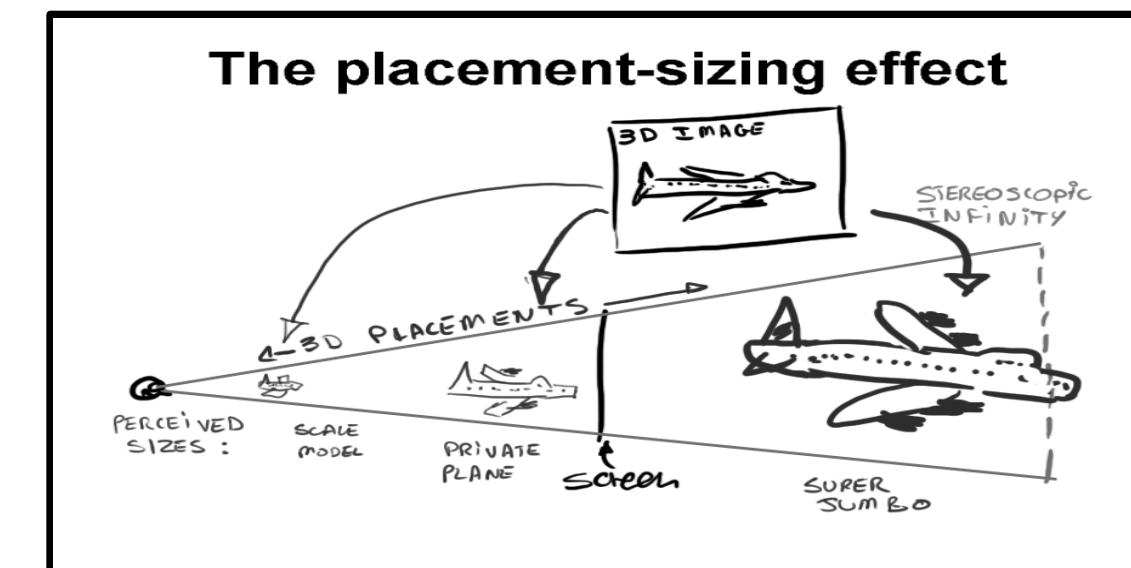


The 3D Size Effect

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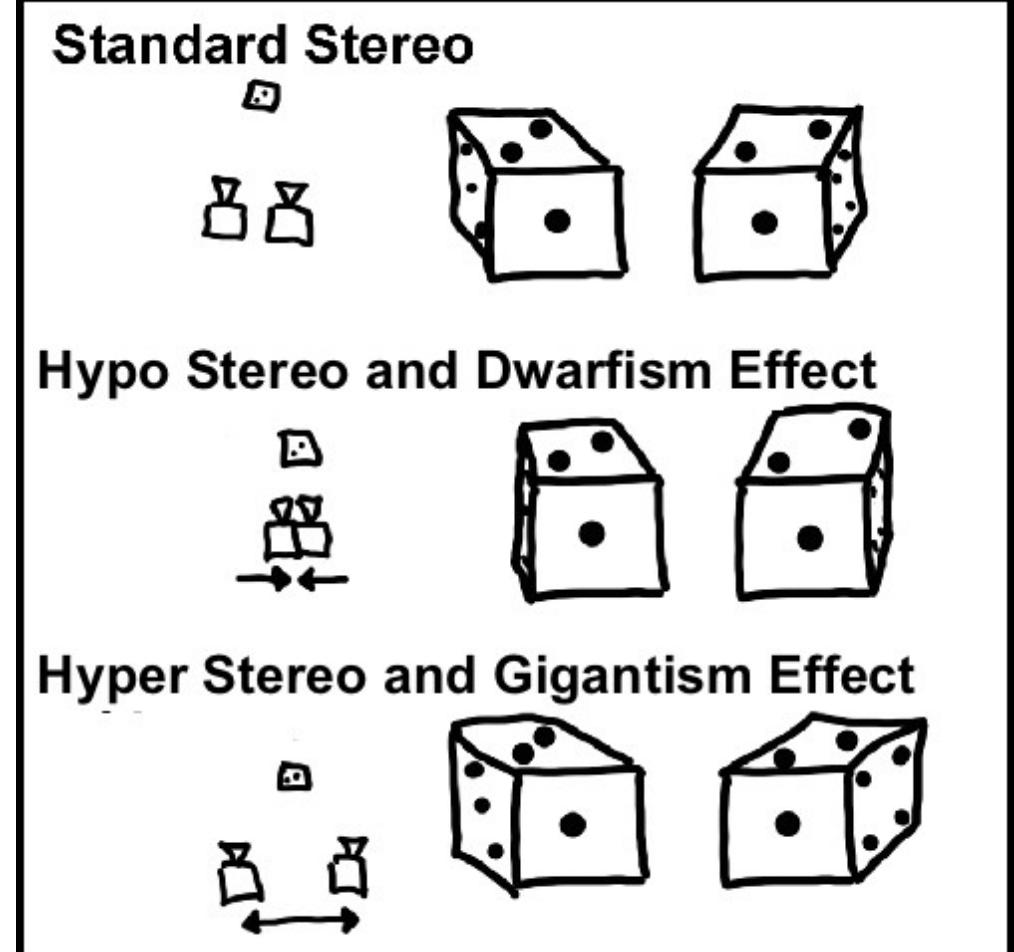
- New Constraint
 - A 2D image has a Scale
 - A 3D object has a Size
- H.I.T. Changes the objects' sizes
 - Far Away, it's a Jumbo Jet
 - Inside the room, it's a Scale Model
- Can be used for storytelling
 - Push the Trolls
 - Pull the Hobbits



The Audience Sizing



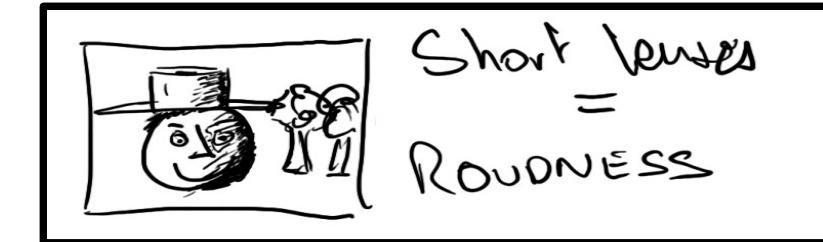
- New Constraint
 - A 2D camera has a focal length
 - A 3D camera rig has a Size
 - The audience identifies with camera size
- Hypo Stereo: Audience Shrink
 - Inter-Axial set to less than Human I.O.
- Hyper Stereo: Audience Giantism
 - Inter-Axial set to more than Human I.O.
- Can be used for storytelling



The 3D Volume



- New Constraint
 - A 3D object has a volume, or “Roundness”
 - The “Roundness Factor” is Relative to Natural
- How to assess “Roundness” ?
 - 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
- What if you have reach the limits?

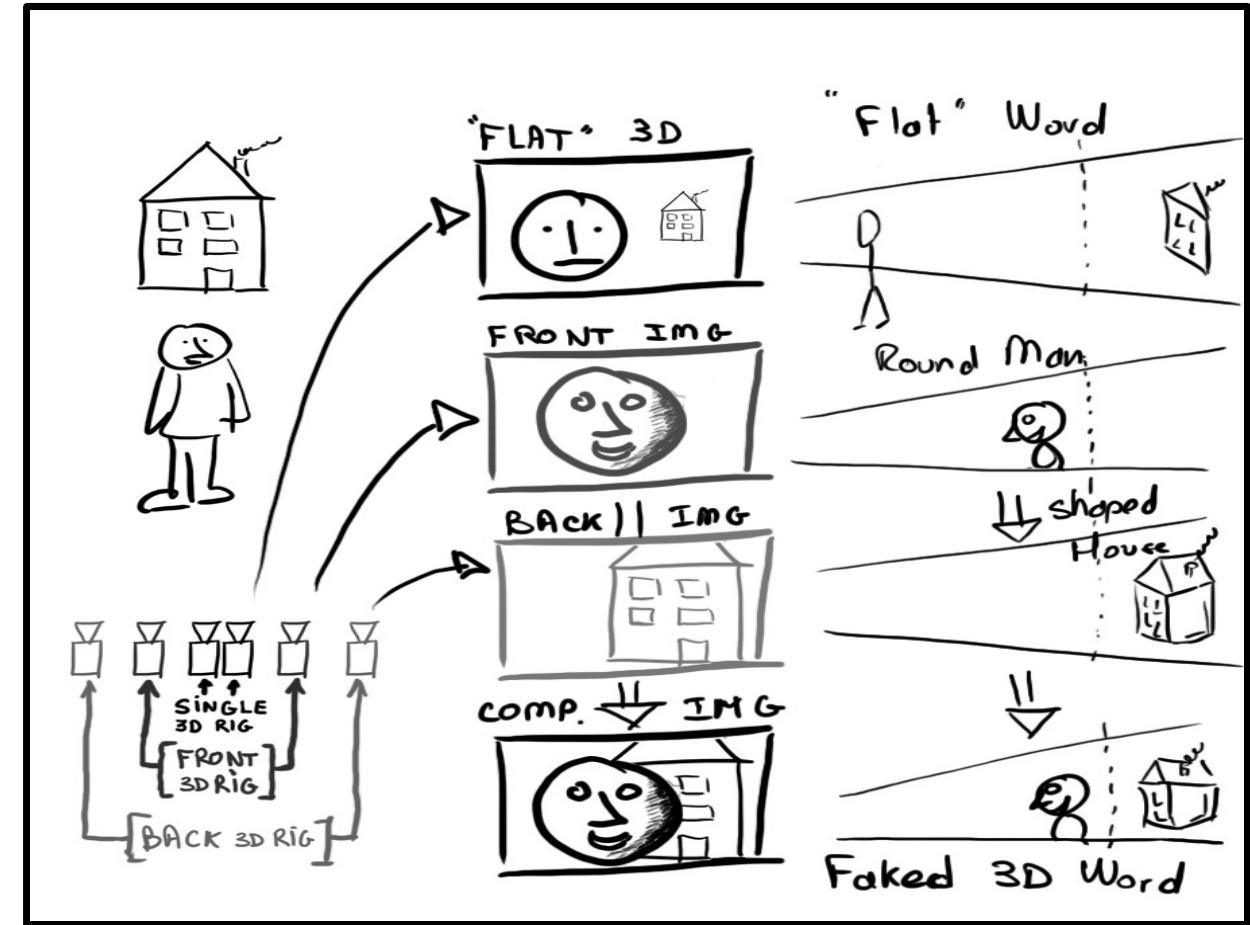


Multiple Rigs

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- One rig per needed depth setting
 - Rig A for foreground
 - Rig B for background
 - Composed 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...



2D to 3D Conversion



- “We'll make it 3D for less than the cost of shooting it”
- We warranty;
 - NO Camera rig issues
 - NO 3D settings issues
- As simple as 2D and a Purchase Order
 - “How much 3D in your coffee this morning?”

Future: Space Warping

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- Space Warping is to Depth what HDR is to Saturation
 - Depth does not have to be *realistic*
 - It has to be *entertaining* and *enjoyable*
- Short Term: View Synthesis
 - 2D+Depth Map = 3D (3D conversion method)
 - Non-linear Depth Functions (L.U.T.)
- Mid-Term: Non-Linear Depth Function
 - Integral Imaging Cameras
 - Full-Scene Photo Modelization
 - Virtualization of Camera and Optics
- Objective: “Per Pixel Depth Setting”

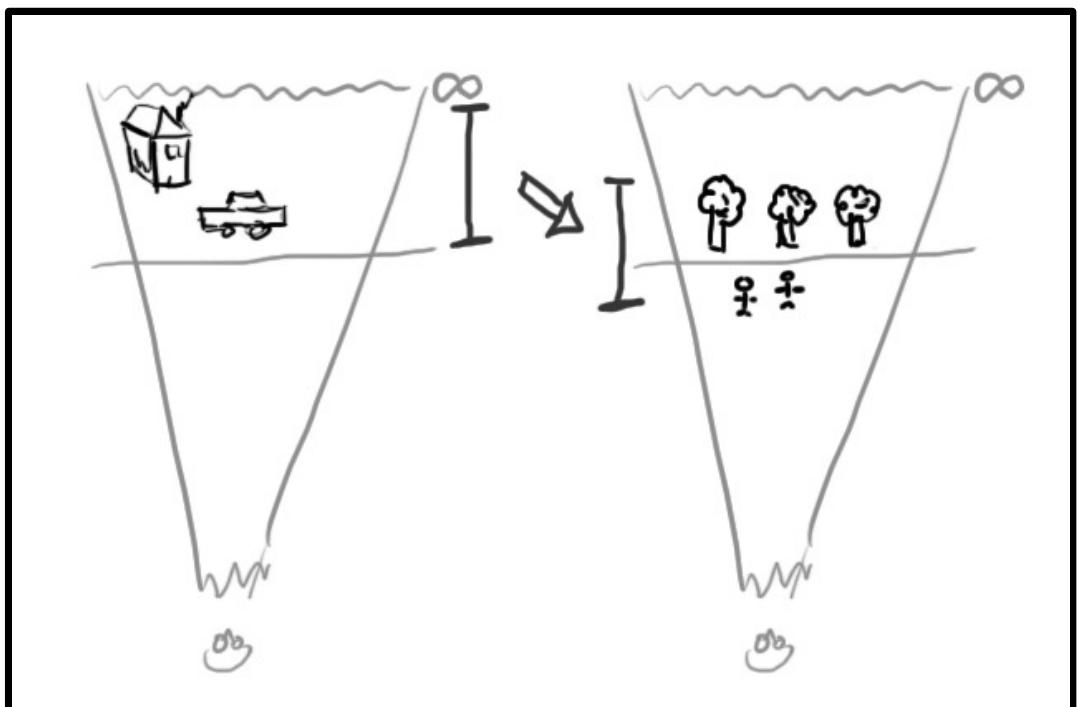


Depth Continuity

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- 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



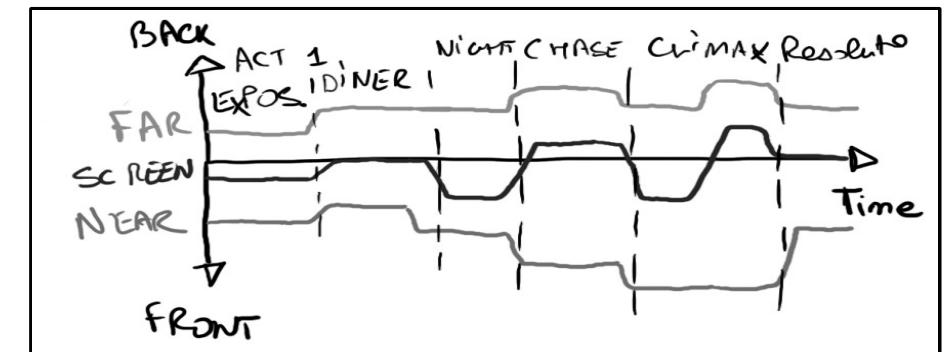
Depth Velocity



- 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”

New Language: Writing with Depth

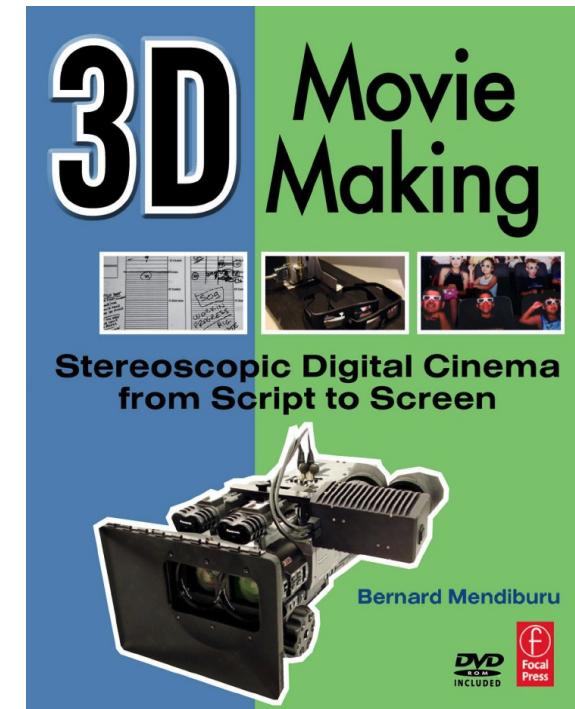
- Depth Treatment
 - Depth Strength
 - Depth Realism
 - Stereoscopic Window
 - Distance to Action, Distance to Screen
- Depth Rhythm
 - Sequences' Depth Budget modulation
 - Shots' Depth Velocity
- Artistic Dimension of Depth



Learning more about 3D



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



Any Questions?



- **Bernard Mendiburu**
 - Lectures, Seminars and Workshops on 3D
 - pro@mendiburu.net
 - www.3DTV.FR