



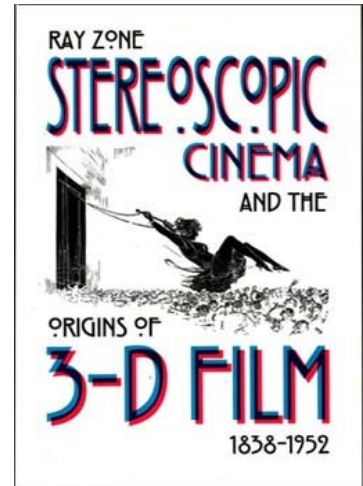
**Fundamentals of  
Stereoscopic Imaging**  
Bernard Mendiburu

**NABSHOW™**  
*Where Content Comes to Life™*

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

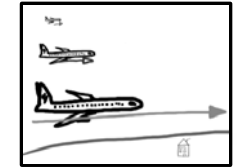
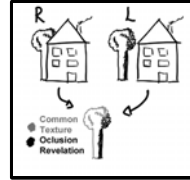
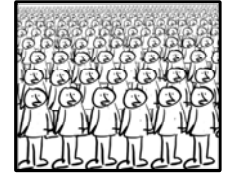
# Some 3D History

- 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

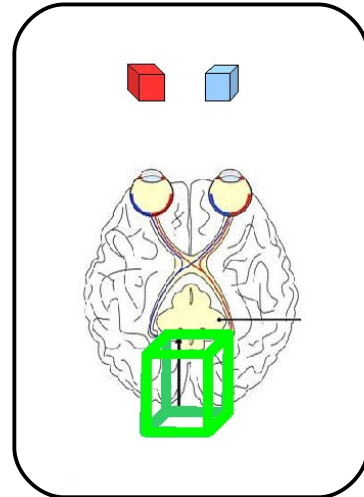


# Depth Cues

- 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 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**

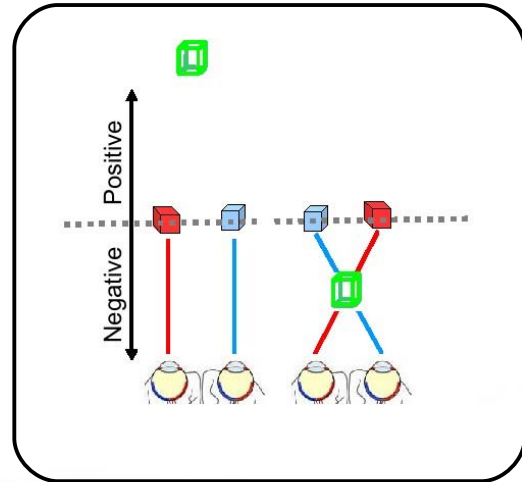
# Stereoscopic Projection

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



# The Stereoscopic Parallax

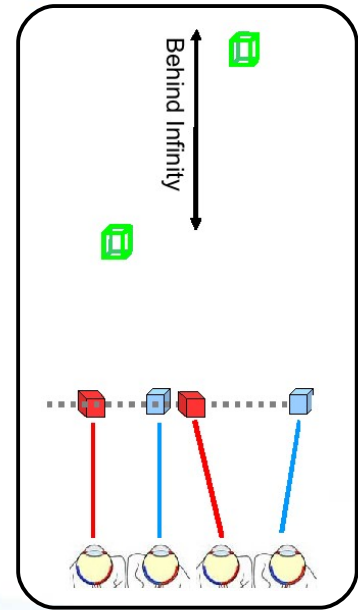
- Distance on the screen between left and right images of an object
  - Positive : Far Away
  - Negative : “In your face”





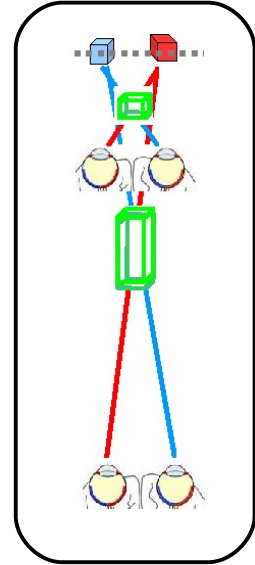
# Maximum Positive Parallax

- **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?



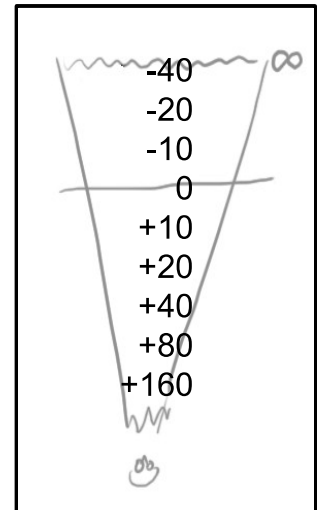
# Negative Parallax

- 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  
= (Max. Neg. Px. + Max. Pos. Px.)
- Counted in pixels
  - MNP and +/- 30pxls at 2K on 30'
  - Actually -50 to +150 for strong 3D effects



- The modulation of the depth used to tell your story

- Ranging from 0 to 10

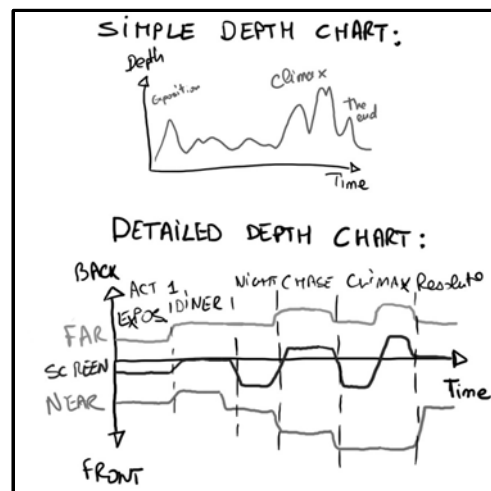
- Zero is flat, 10 is full range, 11 is grand finale

- Sets the Sequences' Depth Budget

- According to the ongoing story, challenges and drama

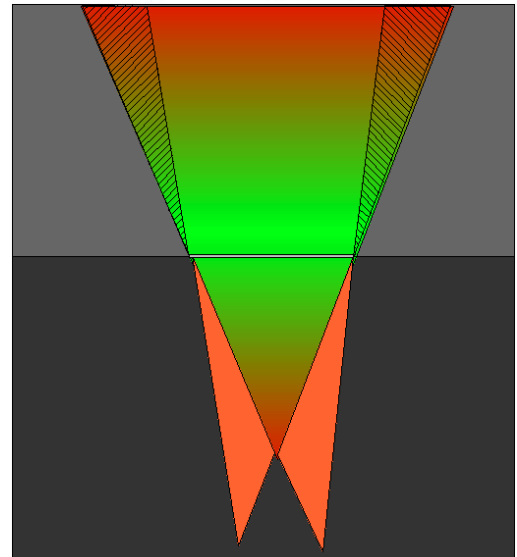
- Needed for visual comfort

- 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



- Pair of Camera on an apparatus that replicates human vision

- **Matching Geometry**

- Same Camera
- Same Lens
- Optical Axis forming an horizontal plane

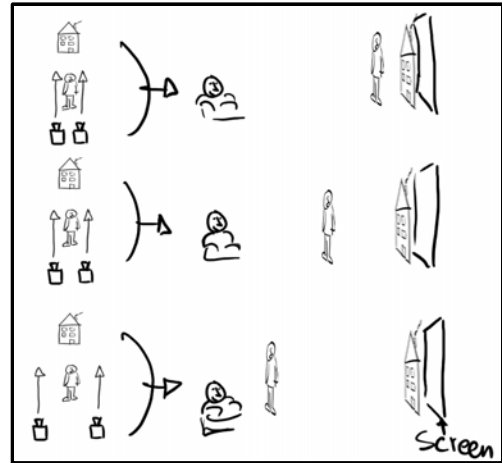
- **Matching Photography**

- Same speed, shutter, color, everything
- Pixel Accurate Genlock



# The Inter-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



# The Convergence

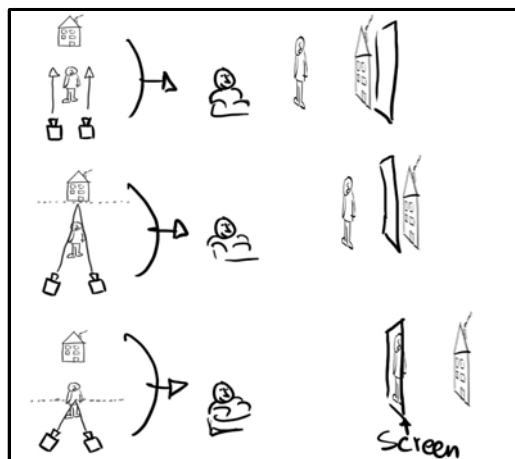
- Angle formed by the cameras' optical axis

- **Sets the Depth Position**

- Moves the scene along Z axis
- Does not affect Depth Bracket
- Should keep Bracket in Budget

- **Created**

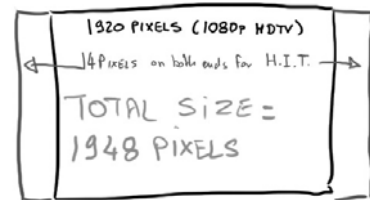
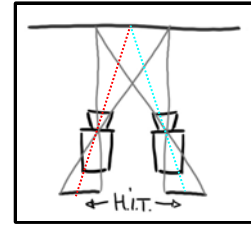
- On Set: Toe-in, creates Keystone issues
- On Set: Shifting camera's backs or lenses
- On Post: Re-convergence. H.I.T





# Post Convergence

- 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

- 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

- 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

---

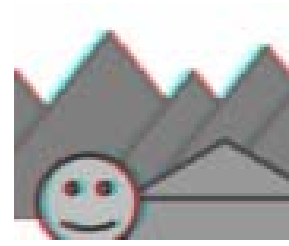
## PART 2: Advanced Stereoscopy

---

- 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**

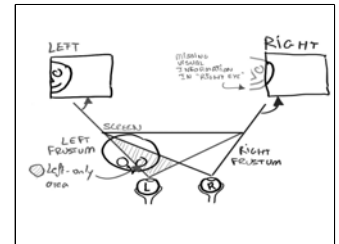
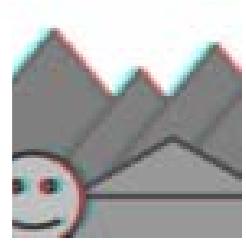
# The Stereoscopic Window

- 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



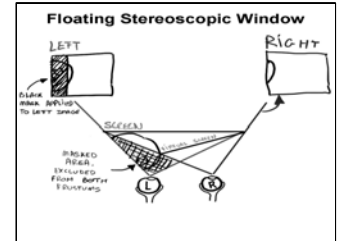
# Stereoscopic Window Violation

- 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

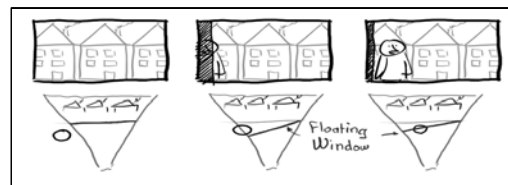
- Virtual screen that seems to float in the theater room
- Created Masking the side of the pictures
  - Simple Black Mask
  - Asymmetrically applied on Left and Right Eyes
- That virtual screen
  - Can be set floating in the room
  - Can be pushed behind the screen
  - Can be Twisted, Bended, Rotated



# Dynamic Floating Window

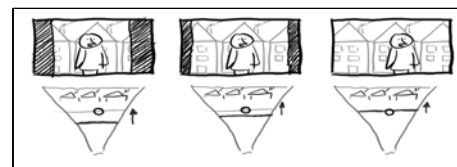
- **Floating Windows can be animated**

- 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**

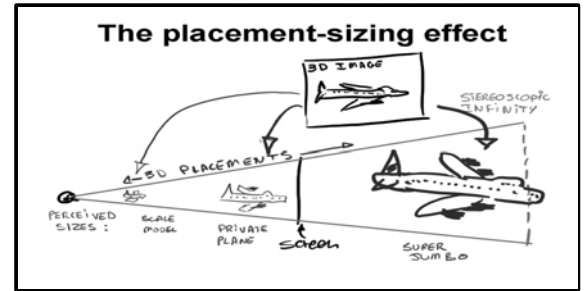
- The director can “tune up” the 3D effects
- Powerful Depth Touch-up Tool





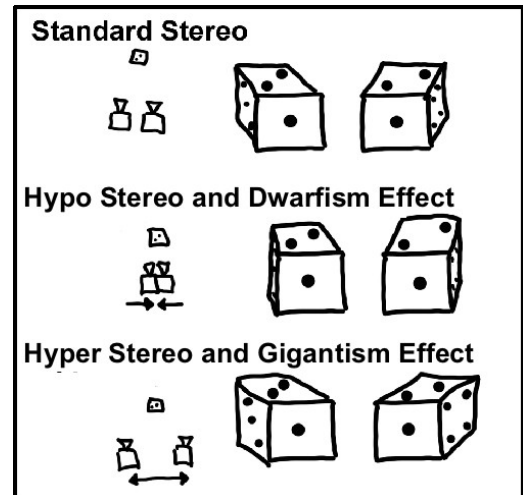
# The 3D Size Effect

- **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**



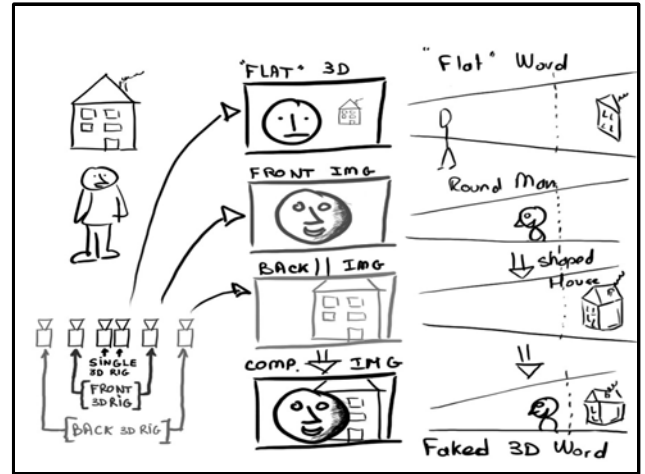
# The 3D Volume

- **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

- One rig per needed 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...



# 2D to 3D Conversion

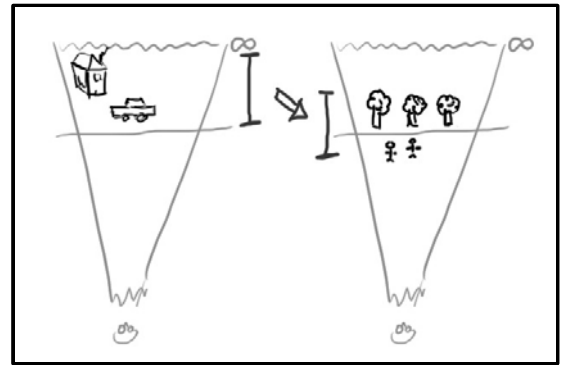
- “We'll make it 3D for less than the cost of shooting it”
- We warranty;
  - NO Camera rig issues
  - NO 3D settings issues
- As simple as 2D and a Purchase Order
  - “How much 3D in your coffee this morning?”

# Future: Space Warping

- 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”



- **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

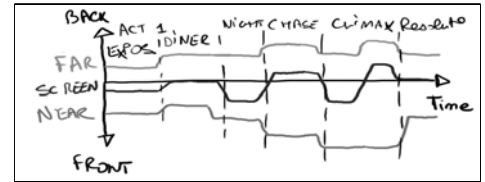


- **In-shot Depth Velocity**
  - I.O. animation for camera effects
  - Action on screen, flying objects...
- **Across-Shots Depth Velocity**
  - Depth Jump cuts
  - Active Jump Cuts
  - Dynamic Stereo Window Velocity
- **Effect on Story Telling**
  - Changes in depth position increase reading time
 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



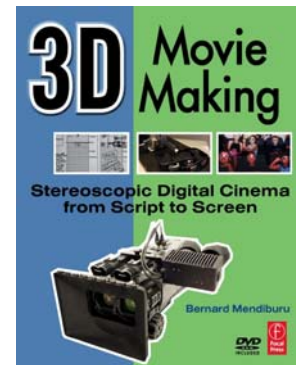
# New Language: Writing with Depth

- **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 !



- **Bernard Mendiburu**
  - Lectures, Seminars and Workshops on 3D
  - [pro@mendiburu.net](mailto:pro@mendiburu.net)
  - [www.3DTV.FR](http://www.3DTV.FR)