3D Image and Video Quality Summary

Prof. Ioannis Pitas
Aristotle University of Thessaloniki
pitas@csd.auth.gr
www.aiia.csd.auth.gr
Version 2.0

Artificial Intelligence & Information Analysis Lab

3D Image and Video Quality

- **Introduction**
- Visual Discomfort
- Visual Discomfort Assessment
- Physical Immersion Effects
- Stereoscopic Window Effects
- Depth Perception Effects
- 3D Video Quality

Introduction

- In ***stereoscopic vision***, humans fuse two retinal images (from the left and right eye).
- 3D technology is highly demanding with respect to comfortable stereoscopic viewing.
- Multiple problems must be addressed, mainly regarding visual discomfort.
- Any failure results in degraded viewing experience.

3D Image and Video Quality

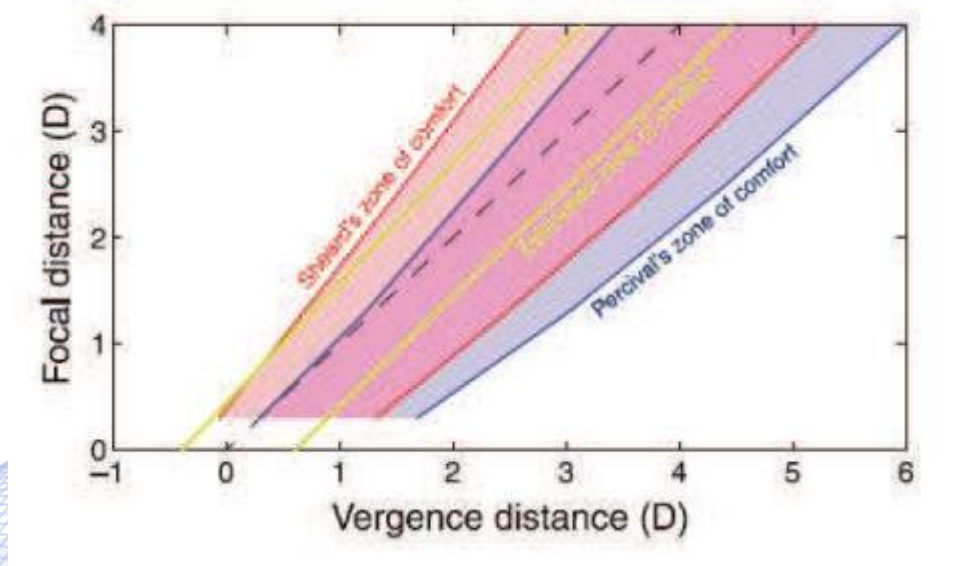
- Introduction
- **Visual Discomfort**
- Visual Discomfort Assessment
- Physical Immersion Effects
- Stereoscopic Window Effects
- Depth Perception Effects
- 3D Video Quality

Visual Discomfort

- ***Accommodation***: The procedure of trying to focus eye vision on a 3D object.
- ***Vergence***: Left-right eye convergence on a 3D object.
- ***Vergence-Accommodation conflict***: Vergence and accommodation distance inconsistencies in stereo vision, when we see 3D videos.
- ***Zone of Clear Single Binocular Vision*** (***ZCSBV***) is the region between the minimum and maximum boundaries for the vergence and focal stimuli, in which a human can see clearly.

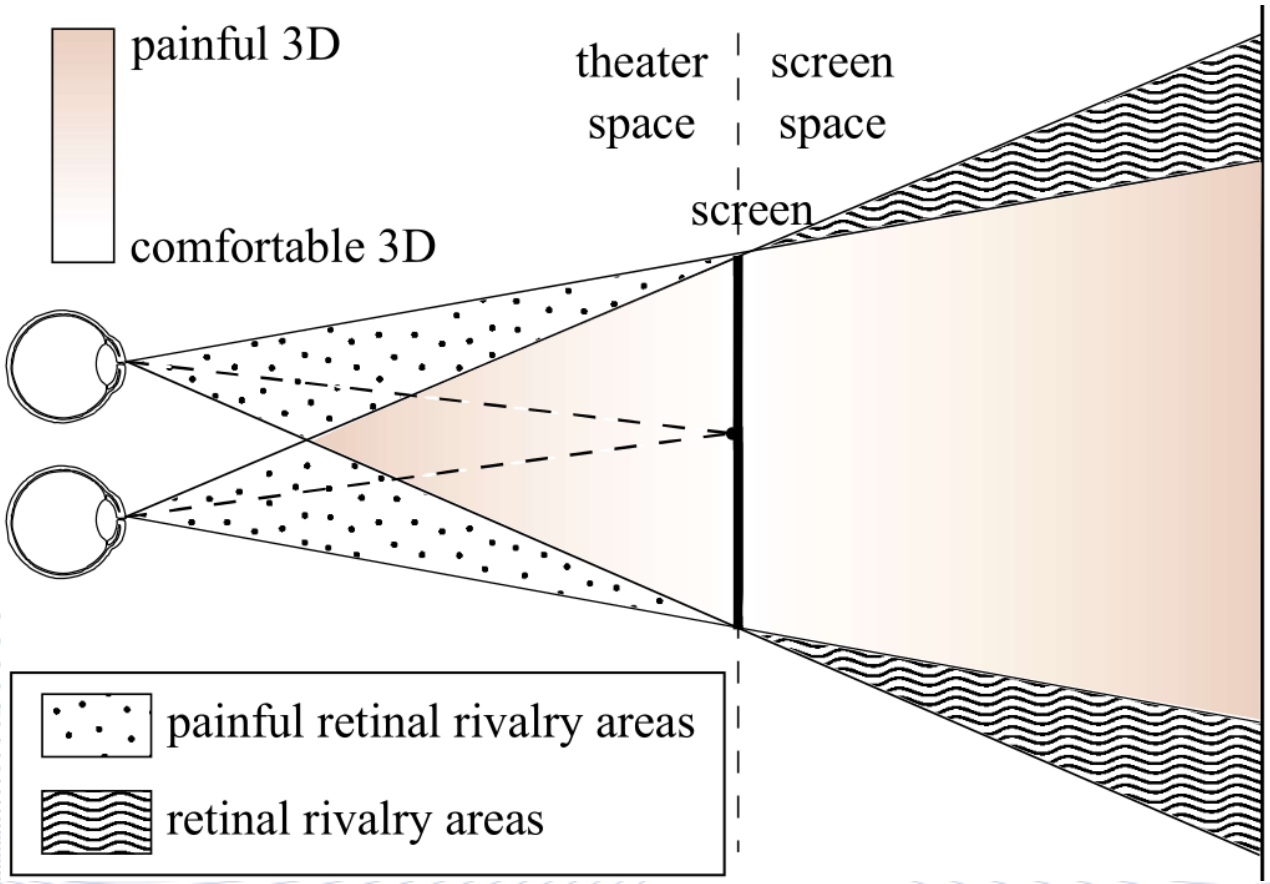
Visual Discomfort

- There are minimum and maximum boundaries for comfortable 3D viewing.
- ***Zone of Comfort*** (***ZoC***) is the region between these boundaries.
- Percival & Sheard Zones of Comfort.



Zones of Comfort [SKHB11].

Visual Discomfort



Zones of Comfort in 3D cinematography.

Sources of Visual Discomfort

- ***Stereo image display mistakes***: x axes should be horizontal while x axes should be parallel.
- ***Retinal Rivalry***: Objects are placed in such way, that they are seen from just one eye.

- ***Comfort zone violations***.

3D Image and Video Quality

- Introduction
- Visual Discomfort
- **Visual Discomfort Assessment**
- Physical Immersion Effects
- Stereoscopic Window Effects
- Depth Perception Effects
- 3D Video Quality

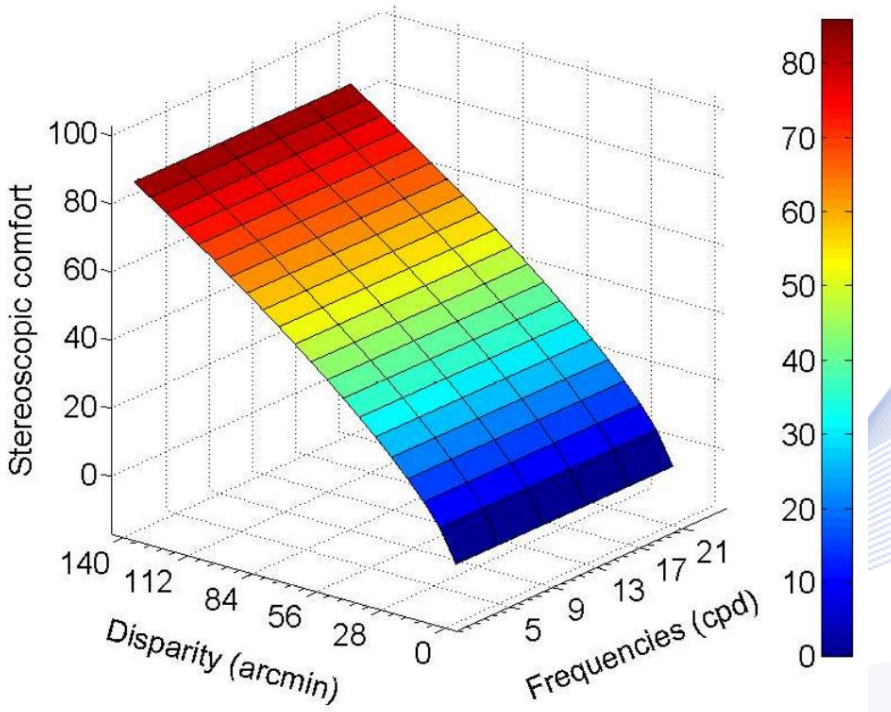
Visual Discomfort Assessment

Stereoscopic Comfort function:

$$C(d, f) = -0.010(d - 19 - 22f^{0.74}).$$

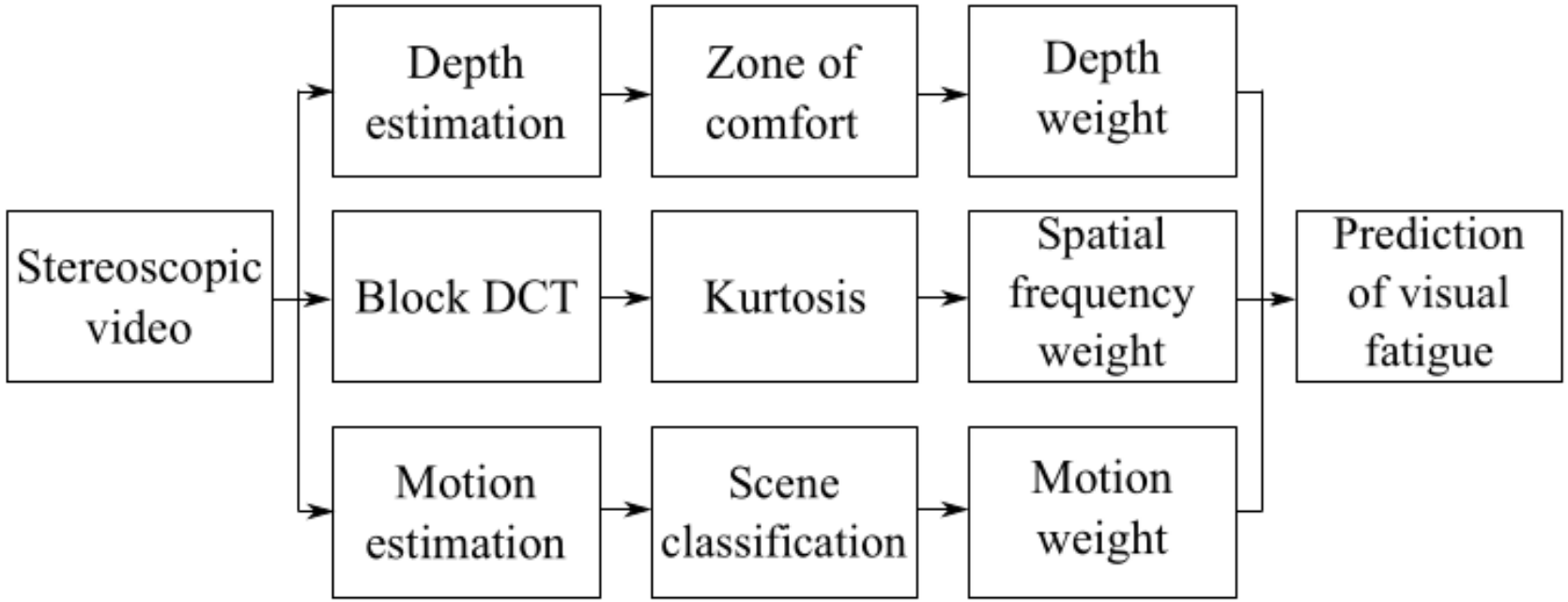
- d: binocular disparity (arcminutes).
- f: spatial frequency (cycles per degree of the visual field).

- The most comfortable 3D viewing setting is for small disparity and low spatial frequency values.



Stereoscopic Comfort function.

Visual Discomfort Assessment



Visual Discomfort Prediction Scheme combining depth, spatial frequencies and motion into a visual fatigue prediction model.

3D Image and Video Quality

- Introduction
- Visual Discomfort
- Visual Discomfort Assessment
- **Physical Immersion Effects**
- Stereoscopic Window Effects
- Depth Perception Effects
- 3D Video Quality

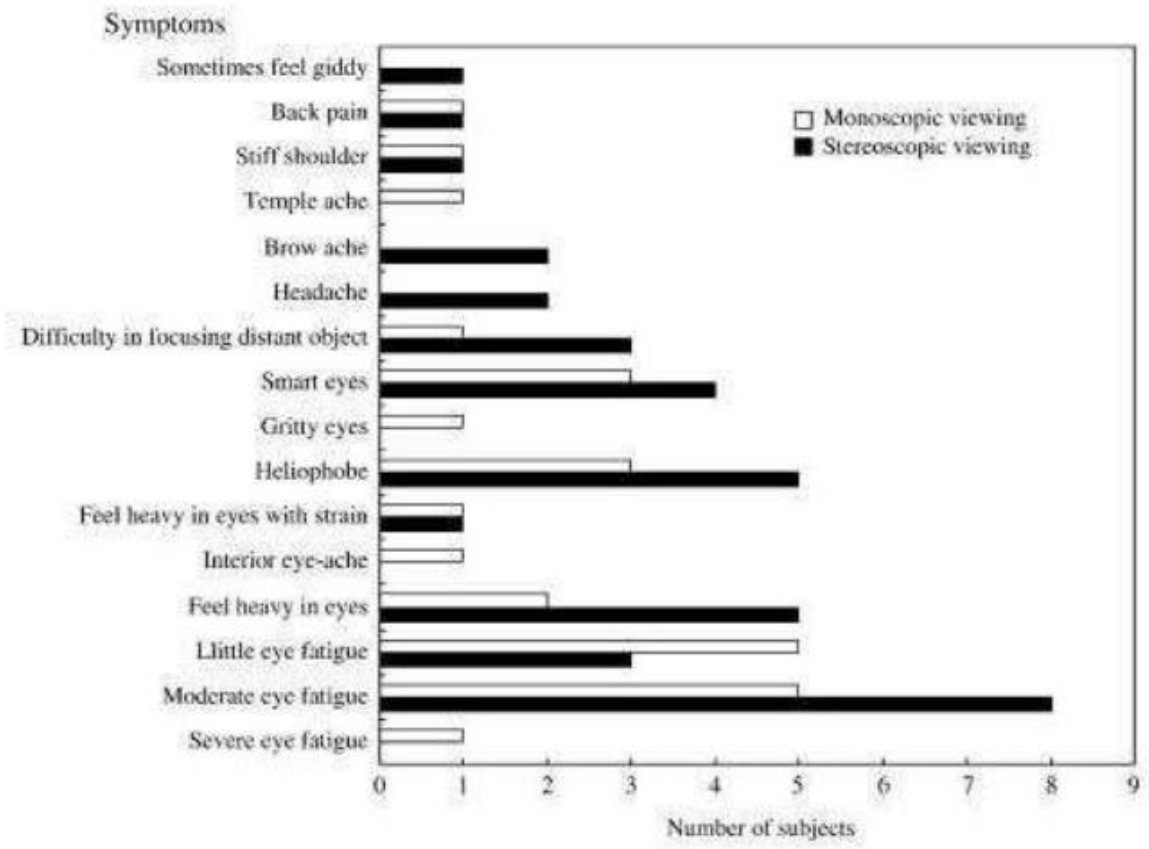
Physical Immersion Effects

- Nausea, disorientation in passive viewers.
- Fatigue, blurred vision and irritation.

- Immersion device ranking of devices based on symptom intensity:
  1. Head-mounted displays.
  2. Projection displays & Reality theaters.

Physical Immersion Effects

Symptoms
- Tiredness
- Sleepiness
- Boredom.



Symptoms after monoscopic and stereoscopic viewing.

3D Image and Video Quality

- Introduction
- Visual Discomfort
- Visual Discomfort Assessment
- Physical Immersion Effects
- **Stereoscopic Window Effects**
- Depth Perception Effects
- 3D Video Quality

Stereoscopic Window Effects

Stereoscopic window is the 3D TV or cinema screen.

- Stereoscopic quality issues:
  - ***Stereoscopic window violations***: when an object part is cut off by a vertical display border.
  - ***Bent Window effects***: when an object part is cut off by a horizontal display border.

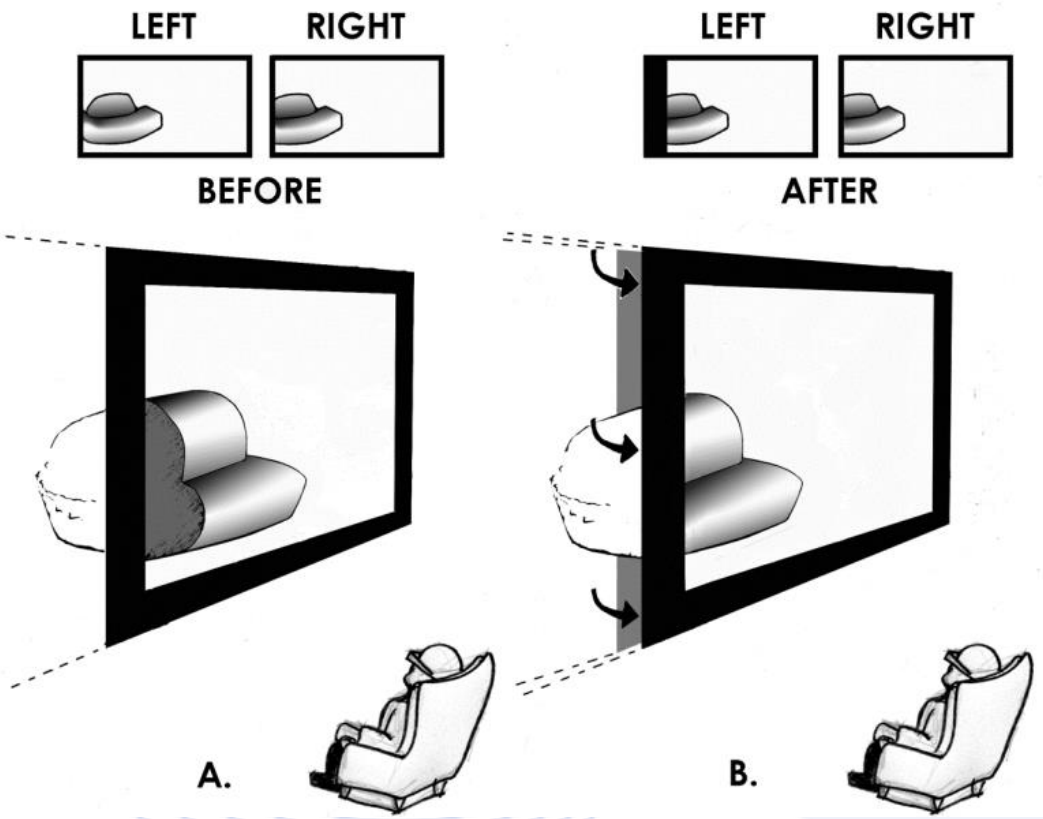
Stereoscopic Window Effects

Stereoscopic Window violations

- Objects that exit, enter or traverse the video frame in no more than half a second, cause no problem.

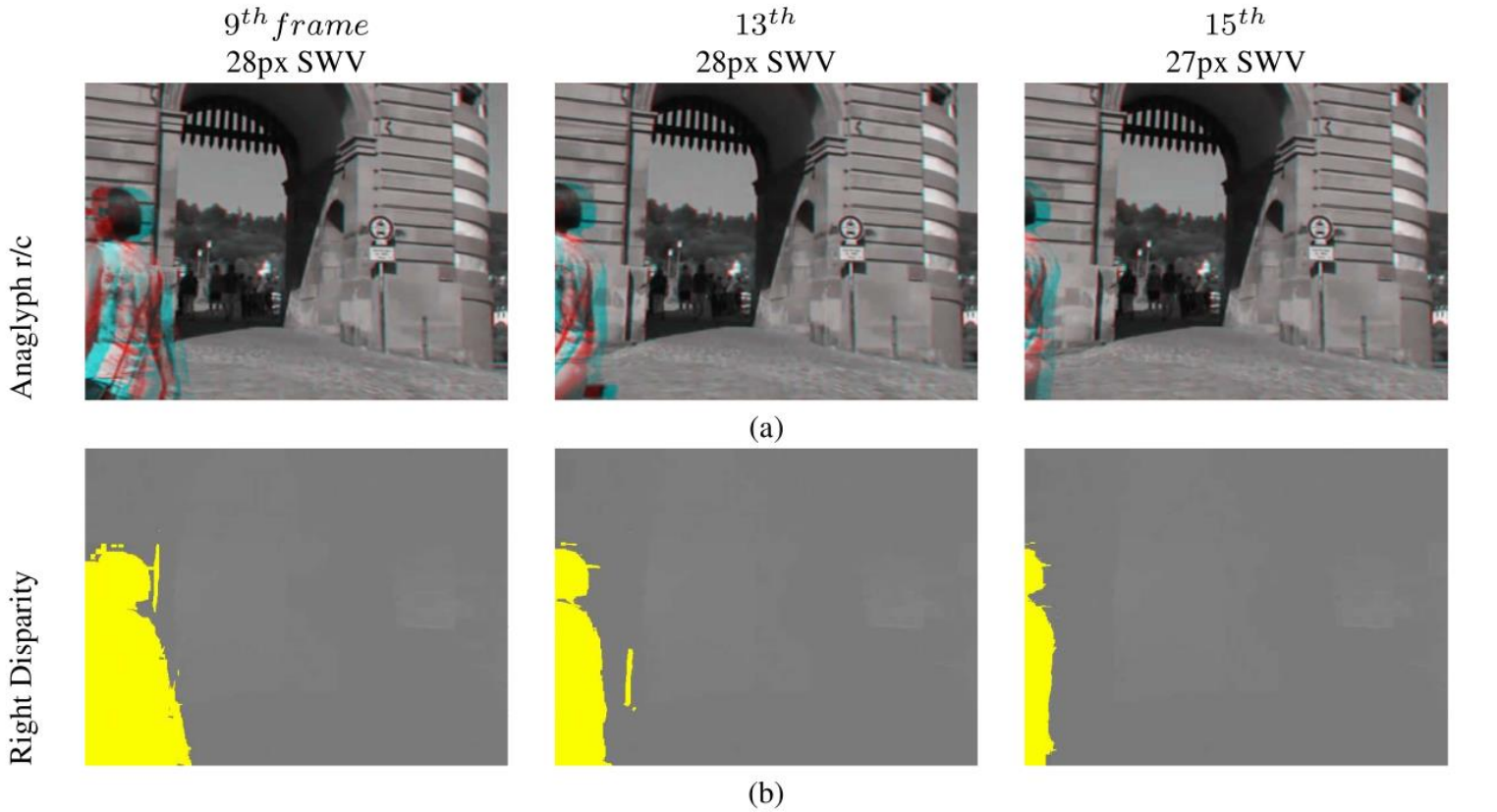
A known fix is ***floating window***:

- A vertical mask is added on the responding border.



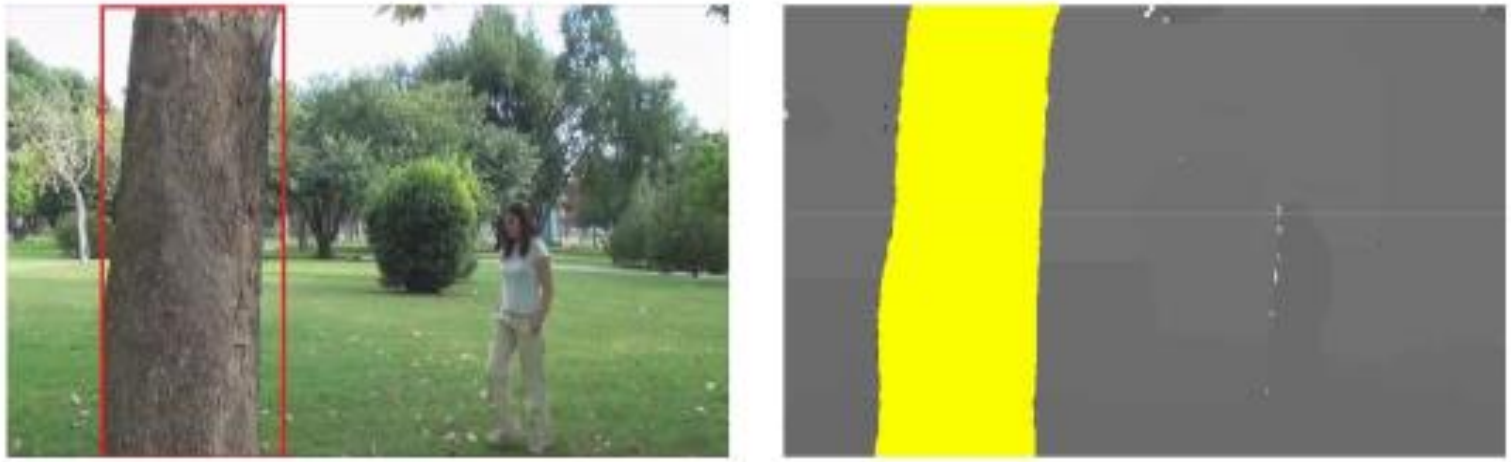
Floating window technique [GARD11].

Stereoscopic Window Effects



Example of left stereoscopic window violation: stereo anaglyphs and right disparity maps (yellow marked pixels have disparities > 5 pixel).

Stereoscopic Window Effects



Bent window effect. Tree trunk has strong negative disparity (-30 pixels).

3D Image and Video Quality

- Introduction
- Visual Discomfort
- Visual Discomfort Assessment
- Physical Immersion Effects
- Stereoscopic Window Effects
- **Depth Perception Effects**
- 3D Video Quality

Depth Perception Effects

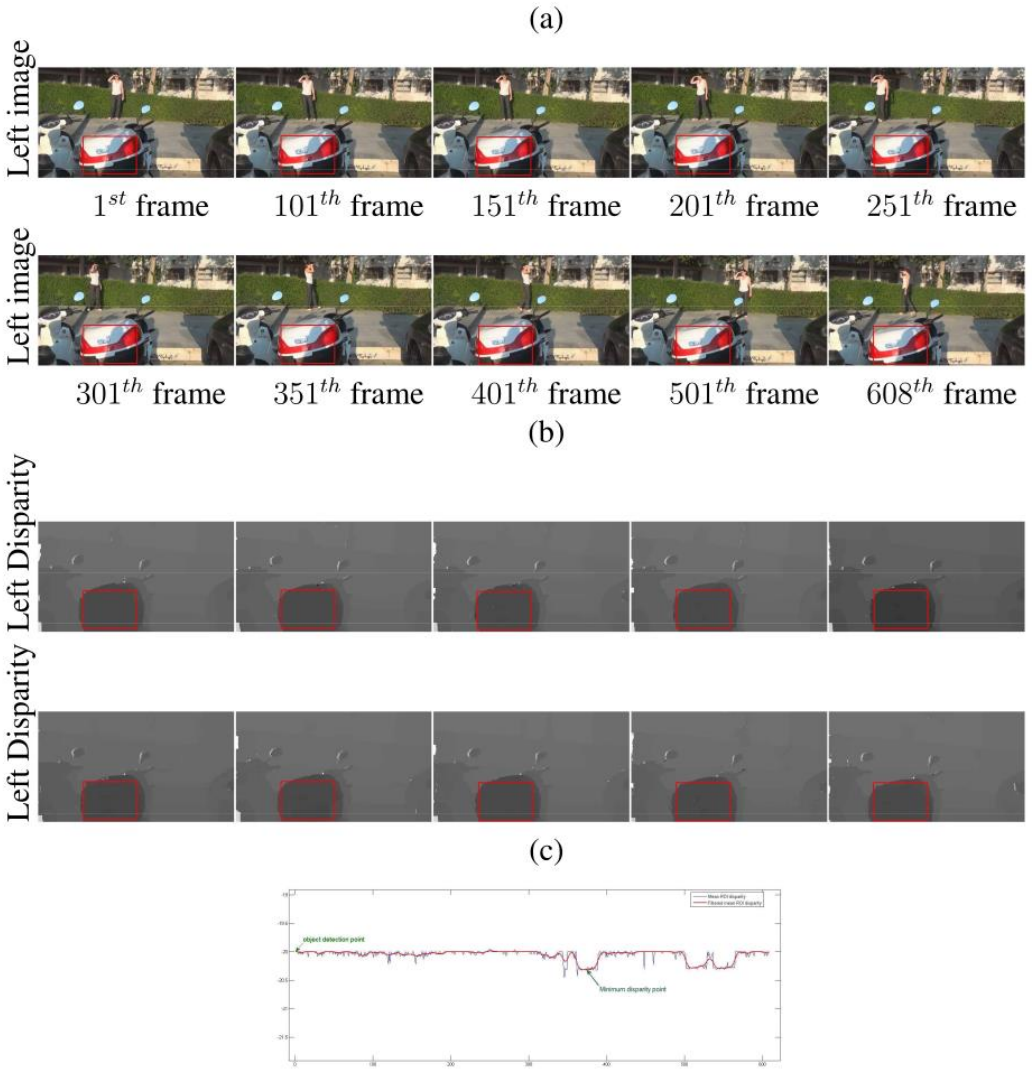
- 3D Video Perception is sensitive to depth information.

- Visual discomfort can be caused by:
  - Improper placement of objects in depth.
  - Sudden changes in video disparity:
    - UFO objects.

Depth Perception Effects

UFO Objects Detection

a) A static UFO object;
b) Disparity maps;
c) Mean UFO disparity.



Depth Perception Effects

Detection of Depth Jump Cuts

- There is no objective definition of “matching depth” between two video shots (viewer-dependent).
- Example of non-matching depth cut:
  - First shot: wide, objects positioned behind the screen.
  - Second shot: close-up, inside the theatre space
- In such scenarios, the viewer loses 3D perception, until it is readapted.

Depth Perception Effects

- ***Forward/backward Jump Cut***: convergence point moves closer to /away from the viewer.
- ***Active Jump Cut***: a cut between two shots with "non-matching" depth is absolutely necessary.
- Example: live concert shooting
  - First shot: Orchestra
  - Second shot: Audience.

Depth Perception Effects

Correcting Depth Jump Cuts

- Non-linear disparity adaptation for interpolating depth jump cuts.
- A viewer-centric 3D video editor can apply ***cross fading***:
  - Change of convergence point before and after the cut.
  - Matching depth of incoming video shot to the one of the out-coming shot.

Depth Perception Effects
Algorithm for Detection of Depth Jump Cuts

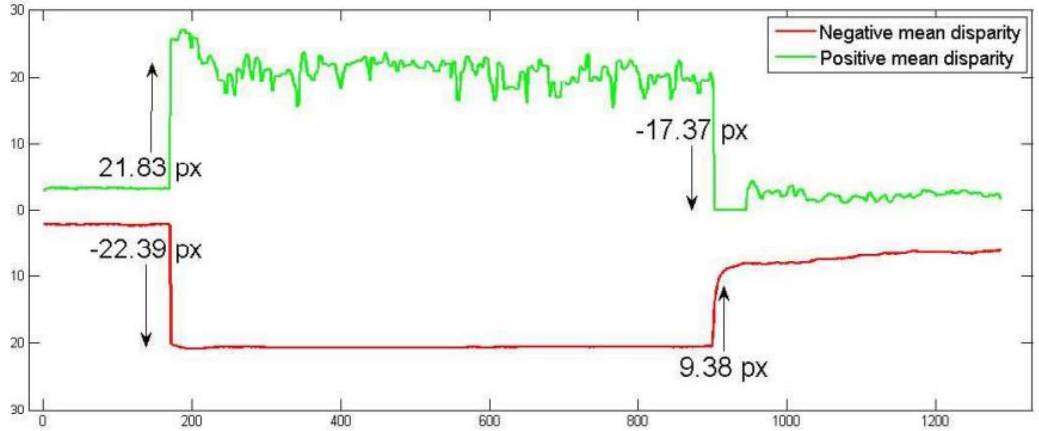
- Calculation of mean positive d^+ and negative d^- disparity, for every disparity map for every video frame n.
- The temporal derivative is calculated, finding the change of average disparity.
- Then thresholds are set for this change.
- If exceeded, we detect a jump cut.

Depth Perception Effects

Depth jump cut example:
a) Video frames; b) Mean disparities

- Frame 170: A “Highly Uncomfortable” depth jump cut.
- Frame 902: A “Mildly Uncomfortable” depth jump cut.

(a)



(b)

Focal length effects

Cardboarding Effect:

- Fixed interaxial distance
- Focal length gets longer:
  - 3D scene depth layers get separated.
  - Background moves away.
  - 3D volumes get flatter.

3D Video Quality

Stereoscopic image quality issues

- Colorimetric mismatch
- Sharpness mismatches
- Synchronization mismatch
- ***Binocular rivalry***:
  - One eye view having best quality tries to dominate.
- ***Crosstalk***:
  - Information from the two video channels is cross-blended.

3D Image and Video Quality

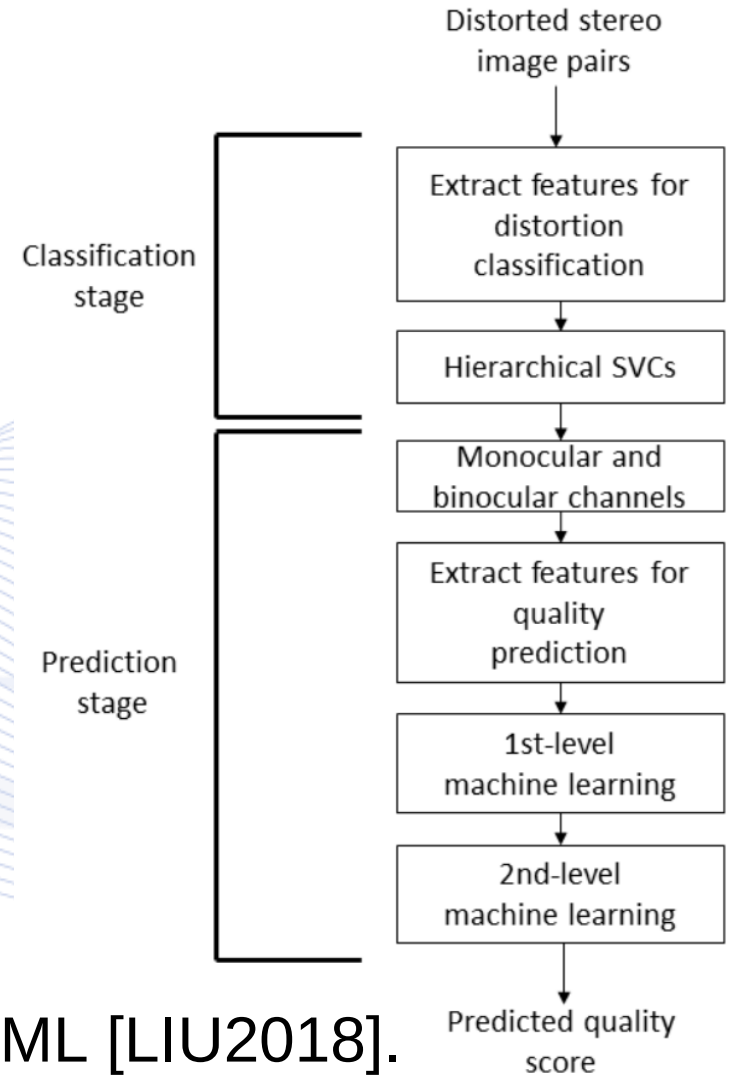
- Introduction
- Visual Discomfort
- Visual Discomfort Assessment
- Physical Immersion Effects
- Stereoscopic Window Effects
- Depth Perception Effects
- **3D Video Quality**

3D Video Quality

Parameters affecting 3D Image and Video Quality:

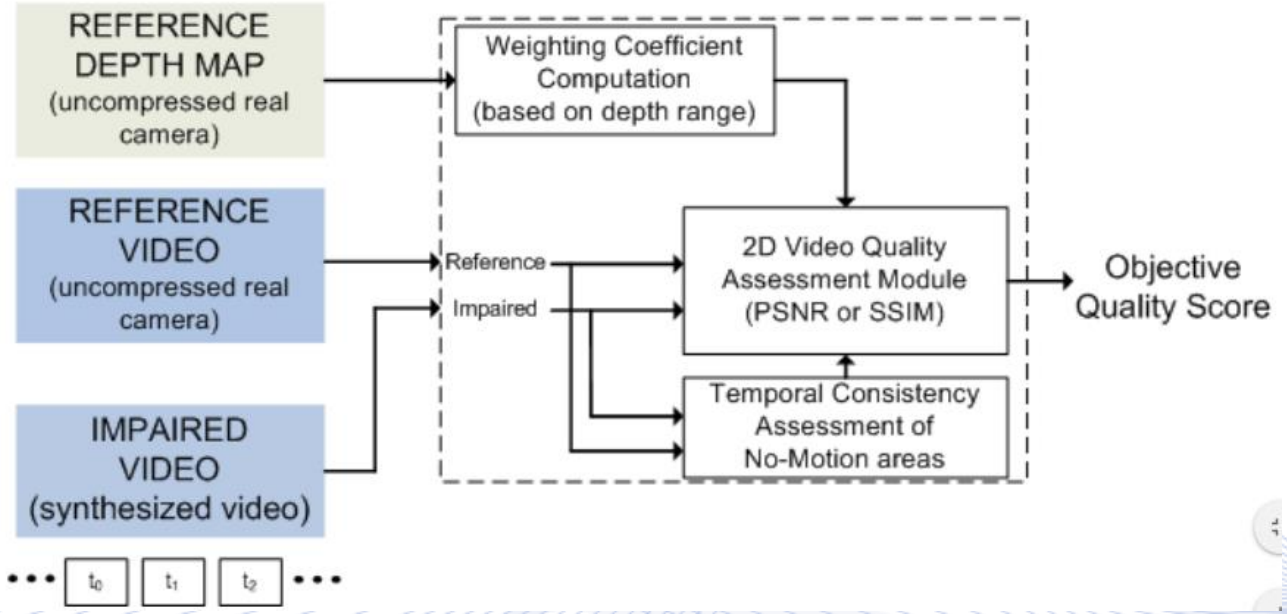
- Image/video Noise.
- Compression.
- Transmission errors, congestion, delays.

- Inter-view interaction.
- Quality of both 3D views.
- Visual comfort.
- Depth perception.



3D Image Quality Assessment by ML [LIU2018].

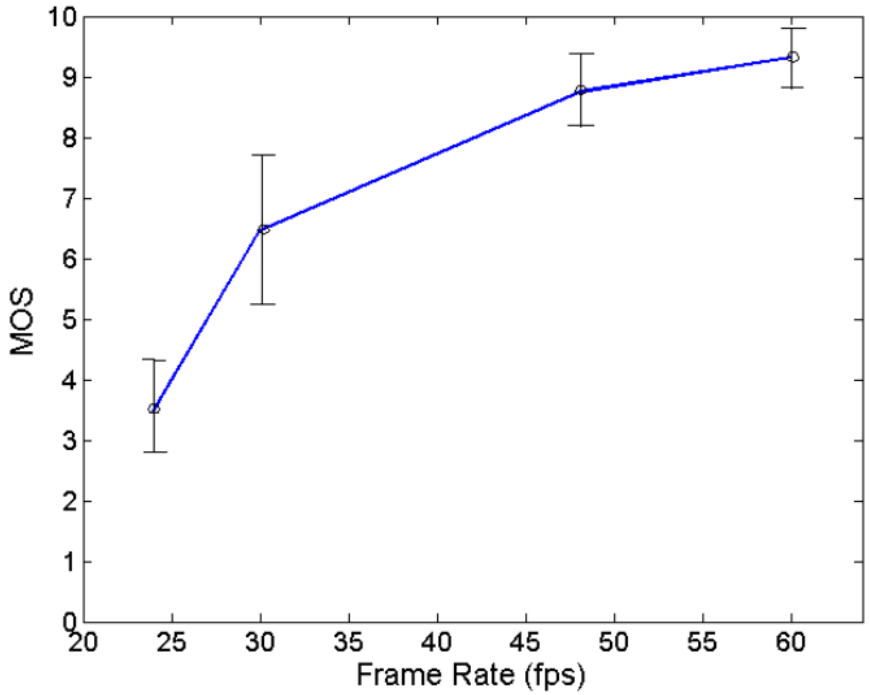
3D Video Quality



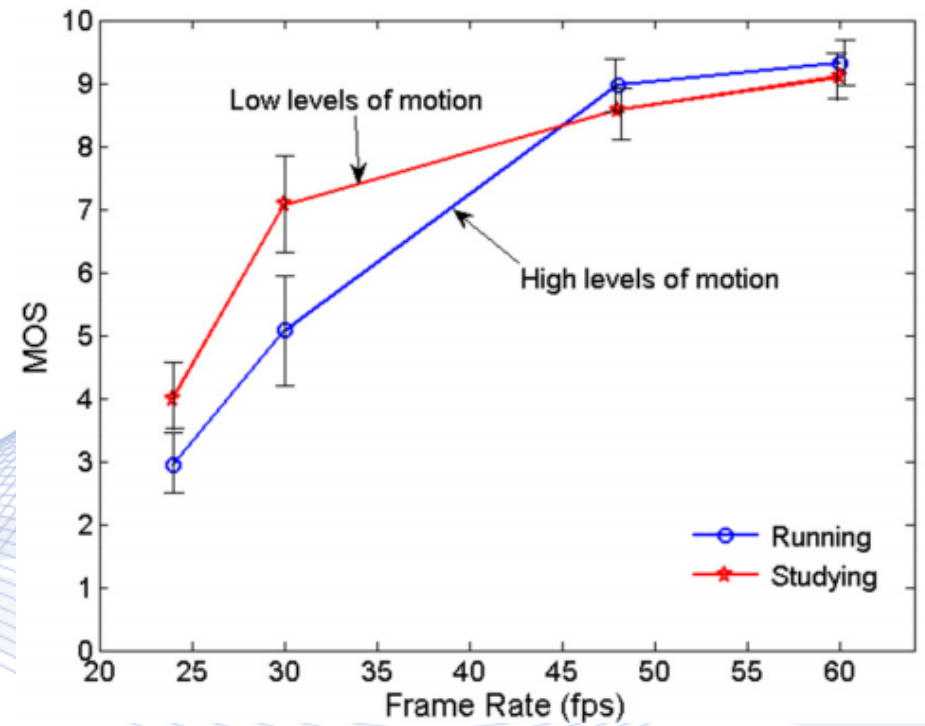
Objective 3D Video Quality Assessment.

3D Video Quality

Effect of Frame Rate on 3D Video Quality [BAN2015].



a) Mean Opinion Score on different fps



b) Mean Opinion Score on different fps and scenes.

References

[BAN2015] Amin Banitalebi-Dehkordi, Mahsa T. Pourazad & Panos Nasiopoulos, The Effect of Frame Rate on 3D Video Quality and Bitrate, 2015

[GARD11] Gardner, The dynamic floating window: a new creative tool for 3d movies, 2011

[MES2020] Oussama Messaia, Fella Hachoufa, Zianou Ahmed Seghirb, Adaboost Neural Network and cyclopean view for no-reference stereoscopic image quality assessment, 2020

[SKHB11] The zone of comfort: Predicting visual discomfort with stereo displays, 2011

[YIN2020] Hongwei Ying, Mei Yu, Gangyi Jiang, Zongju Peng, Fen Chen, Perceived depth quality - preserving visual comfort improvement method for stereoscopic 3D images, 2020

[XU2019] Xiaogang Xu, Bufan Shi, Zijin Gu, Ruizhe Deng, Xiaodong Chen, Andrey S. Krylov, Yong Ding, 3D No-Reference Image Quality Assessment via Transfer Learning and Saliency-Guided Feature Consolidation, 2019

[ZHA2019] Yun Zhang, Xiangkai Liu, Huanhua Liu, Chunling Fan, Depth perceptual quality assessment for symmetrically and asymmetrically distorted stereoscopic 3D videos, 2019

References

[MOC2014] Decebal Constantin Mocanu, Georgios Exarchakos, Antonio Liotta, Deep Learning for Objective Quality Assessment of 3D Images, 2014.

[LIU2018] Tsung-Jung Liu, Ching-Ti Lin, Hsin-Hua Liu, Soo-Chang Pei, Blind Stereoscopic Image Quality Assessment Based on Hierarchical Learning, 2018

[EKM2010] E. Ekmekcioglu, S. T. Worrall, D.V.S.X. De Silva, W.A.C. Fernando, A. M. Kondoz, Depth Based Perceptual Quality Assessment For Synthesised Camera Viewpoints, 2010

Q & A

Thank you very much for your attention!

Contact: Prof. I. Pitas
pitas@csd.auth.gr