Perceptual Analysis of Perspective Projection for Viewport Rendering in 360° Images

FALAH JABAR ET AL.

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Introduction

In most works, the impact of the final projection that creates the viewport to the user are ignored

To characterize the geometric distortions in the viewport rendering process, namely using the Tissot indicatrix

Performing a subjective assessment of the rendered images, to understand the visibility of these distortions

Perspective Projection Equation

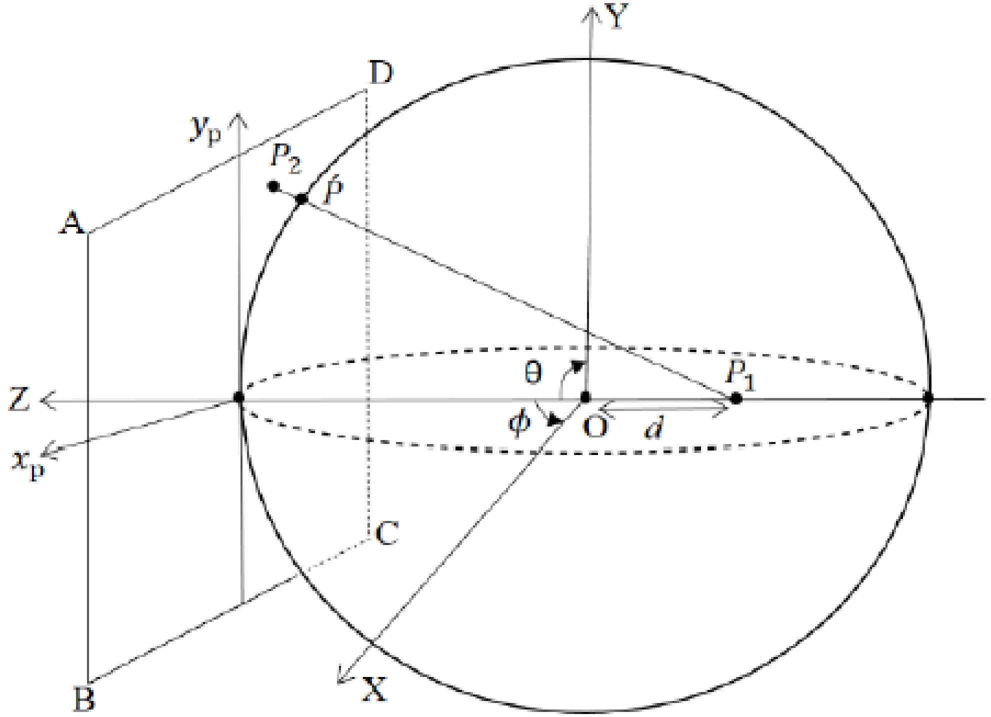
Cartesian coordinates (X, Y, Z)

Spherical angle (ϕ, θ) (longitude, latitude)

$$X = cos\theta sin\phi$$

$$Y = sin\theta$$

$$Z = cos\theta cos\phi$$



Viewer Center distance

$P_1(0,0,-d)$, $\acute{P}(X,Y,Z)$, $P_2(x_p, y_p, 1)$

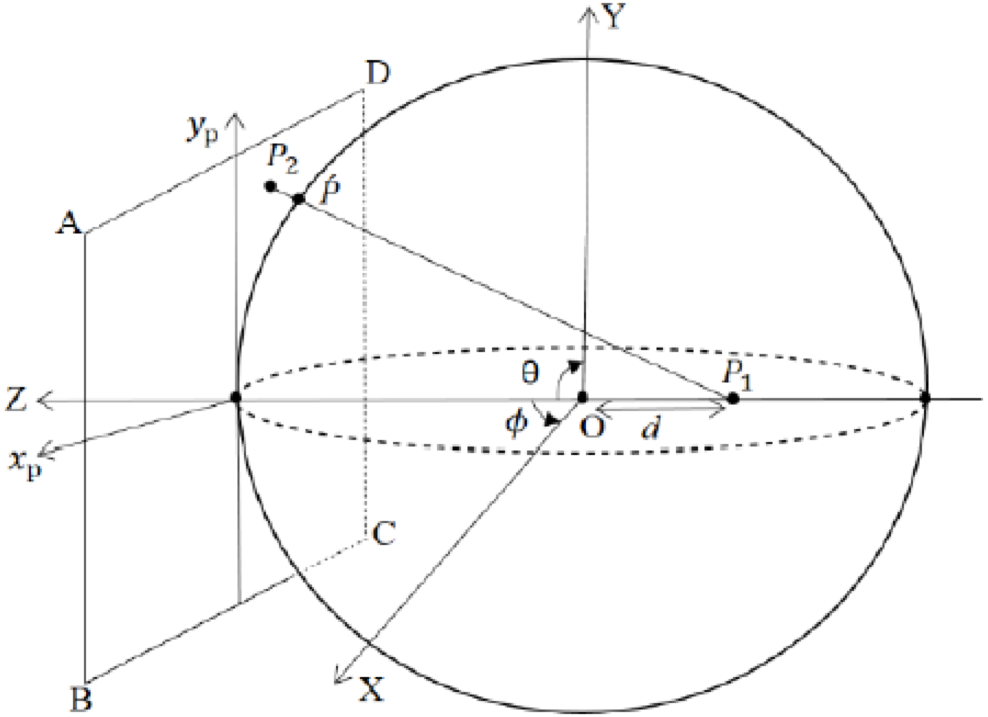
$\acute{P} = P_1 + \lambda(P_2 - P_1)$

$$x_p = X\frac{1+d}{Z+d}$$

$$y_p = Y\frac{1+d}{Z+d}$$

- $X = \lambda x_p$
- $Y = \lambda y_p$
- $Z = \lambda(1+d) - d$

$$\lambda = \frac{d(d+1) + \sqrt{\left({x_p}^2 + {y_p}^2\right)(1-d^2) + (d+1)^2}}{{x_p}^2 + {y_p}^2 + (d+1)^2}$$

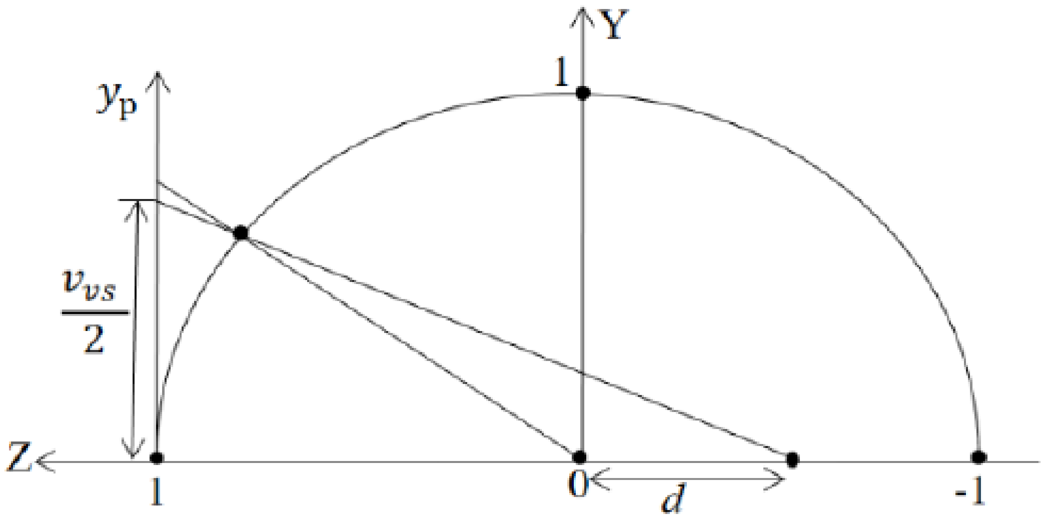


Viewport Rendering

With horizontal and vertical FoV, F_h and F_v, we can get viewport size v_{vs} and v_{hs}

$$v_{vs} = 2(d+1)\frac{sin\frac{F_v}{2}}{d+cos\frac{F_v}{2}}$$

$$v_{hs} = 2(d+1)\frac{sin\frac{F_h}{2}}{d+cos\frac{F_h}{2}}$$

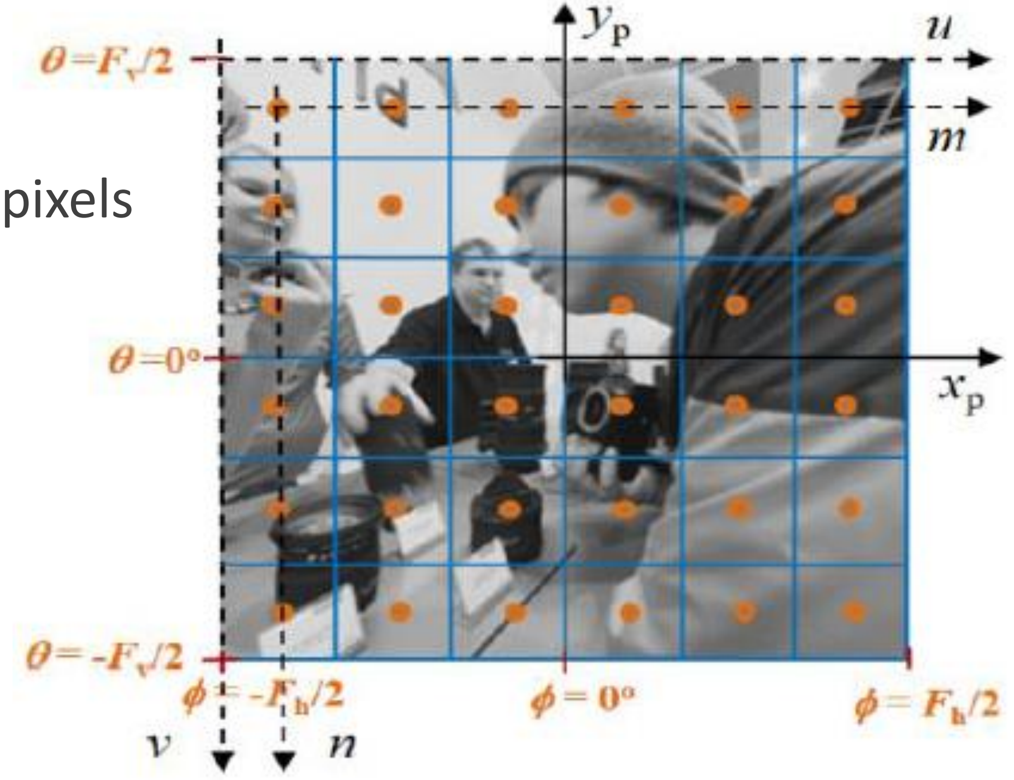


Viewport Rendering cont.

$$u = (m + 0.5)\frac{v_{vs}}{W}$$

$$v = (n + 0.5)\frac{v_{hs}}{H}$$

- *W* and *H* are the viewport width and height in pixels
- Use bilinear interpolation if needed



$$x_p = u - \frac{v_{hs}}{2}$$

$$y_p = \frac{v_{vs}}{2} - v$$

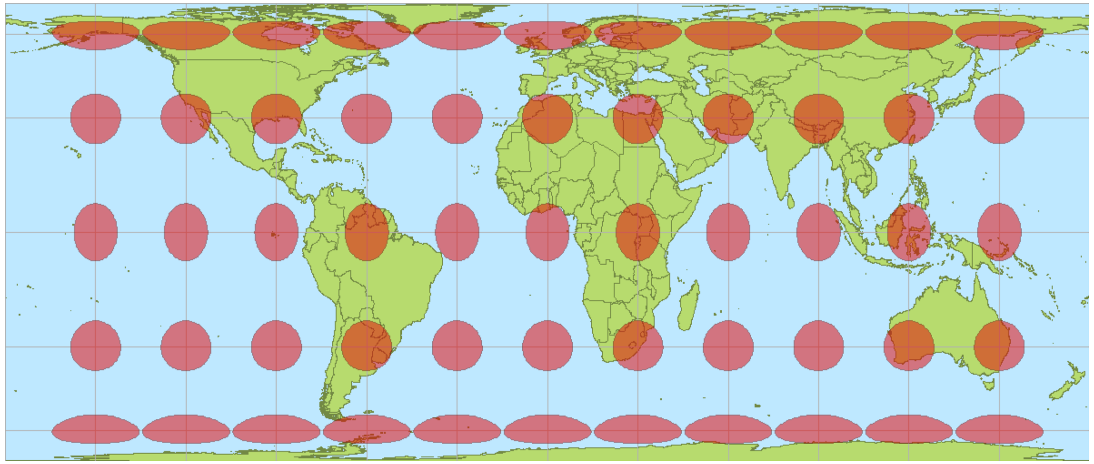
Rendering Results

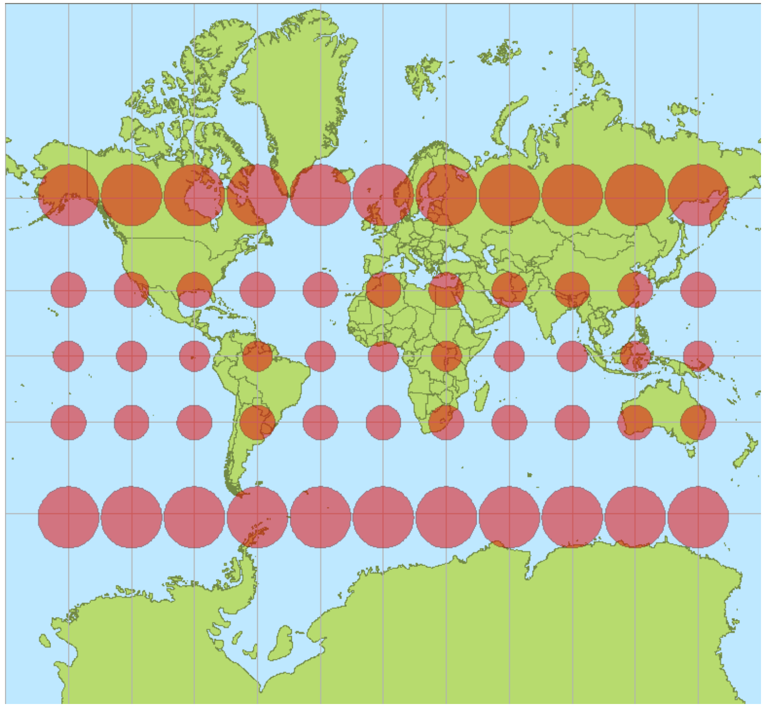
a) d=0 b) d=0.25 c) d=0.75 d) d=1

Tissot's Indicatrix

An graphical analysis of the local distortion when performing map projection

The shape of ellipse is related to the scale distortion and to the angular deformation





Math Concept

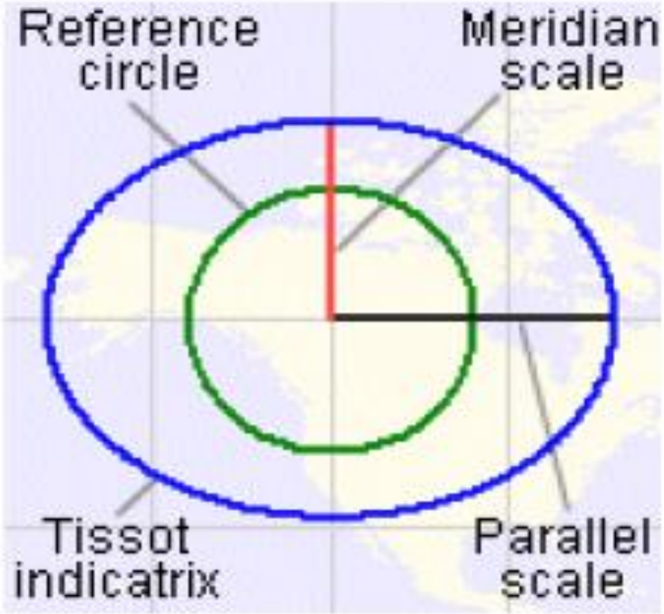
Goal: maximum and minimum scale factors (a, b)

Meridian scale h, parallel scale k, and the angular deformation θ'

$$h = \sqrt{\left(\frac{\partial x_p}{\partial \theta}\right)^2 + \left(\frac{\partial y_p}{\partial \theta}\right)^2}$$

$$k = \frac{1}{cos\theta}\sqrt{\left(\frac{\partial x_p}{\partial \phi}\right)^2 + \left(\frac{\partial y_p}{\partial \phi}\right)^2}$$

$$sin\ \theta' = \frac{1}{h\ k\ cos\theta}\left(\frac{\partial y_p}{\partial \theta}\frac{\partial x_p}{\partial \phi} - \frac{\partial x_p}{\partial \theta}\frac{\partial y_p}{\partial \phi}\right)$$



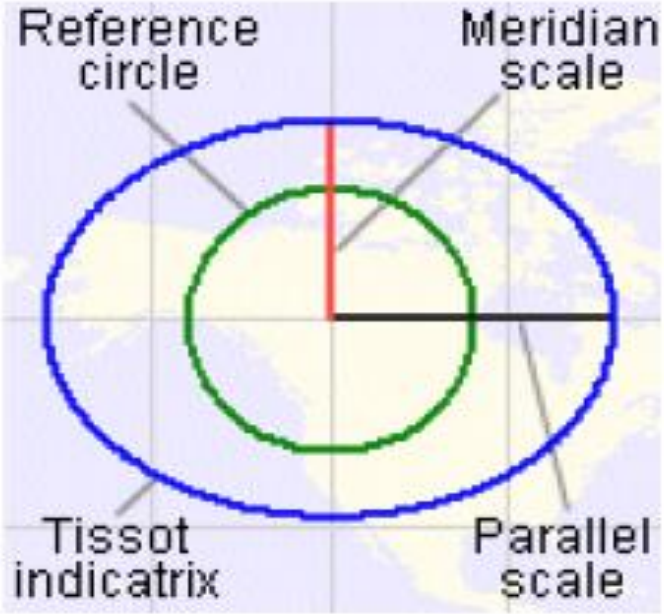
Math Concept cont.

Auxiliary terms a’ and b’

- $a' = \sqrt{h^2 + k^2 + 2hk\ sin\theta'}$
- $b' = \sqrt{h^2 + k^2 - 2hk\ sin\theta'}$

And finally got a, b

- $a = \frac{a'+b'}{2}$
- $b = \frac{a'-b'}{2}$



Analysis Metrics

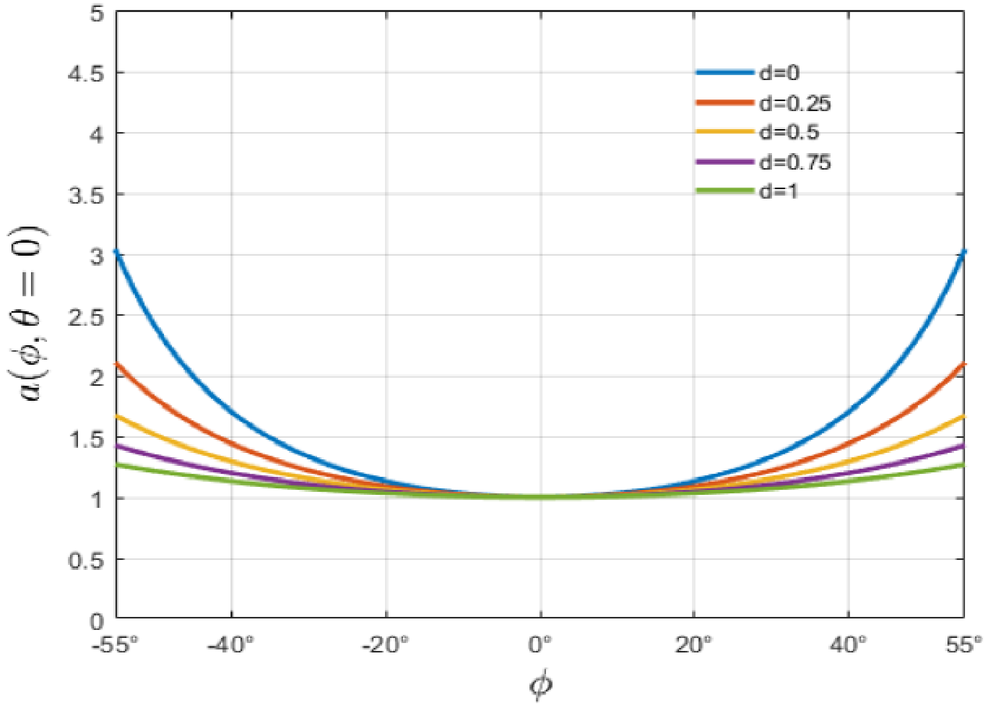
The amount of inflation or deflation in the area, s, and the shape distortion, t, are given by:

$$s = a \cdot b$$

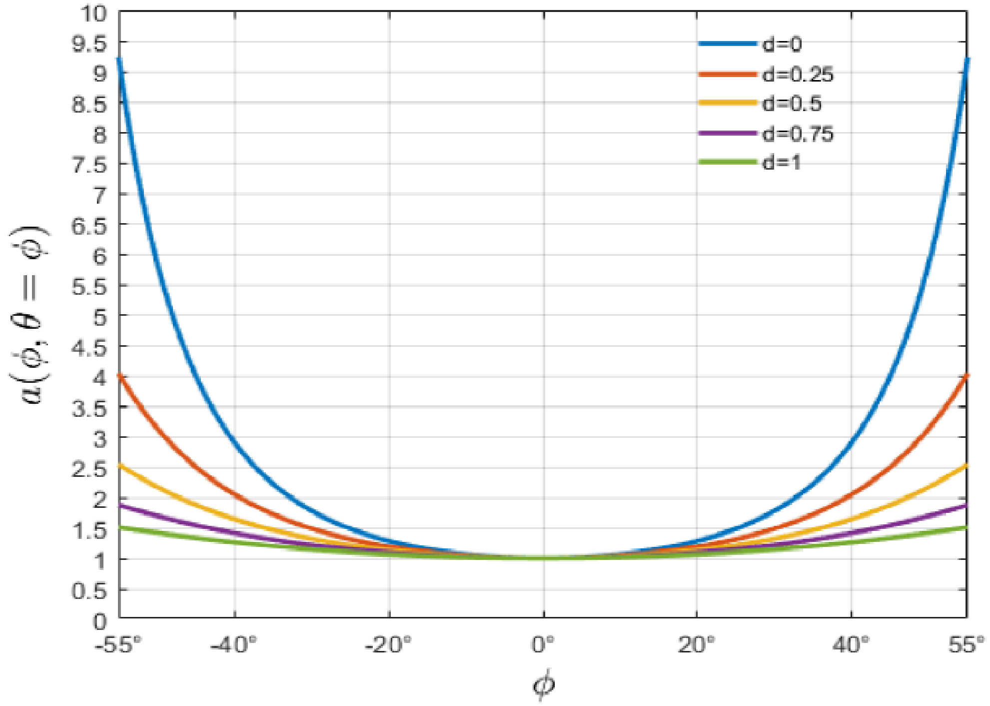
$$t = a/b$$

Indicatrix Analysis

Resulting a as a function of the longitude (ϕ)



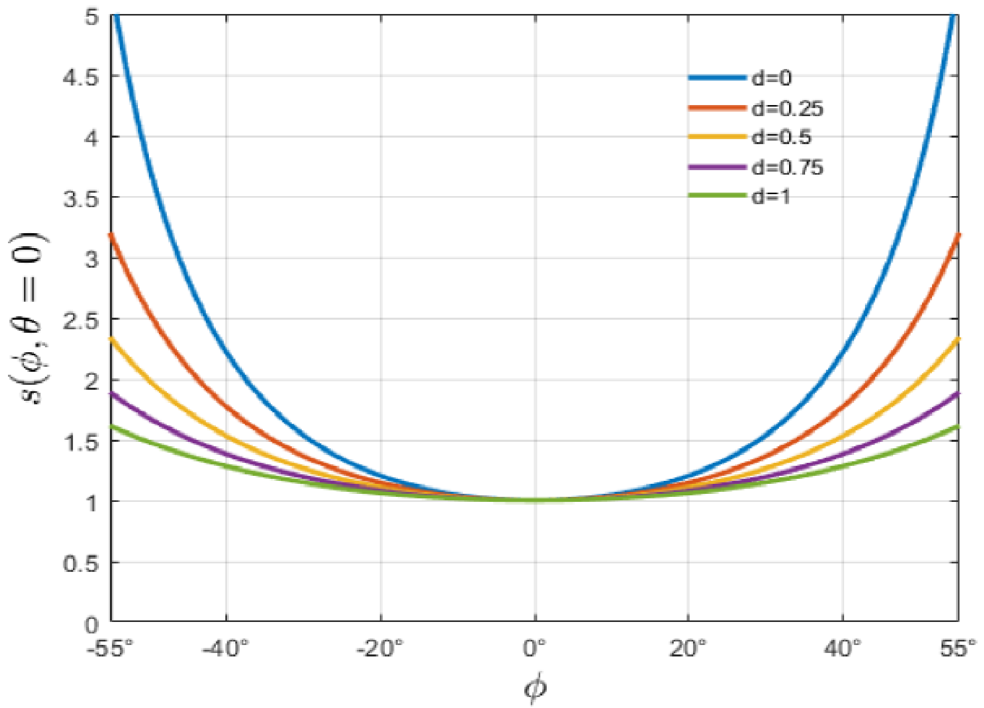
a)



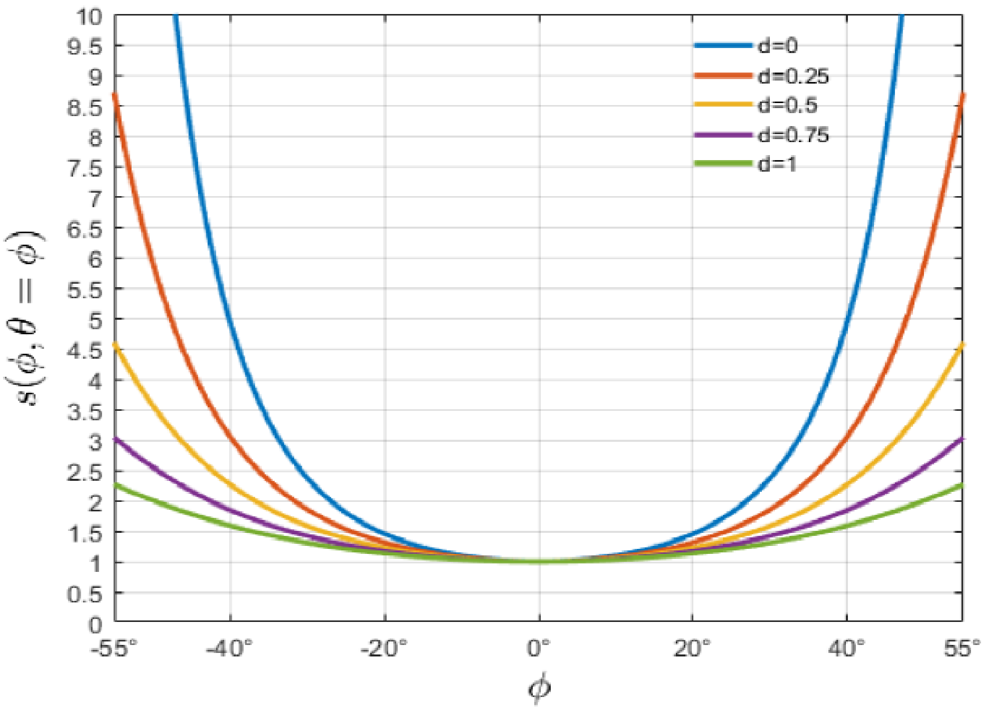
b)

Indicatrix Analysis cont.

Resulting s as a function of the longitude (ϕ)



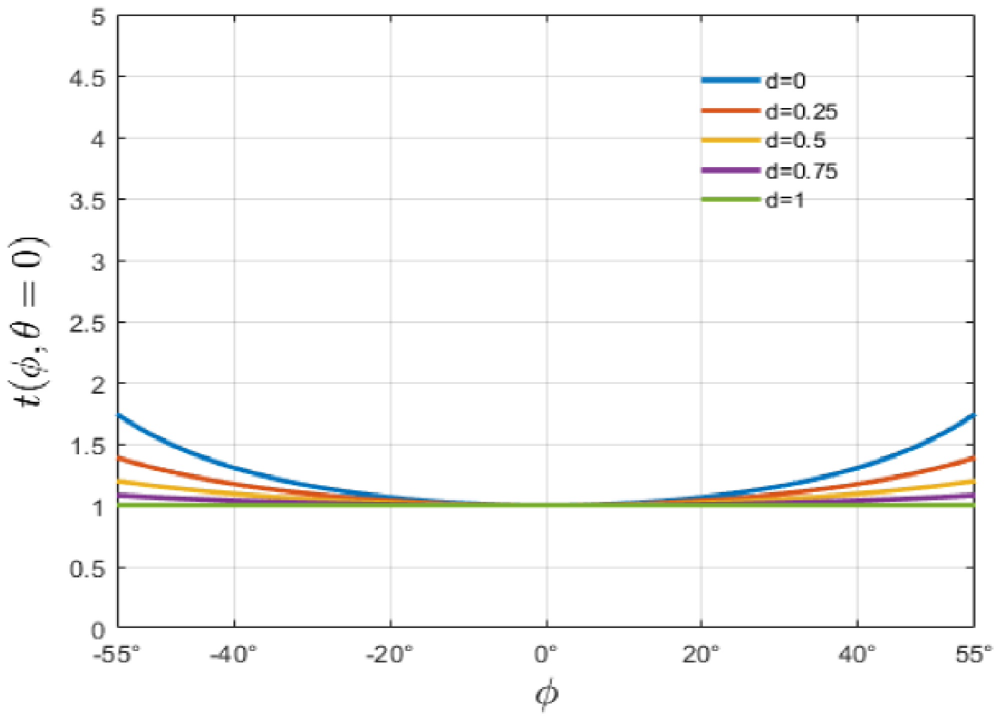
c)



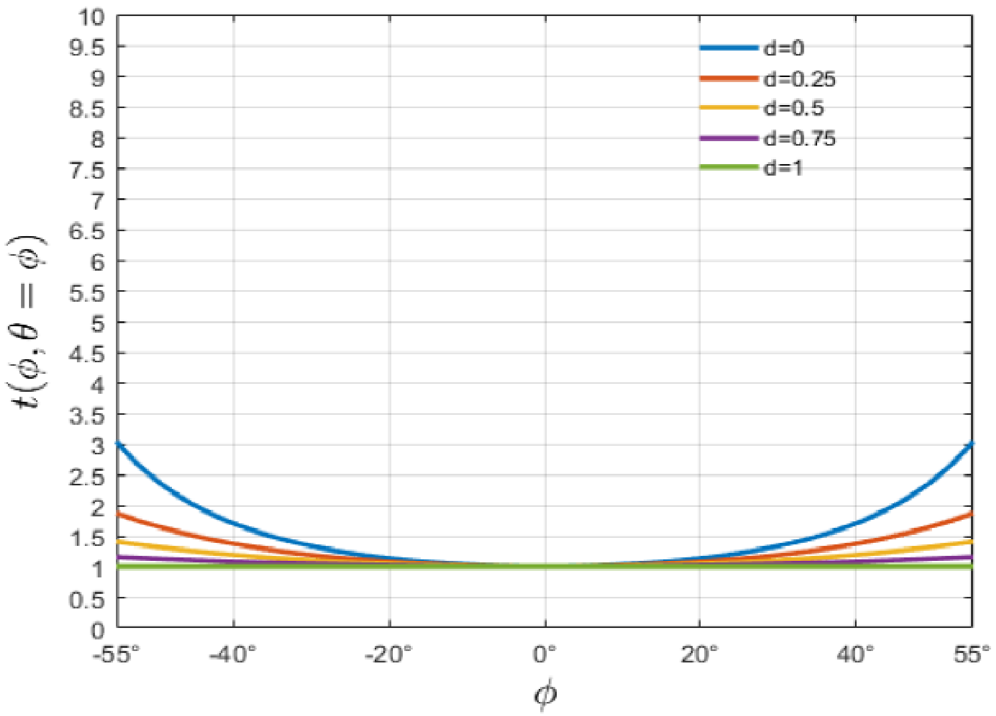
d)

Indicatrix Analysis cont.

Resulting t as a function of the longitude (ϕ)



e)



f)

Subjective Evaluation

a) Image 1

b) Image 2

c) Image 3

d) Image 4

Test Materials

Each viewport corresponding to a pair (d, FoV)

$d \in \{0, 0.25, 0.5, 0.75, 1\}$

$FoV \in \{75°, 90°, 110°\}$

15 images would be generated for each viewport

Viewport
856*856

Evaluation Methods

1. Use rectilinear projection (d=0) as references
2. Two images of the same viewport were displayed side by side
3. 20 participants, give opinion about the viewport with a score 0~3

4. Finally for each evaluated viewport, it'll get a score between -3 and 3
5. Normalize the score to [0, 10]
6. Get the MOS for each viewport

Perceptual Evaluation Analysis

*pr*1 to *pr*4 are corresponding to *d* = {0.25, 0.5, 0.75, 1} respectively

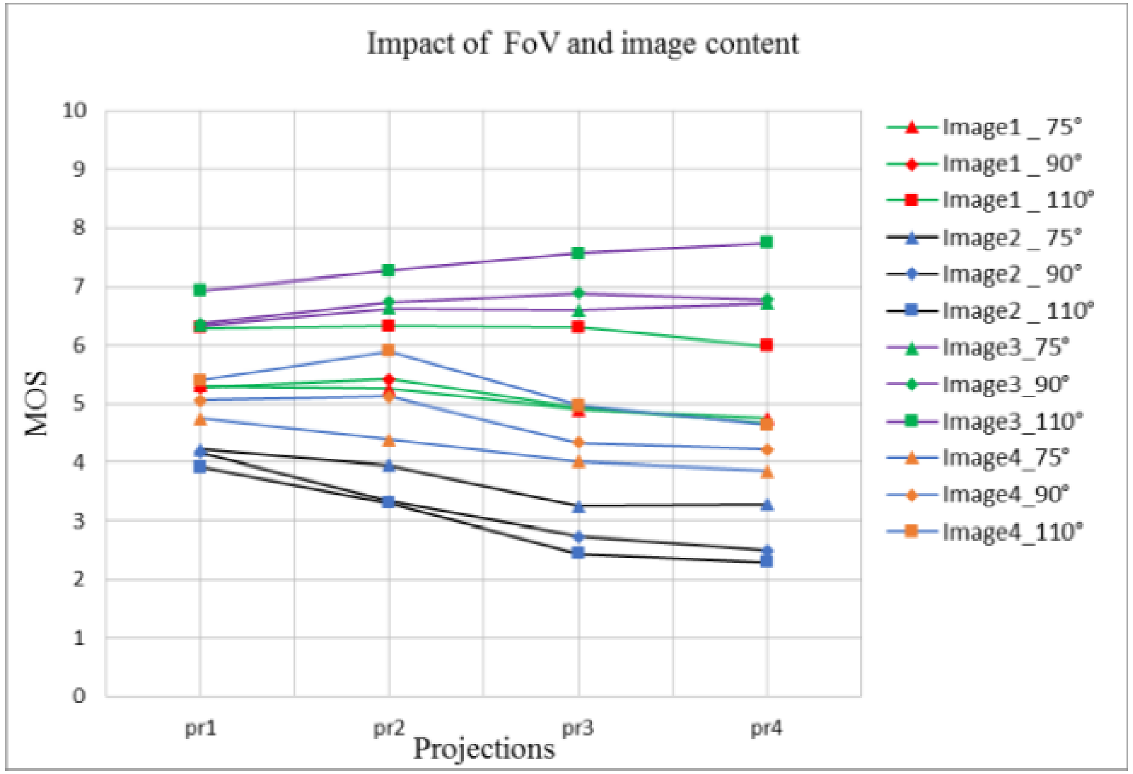


Fig. 8. MOS as a function of the projection center for the test images and FOVs.

Perceptual Evaluation Analysis cont.

MOS is the average value over the 5 viewing directions and over the 3 FoVs

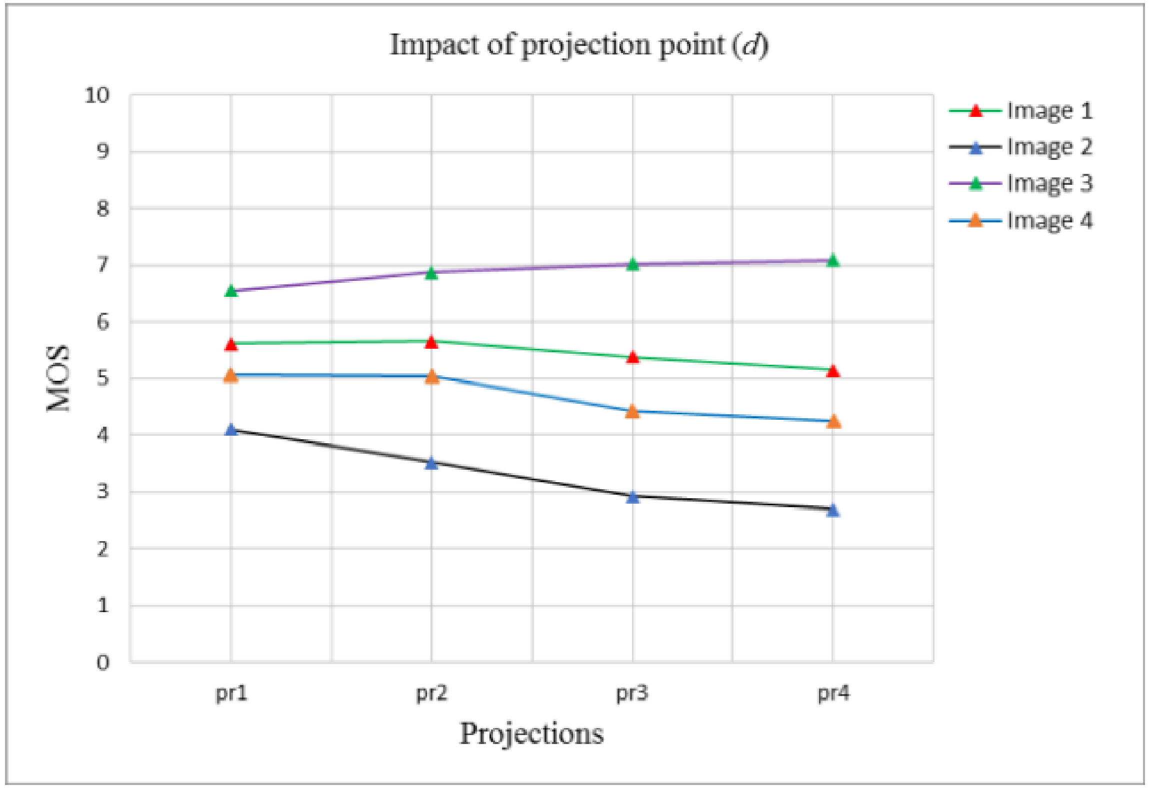


Fig. 10. Overall scores for each projection.

a) d=0 b) d=1

c) d=0 d) d=1

Fig. 11. Example of viewports with FoV=110° and rendered with rectilinear projection (a) and c)) and stereographic projection (b) and d)).

Conclusion

Tissot indicatrices may explain some of the visual distortions, it provides only a distortion measurement that is local and independent on the video content

The resulting geometric distortions are not only dependent on the considered projection and FoV, but also on the image content

Thanks for Listening

ANY QUESTION?