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Equi-radial Vehicular laser shadowgraphy

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Abstract: In this work a laser shadowgraphy technique designed to test and enhance the automotive visual ergonomics is described. An experimental setup is used to test the field of view (FOV) of three sample cars through equi-radial laser beam shadowgraphy from driver's cyclopean eye position. A resulting shadowgraph is analyzed to retrieve ergonomic drawbacks of each sample design. this technique we helps in the design of safer cars and also can be used to differentiate between several competitive cars from the same class whenever on ergonomic bases to lower collision probability due to bad designed driver's FOV. A complete modeling of experimental parameters is inclusive.

Keywords:

FOV, Ergonomics, Laser shadowgraphy, In-car design evaluation, Blind zones, cylindrical plot, automotive interior

1. Introduction

In order to increase the safety of drivers and passengers, several techniques are used to investigate the field of view (FOV) of vehicles[1-19]. Most of these techniques are very sophisticated in terms of practical analysis. We decided try another approach by using laser shadowgrphy from in-car to regenerate a panoramic scene that simulates driver's FOV. This scene is used to judge the safety of the investigated car according to the amount of dead visual zones in the FOV resulting from the shading of car cabin pillars and interior components. Also the yielded scene can be can be considered as test used to differentiates between the driver ergonomics of several competitive vehicles of the same automotive class.

2. Test Theory

The theory of our test is based on projecting a high divergence 2 Radian laser beam from car interior on a cylindrical screen surrounding the vehicle of height L =2.5m, where the projection center as well as the screen center is the driver cyclopean eye position as seen in figure 1. At the same time a narrow field camera ganged axially to the used laser is allowed to take successive shots to form the panoramic scene.

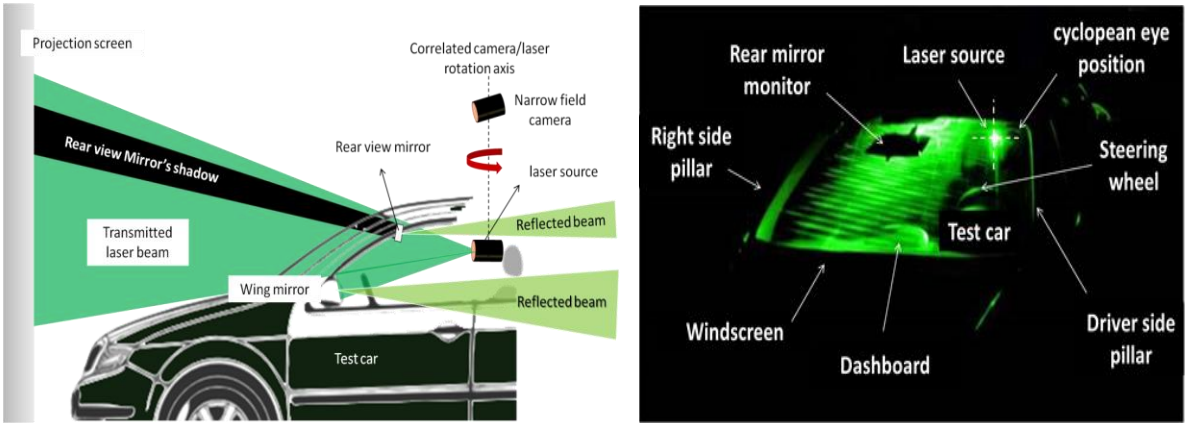
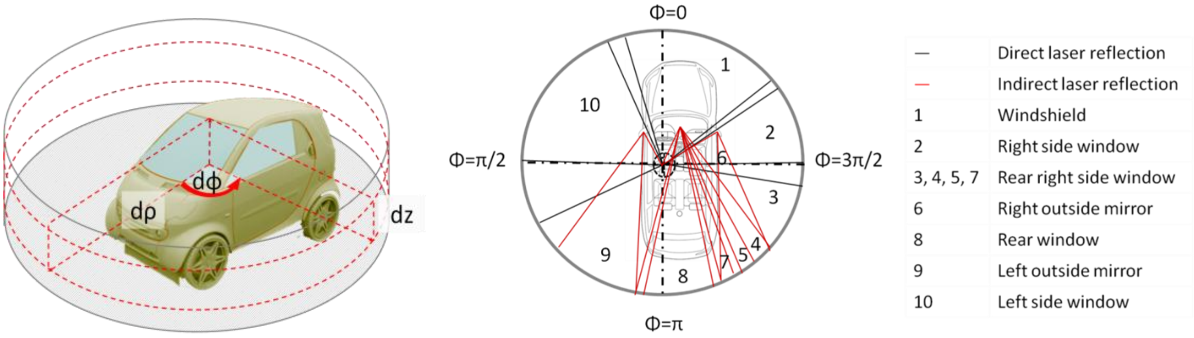


Figure 1. Laser shadowgraphy method

To model the test mathematically, we used cylindrical coordinates to match to symmetry of the test setup as shown in figure 2a. Where the coordinate center is the cyclopean eye center and hence:

$$dA = \rho d\varphi \times dz \tag{1}$$

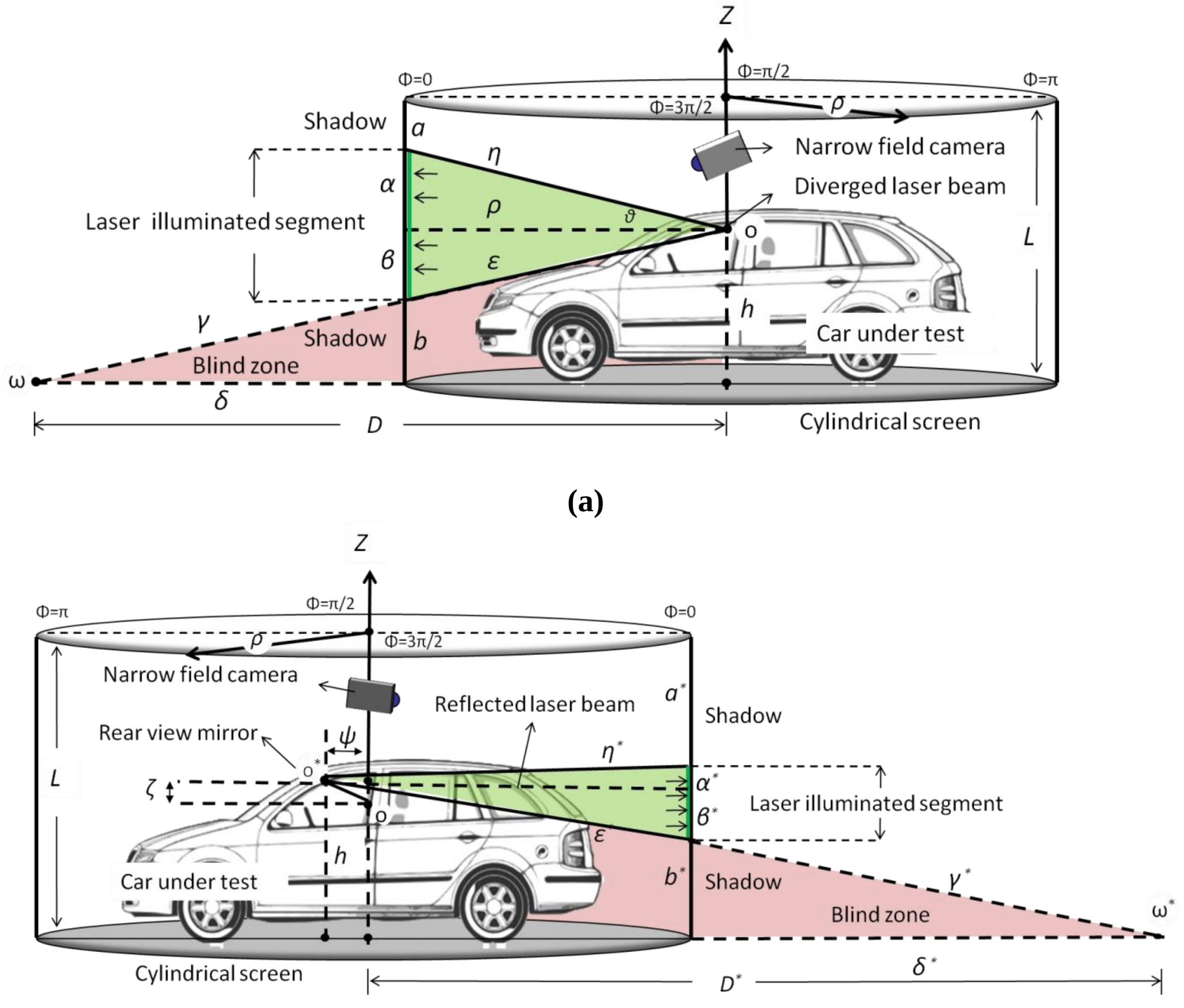
The project shadowgram is equiradial as shown in figure 2b, the thing that may ease the analysis of FOV.



(a) **(b)**

Figure 2. illustration of (a) cylindrical coordinates modeling and (b) the equiradial shadowgraphy.

Now we have two FOV situation, the first is the direct FOV formed by direct eye sighting and the second is the indirect FOV through mirrors. Both situations are analyzed in figure 3.a and figure 3.b successively.



(a)

(b)

Figure 3. FOV modelling (a) direct FOV (b) indirect FOV

From the geometries of figure 3, the span of the blind zoon in the direct FOV is calculated from the equation:

$$D(\varphi) = \delta + \rho = \frac{\delta h}{b} = \frac{\rho h}{h-b} \tag{2}$$

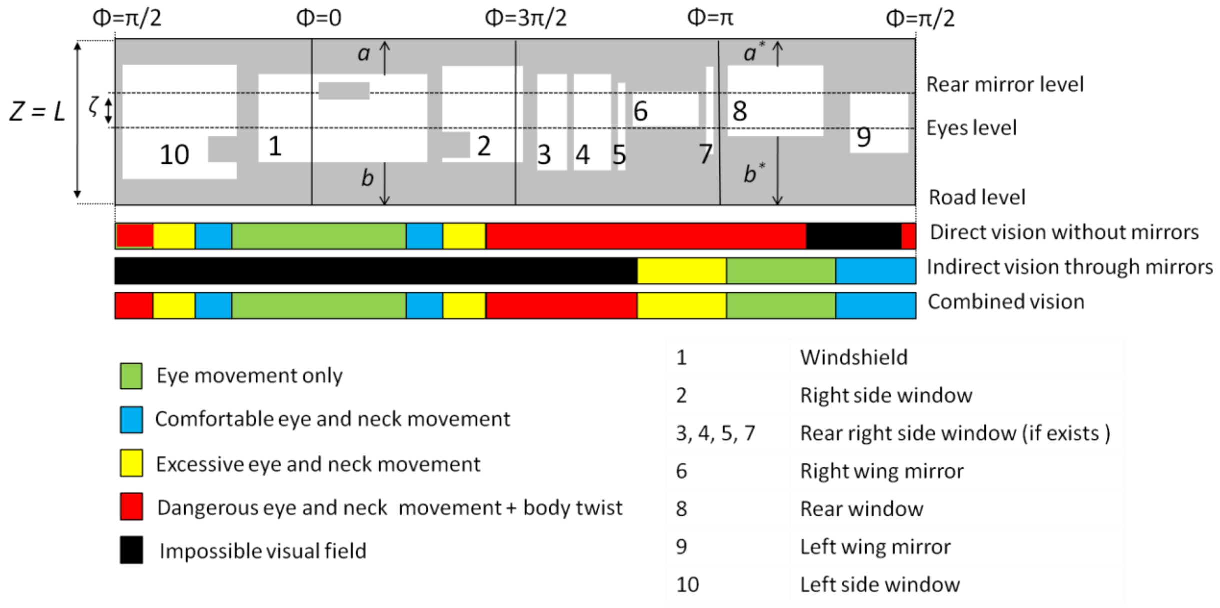
In analogy, the the span of the blind zoon in the indirect FOV is calculated from the equation:

$$D^*(\varphi) = \delta^* + \rho = \frac{(h+\zeta)\rho + b^*\psi}{(h+\zeta) - b^*} \tag{3}$$

The vertical sighting angle limit is given by the equation:

$$\theta(\varphi) = \tan^{-1}(\alpha/\rho) = \tan^{-1}\left(\frac{L-a-h}{\rho}\right) \tag{4}$$

Figure 4 illustrates the yielding FOV panoramic scene obtained by equiradial shadowgraphy from vehicle interior.



1	Windshield
2	Right side window
3, 4, 5, 7	Rear right side window (if exists)
6	Right wing mirror
8	Rear window
9	Left wing mirror
10	Left side window

Figure 4. Illustration of FOV panoramic scene obtained by equiradial shadowgraphy

Experimental testing

We applied equiradial shadowgraphy on three test cars of different classes as shown in figure.

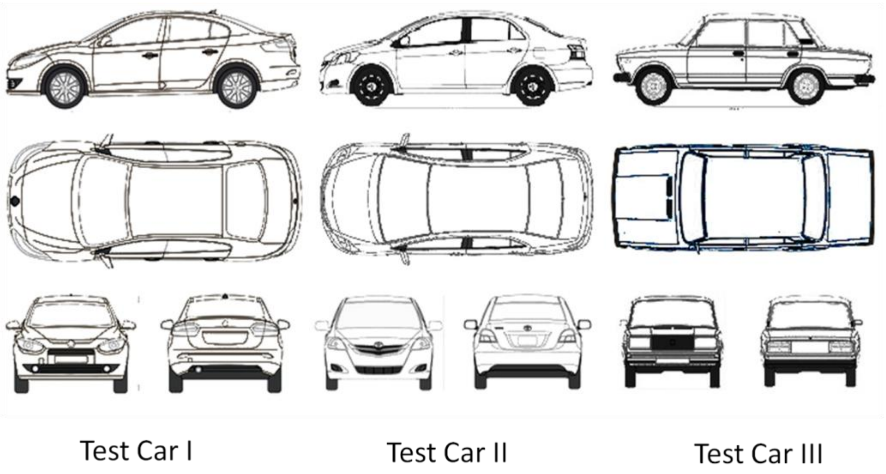


Figure 5. blue print of test cars

The screen diameter was 8 meters wide made of white printing plastic paper hanged on ground supports as we perform equiradial shadowgraphy using a one watt military green laser diode. As shown in figure 6.


(a) (b)

Figure 6. practical FOV testing (a) cylindrical screen. (b) laser backlighting.

3 Experimental results

As shown in figure 7, we made a comparative shadowgraphic FOV panorama plot resuming all results in on sheet to reveal the ergonomic aspects of each car FOV design.

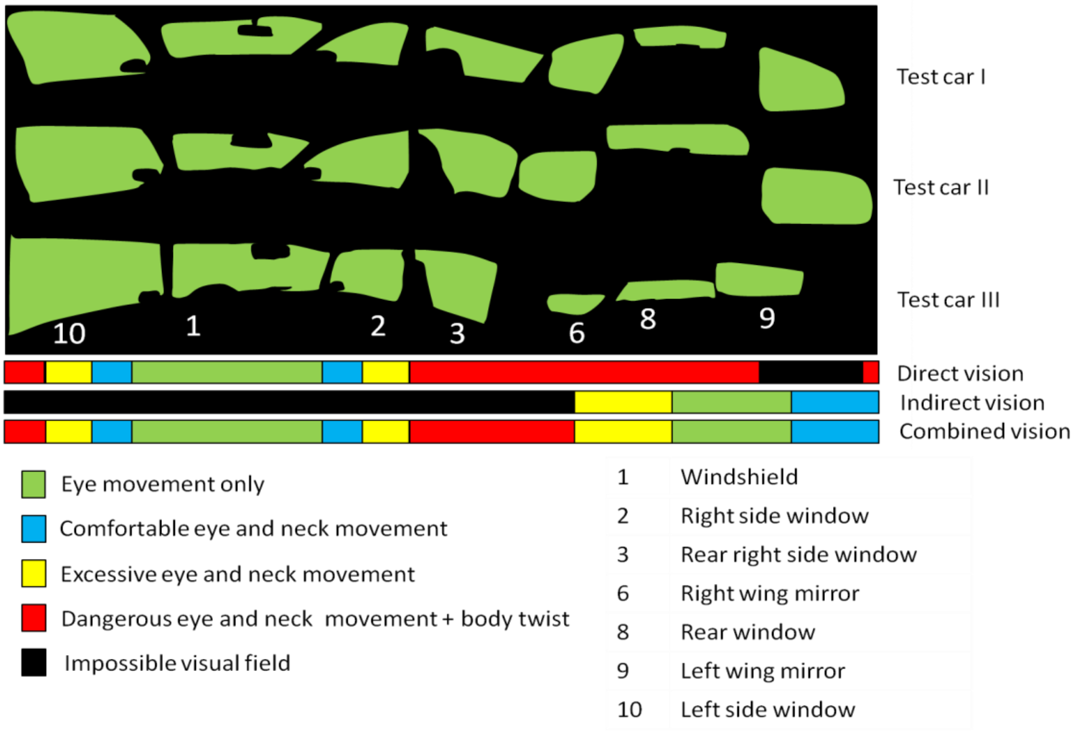


Figure 7. Comparative FOV plot

From the proceeding result we can conclude that, the inclination angle of car cabin pillars, decreases the driver’s FOV, and that the indirect FOV is so much affected by the mirror type, area and presetting.

Conclusion

Equiradial shadowgraphy is a new laser technique that allow easy automotive testing and investigation of both direct and indirect driver’s FOV. The technique also permits comparative testing between several competitive cars in order to judge their safety. It may be also suitable to investigate drivers ergonomics and can be used to test a wide variety of vehicles with low cost instrumitations, yielding a characterizing FOV plot for the tested item that helps in the future design problem solving.

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