Problem #1:

Assume that you have a camera with a resolution of 10MP where the camera sensor board has dimensions of a width of 14mm and height of 10mm. It is also given that the focal length of the lens of the camera is 25mm.

1. Compute the Field of View of the camera in the horizontal and vertical directions. [20]

2. Assuming you are detecting a human that is moving in front of the camera. The minimum distance that this human can be from the camera is 10 meters and the maximum distance is 50 meters. Assuming that an average human height is 5’ 7” and width is 50 cm, compute the minimum and maximum number of pixels that this person will occupy in the camera as images when passing in front of the camera. [40]

3. Compute the distance that you will need to focus your camera to, to get the best performance, given that the aperture diameter is 8.9 mm. The circle of confusion is 0.019 mm. Justify your answer. [40]

Hint : Experiment with different focus distances of 7m, 8m, 9m, 10m and 11m to find the most suitable value.

Qn1. Field of View

Answer:

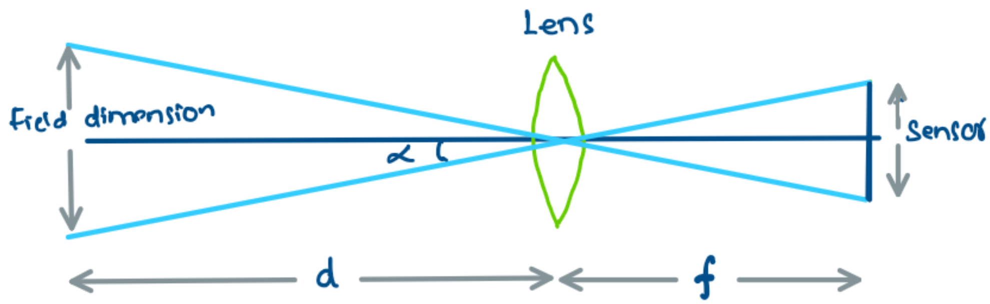
Given:

Camera Resolution: 10 MP

Camera Sensor Board Width: 14 mm

Camera Sensor Board Height: 10 mm

Focal Length of Camera: 25 mm



Width = 14 mm
Height = 10 mm

$$V.\ FOV = 2 \times \tan^{-1}\left(\frac{(10/2)}{25}\right)$$
$$= 2 \times \tan^{-1}\left(\frac{5}{25}\right)$$
$$= 2 \times \tan^{-1}(1/5)$$
$$= 22.62\ deg$$

$$H.\ FOV = 2 \times \tan^{-1}\left(\frac{7}{25}\right)$$
$$= 31.28\ deg$$

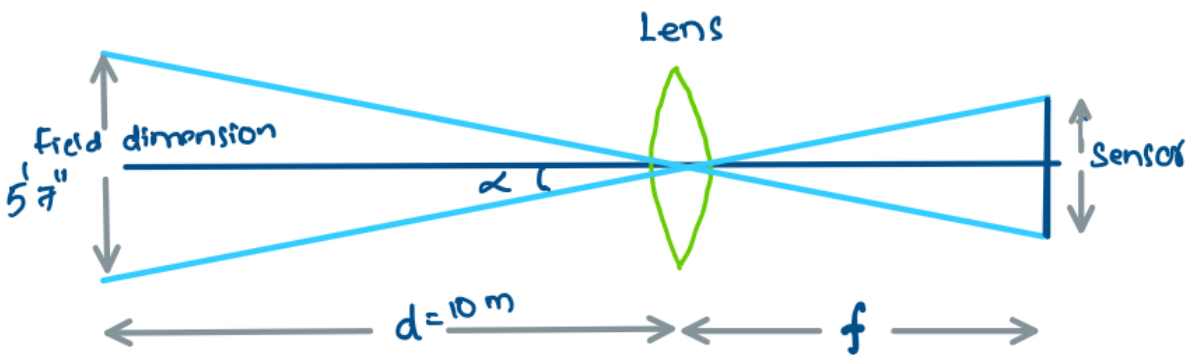
Qn2. Minimum and maximum number of pixels of a Person

Answer:

Given: Let ‘x’ and ‘y’ be the sensor board dimensions (height and width respectively)

Thin Lens Eqn:

$$\frac{\text{Sensor dimension}}{\text{Focal length}} = \frac{\text{Field Dimension}}{\text{Distance to Field}}$$



Field	Sensor

$$\frac{5'7''}{10\ m} = \frac{y\ mm}{25\ mm}$$

$$\frac{1701.8\ mm}{10\times1000\ mm}$$

$$0.17018 \times 25\ mm = y$$

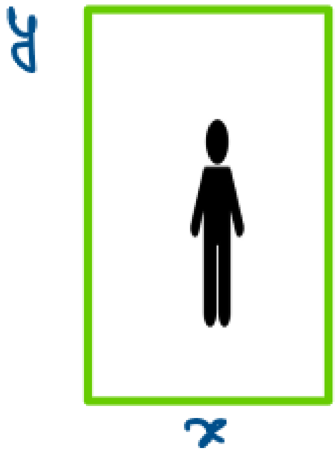
$$y = 4.2545\ mm$$

$$\frac{50\ cm}{10\ m} = \frac{x\ mm}{25\ mm}$$

$$\frac{50\cancel{0}\ mm}{10\times 10\cancel{00}\ mm} = \frac{x\ mm}{25\ mm}$$

$$\frac{5}{\cancel{100}_{4}} \times \cancel{25} = x$$

$$x = 1.25\ mm$$



<---- The approx. area of the person in the sensor board

When the person is standing at a distance of 10 cm (Maximum distance):

If 10 mm x 14 mm area corresponds to 10 Mega pixels, then the pixels for the above rectangle area can be computed as below:

$$10 \times 14 \xrightarrow{mm^2} 10 \times 10^6 \text{ Pixels}$$

$$4.2545 \times 1.25 \; mm^2 \longrightarrow \; ? \quad \text{Pixels}$$

$$\text{No. of Pixels} = \frac{\cancel{10} \times 10^6}{\cancel{10} \times 14} \times 4.2545 \times 1.25$$

$$= 0.379866071$$

$$\approx 379866 \text{ (or) } 0.38 \text{ MP}$$

If the person is Standing at 50 m

$$\frac{1701.8}{50\times 1000} \times 25 \text{ mm}$$

$$y = 0.8509 \text{ mm}$$

$$\frac{50 \text{ cm}}{50 \text{ m}} = \frac{x \text{ mm}}{25 \text{ mm}}$$

$$\frac{\cancel{500} \text{ mm}}{\cancel{50} \times \cancel{1000} \text{ mm}} \times \cancel{25} \text{ mm} = x$$

$$4$$

$$x = 0.25 \text{ mm}$$

$$\text{No. of Pixels} = \frac{\cancel{10}\times 10^6}{\cancel{10}\times 14} \times 0.25 \times 0.8509$$

$$= 0.015194 \times 10^6 \text{ Pixels}$$

$$= 15{,}194 \text{ Pixels or } 0.015 \text{ MP}$$

Therefore, the minimum and maximum number of pixels that this person will occupy in the camera as images when passing in front of the camera are -

Maximum number of pixels: **379,886 pixels**

Minimum number of pixels: **15,914 pixels**

Qn3. Distance to Focus the Camera for best Performance:

Answer:

Given:

Aperture diameter: 8.9 mm

The hyperfocal distance is given by the following formula.

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$$H = \frac{f^2}{Nc} + f$$

$$N = \frac{\text{focal length}}{\text{aperture diameter}} = \text{f-number}$$

$$= \frac{25\ mm}{8.9\ mm}$$

$$= 2.809$$

$$H = \frac{25^2\ mm^2}{2.809 \times 0.019\ mm} + 25\ mm$$

$$= 11710.48 + 25$$

$$= 11735.48\ mm$$

$$= 11.735\ m$$

greatest depth of field for acceptable sharpness

Case 1: Focus distance 7m:

$$D_n = \frac{S(H-f)}{H+S-2f}$$

$$= \frac{7000(11710.48)}{11735.48 + 7000 - 2 \times 25}$$

$$= \frac{7000 \times 11710.48}{(11735.48 + 7000 - 50)}$$

$$= 4387\ mm$$

$$\simeq 4.39\ m$$

$$D_f = \frac{S(H-f)}{H-S}$$

$$= \frac{81973360}{4735.48}$$

$$= 17310.46\ mm$$

$$\simeq 17.31\ m$$

Similarly,

Focus Dist.	Dn	Df
8 m	4.76 m	25.08 m
9 m	5.1 m	38.53 m
10 m	5.4 m	67.48 m
11 m	5.68 m	175.14 m

It can be seen from the above calculations, that when the aperture diameter is 8.9 mm, the distance that is needed to focus, to get **the best performance (focus at infinity)** is its hyperfocal distance, which is **11.3 m**. It is also evident that as the focus distance increased, the 'near distance of acceptable sharpness' and the 'far distance of acceptable sharpness' are increased.