Basic Optical Principles and Imaging Systems

Examples and component selection

Basic mechanisms of changes in light characteristics to dimensional measurement

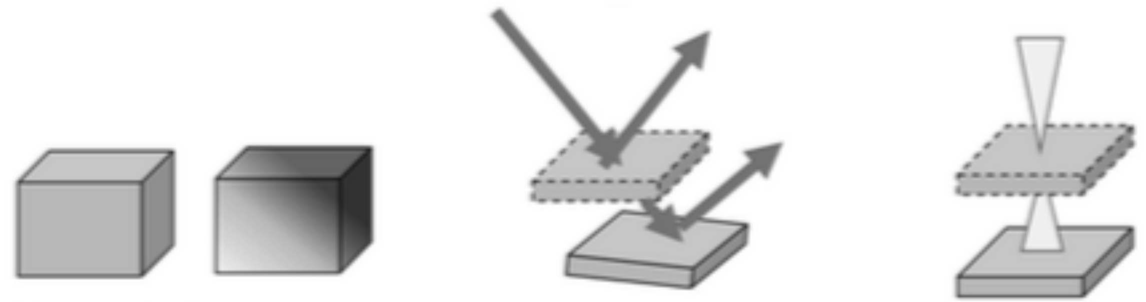


Figure 1.3 Simple illustrations of the basic mechanisms of changes in light characteristics in response to dimensional measurement.

Basic components of a machine vision system

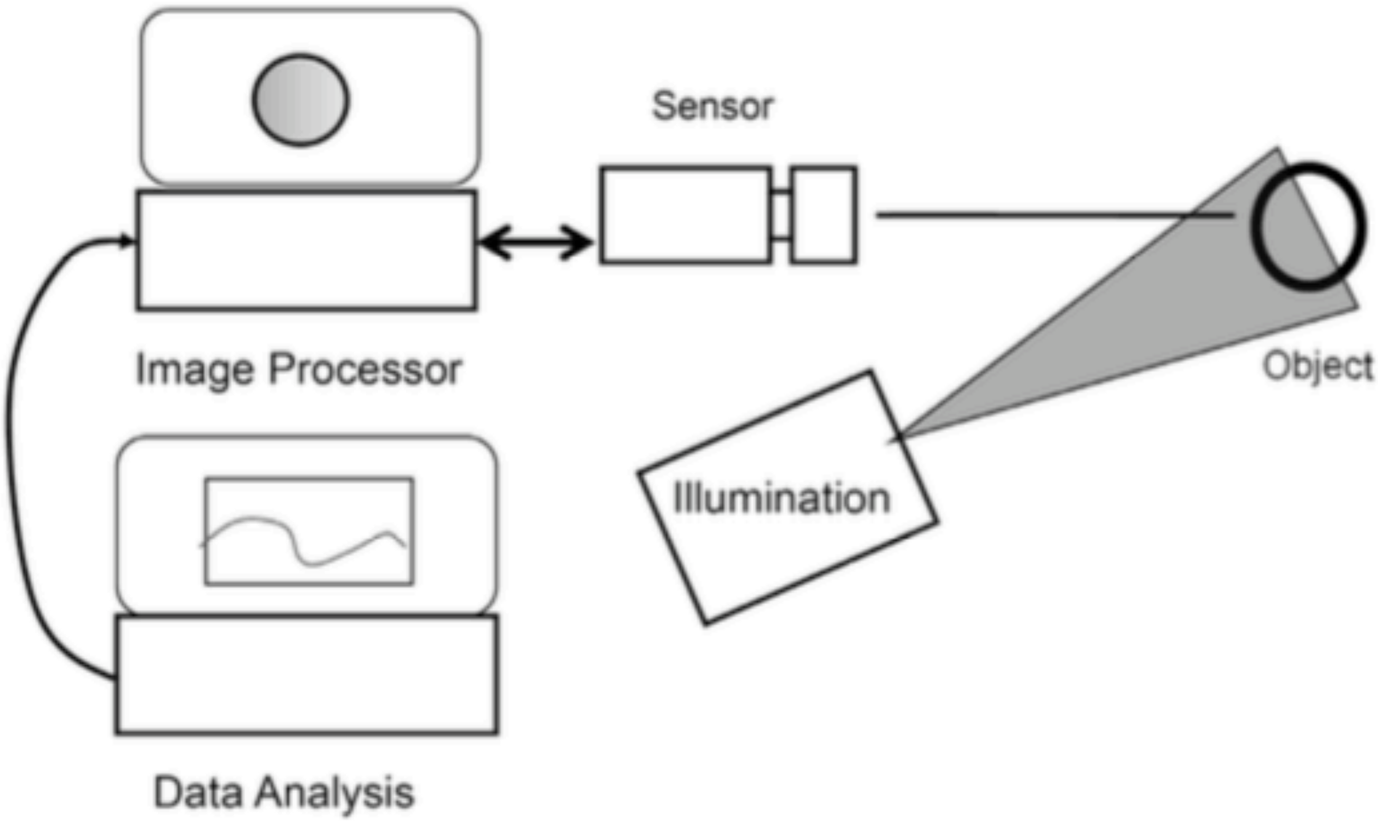


Figure 2.3 The basic components of a machine vision system.

Lighting methods for machine vision

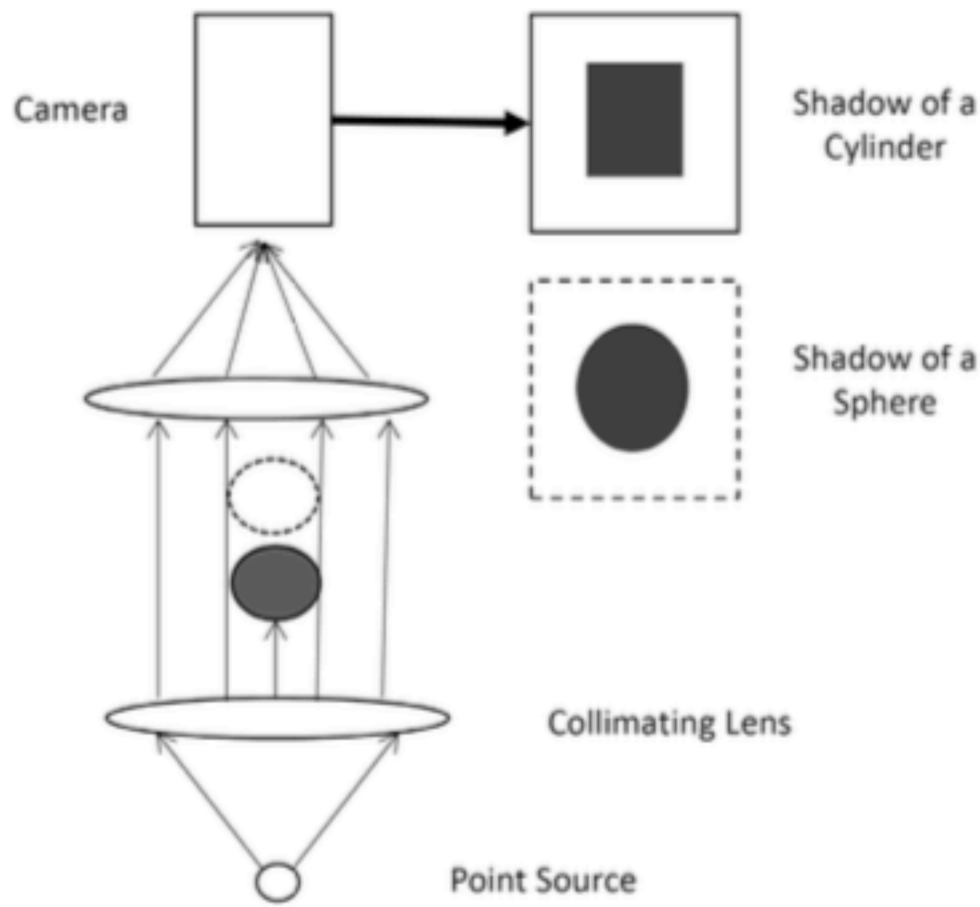


Figure 2.5 A collimated backlight provides an outline of the widest edges of a part, independent of height.

Lighting methods for machine vision

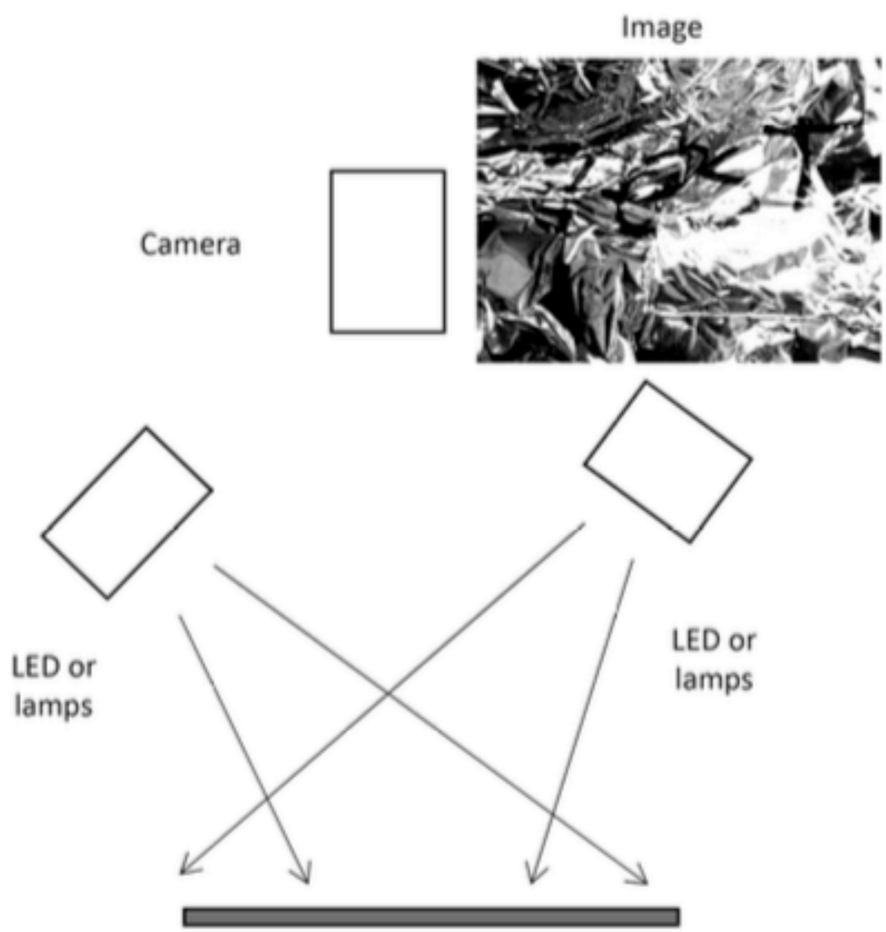


Figure 2.6 A simple, direct frontlight provides an image of a part surface, including shading due to surface bumps.

Lighting methods for machine vision

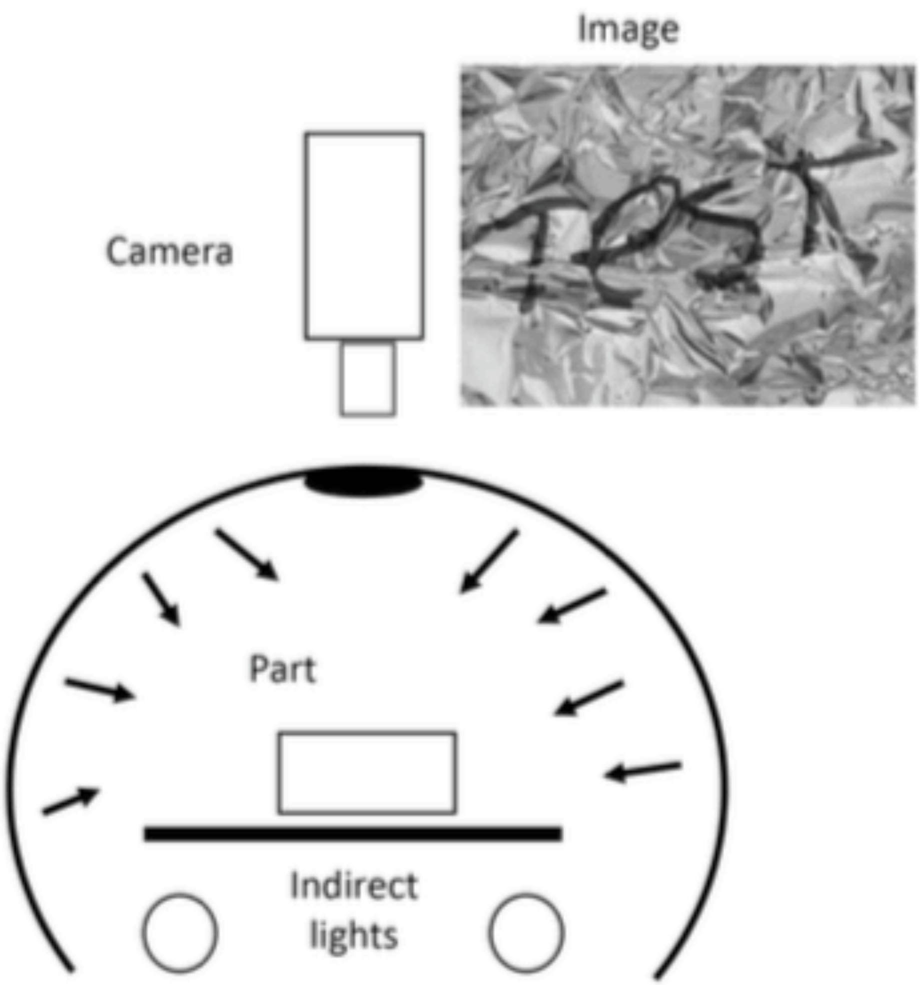
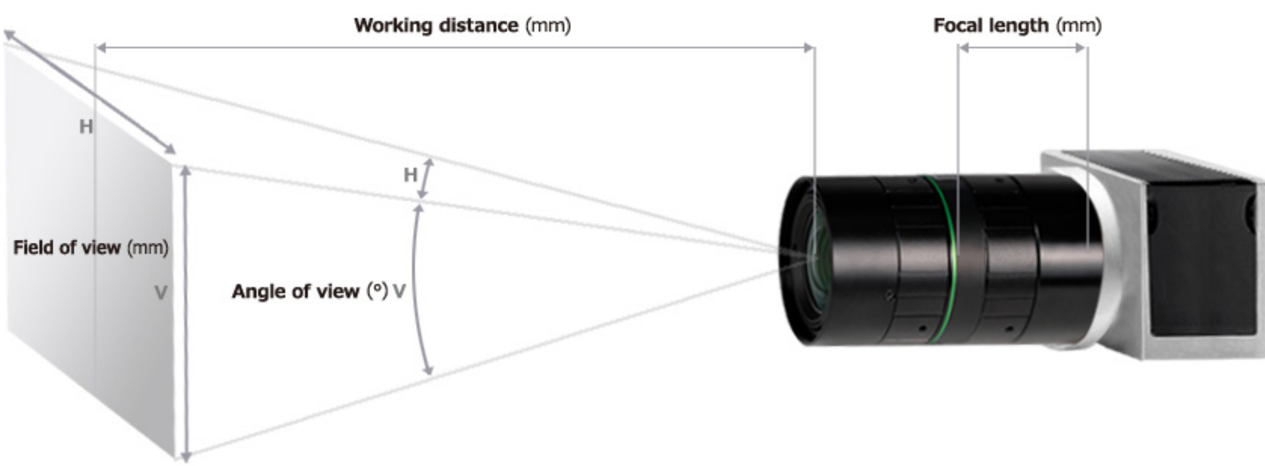
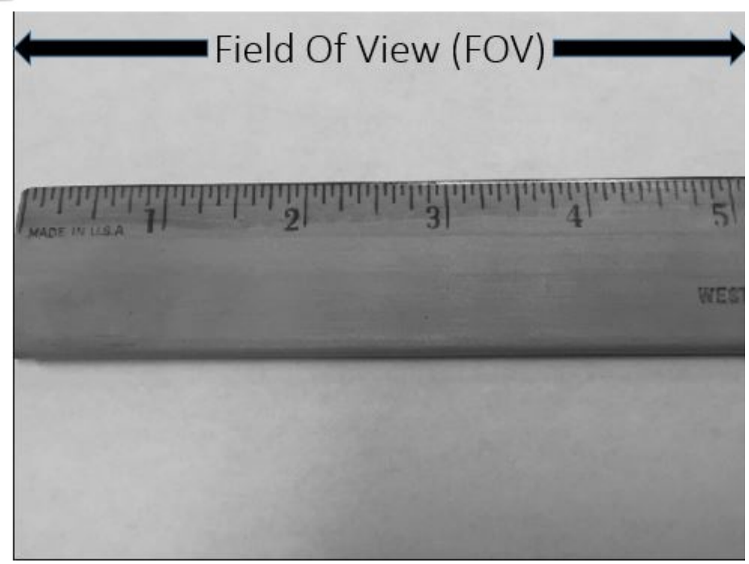


Figure 2.7 A diffuse light illuminating uniformly from all directions produces an image of a part surface without shading due to surface bumps.

Lens selection

In many cases, our working distance of our lens is constrained and may have to mount the camera closer or further from the object plane. Once set, this defines our working distance (WD) for the lens. In addition, we have a given field of view (basically the dimension across the image) of the desired object.





Lens selection

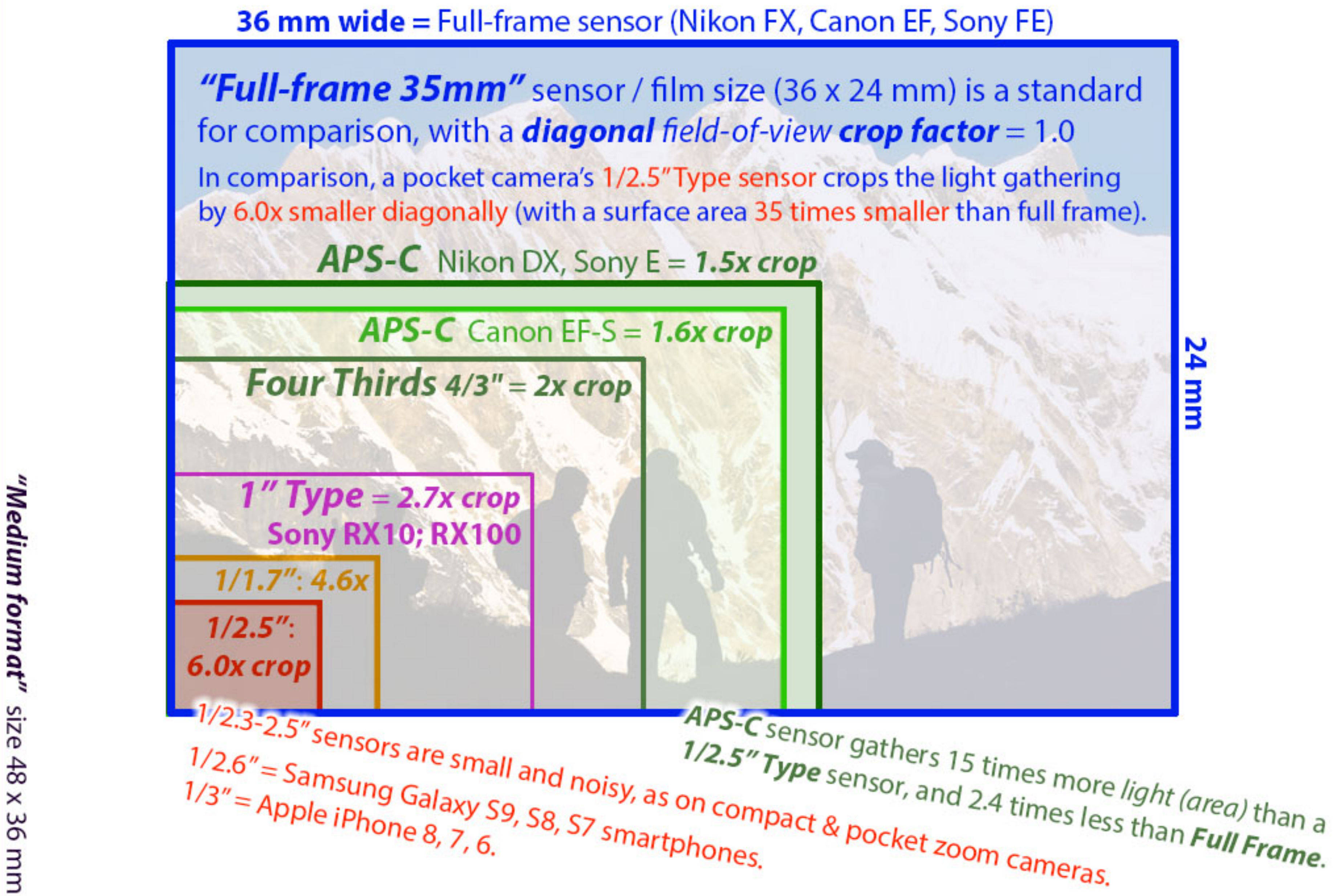
To select the correct focal length lens which is denoted in millimeters (i.e 25mm focal length), we need additional information on the camera sensor. Camera sensors come in various “Image formats”. The chart below indicates some common formats which relate to the sensor size. The sensor size can be found on the actual sensor datasheets if not available in a given chart.

Format Type					
			CCD Sensor sizes (mm)		
Format Type	Aspect Ratio	Ø Dia.(mm)	Diagonal mm	Width mm	Height mm
1/4"	4:3	7.056	5.000	3.600	2.700
1/3.6"	4:3	7.056	5.000	4.000	3.000
1/3.2"	4:3	7.938	5.680	4.536	3.416
1/3"	4:3	8.467	6.000	4.800	3.600
1/2.7"	4:3	9.407	6.721	5.371	4.035
1/2.5"	4:3	10.160	7.182	5.760	4.290
1/2"	4:3	12.700	8.000	6.400	4.800
1/1.8"	4:3	14.111	8.933	8.5	6.8
1/1.7"	4:3	14.941	9.500	7.600	5.700
2/3"	4:3	16.933	11.000	8.800	6.600
1"	4:3	25.400	16.000	12.800	9.600

Sensor size comparisons for digital cameras.

PhotoSeek.com

A bigger **sensor area** captures better quality, but requires larger-diameter lenses. Smartphones compensate for tiny sensors via computational power. In 2018, a ***1-inch Type sensor*** optimizes portability for top **travel cameras**.



Lens selection

For this exercise, we want to image an object that is 400mm from the front of the lens to the object and desire a field of view of 90mm.

We have selected a camera with the Sony Pregius CMOS IMX174 sensor. This uses a 1/1.2" format which measures 10.67mm x 8mm.

We have the following known values at this point:

Field of View (FOV) = 90mm
Working Distance (WD) = 400mm
Sensor Size = 10.67mm – We will calculate for a 90mm horizonal FOV, in turn use the horizontal sensor dimension

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Working Distance (WD) = 400mm
Sensor Size = 10.67mm – We will calculate for a 90mm horizonal FOV, in turn use the horizontal sensor dimension

Lens selection

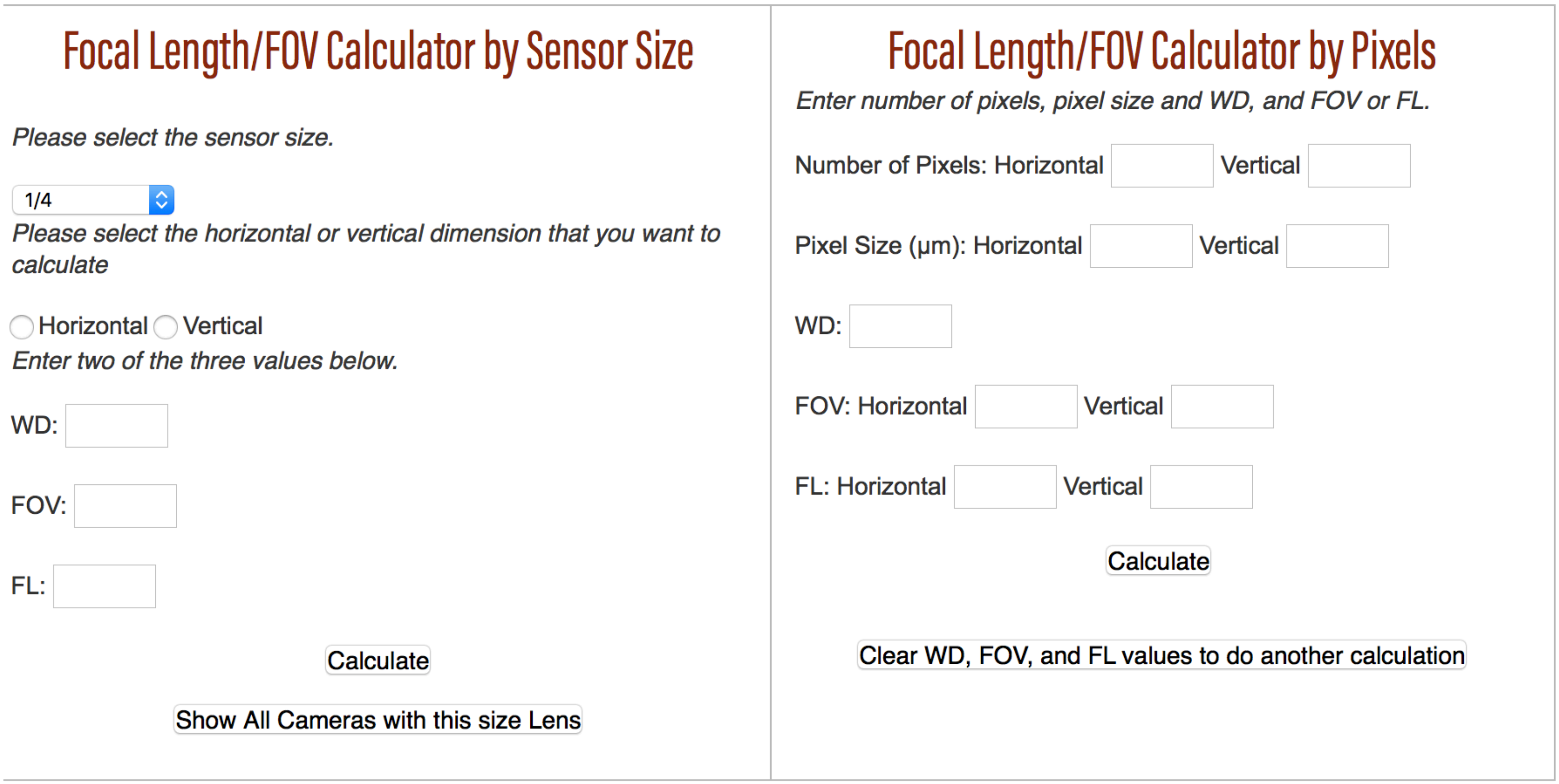
Lenses are only available off the shelf in various focal lengths (i.e 25mm, 35mm, 50mm), so this calculate is theoretical and may need an iteration to adjust working distance. Alternatively, if your application can have a slightly smaller or larger FOV, the closest focal length lens to your calculation may be suitable.

A few additional considerations when selecting a lens:

- Lenses have minimum working distances (MOD), so this should be considered when reviewing a lens setup. MOD's can be found on the lens page for the given lenses.
- Lenses need to be paired with the appropriate sensor. For example, if you have a 1/2" sensor, you need to ensure you are using a 1/2" format lens or larger.
- In selecting a lens, you need to ensure the lens has enough resolution (in lp/mm) to resolve the pixels on your camera. Be sure to review this data carefully once you ID the desired focal length.

Lens selection

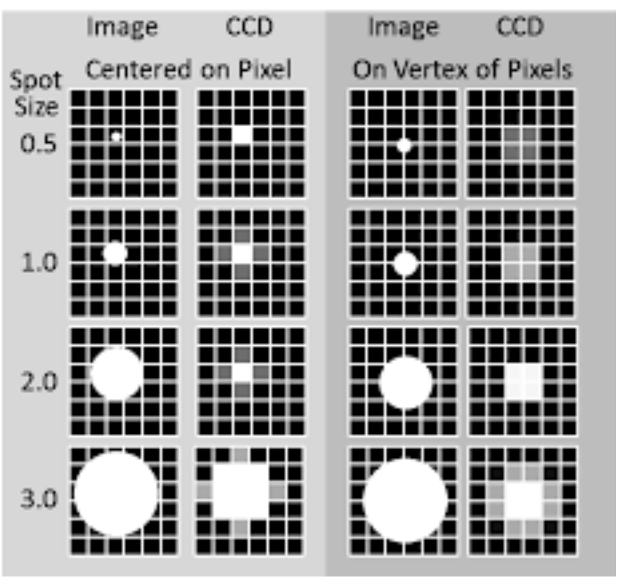
https://www.1stvision.com/lens/fov-lens-calculator

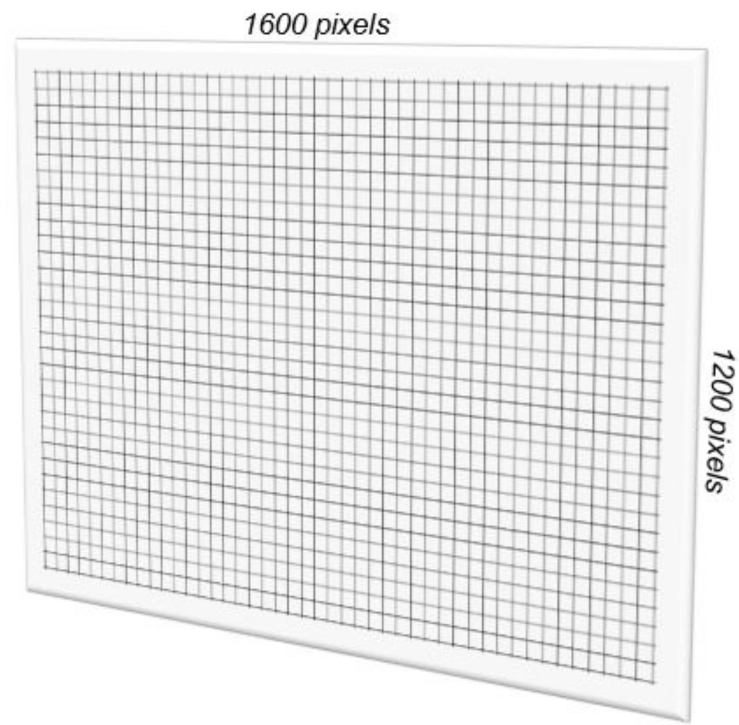


Calculating resolution for machine vision

Camera image resolution is defined by the number of pixels in a given CCD or CMOS sensor array. This will be identified in a camera data sheet and shown as the number of pixels in the X and Y axis (i.e 1600 x 1200 pixels).

The application will determine how many pixels are required in order to identify a desired feature accurately. This also assumes you have a perfect lens that is not limiting resolving the pixel (see Demystifying lens specifications). In general, more pixels is better and will provide better accuracy and repeatability.





Calculating resolution for machine vision

- If for example you have a dark hole on a white background filling your field of view (FOV) by 90%, you will have many pixels across the feature.
- On the contrary, if we have a small pin hole that is within the same field of view, we may not have enough pixels across the hole to identify the feature.
- In order to find an edge, you need at a minimum of 2 pixels given excellent contrast. In order to be robust, you ideally will want 3-4 pixels across a edge or feature.

This leads us to identifying the resolution required given the size of a feature. We will do this with an example and provide the needed formulas.

Example: The vision inspection is to locate a pin hole which is 0.25mm in diameter on a part which is 20mm square. In order to compensate for any misplacement of the part, we will set our FOV to 40mm x 30mm. We would also like to have a minimum of 4 pixels across the 0.25mm feature.

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Calculating resolution for machine vision

- We have now determined that we need a minimum resolution of 640 pixels in the x-axis to provide 4 pixels across our feature that is 0.25mm in diameter.
- The camera resolution can now be selected!
- In today's world, we could select a VGA (640 x 480) camera for the application. As a note, the number of pixels required depends on many aspects of lighting, optics and algorithms used for processing. This calculation method assumes optimum conditions.