Machine Vision

Presented by
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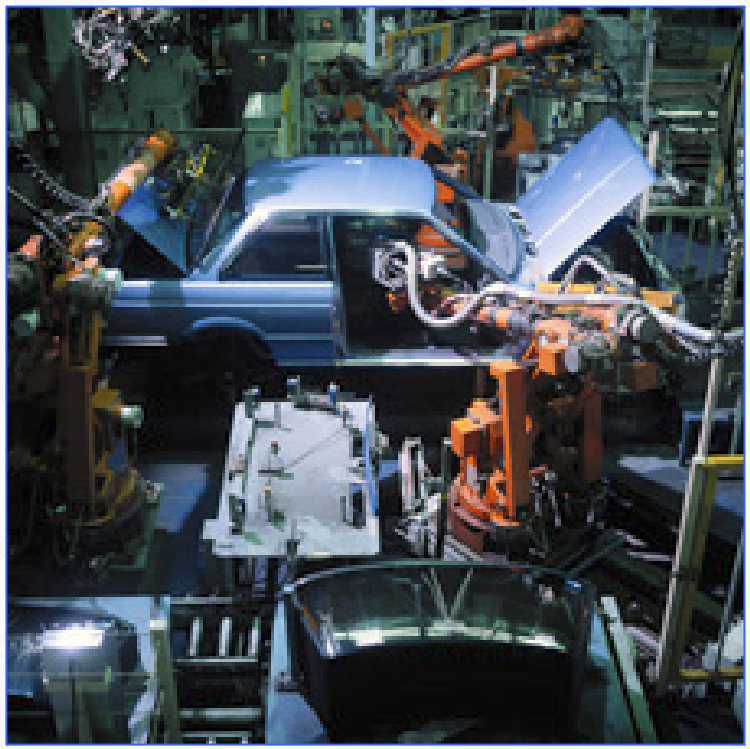
What is Machine Vision?

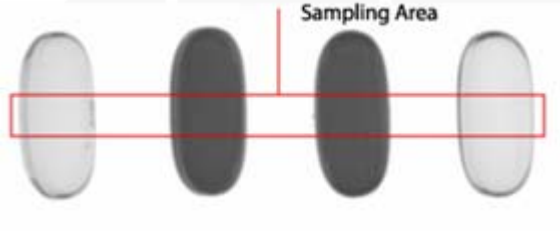
The merging of imaging and computing. Collecting data, analysis, and making a decision based on image information.

Where is Machine Vision Used?

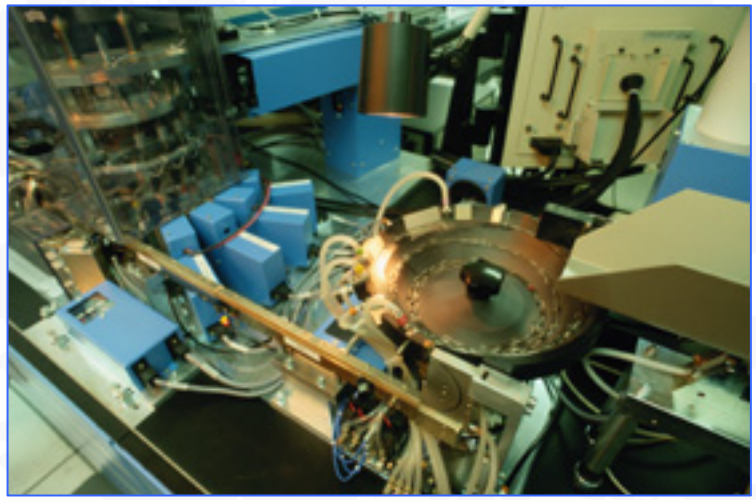
Automotive



Where is Machine Vision Used?



Pharmaceutical



Medical

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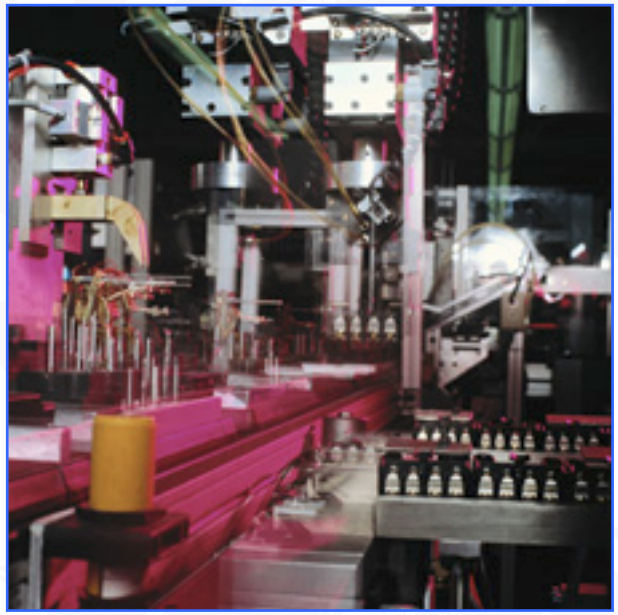
Where is Machine Vision Used?

Food packaging

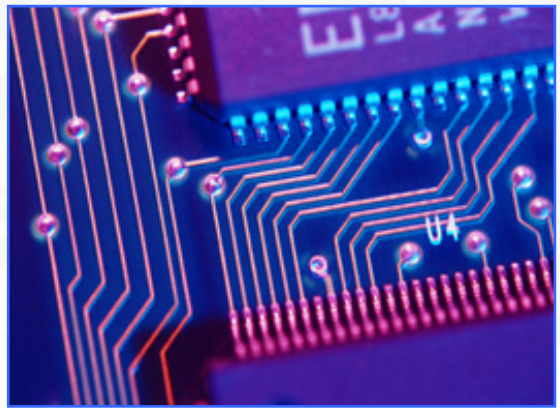


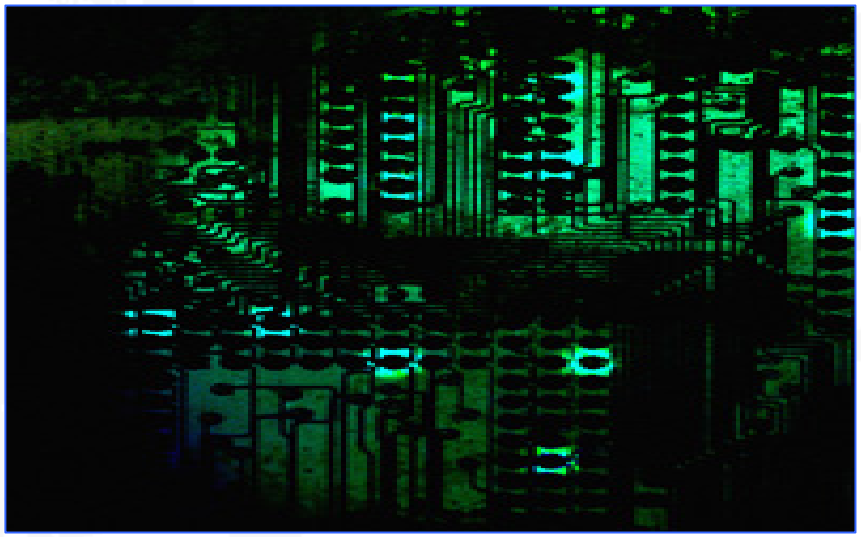
Where is Machine Vision Used?

Biometrics

Where is Machine Vision Used?

Semiconductor





What is Machine Vision Used for?

- Dimensional Measurement
- Part Presence
- Defect Detection
- Sorting
- Part Orientation

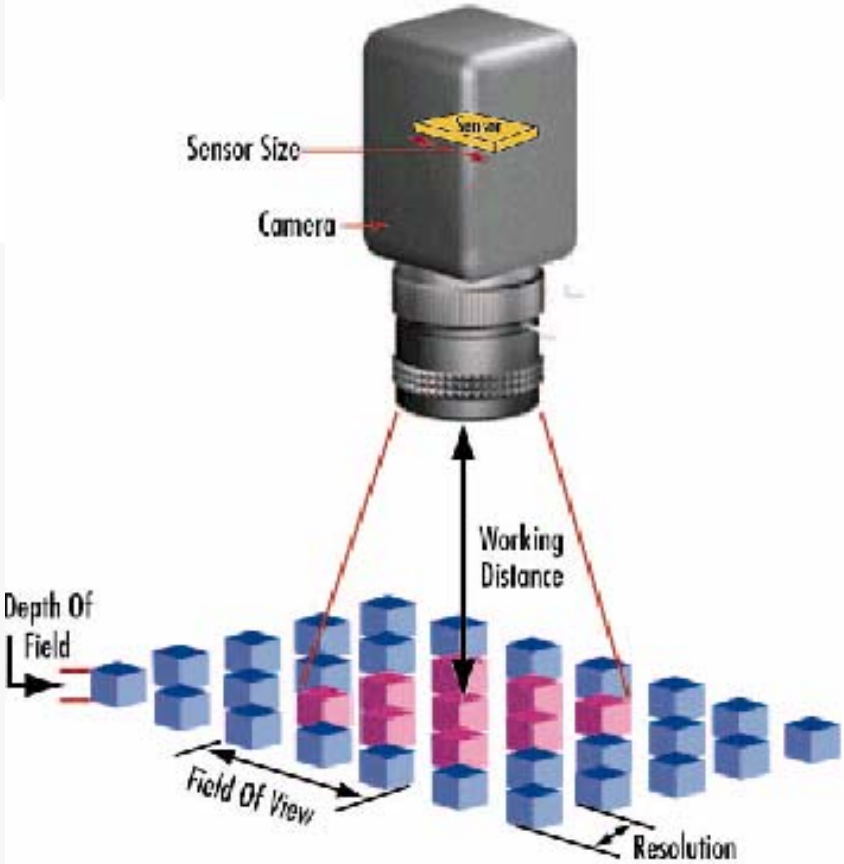
Turning the Application into a Specification

Determine the fundamental parameters of an imaging system

Determine the required image quality

Design a solution

Fundamental Parameters of an Imaging System



Field of View- How much do you need to see?

Working Distance- How much clearance do you need?

Why not Mag?

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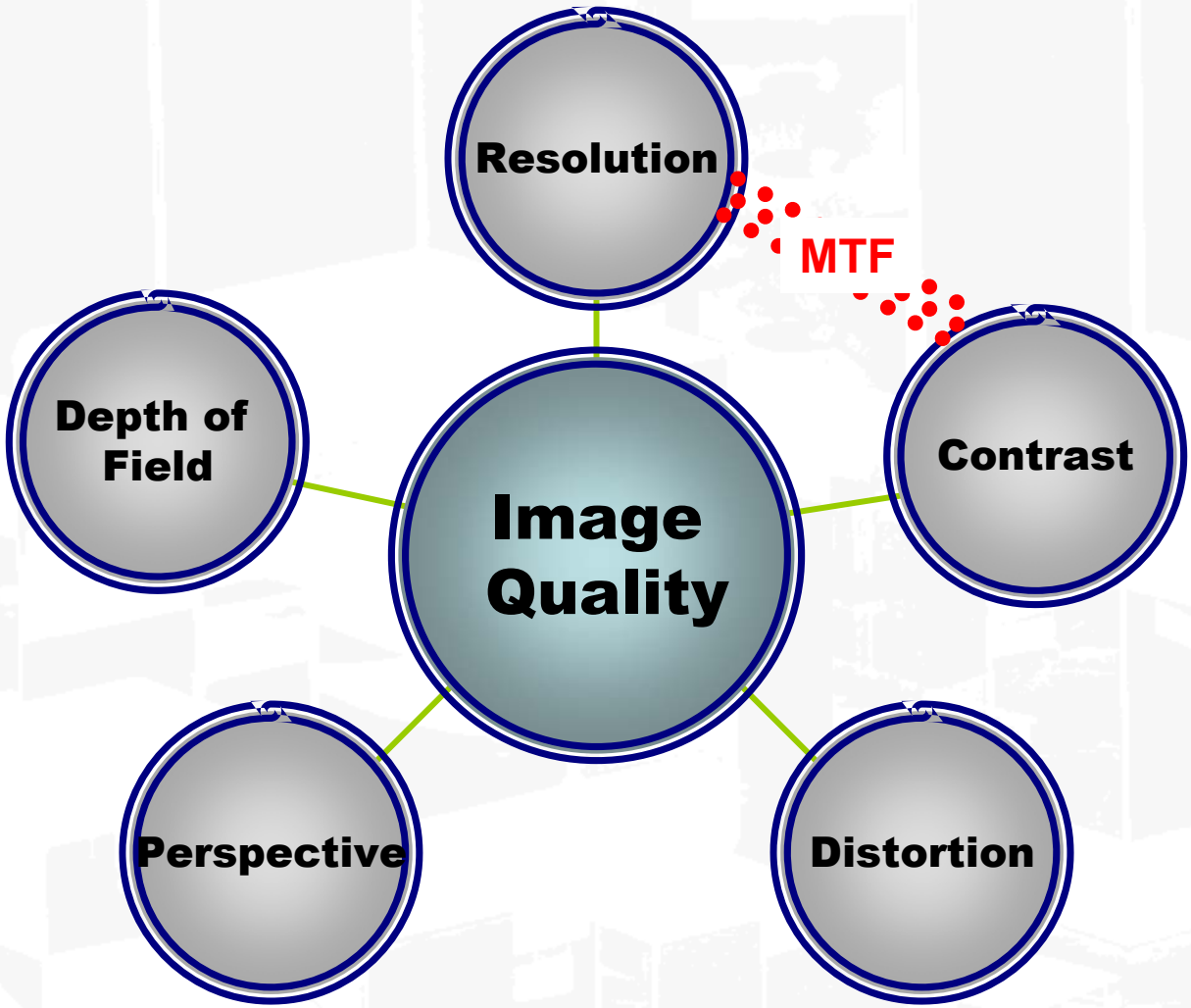
Image Quality



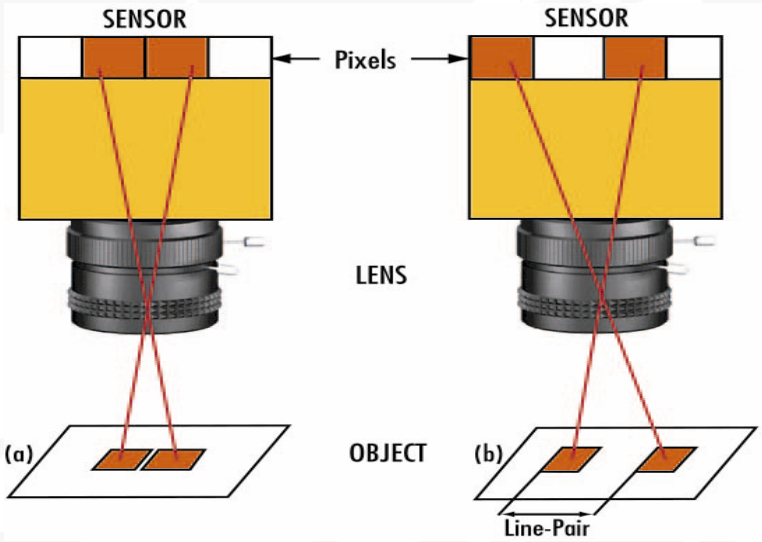
These 5 parameters define the Image quality

How Much Image Quality is Necessary?

An imaging system should create sufficient image quality to allow one to extract desired information about the object from the image.

Note that what may be adequate image quality for one application may prove inadequate in another.

How Do We Define Resolution



Resolution is a measurement of the smallest discernable feature.

Note software people often define in Pixel density, Optical people define in lp/mm

How Do We Use Object Space and Image Space Resolution

Object Space resolution defines the size elements in the object that can be resolved

Image space resolution is the resolution at the image plane (CCD sensor)

Image space resolution and object resolution are related by the Primary Magnification (PMAG)

$$\text{Object Space Resolution}(\mu m) = \frac{\text{Image Space Resolution}(\mu m)}{\text{PMAG}}$$

Object Space Resolution(lp/mm) = PMAG x Image Space Resolution(lp/mm)

Image Space Resolution is a combination of the Lens resolution and the camera resolution

Camera resolution (μm) = 2 x Pixel Size(μm) {resolution is always defined by pairs}

Converting Resolution

Resolution(µm)/1000 = Resolution(mm)

1/Resolution(mm) = Resolution(lp/mm)

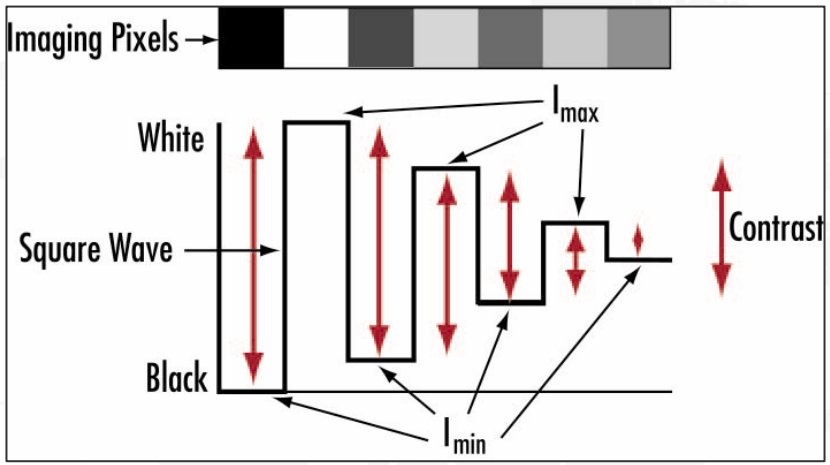
MTF

As you know from earlier lectures resolution is actually described at a specific contrast value and can be plotted out as MTF.

How Do We Define Contrast

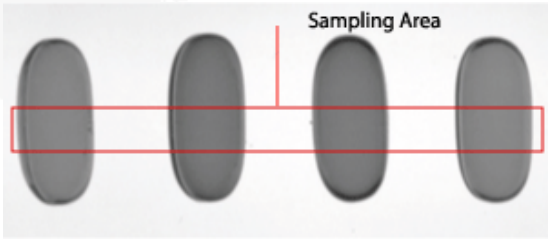
Contrast defines the separation of intensity of blacks and whites

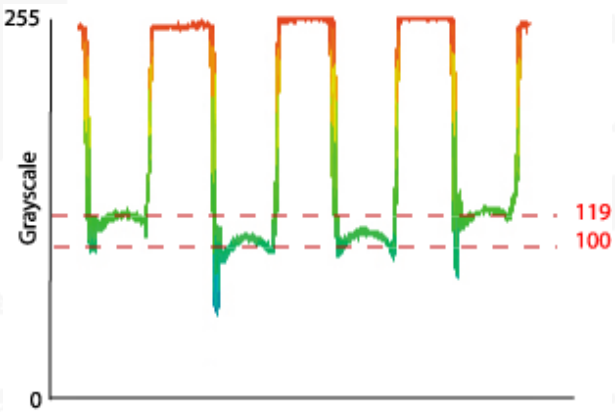
$$\% \text{ Contrast} = \frac{I_{max} - I_{min}}{I_{max} + I_{min}}$$



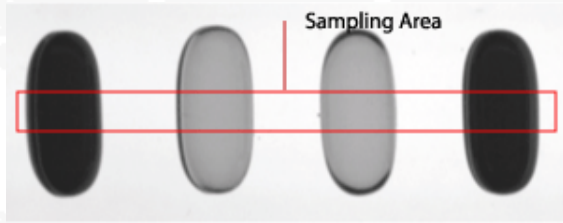
Example of Contrast in Imaging

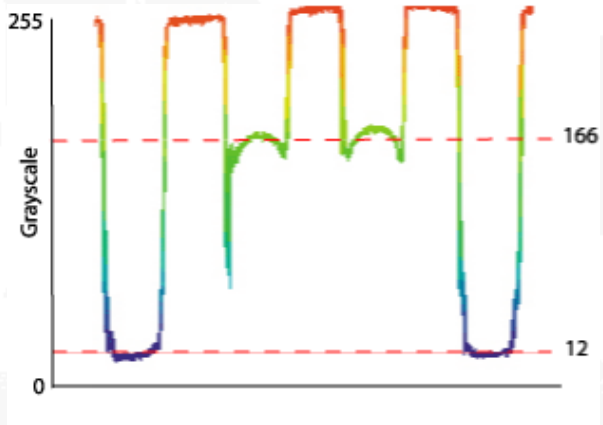
Red and green pills back lit viewed on B&W camera. Red pills are on the ends, green are in the middle





No filter





With a green filter on the lens

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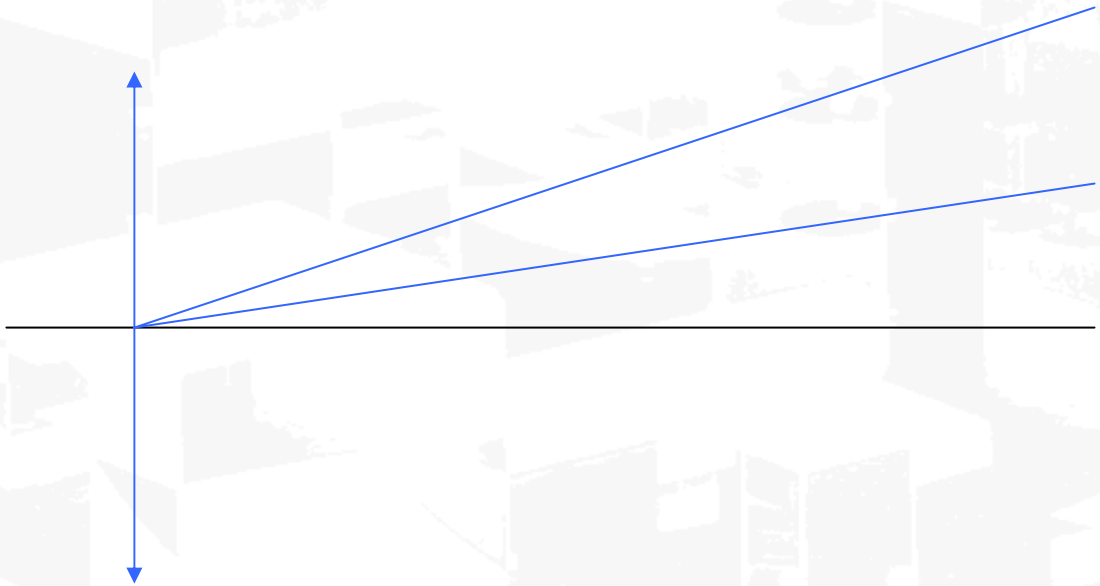
Example of the Need for High Contrast across the Field

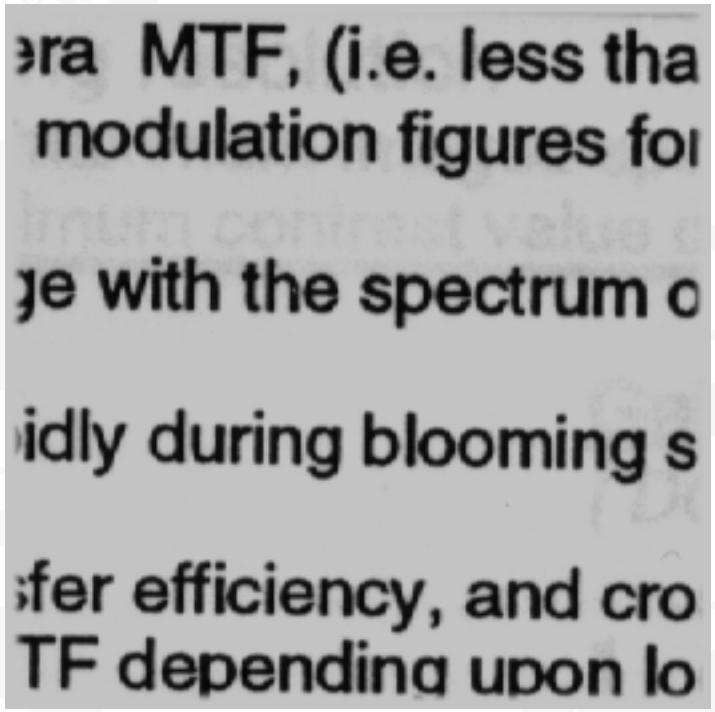
Cosine-to-the-fourth fall off- for any lens the relative intensity of any portion of the image will be limited to a cosine^4(θ) where

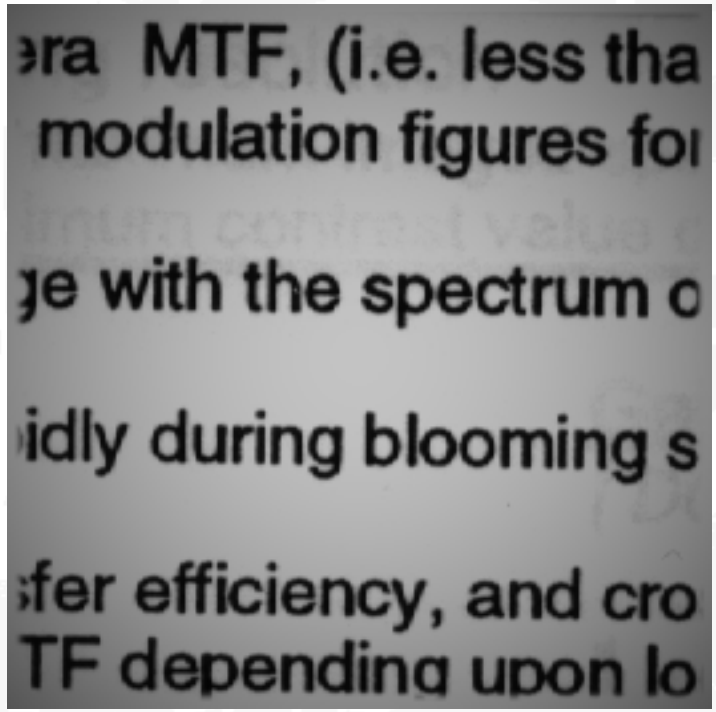
Θ is the the chief ray angle.



Relative Contrast

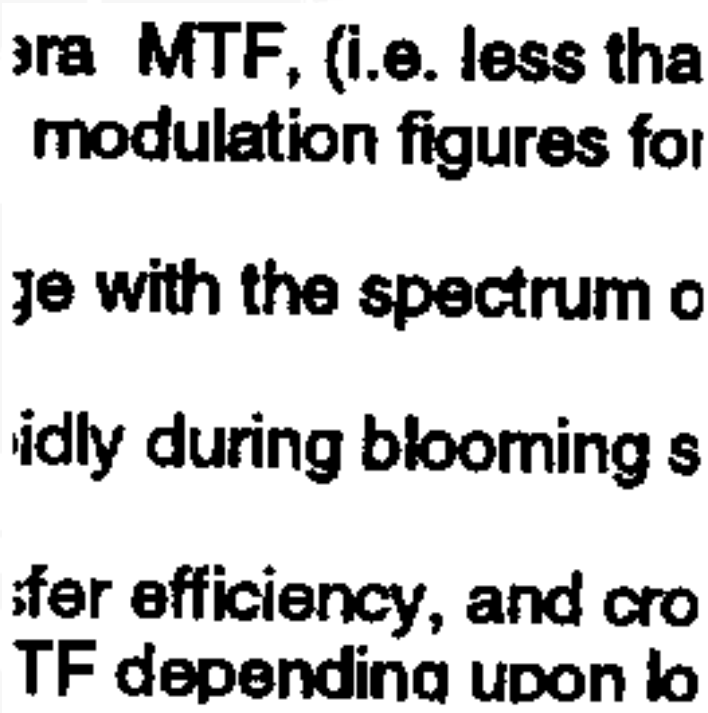
Two lenses, the one on the right has a near zero degree chief ray angle and no fall off, the on the left has a 23.5 Degree chief ray angle and about a 70% relative intensity.



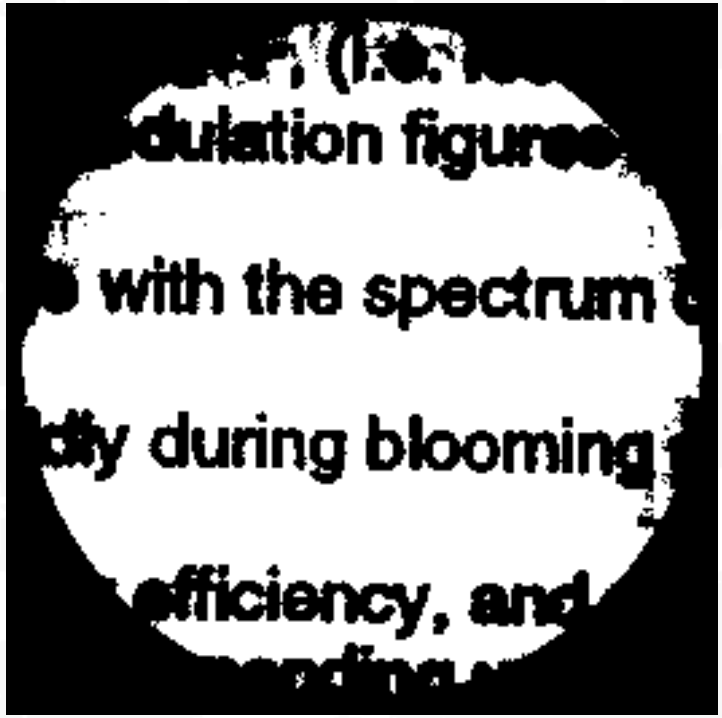


Relative Contrast Cont.

Same images if you make them binary with a 140 count threshold



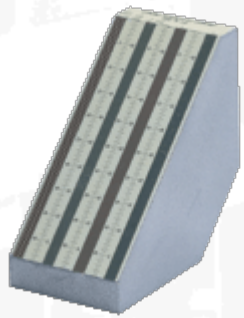
S5



S6

Defining Depth of Field

- The depth of field (DOF) of a lens is its ability to maintain a desired amount of image quality as the object is moved from best focus position
- DOF also applies to objects with depth, since a lens with high DOF will allow the whole object to be imaged clearly
- As the object is moved either closer or further than the working distance, both contrast and resolution suffer
- The amount of depth must be defined at both a contrast and a resolution.



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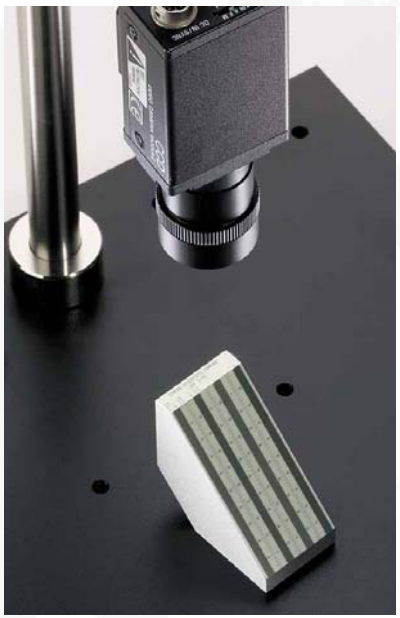
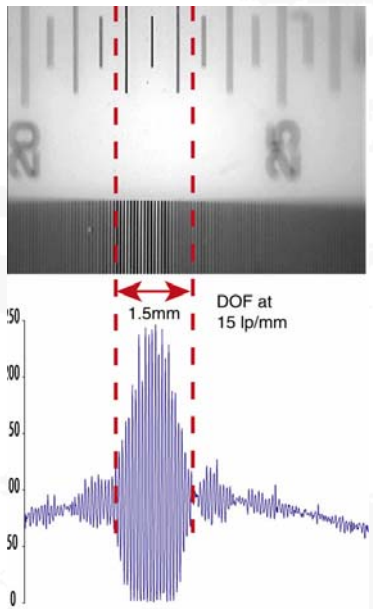
Depth of Field Cont.

- DOF is often calculated using diffraction limit, however this is often flawed if the lens is not working at the diffraction limit
- Increasing the F/# to increase the depth of field may limit the overall resolution of the imaging system. Therefore, the application constraints must be considered
- An alternative to calculating DOF is to test it for the specific resolution and contrast for an application

How Do We Test Depth of Field

By placing a target at an angle toward from the optical axis you can measure the depth of field directly. Choose the frequency of the target to match the resolution you are defining the DoF at, remember there is a sine factor between what is on the face of the target and what is in the plane of the image.

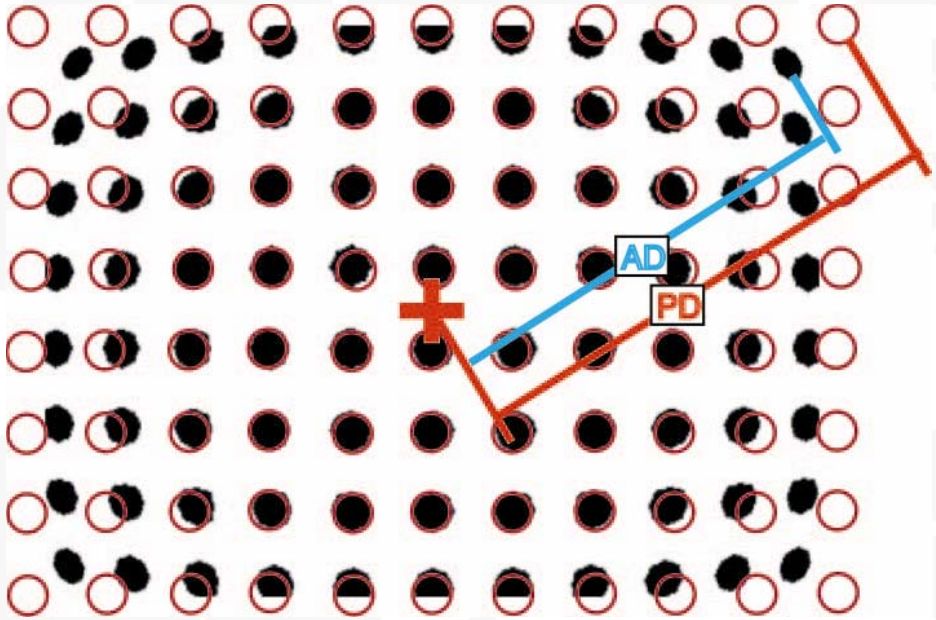




To the left is an image of DOF test target, object space resolution being tested is 15 lp/mm at a contrast of less than 10%

We can either see visually where the image blurs out or we can look at a line spread function and calculate contrast from the grayscale values.

Defining Distortion



$$\% \text{ Distortion} = \frac{(AD-PD) \times 100}{PD}$$

Above is an example of negative distortion

AD is Actual Distance that an image point is from center of the field

PD is the Predicted Distance that an image point would be from the center of the field if no distortion were present

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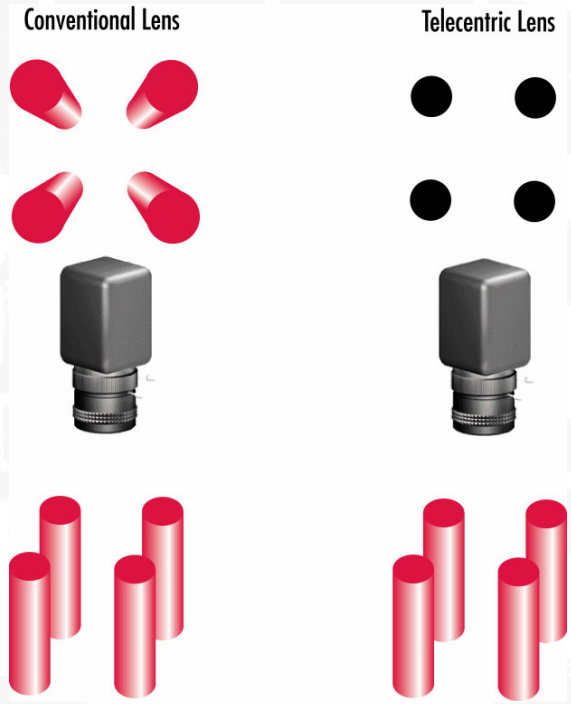
Distortion Continued

Distortion is a misplacing of image information. Very little information is lost, so the information can be remapped to the proper location in software to correct the error.

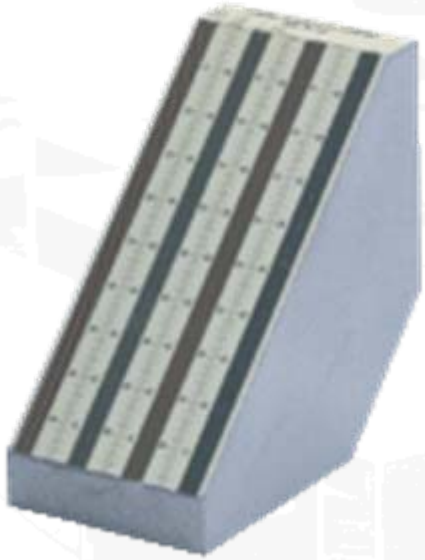
Defining Perspective error

- Perspective error, also called parallax, is change in magnification with a change in working distance
- This is how we perceive distance with our eyes
- Though useful for perceiving distance, this is harmful when trying to make measurements
- Telecentric lenses are designed to minimize perspective error
- Unlike distortion information is lost and can not be corrected with software

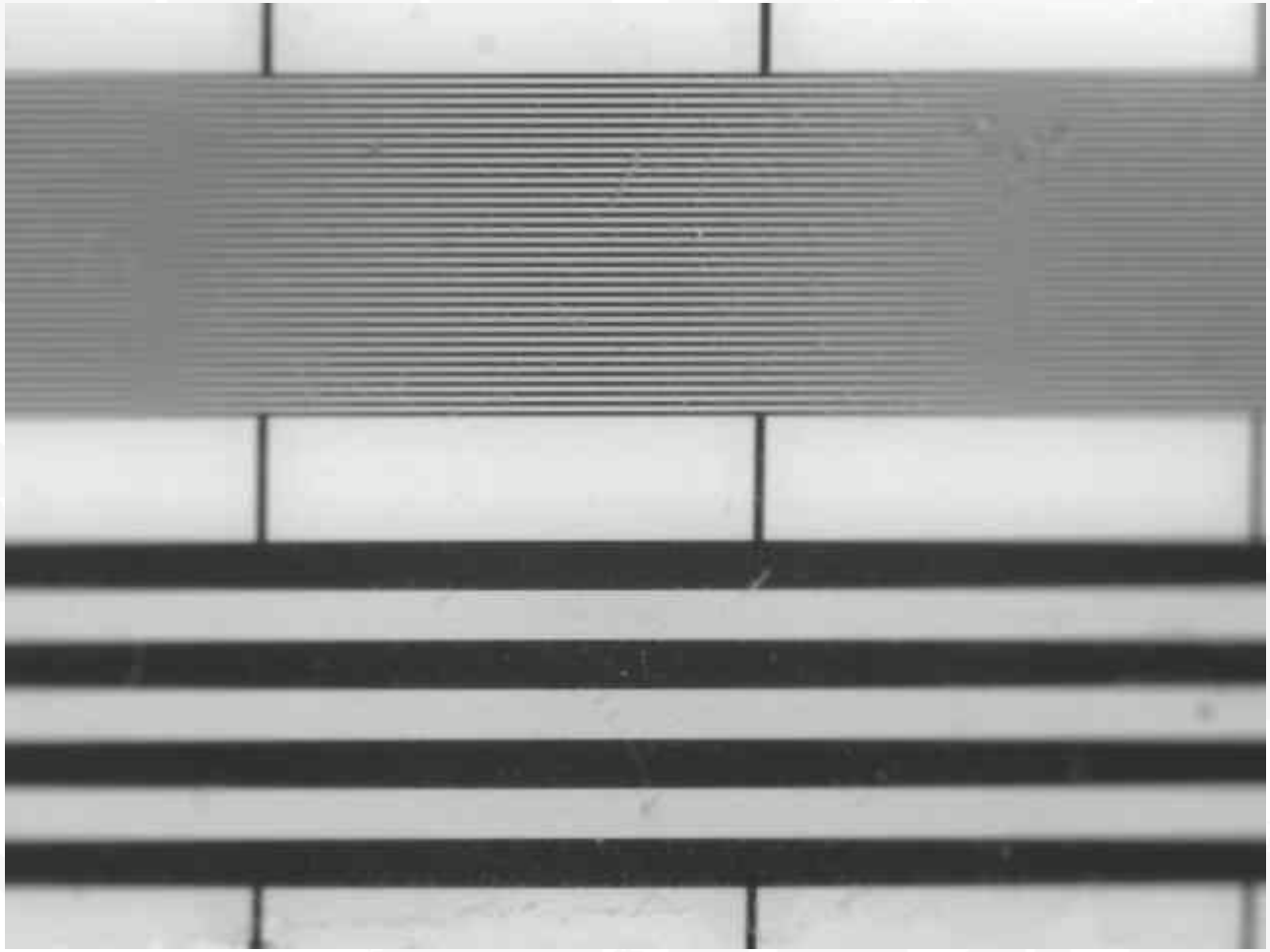


An Example of Telecentric Error

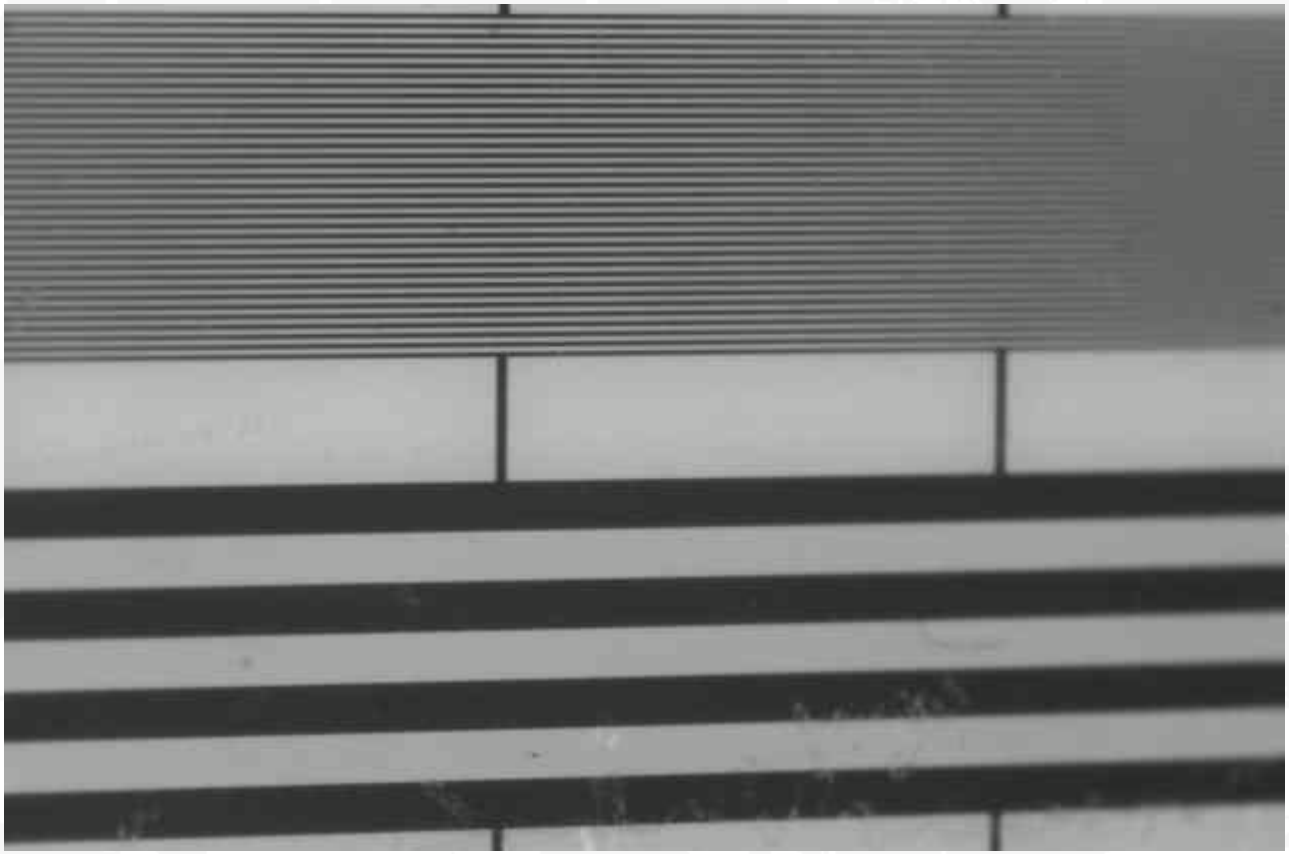
- Test piece is the depth of field target looking at the parallel lines running down the 45 degree target
- The left side will be farthest from the camera
- Telecentricity is demonstrated by the line converging as they get farther from the lens



Measurement With a Telecentric Lens



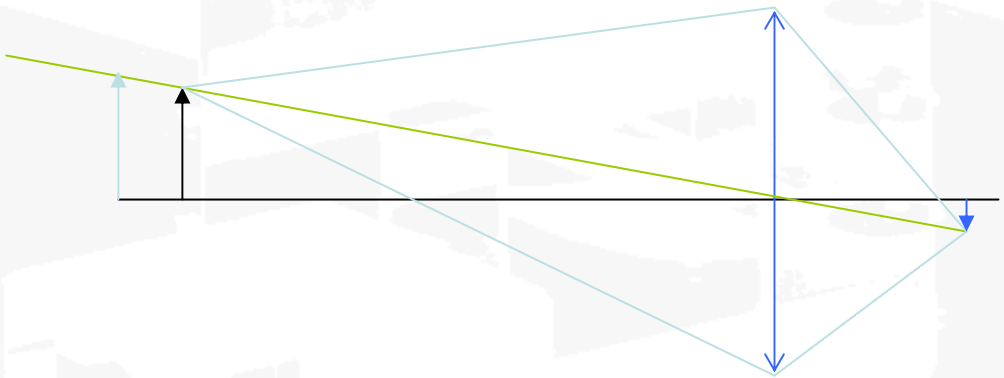
Measurement with a Conventional Lens



Prospective error

Where Does Perspective Error Come From

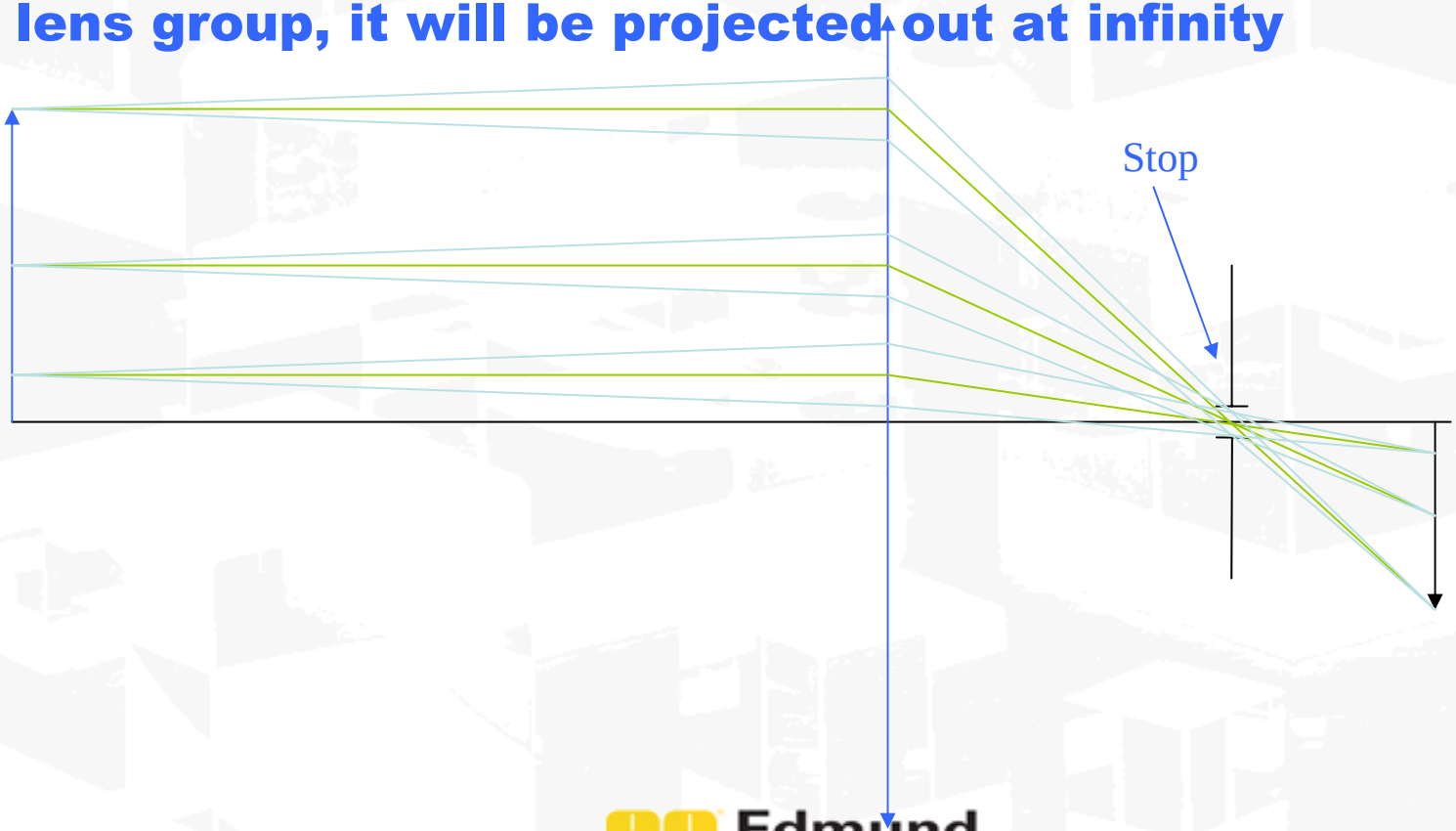
Chief ray angle- The chief ray angle will determine how much the field of view grows as the working distance increases



Telecentric Lens

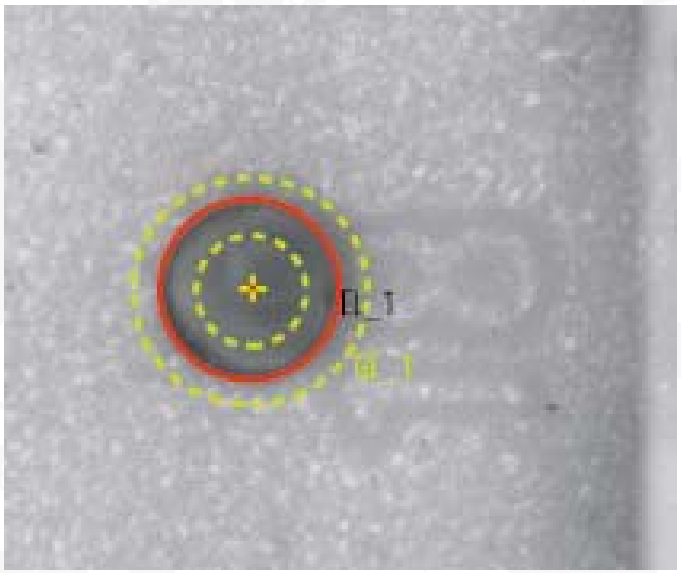
In a telecentric lens the stop is projected to infinity which causes all the chief rays to be parallel to the optical axis.

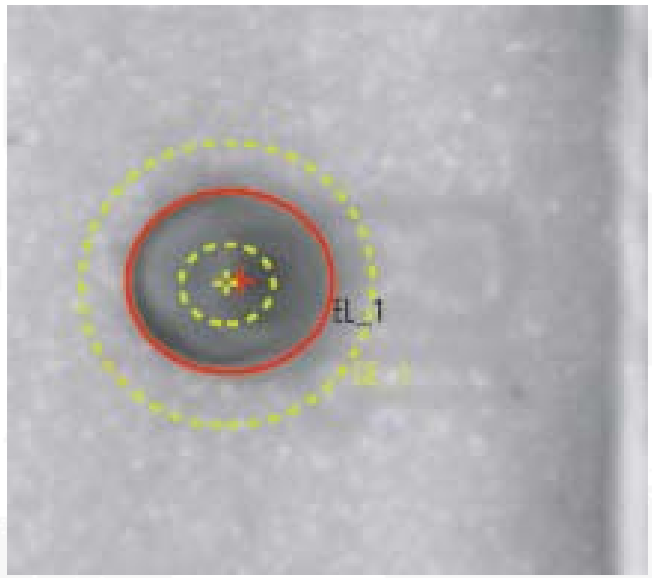
By placing the stop a focal length away from you front lens group, it will be projected out at infinity



Symmetric blurring

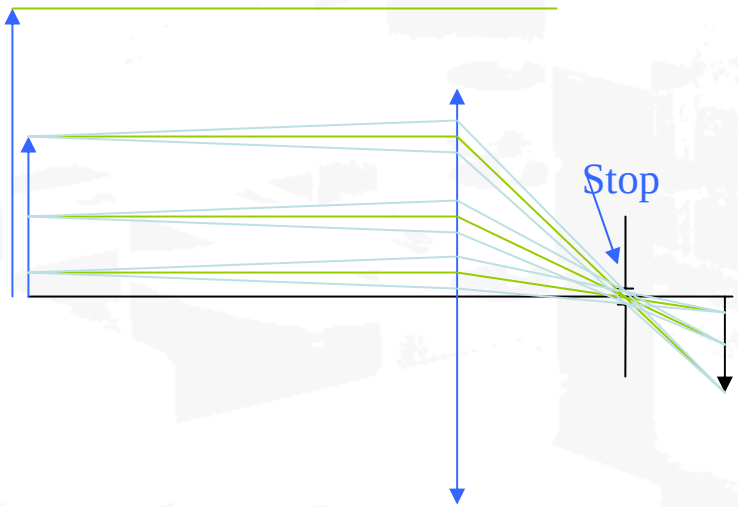
Because the defocus will blur symmetrically around the parallel chief rays, finding edges and centers of holes becomes more accurate with a telecentric lens





Limitations of a Telecentric Lens

Due to the need for the chief ray angles to be parallel the front lens group must be larger than the object



Conclusion

The Engineer can find an imaging solution once they have translated the application into specifications that they can design to.

The specifications we use are the Field of View, Working Distance, Resolution, Contrast, Depth of Field, Distortion, and Perspective Error