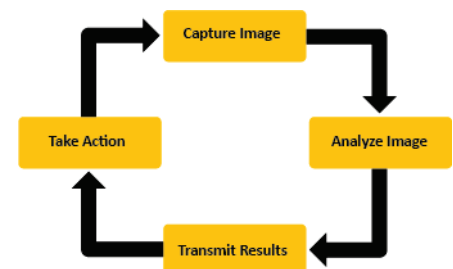


Machine vision is a technology used to replace or complement manual inspections with image processing. The technology is used by industries such as food and beverage, packaging, pharmaceutical, and automotive to automate production and help these industries improve product quality and reduce waste.

Before designing an automated machine vision solution for an application in a harsh or rugged environment, there are some basic concepts you need to understand.

Machine Vision is a Four-Step Process

1. Capture an image.
2. Analyze the image.
3. Transmit the result of the analysis to the controlling system.
4. Take action depending on the result (for example, initiate a reject mechanism to reject a “bad” part).



Machine Vision Components

The first goal for every successful vision application is to capture a high-quality image of an object or part. There are several components involved in this process:

- Imager
- Lens
- Lighting
- Image Analysis

Imager

At its heart, a vision sensor is essentially an electronic light meter. The sensor uses an imager chip to measure light levels across an area. The imager chip is made up of hundreds of tiny light-sensitive elements, each of which creates an electrical signal proportional to the amount of light striking that element.

These light intensity values are measured on an 8-bit scale that varies from 0 (darkest) to 255 (brightest). Each of the light-sensitive elements on the imager chip is called a “picture element” or “pixel”. Each pixel has only two properties: a location (X and Y coordinates) and a gray scale value (between 0 and 255). The image that comes from the sensor is made up of hundreds of individual light measurements.

Exposure

Just like an everyday camera used to take any picture, exposure is the amount of light detected by the imager. The exposure amount is determined by the exposure time, which is the amount of time the camera allows light to energize the image chip. Increasing the exposure time allows more light to energize the imager chip, which brightens the image. Overexposure and underexposure result in less detailed images. Overexposed images have too much light and appear mostly white, whereas underexposed images are very dark. This is why correct lighting is so important to the success of a machine vision inspection.

Gain

Gain is an electronic boost to the image signal. Increasing gain is a simple way to increase image brightness without increasing exposure time.

Contrast

A successful vision application is almost all about creating contrast between the feature of interest and the background. In this usage, contrast essentially means the pixels making up the feature of interest have different gray scale values from the surrounding background pixels. The greater the difference, the better.

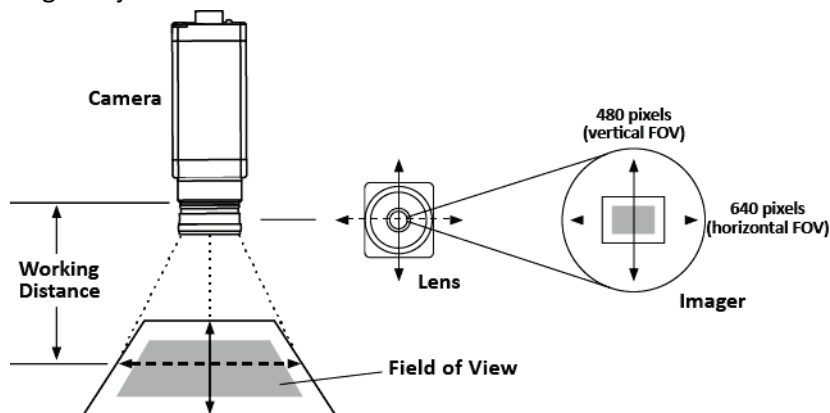
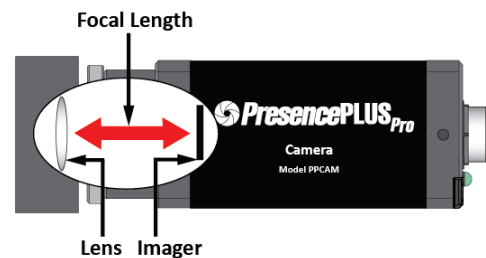
Most commonly, contrast is created through proper lighting. Generally, it does not matter whether the feature of interest looks bright against a darker background or vice versa. Only the fact that they are different enough in gray scale value matters. If conditions allow, backlighting a part is almost always the best choice because there is a stark contrast between the dark silhouette and the bright backlight itself.

Lens

The lens focuses the light that enters the camera in a way that creates a sharp image. An image in focus means that the object edges appear sharp. If the object is out of focus, the image is blurred.

An important consideration when choosing a lens is the focal length of the lens. The focal length is the distance between the rear nodal point of the lens (the point where the light rays leave the rear of the lens) and the camera's imager.

The lens focal length sets up the (fixed) relationship between the Field of View (FOV) and the working distance. FOV is the area of the inspection captured on the camera's imager. The size of the FOV and the size of the camera's imager directly affect the image resolution (one determining factor in accuracy). Working distance is the distance between the back of the lens and the target object.



Lighting

Lighting is crucial to any machine vision application. The goal of lighting in machine vision is to enhance the features of the object being inspected and to make sure that the quality of the captured image is repeatable in the environment.

The following are some general lighting considerations for vision applications:

- Keep the lighting constant (unchanging over time).
- Keep the lighting consistent (no shadows or hot spots).
- Capture the shape and form of the target object with lighting that optimizes its contrast and separates it from the background.
- Keep the effects of room lights, sunlight, or other ambient light sources to a minimum.
- Choose a lighting technique and light source appropriate for the size, shape, texture, color, transparency, reflectivity, and heat tolerance of the target object.
- Adjust for the best exposure time of the camera.
- Adjust for any physical constraints in the inspection area.



Lighting Options

There are many lighting options for vision applications. The following highlights some of the common ones.

Backlight

Generally the first choice for most machine vision applications, backlighting provides even, low-intensity illumination. The backlight is placed behind the target object and aimed directly back toward the camera, and the resulting silhouette can be inspected for proper size or shape.

Advantages

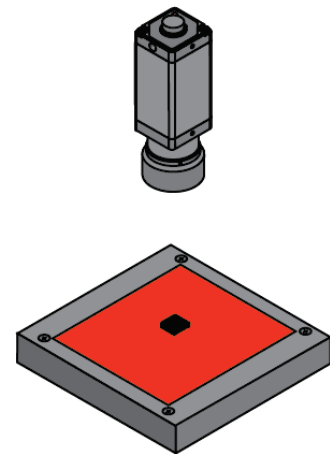
- Shows the diameter of rounded target objects.
- Shows through-holes in target objects.
- Provides a clean image.

Disadvantages

- Does not reveal surface qualities.
- Since the backlight creates a silhouette, the light must be larger than the object.

Application Examples

- Detect foreign material on a clear web.
- Sort parts by size and shape.
- Measure spacing between the leads of an IC chip.
- Measure the height of a cap on a clear bottle.
- Inspect for cracks or holes in sheet metal.



Ring Light

A ring light provides diffused illumination over a small area. With the lens axis through the center opening of the ring light assembly, the ring light illuminates the area directly in front of the camera.

Advantages

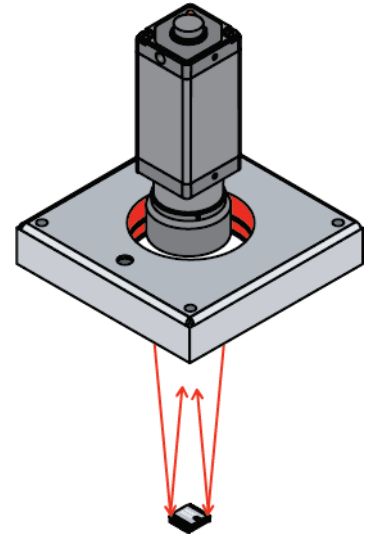
- Provides even illumination for small objects.
- Reduces shadows on images with protrusions.
- Centers the light on the image.
- Can be mounted directly to the camera.

Disadvantages

- With large objects, the corners of the image may lose illumination intensity, creating a halo of dark pixels along the outer edge of the image.
- With highly reflective surfaces, the image may contain a circular glare pattern of reflected light.

Application Examples

- Verify date or lot codes on labels.
- Detect label presence.
- Detect double sheets.



Directional Lighting

Directional lighting provides even illumination in a concentrated area. Well-placed area, linear array, or spot lights can purposely create shadows and glare, allowing the camera to detect the presence or absence of a feature.

Advantages

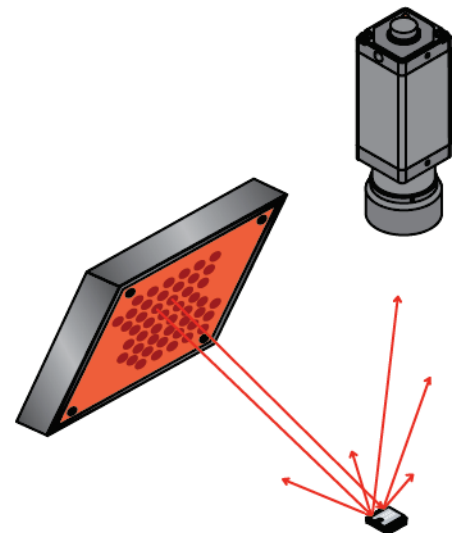
- Creates shadows to detect changes in depth.
- Illuminates specific surface angles for detection.
- Avoids glare of reflective surfaces when directed at an angle away from lens.
- Provides lighting at distances greater than 12 inches.

Disadvantages

- May create unwanted glare and shadows.
- May create hot spots or glare from highly reflective surfaces.

Application Examples

- Detect notches in ceramic rings.
- Detect dents in metal tubing.
- Verify printing on reflective surfaces.
- Distinguish between rough and smooth surfaces.



On-Axis Lighting

On-axis lighting provides even, diffused illumination. A beam splitter directs the light rays along the same axis as the camera lens. Reflective surfaces perpendicular to the camera appear bright. Surfaces at an angle to the camera and non-reflective surfaces appear dark.

Advantages

- Provides more even illumination than a ring light.
- Fills in the hole of light that is created with a ring light.

Disadvantages

- The light level received by the camera lens is only 25% of the light output.
- The light source must be close to the target object.
- The light must be larger than the target object.

Application Examples

- Detect markings on brushed metal surfaces.
- Verify date codes on reflective materials.

Diffused Lighting

Highly-diffused lighting, such as a domed light, provides soft illumination from multiple directions. Diffused light minimizes glare and shadows.

Advantages

- Minimizes glare and shadows (with a domed light, glare and shadows are almost eliminated).
- Illuminates curved surfaces softly and evenly.
- Minimizes texture.

Disadvantages

- Brings out surface features less distinctly than direct light.
- The area of illumination must be three times larger than the area of inspection.
- Minimizes texture.

Application Examples

- Verify date-code ink on curved metallic surfaces, such as soda can bottoms.
- Read printing on clear plastic.
- Verify printing on plastic bottles.

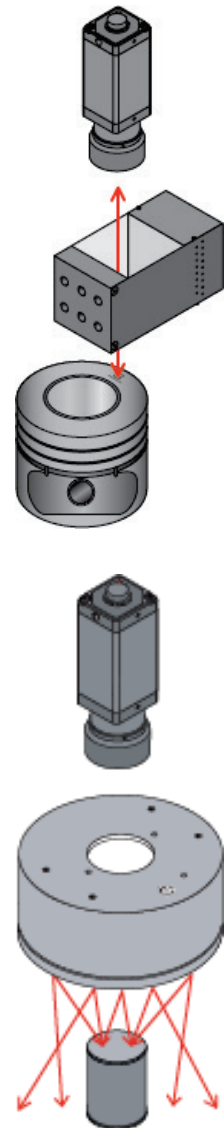


Image Analysis

After an image is captured, the next step in a vision application is to analyze the image. This is where the desired features are evaluated. A feature is the general term for information in an image, for example a dimension or a pattern.

Region of Interest

A Region of Interest (ROI) is a selected area of concern within an image. The purpose of using ROIs is to restrict the area of analysis.

Edges

Many tools look for “edges”, or locations where the gray scale value of neighboring pixels is drastically

different. In a good high-contrast image, these edge pixels are present at the boundaries between the feature of interest and the background. Thus, if we can identify the edge pixels, we can identify the feature of interest.

The first class of tools concerned with finding edge pixels are the linear vision tools. The linear tools include the Locate tool, the aptly named Edge tool, and the Object tool. All are variations on a single theme: the user defines a line of pixels that they would like to investigate and then the tool examines the pixels along that line for abrupt changes gray scale value. By changing the linear tools' Threshold method, a user can define how drastic a change is necessary to constitute an edge.

Blobs

A Blob stands for Binary Large Object and is any area of connected pixels that fulfill one or more criteria, for example having a minimum area and intensity within a gray value interval.

Pattern Matching

Pattern matching is the recognition of a previously taught pattern in an image. Pattern matching can only be used when there is a reference object and the objects to inspect are (supposed to be) identical to the reference. Pattern matching can also be used to locate objects, verify their shapes, and to align other inspection tools.

Barcode Reading

Barcodes are printed on products and packages to enable fast and automatic identification of a product. Barcodes are taught to a sensor, thus allowing the sensor to inspect and verify them at extreme speeds.

OCR/OCV

Optical Character Recognition (OCR) and Optical Character Verification (OCV) are used when text reading is used in packaging to inspect print quality and verify or read a printed message.

Color Analysis

A color vision sensor has an imaging chip that, rather than providing just a gray scale value along with the grid location, actually provides a color intensity value for each of the primary colors of light: red, green, and blue. Variations of color intensity for each of these primary colors provide all other shades of colors.

Red, Green, Blue (RGB)

Red, green, and blue (RGB) is a representation of additive color space where red, green and blue are combined to create other colors. This is the primary method for showing color on monitors and televisions.

The RGB color space is represented as a cube with the three primary colors whose axes are perpendicular to each other. Black is the absence of all primary colors; that is, the intensity of all three primary colors is zero [0,0,0]. White is the presence of all primary colors; that is the intensity of all three primary colors is 255 -- [255,255,255].

A color value is specified with three numbers between 0 and 255, each representing red, green and blue.

Hue, Saturation, Intensity (HSI)

Another way to look at color is not in terms of red, green, and blue, but as hue, saturation, and intensity (HSI). We generally do not see things as quantities of primary colors mixed in certain proportions. Rather, we see things as colors, or hues, that either are “washed-out” or vivid. This means having low or high saturation, respectively.

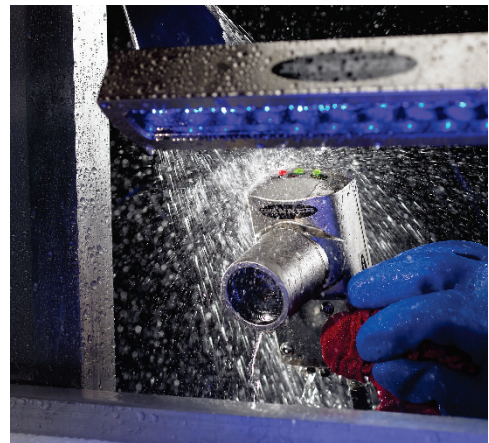
Hue, saturation, and intensity, then, are three dimensions that provide a representation of color space that is closer to human perception of color dynamics. “Colors” defined as H, S, and I ratios are represented as a cone. The cone shape has one central axis representing intensity. Along this axis are all the gray values, with black at the pointed end of the cone and white at its base. The greater the distance along this line from the pointed end, or origin, the brighter or higher the intensity.

Color Analysis involves looking at all colors in a ROI and reducing them to the average of the combined colors in the ROI or to group adjacent pixels within the same color range together to form a color BLOB and to analyze parts with color variations that cannot accurately be detected by gray scale sensors.

Considerations for Harsh Environments

Vision sensors are often deployed in harsh environments. These environments are dusty, where there is a lot of heavy equipment and therefore lots of vibration, or environments where vision components can be exposed to fluids, such as those environments that require periodic washdowns. Generally, these conditions can damage a vision sensor or one of its components.

One approach to protect vision sensors in harsh environments is to build custom enclosures. Although custom enclosures can improve the overall protection of the sensor, they can be expensive and also increase the overall size of the sensor, making it difficult to use in space-constrained applications. Additionally, custom enclosures can negatively affect optical performance by deforming the image or by introducing illumination problems such as unwanted reflections or stray light.



Vision sensor manufacturers have developed cost-effective ways to make more robust vision components for these environments.

- The sensor electronics and lens can be sealed in a single body, ruggedized housing, such as die-cast nickel-plated aluminum with an acrylic or glass lens cover.
- Locking screws can be used to prevent vibration from unthreading the lens from the camera and thereby altering the focus.
- Threaded connectors and high-flex cables can be used where there may be repetitive motion.
- Lighting can be sealed in a ruggedized housing such as diecast nickel-plated aluminum and stainless-steel.

For more information, visit www.bannerengineering.com