Video Cameras for Machine Vision

Many cameras are available for machine vision. They incorporate different sensors and different interface electronics, and they come in many sizes. Together, the camera and lens determine the FOV, resolution, and other properties of the image. Many cameras are designed specifically for machine vision applications. This section outlines key issues that should be addressed when choosing a camera lens—particularly those that also affect the choice of a lens.

Camera Types

SENSORS

Most machine vision cameras use charge-coupled device (CCD) image sensors. Charge from each line of pixels is transferred down the line, pixel by pixel and row by row, to an amplifier where the video signal is formed. CCD cameras are available in a wide variety of formats, resolutions, and sensitivities. They provide the best performance for most applications.

Complementary metal-oxide semiconductor (CMOS) sensors are becoming available for some applications. Because they are made using the same processes used to fabricate computer chips, they can be produced very inexpensively. Low-cost CMOS cameras are already used in toys and in webcams. Unlike CCD sensors, which must be read out one full line at a time, CMOS sensors can be read pixel by pixel, in any order. This is useful for time-critical applications in which only part of the image is of interest. At present, the noise performance of CMOS sensors is inferior to that of CCDs.

INTERFACES

Two types of camera interfaces are in use: analog and digital. In an analog camera, the signal from the sensor is turned into an analog voltage and sent to the frame-grabber board in the vision-system computer. EIA, RS-170, NTSC, CCIR, and PAL are all common analog interface standards. Analog cameras are inexpensive, but they are subject to noise and timing problems.

Most new machine vision cameras use a digital interface. The signal from each pixel is digitized by the camera, and the data are sent in digital form directly to the computer. CameraLink® and Firewire® are two popular digital interface standards. The digital signal is not subject to noise, and there is a perfect correspondence between each pixel on the sensor and in the image. Digital cameras support a wide variety of image resolutions and frame rates. Since the signal is already digitized, a simple interface board replaces the frame-grabber.

REMOTE-HEAD CAMERAS

Machine vision cameras are now quite compact; many are smaller than 50-mm cubes. Remote-head cameras have an even smaller camera "head" consisting of the sensor chip in a protective enclosure, connected to the camera body by a short (<1 m) length of cable. Microhead or "lipstick" cameras can be very small, but they are also much more expensive than single-piece cameras.

COLOR CAMERAS

Most color CCD cameras use a single sensor with an array of color filters printed over their pixels. Adjacent pixels sense different colors, so the resolution at each color is lower than that of a similar monochrome sensor. Some high-performance cameras use a color-separation prism to send light to three separate CCDs. These cameras provide full resolution at each color. Lenses for these "three-chip" cameras must have sufficient back working distance to allow room for the prism.

LINE-SCAN CAMERAS

Line-scan cameras have a single row of pixels, 1000, 2000, 4000, or more pixels long. They record images one row at a time. Often the object moves past the camera to provide the second dimension (e.g., a web of paper being inspected during manufacture). Line-scan cameras provide high-resolution images at very high data rates. Long line-scan sensors require large-format lenses to cover their length. In addition, because each line of pixels is exposed for only a very short time, line-scan cameras require intense lighting and large-aperture lenses.

CAMERA FORMATS

The size of an image sensor is called its format (figure 6.17). The name of a format does not correspond to any dimension. Historically, a ½-inch format is the size of the sensing area of a vidicon tube, which is ½ inch in diameter. It is important to choose a lens that covers the camera format. For a given FOV, the camera format determines the required magnification. A larger sensor requires a larger magnification for a given FOV.

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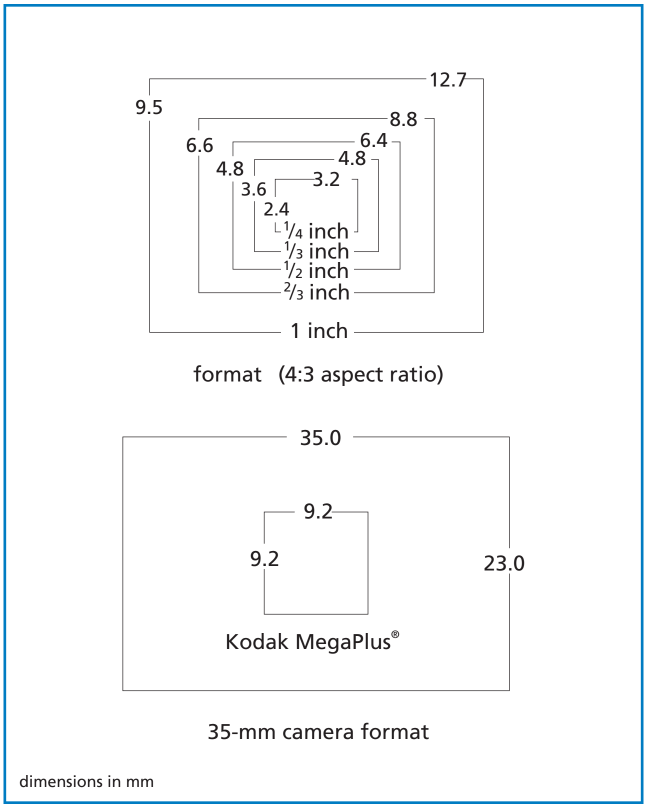

Figure 6.17 **Camera formats**

Lenses for High-Resolution Cameras

To improve sensitivity, many high-resolution CCD sensors include microlens arrays on their surfaces. These arrays make the active area of the pixels appear larger, so that the active-area fraction (fill factor) appears to be near 100 percent. Unfortunately, this is true only for light that is nearly normal to the sensor surface. Light reaching the sensor at greater angles (e.g., >5 deg) misses the active area and is lost. This means that lenses used with these sensors must have a long exit-pupil distance and should not have a very small f-number; otherwise the edges of the image will appear dark.