

An Introduction to Color Machine Vision

Measurement and control of product color is critical in many industries including food, pharmaceutical, and packaging. Color machine vision systems replace slow and unreliable human vision for inspecting colored objects, such as closures and labels. I'll discuss important issues in applying color machine vision (CMV) and, as an example, how CMV is used to inspect baked goods on a production line.

Human perception of color is influenced by genetic factors, experience, disease, age, adaptation, lighting, and the colors in the immediate environment. For example, a color can appear different when put next to another color or as the size of a colored object changes. These factors help explain why people disagree about paint colors and why a painted wall doesn't look like that little color sample from the paint store. They also show that we are not reliable color measuring instruments.

A photometer or other color measurement machine "sees" color based on integrated products of the illumination, the object's surface reflectance and the machine's sensors response. If we want to use a machine to approximate human color response, then the CMV system is calibrated in terms of a "standard observer" – an average of many people's perceptual responses to colors.

In both machine and human color vision it is common to have three sensor (receptor) types with broadband responses in the red (long), green (medium) and blue (short) wavelengths of light. Colors result from relative proportions of these three components. The broadband response of the sensors means that colors with different spectra sometimes cannot be distinguished; these unintended matches are called "metamers." For example, light with a wavelength of 580 nanometers (nm) looks yellow, but a combination of green light at 540 nm and red light at 680 nm can also appear to be the same shade of yellow. Multiple narrow-band spectral sensors are used to distinguish between metamers in some industrial processes, such as judging moisture content or pigment matching, but most applications of color machine vision are satisfied with three, broadband sensor types that approximate the response of the color sensors in our eyes.

A color machine vision application requires controlling both the intensity and spectrum of the inspected object's illumination. Incandescent light sources have a broad spectrum that makes color matching easier, but suffer from spectral shifts with temperature and hence time and input power. Most applications use fluorescent or "white" LED lights. The spectrum from these lights is quite uneven, typically with intensity peaks in the blue end of the spectrum, but their spectrum is relatively constant over time and temperature.

A "reference patch" is usually included in the field of view of the CMV system. This is a neutral, diffuse, white patch that reflects the illumination. The CMV measures the spectrum of this reflected illumination and uses it to compensate for changes in the illumination spectrum. Regular calibration and replacement of the illumination is also advisable.

The angle of the part, with respect to both the light and the CMV system's camera, influences the measured color. Diffuse objects, such as matte plastic caps, are less affected by angle changes, than surfaces with "depth," such as glossy, printed surfaces. You should present the objects or parts to be measured to the CMV system in a known orientation to reduce the effects of color changes with angles of illumination and view.

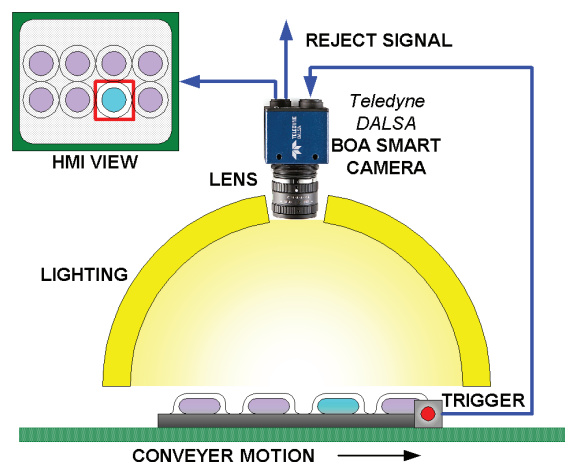


Figure 1 - Diagram of a BOA "smart camera" used for pharmaceutical color inspection. Diffuse light illuminates colored pills in a blister pack while suppressing reflections off of the blister pack plastic. The leading edge of a card of pills is detected by the part-in-place sensor and triggers image acquisition and analysis. Incorrectly colored pills (blue, in this example) are detected and rejected downstream. Errors are communicated to the plant's quality control system by standard control protocols over Ethernet or digital I/O.

Color Machine Vision Systems

A color machine vision system includes a color camera, a processor, software to make color measures, and communication of results. Teledyne DALSA's BOA smart camera combines the color camera, processor, software, and communications into one small package (see Figure 1). Teledyne DALSA's iNspec software is designed to be easy to set up and use, with most operations done graphically and no programming language to learn (see Figure 2).

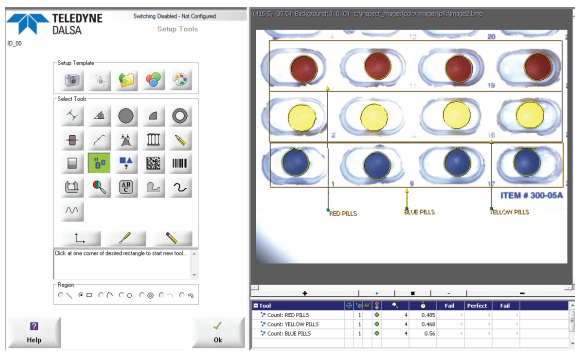


Figure 2 - An example screen from the iNspec software running on a color BOA smart camera. Inspection options are clearly and graphically presented to minimize set-up time.

Most color cameras use a monochrome sensor overlaid with a pattern of red, green and blue filters, called a "Bayer Pattern" after the inventor, to get the three broadband sensor types. This reduces the camera cost but also reduces the camera's spatial resolution. Therefore, measure part dimensions using a Bayer Pattern color camera can be tricky. Instead, we recommend measuring color areas, such as the amount of each color on a label or offset press printed cap.

The CMV software can report colors in different "color spaces," that is, standard representations for colors. For many applications red, green and blue values are sufficient but when we want to approximate human perception, then reporting is usually in a color space related to the CIE color space, such as L, a*, b* (Lightness, and a, b color components).

Inspecting Baked Goods

As an example, consider the inspection of baked goods such as hamburger buns, English muffins or tortillas. These baked products are sent by conveyer belt through an inspection station. At the inspection station a laser profiler measures the product's three-dimensional structure and a bright light and a color camera are used to measure product color (see Figure 3). The product moves quickly, so the bright light is needed to give the color camera enough reflected photons to form an image. This video shows some of the process of making English muffins:

www.sugden.ltd.uk/products/EMPLANT.asp

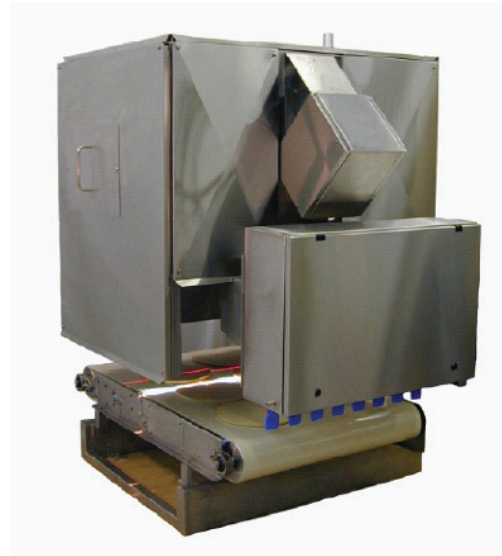


Figure 3 - A baked goods inspection station for tortillas, by Montrose Technologies Inc. The red laser line is used for measuring 3D shape and the bright white line is used for measuring color. The blue nozzles protruding from the box below the laser camera box are "air knives" that blow defective product down and out of the gap between this station's conveyer belt and the next conveyer belt. See www.montrose-tech.com

The color image of the baked goods is examined to ensure that it exhibits the proper colors. Obviously incorrect colors, say green or orange, might indicate mold or contamination and must cause product rejection. More subtle are colors that suggest to us that the baked goods are properly cooked. Consider “toast marks,” on English muffins for example. English muffins are baked in tins and the heel (bottom) appears brown with black marks. The heel also has a dusting of farina or corn meal to prevent the muffin from sticking to the tin and to add taste and visual texture.

After the muffin is cooked, a “toast mark” is applied to the top of the muffin by briefly cooking it on a griddle (see Figure 4). Without this “toast mark,” people think the product hasn’t been properly baked. In fact, the product could be pasty white (assuming no contamination now!) and still be properly baked. So “toast marks” send the consumer a subliminal message that the product is properly cooked.



Figure 4 - The heel or bottom of an English muffin is on the left, and the top of the muffin on the right. The toast mark is the irregular brown and black area on the top of the muffin.

Brown is a difficult color to measure – it is a “non-spectral” color, as there is no wavelength in the physical spectrum that is brown. Low intensity reds to orange wavelengths can be perceived as brown.

On English muffins, the brown is measurable by a color machine vision system and so the “toast mark” can be quantified by color and extent. These measures could be used to adjust the temperature of the upstream toasting to give the desired mark color and extent. Because we are matching human perception, color values are reported in as L, a*, b* components.

As English muffins come out of the inspection system, incorrectly toasted product is blown off conveyer using one or more “air knives.” This is shown in this video: www.youtube.com/watch?v=6SclHMxyDI The results of inspections are sent to the plant’s process monitoring system. These results signal production problems and help the manufacturer adjust the production process.

Using proper lighting, part presentation, processing, and communications, a color machine vision system can take over human visual inspection of colored products. With easy-to-use color machine vision software and hardware designed for factory integration, subjective human color inspection can easily be automated.

Americas

Boston, USA
+1 978-670-2000
sales.americas@teledynedalsa.com

Europe

Munich, Germany
+49 8142-46770
sales.europe@teledynedalsa.com

Asia Pacific

Tokyo, Japan
+81 3-5960-6353
sales.asia@teledynedalsa.com

Shanghai, China
+86 21-3368-0027
sales.asia@teledynedalsa.com