A Practical Guide to Machine Vision Lighting - Part II

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Overview

It is well understood that the quality and appropriateness of lighting are critical aspects for creating a robust and timely vision inspection. In addition to an understanding of illumination types, techniques, geometry, filtering, sensor characteristics, and color, a thorough analysis of the inspection environment (including sample presentation and sample-light interactions) provides a foundation upon which to design an effective vision lighting solution. It is suggested that designing and following a rigorous lighting analysis sequence will provide a consistent and robust environment, thereby minimizing required time, effort, and resources that can be better used in other critical aspects of vision system design, testing, and implementation.

This application note is the second document in a three-part series written by Daryl Martin, from Advanced Illumination, that demonstrates machine vision lighting concepts and theories. Refer to A Practical Guide to Machine Vision Lighting – Part I and A Practical Guide to Machine Vision Lighting – Part III for further discussion of machine vision lighting design.

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1. Factors to Consider for an Optimal Lighting Solution

This document is part of the
Machine Vision
Fundamentals Series

With respect to the lighting environment, there are 2 aspects to evaluate when determining the optimal lighting solution:

1. Immediate inspection environment
2. Sample – light interaction

All the information from these evaluations should be considered together with the available optics, lighting types, techniques, and the four cornerstones to develop a sample-appropriate lighting solution that meets the 3 acceptance criteria listed in Part I of the series.

Immediate Inspection Environment

Fully understanding the immediate inspection area's physical requirements and limitations, in 3-D space, is critical. In particular, depending on the specific inspection requirements, the use of robotic pick and place machines, or pre-existing, but necessary support structures may severely limit the choice of effective lighting solutions by forcing a compromise in not only the type of lighting, but its geometry, working distance, intensity, and pattern as well. For example, it may be determined that a diffuse light source is required, but cannot be applied because of limited close-up, top-down access. Inspection on high-speed lines may require intense continuous or strobed light to freeze motion, and of course large objects present an altogether different challenge for lighting. Additionally, consistent part placement and presentation are also important, particularly depending on which features are being inspected; however, even lighting for inconsistencies in part placement and presentation can be developed, as a last resort, if fully understood.

Ambient Light Contribution

As mentioned earlier, the presence of ambient light input can have a tremendous impact on the quality and consistency of inspections, particularly when using a multi-spectral source, such as white light. The most common ambient contributors are overhead factory lights and sunlight, but occasionally errant vision-specific task lighting from other inspection stations, or even other stations in the same work cell can have an impact.

There are 3 active methods for dealing with ambient light – high power strobing with short duration pulses, physical enclosures, and pass filters. Which method is applied is a function of many factors, most of which will be discussed in some detail in later sections. High-power strobing simply overwhelms and washes out the ambient contribution, but has disadvantages in ergonomics, cost, implementation effort, and not all sources can be strobed, e.g. - fluorescent. If strobing cannot be employed, and if the application calls for using a color camera, multi-spectral white light is necessary for accurate color reproduction and balance. Thus, in this circumstance a narrow wavelength pass filter is ineffective, as it will block a major portion of the white light contribution, and thus an enclosure is the best choice.

There are exceptions to this rule-of-thumb, however. For example, a 700 nm short pass filter, otherwise known as an IR blocker is standard in color cameras because IR content can alter the color accuracy and balance, particularly of the green channel. Figure 5 illustrates how the use of a pass filter can block ambient light very effectively, particularly when the light of interest is low yield fluorescence.

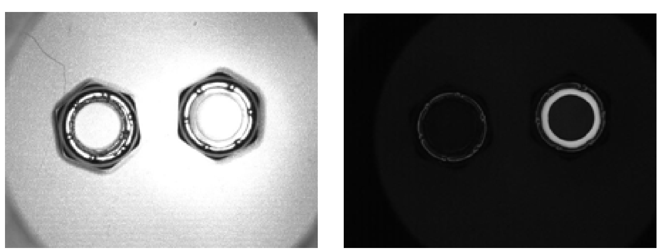

Figure 5 – Nyloc Nuts. Left: Imaged with a UV ring light, but flooded with red 660 nm "ambient" light. The goal is to determine nylon presence / absence. Given the large ambient contribution, it is difficult to get sufficient contrast from the relatively low-yield blue fluoresced light from the sample. Right: Same lighting, except a 510 nm short pass filter was installed on the camera lens, effectively blocking the red "ambient" light and allowing the blue 450 nm light to pass.

Sample - Light Interactions

How a sample's surface interacts with task-specific and ambient light is related to many factors, including the gross surface shape, geometry, and reflectivity, as well as its composition, topography and color. Some combination of these factors will determine how much light, and in what manner, it is reflected to the camera, and subsequently available for acquisition, processing, and measurement. For example, a curved, specular surface, such as the bottom of a soda can (Figure 6), will reflect a directional light source differently from a flat, diffuse surface, such as copy paper. Similarly, a topographic surface, such as a populated PCB, will reflect differently from a flat, but finely textured or dimpled (Fig. 7) surface depending on the light type and geometry.

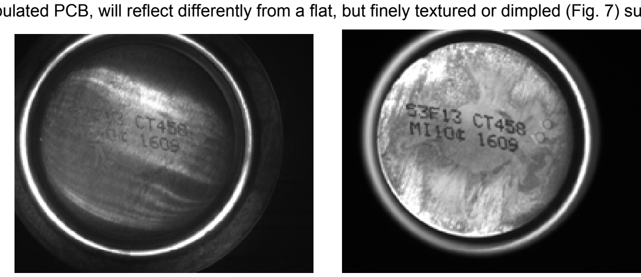

Figure 6 – Bottom of a soda can. Left: Illuminated with a bright field ring light, but shows poor contrast, uneven lighting, and specular reflections. Right: Imaged with diffuse light, creating an even background allowing the code to be read.

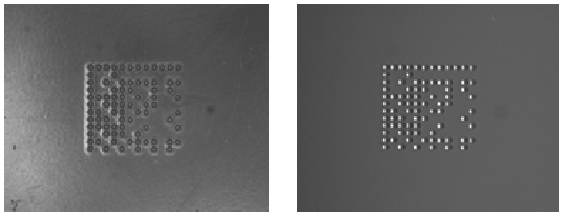

Figure 7 – 2-D dot peen matrix code. Left: Illuminated by a dome light. Right: Imaged with a low angle linear dark field light. A simple change in light pattern created a more effective and robust inspection.

Color Analysis

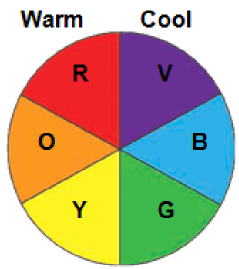

Figure 8 - Color Wheel

Materials reflect and/or absorb various wavelengths of light differentially, an effect that is valid for both B&W and color imaging space. As we all remember from grammar school, like colors reflect, and surfaces are brightened; conversely, opposing colors absorb, and surfaces are darkened. Using a simple color wheel of Warm vs. Cool colors (Fig. 8), we can generate differential contrast between a part and its back-ground (Figure 9), and even differentiate color parts, given a limited, known palette of colors, with a B&W camera (Figure 10).

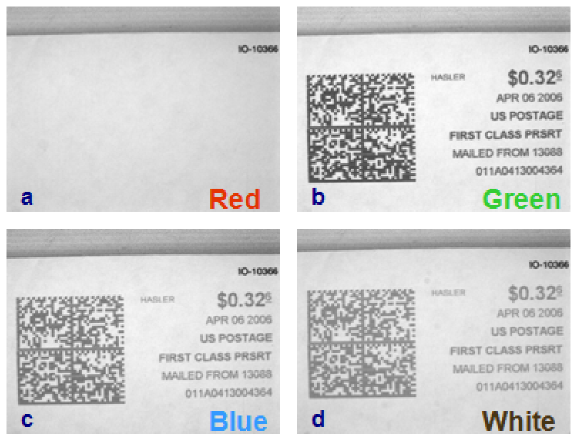

Figure 9 a – Mail stamp imaged under Red light, b - Green light, c - Blue light, generating less contrast than green, d – White light, generating less contrast than either Blue or Green light. White light will contrast all colors, but it may be a contrast compromise.

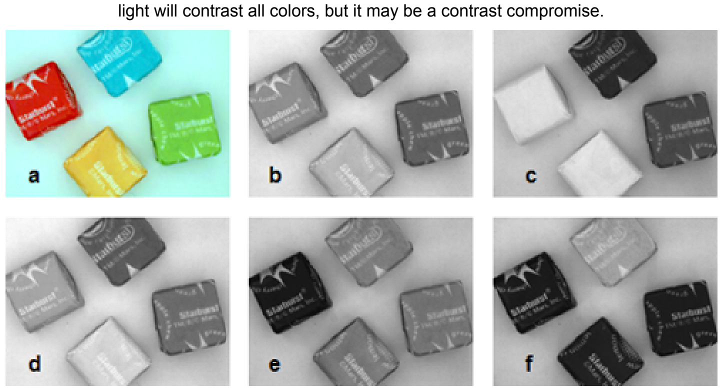

Figure 10 a - Candy pieces imaged under white light and a color CCD camera, b - White light and a B&W camera, c - Red light, lightening both the red & yellow and darkening the blue, d – Red & Green light, yielding yellow, lightening the yellow more than the red, e – Green light, lightening the green & blue and darkening the red, f – Blue light, lightening the blue and darkening the others.

Sample Composition and Transmittance

Sample composition can greatly affect what happens to task lighting impinging on a part. Some plastics may transmit light only of certain wavelength ranges, and are otherwise opaque; some may not transmit, but rather internally diffuse the light; and still some may absorb the light only to re-emit it at the same wavelength, or at a different wavelength (fluorescence). Fluorescence labels and dyes are commonly used in inks for the printing industry as well (Figure 11).

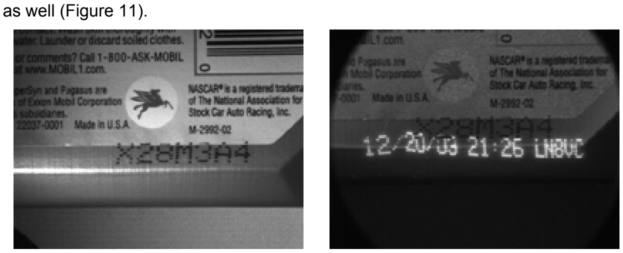

Figure 11 – Motor oil bottle. Left: Illuminated with a red 660 nm ring light. Right: Illuminated with a 360 nm UV fluorescent light.

The properties of IR light can be useful in vision inspection for a variety of reasons. First, IR light is effective at neutralizing contrast differences based on color, primarily because reflection of IR light is based more on sample composition, rather than color differences. This property can be used when less contrast, normally based on color reflectance from white light is the desired effect (See Fig. 12).

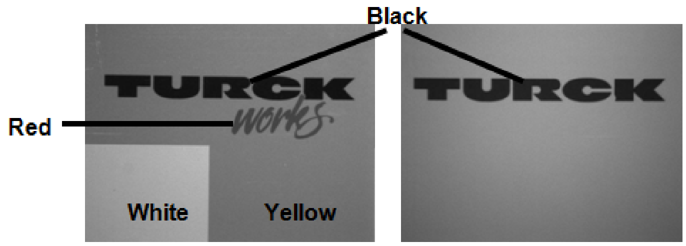

Figure 12 – Glossy paper sample. Left: Under diffuse white light. Right: Under diffuse IR light.

The penetration depth of light into some materials is directly proportional to the light's wavelength. IR light is considerably more effective at penetrating polymer materials than is deep blue or UV light (see Figure 13). It is this lack of penetration depth, however, that makes blue light useful for imaging surface features of black rubber compounds, for instance.

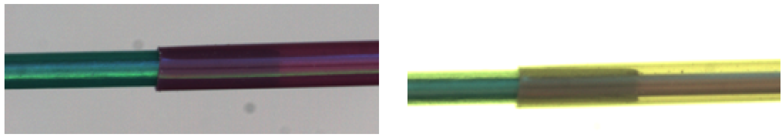

Figure 13 – Polymer-coated wire. Left: With a white back light and color camera. Right: With an IR back light – note the much improved penetration, revealing the wire, and necessary overlap in the 2 polymer coatings.

Polarizing filters, when applied in pairs, one between the light and sample, the other between the sample and camera, typically affixed to the lens via screw threads, are useful for: 1) detecting differences in mechanical damage in otherwise transparent samples (Figure 14), and 2) reducing glare (Figure 15).

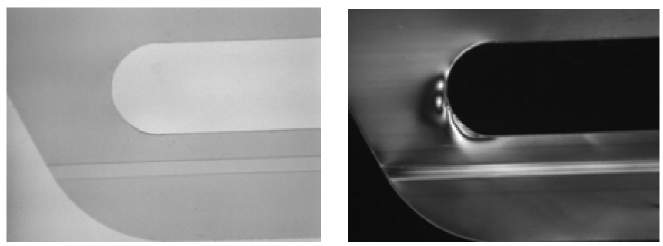

Figure 14 – Transparent plastic 6-pack can holder. Left: With a red back light. Right: Same, except for the addition of a polarizer pair, showing stress fields in the polymer.

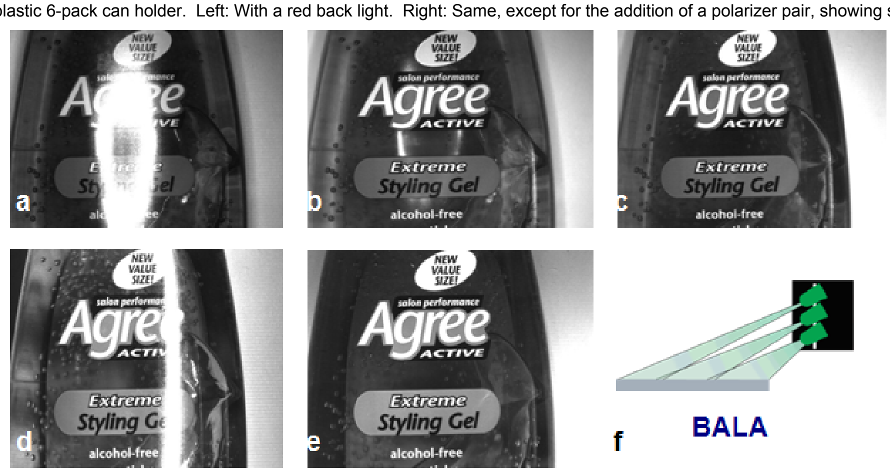

Figure 15 - A change in lighting – sample – camera geometry or type may be more effective than applying polarizers to stop glare. a – Coaxial Ring Light w/o Polarizers. b – Coaxial Ring Light w/ Polarizers (note some residual glare). c – Off-axis Ring Light w/o Polarizers. d – Off-axis Linear Array Light (BALA) oriented parallel to the bottle long axis. e – Off-axis Linear Array Light oriented perpendicular to bottle long axis. f – BALA light function diagram.

2. Related Links

Return to Part I or continue on to Part III to learn more about machine vision lighting concepts and theories. Part I introduces concepts important to machine vision lighting systems. Part III introduces various lighting techniques and a method for systematically designing a robust lighting system.

- A Practical Guide to Machine Vision Lighting – Part I
- A Practical Guide to Machine Vision Lighting – Part III