



SMART CAMERA MODULARITY

Modular smart cameras offer flexibility and enhanced performance for machine vision applications

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As every systems integrator is aware, the choice of cameras, lighting, and lenses for every machine vision application is different. While some applications require a part to be backlit to enhance the silhouette of a feature, others require on-axis illumination to highlight a pattern or read a code on a label. Similarly, an application that involves high tolerance gauging requires a higher resolution lens solution, while others simply need to detect presence/absence of varying features. There are countless combinations of lens, lighting, and resolutions of machine vision systems to meet the application needs of today. For these reasons, it is important to look at the flexibility and adaptability of the vision system as new application requirements surface.

Depending on the application, developers have a few options when it comes to building machine vision systems with the top three options being: PC host-based, embedded vision controller-based, and smart camera-based. PC-based systems offer the greatest flexibility, including virtually any combination of cameras, lenses, frame grabbers, lighting controllers, and I/O peripherals. Embedded controllers offer flexibility within OEM-mandated cameras, lenses, processors, lights, and I/O peripherals. While flexible, both PC-host and embedded vision controller solutions demand significant engineering knowledge from the initial design through repairs, and often require being installed in a cabinet to meet the IP rating of the assembly line.

Smart cameras provide an easier software and hardware setup and typically include integration with the camera, CPUs, lighting, lensing, on-board software, and I/O control in one compact design. (Figure 1) Most smart cameras have a rugged IP rating and can be installed directly on the assembly line. Like embedded vision controllers, the supported lighting and lensing is predetermined by the vendor. However, many smart camera vendors are integrating more flexibility into their systems to support additional combinations of lighting and lensing, without increasing the system footprint on the line or compromising IP ratings. In this way, a single piece of highly “modular” vision hardware can solve a wide range of vision applications. For that reason, modular smart camera solutions can reduce the total cost of ownership by allowing technicians to make reconfigurations in the field, including lighting and lensing during repairs, or re-tasking the system to accommodate new product varieties or entirely new applications.

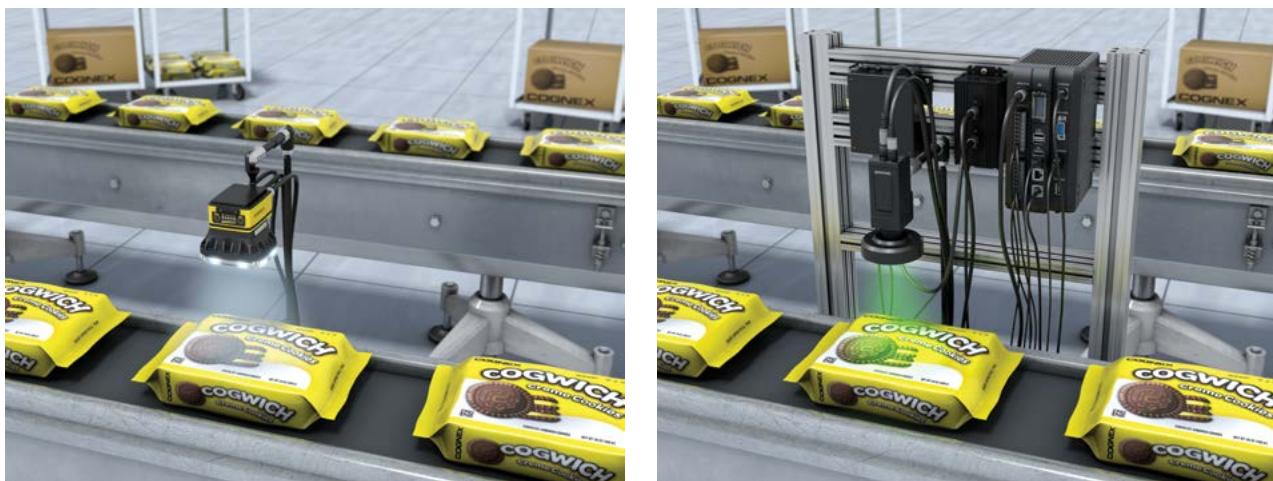
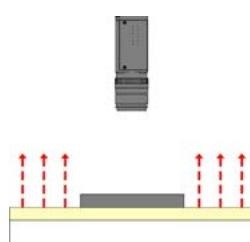


Figure 1: An example of an integrated smart camera and embedded controller system. Both have advantages in flexibility and development.

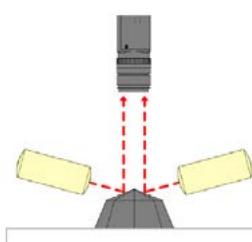
LIGHTING CHOICES

External lighting, installed separately from the camera, offers extensive possibilities from backlight techniques for highlighting the outer edges of a product, to diffuse on-axis light for illuminating reflective flat surfaces such as metal, glass, or plastic. These lights often require a separate power supply and controller, which increases the machine vision solution footprint on the assembly line.



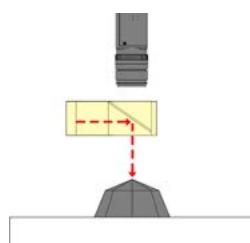
Back lighting

Back lighting enhances an object's outline for applications that need only external or edge measurements. Back lighting helps detect shapes and makes dimensional measurements more reliable.



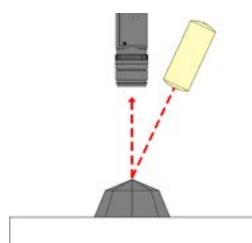
Dark-field illumination

Directional lighting more easily reveals surface defects and includes dark-field and bright-field illumination. Dark-field illumination is generally preferred for low-contrast applications. In dark-field illumination, specular light is reflected away from the camera, and diffused light from surface texture and elevation changes are reflected into the camera.



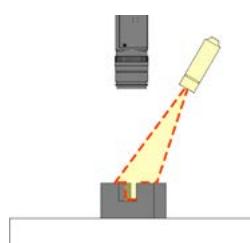
Axial diffuse lighting

Axial diffuse lighting couples light into the optical path from the side (coaxially). A semi-transparent mirror illuminated from the side, casts light downwards on the part. The part reflects the light back to the camera through the semi-transparent mirror resulting in a very evenly illuminated and homogeneous looking image.



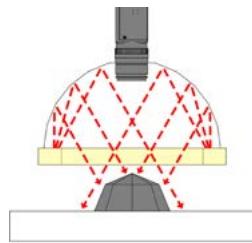
Bright-field illumination

Bright-field illumination is ideal for high-contrast applications. However, highly directional light sources such as high-pressure sodium and quartz halogen may produce sharp shadows and generally do not provide consistent illumination throughout the entire field of view. Consequently, hot-spots and specular reflections on shiny or reflective surfaces may require a more diffused light source to provide even illumination in the brightfield.



Structured light

Structured light is the projection of a light pattern (plane, grid, or more complex shape) at a known angle onto an object. It can be very useful for providing contrast-independent surface inspections, acquiring dimensional information and calculating volume.



Diffused dome lighting

Diffused dome lighting gives the most uniform illumination of features of interest, and can mask irregularities that are not of interest and may be confusing to the scene.

Smart cameras remove the additional footprint of external lighting hardware by integrating the lighting directly with the camera itself. Most integrated lighting offers a diffuse on-axis light technique, which provides good lighting for many applications. Adding flexibility in the lighting—like the ability to turn on only a portion of the total light to highlight an edge, or the ability to swap out the light color—expands the number of applications a smart camera system can solve. (Figure 2) While integrated lighting may solve most applications, an external light, like a large low angle light, may be needed to highlight a larger area. Some smart cameras have direct power and control connectors for external lights, offering more capability and lighting flexibility while minimizing the total lighting footprint on the line.

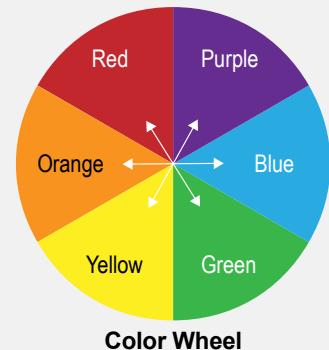


Figure 2: Example of integrated light made up of four banks of LEDs. Each bank (or portion) of the light can be enabled or disabled to create the lighting effect needed for the application.

Making colored text easier to read

Problem: Performing optical character recognition (OCR) requires high contrast text. Colored text can pose a challenge for OCR algorithms, especially on reflective surfaces.

Solution: By using complimentary colors (colors "opposite" on the color wheel) between the light and the target color of the text, contrast is created for easier to read characters on a part. For example: red text is displayed in high contrast when using a blue light because blue and red are opposite colors on the color wheel.



Original color image,
ambient light



Monochrome camera
image with blue light



Part with blue font,
under ambient light,
with a monochrome
camera



Monochrome camera
image with red light

SPECIALIZED FILTERS

Beyond light color, filtering is also useful in creating contrast by limiting ambient light or restricting specific wavelengths of color from the image. In some cases, using a monochrome camera with a filter is all that is needed to detect a difference in part color. There are many different types of filters that can be attached to the lens or lights (or both) of the vision system, ranging from bandpass filters to polarizing filters.

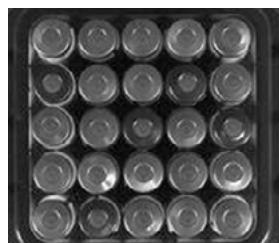
Bandpass filters limit the color (wavelength) seen by the camera. If using a monochrome camera and inspecting a specific color feature, a bandpass filter may be an easy solution. For example, if the intention is to count the number of red parts on a tray, using a blue filter with a simple white light will create adequate contrast in the image. (Figure 3)

Another type of filter is a polarizer. Polarizing filters remove stray or scattered light, which causes glare and often obstructs the features on the inspected part. Polarizers pass only the light from a specific linear direction and remove the "hot spots" or noise reflected into the imager.

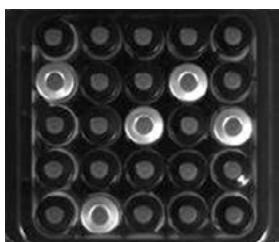
Smart cameras allow filters and lighting to be integrated into the camera itself so the entire lighting solution is contained within a small rugged package. Additionally, a modular smart camera design allows for easy replacement and reconfiguration of lighting and filtering for changing application needs.



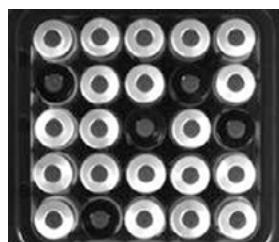
Original color image



No filter



Blue Bandpass Filter



Red Bandpass Filter

Figure 3: Bandpass filters limit the color seen by the camera to help inspect for specific colors

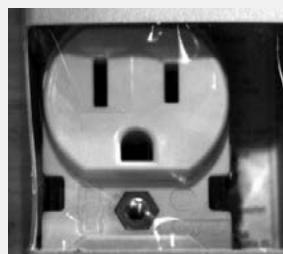
Inspect the feature and not the glare

Problem: The packaging and light cause unwanted specular glare on the part, limiting the effectiveness of the 3-prong outlet inspection.

Solution: Add a polarizer on the filter and lens. This reduces the specular reflections so the outlet in the package can be properly inspected.



No filter specular glare



With a linear polarizer for the lens and linear polarizer for the light source

LENS CONFIGURATIONS

Just as numerous lighting and filter techniques are used to increase the image contrast captured by the smart camera, several different lenses can be selected to improve image quality for the application as well. Lens types range from C-mount lenses to the newest liquid lens technology.

C-mount lenses offer the most versatility. They can range from 1/3" to 4/3" lenses, depending on the camera's image sensor size. These lenses can be fixed or have an adjustable focus to accommodate a range of working distances. C-mount lenses need to be physically adjusted on the camera to get the inspected part in focus. On the other hand, autofocus and liquid lenses remove the physical adjustment and allow the lenses to be automatically adjusted from the smart camera software. Autofocus lens modules move the lens closer or farther away from the sensor to provide varying focal distances while keeping the camera mounted in the same place. Autofocus allows the smart camera to automatically adapt to changes in working distances (camera to part), whether the result of product changeover or new applications.

Liquid lenses are the latest addition to the autofocus optical line. Liquid lenses consist of a sealed cell containing oil and water, where the shape curvature between the oil and water barrier is changed by electrostatic pressure; this changes the focal point of the lens. (Figure 4) While mechanical autofocus lenses can be used to accomplish the same focus task using a motorized lens, liquid lenses have no moving parts. This is especially important in applications such as barcode reading where Data Matrix or direct part mark (DPM) codes may be presented at different distances from the camera during runtime operation.

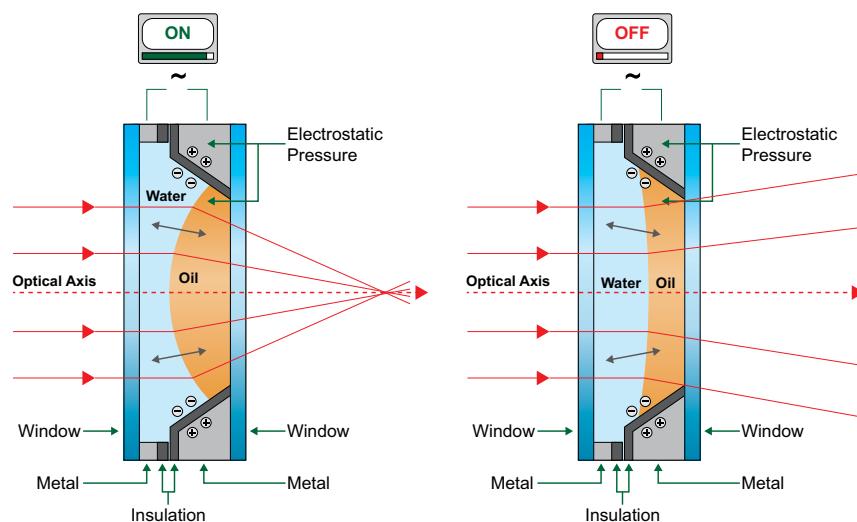


Figure 4: The key advantages of the liquid lens are its fast response times, good optical quality, low power consumption, and size. The liquid lens can simplify installation, setup, and maintenance by eliminating the need to open the reader and manually touch the lens. Relative to other autofocus mechanisms, the liquid lens has extremely fast response times. It is also ideal for applications with reading distances that change from part to part or during part changeover.

Regardless of the lens choice, modular smart cameras provide flexibility in lensing by supporting the latest autofocus lenses and the standard C-mount lenses within a self-contained package that can be modified for either configuration.

CONCLUSION

Modular smart camera solutions are helping integrators and end-users solve more applications cost-effectively through their inherently flexible design. By adopting more modular machine vision systems that support a variety of lighting, lensing, and filter solutions, integrators and end-users can customize the systems on the factory floor to solve current inspections or repurpose them to solve new applications. Adopters of modular machine vision systems are more likely to realize higher returns on their automation investments through reuse, re-tasking, and reprogramming of these machine vision solutions.

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