

What is Spectral Imaging And When Should I Use It?

When seeking a solution to a problem, or a means to exploit an opportunity, it is often difficult to identify the appropriate technology for the task. This brief white paper provides an overview of spectral imaging to help determine whether or not it might be a useful component in a successful solution.

What it is: Spectral imaging, also known as hyperspectral imaging, provides a digital image with far more spectral (color) information for each pixel than traditional color cameras. The raw data output is often visualized as a “*datacube*.” This can be thought of as a stack of tens to hundreds of pictures with each successive image representing its own specific color (spectral band), or equivalently, as a detailed spectral curve for each pixel. An example of a datacube is shown in Figure 1, with two dimensions in space (x and y) and one in wavelength (λ).

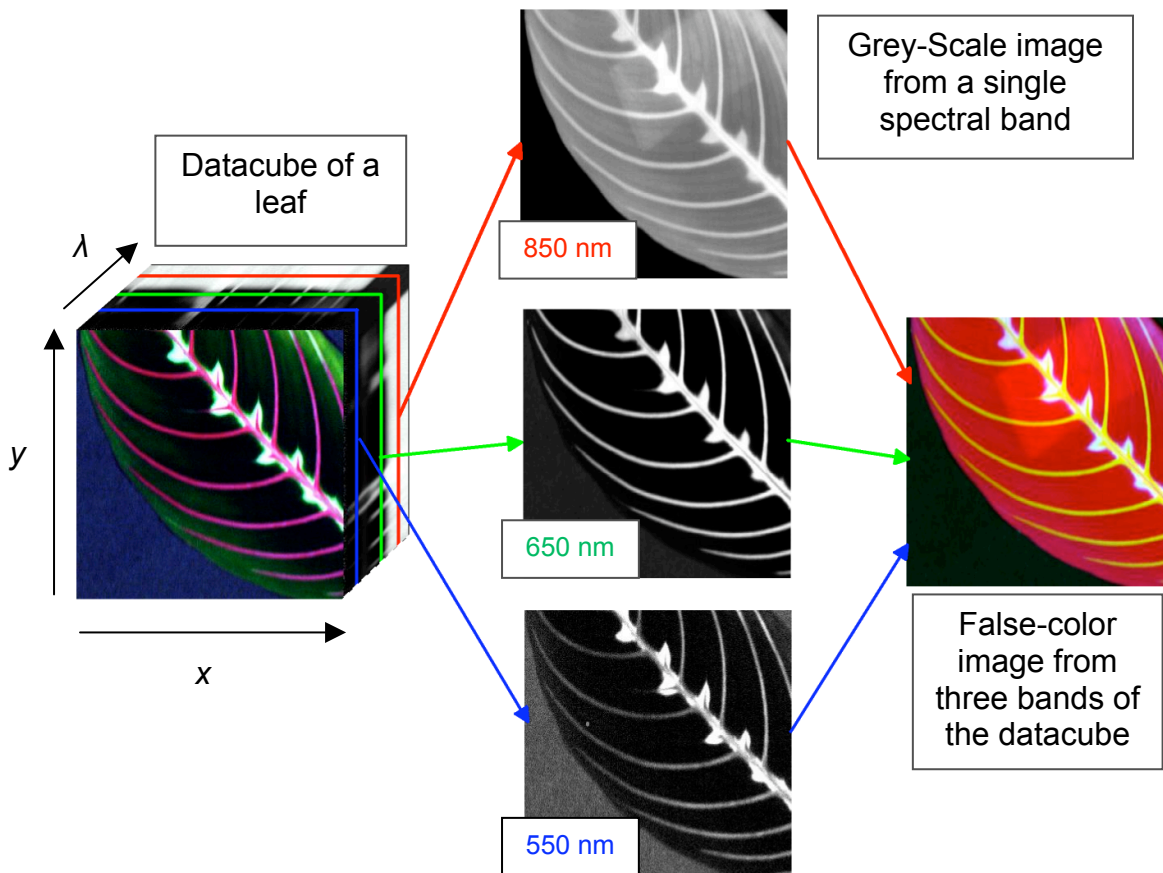


Figure 1. The data from a spectral imager can be viewed as a stack of images, with each image corresponding to a different color or spectral band. The three bands labeled were used to generate a false-color image of a leaf.

Why it is useful: In contrast to a human brain, which uses only three primary colors seen by the human eye, computer vision systems can utilize many more color channels. With this additional spectral (or color) information, spectral machine vision systems often exhibit greatly improved color differentiation as compared to conventional color imaging. Additionally, spectral imaging systems can access spectral regimes such as the infrared, which enables machine vision system to exploit reflectance differences humans cannot see.

When to use it: Spectral imaging may be a good solution to your machine vision needs when:

1. Precise spectral or color information is needed. (E.g., you need to distinguish between similarly colored objects, measure absolute color such a CIE LAB, measure overlapping fluorescent signals.)
2. An image of the scene is necessary. (I.e., the object of interest is not uniformly one color, the area of interest contains multiple objects, scenes in which a single-point spectrometer would not accurately sample or cover the area of interest.)

The following example may help make these two points more clear.

Example: A spectral image was recorded of cooked chicken nuggets with two types of blemishes: (1) Each nugget has a region where the breading is missing; and (2) One nugget has a very dark and crispy region where two chicken nuggets were in contact when cooked, resulting in an oblong ring of excess batter. Three bands of the spectral image were used to generate a True Color image of the chicken nuggets, which is shown in Figure 2. A “True Color” image rendering is generated by choosing 3 bands of the spectral image that approximates how the scene appears to humans. Other image renderings, such as the false color image rendering shown in Figure 1, may be used to help identify or highlight features of interest.

In addition to the blemishes, one can identify regions on the nuggets that have a light, golden color, and other regions that have a dark, golden color.

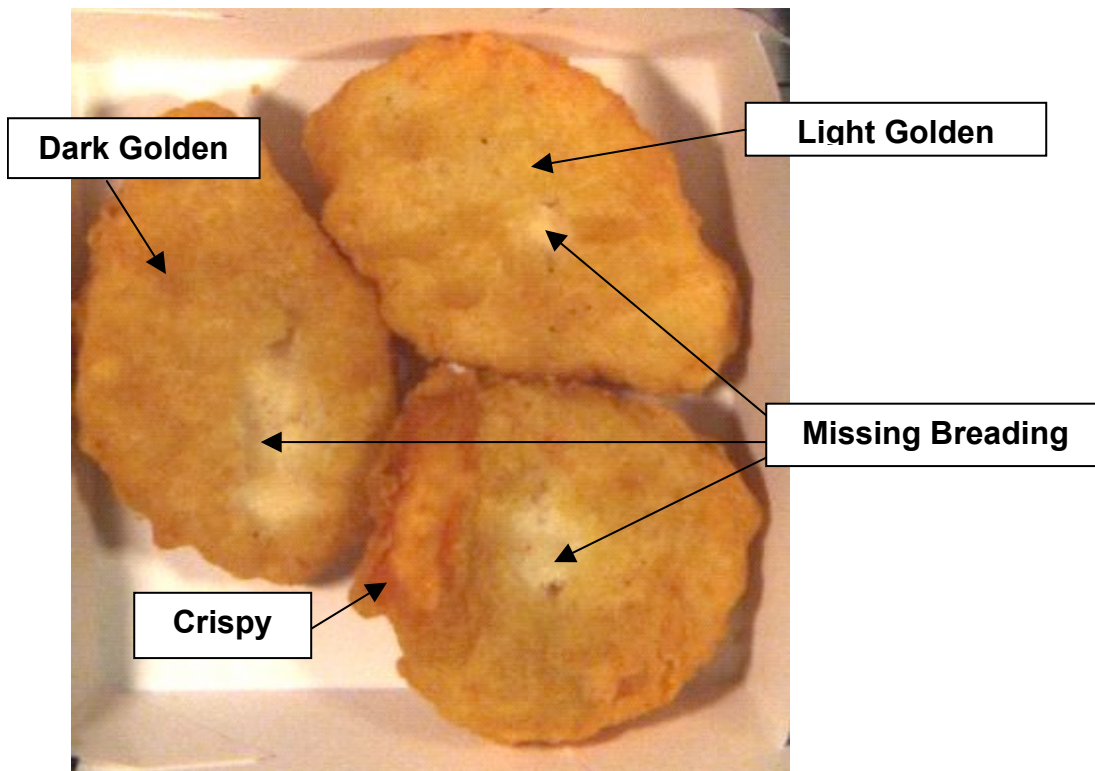
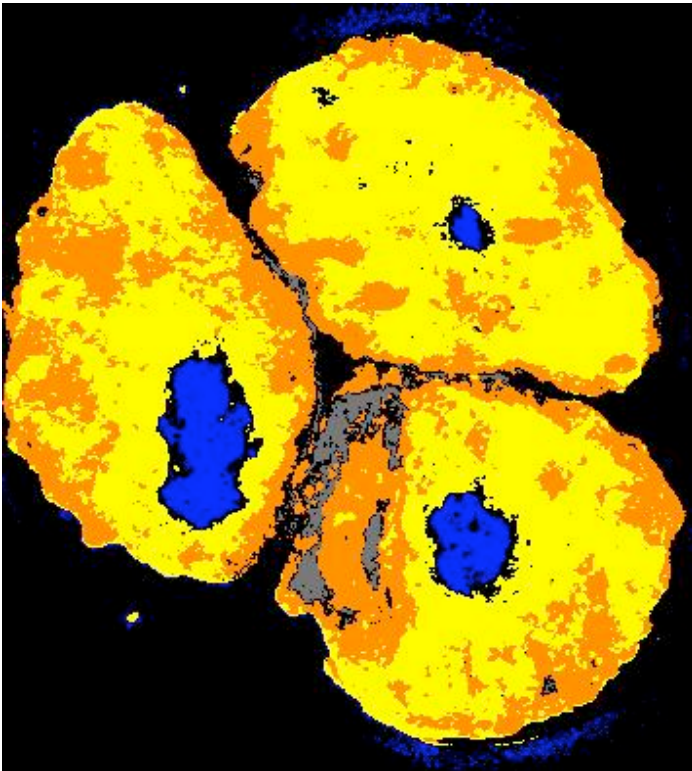


Figure 2. Cooked chicken nuggets with blemishes.



	Light Golden
	Dark Golden
	Crispy
	Missing Breading

Figure 3. Classification map of the chicken nuggets shown in Figure 2.

Figure 3 shows a classification map of the same chicken nuggets. The regions with missing breading are classified as blue, the region with excess batter, or overly crispy region, is classified as dark tan. Additionally, yellow and orange are used to distinguish between the light golden regions and the darker golden colors. Pixels that did not classify as any of these regions are colored black. In practice, one could use these results to discard nuggets with major blemishes, as well as utilize the ratio of light-golden pixels to dark-golden pixels to control the cooking process, or blend the nuggets after cooking to insure that every batch has a pleasing mixture of light- and dark-golden nuggets.

How it works: Each class of interest is associated with a representative spectrum. For example, for the results shown in Figure 3, the spectra from several pixels of each class were chosen and averaged together to form the representative spectral curves shown in Figure 4. Note that in addition to amplitude differences, the representative spectral curves have slightly different shapes. These curves were then compared to the spectral curve from every pixel in the image – there are a variety of algorithms available for this comparison. In practice, natural variability and noise keep the representative curves and the spectra from individual pixels from matching perfectly. Therefore one sets thresholds that are used to accept or reject pixels for each classification.

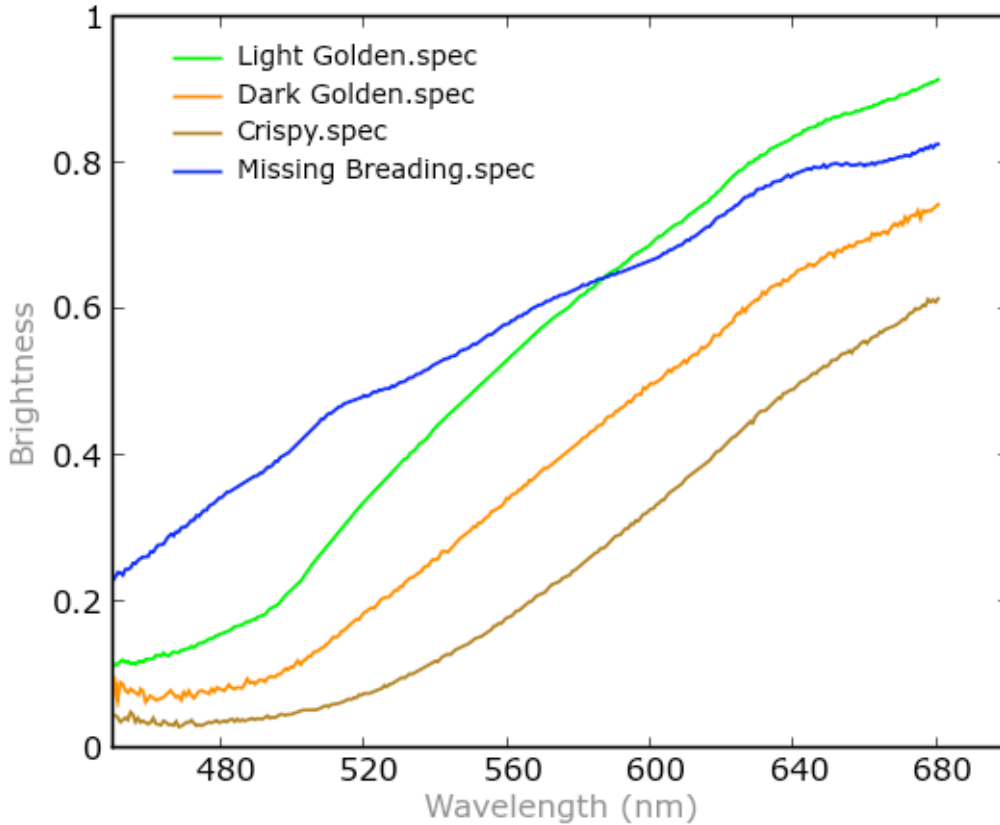


Figure 4. Representative spectral curves for the four pixel classifications shown in Figure 3.

Concluding remarks: Spectral imaging is a powerful tool for machine vision applications that is particularly useful for applications that require distinction between similarly colored objects or regions. Much like the human eye, spectral imaging can be applied to a wide range of applications, including quality control (lumber, textiles, paper, building materials, drugs), process control (thin films, moisture content, color), sorting (food, recyclable materials, minerals), remote sensing (ocean color, environmental monitoring, agriculture), and much more. With the development of compact, low-cost spectral imaging systems, this technology can be applied to ever widening uses, with platforms ranging from microscopes to airplanes.

For additional information on how spectral imaging might be used to solve your problem, please contact Resonon.