A New Innovative Spectrolight's Hyperspectral Camera

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Hyperspectral imaging is a non-destructive, non-contact technique for identifying substances by collecting information from images created by the electromagnetic spectrum of a sample. Hyperspectral imaging accounted for 2.5% of the global optical imaging market in 2015, but it has grown rapidly in the last few years due to the development of new light sources.1 Compared to optical coherence tomography (OCT), its faster imaging speed and non-invasiveness have led to increased demand in various fields such as remote sensing, food inspection, recycling, forensics, counterfeit detection, military applications, biomedicine, and many other applications.

The concept of hyperspectral imaging can be easily figured out by comparing images of the color blindness test sheet obtained with 500 nm and 600 nm wavelengths (**Figure 1**).

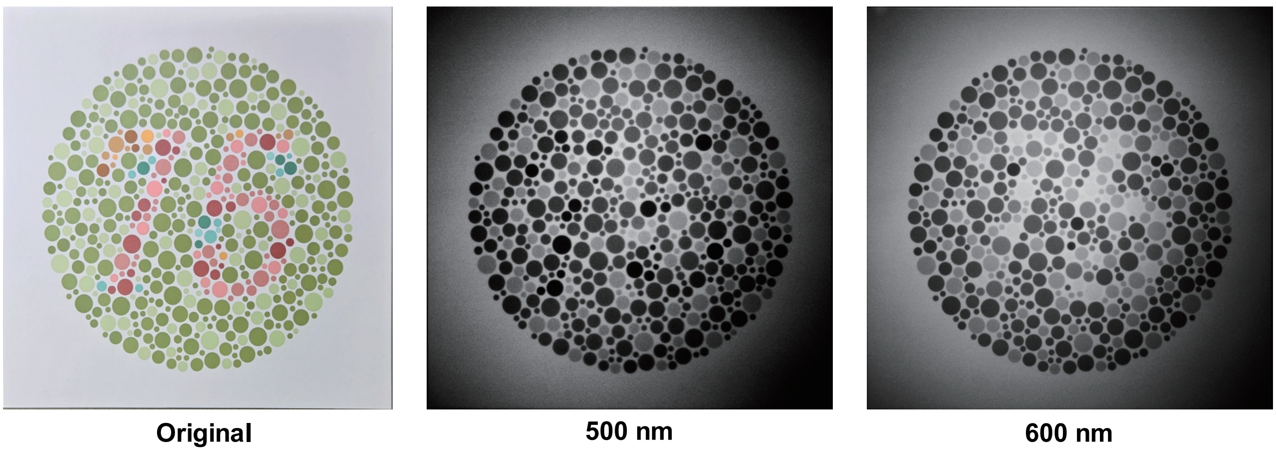

Figure 1. Hyperspectral images of the color-blind test sheet were obtained with two different wavelengths. It is not visible at 500 nm but visible at 600 nm.

Hyperspectral imaging is a technique that uses spectroscopy to obtain images as a function of wavelength using spectroscopy and analyzes an object's state, composition, characteristics, and variations. Hyperspectral imaging uses hypercubes to distinguish or classify sample types that cannot be distinguished or classified using conventional color imaging methods(**Figure 2**).[2] A hypercube is a three-dimensional image bundle that includes spatial and spectral information. An image containing less than 10 spectral bands is called a multispectral image. If there are 10 to 100 spectral bands in one image, it can be classified as hyperspectral imaging(**Table 1**).[3]

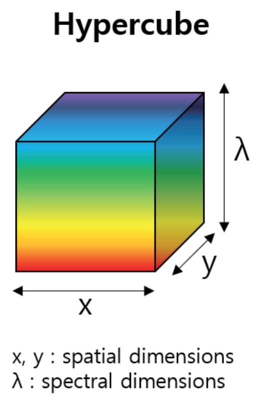

Figure 2. Schematic representation of a hyper cube.

	Multispectral Imaging	Hyperspectral Imaging
Number of Spectral bands	< 10	10 - 100
Spectral information	Limited	Providing more detailed information

Table 1. Comparison of multispectral and hyperspectral imaging.

Hyperspectral imaging is primarily divided into spatial scanning and snapshot methods (**Figure 3**).[4] The spatial scanning method requires a prism or grating and can be divided into point and line scanning. It is a method of simultaneously measuring a specific spectral region and is a method of moving in the form of a point or line while measuring with a spectrometer or spectrograph. The obtained signal shows the intensity of light according to the wavelength, but since there is no spatial information, the entire hyperspectral image is obtained by scanning the optical system or the target sample. This method can obtain a higher resolution image than the spectral scanning method since information can be obtained by point- or line scanning. However, if the sample moves or deforms its shape during scanning, there is a higher probability of artifact compared to spectral scanning, which obtains images by fixing the sample. Therefore, after obtaining all the images, a reconstruction process is required to correct the images. Also, since it obtains spectral information for one part of the image at a time, the tact time is slow compared to other methods. There are two methods to obtain spectral information with the camera, across-track(whiskbroom) and along-track(pushbroom). Whiskbroom scanner uses a rotating mirror and a pinhole to scan across sample to collect data. It reflects the light onto a single sensor and records the data one pixel at a time. Therefore, point-by-point scanning is required to obtain a full 2D image, which can take quite a long time. Pushbroom scanner collects data along sample using a row of sensors arranged perpendicular to the direction of movement. Since data is collected row by row using slits, line-by-line scanning is required. This is faster than point-by-point scanning methods, as only 1-D of the image needs to be scanned. However, these spatial scanning methods are much slower than the following snapshot method.

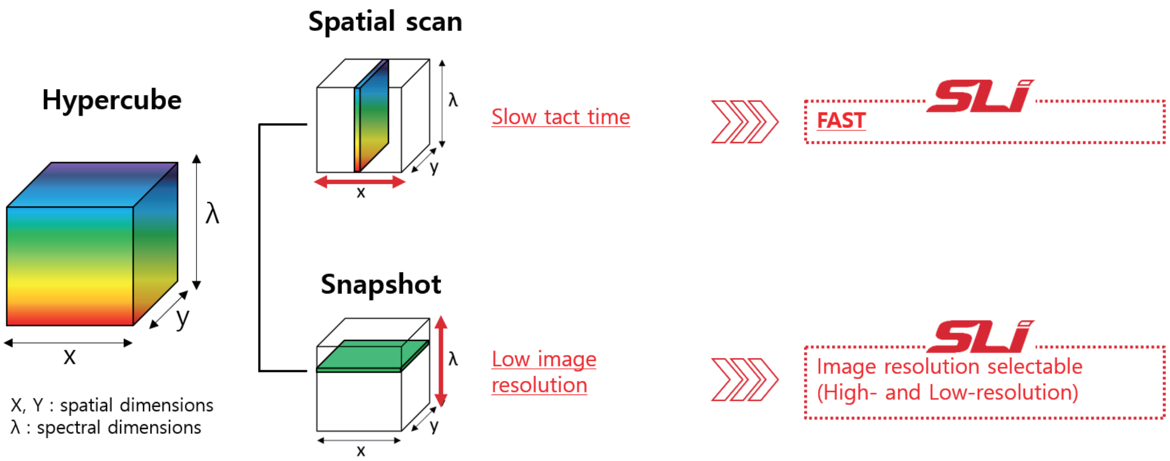

Figure 3. Two acquisition methods of hyperspectral imaging.

The snapshot method is non-scanning and obtains spectral and spatial information simultaneously with a single measurement. By placing a large number of narrow-band bandpass filter arrays in front of the camera sensor, snapshot images can be obtained without scanning. This method has the advantage of allowing fast imaging and obtaining hyperspectral imaging with only simple changes or modifications. However, it has the disadvantage that a demosaicing process is required later because each camera pixel obtains a different wavelength spectrum, and demosaicing will reduce spatial resolution. (**Figure 4. (A)**)

Spectral scanning is another snapshot method that obtains an image of the entire measurement area by sequentially changing the wavelength. A single measurement allows obtaining a 2D image in a specific wavelength range. Then, moving to a different wavelength range, a full hyperspectral image can be obtained through repeated image acquisition. In this method, a specific wavelength region is passed through a spectral filter, and a monochrome camera obtains a 2D image. The advantage of this method is that hyperspectral imaging can be performed with minimal changes to existing spectroscopy equipment. The disadvantages are the additional time required to traverse the wavelength range and, similar to a turret, the smaller number of wavelengths means lower spectral resolution. (**Figure 4. (B)**)

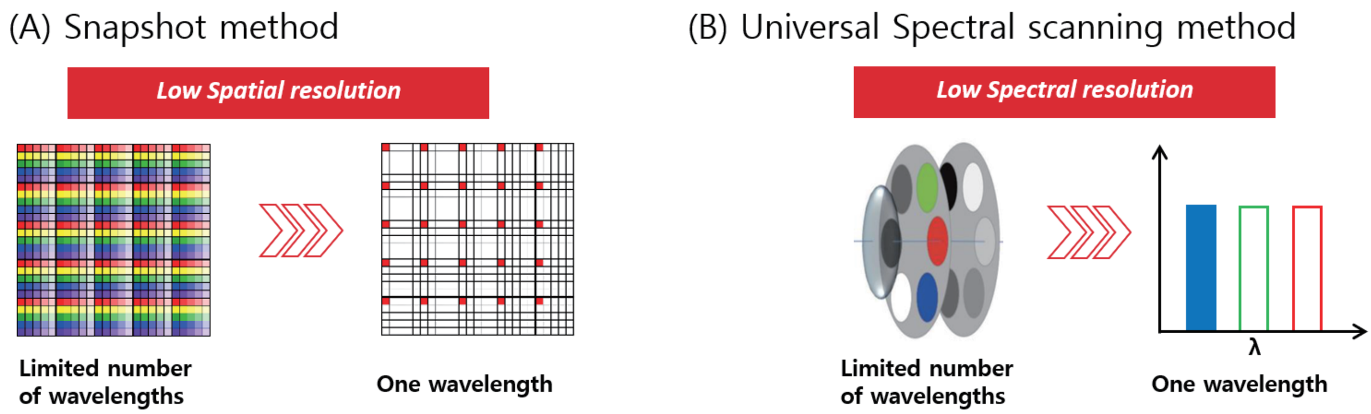

Figure 4. This is a limitation of the existing snapshot method for wavelength selection. The snapshot method sets the wavelength at the sensor stage, resulting in low spatial resolution. In the conventional turret scanning method, if a single wavelength is selected, the spectral resolution is reduced due to the fixed number of wavelengths.

Spectrolight Inc. (**SLi**) developed a NEW hyperspectral imaging camera system that combines the advantages of a new imaging approach to overcome the limitations of both spectral and spatial resolution. This system consists of a hyperspectral imaging module and a camera and has the following representative features. (**Figure 5**) 1) In addition to standardized products, it is possible to manufacture customized products according to the user's needs. 2) There are no restrictions on the lens installed in front of the system. It is user-selectable/free-adjustable because far-field and near-field lenses can be freely used depending on the desired field of view. 3) Hyperspectral imaging module can accurately select center wavelength and constant scanning interval. The user can select the scanning interval and bandwidth. Other products have irregular wavelength intervals or irregular bandwidths between wavelength ranges compared to other companies' modules. However, SLi products have the same wavelength interval and can freely adjust the interval. In addition, the bandwidth is constantly adjusted between wavelength regions, and the bandwidth value itself can be freely adjusted. (2-15 nm, nominal). Also, it has a significantly wider spectral range (255-1700 nm) compared to the other products, and has the feature of covering UV, VIS, IR, and SWIR ranges as desired by the user.

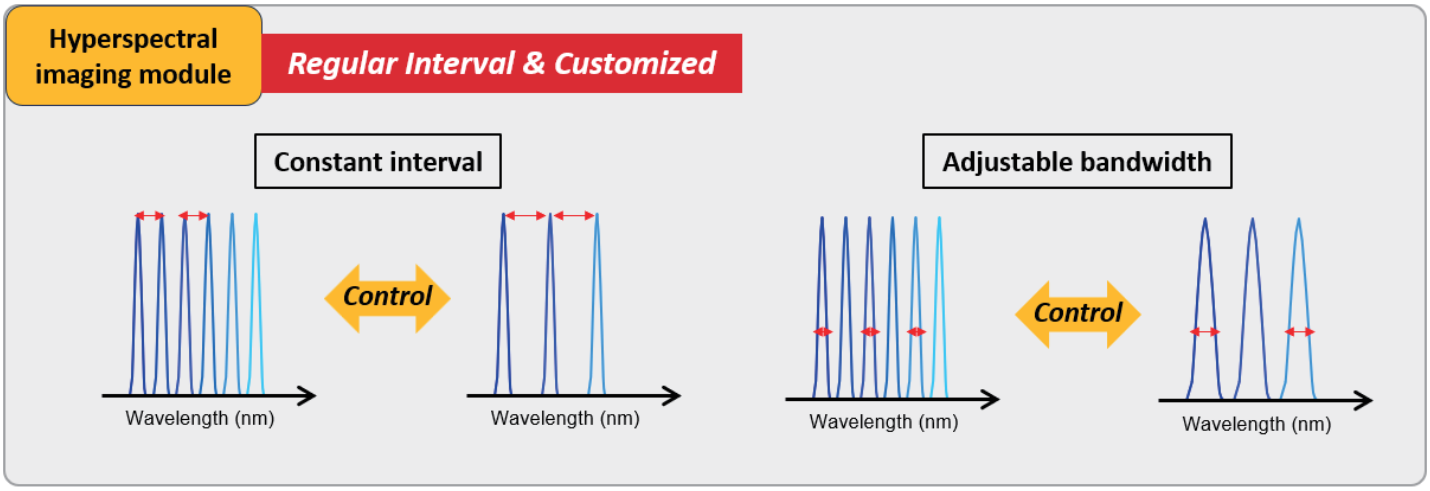

Figure 5. Representative features of Spectrolight's hyperspectral imaging camera system.

A variety of camera types are available. CCD or CMOS can be used in the VIS region, while InGaAs cameras (900–1700 nm) and SWIR cameras (400–1700 nm) can be used from VIS to SWIR regions, respectively. It is highly compatible, so anyone who already has a camera can combine it. While other hyperspectral modules that use the snapshot method obtain images with lower resolution than the original module, the SLi hyperspectral module can obtain the same image resolution and quality as the original one due to its unique data acquisition method.

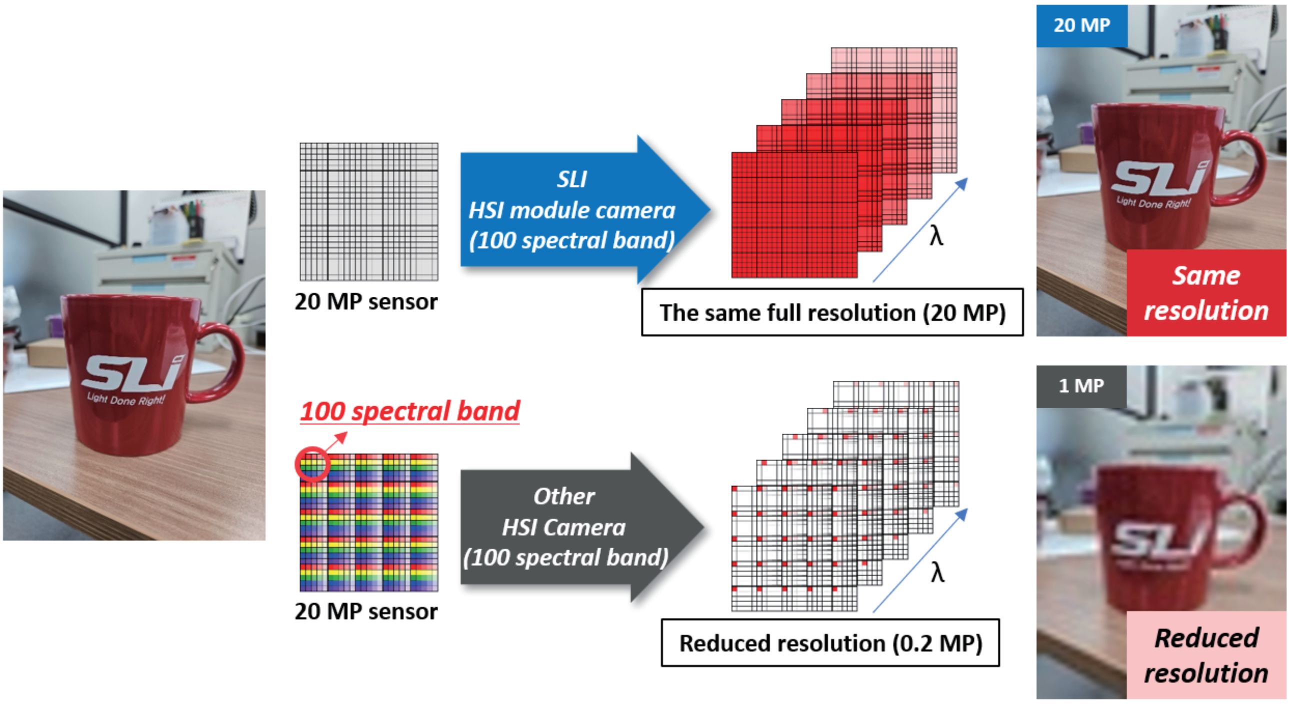

Figure 6. Comparison of resolution of the final hyperspectral images obtained with SLi's camera and the other commercially available snapshot type camera.

As shown in the **Figure 6**, hyperspectral images acquired by snapshot method have low resolution because the camera module has multiple narrow bandpass filter arrays to obtain spectral information in a specific wavelength range. Current snapshot-style imaging inevitably disables a large number of sensors while acquiring information at a particular wavelength.

This is why the final resolution of the image is lower than the original resolution. However, SLI products can obtain images without any degradation in image quality because they work as a mechanism to obtain high spatial resolution images for one wavelength in a single shot. (**Figure 6**). Finally, SLi's hyper-spectral imaging module can be customized using individual components or configured as a standalone unit. Users can individually customize the lens, camera, hyperspectral image module, etc., according to their own equipment, or as another option, choose a standalone product that includes each component according to specific specifications, so there is a wide range of choices depending on the user's needs.

In conclusion, the hyperspectral module developed by SLi is an innovative technology that overcomes the disadvantages of existing methods of obtaining hyperspectral images and takes only the advantages and combines them, enabling fast data acquisition time and high-resolution images identical to the original. It is also an expandable product that allows various configurations according to the user's needs.

References

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