WHITE PAPER:

SpecimONE: A Complete Hyperspectral Imaging Solution

POWERFUL HYPERSPECTRAL PLATFORM FOR THE SORTING INDUSTRY

SPECIM

A Konica Minolta Company

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01. Technology basics

Hyperspectral imaging is a fascinating technology that was initially developed as a scientific method and has only been used in industrial applications for a relatively short time. It differs fundamentally from systems based on conventional image processing, in which parameters such as sizes, geometric shapes, and colors are analyzed to examine the quality of objects and identify defects or impurities.

Systems based on hyperspectral imaging (HSI) work on a different physical basis: they examine test objects using spectroscopic analysis, recognize the chemical composition of the tested materials and enable an exact classification of the objects.

Suppose you look at the spectral responses of different materials obtained in this way. In that case, they show different spectral curves that are unique for the respective material, as the following picture clearly shows using the example of various textiles, as seen in image 1.

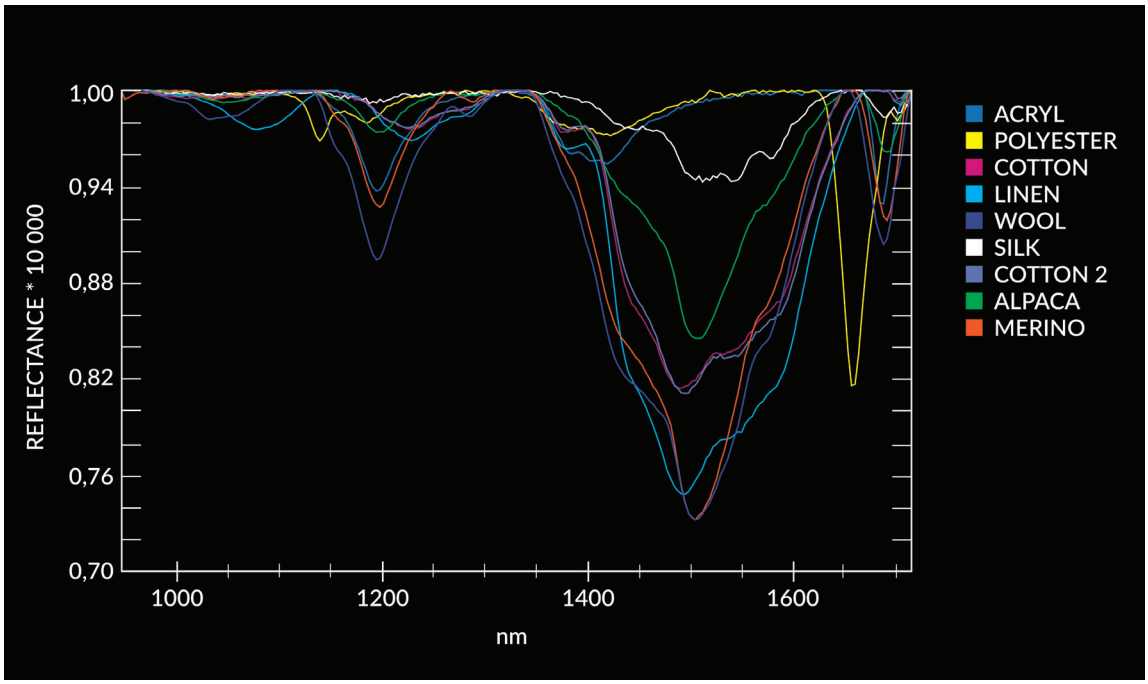

Image 1: Example of different textiles spectral response

Suppose the spectral response of a test object is recorded at many individual points. In that case, an HSI system can precisely determine which material or material composition is present at in which position. Depending on the application, hundreds, thousands, or even hundreds

of thousands of such spectra are recorded with hyperspectral systems. The results are displayed in three dimensions in so-called data cubes.

There are different methods for acquiring hyperspectral images. In industrial applications, line-scan camera-based systems are prevalent and known as push-broom technology. These systems collect full spectral and spatial information of the target line by line. Push-broom cameras consist of a lens, a spectrograph, and an image sensor. All of these components must be optimized for the selected wavelength range to achieve good results.

A relative movement between the camera and the test object is required to acquire images line by line. In many industrial processes, products are passed on from one process step to the next via transport systems such as conveyor belts. The image acquisition for analysis can occur during this transport phase by mounting a hyperspectral camera above a conveyor belt. It records line-by-line images of the test objects passing under the camera (image 2.)

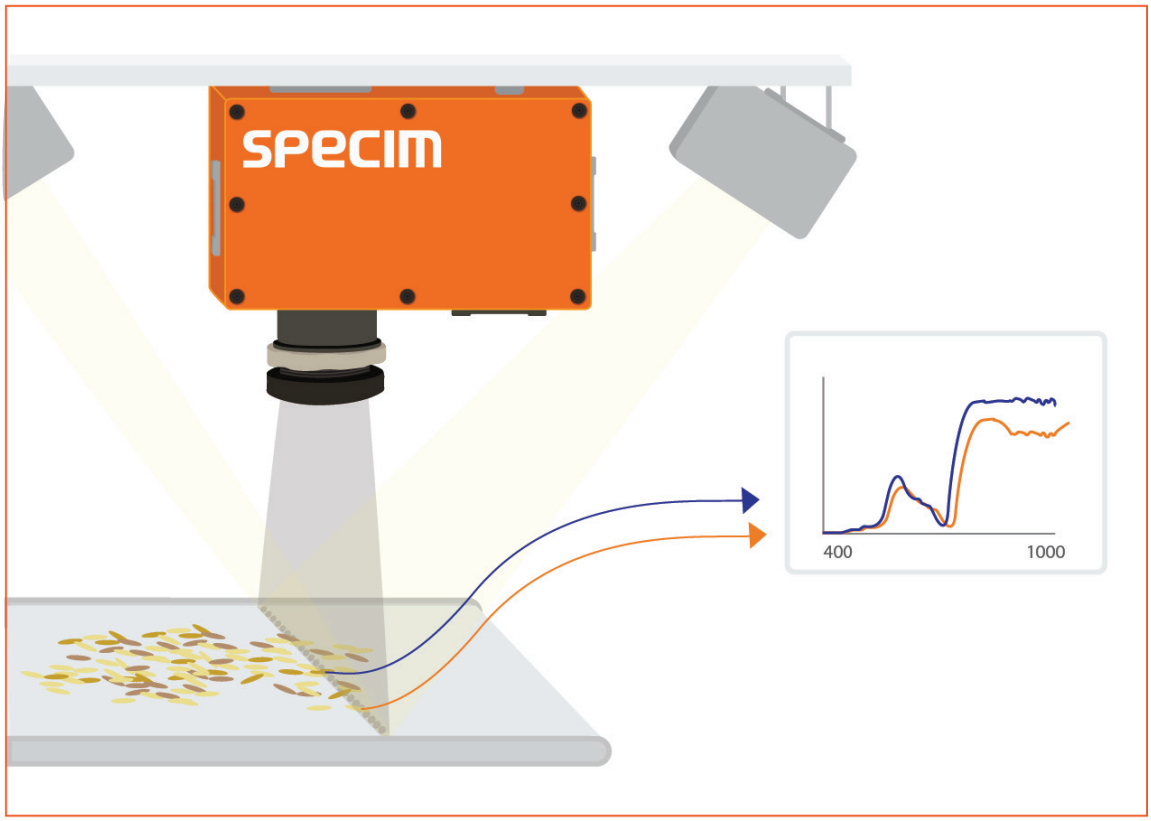

Image 2: Linescan application

02. HSI user challenges

Users who want to use HSI systems in their machines have to master many challenges to achieve this technology's desired results (table 1). For example, in sorting systems, one of the main fields of application for hyperspectral imaging, high accuracy is required to ensure that reliable sorting results can be achieved. Simultaneously, however, such systems sometimes work at very high speeds, which means little time is available for analyzing the incoming images. For that reason, reliable detection of particular objects or errors is much more complicated and requires robust, fast HSI systems.

These must also be closely integrated into the system to reliably and precisely control the subsequent systems for rejecting defective parts. Technically, exact timing and fast communication between the HSI system and the machine control system must be implemented to remove detected defective parts with ejection or blow-out units effectively. Often only short time spans in the range of a few milliseconds are available for calculating the results from the acquired images.

When developing an HSI solution, users are usually faced with the difficult task of selecting suitable components. The hyperspectral camera must work in the correct wavelength range and provide sufficient resolution and speed. Also, the lighting used must be ideally suited to the prevailing conditions.

Choosing the right software for evaluating the hyperspectral images is equally important. Since HSI technology generally requires a relatively high level of physical understanding, it is even more critical that the analysis software's development environment is as intuitive as possible and supports the user in the best possible way.

To achieve the required speed of an HSI solution, the computing platform must also have satisfactory performance and contain the necessary interfaces to supply a fast and stable link to the higher-level system control.

In addition to this multitude of requirements for the HSI user, the necessary components, i.e., the hyperspectral camera, the software, and the evaluation computer, usually come from different suppliers. Implementation, updates, or changes in the event of a fault can therefore be time-consuming and difficult.

Challenge	Need	Things to consider
Performance	Enable high throughput of sorting machine with HSI system	Speed of moving objects and how does it relate to HSI system frame rate and processing latency
Accuracy	Better accuracy enables to detect smaller objects with higher detection rate enabling higher Return-of-Investment	HSI camera optical parameters and how many bands are available
Flexibility	HSI system can be optimized and models changed to detect different type of materials allowing more usecases	Available spectral range and modification/ optimization of classification models
Investments	Less time spend to integrate HSI technology decrease the overall costs	Easy-to-use tools with support

Table 1

03. Industrial HSI applications

The industry is an important sector where the use of hyperspectral imaging has multiplied in recent years. Several process industries like food, pharma, and recycling have already proven the benefits and value of spectral imaging technology. Modern industry reveals continuously new use cases to achieve a sustainable society by introducing more efficient processes and higher-quality products.

With the performance-to-cost ratio that now meets the industrial requirements, hyperspectral imaging has become a quickly growing part of the machine vision solutions market, among other technologies such as X-ray, RGB, and 3D as an integrated technology to a conveyor and robotic systems for inline inspection in real-time. In industrial applications, it is essential that the camera speed is adjustable and synchronized with the production line's speed. The entire material stream is chemically inspected with no interference with the material itself. Thus, no waste is caused by sampling, and inspection covers 100% of the stream in real-time.

One of the main application areas for hyperspectral technology is sorting processes, like recycling and waste management. The efficient recycling of waste into reusable raw materials is one of humankind's most significant efforts to stop global warming and over-exploitation of natural resources. Efficient sensor-based sorting and recycling of different materials can be turned into profit with proper material handling methods and hyperspectral imaging technology. Such applications exist

in numerous industries, e.g., for sorting waste and separate plastics, textiles, metals, glass, paper, cardboard, or other materials. This is also the case for construction waste, where hazardous materials such as asbestos are always a concern. With hyperspectral imaging, it is possible to sort valuable and reusable materials such as concrete, wood, or tiles without exposing people to hazardous materials.

These are just a few examples where hyperspectral imaging already supplies a reliable and cost-effective solution for the industry. There are many more current use cases. The number of exciting applications that can only or best be solved by HSI systems is continuously growing.

04. The SpecimONE solution

Specim has been a pioneer in HSI technology for many years and is leading the industrial spectral camera market with the FX series cameras explicitly designed to meet industrial applications' requirements. When looking at HSI users' challenges, it became clear that it is a massive problem for developers to rely on different suppliers for a hyperspectral camera, the required software, and a processing unit. For that reason, Specim decided to develop a complete, powerful solution that combines a camera, software, and computing power and thus creates a platform for hyperspectral imaging available from just one supplier. This unique, complete hyperspectral imaging solution is called SpecimONE. With this combination, Specim provides users with a hyperspectral solution that significantly simplifies the use of HSI technology.

SpecimONE consists of three essential and perfectly coordinated elements: the cameras of the FX series, the SpecimCUBE processing unit, and the SpecimINSIGHT software. Like all hyperspectral systems, Specim FX series cameras allow the detection and classification of test objects' chemical composition using a non-contact, non-destructive optical process. The FX camera series was the first set of hyperspectral cameras that were specially developed for industrial use and met its high demands in terms of speed and robustness. These products, which have been Specim's core business for many years, have already proven themselves in numerous applications.

The FX series of high-performance cameras impress with their excellent optical performance and features such as MROI (Multiple Regions Of Interest) that focus on certain wavelength bands to enable maximum performance and speed.

Through close contact with many users of the FX cameras, Specim has developed an enormous knowledge base over the years for the evaluation of hyperspectral images with the help of suitable software. These valuable experiences were integrated into the second component of SpecimONE: the SpecimINSIGHT software. It is an easy-to-use software that helps users effectively create classification models of the inspected materials. SpecimINSIGHT compresses Specim's software experts' internal know-how and provides users with extensive and proven algorithms for the effective development of hyperspectral solutions and optimized processing power for HSI applications.

The recorded hyperspectral image data is processed by the third element of SpecimONE, the powerful industrial computer SpecimCUBE, which was specially developed for hyperspectral systems in the sorting industry. The GPU component (Graphics Processing Unit) provides exceptionally high state-of-the-art computing power with low latency. It allows the camera data to be evaluated in real-time.

Step	Time (ms)	Description
X frames received	Some ms	Depends of frame rate and how many frames are batched.
Exposure	Less than ms	Exposure time (adjustable)
Readout	Basically irrelevant	Readout time inside FX camera - static but adjustable by MROI
Aberration Correction	Basically irrelevant	Aberration correction in FPGA - static but adjustable by MROI
Transfer to GPU	Some ms	Transfer through CameraLink - static but adjustable by MROI, thread scheduler, grabber to GPU, copy to memory etc
Processing	Some ms	Actual application and latency depends of reflectance, if preprocessing is used, selected algorithms and output type.
GigeVision send	Less than ms	Memory copy, framerate simulation, sending 1920 bytes of frames roughly at the maximum 1GigE speed.
Total	**Some ms**	Total delay of a single frame after the whole system.

05. SpecimONE benefits

The fact that all three components of SpecimONE were developed and produced by one manufacturer leads to a considerable advantage for users. The SpecimINSIGHT software is optimized for combination with the FX cameras and the SpecimCUBE processing platform. This applies to the operating system as well as to the software for evaluating the image data. In this way, all requirements are met to achieve maximum throughput and minimum latency and jitter. This precisely coordinated triad creates the ideal conditions for users to implement real-time inline applications.

An easy way to develop an HSI application is one of the main benefits of SpecimONE. To create an application, the user first needs training images. Classifiers are modeled with the SpecimINSIGHT software to design the application according to the existing requirements.

As soon as the final model has been validated this way, it is loaded onto SpecimCUBE and is then available for real-time operation in the system. In actual operation, the SpecimCUBE computing platform receives the data from the FX cameras. It uses the SpecimINSIGHT software to process the results based on the model created previously. SpecimCUBE forwards these results to the plant's subsequent systems, such as spatial analysis systems or sorting machine's logic controller, to sort out detected defective parts.

Suppose the need arises to adapt or optimize the system. In that case, this can be done very quickly. The user needs only to modify the existing model in SpecimINSIGHT and reload the new model onto SpecimCUBE, and the adaptation completed. It is also possible to load several models onto the processing platform and switch quickly and easily between them, such as changing the test objects. For users of SpecimONE, it is therefore straightforward to create and modify models for the detection of objects to operate inline hyperspectral imaging systems.

HSI developers benefit from the fact that Specim entirely developed the SpecimONE solution and that all components come from a single source. The company designed them according to industrial use requirements, produces the cameras and software in-house, and can therefore guarantee the platform's performance with a clear conscience.

Further, Specim supports that platform's users in developing their solutions through competent support, which also leads to a shorter time-to-market and thus to a faster amortization of the investment. Due to the ease of use, the high flexibility, and the performance, SpecimONE is an attractive option for solving hyperspectral tasks. It enables a faster, cheaper, and easier entry into this technology than ever before.

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Specim – Making Spectral Imaging Easy

Specim, Spectral Imaging Ltd. is the world-leading manufacturer of hyperspectral imaging instruments and systems. Specim's success is driven by our passion for light. Today, that passion has resulted in a range of products from the most advanced remote sensing applications to the industrial OEM segment and easy-to-use handheld devices.

For more information visit www.specim.com