

Automated Spectral Image Measurement Software

Jukka Antikainen¹, Markku Hauta-Kasari¹, Jussi Parkkinen¹ and Timo Jaaskelainen²

¹Department of Computer Science and Statistics, ²Department of Physics, University of Joensuu, Finland

Abstract

In this paper, we describe how the line scanning based spectral colour measurement system can be automated and what benefits we can achieve with it. We introduce spectral colour measuring software which we produced for capturing spectral images. Main point of the paper is to describe, how we can automatize capturing of spectral images by using line spectral camera and multiple sample sliders. In this case, spectral camera measurement system contains one spectral camera and three sample sliders in x, y and z directions. Sample sliders can be different sizes and they can have different gear ratios. We can control spectral camera features and sample sliders options directly from graphical user interface.

Introduction

Colors and their accurately defined spectra are showing important factor in many industrial targets such as in quality control and recognizing product authenticity. Line scanning based spectral cameras has been used in many research and industrial targets^{1,2}.

When we are going to make measurements, we need to use some kind of software to do that. Sometimes we can simply use spectral camera's manufacture provided software for measurements. But then, when we must measure and imagine larger objects automatically with line based spectral camera, we may need to use automated software to do that. Because spectral imaging isn't so commonly used and spectral measurement systems are typically very dissimilar, there aren't commercial programs which we can use. Thus, we need to generate own spectral measurement software for our spectral imaging system. Created software is designed to be easily

implemented to another line based spectral imaging system.

Software supports currently two different line scanning based spectral cameras. Used spectral camera in this paper was ImSpector V10 direct sight imaging spectrograph¹ combined with Adimec 1600m/D 1600x1200 CCD camera. Camera's spectral wavelength area is between 400nm-1000nm. Another supported spectral camera is ImSpector V8 spectrograph combined with PixelFly 230XS CCD camera which spectral wavelength range is from 380 nm to 780 nm.

Spectral Imaging System

Spectral imaging system is build from sample sliders and line scanning based spectral camera³. Sample sliders forms x, y, z -table where we can move measured sample. Usually we use only x, y -directions for the measurements. Sample is illuminated with a filtered halogen lamp Spectralight III daylight simulator. Spectral camera and the light source forms 45 degrees angle to surface of the target object. Figure 1 shows spectral imaging system configuration with two sample sliders, Spectralight III illuminator and Adimec 1600m/D spectral camera.

Main idea of the measurement process is that we measure one line's spectra and move the target a little bit and measure another line. This procedure continues until all wanted areas are measured.

With this spectral imaging system, we can scan large objects spectra automatically. Sample size is limited only by the sample sliders sizes which are 120 cm in x, y -directions. The spectral imaging system is presented with more detail in Reference 3.



Figure 1. Spectral imaging system. A is illuminator, B is X, Y-table and C is spectral camera.

Spectral Measuring Software

Measuring software is written in C++ using Microsoft Foundation Class library (MFC). MFC-library and all simultaneously parts are created by using threads. Threads provide more efficient measurements and management for the system⁴. Software works currently only under Windows operating system environment. All devices are controlled by our created drivers except spectral camera is controlled by manufacture provided drivers.

Figure 2 is main window from created software's graphical user interface where we can for instance live preview measured line spectra. Live previewing is multi threaded so we can use program at the same time when we are previewing the target spectra. In preview window, measured line width is presented in horizontal direction and line's spectra are presented in vertical direction. Figure 2 shows, how spectra are presented when we measure one line from printed color table. Gray levels in lower figure corresponds the intensity in 12 bits of the spectral components from 400 nm to 1000 nm in vertical direction.

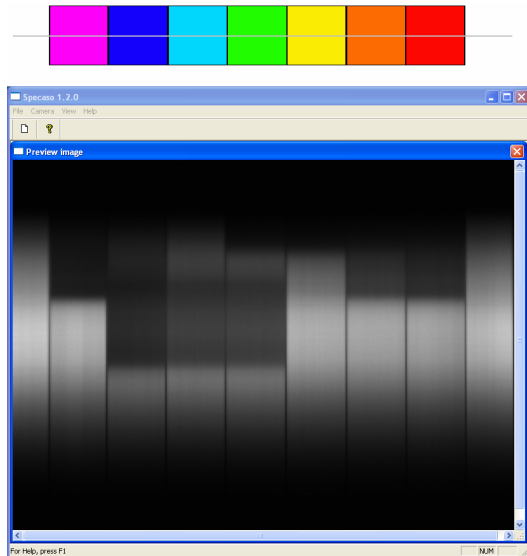


Figure 2. Spectral camera's live preview spectra from measured line (grey line) using A lamp.

From the upper menus we can select all necessary things such camera options, sample slider options, image wavelength correction and all measurement system configuration options which are needed for the measurement process. Thus, we can easily configure spectral camera's options like integration time from the graphical user interface. Spectral camera's configuration window is presented in Figure 3. We can change spectral camera's options on the same time, when we are live previewing target's line spectra. In this way we can easily seek and configure wanted camera options for each measurement cases.

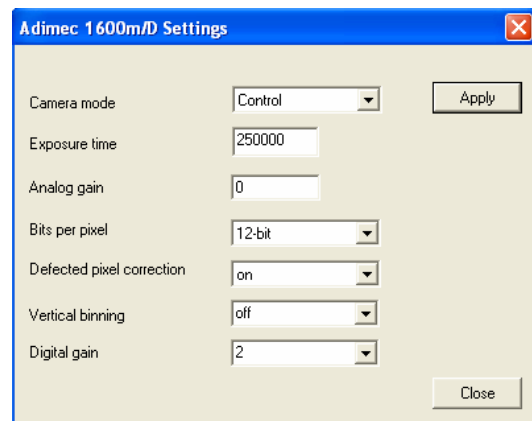


Figure 3. Configuring spectral camera's options.

Measuring system contains sample sliders whose without we can't measure large objects. There are different sliders with different gear ratios so we have

to configure each sample slider individually. If gear ratios are misconfigured, movement sizes could be wrong. Therefore, gear ratios should be correctly configured for accurate measurements. Figure 4 presents sample sliders configuration window where we can set all necessary options for each sample sliders. Sample sliders uses serial port connection whereby we can easily control them.

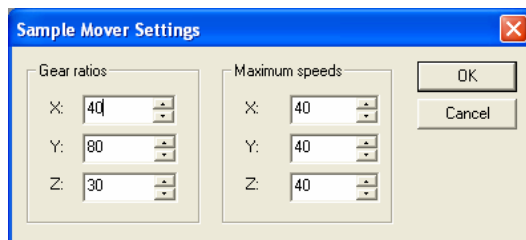


Figure 4. Configuring needed sample sliders options. These options can be different for another sample sliders.

We can easily change sample sliders because we can choose individual gear ratios and speed options for each of them. Therefore, the software can be easily configured to another system with different sample sliders.

We can easily move sample sliders from graphical user interface and configure origin position for the sample sliders. Origin position is starting point of the measurement. Figure 5 presents dialog for controlling sample sliders directly. If we need to measure multiple samples we need to set origin only once for the measurement process, assuming that, samples are always placed at the same position.

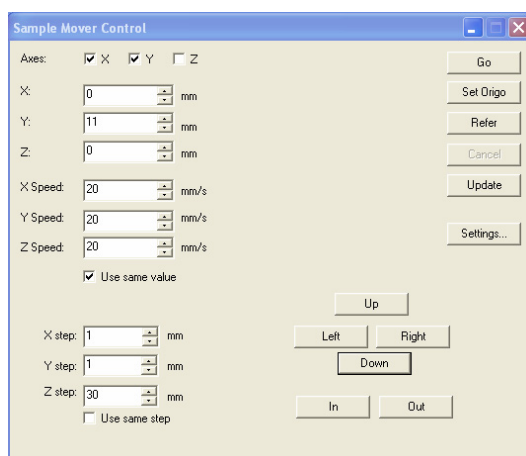


Figure 5. Configuring sample sliders positions and setting the initial position for the sliders.

Most important part of the program is showed in Figure 6 where all measurement options can be modified. In software, we can automatically create corrected data from measured raw data and reduce scanned image sizes. For example if we want only wavelengths from 400 nm to 1000 nm by 5 nm steps, which is still a good sampling resolution for most of cases⁵. We can reduce image size to tenth part from the original raw image.

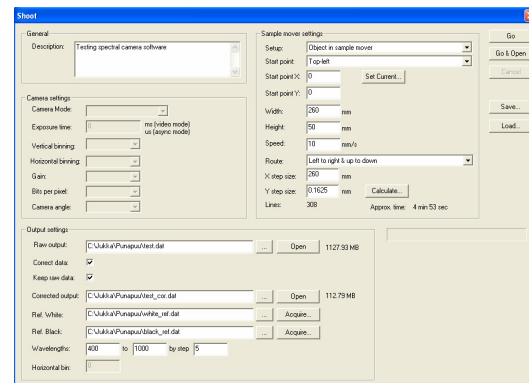


Figure 6. Main measurement dialog where all measurements options can be selected.

Figure 6 shows what options we can use in measurement process. We can choose a size for the sample and how the sample is related to the measurement process, does the sample moving or is the spectral camera moving around the sample.

Software can automatically calculate amount of movement for the sample sliders so that scanned spectral lines produces square pixels. Movement step calculation is done by dividing measured line width at the spatial resolution which is in this case 1600. Movement step is directly proportional to measured line width. If the line is wider then movement step is longer. When movement step is increased, measuring accuracy and the measuring time are decreased. Program shows, how much space measured image will take in raw format and how much space is taken when we like to make wavelength correction to the image. Software also shows how many lines its have to measure for covering whole measure area.

When spectral lines are measured in correct step sizes, we can afterwards produce RGB -images from the target object. If movement value was wrong, regenerated images are stretched and if we want to

keep original geometry of the scanned objects, they need to be modify with various pixel combination routines. If movement value is too high, we may loose important spectral information from the measured target. Figure 7 show RGB -presentation of measured color checker board.

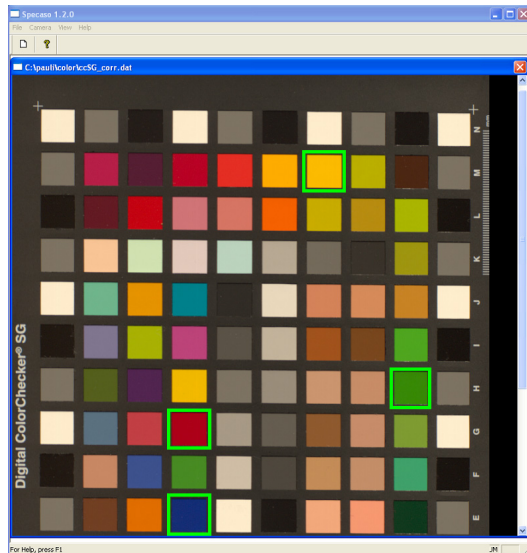


Figure 7. Measured spectral image from color checker board converted to RGB-image.

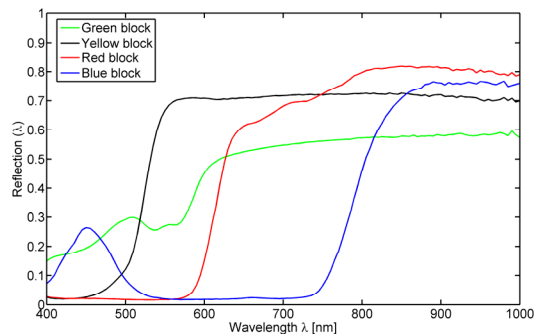


Figure 8. Selected green boxes spectra from Figure 7.

RGB -conversion is done by following steps: first measured spectra are converted to CIE XYZ⁶ tristimulus values using D65 illumination source and after that, those values are converted to sRGB values⁷. As we can see, the measured spectral image looks accurate and color presentation seems to be similar compared to original image.

There is option in the software's source code where we can choose which illumination we use in conversion process from spectral image to RGB - image. Figure 9 presents image correction window

where user can afterwards make corrections to the measured data. With wavelength correction we can make multiple spectral images from the target using different wavelengths. This could be useful in some cases where we like to make comparison between images with different wavelengths.

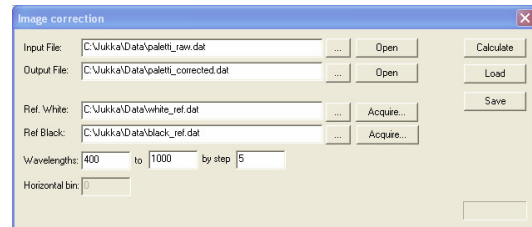


Figure 9. Spectral image correction with selectable references and wavelengths

When we are making measurements, we need to measure white and black references which we can use for correcting measured data. We can shoot references with simple dialog which is showed in Figure 10. We can choose, how many repeated measurements we like to take for averaging the reference values. In this way we can reduce possibilities of noise errors. We can use this same dialog to measure both black and white references.

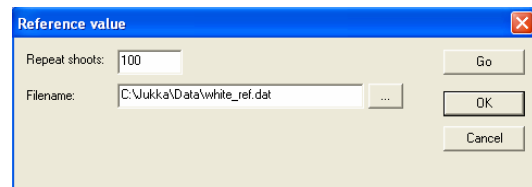


Figure 10. Acquiring reference images which can be used for correcting measured data.

Wavelength correction

Every pixel on the CCD camera responses one wavelength value. The correct wavelength value in current pixel depends from spectral camera's properties. If we want to use only wavelength values from 400 nm to 1000 nm by 5 nm step, we must calculate those wavelengths from raw spectral image. We can automatically select desired wavelengths λ from the measured spectral image by using second degree polynomial

$$\lambda = An^2 + Bn + C \quad (1)$$

where constants A , B and C are obtained from spectral camera's manufacturer and n is spectral camera's pixel in spectral direction. There could be situations when we can not get exact value for wanted wavelength. Therefore, we may need to interpolate wanted wavelength value from its neighbour pixel values.

Used Data Format

Measuring software uses simple binary format for saving the results. Binary format can be easily converted to another spectral image formats⁸. Binary data contains header block and measured spectral lines. File structure S is build as follows

$$S = [H, L_1, L_2, \dots, L_{n-1}, L_n],$$

where H is a header block and L_i are measured lines. Thus, each measured files contains file header H which tells basic information of the file

$$H = [\text{width}, \text{height}, \text{resolution}, \text{depth}],$$

where width is spectral camera's spatial resolution multiplied by measured columns, height is measured lines count, resolution is used spectral camera's spectral resolution and depth is used spectral camera's pixel depth. If depth is 8 bit, then software use only 8 bits for each number, but if depth are 10 bit or 12 bit then we must use 16 bits for saving each pixel.

After header block, file contains all measured lines L_i . Saving structure for each line and their spectra are done as follows

$$L_i = [1. \text{ pixel}, 2. \text{ pixel}, \dots, d. \text{ pixel}],$$

where i is line number index and d is used spectral camera spatial resolution. Each pixel contains as many numbers of spectral values than spectral camera's have spectral resolution.

Applications

Created software can be used in many scientific research and industrial targets. Software was been used in many different scientific cases like wood measurements, skin color detection, art measurements and many other important research areas. Many paper industrial projects are considering measurements of printed texts and images ink dots and those quality.

Results

We have been created useful and speed efficient

software for measuring spectral images. Measuring speed depends very much about used spectral camera's integration time. If we can use more efficient illumination, measuring time will be decreased.

Conclusion

The software developed in this study can be easily modified for different line scanning based spectral camera models. The proposed system has been used in many scientific and industrial projects at the University of Joensuu, Finland.

We have also planned to implement a second spectral camera in to the automated process. In that way, we could use two spectral cameras with different spectral areas at the same time and program can automatically combine different wavelengths to one long continuous spectrum from visible wavelength area to infrared.

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Biography

Jukka Antikainen graduated as Master of Science in Computer Science from the University of Kuopio 2006. The subject of master thesis was parallelization of matrix operations. Now he has started to work with his doctoral thesis in University of Joensuu at InFotonics Center. Thesis is concerning about spectral colour research in industrial applications, like generating new spectral measurement systems for different industrial targets.