GEOMETRIC AND RADIOMETRIC INVESTIGATION OF THE PHOTOGRAMMETRIC IMAGE SCANNER RASTERMASTER RM1

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ABSTRACT:
The geometric accuracy and geometric dependencies of the Wehrli Rastermaster RM1 have been tested several times. The accuracy is on the level of usual analytical plotters,
In addition the radiometric reaction was investigated. This was required after a change of the light source which has improved the scanning of the blue spectral range. The inspection of the radiometric behavior by a spectrometer has shown a very good separation of the 3 spectral bands for color images. Within the used area of the TDI-sensor the radiometric homogeneity is sufficient also for areas with very poor contrast.

The Wehrli Rastermaster RM1 of the Institute for Photogrammetry of the University of Hannover is used for production since January 1995. Beside the production rate the instrument was analyzed intensively. Against the original equipment, the light source has been changed. The new light source, which is now standard for the new RM1, has a better characteristic in the blue spectral range.

Instead of an empiric test of the radiometric behavior, the light source and the filters have been inspected in detail with a spectrometer Zeiss MCS. Together with the known sensitivity over the used spectral range of the TDI sensor, this gives a better information of the radiometric characteristic.

The Rastermaster RM1

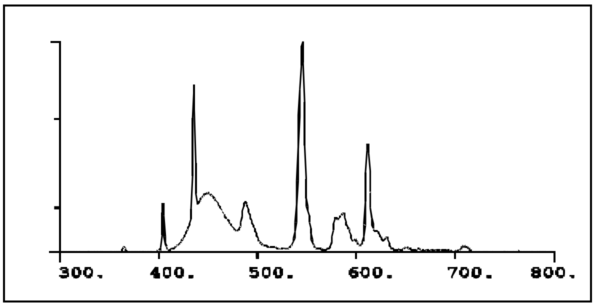
The geometric function of the RM1 is corresponding to an analytical plotter. The movement in the x- and y-direction is controlled by servos based on linear encoders. As sensor a DALSA TDI CL-E1-2048A with 2048 x 96 elements is used. The Time Delay and Integration sensor has the advantage of the use of 96 sensor elements during the scan process for the same image pixel. This extends the sensitivity and causes more homogeneous gray values.

The pixel size of 12µm corresponds to the usual image resolution of 40lp/mm. Only 1024 pixel of the sensor center are used. This avoids the small loss of light at the more outmost areas of the sensors. So no improvement of the gray values are required, which could enlarge the noise.

A color scan has to be made separately for each color. This takes more time but it guarantees a better color separation than a 3-line-sensor and the blue spectral range with the lower sensor sensitivity can be scanned with a lower speed, creating less noise than just with a numerical change of the gray values.

Radiometric Situation

For the spectral information of a scanned image the whole system, containing lamp, filter and the sensor have to be taken into account. The spectral behavior of the lamp, the filter and lamp through filter have been analyzed with the Zeiss spectrometer MCS.



small spectral bands in blue, green and red are shown. This makes it more easy to separate the color in the case of a color scan through filters.

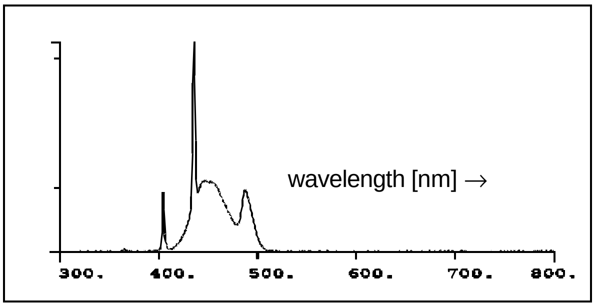


Fig. 2: spectral intensity - light source through blue filter

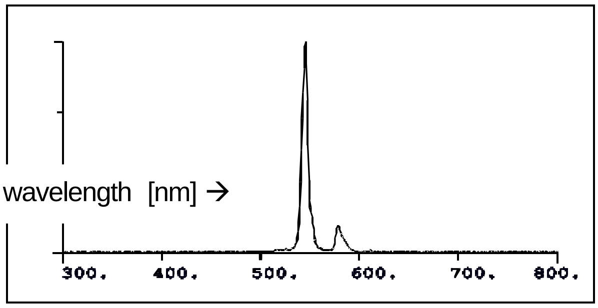


Fig. 3: spectral intensity - light source through green filter

wavelength [nm] →

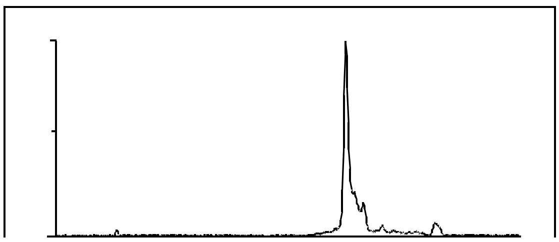
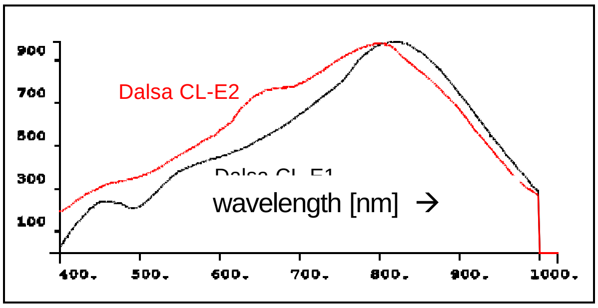


Fig. 4: spectral intensity – light source through red filter

The spectral separation of the filters are slightly overlapping. This usual situation has no influence like the transmission in the ultra violet range (<400nm) and the transmission in the infra red range above a wavelength of 750nm. The energy of the light source is limited to the spectral range from 400nm to 720nm, so the transmission of the filters outside this range is unimportant and the light has a reduced intensity in the overlapping areas of the filters.

Important is the intensity of the light source through the filters (figure 2 – 4). This shows a very clear separation of



the 3 basic colors. The unequal distribution of the energy in the 3 spectral ranges is not causing problems because the color of the scanned images is always a mixture of the 3 color layers of the film and it is not a continuous spectrum.

Fig. 5: spectral sensitivity of the DALSA CL-E1 and E2

In addition to the intensity of the light through the filters, the sensitivity of the used sensor is important. In general the CCD-line or –array sensors are showing a similar dependency as a function of the wavelength like the used TDI-sensor DALSA CL-E1 and the also investigated DALSA CL-E2 (figure 5). In the blue spectral range they are not so sensitive like in green or in red. The integrated intensity of the light through the filters showed the blue range with 44% and green with 94% of the power like in the red range. The power is integrated in the case of a scan without filters. The Rastermaster RM1 has to scan color images separate for each spectral range. This is more time intensive, but it includes the advantage of a scan with the optimal speed for every spectral range. The blue scan will be done with a slower speed and has by this reason a lower noise than in the case of a scan with a 3-color CCD-line-sensor. The 3-color-CCD-line sensor has to equalize the gray values by a lookup table and this enlarges the noise linear in the blue spectral range by the factor 2.

Not only the spectral dependency is important, the sensitivity of each sensor element should be checked. The used TDI-sensor always takes for each pixel the mean response of 96 sensor elements, so the situation is much better than with simple CCD-line-sensors. But nevertheless also the TDI-sensors are showing differences in the sensitivity of the mean values over the 96 physical elements for each row. A calibrated gray scale has been scanned. It shows a small variation of the registered gray values and a small light fall off in the not used part of the sensor. Of course this may be influenced by dust and unavoidable dirt, but it is realistic for usual operation. Not the whole sensor line has been inspected, the first 512 elements are not recorded, but the standard program of the RM1 is only using the 1024 center elements.

The result doesn't show exactly the same sensitivity for each row. The difference in the sensitivity are depending upon the gray values itself. For the mean gray value 248, the gray values do have a mean square difference against the mean value of +/-1.5 gray values. The mean square differences are approximately linear depending upon the gray value, so for the gray value 15, the mean square differences are reduced to +/-0.1. The gray values by theory can be improved to a more equal situation by an individual correction with a constant shift plus a factor linear depending upon the gray value. Based on the used 17 different gray scales, such an improvement leads to remaining +/-0.43 gray values for the gray values 250.

Like an analytical plotter, the movement of the sensor line is controlled by a servo. If the actual position does not agree with the planned position, the speed will be enlarged or reduced. This is causing an oscillating change of the scan speed. A slower speed is raising the gray value, a faster speed is reducing the gray values. The change of the mean gray value of the same field of a scanned calibrated gray scale is in the range of +/-1.2 up to 2 gray values.

The described effects are not special problems of the Rastermaster RM1, they have been seen also at other scanner. The deviations of the gray values usually can not be seen, only in the case of very homogeneous areas with low contrast and a strong contrast enhancement, like in wetlands, it is necessary to improve the data.

Geometric Condition

The radiometric problems have been described at first, because there are the main problems. But also the geometric accuracy should be checked, because with some other scanner types problems have been seen. The geometric calibration was made with a reseau platen with 121 x 121 grid crosses. In any case the scan was made with 12µm pixel size. The positions of the grid crosses are known with an accuracy better than 1µm. The center position of the scanned reseau crosses have been determined by an optimized program. Not all reseau crosses can be determined, but the final 12 803 are still enough for a detailed analysis.

With the Hannover program POCOR the calibrated reseau positions are transformed affine to the determined positions and analyzed for random and systematic effects. Affine errors of the scanner are not taken into account, because usual aerial images do have affine errors and must be transformed affine to the calibrated fiducial marks. Such a transformation also will also respect affine errors of the scanner.

The separation of random and systematic errors is required for a better understanding. Systematic errors can be respected automatically by a block adjustment with self calibration by additional parameters, but it is also possible to use the determined effect for an improvement of the height values coming from image matching. For other purposes the accuracy is usually not so critical. A part of the random errors can also be caused by the automatic determination of the reseau crosses, but this effect seems to be small.

The determination of the systematic errors is done in the same way like the self calibration by additional parameters in the block adjustment. Of course the formulas for the "additional parameters" have to respect the special geometric situation of the scanner. Also the influence of a not optimal calibration of the sensor line has to be respected. The sensor line must be orthogonal to the scan direction and the width of the sensor line must fit exactly to scan width, that means the distance between the neighbored scan lines..

The very high number of observations enables a clear separation of the systematic effects. The mean square of the random plus the systematic errors are in the range of +/-4 µm, that means, it can be compared with the accuracy of analytical plotters.

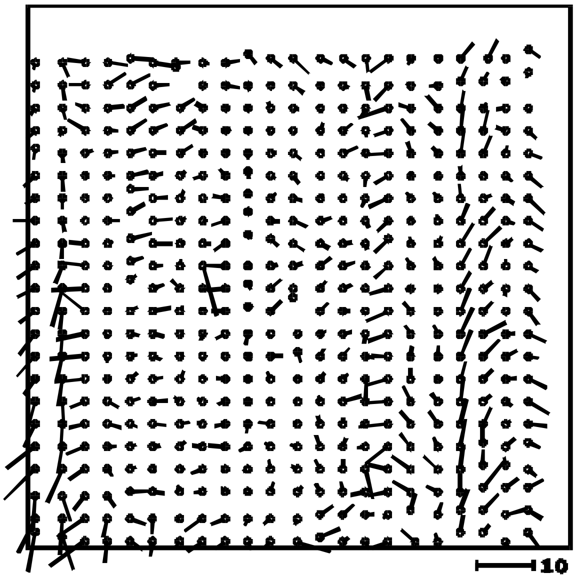


Fig.6: remaining errors after elimination of major systematic errors (reduced number of vectors)

After reduction of the major systematic errors in both coordinate components only +/-1.9µm are left.

Experience

The production over longer time period resulted in a save standard procedure. It has been shown that the inspection of every scanned image for dust and dirt particles and also for the sufficient settings is required. Especially the fiducial marks should be checked because their contrast and photographic density is often different from the image itself. Problems are existing with the scan of black/white negative images. In the case of larger contrast it is better to scan a diapositive copy. But this problem exists also for other scanner.

In a test project images have been scanned with the Rastermaster and also with the SCAI. The final results of image correlation with OrthoMax in relation to independent check points resulted in very similar differences.

Conclusion

The geometric accuracy of the Rastermaster RM1 is sufficient for all purposes. The radiometric resolution is still limited for all types of sensors in relation to the photographic density range of photos, by this reason, the settings of the scanner have to be handled careful. The special type of light source has an advantage for the color separation. Each band can be scanned in the optimal manner.

References

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