

COMPARISON OF QUALITY AND INFORMATION CONTENT OF DIGITAL AND FILM-BASED IMAGES

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ABSTRACT

Digital cameras have started to replace analog film cameras for many applications. Considering the huge consumer market of small format cameras and compact cameras or the professional medium format or large format photography, digital sensors are on the advance.

The comparison between digital and film-based data is done taking into account photographic and photogrammetric issues. Not only radiometric quality, but also the geometric performance of digital and analog cameras are investigated.

When trying to compare the quality and the information content of panchromatic digital images versus analog film, only a small amount of literature is available to brush up one's mind. Encouraged by this situation, we have investigated different film types and a digital sensor and their output in order to better understand how to compare and to judge image data.

1 INTRODUCTION

For a long time, images acquired from analog film and digitized by scanners were used for digital image processing purposes. Now that digital cameras have started to replace analog ones, this new digital data is used directly.

To get a digital image from a film-based camera, you have to take a photograph, develop the film in a photo lab and finally digitize the negative with a scanner. With a digital camera, these steps are not necessary, which is a save of time and money. Consequently it is a big advantage to use digital cameras - but what about the quality of the images?

In this paper, we compare image quality and information content of images taken by different sensors. We investigate three kinds of analog films and one digital camera set. We will only take into account the digital images, not the analog film development and scanning procedure. Figure 1 shows a test target acquired by different films and CCD (Charge Coupled Device) sensor. At first sight it is obvious that the image taken by CCD sensor is clearer and contains less noise.

In section 2, we explain the test data used and present some experiments on how to measure image quality. Finally we give a conclusion in section 3.

2 EXPERIMENTS

For the experiments, we have used the following devices for taking film-based images. Three middle format films ($55mm \times 55mm$) Agfa APX 100 ASA, Ilford FP4 Plus 125 ASA and Agfa Scala 200 ASA (denoted as apx, fp4 and sca in the rest of this paper). Specifications of the films can be found in [1] and [5]. The photographs were taken with a Rollei 6006 metric high accuracy photogrammetric camera, with $50mm$ focal length. The developed

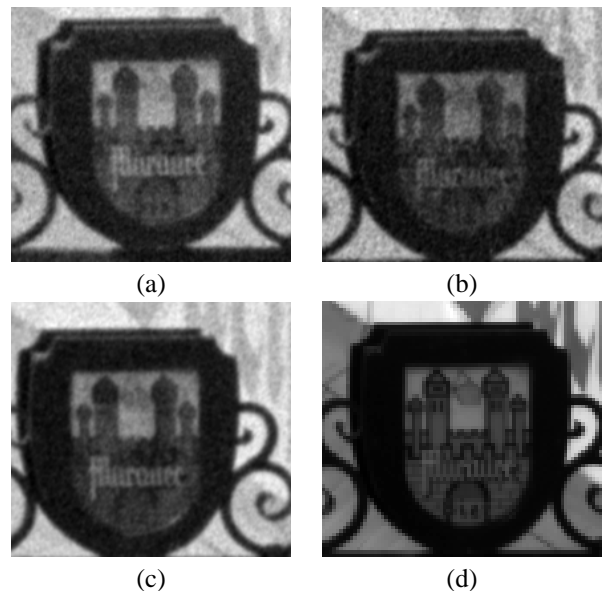


Figure 1: Detail of an advertisement sign captured with different devices, (a)-(c) analog films scanned with $5\mu m$ (a) Agfa APX 100 (b) Ilford FP4 Plus 125 (c) Agfa Scala 200 (d) Philips CCD with $12\mu m$ pixel size. Shown are 211×192 pixels in (a)-(c) and 81×74 pixels in (d).

negatives were scanned with UltraScan 5000 by Vexcel Imaging Austria with $5\mu m$, $10\mu m$ and $15\mu m$. Direct digital images were acquired with Narragansett digital camera module FMM3020D/2 containing Philips FTF3020-M panchromatic CCD image sensor with 6 mega-pixel (3072×2048 pixel) and $12\mu m$ pixel size (denoted as ccd in the rest of this paper). More detailed specifications of the CCD sensor can be found in [6]. Schneider Digitar 5.6/47 optics were used with effective focal length of $47.5mm$.

The scale factor between ccd and analog film scanned at $15\mu m$ is $\frac{47.5mm}{50mm} \frac{15\mu m}{12\mu m} = 1.1875$, so the ccd images are about 19% larger.

2.1 Noise

Noise is an important criterion for measuring image quality. In our test data, noise in the scanned film images is mainly caused by the granularity of the film. To measure noise the entropy is calculated in homogenous patches of the test images. To get more reliable results, these patches are described by the so-called co-occurrence matrix introduced by Haralick [2]. Common features computed out of co-occurrence matrix are [3]: entropy, energy, maximum probability, contrast, inverse different moment, correlation and homogeneity. Since energy is a homogeneity measure (the larger the value, the more homogeneous the image), and contrast measures the local image variation, these values are considered to be best to measure noise.

In Figure 2 we added up the co-occurrence matrices from the four main directions 0° , 45° , 90° and 135° . Table 1 gives the statistics of one homogenous patch. CCD performs best - least number of gray values, lowest standard deviation and entropy and also best values for entropy, energy and contrast of co-occurrence matrix.

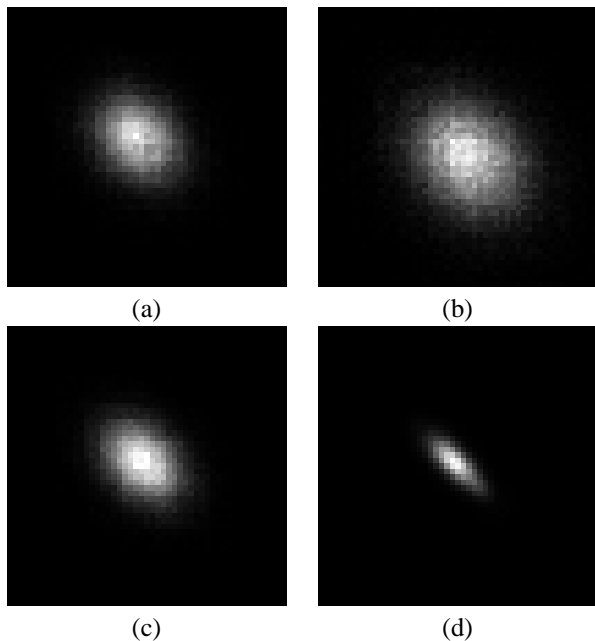


Figure 2: Co-occurrence matrices (a) apx $15\mu m$ (b) fp4 $15\mu m$ (c) sca $15\mu m$ (d) ccd, the non-zeros elements of upper-left to lower-right diagonal of the matrix represents the number of grayscales in the image. The more homogenous the image, the more diagonally dominant the co-occurrence matrix.

	nr	std	ent	co-occurrence		
				ent	energy	contrast
apx	70	9.33	3.64	7.21	0.00098	121.67
fp4	78	10.75	3.79	7.49	0.00075	162.74
sca	72	8.63	3.57	7.06	0.00113	103.51
ccd	17	2.09	2.15	3.83	0.02922	2.05

Table 1: Statistics of homogeneous image area. The number of different grayvalues, standard deviation and entropy (ent) of the image is shown. The co-occurrence statistics on the right shows entropy (ent), energy and contrast.

2.2 Test Patterns

We have captured a wall with several test patterns. Figure 3 shows images of a regular grid and the horizontal profiles. Here, the difference between film-based and ccd images is tremendous. Because of the large amount of noise in the film-based images, the grid can hardly be detected. Even in higher resolution ($5\mu m$ or $10\mu m$) it's not easier to find the grid lines. Figure 4 shows the grid taken by Agfa Scala 200 film, scanned with $5\mu m$, $10\mu m$ and $15\mu m$. It seems that there is not any more information in the $5\mu m$ scanned image than in the ones scanned with lower resolution. Figure 5 shows the captured circles test pattern which contains 10 circles decreasing in size. In the film-based images only 6 circles are visible, while in the ccd image 9 circles are visible and 7 of them are easily detected by the profile.

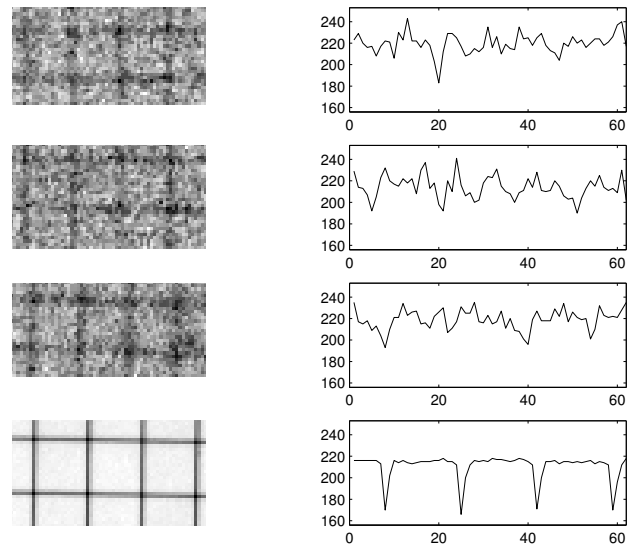


Figure 3: Regular black grid on white background. left: captured image, right: horizontal profile. From top to down: apx $15\mu m$, fp4 $15\mu m$, sca $15\mu m$ and ccd.

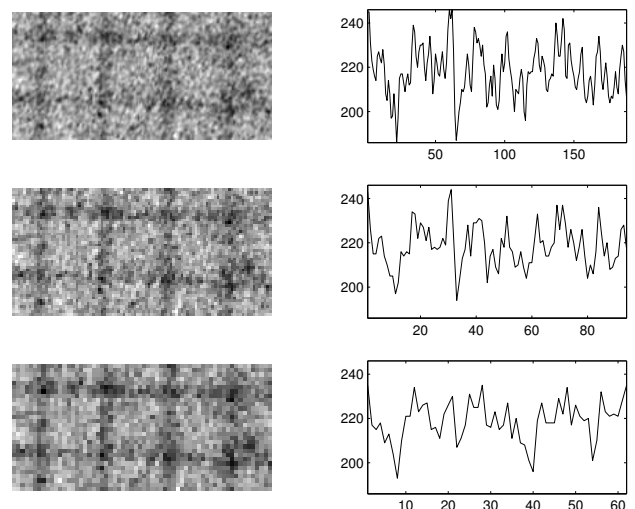


Figure 4: Regular black grid on white background taken from Agfa Scala 200 film and scanned with different resolution. left: captured image, right: horizontal profile. From top to down: $5\mu m$, $10\mu m$ and $15\mu m$.

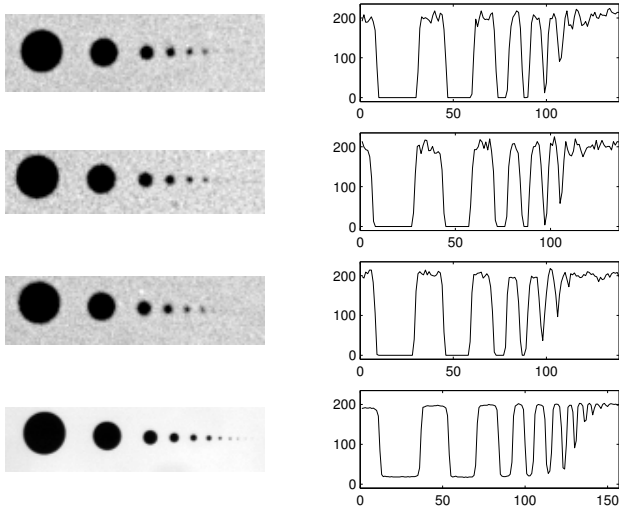


Figure 5: Black circles with decreasing size on white background. left: captured image, right: horizontal profile. From top to down: apx $15\mu\text{m}$, fp4 $15\mu\text{m}$, sca $15\mu\text{m}$ and ccd.

2.3 Line detection

In this test, a line detector is applied on a Siemens star which contains 72 lines. Figure 6 shows the star captured with the ccd sensor. All 72 lines were found in each of the images. As quality measures, the number of edge elements also called edgels found per line (Test 1) and the average normal distances of all edgels with respect to one line (Test 2) were taken. Results are shown in Table 2 and Table 3. While the differences between the empirical distribution functions of Test 2 do not reach the level of statistical significance, using Kolmogorov-Smirnov goodness-of-fit hypothesis test with significance level of 0.05, the results of Test 1 are significantly different and ccd performs best. The main predication of this test is, that the same results are collected from film-based and ccd-based images, but the results of ccd images are more stable, because more edgels are found for each line.

	min	max	mean	std
apx	42	66	52.81	5.545
fp4	36	62	51.99	5.718
sca	45	64	52.26	4.976
ccd	48	75	62.46	5.943

Table 2: Statistics of number of edgels with respect to one line. Minimum, maximum, mean and standard deviation is shown. Result of ccd is best and the empirical distribution functions are statistical different using Kolmogorov-Smirnov test with significance of 0.05.

	min	max	mean	std
apx	0.00134	0.0806	0.0317	0.0284
fp4	0.00415	0.1187	0.0385	0.0352
sca	0.00105	0.1163	0.0381	0.0352
ccd	0.00037	0.0834	0.0300	0.0293

Table 3: Statistics of average normal distances of edgels according to one line. Minimum, maximum, mean and standard deviation is shown. Result of ccd is best but empirical distribution functions are not different in the statistical sense.

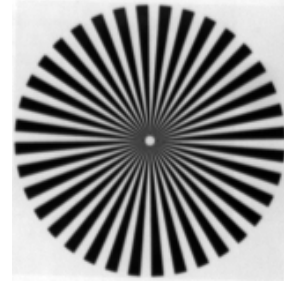


Figure 6: Siemens star taken with ccd sensor for line detection.

2.4 Stereo matching

A points of interest matcher, using Harris corner detector [4], normalized cross correlation and least squares method for refining the results to subpixel accuracy, is tested on several images. We choose a street-scene for this test, one of the stereo images is shown in Figure 7.



Figure 7: Street scene taken with ccd sensor.

Two images taken by the same films/ccd from nearly the same spot (30cm baseline) were correlated. 4000 points of interest were searched on a regular grid. Figure 8 shows the histograms of the correlation coefficients (correlation coefficient threshold was set to 0.4). Best results are reached with the ccd sensor and statistical test proves that the distributions are not equal, using Kolmogorov-Smirnov goodness-of-fit hypothesis test. Percent of successfully matched points of interest are 70%, 53%, 75% and 81% for apx, fp4, sca and ccd.

Figure 9 shows the normal distances from matched points to their corresponding epipolar lines, whereas the fundamental matrix is calculated via RANSAC algorithm and refinement of results was done using the eight point algorithm [7]. Outliers with a distance bigger than 2 pixels were excluded from the statistics. The mean normal distances are smallest for ccd images, but the mean value of sca and ccd are equal using statistical hypothesis t-test with significance 0.05.

When increasing the number of points of interest, the histograms stay similar, but the percent of matched points is decreasing. When searching for 20000 points of interest, only 38%, 34%, 42% and 72% for apx, fp4, sca and ccd are found. Note that nearly twice as many points were found in ccd images in comparison to film-based images. This leads to the same assumption as in the line detection test: good results are found with both, film-based and ccd images, but

results from ccd images are more stable and reliable. In this special case, points can be matched in less structured regions only in ccd-based images, because in film-based images the noise is so high, that less significant contents of the images is vanishing.

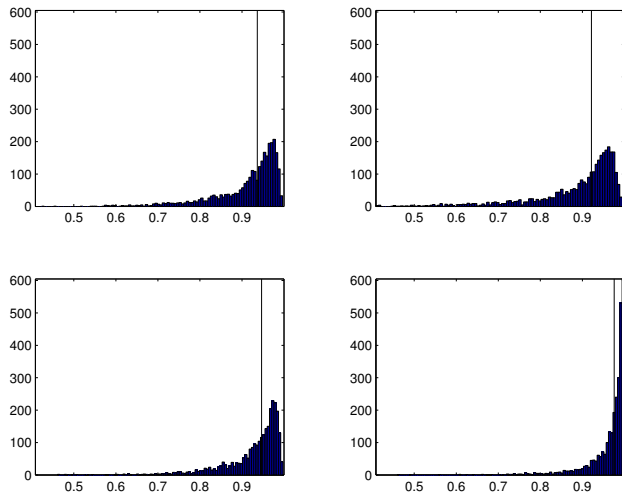


Figure 8: Histograms of correlation coefficients, upper left: apx $15\mu m$, upper right: fp4 $15\mu m$, lower left: sca $15\mu m$, lower right: ccd. Mean values are 0.9126, 0.8894, 0.9260 and 0.9643 (in pixels). Results of ccd are best and the distributions are statistical different. The vertical lines show the equal probability masses with values 0.9126, 0.8894, 0.9260 and 0.9643.

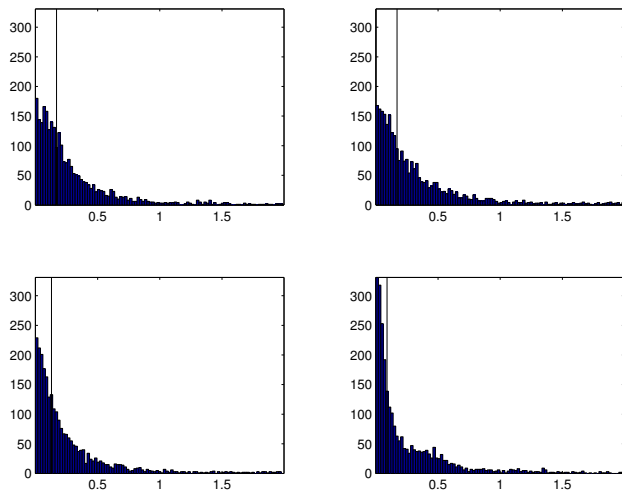


Figure 9: Histogram of normal distances of matched points from epipolar lines, upper left: apx $15\mu m$, upper right: fp4 $15\mu m$, lower left: sca $15\mu m$, lower right: ccd. Mean values are 0.2838, 0.3192, 0.2598 and 0.2503 (in pixels). Results of ccd are best, but the mean value of sca and ccd are equal using statistical hypothesis t-test with significance 0.05. The vertical lines show the equal probability masses with values 0.2838, 0.3192, 0.2598 and 0.2503.

3 CONCLUSION

We have compared film-based and ccd-based digital images. We suggested test methods of how to compare this different data. Because film-based images are noisy, which is caused by the granularity of the film, several algorithms yield more stable results for ccd-based images. Regarding

to pixel size, tests show that scanning our test films with $5\mu m$ is not useful, because there is not any more information in it, than scanning them with $15\mu m$. The information content of $12\mu m$ per pixel ccd sensor is higher than the content of a $5\mu m$ scanned analog film.

We consider it as an interesting task to expand this study to color images.

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