CCDS communication & design GmbH

Competitive Image Quality Analysis of Digital Print Presses

HP Indigo press 5500
Xerox iGen3
Xerox iGen4
Kodak NexPress 2100

Version 1.1

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1 Abstract

Over the last years digital print presses have gained a fundamental position among the output devices in photo finishing. New products besides the classic photo print have become popular such as all types of individually designed calendars, greeting cards, folded cards, business cards, posters etc. These products excite the end consumers and inspire to have photos printed from their meanwhile mostly digital image storage. Among these products one has initiated a real boom and a come-back of printing – the photo book.

While the numbers of prints made in classic photo finishing stagnated or were declining, the number of photo books was rapidly growing and have even multiplied many times over the last few years. The market leading whole sale photo finisher in Europe CEWE published an increase of photo books from 71.000 in 2005 to more than 2,5 million samples in its factbook 2008 (CEWE: “Factbook 2008”; www.cewecolor.de/index.php?id=93&L=1, November, 2008). The printing industry has responded with a large number of solutions to produce the books demanded. However, the vast number of photo books is produced with digital print presses.

The aim of this research is to compare the print quality obtained by the leading digital print presses, HP Indigo press 5500, Xerox iGen3 and iGen 4, Kodak NexPress. Hewlett-Packard Indigo Ltd. entrusted CCDS communication & design GmbH to perform an independent and impartial image quality analysis in regards of prints by the mentioned competitors.

For the research sets of 94 images, specifically selected for this purpose, were printed with several competitive print presses. This report includes a visual expert analysis describing the characteristics of the printer’s color reproduction properties and providing a quality ranking. Colorimetric measurements and evaluations complete the analysis and quantify the effects. Additionally a choice of the same images was shown to several laymen in order to proof and confirm the relevance of the expert’s assessment for potential end consumers in the photo market. The survey reflects the Mid-European market and allows good prognoses for the North-American market as well.

The expert’s evaluation supported by densitometric and colorimetric measurements as well as the average layman polled in the survey came to the same result. The Hewlett Packard Indigo press 5500 outperformed the competitive digital print presses Xerox iGen3, Xerox iGen 4 and Kodak NexPress 2100. Only slight differences between Xerox iGen3 and iGen4 were found. Both machines were ranked in second place. Kodak NexPress ended in third place. This report will point out the characteristics of the tested digital print presses in detail.

2 Analysis

2.1 Choice and set-up of printers

The machines chosen for this analysis were:

Xerox iGen3
Xerox iGen4
Kodak NexPress 2100
Hewlett Packard Indigo press 5500

All printers are digital print presses. While the images of the Kodak NexPress and the Xerox iGen were printed with CMYK toners, the prints with HP Indigo press were six-color prints C,M,Y,K, LC, LM (LC: light cyan, LM: light magenta).

All output devices are located in commercial printing finishing locations. The machine adjustments are carried out according to the preferences of the plant owner, so it represents the preferences of his market. We did not exert influence on the calibration of the printers. However, we controlled and evaluated the color and tone value accuracy by densitometric and colorimetric measurements. We had test prints made in various production locations. For the evaluation within the present analysis the samples showing the highest quality were examined. The prints of the commercial HP Indigo print plants were double-checked with prints coming from the British HP demo center. Three Kodak NexPress and two Xerox production sites were evaluated. The providers were asked to deliver best possible print quality.

All prints were made without applying automatic image enhancement software on high gloss paper 250 g/m². Each of the printing plants used paper of its preferred provider but of the same high standard. There is no visible difference in quality among the papers processed.

2.2 Test Images

For the print comparison a batch of 90 selected images and 4 test charts generated with Adobe Photoshop were used. The selected images were taken with several digital cameras of various manufacturers and performance classes. It includes photos from amateurs as well as from semi-professional and professional photographers in order to gain a representative profile. Besides well exposed and arranged photos, the batch also includes images with typical failures made during exposure and also images, which provoke output mistakes (e.g. when the color management is poor). The contents of the images are the following:

- Portraits of people with different colors of skin
- Flashlight scenes (bright scene, dark background)
- Over and underexposed images
- Images of high and low tonal range
- Vegetation, nature
- Architecture
- Images with fine detail (high spatial frequencies)
- Landscapes, sky scenes
- Themes of high and low saturation (including colors, which are located beyond the gamut of photographic system)

- Images including dominant colors and color gradients of the full spectrum
- Black and white photos

The test charts were printed for the colorimetric analysis, by which we evaluate the accuracy of color rendition all over the in- and output color space as well as the reproduction of tonal values. Further test charts help to evaluate the effective print resolution, sharpness and accuracy of color gradients of memory colors like skin-tones, vegetation and sky. The results are described together with the expert's image quality evaluation and proof the results.

The appraisals of the prints by the experts and the laymen took place with the help of a color controlled daylight D50 light source.

2.3 Visual image evaluation by experts

The expert's image quality evaluation is done regarding a set of well tested and proven criteria, which are:

- Quality of tonal value reproduction:
  - Minimum density (maximum paper whites)
  - Maximum density (maximum black)
  - Tonal value reproduction of highlights
  - Tonal value reproduction of shadows
  - Basic set-up of brightness
- Homogeneity of print:
  - Raster dots
  - Mottling/Clouds
  - Banding (horizontal and vertical stripes)
- Impression of sharpness:
  - Resolution
  - Contrast
  - Sharpness of edges/blur
- Basic setup of color:
  - Color balance/neutrality
  - Color fading
  - Overall saturation
- Color rendering of memory colors
  - Yellow
  - Red
  - Green
  - Blue
  - Skin shades

The classification is as follows:

++ excellent
+ good
0 well accepted
- inferior quality, but still acceptable
-- not acceptable

Quality Criteria	HP Indigo press 5500	Xerox iGen3	Xerox iGen4	Kodak NexPress 2100
Homogeneity of prints	**++**	**-**	**-**	**-**
Raster dots	++ Barely visible raster dots provide smooth prints	- Visible raster dots	0 Visible raster dots, slightly better than Xerox iGen3	-- Significant raster dots
Clouds/ Mottling	++ No visible mottling or clouds at all	-- Irritating clouds and mottling	- Visible mottling	0 Some mottling can be observed
Banding (horizontal and vertical stripes)	++ No visible stripes at all	0 Visible banding, but less significant compared to Xerox iGen4	- Significant banding	-- Most significant banding
Tonal value reproduction	**+**	**++**	**+**	**0**
Minimum density	++ No visible difference among the used papers	++ No visible difference among the used papers	++ No visible difference among the used papers	++ No visible difference among the used papers
Maximum density	++ D_v= 2.65 Highest maximum density among the competitors and hence deepest blacks	+ D_v= 2.20 Good blacks, however not as deep as those of HP Indigo press	+ D_v=2.25 Good blacks, however not as deep as those of HP Indigo press	- D_v= 1.89 Deep blacks and shadows appear grey

Quality Criteria	HP Indigo press 5500	Xerox iGen3	Xerox iGen4	Kodak NexPress 2100
Tonal value reproduction of highlights	+ Excellent differentiation of highlights, but a slight magenta cast was detected in highlights	++ Excellent differentiation of highlights	++ Excellent differentiation of highlights	0 Good differentiation of highlights, slight magenta cast
Tonal value reproduction of shadows	0 Excellent differentiation of shadow details, excellent deep blacks. However, the darker mid-tones and shadows appear brighter and hence there is a loss of brilliance compared to Xerox iGen prints.	+ Satisfactory differentiation of shadow details. However, due to the darker shadow rendition in some of the prints the contrast (gradation) of mid-tones is higher and hence the appearance is more brilliant compared to the competitors' prints	0 Weak differentiation of shadow details, shadow information gets lost. However, due to the darker shadow rendition in some of the prints the contrast (gradation) of mid-tones is higher, hence the appearance is more brilliant compared to the competitors' prints	0 Excellent differentiation of shadow details. However the shadows appear too bright and hence the images not as brilliant as the competitor's prints
Basic setup of brightness	+ Good but slightly bright basic setup	++ Excellent basic setup of brightness	++ Excellent basic setup of brightness	0 Acceptable but too bright setup

Quality Criteria	HP Indigo press 5500	Xerox iGen3	Xerox iGen4	Kodak NexPress 2100
Impression of sharpness	**0**	**+**	**+**	**0**
Resolution	++ Very high resolution of image details	0 Acceptable resolution	0 Acceptable resolution	- Lowest resolution among the competitors
Contrast	0 Contrast in mid-tones is comparatively low, which results in a loss of sharpness impression compared to the Xerox iGen	+ Contrast in mid-tones and shadows is comparatively high, which results in an advanced sharpness impression compared to the HP Indigo press and NexPress in most of the prints	+ Contrast in mid-tones and shadows is comparatively high, which results in an advanced sharpness impression compared to the HP Indigo press and NexPress in most of the prints	0 Contrast in mid-tones is comparatively low, which results in a loss of sharpness impression compared to Xerox iGen
Sharpness of edges	- No sharpening of edges by image enhancement algorithms detected, images appear blurred in some cases	+ Sharpening of edges by image enhancement software assumed	+ Sharpening of edges by image enhancement software assumed	+ Sharpening of edges by image enhancement software assumed
Basic setup of color	**0**	**0**	**+**	**0**
Color-balance	+ Neutral setup, slight cyan cast of the tested machine	0 Bluish basic setup of tested machine	+ Neutral setup, slight blue cast observed with the tested machine	+ Neutral setup, slight cyan cast of the tested machine
Color-fading	0 Slight magenta cast in the highlights, neutral blacks	0 Neutral highlights and shadows, bluish mid-tones	+ Neutral highlights and blacks	0 Slight magenta cast in the highlights, neutral blacks

Quality Criteria	HP Indigo press 5500	Xerox iGen3	Xerox iGen4	Kodak NexPress 2100
Overall saturation	0 Seems lower compared to prints from the Xerox iGen3/4	0 Very high (nice in colorful images, but sometimes overdone)	0 Very high (nice in colorful images, but sometimes overdone)	- Is comparatively low. Hence, the prints a bit pale sometimes
Rendition of color	**+**	**+/0**	**0**	**0**
Rendition of yellow shades	0 Good and natural reproduction of yellow shades. The saturation is lower compared to prints of iGen3/4	+ Appear slightly warm (shifted towards orange). The saturation of yellow is very high	+ Appear slightly warm (shifted towards orange). The saturation of yellow is very high	+ Appear slightly cold (shifted towards green). The saturation is lower compared to prints by the Xerox iGen3/4. There is a loss of information in highly saturated yellow (clipping)
Rendition of red shades	++ Very good rendition: exact reproduction of hue, vivid and saturated appearance and no loss of information even with highly saturated red	+ Slightly cold appearance (slightly shifted towards magenta), maximum saturation of red is lower compared to the HP Indigo press	0 Cold (magenta) appearance of red shades (shifted towards magenta), maximum saturation of red is lower compared to the Indigo press. In a few prints we found some clipping of red in highly saturated shades	- Is shifted towards orange and rendered at lower saturation compared to the HP Indigo press. There is good differentiation of highly saturated red shades

Quality Criteria	HP Indigo press 5500	Xerox iGen3	Xerox iGen4	Kodak NexPress 2100
Rendition of green shades	+ The overall appearance is natural. The saturation is high and the colors appear vivid. However, there is a hue-shift of highly saturated green towards yellow, which results in some posterization artifacts in green gradients (blurred backgrounds)	- Bright and mid-tone green is strongly shifted towards yellow, which results in significant posterization artifacts. The overall saturation is about the same as HP Indigo press, however highly saturated green is rendered slightly less saturated	- Bright and mid-tone green is strongly shifted towards yellow, which results in significant posterization artifacts. The overall saturation is about the same as HP Indigo press, however highly saturated green is rendered less saturated	+ Green shades appear natural. No shifts of the hue were visible. However, parts of images green are rendered less saturated than those of competitors and appear a bit pale
Rendition of blue shades	+ We found a very natural rendition of cyan and blue shades. There were hue shifts detected. Additionally we consider the saturation as natural. This is especially helpful for sky scenes.	+ The rendition of cyan and blue shades was evaluated as good. There is a slight (barely visible) shift of blue towards cyan. No disturbing hue shifts were found. The saturation is slightly higher compared to the HP Indigo press.	- There is a significant shift of highly saturated blue shades towards cyan. The saturation is often very high and especially when the saturation of the original is high as well the rendition appears overdone.	0 Besides a slight shift of bright blue towards violet, the rendition of blue shades is good. The saturation is natural and about on the same level as of the HP Indigo press

Quality Criteria	HP Indigo press 5500	Xerox iGen3	Xerox iGen4	Kodak NexPress 2100
Rendition of skin shades, portraits	+ Skin shades are slightly shifted towards red. Due to flat mid-tone gradation and especially due to high resolution of indigo as well as perfect homogeneity of Indio press, faces appear very smooth and handsome	0 Skin shades appear natural (for the European taste). However due to the visible raster dot and the mottling effect, faces sometimes appear blotchy and by far not as smooth as those printed with Indigo press	0 Skin shades appear natural (for the European taste). However due to the visible raster dot and the mottling effect, faces sometimes appear blotchy and by far not as smooth as those printed with Indigo press	- Skin shades are shifted towards yellow. In shadows of skin there is even a greenish appearance. The raster and mottling effect let faces and skin feel blotchy and not as smooth as those of the HP Indigo. Faces sometimes appear pale
Average Total	**+**	**+/0**	**+/0**	**0**
Ranking	**1**	**2**	**2**	**3**

We see the HP Indigo press 5500 as the best among the tested digital print presses. From our point of view the major advantages of Hewlett Packard Indigo press 5500 are the incredibly high resolution and the fantastic homogeneity of the prints, which result in smooth image impression (see Image 1 and 2). The print results come very close to the impression of conventional real halftone silver halide prints. The reproduction of tonal values provides smooth prints without any loss of image information. From our point of view the color rendition is most natural (in terms of color-management most precise) among the competitors. Although skin shades are rendered with a shift of hue towards red, portraits appear very handsome due to the flat mid-tone gradation and the well balanced homogeneity of Indigo prints.

The printing results of Xerox iGen3 and iGen4 are very close together. There is just a slight difference in the arrangement of raster dots and the raster angles of the color separations (see Image 1 and 2). However, this results in a lower visibility of the raster elements and hence in a better homogeneity of the prints. Additionally the mottling effects were slightly better for the Xerox iGen4 compared to iGen3. The device used for the test showed a loss of shadow information, which we guess is a matter of adjustment and not a general attribute of iGen4. Additionally we found a slightly better color calibration of iGen3 compared to iGen4.

The prints of Xerox iGen cannot compete against those of the HP Indigo in terms of homogeneity and resolution. At a first glance the prints appear more saturated, more brilliant and sharp compared to the HP Indigo, however at costs of tone value differentiation and detail accuracy.

The prints made with the Kodak NexPress show acceptable image quality. However, they could not compete against the HP Indigo's overall performance. The major disadvantages in our eyes are the low resolution, the significant raster dots as well as the poor banding and mottling characteristics. On the other hand there is a quite obvious yellow shift of skin shades, which we consider as a borderline case for acceptance in Europe and America and don't consider as acceptable for the Middle-East, Asian and African markets.

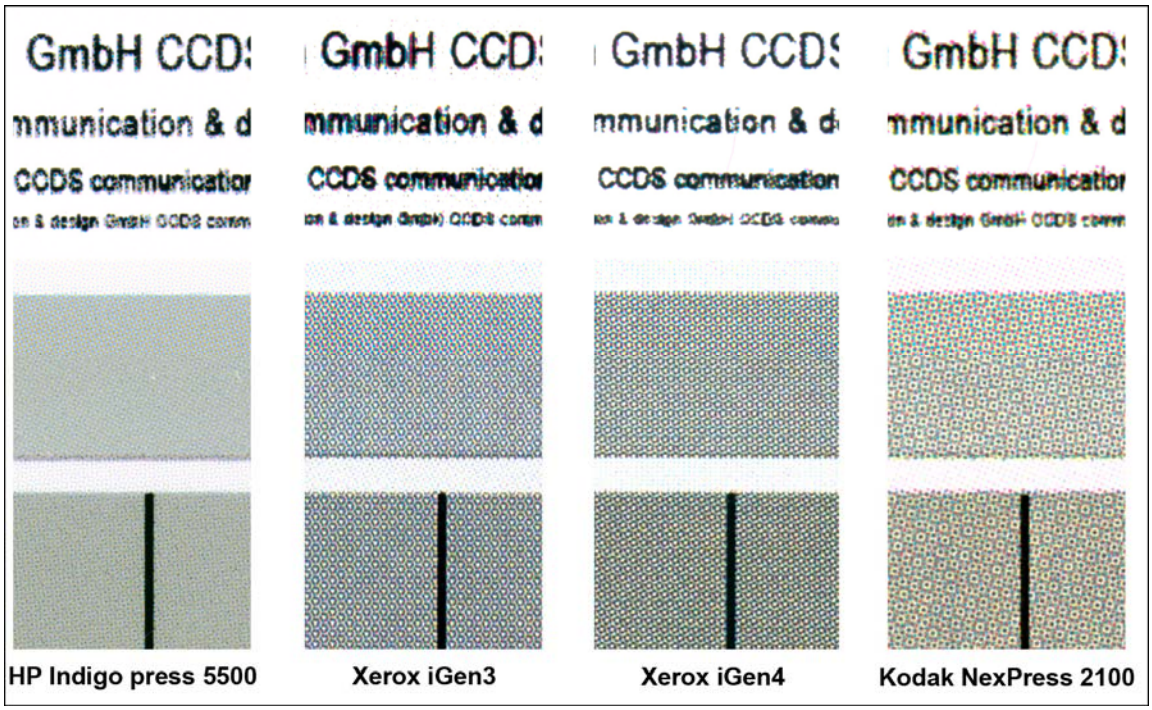

Image 1: Detail enlargements of prints produced by the tested digital print presses, demonstrate resolution, raster dot size and raster angles

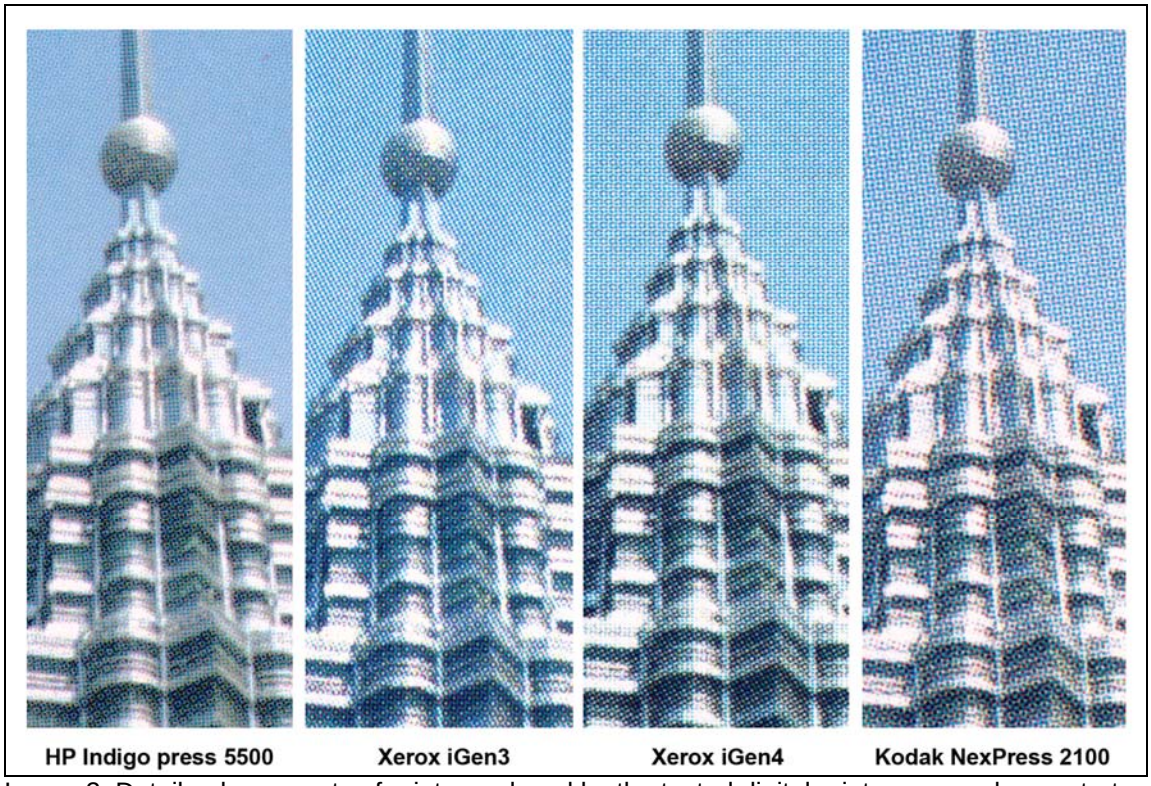

Image 2: Detail enlargements of prints produced by the tested digital print presses, demonstrate resolution, raster dot size and raster angles

2.4 Laymen survey

In order to proof the relevance of the expert's opinion, for the potential target groups of photo books and other personalized photo products, a choice of 25 images was shown to ten independent observers, who were not involved in or knew about the project. In order to obtain a representative result, the polled persons were between 25 and 50 years old. They had different photographic skills and experience, used different types and quality of photographic equipment, had different photo editing habits and different consumer behavior regarding output or respectively printing of their taken images. All of the participants had heard of photo books, three of them were interested to produce their own photo books once, but only one of them has ever made a photo book.

The survey was performed in Germany and is hence not representative for markets all over the world. However, former surveys have shown it is relevant for Europe and North America.

The chosen images were an extract from the prints evaluated by the s.c. experts. The laymen observers had to judge the prints under the standard lighting conditions (D50). They were asked to rank from 1 to 4 for each set of photos of the same image file printed by the four different digital print presses (1 = best accepted print, … , 4 = least accepted print). The order of the prints belonging to a certain printer was randomized. This was done for all 25 photos. For every printer the arithmetic average over all ratings per observer was calculated as well as the arithmetic average over all observers. The result is a ranking per observer and an overall ranking calculated using all observers' results.

The following table shows the individual and total raking over all images.

Observer	HP Indigo 5500	Xerox iGen3	Xerox iGen4	Kodak NexPress 2100
Observer A	1,36	2,32	3,00	3,28
Observer B	1,48	2,72	2,96	2,84
Observer C	1,92	2,48	2,68	3,00
Observer D	2,32	2,64	2,40	2,64
Observer E	3,08	2,08	1,84	3,00
Observer F	2,60	2,04	2,12	3,20
Observer G	1,60	2,88	2,36	2,84
Observer H	1,76	2,08	2,32	3,76
Observer I	1,84	2,44	2,52	3,24
Observer J	1,60	2,76	2,92	2,64
Total Average	**2,02**	**2,45**	**2,46**	**3,07**
root mean square deviation	0,55	0,31	0,38	0,34
absolute error	0,17	0,10	0,12	0,11
relative error	8%	4%	5%	4%

Table 1: Average ranking over 25 test prints per observer, total average and statistic errors

The average over the observers saw the HP Indigo press as the winner among the tested digital print presses. There is no significant difference in image quality between Xerox iGen3 and iGen4 of the observer's average opinion. The Kodak NexPress' image quality is considered to be third place in the overall ranking. Besides the ranking for the Xerox iGen3 and iGen4 the statistical error (absolute

error) is smaller than the effects. Hence, the survey can be considered to be representative.

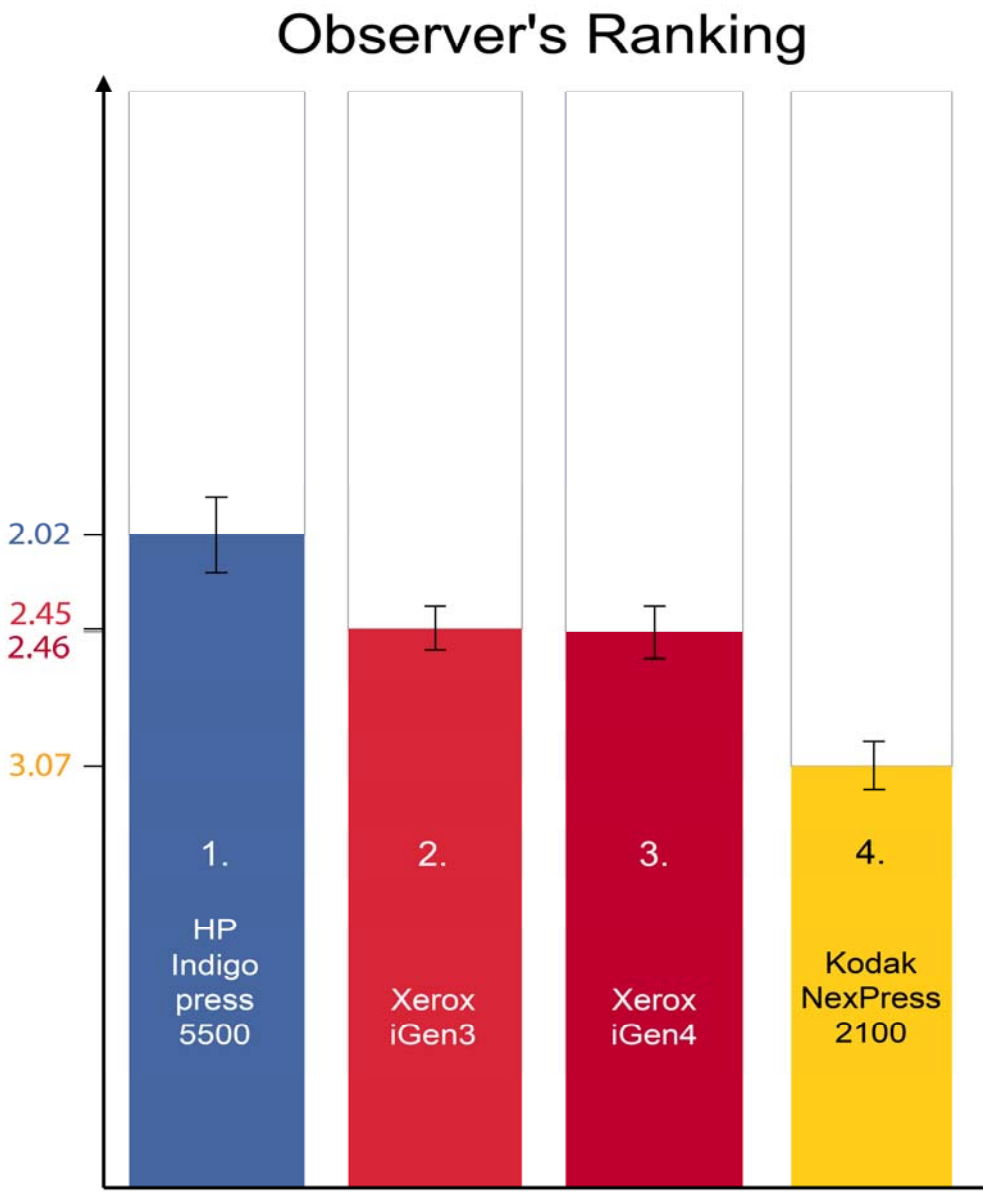

Image 4: Observer's ranking regarding print quality of the tested digital print presses.

There is a very good correspondence between the layman's and the s.c. expert's opinion.

During the survey we asked the observers to specify their preferences and to describe their thoughts and opinions regarding the print results.

As in many other surveys before, we found the observers often do not know about the technical terms, but are able to see and describe their own preferences as well as differences, advantages and disadvantages of the print results very well.

All observers agreed that the prints by the HP Indigo press 5500 best homogeneity and resolution. This is one of the reasons why most of the portraits from this print press were preferred although the skin tones were considered as too magenta in some cases. On the other hand the comparatively poor homogeneity was often the

reason, why the respondents ranked the prints last, although they liked its well balanced color reproduction. Most of the observers remarked a lower impression of sharpness of the HP Indigo's prints compared to Xerox iGen. For portraits they liked it but for architecture they often didn't. For very multi-colored images the interviewees opinion was fluctuant, some found iGen's saturation fancy, others described it as overdone. For the Kodak NexPress the yellow shift of skin shades was a reason for a negative ranking.

3 Conclusion: Hewlett Packard's Indigo press 5500 outperformed the competitor's presses Xerox iGen3 and 4 as well as Kodak NexPress 2100

The expert's evaluation supported by densitometric and colorimetric measurements as well as the average layman polled in a survey came to the same result. The Hewlett Packard Indigo press 5500 (LC/LM) won the competition digital print presses and outperformed Xerox iGen3, Xerox iGen 4 and Kodak NexPress 2100.

The major advantages of Hewlett Packard Indigo press 5500 are the incredibly high resolution and the fantastic homogeneity of the prints, which result in smooth image impression. The print results come very close to the impression of conventional real halftone silver halide prints. The reproduction of tonal values provides smooth prints without any loss of image information. The color rendition is very natural. We found vivid red, green and blue shades that remind the consumer to the originally taken themes. Although skin shades are rendered with a shift of hue towards red, portraits appear very handsome due to the flat mid-tone gradation and the well balanced homogeneity of the Hewlett Packard Indigo prints.

The printing results of Xerox iGen3 and iGen4 are very close together. The laymen even found no significant difference between the overall print qualities of both machine versions. The examination with a loupe identified a slight difference in the arrangement of raster dots and the raster angles of the color separations (see Image 1 and 2). However, this results in a lower visibility of the raster elements and hence in a better homogeneity of the prints, which was detected by the laymen very well. Additionally the mottling effects were slightly better for the Xerox iGen4 compared to iGen3. The device used for the test showed a loss of shadow information, which we guess is a matter of adjustment and not a general attribute of iGen4. Additionally we found a slightly better color calibration of the Xerox iGen3 compared to iGen4.

Altogether the prints of the Xerox iGen cannot compete against those of the HP Indigo in terms of homogeneity and resolution. At a first glance the prints appear more saturated, more brilliant and sharp compared to the HP Indigo, however at costs of tone value differentiation and detail accuracy.

The prints made with the Kodak NexPress ranked behind Hewlett Packard Indigo press 5500 and both Xerox iGen presses. The major disadvantages in our eyes are the low resolution, the significant raster dots as well as the poor banding and mottling characteristics. On the other hand there is a quite obvious yellow shift of skin shades, which we consider as a borderline case for acceptance in Europe and America and don't consider as acceptable for the Middle-East, Asian and African markets.

4 Attachment

4.1 A choice of our test prints

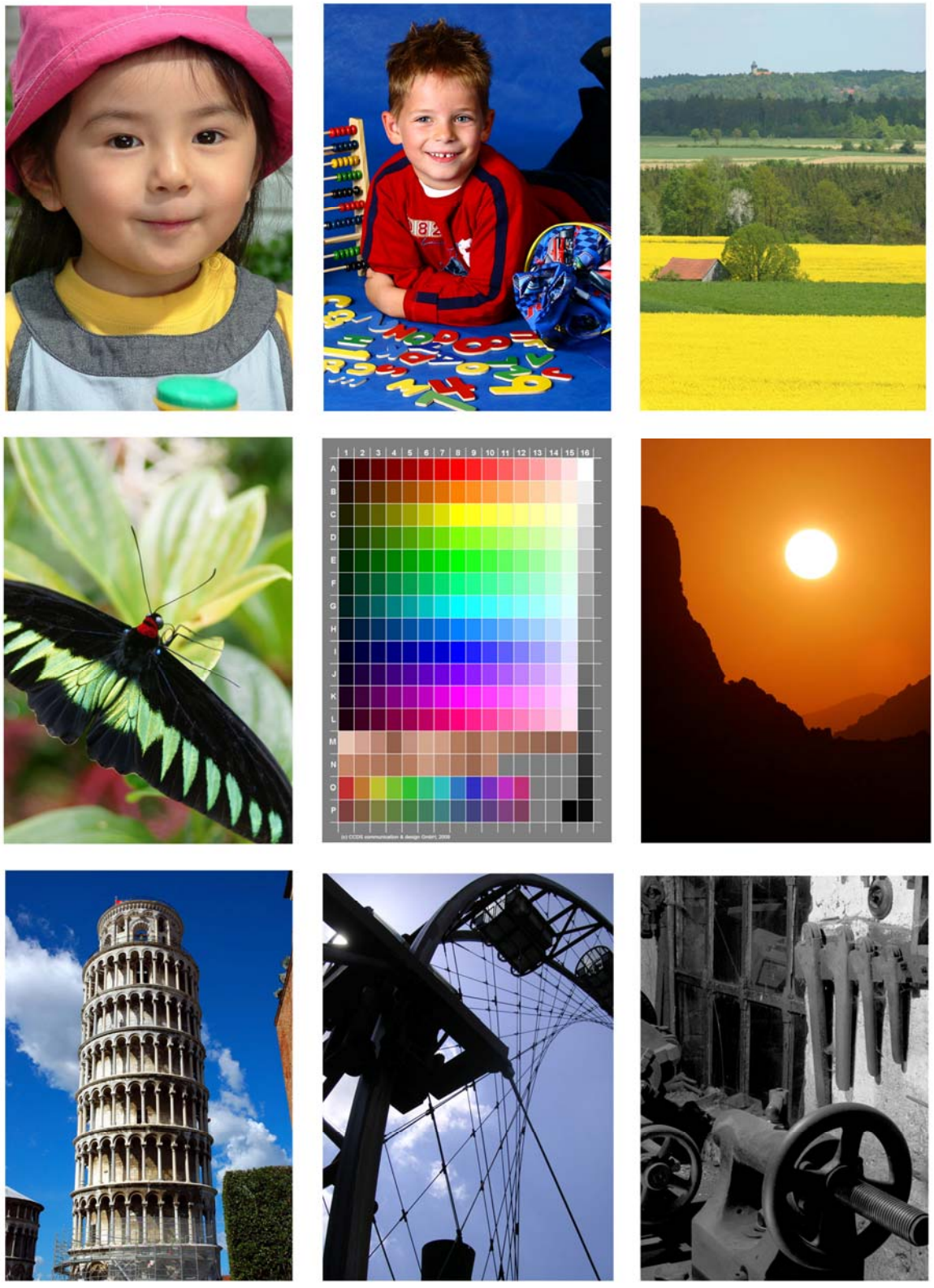

Image 5: A small choice of used test images

4.2 About CCDS communication & design GmbH

CCDS communications and design GmbH was founded in 1992 as a service provider for the technical support hotline for Minolta digital cameras by Peter Cassel, the Managing Director. Digital photography has been the core competence of CCDS in its history. Our team of 22 employees mostly consists of photographic engineers (Masters of Media and Imaging Technology) and is among others completed by graduated designers, translators and IT-specialists.

Today CCDS covers a wide range of services in the field of state of the art photo and media technology:

- Media productions
- Image Enhancement Technologies
- Photographic Image Recording Technologies
- Consulting photographic systems
  - Benchmarking of photographic input and output devices
  - Conception and realisation of projects regarding image quality improvement of photographic output devices
  - Colormanagement projects and consulting
  - Trade-marketing activities
- Web applications and websites / E-Commerce
- Trade fairs & Promotions
- Training and Consulting (national and international)
- Support/Call Center

Furthermore CCDS covers services in the field of Project Management as well as Product Management and Development.

We can count to our satisfied customers among others:

- Hewlett Packard GmbH (EMEA)
- Hewlett Packard Indigo Ltd.
- Konica Minolta Europe/Germany GmbH
- Daymen
- Sony Europe/Germany

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