Journal of
Print and Media Technology Research

Scientific contents

Journal of Print and Media Technology Research

A peer-reviewed quarterly

A mission statement

To meet the need for a high quality scientific publishing in its research fields of interest, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries (iarigai) publishes the peer reviewed quarterly Journal of Print and Media Technology Research.

The Journal is fostering multidisciplinary research and scholarly discussion on scientific and technical issues in the field of graphic arts and media communication, thereby advancing scientific research, knowledge creation and industry development. Its aim is to be the leading international scientific periodical in the field, offering publishing opportunities and serving as a forum for knowledge exchange between all those scientist and researchers interested in contributing to or benefiting from research in the related fields.

By regularly publishing peer-reviewed high quality research articles, position papers, survey and case studies, the Journal will consistently promote original research, networking, international collaboration and the exchange of ideas and know how. Editors will also consider for publication review articles, topical and professional communications, as well as opinions and reflections of interest to the readers. The Journal will also provide multidisciplinary discussion on research issues within the field and on the effects of new scientific and technical development on society, industry and the individual. Thus, it will serve the entire research community, as well as the global graphic arts and media industry.

The Journal will cover fundamental and applied aspects of at least, but not limited to the following fields of research:

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◇ Printed fuel cells and other printed functionality
◇ Printing on biomaterials
◇ Textile and fabric printing
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Social impacts

◇ Environmental issues and sustainability
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Contents

A letter from the Editor

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We came to the first issue of the Journal of this year, which is, at the same time the first online issue, with new assigned ISSN 2414-6250 (Online).

This change means great improvement of the distribution of the Journal, which will hopefully become available more widely to all researchers, professionals, students and others who are interested in innovations in the printing and media technology, as well as the study and development of all forms of print and media communication. All recipients of digital version of the Journal are invited to disseminate this publication and inform their colleagues and co-workers at their institution, through the library, or in another appropriate manner, to provide access to all those who are entitled to it, thus primarily members of iarigai – The International Association of Research Organizations for the Information, Media and Graphic Arts Industries, and subscribers. All other interested readers can access the archive copies free of charge, they are invited to become a subscriber or to order access to certain recent papers published in current issues.

In this edition six research papers are published, again the most basic research areas covered by the Journal are included: the challenges on printed electronics, the challenges of varnishing in flexography with water-based inks and varnishes, evaluation of color spaces in a color managed print processes, the effectiveness of advertising messages with large posters, portraits used for the protection of banknotes against counterfeiting and the use of CSS3 tools for online publishing in prepress. Approaches of the authors to such various topics, of course, vary considerably, however they also presents challenges for the reviewers and editors. Their efforts are recognized as an important contribution to the comprehensive development of the common research field.

Markéta Držková (marketa.drzkova@jpmtr.org) provided again an overview of defended thesis, new interesting publications and events. In 2016 we are all expecting drupa in Düsseldorf, Germany, which will once again outline the guidelines for our development in the coming years. After the economic crisis, major technological revolutions, changes in consumer habits and expectations, the first research projects and their realization in the field of new media, printed electronics, functional and industrial printing, will be reliably reflected at this event. We can expect a confirmation of our expectations, and new challenges and ideas for the future. Some of our research activities, oriented into future, will be evident in the next issue of the Journal, dedicated to 'Audience, business and design factors in new media innovation'. Special edition will be edited by the guest editors David Frohlich and John Mills.

Next major event is an international research conference iarigai in Toronto, which will be carried out this year already in August. The deadline for submissions has already expired, however we still have sufficient time for registration and participation in the event, which every year significantly impacted our community.

iarigai offers a new opportunity to researchers with a call to the iarigai Research Grant, which is mainly dedicated to researchers from member institutions, given them an opportunity for closer integration and exchange of experience in print and media research field. These activities are opening access to cutting-edge research equipment, the creation of new teams, exchanging of new ideas and closer cooperation between institutions. We are expecting excellent research results and we will be happy to post resulting new papers in one of the next issues of the Journal.

Ljubljana, March 2016

Errata

The following corrections are to be made:

4(2015)4

Page 263:   The incorrect Figure 6 with incomplete legend was printed.
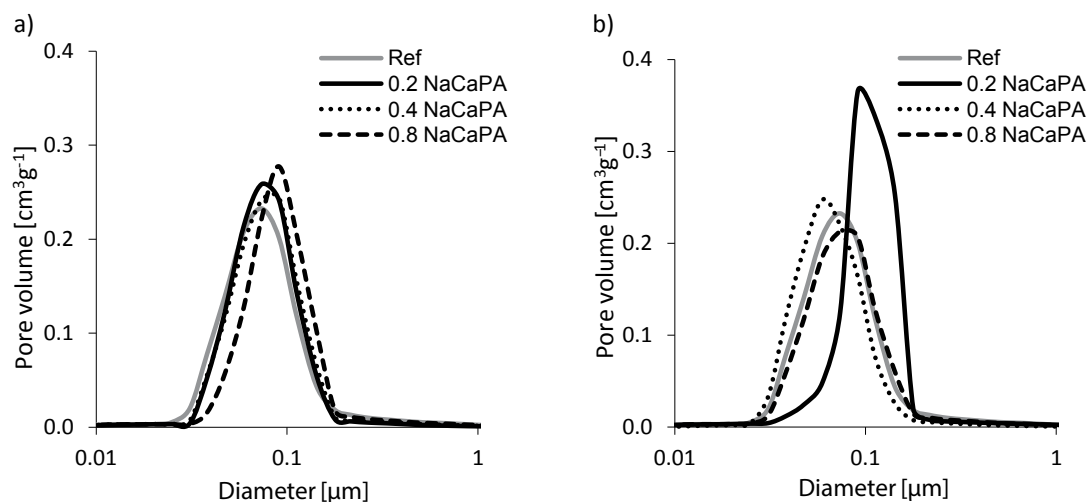The correct Figure 6 is reproduced below.

Figure 6: The pore volume [cm³·g⁻¹] of dried coating colours containing a) increasing amounts of NaPA and b) increasing amounts of NaCaPA

Improving the electrical performance and mechanical properties of conductive ink on thin compound substrate

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Abstract

In printed electronics applications, very often conductive lines have to be printed and there are several ink/paste and substrate combinations to choose from. Silver ink is usually used due to its high electrical conductivity. Carbon black and PEDOT:PSS are also very common. Substrates are available in a broad variety. Flexibility, good adhesion of the ink, processability, and a maximum processing temperature compatible with the curing temperature of the functional inks is important. If barrier properties, e.g. against the permeation of oxygen, carbon dioxide or water vapour are required, a compound substrate may be necessary, consisting of two or more layers of different materials. The motivation for this investigation was the need for improving the stability and processability of a given substrate chosen for printed batteries. The substrate consists of three layers, namely polyethylene (PE), aluminium and polyethylene terephthalate (PET). This compound foil is rather thin (100 μm) and very flexible. This is a major requirement for the application. The aluminium sandwiched between two polymer layers provides sufficient barrier properties. PET is commonly used as a substrate for printed electronic applications. PE is not as easy to print on, but with e.g. plasma treatment the adhesion of printing inks is sufficient. The weldability of PE is beneficial for the screen-printed battery application, although poor printability without surface treatment and the thermal mismatch of the asymmetric polymer compound (PE–PET) renders processing rather difficult. In this work, the authors examined a route for printing on PE without the need of pre-treatment of the substrate with plasma or corona. Instead, it was found that an UV-ink layer used as adhesion promoter provided sufficient adhesion and improved mechanical stability, i.e. cohesion of the successively printed silver ink layer. Additionally, the thermal treatment of the conductive ink was optimized by comparing heat press and hot stamp curing with batch oven curing.

Keywords: printed electronics, printed battery, conductive ink, UV-curing, laminated substrate

1. Introduction and background

The choice of substrate in the field of printed electronics is very important. If one considers organic light emitting diodes (OLED) or – as in the underlying case – printed batteries, it is necessary to ensure the encapsulation of the chemical system during manufacturing and lifetime of the device. Without the appropriate barrier materials, the lifetime is drastically lower (Bülow et al., 2014; Park et al., 2011; Wendler, Krebs and Hübner, 2010; Yoshida et al., 2001). Usually, the application determines the inks, the substrates and the preferable printing method. Trade-offs have to be made, if requirements are conflicting. The authors chose a compound laminate consisting of polyethylene, aluminium and polyethylene terephthalate layers (PE-Al-PET) as substrate for printed batteries as part of a research project (KoSiF, 2013). The conflict in choosing this substrate lies in the favourable weldability and the poor printability of PE. Due to wettability reasons, printing on PET is uncomplicated, whereas printing on PE is quite difficult. Pre-treatment of the PE surface is necessary in order to achieve adhe-

sion of the print layer on the polymer (Rossmann, 1956; Lommatzsch et al., 2007). In roll-to-roll production lines, corona or plasma pre-treatment devices can be implemented. However, if a sheet-fed lab machine is used and the available plasma/corona device has a limited spatial work area or if even no corona or plasma device is accessible at all, another approach to the problem may be useful.

One part of this paper is the examination of an ink layer that promotes the adhesion of silver ink on PE without prior application of corona or plasma treatment. An UV-curing printing ink is used as an adhesion agent, since the processability is very good as well as the adhesion of silver ink on top of the UV-ink layer. The second part of the paper reports on the examination of alternative thermal processes that are capable of curing electrical conductive printing inks. The thermal treatment after printing is essential for optimizing the electrical conductivity.
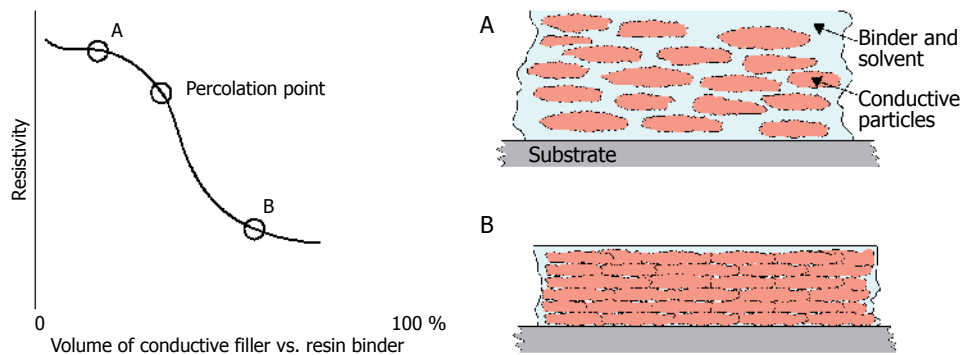
Figure 1: Pigment filled conductive inks need thermal treatment in order to establish electrical pathways between the single particles, modified from Banfield (2000)

The mechanism behind metal particle filled inks requires thermal post-treatment after printing (Banfield, 2000). A curing temperature of 120 °C for at least 10 minutes is mostly stated as the minimum requirement for achieving a reasonable conductivity. The conductance, the reciprocal of the ohmic resistance, increases with higher temperature and longer curing time. It is usually the substrate, what limits the maximum processing temperature, e.g. PET substrates do not withstand temperatures higher than 150 °C. According to Figure 1, the evaporation of the solvent and the shrinkage of the binder reduce the height of the ink layer, thus increasing the contact area of the conductive particles. The maximum continuous service temperature of some polymers, e.g. PE and PP, is below 100 °C. Thus, the compound foil examined in this paper (PE-Al-PET) is very prone to thermal stress; especially the asymmetry (PE–PET) leads to a pronounced tendency to curl.

Since the composite film used for the investigation was provided on a roll, it already showed distinct memory curl if cut in sheets for processing on a flatbed screen printing press. To prevent the curling of the substrate during the investigations completely, the compound films were laminated on a rigid carrier substrate, which can withstand temperatures of at least 120 °C for several minutes without deforming.

1.1 Preliminary tests

In a preliminary test series, the materials listed in Table 1 were examined. Without lamination to a carrier the compound foil curls immediately even when heated at low temperature, starting already from 40–50 °C. The substrate carrier supports the compound foil, which is laminated onto the carrier by printed adhesives. As can be seen in Figure 2, if the adhesion of the foil to the carrier is not good enough the foil delaminates and curls severely. Two adhesives were printed in three different patterns. The honeycomb pattern showed good adhesion, but the pattern was visible in the image printed on the laminated compound foil. Rigid substrate carriers like the phenolic paper improve the processability, whereas the cardboard used here also tended to curl (see Figure 3). Both adhesives performed similar and showed promising results. The solvent-based adhesive was chosen for further tests because of ease of use. Based on the results of the preliminary tests the examination of alternative thermal techniques that avoid oven treatment and maybe curl gains more and more attractiveness.

1.2 Alternatives to thermal treatment in an oven

Looking for alternative technologies for the thermal treatment of functional layers is a constant topic of research in the field of functional coatings and especially in the field of nanoparticles (German, 1996). Processes such as e.g. microwave (Perelaer, de Gans and Schubert, 2006), or IR-treatment (Tobjörk et al., 2012) and others have been tested. In this investigation, two techniques of applying heat have been tried. These two devices, which are commonly used in the graphic arts industry − a heat press usually used for

Table 1: Preliminary tests for identifying the main problems of processing the PE-Al-PET compound foil

Substrate carrier	Cardboard or phenolic paper
Adhesive	Water based dispersion or solvent based
Adhesive pattern	Full area, frame or honeycomb pattern
Screen mesh	Sefar PET 1500 120-34 or Sefar PET 1500 77-48
UV ink	SunChemical SunTronic 680 or Marabu Ultraswitch UVSW
Silver ink	Acheson Electrodag® PM-406

textile prints and a hot stamping machine – in the following are compared to oven drying. Both devices provide temperature and pressure at the same time. The pressure, however, was neglected in this examination and was set to a minimum. The heat press applies heat and pressure on an area of 37.5 cm × 27.5 cm. The hot stamping machine utilizes interchangeable stamps such that only the area of interest is pressed and heated.

The stamp used in the tests was of the same size as the test structure. This is considered as a major advantage of the hot stamping process, because the thermal loading to the substrate and the dimensional instability is assumed being less with the hot stamping. The thermal and mechanical impact on the printed layers may also have positive impact on the adhesion to the investigated substrate.
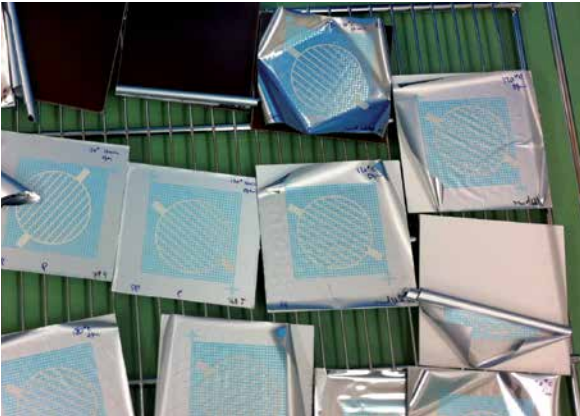
Figure 2: Effect of oven treatment on the dimensional stability of the laminated substrate; if the adhesion to the carrier was too weak, the samples pulled off and curled

a)   b)   c)
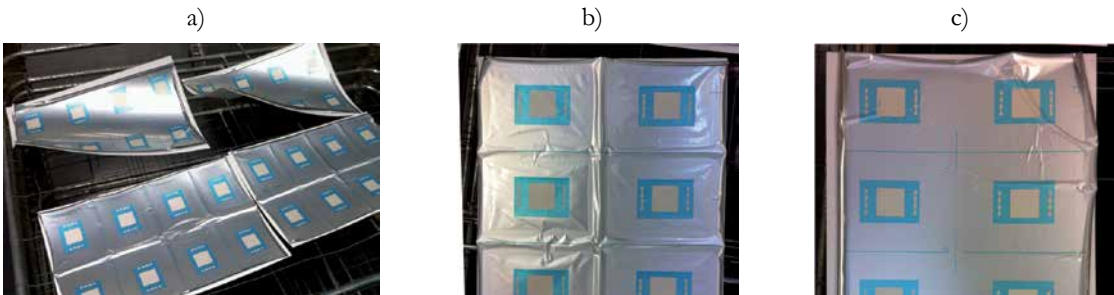
Figure 3: The full area adhesive sheets on cardboard are curling – two samples in rear of a) and sample in c), whereas the adhesive free parts of the frame laminated substrates at two foremost samples in a) and b) act as a kind of "expansion joint" due to different shrinkages

2. Materials and methods

2.1 Materials

The materials and patterns that were chosen for further experiments were based on the preliminary tests. The experiment setup is listed in Table 2.

The cardboard laminates were susceptible to the temperature impact in the batch oven. Since the investigation is aiming towards less temperature loading to the substrate, cardboard is a good indicator for excessive thermal loading.

The frame-patterned adhesive allows for better removal of the attached substrate, whereas the full area printed adhesive may show improved stability during printing and further processing.

2.2 Methods

The UV-curing ink is printed on the substrate without plasma treatment. In the preliminary tests, the Sun Chemical ink provided good results. Other UV inks and solvent-based inks were not able to adhere to the untreated PE surface. The silver ink test patterns – as shown in Figures 3 and 4 – are used for electrical measurements with a four-point probe setup. The printed square was used for crosscut tests. The ink layer thickness was measured with an optical 3D-microscope and

Table 2: Materials and adhesive patterns

Substrate Carrier	Cardboard
Adhesive	Solvent based KIWOPRINT TC 2500/1
Adhesive pattern	Full area or frame
UV Ink	SunChemical SunTronic 680
Silver Ink	Acheson Electrodag® PM-406
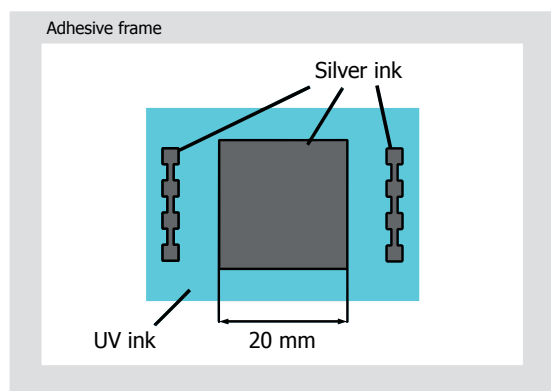
Figure 4: The test layout consisting of an adhesive frame (or full area printed adhesive, not shown), UV curing ink and silver ink test structure (1 mm width – left; 0.75 mm width – right) for four point probe measurement and area for crosscut tests

verified with a mechanical thickness tester. The electrical measurements were performed with a digital multimeter.

The samples were printed on cardboard reinforced PE-Al-PET compound foil with an EKRA X-1 screen printer (EKRA GmbH, Germany). Prior to printing the test samples, the adhesive KIWOPRINT TC 2500/1

3. Results and discussion

3.1 Effect of thermal process on ohmic resistance

Thermal treatment of conductive inks printed on sheet-fed material is mostly performed in batch ovens. These allow curing of functional inks from room temperature up to roughly 300 °C. Curing temperature and time are limiting factors for manufacturing processes in printed electronics. In this specific scenario, the temperature is even more critical, since it causes dimensional distortion due to the low maximum processing temperature of PE and mismatch in the thermal shrinkage behaviour of the two polymer layers. This results in registration difficulties of the successively printed ink layers. The batch oven curing process is therefore not useful for processing this specific substrate. Samples, which were cured in the batch oven, are the reference samples to compare with the alternative processes. The negative impact (curl, pronounced shrinkage) of the batch oven curing is shown in Figures 2 and 3.

Figure 5 shows the ohmic resistance results of the reference samples for the two different line widths (0.75 and 1 mm) of the silver printed line patterns (see Figure 4).

In Figure 6, the influence of the heat press is illustrated. The effect of temperature is shown in the diagram in Figure 6a. The higher the temperature, the lower is the ohmic resistance. In Figure 6b, the effect of

was printed onto the cardboard substrate carrier and laminated with the compound foil. The screens were tensioned with PET 1500 120-34 and 77-48 meshes (SEFAR AG, Switzerland). The stencils were made of AZOCOL Z 160 HV emulsion (Kissel + Wolf GmbH, Germany). The UV curing dielectric ink SunTronic 680 (Sun Chemical Corporation, USA) was used as the adhesion agent. The silver ink Acheson Electrodag® PM-406 (Henkel AG & Co. KgaA, Germany) was used for electrical characterization of the print samples. Plasma treatment was performed with a desktop ambient atmosphere plasma-device (Plasmatreat GmbH, Germany). The oven-cured samples were processed in a batch oven (Binder, Germany). The heat press picollo plus (Walter Schulze GmbH, Germany) and the hot stamping press (Robertshaw, USA) were used for examining alternative thermal treatment. Four point probe measurements were performed with spring-loaded round-shaped probe heads (Feinmetall, Germany) and a digital multimeter M3510A (Picotest Corp., USA). Adhesion was tested with a Cross-Cut-Tester, 1 mm, DIN/ISO (BYK-Gardner GmbH, Germany). The thickness of the layers and overall roughness were determined with an optical microscope Infinite Focus (Alicona Imaging GmbH, Austria).

pressing time is shown at 5, 10 and 15 seconds, which is in accordance to the literature (Xu et al., 2013). As expected, the ohmic resistance is linearly decreasing with increasing process time. The way the compound foil is attached to the substrate carrier seems to influence the ohmic resistance as well. At least there is a tendency of increased ohmic resistance when the adhesive for laminating the compound foil on the carrier covers the full area. The samples which are laminated by using only a frame of adhesive surrounding the image area show slightly lower ohmic resistances.

The same effect of processing time on the ohmic resistance is evident in the case of the hot stamping processed print samples. In Figure 7, the percentage of ohmic resistance reduction is plotted. In Figure 7a of the diagram the influence of the processing temperature is shown, whereas Figure 7b shows the effect of the processing
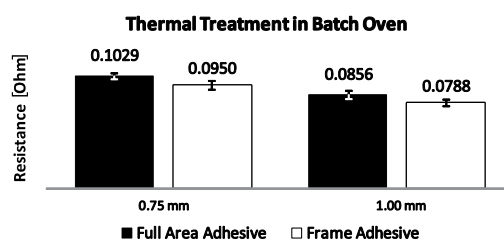
Figure 5: The thermal treatment in the batch oven is the reference for alternative curing processes

a) Heat Press: Temperature Effect
■ 80 °C ■ 100 °C □ 120 °C   Pressing Time: 15 s

b) Heat Press: Pressing Time Effect
■ 5 s ■ 10 s □ 15 s   Temperature: 80 °C
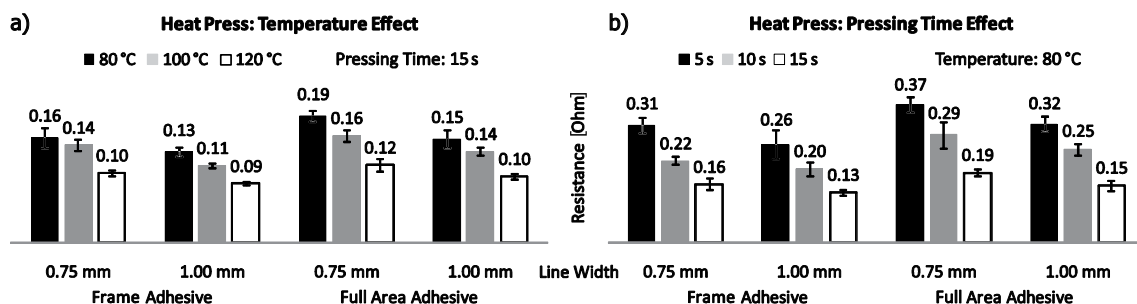
*Figure 6: The heat press is capable of reducing the ohmic resistance,
where the achievable resistance is in the same order of magnitude as with oven-dried samples*

a) Hot Stamp: Temperature Effect
■ 80 °C ■ 100 °C □ 120 °C Pressing Time: 1 s

b) Hot Stamp: Pressing Time Effect
■ 15 s ■ 30 s □ 1 s   Temperature: 120 °C
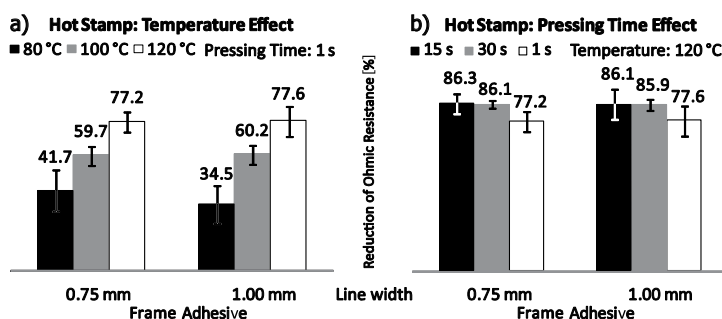
Figure 7: The process of hot stamping provides an efficient way of reducing the ohmic resistance

time. Even at a low temperature of 80 °C and with a very short processing time of one second, the reduction is very high, achieving ~ 40 % ohmic resistance reduction. At higher temperatures and longer pressing times of 15 seconds, the ohmic resistance is reduced about 86 %. Increasing the impact time from 15 to 30 seconds or even to 60 seconds does not reduce the ohmic resistance any further. It seems reasonable that at this point the maximum percolation of the conductive particles is achieved. Moreover, the print samples are deformed when pressing for 60 seconds.

As depicted by Figure 8, the samples dried at room temperature show the highest ohmic resistance. The resist-

ances of the heat press samples are slightly higher than the batch oven results. The lowest ohmic resistance is achieved by the hot stamp samples. The advantage of hot stamping is faster processing and less impact on the substrate. The heat press is less efficient and more harmful to the substrate than hot stamping.

3.2 Impact of stress on morphological parameters

In order to identify the mechanical stress of the heat pressing and hot stamping on the printed layers, the morphological properties were measured. Important parameters are the surface roughness, layer thickness and adhesion to the underlying substrate. Roughness and

Impact of Thermal Processing on Ohmic Resistance

■ Room Temperature
■ Heat Press, 120 °C, 15 s
▪ Batch Oven, 120 °C, 15 min
□ Hot Stamping, 120 °C, 15 s
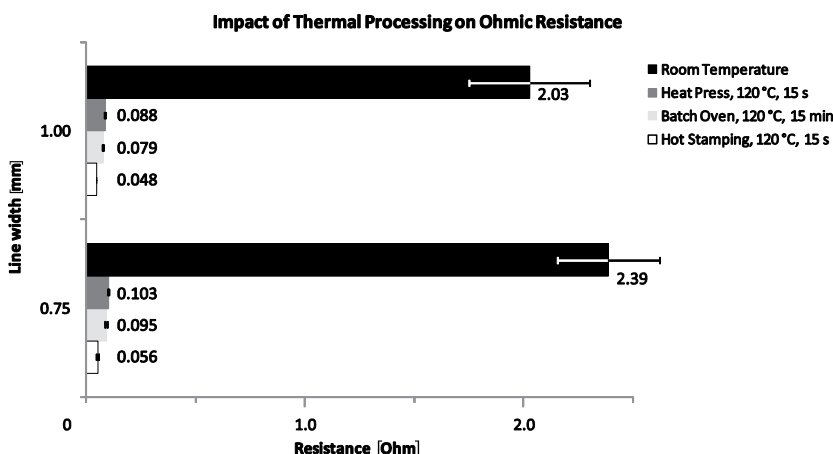
Figure 8: Comparison of the investigated routes for post-treatment of conductive silver ink
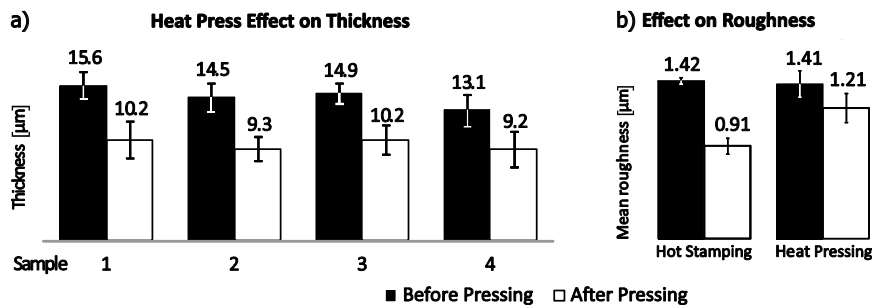
Figure 9: Decreased layer thickness after heat pressing at 120 °C for 15 s a), and the heat pressing effect on the roughness Sz maximum height parameter b)

thickness values were obtained by optical 3D-microscope measurements based on focus variation (Alicona infinite focus). Thickness and roughness data were obtained before and after the treatment with heat pressing and hot stamping at 120 °C for 15 seconds. The adhesion strength of the ink layer was tested in crosscut and tape-tests.

3.2.1 Thickness and roughness

The heat press processed samples showed thickness differences after pressing. Reliable thickness data could only be obtained from the samples, which were processed with the heat press. The results of the thickness measurements for a process temperature of 120 °C and a processing time of 15 seconds are given in Figure 9a. The samples were printed on full area laminated substrates.

On average, the layer thickness decreased about 30 %. Values dropped from roughly 13–15 μm to about 9–10 μm. The heat press process did not damage the samples, whereas visual inspection clearly showed the impact of the hot stamp on the samples (imprint of the stamp). It is likely that the pressing process leads to a densification of the silver layer that decreases the overall thickness. This observation is supported by the fact that the surface roughness changed, too.

After thermal treatment by hot stamping or heat pressing, the roughness of the silver layer decreased notice-

ably. The overall mean roughness seems to be lower for the samples which were processed with the hot stamp. Deviations in terms of surface roughness (Sz, maximum height of the surface) are in the range of 15 % for the heat pressed samples and up to 35 % for the hot stamped samples.

It is assumed that the significantly higher pressure of the hot stamping influenced the surface of the samples largely, what can be observed visually. An image, which clearly shows the imprint of the stamp on the sample, is given in Figure 10.

3.2.2 Crosscut, tape test and creasing test

The general adhesion of the ink on the substrate was tested in two experiments: crosscut-test and tape test.

Samples were crosscut in a 90° angle. This led to 25 equally shaped squares. The test procedure is in accordance with ISO 2409 and ASTM D 3359-97 (Byk-Gardner, 2015; Deutsches Institut für Normung, 2013). This partially removed the small squares from the surface. Figure 11 shows the count of removed squares giving an indication of the adhesion of the ink.

Crosscut-tests on samples which had atmospheric plasma pre-treatment showed very good adhesion on the underlying substrate. The crosscut did not influence the adhesion at all.

a)　　　　　　　　　　　　　　　　　　　　　　　*b)*
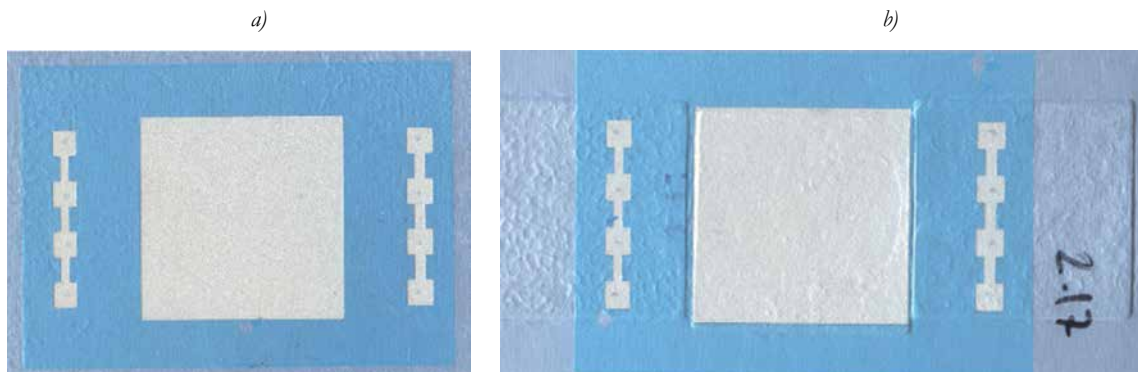
Figure 10: Heat press a) and hot stamping b), where the impact of the stamp is clearly visible
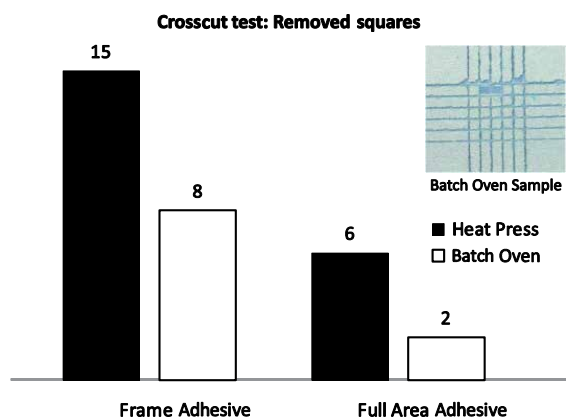
*Figure 11: Crosscut test on heat press
and oven-dried samples (120 °C, 15 min)*

The patterning of the adhesive layer (full area or frame laminated) seems to have an effect on the adhesion. According to Figure 11, the full area adhesive samples show fewer failures.

The adhesion of the ink layer seems to be temperature dependent as well. Samples which were heat pressed at 80 °C for 15 seconds showed less adhesion to the substrate compared to samples which were pressed at 120 °C for the same time. However, this test was done manually and thus slight variations in downwards pressure and cutting speed cannot be avoided. This could be optimized by an automatic crosscutting machine, which was not available. Further tests need to be done in order to prove this.

3.2.3 Tape test

A tape test was carried out, which partially or fully removed the ink layers from the substrate. This was true for all samples except for samples that were treated with plasma prior to printing. No tendency in terms of temperature related adhesion could be noticed regarding the tape test.

3.2.4 Creasing test

A manual crease roller was used to simulate mechanical stress on the functional ink layers. After creasing the samples, the compound foil and the substrate carrier were bent by 180°. A four-point probe measurement was performed after re-flattening the samples.

The increase in ohmic resistance was massive, but most of the samples still showed electric conductivity. It is only possible to judge the outcome of this test qualitatively, because the ohmic resistance measurement showed no consistently repeatable results and lacked reliability, as indicated by the huge error bars in Figure 12. Thus, the creasing test only provides the mere result of continuity or discontinuity of the electric pathway. However, as shown with this crease roller test, even a quite violent handling of the print layers does not destroy the functionality.
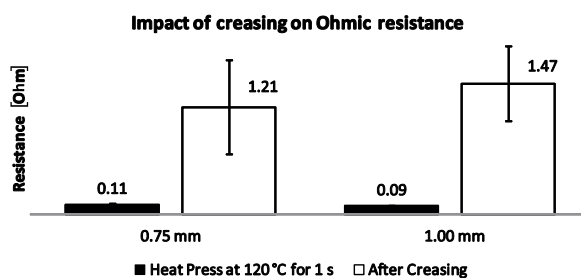
*Figure 12: Creasing the printed structures and bending the
compound film on the substrate carrier resulted in a massively
increased ohmic resistance*

4. Conclusions

The goal of this examination was to establish a route for screen printing electrically conductive structures on PE-Al-PET substrate. These structures are part of a printed battery that benefits from the properties of the compound substrate, i.e. the PE-weldability and the thin substrate thickness.

An UV-curing ink was introduced to act as an adhesion agent. This UV-ink improved the mechanical stability of the print samples. The formerly crumbling silver layers gained elasticity by the underlying UV-ink layer. The adhesion to the untreated substrate improved as well, but it is certainly less effective than a plasma treatment.

The heat press and hot stamping curing as an alternative to oven treatment showed also an improvement of the adhesion to the untreated substrate. Additionally, the ohmic resistances of the pressed samples were comparable (heat press) to or lower (hot stamping) than the samples post-treated in the batch oven at 120 °C for 15 minutes. The average thickness and roughness of the screen-printed silver layers seem to be influenced by the hot stamping and the heat pressing process, respectively. The crosscutting and tape test showed certain tendencies that need to be further investigated. Especially the influence of the temperature on the adhesion needs to be considered.

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Improvement of abrasion resistance by over-varnishing in the case of water-based flexographic printing

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Abstract

The objective of the research was to analyse the abrasion resistance in flexographic printing with water-based inks, covered with different water-based varnishes. Print rub-off tests in the Ink Rub Tester were performed for one water-based ink and three different water-based varnishes used in flexographic printing. The rub-off resistance was evaluated by spectrophotometric methods and visual observations. The ΔE^{*}_{ab} parameter was used in evaluation. The 3D optical microscope was used to analyse the obtained test results. It was observed that the varnishing process significantly improves the abrasion resistance of the prints. The type of the varnish used in the research does not have such an influence on improvement of abrasion resistance as that of the varnishing process itself. Considering the average surface roughness it could be deduced that the varnishing process increases the surface roughness for both the paper base and for the polyethylene foil. The greater the surface roughness the better is the resistance to abrasion.

Keywords: water-based ink, water-based varnish, surface roughness, spectrophotometric measurement,
ΔE^{*}_{ab} colour difference

1. Introduction and background

Flexography is a very rapidly developing technology, therefore it is very important to solve existing problems, search for new materials and improve their properties and also environmental friendliness to obtain high quality prints. That was the reason to become involved in the subject of water-based flexographic inks and varnishes.

It was observed that the popularity of water-based inks has increased significantly in recent years because water is the major component of these products. It was undoubtedly due to their properties such as environmental friendliness, inexpensiveness, non-flammability, work friendliness, etc., especially due to legal requirements on environmental friendliness. Nevertheless, water-based inks can cause problems in the printing process, despite given advantages. The high surface tension of water-based flexographic inks significantly reduces their adhesion to plastic substrates. Their adhesion is much lower than that of other inks used in this printing technology. Many authors, e.g. Mesic et al. (2005) and Mesic, Lestelius and Engström (2006) have addressed the subject of water-based inks and of the surface free energy of the substrate and the ink, but the findings presented in our research

on the quality of water-based flexographic inks may also contribute to development and improvement of these environmentally friendly inks. It is, therefore, important to investigate such properties as ink adhesion to the printing substrate or ink resistance to abrasion processes.

The issue of abrasion resistance improvement is within the scope of interests of the authors of the presented article (Gajadhur, 2012; Gajadhur, 2013; Gajadhur, 2014; Gajadhur and Wysokińska, 2013; Gajadhur and Jaszczuk, 2012). The detailed review of international standards for abrasion testing resistance was performed (American Society for Testing and Materials, 2004; International Organization for Standardization, 1997, 1997a, 1999, 1999a, 2000, 2003, 2009; Technical Association of the Pulp and Paper Industry, 1999) to define the existing knowledge base. The published papers on abrasion resistance (Ridgway, Gane and Gliese, 2006; Podhajny, 2005; Zhou et al., 2012; Zhao et al., 2012; Podhajny, 2000; Gane, Kozlik and Schoelkopf, 2005; Koivula, Gane and Toivakka, 2008; Mesic et al., 2005; Mesic, Lestelius and Engström, 2006; Salesin and Burge, 2011; Salesin et al., 2008; Hartus and Gane, 2012; Rentzhog and Fogden, 2006) were also analysed.

Podhajny (2005) indicates that in order to obtain a good scratch and abrasion resistance, an ink of appropriate composition is required. Ink containing an adequate amount of silicones or waxes can be more scratch and abrasion resistant. Zhao et al. (2012) considered the impact of varnishes on abrasion and scratch resistance. They studied how different waxes and resins and their respective content in the varnish can influence scratch and abrasion resistance. It was proved that the type of the resin and wax as well as their amount has a significant effect on resistance to abrasion and scratching. Evaluation of the 'rub off' resistance was based on the measurement of the gloss value before and after the abrasion process. A difference in gloss values of 1.5–6 % was found for different types of resins and waxes.

Zhou et al. (2012) addresses the influence of the substrate on the abrasion resistance of prints. The study involved seven different coated substrates – both glossy and matte – of various grammage. The abrasion resistance of printed matter was assessed, based on the change in optical density and changes in the ΔE^*_{ab} parameter. The research was based on one type of ink, namely the cyan offset ink. Viscosity modification was also included in the research. Prints were obtained from the IGT AIC-2-5 device. Abrasion resistance tests were performed with a Sutherland ink rub tester. The printed paper was rubbed in dry conditions with unprinted paper of the same type. Prints executed using different viscosity inks were also tested for rub off resistance. It was found that the absorption by the substrate and its smoothness has a great impact on abrasion resistance, whereas the viscosity of the ink has no significant effect on this parameter.

In their study, Chen and Liu (2008) presented abrasion resistance of a new type of UV inks designed for flexographic technology. Apart from abrasion resistance, other types of tests were performed, such as scratch resistance, 'Tessa® tape' tests on adhesion, and resistance to chemical agents. Abrasion tests were performed also on a Sutherland device. Polypropylene, polyester and polycarbonate foils were used in the studies. The study was performed to compare environmentally friendly UV inks with conventional UV inks.

Reduced resistance to abrasion may be caused by the low or insufficient surface free energy of the substrate. Surface wettability is characterised by direct contact angle measurements and spreading coefficient. The matter concerning the surface energy problem was presented by Mesic, Lestelius and Engström (2006). The print quality of water-borne inks applied on the LDPE (low density polyethylene) coated paperboard was studied. The LDPE layer was corona treated and the contact angle measurements were performed. The prints were made with an IGT F1 device, 432 hours after the corona treatment. The print properties such as print density, dot gain and mottling of cyan ink applied on the surface were examined.

In previous study by Mesic et al. (2005) it was shown that the surface roughness and corona treatment of polyethylene coated paperboard printed with water-borne flexographic inks significantly influence the rub off resistance of the printed sample. It was also proved that the surface free energy of the ink does not influence the print quality. The set of LDPE materials with different surface free energy and different surface roughness were examined in this study. The rub resistance was evaluated via such parameters as print density, white areas, dot gain and mottling. The cyan ink of 30 s Zahn cup # 2 viscosity was used in this study, and 1 % of surfactant was applied into the ink to reduce its surface energy. Prints were made both with modified and unmodified inks. It was proved that the corona treated samples display better abrasion resistance. Abrasion resistance was evaluated with the use of image analysis software. No influence of surfactant on the rub resistance of tested inks was observed. It was, however, observed that the surface roughness increased after corona treatment.

The problem of adhesion in the printing process studied by Mesic et al. (2005), and Mesic, Lestelius and Engström (2006), was considered also by Wolf (2010) in his research.

The problem of water-based flexographic inks applied on polymers was analysed in detailed studies by Rentzhog (2004), Rentzhog and Fogden (2006), and Rentzhog (2006). Three different printing materials, LDPE, oriented polypropylene (OPP) and polypropylene (PP), and differet inks were analysed by Rentzhog and Fogden, (2006). Wet rub and scratch resistance were evaluated. It was proved that the addition of silicone to the ink worsens the rub resistance, whereas the surface treatment of the substrate improves it. Moreover, it was proved that the rub resistance decreases from LDPE to PP to OPP substrates.

In the research of Zhao et al. (2012), the influence of different water-based varnishes in the printing production was studied only in the case of gloss value changes due to the influence of the abrasion process, but not in the case of abrasion resistance of the prints in respect to colorimetric properties.

The abrasion resistance of different varnishes (cellulosic, synthetic, polyurethane, water-borne and acid hardening) dedicated to wood technology was studied by Keskin and Tekin (2011). however not concerning the printing materials such as paper or foils. The rotation disc was used in these studies. The abrasion resistance was evaluated visually. If 50 % destruction of the sample was observed, the number of rotations was recognised as the measure for abrasion resistance.

2. Methods

This chapter describes materials and devices used in the research, preparation of the samples, as well as the detailed analysis of rub-off tests and evaluation of the abrasion resistance of the tested samples. The surface evaluation of the prepared samples is also discussed in this section.

2.1 Materials and devices

For the purpose of the study, water-based Pantone orange PMS 164 C ink was used. This ink was chosen for the research because of the previously identified poor abrasion resistance (Tomaszek, 2012).

Three different water-based varnishes intended for flexographic printing were also used in the study, namely:
- high-gloss (Varnish 1),
- standard gloss (Varnish 2),
- matt (Varnish 3).

The following substrate materials and tools were used in the study:
- polyethylene (PE) foil Flexipack M3L white, three-layered (25 %, 50 %, 25 %),
- gloss coated paper (illustrated in Figure 1),
- sand paper made of silicon carbide of granulation P-180, in accordance with the recommendations of ISO 5470-1 (International Organization for Standardization, 1999a),
- grey scales for assessing the change in colour (Figure 2a) and grey scales for assessing the staining (Figure 2b),
- anilox roller with screen ruling 80 l/cm and ink capacity of 10.2 cm³/m²,
- anilox roller with screen ruling 22 l/cm and ink capacity of 50.1 cm³/m²,
- anilox roller with screen ruling 40 l/cm and ink capacity of 39.1 cm³/m².

layer coating 2
layer coating 1
pre-coating layer
bleached pulp (TCF)
pre-coating layer
layer coating 1
layer coating 2

Figure 1: Structure of gloss coated paper base used in the studies

To perform the research it was necessary to use:
- Ford cup ø 4 mm,
- RK Print K-lox manual device (Figure 3),
- TMI Ink Rub Tester with test block weighing 1.81 kg,
- Gretag Macbeth Spectrolino, and SpectroEye spectrophotometer,
- X-Rite KeyWizard software,
- HP LJ100 M175 scanner,
- Bruker Contour GT K1 3D optical microscope.

2.2 Sample preparation

Activated PE foil and gloss-coated paper base were printed with water-based orange PMS 164C Pantone ink in ambient conditions (23 °C and 50 % RH). Prints on PE foil and on coated paper base were obtained with the use of a K-lox RK Print manual device (Kontech). One anilox roller with screen ruling of 80 l/cm and ink capacity of 10.2 cm³/m² was used for obtaining the prints. The K-lox manual device was moved under constant load of approx. 816 g. The width of obtained prints did not exceed 115 mm (Kontech, n.d.). The flat colour print was obtained using the method described.

In the next step, the prints were evaluated visually for the quality of the ink transferred onto the paper or

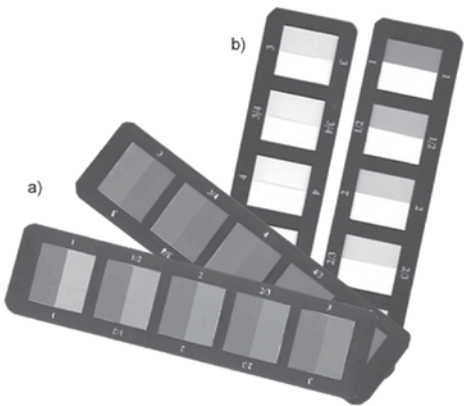*Figure 2: a) Grey scales for assessing the change in colour, b) grey scales for assessing the staining (grey scales prepared by the authors)*
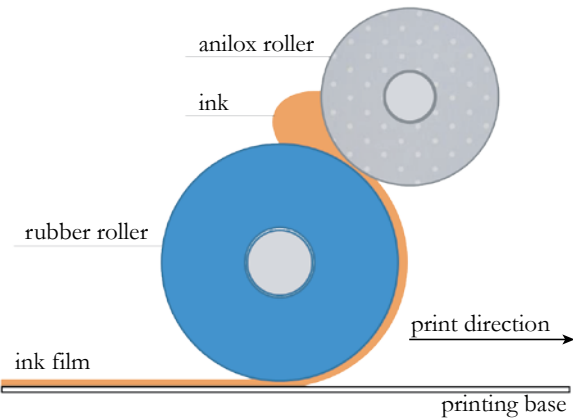
Figure 3: K-lox RK Print device (Kontech)

foil. Only those with a high quality obtained ink layer were selected for further research. After 24 hours, prints were coated with the appropriate layer of the varnish.

The varnish layer was applied to the prints also by means of the K-lox manual device. Two different thicknesses of varnish layer were applied to the prints, using two different anilox rollers, the one with screen ruling of 22 l/cm and ink capacity of 50.1 cm³/m² and the one with screen ruling of 40 l/cm and ink capacity of 39.1 cm³/m². The varnish viscosity was measured using Ford cup ø 4 mm.

2.3 3D surface morphology studies

To analyse the surface morphology of obtained samples, the Bruker Conour GT K1 3D optical microscope was used in the studies (Bruker, 2013). Only the samples varnished with the 40 l/cm anilox roller were analysed.

2.4 Abrasion resistance tests

Varnished prints were tested for abrasion resistance after 24 hours of conditioning in the Ink Rub Tester device, according to the Sutherland method (American Society for Testing and Materials, 2004) and to the method developed in the Department of Printing Technology, WUT (Gajadhur, 2014). The total number of cycles performed in the Ink Rub Tester device was 60 070 cycles. Tests were performed in "dry" conditions, which means that the sample prepared on PE substrate was subjected to rub resistance with contact against the unprinted PE foil (named as PE receptor) and with abrasive paper made of silicon carbide of granulation P-180, according to the recommendations of ISO 5470-1 (International Organization for Standardization, 1999a), whereas the sample prepared on gloss-coated paper base was abrasion tested with contact against the unprinted gloss-coated paper (named as paper receptor). The test block weighing 1.81 kg was used. The device speed of 100 cycles/min was applied in the research.

Samples for the Ink Rub Tester device (TMI, 2015) were prepared in the following manner: the backing material of 152 mm × 76 mm size was attached to the Ink Rub Tester device table using adhesive tape; then the printed sample of 152 mm × 60 mm size was attached to the backing also with adhesive tape; finally, the receptor –

unprinted material (film, paper or abrasive paper) with dimensions of 178 mm × 51 mm – was bent and placed on the test block. Each sample was tested for 5 000 abrasion cycles.

A visual assessment of abrasion and spectrodensitometric measurements were performed every 100 cycles from 0 to 500, then every 500 cycles up to 5 000 cycles. Also, the sample was scanned at each stage of the abrasion tests in order to register occurring changes. The spectrophotometric measurements were collected with the use of KeyWizard X-Rite software. At each stage of abrasion, CIELAB values, CIELCH, and the main partial optical density of process colours were measured on the sample and the receptor. Three measurements were taken both for the sample and for the receptor, i.e. a polyethylene foil or unprinted gloss-coated paper base, at every stage of the abrasion tests, respectively. These measurements were performed each time in the same square 5 mm × 5 mm that was marked both on the receptor and on the sample.

The colour coordinates CIELAB, the colour attributes CIELCH and the main partial optical density were measured under the following conditions:
- illuminant D50,
- 2° colorimetric observer,
- density standard DIN NB,
- absolute reflectance,
- no polarization filter.

Firstly, the mean of measured parameters and then the value of the ΔE^*_{ab} parameter ware calculated on the basis of Equation 1,

$$\Delta E^*_{ab} = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2} \qquad [1]$$

where ΔL^*, Δa^* and Δb^* are differences between the coordinates L^*, a^*, and b^* of measured colour and reference.

The results obtained for samples covered with films of different varnish layers were compared to the results obtained for unprotected samples.

The grey scale for assessing the change in colour and the grey scale for assessing the staining (Figure 2) were used in the evaluation of samples.

3. Results

3.1 Surface morphology results

Three-dimensional images of the surface morphology are presented for the PE substrate (Figures 4 and 5) and for the paper base (Figures 6 and 7).

In Figures 4 and 5, the ribbing of the ink and also of the varnish layer is observed on the 3D microscopy maps, changing from short wavelength to longer wavelength in the case of the PE substrate. The similar effect is observed on the paper (Figures 6 and 7), but some-
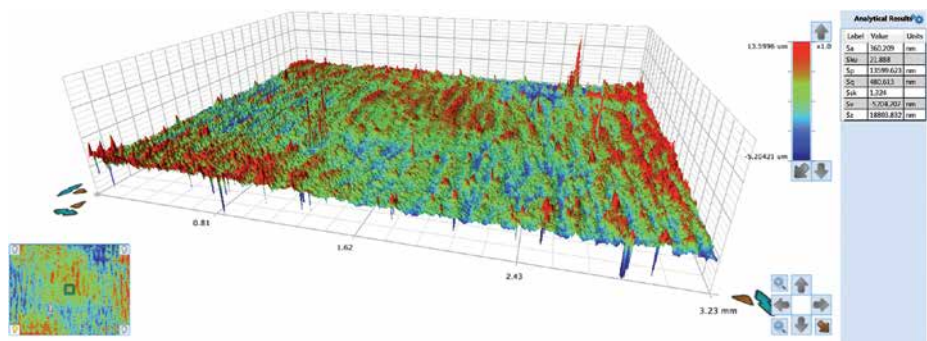
Figure 4: Three-dimensional image of the PE foil surface with the ink layer
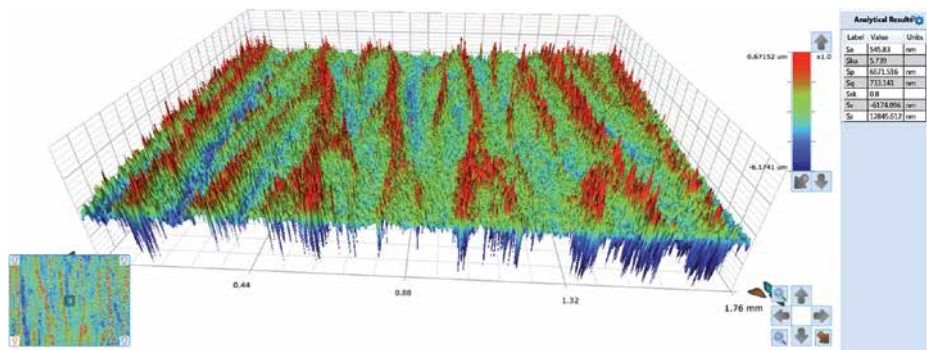
Figure 5: Three-dimensional image of the PE foil surface with the ink and Varnish 3 layer
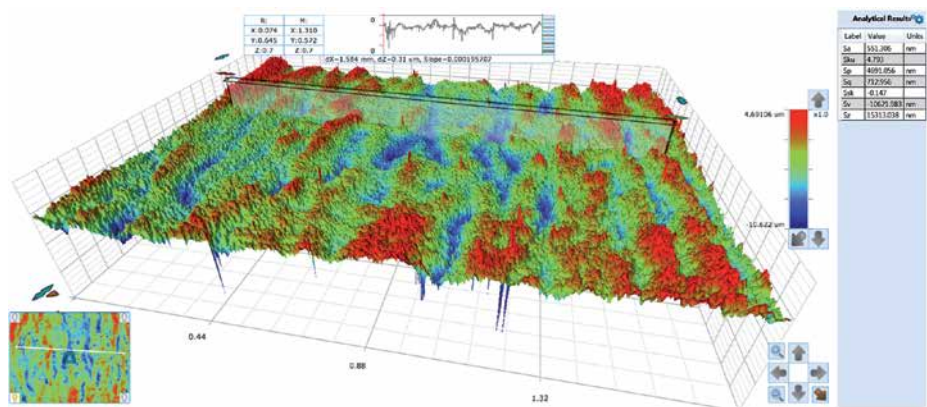
Figure 6: Three-dimensional image of gloss coated paper base surface with the ink layer
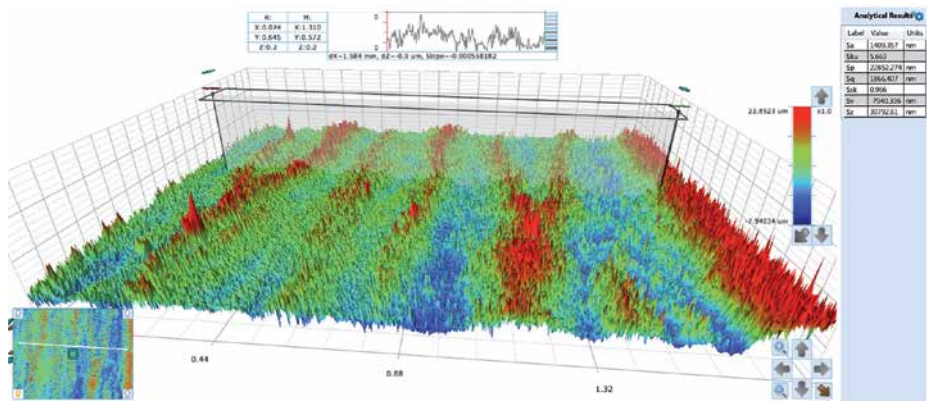
Figure 7: Three-dimensional image of gloss coated paper base with the ink and Varnish 3 layer

what less well formed. Perhaps it is related to a possible different viscoelastic behaviour between the ink and varnish used, leading to a material dependent elastic recovery after the film split.

In Figure 8, the average surface roughness (arithmetic mean height, S_a) is compared in a graphical form both for the paper base and for the PE foil.
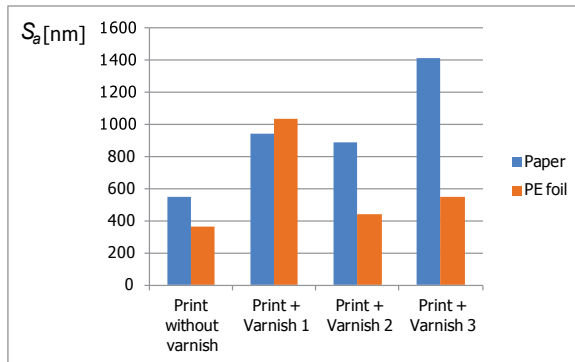
Figure 8: Average surface roughness (S_a) of all tested materials

In Figure 8 it is observed that average surface roughness of the paper samples is roughly twice the value compared to the average surface roughness of the PE samples except for the print coated with Varnish 1. The S_a value for the varnished and unvarnished PE substrate remains at a quite similar level, again with the exception of the print coated with Varnish 1, which has the highest S_a value measured.

3.2 Viscosity of varnish

The results of viscosity measurements with the use of Ford cup ø 4 mm of all varnishes tested in this research are presented in Table 1.

3.3 Abrasion resistance

The ΔE^*_{ab} parameter (colour differences) changes due to abrasion of the prints on PE foil, both varnished with three different varnishes and without varnishing, are presented in Figure 9a for the PE foil sample and in Figure 9b for the PE foil receptor. The varnish layer in this case was obtained with the use of the 22 l/cm anilox roller.

The influence of the varnish layer thickness applied over the print on the rub-off resistance is demonstrated in Figures 10 and 11. Results for three different varnishes are presented. The thicker varnish layer was obtained with the use of the 22 l/cm anilox roller, whereas the thinner with the use of the 40 l/cm anilox roller. The results for both screen rulings are presented. Figure 10 compares results obtained for the printed samples, whereas Figure 11 shows the results of the transfer onto the PE unprinted receptors. Similarly, the results obtained on the gloss coated paper substrate are presented in Figures 12 and 13. In this case the varnish layer was applied only with the use of the 40 l/cm anilox roller. Figure 12 presents the results obtained on the samples, whereas Figure 13 the results obtained on unprinted gloss coated base receptors. Further, printed

Table 1: Viscosity of varnishes measured with Ford cup ø 4 mm (three measurements per sample)

Sample	Viscosity [s]			
	1	**2**	**3**	**Average**
Varnish 1	124	111	112	116 (1 min 56 s)
Varnish 2	212	180	195	196 (3 min 16 s)
Varnish 3	43	43	43	43
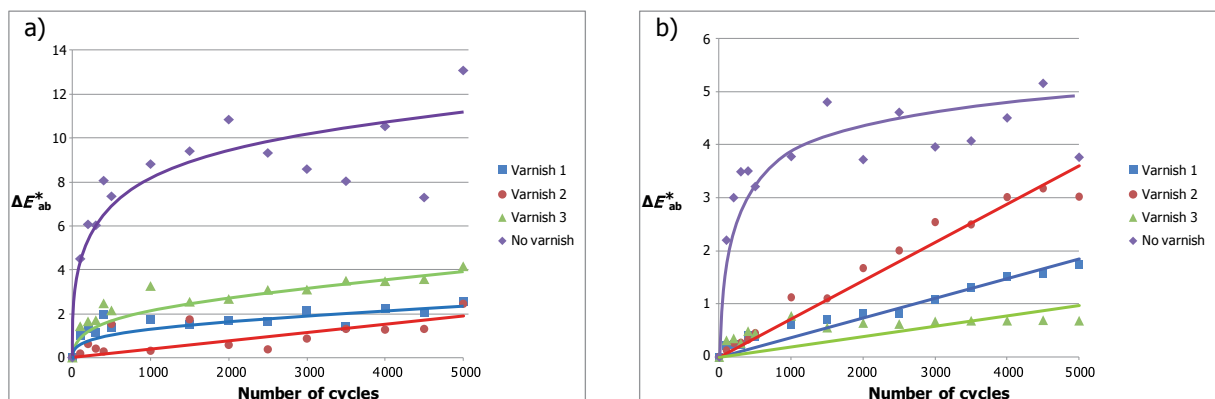
Figure 9: ΔE^*_{ab} parameter changes due to the abrasion resistance process for PE foil a) samples and b) receptors; varnish applied with 22 l/cm anilox roller

a)

b)
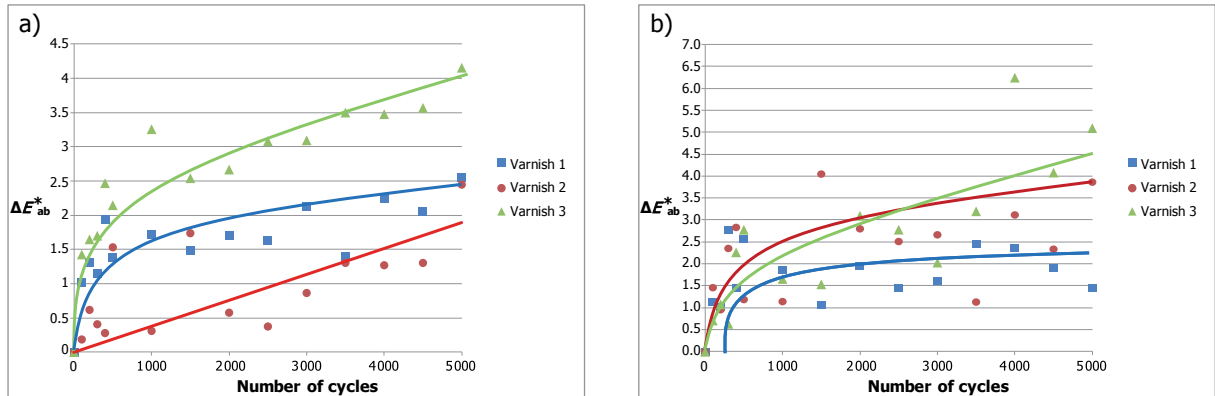
*Figure 10: Comparison of ΔE*_{ab} parameter changes due to the abrasion resistance process for varnishes applied with different anilox rollers, for PE foil samples: a) 22 l/cm, b) 40 l/cm anilox roller*

a)

b)
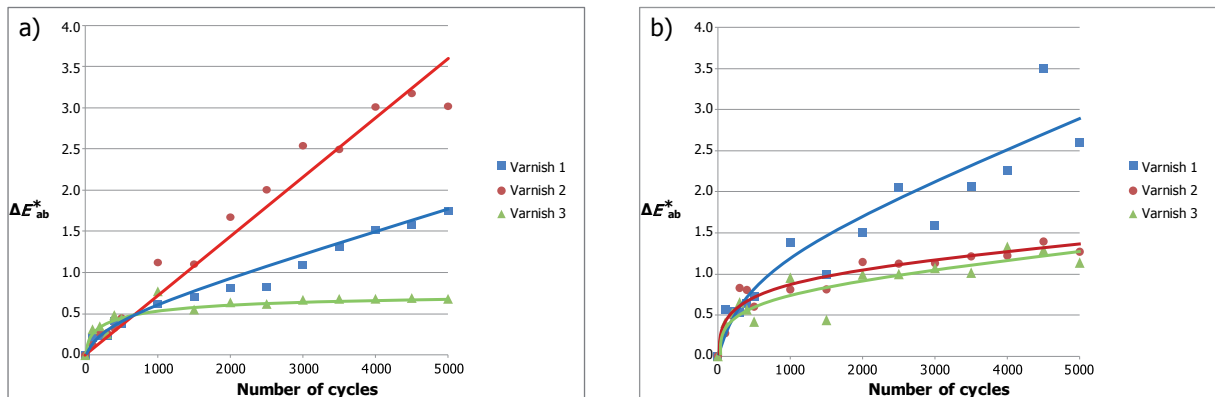
*Figure 11: Comparison of ΔE*_{ab} parameter changes due to the abrasion resistance process for varnishes applied with different anilox rollers, for PE foil receptors: a) 22 l/cm, b) 40 l/cm anilox roller*
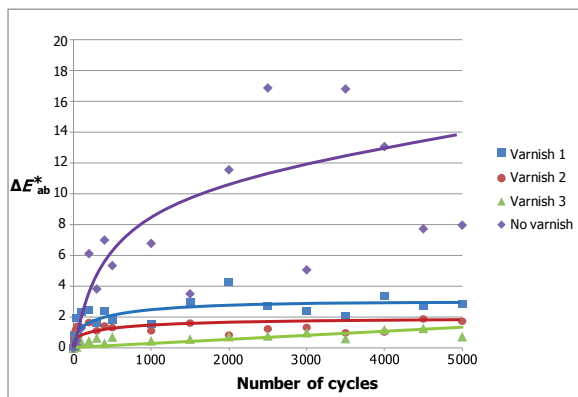
*Figure 12: ΔE*_{ab} parameter changes due to abrasion resistance process, for gloss coated paper samples, varnish applied with 40 l/cm anilox roller*
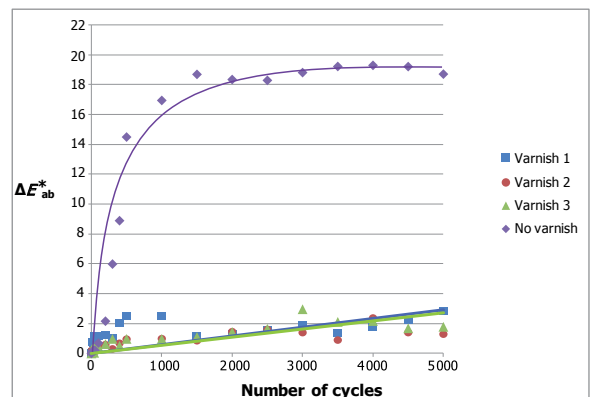
*Figure 13: ΔE*_{ab} parameter changes due to abrasion resistance process, for gloss coated paper receptors, varnish applied with 40 l/cm anilox roller*

samples were tested for abrasion resistance with different materials. The results of the abrasion tests with sand paper are presented in Figure 14. Only the samples printed on PE foil were tested by this means.

Table 2 was created on the basis of the grey scale patch measurements both for assessing the change in colour

and staining. The measurements were performed using two different GretagMacbeth spectrophotometers, i.e. Spectrolino and SpectroEye, with the following measuring conditions: illuminant D50 and 2° colorimetric observer. It should be noted that the values of the ΔE^{*}_{ab} parameter changes described in the standards (International Organization for Standardization, 1993; International
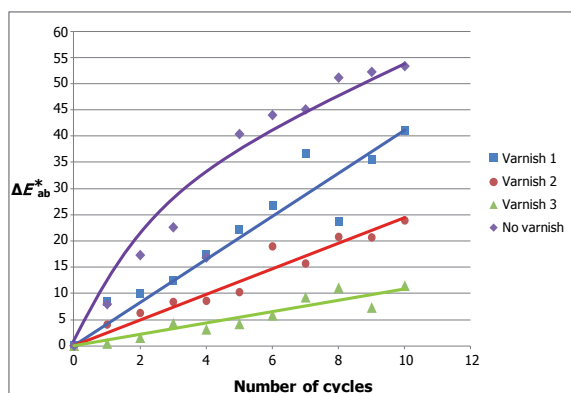
Figure 14: ΔE^*_{ab} *parameter changes due to abrasion resistance process with abrasive paper, for PE foil samples, varnish applied with 40 l/cm anilox roller*

Organization for Standardization, 1993a) apply only to the measuring conditions involving illuminant D65 and 10° colorimetric observer. The methodology for assessing abrasion resistance is described by Gajadhur (2014).

Evaluation of abrasion resistance (Tables 3–5) was performed on the basis of samples and receptors measurements (materials used for sample abrasion), by monitoring the changes with respect to grey scale grades for assessing change in colour and grey scale, for determining the transfer staining, respectively. The evaluation was, thus, based on the ΔE^*_{ab} parameter value after 500 cycles of abrasion on the sample with respect to the grey scale for assessing change in colour and in case of receptors with respect to the grey scale for assessing staining (Table 2).

Table 2: ΔE^*_{ab} *changes according to grey scale for assessing the change in colour and grey scale for assessing the staining*

Grey scale for assessing the change in colour grade		Grey scale for assessing the staining grade	
Grey scale grade	ΔE^*_{ab}	Grey scale grade	ΔE^*_{ab}
5.0	0–0.5	5.0	0–2
4.5	0.5–1.5	4.5	2–4
4.0	1.5–2	4.0	4–6
3.5	2–3	3.5	6–9
3.0	3–4	3.0	9–12
2.5	4–6	2.5	12–17
2.0	6–9.5	2.0	17–24
1.5	9.5–13.0	1.5	24–36
1.0	>13	1.0	>36

Table 3: ΔE^*_{ab} *parameter changes due to the abrasion process on the PE foil after 500 rub-off cycles and evaluation of abrasion resistance according to grey scale for assessing the change in colour and grey scale for assessing the staining (varnish applied with 22 l/cm anilox roller)*

PE foil substrate	Sample		Receptor		Average grey scale grade
	ΔE^*_{ab}	Grey scale grade	ΔE^*_{ab}	Grey scale grade	
Print without varnish	7.34	2.0	3.21	4.5	3.25
Print + Varnish 1	1.38	4.5	0.38	5.0	4.75
Print + Varnish 2	1.53	4.0	0.45	5.0	4.50
Print + Varnish 3	2.15	3.5	0.44	5.0	4.25

Table 4: ΔE^*_{ab} *parameter changes due to the abrasion process on the PE foil after 500 rub-off cycles and evaluation of abrasion resistance according to grey scale for assessing the change in colour and grey scale for assessing the staining (varnish applied with 40 l/cm anilox roller)*

PE foil substrate	Sample		Receptor		Average grey scale grade
	ΔE^*_{ab}	Grey scale grade	ΔE^*_{ab}	Grey scale grade	
Print without varnish	7.34	2.0	3.21	4.5	3.25
Print + Varnish 1	2.57	3.5	0.72	5.0	4.25
Print + Varnish 2	1.19	4.5	0.60	5.0	4.75
Print + Varnish 3	2.78	3.5	0.42	5.0	4.25

Table 5: ΔE^*_{ab} parameter changes due to the abrasion process on the gloss coated paper after 500 rub-off cycles and evaluation of abrasion resistance according to grey scale for assessing the change in colour and grey scale for assessing the staining (varnish applied with 40 l/cm anilox roller)

Gloss coated paper substrate	Sample		Receptor		Average grey scale grade
	ΔE^*_{ab}	Grey scale grade	ΔE^*_{ab}	Grey scale grade	
Print without varnish	5.36	2.5	14.49	1.0	1.75
Print + varnish 1	1.85	4.0	2.52	3.5	3.75
print + varnish 2	1.34	4.5	0.95	4.5	4.50
print + varnish 3	0.73	4.5	0.97	4.5	4.50

An average abrasion resistance grade according to the grey scale for assessing staining and grey scale for assessing change in colour is presented in Figure 15 both for the printed paper substrate varnished with the 40 l/cm anilox roller and for the PE printed foil varnished with the 22 and 40 l/cm anilox roller. The values for samples without varnishing are also presented.

The pictures of abrasion tested samples before and after 500 and 5000 rub-off tests are presented in the Figures 16 and 17. Figure 16 shows the samples on PE substrate whereas Figure 17 the pictures taken from gloss coated paper substrate, both varnished with the 40 l/cm anilox roller.
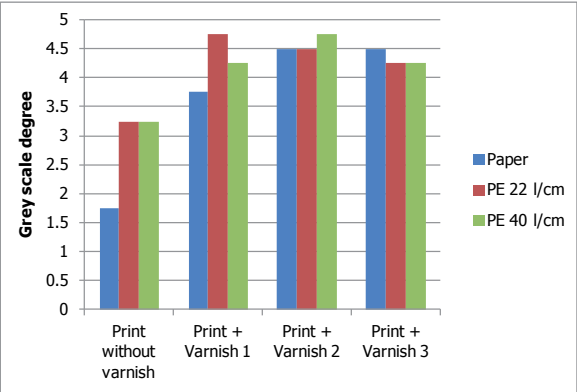
Figure 15: An average grey degree for the sample and receptor of abrasion resistance tested substrates

0 cycles	500 cycles	5 000 cycles
Sample without varnishing		
Varnish 1		
Varnish 2		
Varnish 3		

Figure 16: Pictures of abrasion tested samples of PE foil (varnish applied with 40 l/cm anilox roller)

0 cycles	500 cycles	5 000 cycles
Sample without varnishing		
Varnish 1		
Varnish 2		
Varnish 3		
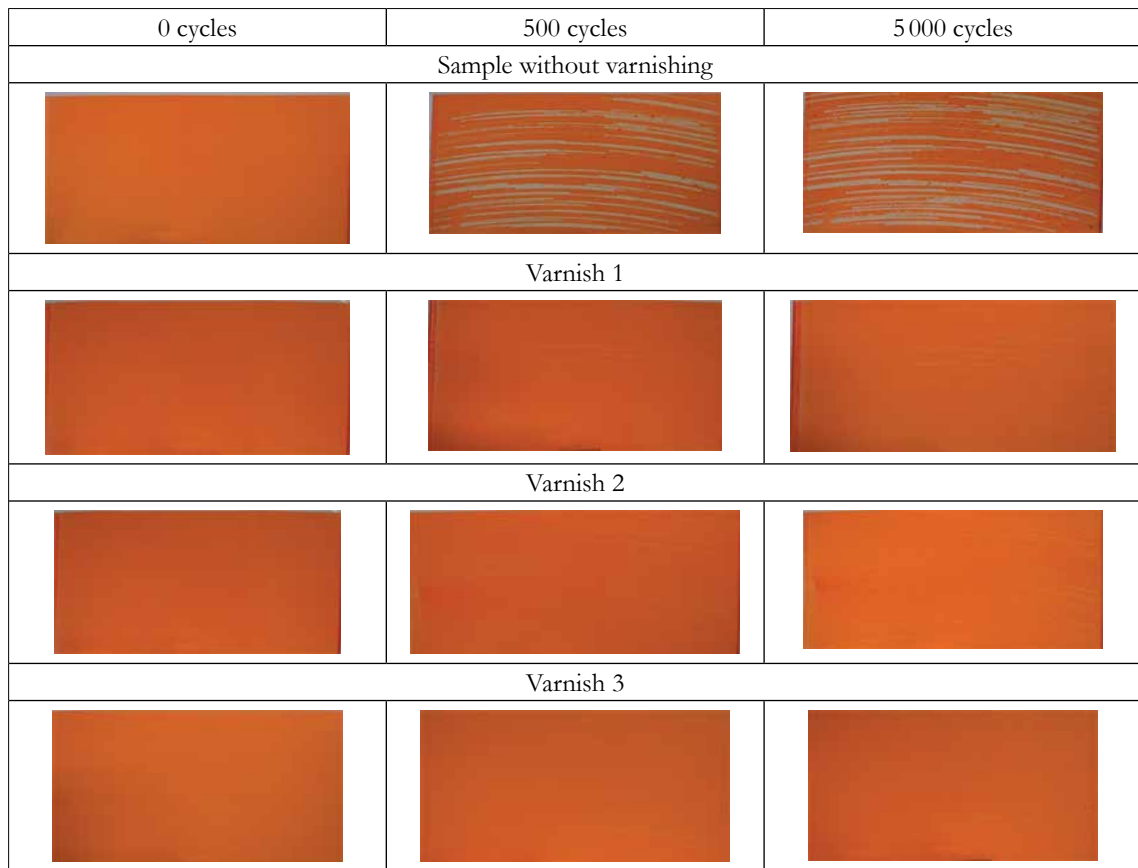
Figure 17: Pictures of abrasion tested samples of gloss coated paper base (varnish applied with 40 l/cm anilox roller)

4. Discussion

It was observed that the varnishing process significantly improves the abrasion resistance of the prints. It may be noted that an improvement of at least two grades of grey scale in the abrasion resistance due to varnish layer applied onto the prints is observed.

A triple abrasion resistance improvement obtained in comparison to the prints, which were not protected by the varnish, was observed for the PE foil substrate. In the case of gloss-coated paper substrate an approximate 8–9 times abrasion resistance increase was observed relative to the prints not protected by the varnish. It was also observed that changes in the parameter ΔE^*_{ab} are significantly greater on a paper rather than on a PE foil substrate in the case of samples not protected by the varnish. It was also found that the type of varnish, the thickness of the applied varnish film (using anilox rollers with 22 and 40 l/cm) and the differences in viscosity of the varnishes used in the study do not have such a significant impact on the improvement of abrasion resistance as the varnishing process itself. The differences in viscosities of applied varnishes resulted in different layer thicknesses. Presumably the thinner varnish layer was obtained for the matt sample (Varnish 3) with the low-

est viscosity whereas the thickest for the Varnish 2 with the highest viscosity. Slightly better abrasion resistance results were observed for Varnish 2. Perhaps applying an even thicker layer of varnish than that obtained with the anilox roller with screen ruling of 22 l/cm might result in greater abrasion resistance improvement.

The wide variation of the results for 'no varnish' PE foil prints (Figure 9a, 9b) as well as for 'no varnish' paper substrate prints (Figure 12) could be caused by poor, stochastic adhesion of the ink. In Figure 13, representing the receptor of the paper base, such a phenomenon of variation is not observed. The problem also is not seen in the Figure 14, where a strongly abrasive contact receptor such as sand paper was used in the studies.

Considering the average surface roughness it could be deduced that the varnishing process increases the surface roughness for both the gloss paper substrate and for the PE foil. According to Mesic et al. (2005) it could be noticed that the greater the surface roughness then the better is the resistance to abrasion. Reduced abrasion resistance of the printed paper substrate without varnish layer on it despite the high roughness coefficient

in reference to PE printed, but not varnished foil, may be caused by the ink penetration into the paper base. In the case of PE foil, the greater amount of the ink and varnish remained on the surface of the tested material causing the better surface abrasion resistance. Reduced abrasion resistance may be also caused by the uneven coverage by the ink due to its penetration into the paper base and insufficient adhesion to the covered substrate.

5. Conclusions

The need for improved resistance to abrasion and scratch resistance of water-based flexographic prints has become ever more relevant recently. It may be noted that an improvement of at least two grades of grey scale in the abrasion resistance by applying a varnish layer onto the prints is observed. In the case of the paper substrate even three grades improvement was observed due to the varnish application. The surface roughness of the tested material is also of great importance in the abrasion resistance process.

The type of the varnish used in the research does not have such an influence on improvement of abrasion resistance as that of the varnishing process itself.

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Evaluation and use of gamut information in ICC output profiles

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Abstract

A device's color gamut is an important parameter in color managed workflows. With the increasing use of expanded gamut workflows and the need for more colorful products in large-format inkjet printing or packaging, the management and prediction of in-gamut colors is critical information for the content creator. When device color capability information is stored within the structure of an ICC profile, this information becomes readily available to any software utilizing the ICC profile in conjunction with an image or image data. A product may for example offer a gamut stain or warning to indicate to the user that the color under consideration is out of gamut of the destination print process. This research compares the gamut predictions of Adobe Photoshop, ArgyllCMS, BabelColor PatchTool, Esko Color Engine Pilot, Little CMS and MathWorks MATLAB. It is shown that the different tools may use different methods to determine the color gamut of a system. In general, the methods available include a Round Trip test, use of the ICC profile Gamut Tag and a Gamut Boundary Descriptor process. The Gamut Tag was read-in and displayed for different ICC profiles and differences in the tag contents was demonstrated. In total, 1729 CIELAB values, representing the PANTONE+ Solid Coated Library V2 were used and the percentage of in-gamut values using each software product was computed for different output print processes. There was a large difference in the predictions between the different products tested; the software tools variously predicted that 30–65 % of the library was in-gamut. A general philosophy of an ICC workflow is predictable result; while the ICC architecture is not intended to change a device's gamut capabilities, it should be able to communicate accurate and consistent gamut information. As more and more software systems are starting to present gamut data, it is important that systems do not predict disparate results.

Keywords: color gamut, color management, lookup tables, PANTONE, ICC Gamut Tag

1. Introduction

A first step in color management is often generation of print characterization data, where target patches of known CMYK inking are printed and measured to produce CMYK-CIELAB pairs. Print characterization data inherently contains color gamut information and therefore so does an ICC profile that is made from this data. Color gamut is defined as the range of colors that a device can reproduce. Gamut information, embodied within an ICC profile, can be accessed by software programs which display to the user whether a requested color is in or out of gamut of a given print process. In this research we use a set of known CIELAB values, in this case the CIELAB values that represent the PANTONE+ Solid Coated Library V2, and compare the gamut predictions of a range of software tools for different characterization datasets and ICC profiles (GRACoL, SWOP #3, SWOP #5, Fogra39, etc.). The software tools used in this project range from mainstream products such as Adobe Photoshop to programmable tools such as MATLAB, ArgyllCMS or C++ libraries from Little CMS.

After color characterization data has been empirically determined for a device, this information is implicitly and explicitly available within an ICC profile. Device gamut information is implicitly available within ICC profile lookup tables that can be used in a *Round Trip* test, or software developers can determine and populate an explicit *Gamut Tag* in an ICC output profile. Finally, color characterization data can be used to determine a *Gamut Boundary Descriptor*. The prediction from the different approaches to describe a device's color gamut are compared in this research.

There are many instances where an accurate description of a device's color gamut is necessary. A software system may offer, for example, a gamut stain or flag warning to indicate to the user that the color under consideration is out of gamut of the destination process and cannot be accurately reproduced. The user can choose to either change the output process or change the color to another color that is within gamut. In a number of packaging workflows, it is important to use

spot colors that are bright and vivid in order to catch the customer's attention on supermarket shelves. It is advantageous therefore to be able to select colors that exploit the color gamut of the output process by choosing the most colorful color that can be accurately reproduced. Gamut data also provides useful information that can be used in studies where we seek to evaluate, for example, different paper or media types and to maximize the color gamut based on the influence of the substrate interactions (Perales et al., 2009). Another use for an empirically derived color gamut is to compare it to the color gamut predicted by an analytical model and hence to see how well the analytical model is suited for the calculation of gamut boundaries (Zhao, 2007).

With the interest in expanded gamut and multi-color workflows, new software tools and dialogs are becoming available to provide gamut warnings and an important issue for the end user is that the different tools provide similar feedback relating to a color's in or out of gamut status. A designer should be able to select a color, verify that it is in-gamut and should not later receive a conflicting message when the file reaches prepress or plate making or press. It is inconvenient and time wasting if one system indicates a color is in-gamut and the user continues with its use only to find that the color is out-of-gamut and they are unable to achieve this color on final output. Software tools are beginning to provide a gamut prediction, so it is important that the information provided is accurate and also consistent between different products. In this research we see that the different programs available to the end user predict widely differing estimates of the percentage of in-gamut colors for a given PANTONE library.

Results are presented that test the gamut ability of a device in terms of the percentage of PANTONE colors that are in-gamut of a system. When PANTONE certifies a manufacturer's printer for reproducing PANTONE colors, this assessment is an important part of that process. The number of in-gamut PANTONE colors is a metric that has been used in marketing information by HP and others.

We note that the HP Designjet Z Photo Printer series makes claims to be capable of successfully simulating over 80 % of a PANTONE library (HP, n.d.). Industry benchmarking studies by IDEAlliance have shown that digital presses can reproduce 40–55 % of a PANTONE library (Sharma, 2009) and in the area of large-format inkjet printing, Sharma and Rong (2014) have shown that commercial devices can reproduce up to 64 % of the PANTONE library. The percentage of in-gamut PANTONE colors is a simple metric that is understandable and relevant to the average user. If a device is able to achieve 50, 60, or 70 % of a given PANTONE library, this is directly related to the

underlying color gamut of the system under consideration and is an easy to understand metric that is directly applicable in a print shop. Consider an alternative metric in which the color gamut volume is expressed in terms of cubic CIELAB units, perhaps a device has 400000 or 420000 cubic volume; it is not easy to interpret or utilize the information when presented in this format.

In this experiment, a set of known CIELAB values was used, in this case the 1729 CIELAB values of the colors composing the PANTONE+ Solid Coated Library V2. However, because of the irregularity of the gamut and the irregularity of the data set, the test process used here may not be applicable to a situation where we seek to compare the gamut volume of two devices. Deshpande, Green and Porter (2014) propose a method to compare color gamuts. Their work looks at how similar two gamuts are in order to determine how well suited a particular gamut is for the color reproduction of another gamut, as relevant in situations where images are being retargeted from one output medium to another.

The structure and format of ICC profiles are specified by the ICC Specification (ICC, 2004) or the corresponding ISO standard – ISO 15076 (International Organization for Standardization, 2005). These documents describe the various profile elements that are available to software developers to use, including an ICC output profile "Gamut Tag". It is useful to note that in order to be a valid output class profile, the Gamut Tag must be present, but the content or "goodness" of any ICC profile tag, including the Gamut Tag, is not described by the ICC Specification nor ISO 15076.

The ICC Specification does not describe the contents of a profile in terms of quality or accuracy (Sharma, 2006). Because the ICC Specification does not stipulate the contents of a profile, individual vendors may populate the contents of a profile's lookup tables with any data they like. This leads to the situation where a profile can conform to the ICC Specification, yet there is no guarantee to the quality of the profile tag behavior. There is much anecdotal discussion relating to the behavior of the Gamut Tag; in this research we demonstrate and document the behavior of the Gamut Tag in a number of different ICC profiles.

In this study, we use the above mentioned processes on a set of CIELAB values to establish whether or not they are in gamut, defined as:
  • Round Trip – where Profile Connection Space (PCS) values are converted to CMYK and back again
  • Gamut Tag – where the 0 values in this look-up table are used to indicate in-gamut values
  • Gamut Boundary Descriptor (GBD) – tetrahedral segmentation search for in-gamut values

When provided with an ICC profile, a number of different commercial, and open source software products have the abbility to flag or stain an image to indicate out-of-gamut colors.

In this project, the following systems were used to estimate the device gamut ability:
- Adobe Photoshop CS6
- ArgyllCMS 1.7
- BabelColor PatchTool 4.7
- Esko Color Engine Pilot v14
- Little CMS 2.7
- MathWorks MATLAB R2015a

The following ICC profiles were used in this project:
- GRACoL2006_Coated1v2 (IDEAlliance's version from ICC profile registry – color.org)
- Coated GRACoL2006 (Adobe's version of the above profile)
- SWOP2006_Coated3v2 (from ICC profile registry – color.org)
- SWOP2006_Coated5v2 (from ICC profile registry – color.org)
- Fogra39L_VIGC_300 (from ICC profile registry – color.org)
- Heidelberg_PM74 (custom profile for Ryerson University's 4-color offset press)

2. Methods for evaluating device gamut

Color characterization data empirically defines the gamut of a device, and this information can be stored implicitly and explicitly within an ICC profile. Given that gamut information is stored within an ICC profile, there are a number of methods to test and see if a CIELAB value is in or out of gamut. Device gamut information is implicitly available within ICC profile A2B/B2A lookup tables that can be used in a *Round Trip test*. Software developers can determine and populate an explicit *Gamut Tag* in an ICC profile. Color characterization data can be used to determine a *Gamut Boundary Descriptor*. We now describe each of these processes in detail.

2.1 Round Trip test

The Round Trip test can be used to determine colors that are out-of-gamut, based on their ΔE^*_{ab} between start and finish. In this process, CIELAB values from the PCS are converted to CMYK using the PCS-to-device part of an output profile, using the absolute colorimetric rendering intent. CMYK values are then processed back to CIELAB, using the device-to-PCS part of the same profile. The ΔE^*_{ab} between the start and finish CIELAB values is calculated. If a color is in-gamut, then the ΔE^*_{ab} between start and finish values is usually very small, based primarily on the mathematical accuracy of the forward and reverse lookup-table interpolation and Color Management Module (CMM) processing errors. If $\Delta E^*_{ab} < 1.0$ between the start and finish values, we can consider this value as the in-gamut one and the differences constitute the cumulative error of all parts of the forward and reverse processing. If a color is out-of-gamut of the device, then the CIELAB value will be clipped and constrained, and on reverse processing we will see $\Delta E^*_{ab} > 1.0$ between start and finish values. A threshold can be used to determine if the color is in or out of gamut of the destination device.

The Round Trip test uses the B2A1 and A2B1, i.e. PCS-to-device and device-to-PCS lookup tables. The Round Trip process was conducted in MATLAB in this testing and also by color software product – BabelColor PatchTool. BabelColor provides a document that describes the Round Trip process and how it is implemented in their software (BabelColor, 2009).

2.2 Gamut Tag in ICC profiles

The structure and format of ICC profiles is specified in the ICC Specification or the corresponding ISO standard – ISO 15076. These documents describe the various profile elements that are available to software developers to use, including the Gamut Tag. The Gamut Tag has a tag name of "gamutTag" and signature of "gamt" – the signature is displayed in the profile header. The Gamut Tag is a required tag in output profiles (it is not required in input, display, abstract, color space or named color profiles). It is useful to note that in order to be a valid output class profile, the Gamut Tag must be present; however as noted earlier, the content of any ICC profile tag, including the Gamut Tag, is not described by the ICC Specification nor ISO 15076.

The Gamut Tag format and structure is a normal lookup table tag type that can be modeled on any of the existing ICC lookup table types – lut8Type, lut16Type, or lutBToAType. These are multi-dimensional structures allowing data to be encoded by some or all of the provided data types including 1-dimensional lookup tables, matrix multipliers and n-dimensional lookup tables. For a definition on the interpretation and processing mechanisms of these lookup table types, Green and Kriss (2010) have provided an excellent compilation of developer-level topics.

The Gamut Tag provides a lookup table in which PCS values are the input and a single output value for each input value is the output. If the output value is 0, the PCS color is in-gamut (Figure 1). If the output is non-zero, the PCS color is out-of-gamut. The Windows Color System (WCS) has also implemented a similar

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Figure 1: The a*b* slice of the Gamut Tag in the GRACoL 2006 ICC profile is shown at L* = 50; this plane has in-gamut values (at the core of the volume) shown by 0 and the extremities of the L*a*b* color space have non-zero values, which indicates the color is out-of-gamut

structure where each byte in an array corresponds to a color element and has an unsigned value between 0 and 255 (Microsoft, n.d.). The value 0 denotes that the color is in gamut, while a nonzero value denotes that it is out of gamut. For any integer n such that $0 < n < 255$, a result value of $n+1$ indicates that the corresponding color is at least as far out of gamut as would be indicated by a result value of n. The out-of-gamut information in gamut tags created in WCS uses a perceptual color distance in CIECAM02, which is the mean square root in CIECAM02 Jab space. The rationale between the differences of ICC's pre-determined rendering and WCS runtime rendering is described by Green and Kriss (2010). In this work ICC based profiles were used.

In Figure 1, the Gamut Tag of the GRACoL 2006 ICC profile for commercial offset lithography, of a $33 \times 33 \times 33$ lookup table is shown, for illustration purposes. We see that in-gamut values are shown by 0 and out of gamut values are indicated by non-zero values. We also note that the table contains numbers that are between 0 and 255, so the system is not binary or quantized and the query for whether a $L^*a^*b^*$ color is in or out of gamut can return a value that can be a qualifier.

Individual vendors may populate the contents of a profile's lookup tables with any data they like as long as it technically conforms to the format of the specification. This leads to the situation where a profile can relate to the same output print process but have different Gamut Tag contents. This situation already exists in other tags, where an output profile can be constructed with different values of maximum ink levels or black generation. In the case of the Gamut Tag, when we have differ-

Figure 2: The Gamut Tag contents in IDEAlliance's GRACoL 2006 profile is compared to Adobe's GRACoL 2006 profile; 3D data is inverted to enable visibility

ences in the Gamut Tag information for the same print process, this would lead to one profile predicting a color is in-gamut while another version of the profile could predict a different result.

Consider the GRACoL 2006 profile. One version of the GRACoL 2006 profile has been created by IDEAlliance and is available from the ICC Profile Registry (ICC, n.d.). This profile is called "GRACoL2006_ Coated1v2.icc". We see that in practical implementation, Adobe has provided within the Creative Suite (CS) and Creative Cloud (CC) a different ICC profile with a similar name. The Adobe's version of the profile is called "Coated GRACoL 2006 (ISO 12647-2:2004)". In examining the profile Gamut Tag (Figure 2), we see that the lookup table contents are different and Adobe's version of the profile will predict that many more colors will be in-gamut.

In Section 4, we use MATLAB to understand the effect caused by the differences between the GRACoL profiles from the ICC Profile Registry vs. Adobe.

2.3 Gamut Boundary Descriptor (GBD)

When processing data using a lookup table, in general there are two conditions – a search for a point that is bounded and contained within known node points and a search for a point that is not totally bounded by known node values. If a point is within the gamut volume and is bounded by known node points then this is a simple interpolation issue and different interpolation techniques are routinely used. If the point is not bounded on all sides and contained within a known set of node points we have to consider a gamut boundary. An issue with the 3D convex hull is that the points can be connected by a straight line, concave or convex line, or a more complex version of all of these. If a concave surface is wrongly assumed, then the color gamut is under-estimated, if a convex boundary is wrongly assumed then the color gamut is over-estimated. A useful summary and accepted reference is the work of Morovič (2008).

The determination of the color gamut volume or gamut boundary can be done using an analytical/model approach or geometric/empirical approach. In the analytical approach spectral data is used to build a model using Neugebauer, Yule-Nielson modified Neugebauer or Kubelka-Munk theoretical models and thus map device colorant instructions (RGB/CMY) to CIEXYZ or CIELAB. This type of model can produce accurate results with a relatively small number of samples, but such characterization schemes rely on the ink-media mixing and are very process dependent, so a model can be used only on a specific type of printing process and it is necessary to develop a new model for each variation of the printing process.

In most ICC applications, an empirical process is employed where many colorimetric measurements are taken from printed patches of known CMYK inking levels. A larger number of patches are needed, compared to the above analytical approach, however with faster scanning spectrophotometers this is no longer such an onerous task. An issue of this approach is that because the test targets are defined in device space (RGB/CMYK) there is no apriori knowledge of the gamut boundary values in CIELAB space, that are on, or inside, the gamut surface. A pre-determined IT8.7/4 or ECI 2002 targets are evenly spaced in ink coordinates which do not consider the natural boundary of a gamut. If the samples cannot describe the gamut surface, or if there are only few points on the gamut surface, an incorrect gamut description will result. Zhao (2007) has compared the analytical and empirical approaches and proposed a generic color gamut descriptor.

In this research, an open source software library called Little CMS (Maria, 2015) was used. Little CMS implements the Segment Maxima algorithm (Morovič and Luo, 2000). Using the Segment Maxima algorithm, the gamut boundary of an output process is described by a table containing the most extreme colors for each segment of color space. This segmentation can be carried out either in terms of L^*, C^*, and h_{ab}, or spherical coordinates, whereby spherical coordinates can be calculated from orthogonal CIELAB coordinates. In this research, the color characterization data was the input to Little CMS, from which the program created gamut information and subsequently the program was able to predict if a CIELAB value was in gamut.

3. Software tools and procedures

Different commercial software products are able to flag or stain an image to indicate out-of-gamut colors. A number of tools were used in this research that ranged from the ubiquitous Adobe Photoshop to command line, C++ libraries in Little CMS. In this section we describe each tool used and where known we indicate which technique each system uses to determine in-gamut colors.

Adobe Photoshop CS6 was used to create a gamut stain and indicate which colors were out-of-gamut. A list of CIELAB values, representing the PANTONE+ Solid Coated Library V2 were converted into a TIFF image, which was opened in Photoshop. With the Color Settings dialog set to Absolute Colorimetric, a Gamut Warning was applied to the image and the number of patches with a stain were considered to be out-of-gamut (Figure 3).
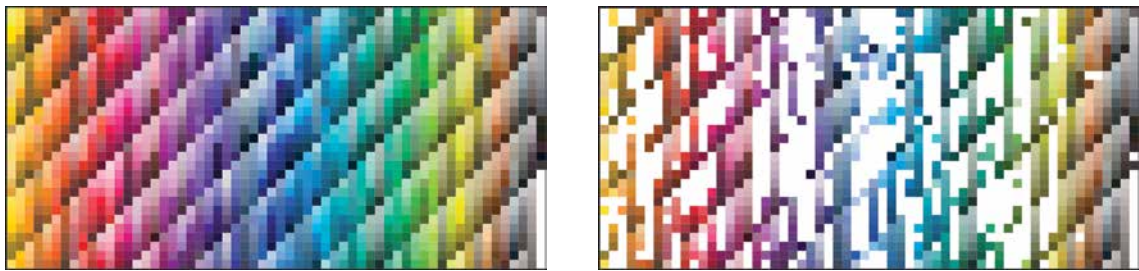
Figure 3: The PANTONE+ Solid Coated Library V2 of 1729 spot colors was converted into a L*a*b* TIFF image (left) and a gamut stain in Photoshop was used to indicate out-of-gamut colors for each ICC profile (right)

The number of patches were counted manually as the stain does not alter the underlying image pixel values and cannot be saved or exported for image processing.

ArgyllCMS 1.7 is a command line program that was run using the Terminal prompt of MacOS X. ArgyllCMS provides the ability to access different profiles, different lookup tables within the profile and process a list of CIELAB values indicating clipped values. ArgyllCMS does a "one way trip" from PCS to CMYK. If there is no CMYK that exactly matches the PCS, the color is out-of-gamut (Graeme, 2015).

BabelColor PatchTool 4.7 is a Windows or MacOS, GUI based software tool. PatchTool provides a number of sophisticated color analysis tools, one of which is gamut "Clip check" (Figure 4).

PatchTool uses the Round Trip method for gamut determination; BabelColor provides a document that

describes the Round Trip process and how it is implemented in their software (BabelColor, 2009).

Esko Color Engine Pilot v14 is a color management tool that is part of the Esko Automation Engine workflow product for workflow automation, targeted primarily at packaging applications. Color Engine Pilot is an example of how vendors are now providing an easy to use dialog to the user to compute in-gamut spot colors for a given print process (Figure 5).

Little CMS 2.7 is an open source color management library that can be used within C++ applications. It is an OEM type library that provides transformations, color space conversions and other color-related functionality. Little CMS is a library and requires a wrapper or program within which it can be implemented. In this research we implemented Little CMS within a Microsoft Visual Studio C++ compiler and development environment. Little CMS creates a GBD from the charac-
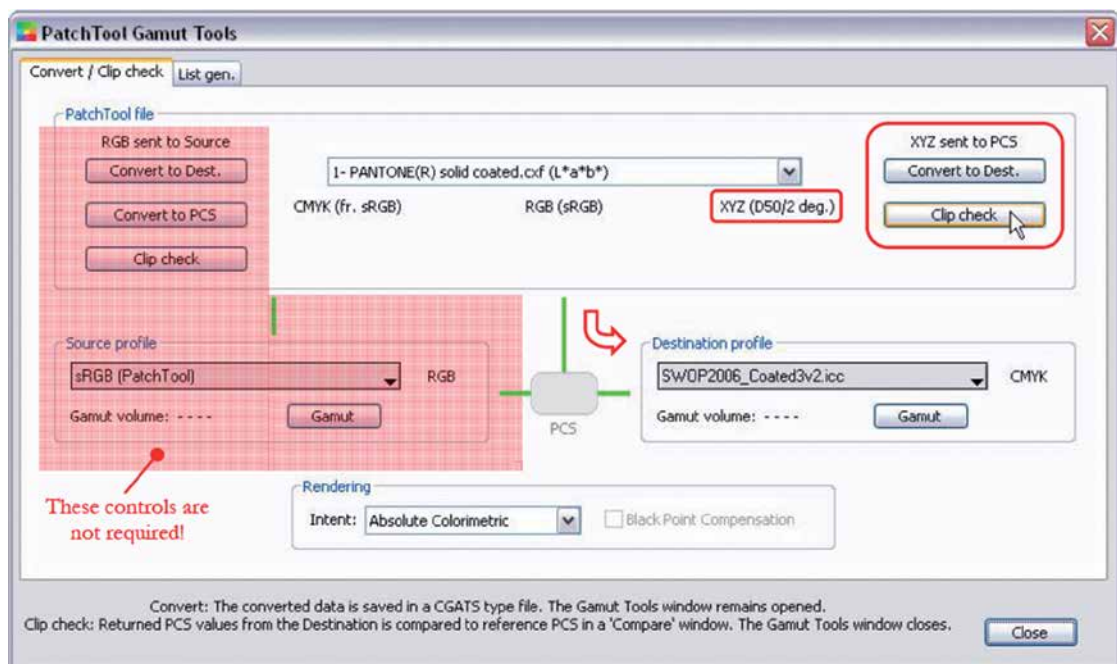

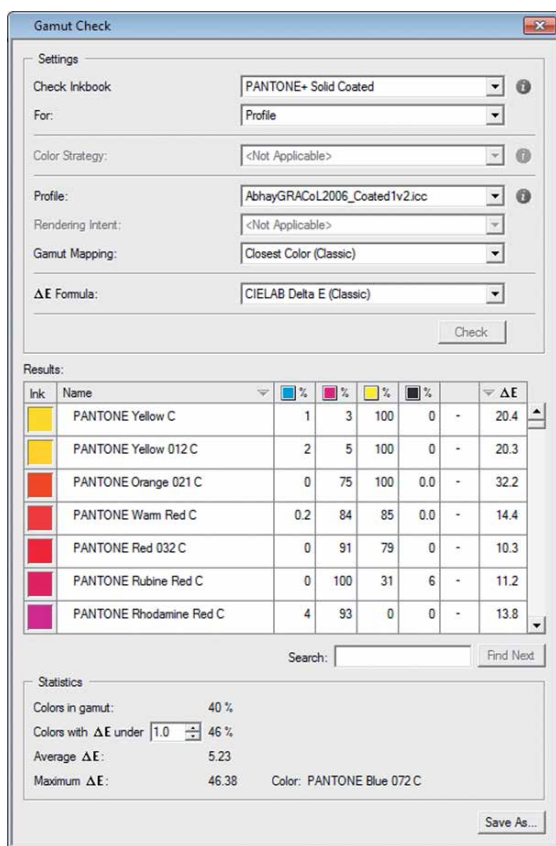*Figure 4: BabelColor PatchTool provides a built-in gamut check function*

Figure 5: Esko Color Engine Pilot has a dialog that allows the user to easily see the number of colors that are in-gamut for a given print process

terization data and does not directly use an ICC profile (Maria, 2015).

MathWorks MATLAB R2015a is an established scientific software program used widely in academic environments and research for software simulation and image processing. MATLAB's Image Processing Toolbox and matrix constructs provide a user-friendly framework for working with ICC profile lookup table information. MATLAB was used in this research to conduct both

4. Experimental results

In the first test we used the list of 1729 CIELAB values, representing the PANTONE+ Solid Coated Library V2, to determine the in-gamut colors for different ICC profiles using the Round Trip test and the Gamut Tag. Useful information can be derived by a comparison of the Round Trip test (that uses the B2A1 and A2B1, PCS-to-device and device-to-PCS lookup tables) with a test that uses the Gamut Tag, both contained within the same ICC profile. In order to determine if the Gamut Tag information correlates with the information within the B2A and A2B lookup tables, MATLAB was used to compare both processes. MATLAB can be directed to

the Round Trip test and testing of the Gamut Tag information.

PANTONE do not make available lists of their libraries as CIELAB values, so PANTONE Color Manager 2.1 program was used (Figure 6). This program can export a PANTONE library in a number of formats from which it is easy to extract a CIELAB list of values. It is possible to export a color library either as a Named Color ICC profile, or CxF (XML) file or other format, from which a list of CIELAB values can be created. The library chosen for this project was the PANTONE+ Solid Coated Library V2, with 1729 spot colors. The CIELAB list was presented to the above list of programs and each program was used to determine which colors from this list were in-gamut. The CIELAB list was also converted into a TIFF image and analyzed for in-gamut information in Photoshop.

Figure 6: PANTONE Color Manager was used to extract and create a list of CIELAB values for the PANTONE + Solid Coated Library V2

process a list of CIELAB values using the B2A1 and A2B1 lookup tables or can be instructed to predict the color gamut using the Gamut Tag lookup table. MATLAB is a useful tool as both processes are available within a single application, this allows us to process B2A/A2B lookup tables or Gamut Tag lookup tables, using a single CMM. A comparison between the two processes was conducted for six different ICC profiles used in this project (Figure 7).

In the Round Trip test, each spot color value was processed from CIELAB to CMYK via each profile used
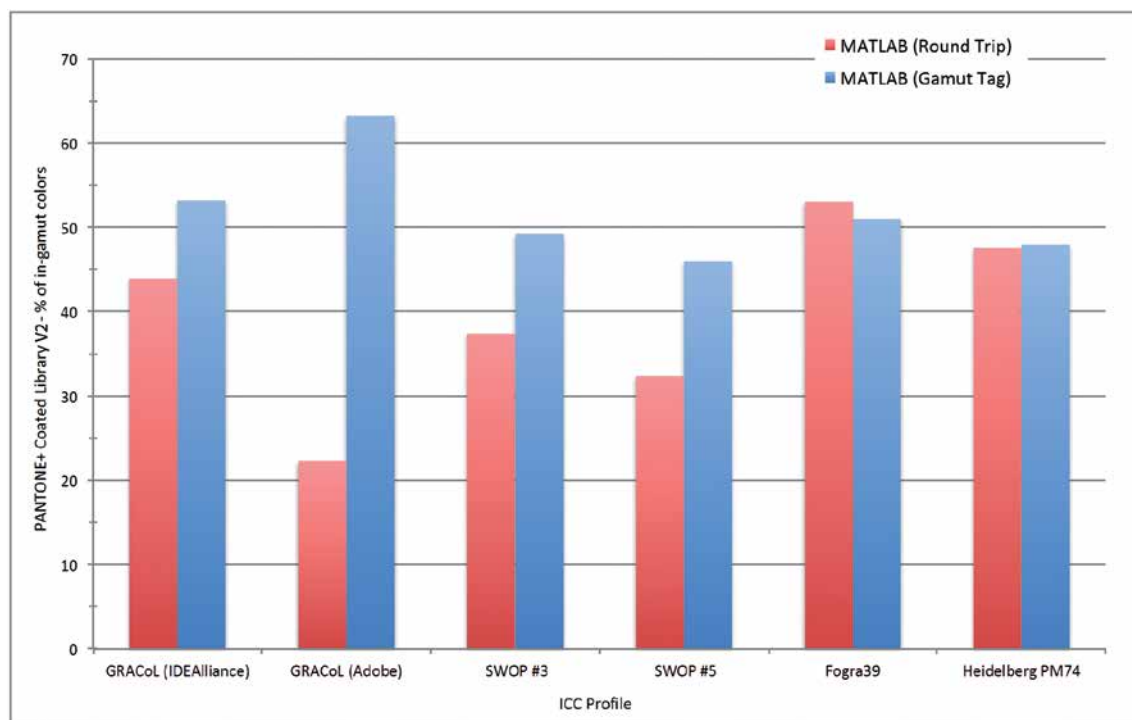
Figure 7: MATLAB computation results of in-gamut colors using the Round Trip and Gamut Tag methods

in this study, with absolute colorimetric rendering. The CMYK values were returned to CIELAB and compared to the original values. If the difference between the starting and returned value $\Delta E^{*}_{ab} < 1.0$, the spot color was considered as the in-gamut one.

Next, the spot color values were processed via the Gamut Tag lookup table. MATLAB extracted the Gamut Tag from an ICC profile and stored it in a lookup table structure and each CIELAB value was processed via this lookup table. The data in a Gamut Tag is 0 for an in-gamut color and non-zero for an out of gamut color. 1-D look-up tables and/or matrix elements were applied as appropriate, and in a Gamut Tag, while they are populated for reasons of conformance, they often have values with null response, such as a unity matrix.

We see that the Gamut Tag in the IDEAlliance's profile predicts 53 % of the colors are in-gamut colors while the same tag in the Adobe's profile predicts 63 % are in-gamut colors. The result is as expected and agrees with Figure 2, where it is clear that Adobe's Gamut Tag will predict more colors are in-gamut.

A general expectation is that both processes – Round Trip and Gamut Tag, should produce similar results. Use of the Gamut Tag may be more succinct and convenient during run time, but should not, in general, differ from the manual approach of processing data from CIELAB to CMYK, and back to CIELAB. From Figure 7, we see that the GRACoL (Adobe) profile has very different predictions for the in-gamut colors based on the Round Trip and Gamut Tag computations, while the Fogra39 and Heidelberg PM74 profiles have very good agreement for these two test methods.

In order to understand this data it is necessary to consider the underlying lookup tables used by these profiles. To do the Round Trip test, a look-up table transform based on the ICC profile absolute colorimetric look-up tables is created. We note that an ICC profile does not explicitly contain the absolute colorimetric look-up tables. At run time, data for the absolute colorimetric intent is generated using the relative colorimetric tables (B2A1/A2B1) via a white point scaling. We consider therefore the lookup table size, for the relative colorimetric tables (Table 1).

Table 1: Analysis of the ICC profile colorimetric lookup tables

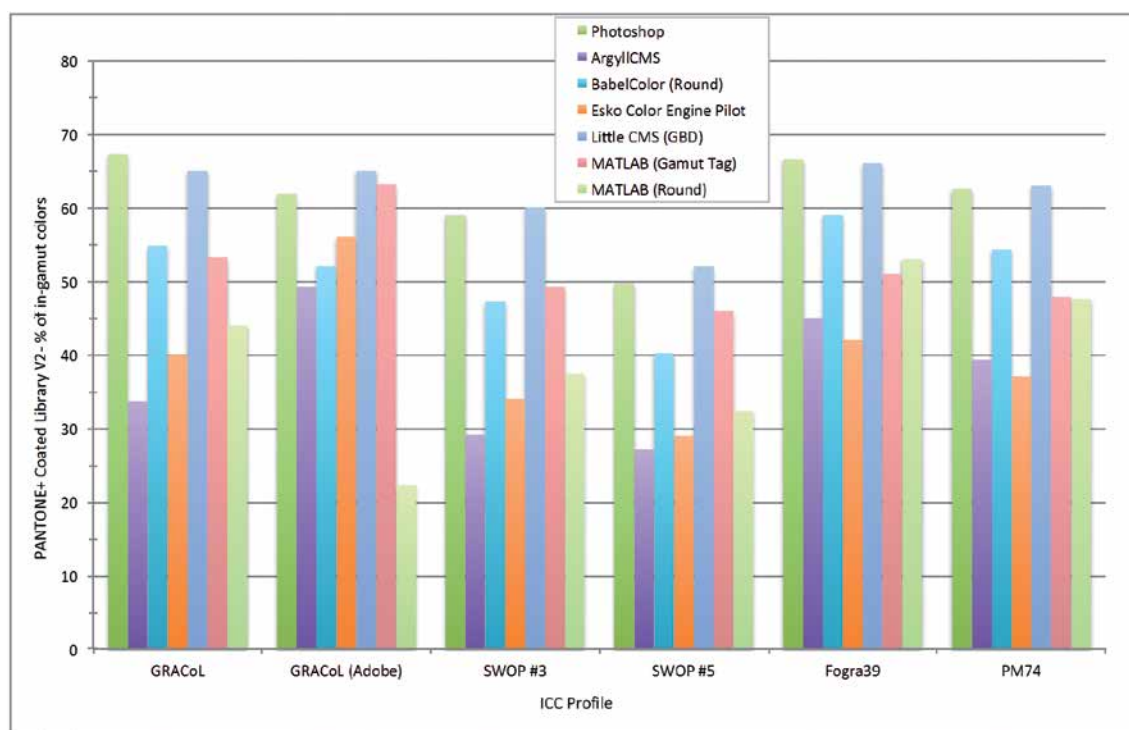| Number of nodes	GRACoL (IDEAlliance)	GRACoL (Adobe)	SWOP #3	SWOP #5	Fogra39	Heidelberg PM74
B2A1	33	33	33	33	37	37
A2B1	17	11	17	17	25	25

Figure 8: Different tools used to predict the number of in-gamut PANTONE colors,
give very different feedback for the same ICC profile, depending on the tool used

The Adobe generated GRACoL profile shows the largest discrepancy between the two tests, where the Gamut Tag predicts 63 % of values are in-gamut and the Round Trip test predicts only 22 % are in-gamut. From Table 1, we see that this profile has only 11 cube nodes in the A2B1 table. We see that the Fogra39 and Heidelberg PM74 profiles have a large number of cube nodes in both lookup tables, 37 nodes in the B2A1 (PCS-to-device) table, and 25 nodes in the A2B1 (device-to-PCS) table. This higher number of cube nodes increases the file size of the ICC profile, i.e. more MB as disk storage, but does provide an increased accuracy for reversibility of the CIELAB data. In the Round Trip test, if the returning CIELAB value had $\Delta E^{*}_{ab} < 1.0$, the color was considered as in-gamut. In order to accommodate for the smaller number of cube nodes and thus reduced accuracy, a similar in-gamut prediction was obtained if the allowable tolerance, for the GRACoL Adobe profile, was set to $\Delta E^{*}_{ab} < 5.5$.

If the Round Trip and Gamut Tag produce similar results, then different software tools can use either process to determine and indicate in-gamut colors. However, due to the decimated lookup tables in some profiles used in this study, these procedures are not equivalent and as a result, for the same ICC profile, one predictive tool may use the Gamut Tag and suggest a color is in-gamut, while another tool may conduct a Round Trip test and suggest the same color is not in-gamut. Only for profiles with a large number of cube nodes in the

A2B and B2A tables, both processes will predict similar results, as we see for the Fogra39L and Heidelberg PM74 profiles.

In the next series of tests, the six selected output profiles were used in turn with each of the six software tools. In each case, 1729 CIELAB values representing the PANTONE+ Solid Coated Library V2 were presented to each program and the number of in-gamut colors predicted by each program was computed (Figure 8).

There are some caveats to the data presented in Figure 8. The Esko Color Engine Pilot application used its own internal version of the PANTONE+ Solid Coated Library V2 and the program reported that is was based on 1799 CIELAB values, while the list used for the other programs contained 1729 values. Another point to make is that the data for the GRACoL 2006 profile when using Little CMS is generated from the underlying characterization data file, so the result for both the IDEAlliance's and Adobe's versions of the profiles is identical and not related to the ICC profile, per se.

From Figure 8 we see that in all cases Photoshop and Little CMS are very similar, thus we may conclude that both these products are using the Gamut Boundary Descriptor method for in-gamut prediction. Generally, BabelColor and MATLAB can produce similar results using the Round Trip methodology, the difference seen in Figure 8 is due to the tolerance of BabelColor that was

not user selectable and in BabelColor $\Delta E^{*}_{ab} < 2.0$, while in MATLAB $\Delta E^{*}_{ab} < 1.0$ was used, thus BabelColor always predicts (in this test) a larger number of in-gamut colors.

ArgyllCMS and Esko Color Engine Pilot produce similar results and as this is true, even for the GRACoL (Adobe) profile, we can assume that these products do not use the traditional Round Trip test to determine in-gamut colors.

5. Conclusions

In this research, we have proved that the different programs available to the end user predict widely differing estimates of the percentage of in-gamut colors for a given PANTONE library. These different gamut predictions are not desirable in printing and proofing workflows. In practice, the implications in a printing workflow of unwittingly selecting an out-of-gamut color is that it cannot be accurately reproduced, which leads to customer dissatisfaction, delays and re-working of the job.

It is an expectation that all products working in compliance with a given specification produce similar results. It is important, therefore, that a gamut metric as calculated in this work shows some consistency, irrelevant of who computes it and how it is computed. To have different results in this part of the system that predicts whether a color is in or out of gamut does not imbue confidence. The unreliability of the gamut prediction also conflicts with the general philosophy of the ICC system that is predicated on a reliable and predictable workflow. The ICC stipulates the structure of an ICC profile tag, but not its contents. This leads to the situation illustrated by the IDEAlliance's and Adobe's GRACoL profiles whereby the two profiles have differing content in the Gamut Tag and also different results on application. A Gamut Boundary Descriptor is being developed in iccMAX specification for a future ICC v5 format.

A metric is suggested whereby the percentage of in-gamut PANTONE spot colors is used as an indicator

of the gamut volume. However, the spread of the spot colors in CIELAB space is not uniform, thus this metric should be used with caution. Nevertheless, it is a metric that is understandable to the average user. In general, in this work, we see that a print process can usually reproduce between 40 and 60 % of the CIELAB values of a PANTONE+ Solid Coated Library V2.

This research provides documentation of the behavior of the Gamut Tag, as compared to the other methods for gamut determination, thus we provide quantitative evidence to the much discussed anecdotal behavior of the Gamut Tag. Given the differences we see in different mainstream commercial products and specialist color image processing tools, it is suggested that the Gamut Tag provided within the ICC architecture be better defined and better implemented. Currently, for example, there is no documentation to describe the non-zero values in the Gamut Tag. There is no documentation to what the values are within a Gamut Tag and how they are to be used, what is the encoding and how should these values be interpreted.

With the growing use of expanded gamut proofers and workflows, and the growing demand for brighter, more vivid colors, there has been an increase in applications and software providing feedback to the user in terms of in-gamut colors. From a user standpoint, it is important that there is some consistency between these products, and we hope that the testing shown here will assist us in creating closer agreement between software predictors.

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The influence of location-related factors on the perception of billboard advertising

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Abstract

The impact that printed out-of-home advertisements have on the consumer's perception is dependent on several location-related factors. For a long time, however, this influence was only indirectly gathered by measuring the relative performance of different locations of billboard advertising: Advertising agencies were traditionally only measuring consumer movement patterns and estimating "exposure opportunities", but no real visual contacts. In this paper, the influence of the factors competition, distance, environmental complexity, occlusion and viewing angle, used with increasing frequency to improve those estimates on billboard perception, is analyzed using eye tracking technology. Two slightly different walks through a city environment are simulated, and changes in gaze behavior due to a variation of the aforementioned location-related factors are recorded and compared. The results confirm the impact of the environmental complexity and occlusion factors, whereas the influence of the other factors is lower or less conclusive. The results presented in this paper help to better understand how these factors affect human attention and allow for a more precise comparison of the relative importance of these location-related factors on the consumer's perception. Furthermore, they might help to improve existing advertisement measurement systems.

Keywords: eye tracking, visual perception, human attention, billboard location, consumer's perception

1. Introduction and background

Printed advertisements play an important role in marketing today. The oldest written advertisements in existence date back to the ancient Egypt (Unger et al., 2007, p. 281). Nowadays, printed advertisements can be found in a huge variety of forms – as newspaper advertisement or billboard poster, advertising supplement, leaflet or prospectus, catalogue, flyer, sticker and so on; all existing in a vast variety of sizes and formats (Esch, 2015). For consumers, printed advertisements are today ubiquitous, and can be found both at home (in newspapers, journals or as advertising mail) and outside – as posters, lamppost banners or billboards near bus stops or on the side of the road.

In today's world of fragmented media, outdoor advertisement plays an important role in reaching an increasingly elusive consumer (Wilson and Till, 2011, p. 909). Out of home advertising is one of the fastest growing media segments (OAAA, 2015, p. 1), and especially billboards or posters that can often be found in high-traffic areas on the side of the road account for 65 % of the industry revenue in the U.S. (l.c.). In Germany, backlit billboard posters represent more than a quarter of the overall market for outdoor advertising today

(Meffert, Burmann and Kirchgeorg, 2012, p. 637). Billboard advertising provides high levels of reach and frequency at a lower cost than other media (Lane, King and Reichert, 2010, p. 371). The contact opportunities are higher than those of other classic advertising media because the majority of the population leaves their house at least once a day (Anspach, 2004, p. 7), so that even consumers that are very mobile and exposed less frequently to traditional forms of media can be reached (Francese, 2003, p. 41; Prasad, 2009, p. 15). Contrary to other forms of advertising, billboard posters cannot be switched, turned off or skipped (Anspach, 2004, p. 7) or interfere with any editorial content – which is probably why it enjoys a comparatively high level of users' acceptance (l.c.; Meffert, Burmann and Kirchgeorg, 2012, p. 651).

Apart from the advertising message and the graphical design of an advertising poster, the location of the billboard on which the poster is presented has important implications for the success of an advertisement as well: While the poster contains the actual information, the backlit billboard has to carry the message on to the target group the advertiser wants to reach (Schweiger

and Schrattenecker, 2009, p. 300). Thus, advertising media bridge the gap of space and time between sending and receiving of an advertising message (Pepels, 2005, p. 21); they form the context of the advertisement (Felser, 1997, p. 267). How efficient this can be done may depend on multiple factors, such as the environment in which the billboard is placed: Are there other outdoor media units competing for the viewers' attention? Is the billboard partly hidden by any obstacles? What is the viewing angle or distance the advertisement is looked at?

Factors like these might influence the impact of out-of-home advertisements, and consequently, the advertising providers assign different performance/price categories depending on the respective placement of their billboards (cf. Bloom, 2000, p. 396; APG|SGA, 2015; Prosser, 2013). In Germany, for instance, the outdoor advertising trade association Fachverband Außenwerbung (cf. FAW e.V., 2012) introduced as of January 1, 2013 a method of measurement called PpS ("Plakatseher pro Stelle"; meaning "poster viewers per billboard location" in German). The PpS method uses GPS data from a representative sample of pedestrians to identify consumer movement patterns (this data is counter checked by a Last Day Recall via telephone interviews). This value is weighted using seven location-related factors, namely the period of exposure, the linear and lateral position of the billboard in relation to the passing traffic, the degree of occlusion of the

billboard's position, the number of competing nearby billboards, the overall complexity of situation and environment, the viewing angle and the lighting conditions (l.c., p. 5). Based on these values, the quality of the different billboard locations are determined – and, consequently, also the price.

Sophisticated as this measuring method may be, it still basically determines how many consumers *walk past* a billboard poster, but not how many people actually *look* at it. Even if these advertisement exposure opportunities are later weighted using the above-mentioned location-related factors, they are still basically estimates, not real visual contacts. The objective of this paper, therefore, is a more thorough analysis of the perceptual impact that the location-related factors have on the human perception of billboard advertising – to find out if the said weighting really leads to an improved visibility assessment. In order to do this, eye tracking technology has been used, and a test scenario was developed that simulated two slightly different walks through the city of Leipzig. Both walks (recreated using two different slideshows) featured out-of-home campaigning at various locations, from different distances, viewing angles, etc. These two slideshows were presented to the two different experimental groups, and their gaze behavior was recorded using eye tracking technology. The eye tracking results allowed a direct comparison of both walks as well as a more detailed assessment of the impact these parameters have on human cognition.

2. Materials and methods

The study described in this paper consisted of two parts. In the first part, the effects of location-related factors on the test viewers' perception and information processing of billboard advertising were analyzed using eye tracking technology. In the second part of the test, the unaided recall, aided recall and recognition of the selected billboard advertising was tested for each of the test participants using printed questionnaires.

In preparation of the eye tracking part of the test, the locations of all 119 cm × 175 cm backlit billboards (also known as city light posters; cf. Unger et al., 2007, p. 285; Ströer, 2015) in Leipzig's city center were determined and marked on a Leipzig city map. Next, a walking route through the city was chosen, which provided the basis for the eye tracking test scenario. The route started at Leipzig central station, followed some prominent arterial roads (passing nine city light billboards on the way) and ended at a certain restaurant which was given as the intended destination to the test viewers.

In order to create a low-involvement situation that is typical for the quite unintentional and casual contact with out-of-home advertising (Bloom, 2000, p. 395),

the test subjects were left unaware of the real purpose of the investigation. Instead, they were told to memorize the way from the central station to the restaurant in order to be able to describe it later to a friend. In reality, however, the perception of the city light billboards and the influence of the above mentioned location-related factors were tested. Nine different situations have been the subject of research in this study: oclusion, environmental complexity, linear distance, competition of nearby billboards and viewing angle.

In order to do this, two slightly different versions of the walking route were simulated using two series of photographs each that were taken under identic lightning conditions from a pedestrians' perspective (cf. Figure 1). The majority of these photos are neutral stimuli showing ordinary street sceneries that are identical in both versions of the walk. The nine others, however, differ in both versions according to the characteristics of the location-related factors named above, and were each displayed to only one of the groups. In the further course of the text, these situations are named by means of the following abbreviations: occlusion (OC 1 and OC 2), environmental complexity (EC 1 and EC 2),

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linear distance (LD 1 and LD 2), competition of nearby billboards (CO 1 and CO 2) and viewing angle.

2.1 Subjects

Sixty test participants (28 males, 32 females) were recruited for the experiments and divided into two groups of 30 persons each. Their age was 24.5 on average, ranging from 17 to 33. Almost all had normal or corrected vision, except for two individuals with a slight cataract and a red-green deficiency, respectively (which, however, had no impact on study results). Although more than three-quarters of the participants attended courses related to media, none of them had special knowledge in outdoor marketing or billboard advertising.

Almost all (95 %) of the participants were residents of Leipzig, and 62 % of them lived there for more than two years. An overall familiarity with the city environment and the approximate location of poster sites there could therefore be assumed as likely.

2.2 Stimuli

As the eye tracking system used for this test was computer-based, two series of photos were used to simulate the walking route mentioned above. Each of these slideshows contained 65 photographs (9 of the relevant city light posters and 56 neutral ones of streets), taken from the perspective of pedestrians (cf. Figure 1). The neutral stimuli were identical in both slideshows, whereas the billboard views varied according to the location-related factors, the linear distance, the degree of occlusion of the billboard's position, the number of competing nearby billboards, the viewing angle and the overall complexity of situation and environment. Each slideshow was presented to the test subjects, one picture at a time, each display lasting 2.5 s (this time interval was determined in pre-tests as a faithful emulation of a normal walking speed). The distribution of billboard advertisements corresponded to their actual placement in the city, and the order and perspective of the photos also reflected reality. However, the photos had on purpose been taken some months beforehand, so that the posters visible on the stimuli where not the ones that were shown on real billboards at the time. Thus, a direct influence of "real" viewings in the preceding week or so could at least be reduced.

The simulated walking route was to reflect a more or less "typical" viewing experience in familiar surroundings – comparable to the situation in which billboard advertising is typically presented and perceived (cf. Deibl, 1997, p. 86; cf. Anspach, 2004, p. 5). The intended destination, the restaurant "PepperHouse Leipzig", on the other hand, was unknown to 82 % of the subjects, so that too intimate a knowledge of the intended path could be considered as unlikely.

2.3 Apparatus and procedure

The stimuli were presented on a monocular, desktop based NYAN 2 XT/EDGE eye tracking system. User reactions were recorded and their visual scan paths were analyzed. In order to assess the relative importance of the main visual components on the billboard advertising, the city light posters were defined as Areas of Interest (AOI) beforehand to compare hit rates, the time to first fixation, gaze durations, etc.

Series 1:

Series 2:

Figure 1: Samples of the two series of photos used in the eye tracking test, where the blue frames (samples (b, f) and (d, h)) mark neutral stimuli that were identical in both series, while green frames test several location-related factors, showing backlit billboards in varying distances (a, e) or a different number of competing nearby billboards (c, g)

The hit rate (in percent) shows the number of participants that fixated the billboard advertising at least once. The time to first fixation (in seconds) indicates when the billboard advertising was first focused. The gaze duration (in seconds) indicates the average viewing time. The fixation count states the number of fixations.

After the test, the participants had to complete a questionnaire, asking them at the outset to name those locations of billboards and all advertising posters shown that they could recall without the aid of a cue or prompt and to mark them on a map (unaided recall). After that, a list of brand names was given to the test participants. They were now asked to identify brands they thought they had seen earlier (aided recall). Finally, the advertising posters in the test (and some others that had not been shown) were presented to the test participants once again, and they had to decide for each of them if they had been part of the test or not (direct recollection).

The statements of the survey were analyzed in order to find tendencies and patterns as to which advertising posters could be remembered and to what extent, and how these recognition values were influenced by location-related factors.

3. Results

In order to assess the eye tracking results presented here, it is helpful to note that the rating system of the German outdoor advertising trade association contains some implicit assumptions on the expected impact of the aforementioned location-related factors. Occlusion of billboards, for instance, is said to lead to a "lower performance" (cf. FAW e.V., 2012, p. 7), competition "reduces the chances of being noticed" (l.c.), and environmental complexity "reduces the impact of the poster site" (l.c.). Therefore, all eye tracking results will be compared with these implicit assumptions in order to find out if the expectations put down in the FAW rating system can be confirmed – or if the gaze behavior leads to different conclusions.

As for the general distribution of attention between the billboard advertising and their environment, the results were largely as expected. In direct competition, the surrounding street life was (on average) not only viewed 4 times longer than the billboards, but it was also fixated 0.5 s faster and over 4 times as often. In sum, however, 61.5 % of the test participants did look at the billboard advertising at any time on average. From a total of 711 fixations on advertisements, 332 (i.e. about half) were first fixations on the corresponding Areas of Interest; 197 fixations were the result of a second look on an area that had already been scanned, and only 182 were third, fourth or further fixations. Thus, the average fixation count for billboard locations was 1.32; implying that the tested advertisements were generally looked at only once or twice. Over 75 % of the first fixations occurred in the first half of the 2.5 s display time; the average time to first fixation was 0.82 s. Furthermore, 56 % of the first fixations on billboard locations were also among the first two fixations on the stimulus as a whole. It is also worth mentioning that in about 40 % of all cases, the fixations on advertise-
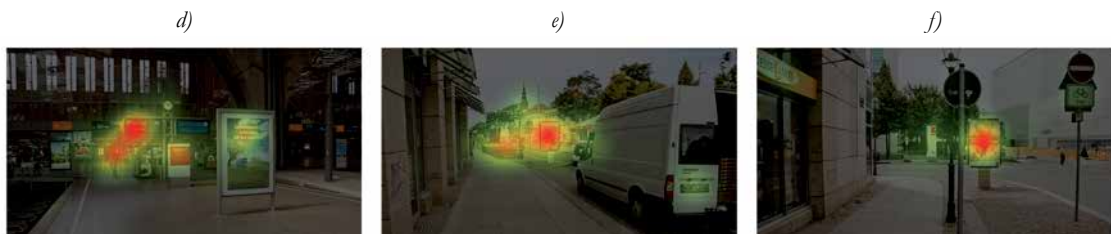
Series 1:
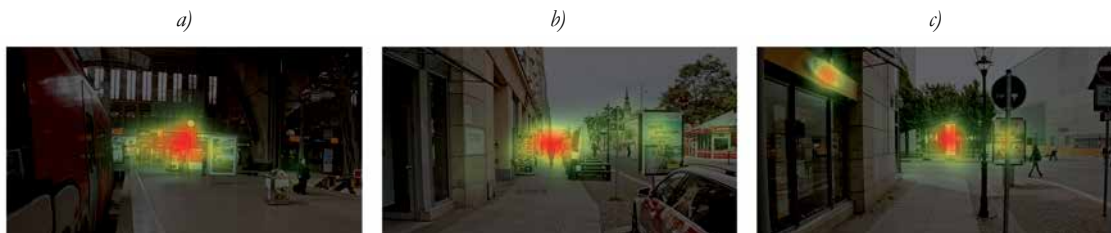
Series 2:

Figure 2: Sample heat maps from location-related factors analysis, where areas of the stimuli that received most attention from the test participants are marked with colored spots (red means a high level of attention, followed by yellow and green), while areas that got minor attention are darkened

ments were long fixations (> 300 ms), which were mostly accompanied by at least one short fixation. The rest of the billboard area fixations were either solitary, short fixations, or sequences of several (i.e. at least two) of these short fixations (about 30 % in both cases). Furthermore, test results showed that location-related factors like linear distance, the number of competing nearby billboards, the overall complexity of the environment, the viewing angle and the degree of occlusion do indeed have an impact on the perception of billboard advertising (cf. Figure 2).

3.1 Impact of the location-related occlusion factor

For the two factors, namely occlusion and environmental complexity, results were more or less as expected. Billboards that were partly hidden by other objects such as a street sign (cf. Figure 2c, 2f; situation OC 1) or pedestrians (situation OC 2), got a considerably lower level of attention than their counterparts without occlusion (cf. Table 1). The corresponding ads were perceived by much fewer participants: on average only 64 % of the subjects fixated partly hidden billboards (47 % in situation OC 1 and 80 % in OC 2, respectively), compared to 90 % fixations on the same ads without occlusion. Both the gaze duration and the fixation count decreased by over 50 % on average, whereas the time to first fixation was on average 0.23 s longer (0.29 s longer in OC 1 and 0.18 s in OC 2, respectively). While unobscured billboards were mostly noticed within the first two fixations on the stimulus as a whole (the average position being 2.52 and 1.67 for situation OC 1 and OC 2, respectively), obscured ads generally needed one fixation more (average position 3.36 and 2.42, respectively).

Moreover, the results differ depending on the cause of the occlusion: If billboards were partly hidden by other objects (such as a road sign), hit rate, gaze duration and

fixation count were significantly lower ($p < 0.05$, where p is the probability of getting the observed or more extreme results given that the null hipothesys is true) compared to the wholly visible variant (the time to first fixation also showed a medium but no significant effect). If the billboards, on the other hand, were hidden by pedestrians, the difference was reduced by more than half, so that only the gaze duration showed a significant difference and a medium effect.

Outdoor advertisements without occlusion got in most cases at least one long fixation (> 300 ms), often accompanied by some short ones (48 % and 52 % of 27 subjects who fixated the ads in situation OC 1 and OC 2, respectively). In situation OC 1, where the ad was hidden by an object, 42 % of only 14 subjects that looked at it did so with one single short fixation only, while in situation OC 2, where the ad was hidden by pedestrians, 54 % of the 24 viewers had at least multiple short fixations.

3.2 Impact of the location-related environmental complexity factor

As for environmental complexity, it was to be expected that billboards positioned in low complexity situations would get higher levels of attention than those placed in a higher environmental complexity. Fittingly, the results showed a positive effect on the attentional values for billboards placed in less complex situations (cf. Table 2). Generally speaking, a lower environmental complexity corresponded to earlier fixations on the billboards (position 1.87 and 2.75 instead of 2.37 and 3.18 on average for the two tested situations). In the situation EC 1, lower complexity also meant one long fixation mostly accompanied by at least one short one (for 60 % of the 30 participants that looked at the corresponding ad), whereas high complexity was linked to multiple short fixations (44 % of

Table 1: Eye tracking results for occlusion (average of all individual results, the highest or earliest values, respectively, are marked for clarity)

Situation	Occlusion	Hit rate [%]	Time to first fixation [s]	Gaze duration [s]	Fixation count
OC 1	with	47	0.85	0.20	0.77
	without	90	0.56	0.70	2.80
OC 2	with	80	0.51	0.44	1.97
	without	90	0.33	0.69	2.77

Table 2: Eye tracking results for environmental complexity
(average of all individual results, the highest or earliest values, respectively, are marked for clarity)

Situation	Environmental complexity	Hit rate [%]	Time to first fixation [s]	Gaze duration [s]	Fixation count
EC 1	low	100	0.40	0.75	2.87
	high	90	0.61	0.58	2.47
EC 2	low	67	0.62	0.27	1.00
	high	61	0.79	0.24	0.96

Table 3: Eye tracking results for linear distance
(average of all individual results, the highest or earliest values, respectively, are marked for clarity)

Situation	Linear distance	Hit rate [%]	Time to first fixation [s]	Gaze duration [s]	Fixation count
LD 1 Figure 2a, 2d	low	60	0.89	0.28	1.13
	high	50	1.19	0.19	0.77
LD 2 Figure 2b, 2e	low	47	0.80	0.23	0.97
	high	69	1.18	0.33	1.17

27 participants). In the second scene EC 2, however, the results were inverse: here, lower complexity was linked to single short fixations for 50 % of the 20 fixating subjects, whereas higher complexity corresponded to longer fixations (47 % of 17 fixation subjects).

Additionally, an increased environmental complexity seems to have a lower impact on the level of attention than might be assumed. Based on the eye tracking data, only a comparatively small difference between high and low complexity situations was noticeable: Only the time to first fixation was significantly lower ($p < 0.05$) in situation EC 1 and showed a medium effect, while all other eye tracking data did not meet statistical significance and showed small effects at best.

So essentially, the additional visual stimuli didn't seem to distract people much. Only approaching persons or objects tended to get a bit more attention. Apart from that, most of the test participants appeared to pursue their primary objective, which in this case was to focus on the route.

3.3 Impact of the location-related linear distance factor

The impact of the other location-related factors on eye tracking results, however, was lower or different than assumed. Here, the viewing patterns and eye movement parameters recorded via eye tracking showed diverging results for the two situations that had been tested for the corresponding location-related factors.

Regarding the linear distance from the point of first visibility, it was assumed that billboards located close to the participants would receive higher levels of attention than far-distant ones. Accordingly, the time to the first fixation

on the advertisement was in both situations higher for the billboards at greater distances (cf. Table 3), and there were more antecedent fixations on other areas of the stimulus. For the situation LD 1 depicted in Figure 2a and 2d, respectively, this assumption was further supported by other results (cf. Table 3): for the billboard at a shorter distance, the hit rate was 10 % higher, the time to first fixation 0.3 s shorter and both the gaze duration (0.28 s vs. 0.19 s) and the fixation count (1.13 fixations on average compared to 0.77 at a greater distance) higher.

However, the analysis of the second situation LD 2 (cf. Figure 2b and 2e and Table 3, respectively) yielded opposite results: the hit rate of 69 %, the gaze duration of 0.33 s as well as the number of fixations of 1.17 on average were higher for the far-distant billboard than the same parameters were for the closer billboard (47 %, 0.23 s and 0.97, respectively). Combining the results of both scenes, the eye tracking data showed no significant differences between shorter and longer distances, and only the time to first fixation had a medium effect size.

3.4 Impact of the location-related competition factor

As for the influence of competition by nearby billboards, it can be stated that astonishingly, in relation to all fixations on the stimulus as a whole, first fixations to ad areas with competition ranked better than those without competition (the position in order of overall fixations being 5.30 and 3.17 for areas without competition, compared to 2.36 and 2.47 for those with competition). Apart from that, the eye tracking results in situation CO 1 showed lower attentional values for a single advertising poster than for the same ad in direct competition, and diverging outcomes in situation CO 2 (cf. Table 4). In the first case, the ad without competition had a significantly lower

Table 4: Eye Tracking results for competition by nearby billboards
(average of all individual results, the highest or earliest values, respectively, are marked for clarity)

Situation	Competition by nearby billboards	Hit rate [%]	Time to first fixation [s]	Gaze duration [s]	Fixation count
CO 1	no	33	1.43	0.12	0.53
	yes	47	0.56	0.17	0.73
CO 2	no	60	0.88	0.26	0.87
	yes	57	0.70	0.25	1.10

time to first fixation ($p < 0.05$, strong effect). In situation CO 2, however, only small effect sizes and no significant results could be detected. Here, it is interesting to note that ads without competition were noticed by more people, but that they were fixated less often and later on than the advertisements with competition.

3.5 Impact of the location-related viewing angle factor

Another interesting result is that no considerable influence of the viewing angle could be detected either, as the values for hit rate, time to first fixation, gaze duration and fixation count did not differ significantly. The only indication that a frontal position might offer a slight advantage can be found in the fact that ads at a 90° angle mostly got longer fixations of more than 300 ms, whereas more acute angles generally led to single short fixations (50 % of 10 subjects looking at the respective ads in both cases).

3.6 Unaided recall, aided recall and direct recognition

The unaided and aided recall test conducted subsequent to the eye tracking test showed that the recall performance was low in spite of the high percentage of viewers that had looked at the billboard ads according to the eye tracking results. The analysis demonstrated that both unaided and aided recall of the advertisements shown (a list of brand names was given to the test participants as aide-mémoire

in the latter case) was only successful for less than one-sixth of the test participants on average. Especially during the unaided recall, recollection was often diffuse and, in some cases, inaccurate. Test viewers, for instance, remembered only the main color of advertising posters and erroneously linked them to other, real-world viewing experiences with (outdoor) advertising; e.g. the color red to Vodafone ads, although no such advertisement was included in the test. In the same way, many viewers thought that the advertising of a telecommunications provider, which featured a smartphone, belonged to a well-known technology company like Sony or Panasonic.

In contrast, the direct visual recognition of the advertising posters shown during the test was at a comparatively high level (cf. Figure 3). When the seven advertisement posters that were used during both tests were presented to the test participants along with three others that were not, the advertisements shown were recognized by 42 % of the participants on average. Compared to that, the number of false positives was comparatively low in two subsequently performed tests (5 %), thereby reaching a high statistical significance level ($p < 0.01$). In one case, however, where an additional poster not used in the test had a coloring similar to an advertising poster actually shown, the number of false positive rose to 18 %. On the other hand, which and how many advertising posters were remembered differed widely amongst test participants.

Figure 3: Selected results of the direct recognition of the advertising posters shown in the eye tracking test and three others that had not been shown; the values of the false positives are marked red

4. Discussion

The study expands the knowledge and understanding of consumer's perception of billboard advertising and the influence of the different location-related factors. In sum, the results indicate that the laboratory environment used in this experiment seems to be appropriate to analyze the attentional impact of billboard advertising. According to the eye tracking data, the desired low-involvement situation was recreated, and several basic assumptions on the perception of billboard advertisements could be confirmed. While some obvious disadvantages of an artificial setting remain (e.g. a limited freedom of movement, discrete stimuli vs. continuous perception), they are outweighed by benefits like a stable, controllable environment that guarantees identical conditions for all test participants, leading to quantifiable results that are easy to analyze and to interpret.

4.1 Some reflections on study design

One aspect that influences the perception of advertisements both in real-life scenarios and simulations in the same way is the influence of familiarity. Therefore, a fundamental question during the study design was to what extent a prior knowledge of the city environment, real poster motifs or brands might influence results. It is, after all, quite conceivable that while processing visual stimuli, familiarity or experience may reduce the cognitive workload; which might manifest itself, for instance, in shorter fixation durations (cf. Young et al., 2009, p. 387). In marketing, it is well-known that a single confrontation with a poster advertisement will hardly have a major impact; on the contrary, repeated viewings are an indispensable prerequisite for advertising effects (cf. Esch, 2011, p. 147; Weber and Fahr, 2013, p. 342; Crijns, 2012, p. 324).

This lead to a basic dilemma during the design of this study: By choosing a test environment well-known to the examinees, pre-knowledge effects could certainly influence results. Trying to rule them out completely by using both self-designed posters and stimuli from a city that was totally unknown to the test participants (or, as an alternative, by creating a completely artificial test environment), would have led to a setting that does not reflect any more the real situation in which billboard advertising is normally presented and perceived. Therefore, for this study, the decision was made to create an environment the attendees were probably familiar with. The advertisements, however, were not the ones that were visible at that time in the city, as the photos for the slideshow had on purpose been taken some months beforehand, so that a direct influence of "real" viewings made in the last week or so could at least be reduced. Thus, pre-knowledge effects were not supposed to be completely ruled out, but should be kept within the limits of a more or less "typical" viewing situation.

4.2 Results on the overall distribution of attention

Comparing the general distribution of attention, it can first be said that the city environment in general gets much more attention than the backlit billboards embedded therein. The eye tracking results show that the billboard areas not only get less attention than their surroundings, but that it also takes longer until they get noticed for the first time.

Of course, one has to consider that the environment occupies much more space on most stimuli than the billboards. Taking this into account, the time to first contact is still comparably low for those billboards that attract any attention at all – the first fixation appearing to be part of an orientation phase. On the other hand, the total number of fixations on a billboard advertisement hardly ever exceeds the number of two. This supports previous statements that outdoor advertising is a glance medium (Pant, 2007, p. 199) with usually only a very brief exposure (van Meurs and Aristoff, 2009, p. 82), where contact is only casual and quite unintentional (Bloom, 2000, p. 395).

Nonetheless, the billboard advertisements do get noticed by the majority of passers-by (61.5 % of the test participants). The minimum fixation duration that is considered to be necessary for information uptake (> 100 ms) is reached in almost all of these cases (cf. Link et al., 2008, p. 374), and in at least one third of the cases, there were even long fixations (> 300 ms) which are likely to indicate more intense cognitive processing (cf. Leven, 1991, p. 93). This is also in line with statements attributing high levels of reach and frequency (Lane, King and Reichert, 2010, p. 371) and a repeated exposure rate (Donthu, Cherian and Bhargava, 1993, p. 70) to billboard advertising, producing a major impact (Prasad, 2009, p. 15).

The results of the unaided recall, aided recall and direct recognition tests performed immediately after the eye tracking test, are also in line with prior assumptions. MacInnis and Jaworski (1989, p. 5), for instance, base their discussion of advertisement perception on the assumption that there are several levels of information processing, each involving greater attentional and/or capacity resources. During casual ad/brand processing, they further argue, only processes utilizing few processing resources can be performed, namely feature analysis (the identification of salient properties of the stimulus) and sometimes basic categorization (a combination of features associated with a specific cue and an assignment of corresponding semantic labels, cf. o.c., p. 6). Only features perceived and/or combined at this stage can later be used for recollection – so, observers always see more than they can remember afterwards (Sperling,

1960, p. 1). This is in accordance with post-test survey results, where ad recollection became considerably better with increasing assistance and was best when the test stimuli were actually shown to the test subjects, so that characteristic visual components like the key visual, the dominating color or the product shot were actually visible. Apparently, these visual features helped the participants to reconstruct and to recall the poster motif correctly. Even for the false positives, it could be observed that particularly noticeable visual elements were remembered, although they were erroneously associated with well-known, popular brands that used similar colors or elements in their poster design. This supports the hypothesis that billboard advertising is indeed perceived only fragmentary and at an unconscious level (which would be a certain analogy to results presented in Nikolaus and Bendlin (2015), where similar effects regarding the recollection of packaging designs could be observed).

4.3 Impact of the location-related factors

As for the impact of the location-related factors on ad processing, the results illustrate that simplistic assumptions (e.g. the nearer a billboard the better) do not accurately reflect the complexity of human perception. For some of the named factors, the eye tracking results showed clear trends, whereas for others the results were ambiguous or, in one case, showed no visible effect.

The impact of the occlusion factor is quite obvious. Billboard advertisements that were partly hidden got significantly less attention than the same posters without obstacles. This is in accordance with results of an earlier eye tracking study, albeit with a slightly different objective, showing diminished attention for partially occluded faces (Jiang, Xu and Zhao, 2014, p. 24). However, current billboard rating systems like the German one seem to focus mainly on the length and the extent of occlusion (cf. Löffler, 2014, p. 10; ESOMAR, 2009, p. 19), whereas the results of this study suggest that the type of obstacle also plays an important role – as a road sign obstructing a billboard had a greater impact on the viewer's attention than an occlusion by pedestrians. A possible explanation for this might be that people generally tend to attract attention (cf. Wagner, Baird and Barbaresi, 1981, p. 197, 201; Holmqvist et al., 2011, p. 80; Busch, 2007, p. 31), and that due to the spatial proximity, attention might be redirected from the pedestrians to the advertisement. Consequently, further analysis regarding the influence of different types of obstacles on human perception might be advisable.

Furthermore, a connection between environmental complexity and the attention for billboard advertising was also recognizable. This is also in accordance with basic assumptions, because an increased complexity of the environment is tantamount to a higher number of visual stimuli that the advertisement posters have to compete with. This supposedly has negative effects on information reception because the limited capacity of the human brain (known as the attentional bottleneck) forces cognitive processes to become increasingly selective (cf. Milosavljevic and Moran, 2008, p. 383; Ratneshwar, Mick and Reitinger, 1990, p. 547) – the screening out of less relevant information being considered to be one of the main functions of attention (cf. Kroeber-Riel and Gröppel-Klein, 2013, p. 62; Ratneshwar, Mick and Reitinger, 1990, p. 547; Taylor, Franke and Bang, 2006, p. 22). However, the influence of environmental complexity seems to be somewhat smaller than initially assumed. The biggest distraction was caused, as already mentioned, by oncoming objects or pedestrians, probably because they could cause a collision in the case of real locomotion. This, again, is in accordance with literature stating that mobile objects and people draw eyes (Wagner, Baird and Barbaresi, 1981, p. 201; Holmqvist et al., 2011, p. 80; Busch, 2007, p. 31).

As for the other location-related factors tested here, the results were not always as expected and in some cases were even inconclusive. One possible explanation for this could be that the analyzed location-related factors might differ in terms of importance for the perception of billboard advertising and supersede or superimpose themselves on factors of lower relevance. Concerning the linear distance, for example, it might be expected that an advertisement at a shorter distance has a higher attentional impact than the same poster further away. This would have been in accordance with an earlier study stating that the number of objects noted by pedestrians on a walk around the block decreases as a function of distance (cf. Wagner, Baird and Barbaresi, 1981, p. 199). The present eye tracking results, however, do not confirm such a simple connection (see below).

A similar picture emerges from the data analyzing the impact of competing nearby billboards. In principle, a higher competition should – due to the increased number of visual stimuli – induce a decrease of attention for each one of them. However, the attentional values for a single advertising poster were even lower in one of the two tested situations than for the same ad in direct competition, whereas the second situation led to mixed results. A closer look at the second stimulus revealed, however, that by trying to include the second billboard in the stimulus, other location-related factors like the linear distance had also been marginally altered. Thus, the latter result might be the result of a mutual superimposition.

Looking at the general distribution of attention between billboards, other billboards competing with them and the surrounding environment, it can be stated that the visual attention of the examinees is usually focused either on the center of the image or on the vicinity of

the expected route. This is in accordance with results in Wagner, Baird and Barbaresi (1981, p. 196) stating that "the lion's share of attention is directed along the road straight ahead" while driving on a highway, and that "[w]hen a person walks, most of his eye fixations are directed forward in line with his intended walking route" (Zohar, 1978, p. 677). In those scenes mentioned above with the unexpected results, the billboards with higher attentional values were always nearer to the main focus point of attention and those at a shorter distance or with less competition but lower attentional values were further away. One possible explanation for these results might be that the proximity to the main point of interest plays a more important role than other location-related factors such as linear distance or competition.

The results concerning the last location-related factor, the viewing angle, proved to be inconclusive. Due to the fact that a frontal view provides optimal visibility of the advertising poster, it was to be expected that billboards positioned directly in front of the test participants would get higher levels of attention than those at a more acute angle. According to the eye tracking data, however, the viewing angle had not much influence on gaining and retaining attention.

4.4 Consequences for the improvement of rating systems

In sum, the results presented here indicate that the various location-related factors are not equally important for the perception of billboard advertising and supersede or superimpose themselves on factors of lower relevance. Regarding this, it is interesting to note that some of the factors with a comparably lower relevance are quite prevalent in the advertisement measuring systems

of different countries. Although there has been some activity to provide more reliable measurement data on the performance of billboard advertising lately (cf. Jarvis and Eddleston, 2003; Lichtenthal, Yadav and Donthu, 2006, pp. 240, 244), a lack of transparency in research led to very different measurement systems internationally (e.g. TAB, 2014, p. 1; MOVE, 2014; Buitenreclame Onderzoek, 2015). Table 5 shows the occurrence of the factors discussed in this paper in rating systems of various Western countries, where, for instance, the viewing angle or the linear distance are very popular, although their impact in this study was rather limited. Then again, the degree of occlusion, having a comparatively strong impact on the perception of billboard advertising in this study, is only included in the German and Irish measurement system (JCDecaux, 2010, p. 2). Although a weighting of the location-related factors seems advisable according to the results presented here, some rating systems remain unweighted (e.g. FAW e.V., 2012, p. 5), whereas in others, the weighting method is not disclosed (e.g. TAB, 2014, p. 1; Route Research, 2014, pp. 5–6).

Furthermore, previous studies focus on the hit rate as the basic measure of visibility, measuring the proportion of respondents who fixated the panel at least once (Barber, Sanderson and Dickenson, 2008, p. 5). However, the hit rate includes all forms of contacts – both the single short fixations for orientation and the long fixations necessary for a deeper processing (Busch, 2007, p. 15). Therefore, the hit rate alone might not be an appropriate measure for the contact quality, which is why additional measures like the time to first fixation, gaze duration and fixation count have been used in this study as well. This could allow for a more precise determination of the relative importance and of the interdependencies of the location-related factors.

Table 5: Distribution of the location-related factors researched in this paper in the rating systems of various Western countries

	Linear distance	Degree of occlusion	Competing nearby billboards	Lateral distance	Overall complexity of situation and environment
Germany	✓	✓	✓	✓	✓
UK	✓	✗	✗	✓	✓
Netherlands	✓	✗	✗	✓	✓
USA	✓	✗	✗	✓	✗
Australia	✓	✗	✗	✓	✗
Ireland	✓	✓	✗	✓	✓
Switzerland	✓	✗	✓	✓	✗

5. Conclusions

Although there has been an increasing research interest in outdoor advertising, it still remains an underresearched topic (cf. van Meurs and Aristoff, 2009, p. 83). Consequently, outdoor advertising is frequently criticized for a lack of verified audience measurement research (King and Tinkham, 1989, p. 47), and there is still very little known about the effectiveness of outdoor advertising (Donthu, Cherian and Bhargava, 1993, p. 70).

The impact of location-related factors on the performance of billboard advertising has for a long time been judged rather than measured (cf. Bloom, 2000, p. 406), and as a result, poster audience research systems differ widely from country to country (Bloom, 2000, p. 396). The usage of eye tracking technology to analyze the impact of billboard advertising on human attention and perception, therefore, might be very helpful to identify those factors that influence the recall and overall effectiveness of outdoor advertising (cf. Donthu, Cherian and Bhargava, 1993, p. 70).

The results of this study seem to confirm some basic assumptions on billboard advertising, namely that it can achieve a large coverage and high levels of reach but that billboard ads are at the same time perceived only fleetingly and without conscious attention. The influence of a variety of location-related factors on the attentional impact of billboard advertisements could equally be confirmed. These factors include, for instance, the environmental complexity and the degree of occlusion of the billboard. The influence of other factors, such as the linear distance to the billboard or the number of competing nearby billboards, was, however, lower than expected; rather, a position near the viewers' main point of attention seems to be decisive. Thus a central billboard position could compensate for the negative impact of other location-related factors.

This might imply that common weighting procedures used to determine the influence of location-related factors on the effectiveness of outdoor advertising should be reconsidered. Currently (at least in the German rating system), all location-related factors are equally involved and deficiencies in one area cannot be compensated by more favorable values in another (FAW e.V., 2012, p. 5). Therefore, the results presented in this paper might help to better understand consumer reactions on billboard advertising and help to improve existing advertisement measurement systems that describe the impact of location-related factors.

As the long-term goals of quantifying and qualifying the impact of outdoor advertising are the same all over the world, it seems advisable to ensure a consistent application of measurement structures and particularly contact definitions (cf. Jarvis and Eddleston, 2003); also across national borders. Therefore, studies like this one might build a foundation for further standardizations and adaptations of both the factors influencing the visibility of billboard advertising and their weighting.

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Features contributing to the genuineness of portraits on banknotes

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Abstract

Portraits have been thought to be one of the most important security features on banknotes for a long time. Portraits are often printed as the main feature of banknotes at a very high resolution in intaglio press. We tried to investigate on how important portraits actually are and what factors were contributing to the perceived genuineness of portraits on banknotes with a psychometric experiment. Banknotes were presented to subjects, enclosed in envelopes to cover the area other than the portrait, and the genuineness of those banknotes were rated. The factors affecting the rating were asked to the subjects at the same time. It was suggested that natural wear and tear strengthen the perceived genuineness of tested banknotes. Even though the inspection of the banknotes was restricted to on and around the portrait, the importance of the portrait was not high compared to other features, and a significant fraction of subjects answered that they paid no attention to any part of the face, which requires reflection and reconsideration of the use of human portraits as a security feature.

Keywords: intaglio printing, security printing, counterfeit deterrence, image quality, face perception

1. Introduction

The first-line security of banknotes or paper money for the general public is based on people's perceptual inspection, and the value of banknotes is the matter of people's subjective confidence in those banknotes (Masuda, Pedersen and Hardeberg, 2015). Human portraits have been used on banknotes for a long time (Hymans, 2004). Portraits of respected persons became popular in European banknotes since the economic crisis of the 1920s to support people's confidence in banknotes (de Heij, 2012). Face perception is, psychologically, known to be special compared to the perception of other objects (Bruce and Young, 2012). The recognition of human faces and that of other objects are thought to be independent to each other according to neuropsychological studies (Moscovitch, Winocur and Behrmann, 1997). Human portraits are usually the main feature of a banknote printed in intag-

lio press with high line contrast and high resolution, and they have been thought to be one of the most important security features on banknotes. However, the rationales for the support of human portraits as a security feature are often only anecdotal (e.g., Colgate, Jr., 1996), and the advent of modern photomechanical and digital reproduction techniques is endangering the raison d'être of intaglio portraits as a first-line security feature (van Renesse, 2005). On the other hand, not a small number of central banks adopt motifs other than human portraits as the intaglio main feature of their banknotes (Cuhaj, 2014; Hymans, 2006).

The purpose of this study is to know whether human portraits are still important as a security feature, and how they are contributing to the perceived genuineness of banknotes.

2. Methods

The subjective genuineness of the tested banknotes was estimated from the rating data of the banknotes. Each banknote was covered by an envelope with a hole, and only the area on and around the portrait was presented

to observers to focus the attention of the observers to the portraits. The factors that the observers were attending to while they were rating the banknotes were verbally reported, then transcribed and interpreted.

Table 1: Banknotes used for the experiment (W and H represent the width and height of each oval hole, respectively)

#	Abbrev.	Banknote	Series	W (mm)	H (mm)
1	AUD5	Australian 5 dollar	2003	51	57
2	AUD10	Australian 10 dollar	2002	51	57
3	AUD20	Australian 20 dollar	2002	51	57
4	AUD50	Australian 50 dollar	2003	51	57
5	CAD5	Canadian 5 dollar	2013	51	64
6	CAD20	Canadian 20 dollar	2012	51	64
7	CLP1000	Chilean 1000 peso	2011	51	57
8	CLP2000	Chilean 2000 peso	2009	51	64
9	MXN20	Mexican 20 dollar	2004	44	57
10	MXN50(I)	Mexican 50 dollar (intaglio)	2004	44	57
11	MXN50(O)	Mexican 50 dollar (offset)	2004	44	57
12	NZD20	New Zealand 20 dollar	1999	51	57
13	RON5	Romanian 5 leu	2005	51	63
14	RON10	Romanian 10 leu	2005	51	64
15	RON50	Romanian 50 leu	2005	51	64
16	RON100	Romanian 100 leu	2005	51	64
17	SGD10	Singaporean 10 dollar	2005	51	63

2.1 Materials

Each of seventeen banknotes as shown in Table 1 was enclosed in an envelope made of black cartridge paper. Each envelope had an oval hole so that the portrait and its proximal background on the banknote was observable. The size of the envelopes was the same for all banknotes, 215 mm in width and 89 mm in height, but the sizes and positions of the oval holes were adjusted according to those of each portrait.

The average width and height of the oval holes were 49.8 ± 2.7 mm (S.D.) and 60.2 ± 3.4 mm (S.D.), respectively. Figure 1 shows an example of the specimens with the Australian 10-dollar banknote.

2.2 Subjects

Twenty one subjects including 18 males and 3 females with a mean age of 32 years (range: 19–61 years) participated in the experiment. They were staff, students, and a visitor of the Faculty of Computer Science and Media Technology at Gjøvik University College, but were not experts in banknote and security printing. They are all color normal, and normal or corrected-to-normal sighted. The instructions to the subjects were given both orally and in writing, and were understood clearly. The familiarity to each banknote was inquired to each subject by a questionnaire before each experimental session, and no one was familiar to any of the banknotes.

Figure 1: An example of the specimens used for the experiment with the AUD10 banknote

Figure 2: Experimental viewing booth

2.3 Procedures

Experimental sessions were conducted in a viewing booth with D50 simulating fluorescent lamps, as shown in Figure 2. The tabletop was 120 cm wide, 85 cm long, 24 degree tilted, and illuminated at 1 400 lx by D50 simulating fluorescent lamps through a diffuser. The illuminance was measured by Konica-Minolta CL-200. The scene was recorded by video camera from the side.

The subjects wore cloth gloves on their both hands, and were allowed to judge the specimens only by vision. She/he was instructed to judge the degree of her/his agreement whether each banknote was genuine according to the 5-category Likert scale. Five white papers indicating the levels of rating, "Strongly agree", "Agree", "Neither agree nor disagree", "Disagree", and "Strongly disagree", were lined up from left to right on the table. The subject picked a specimen from a deck one by one, and put the specimen onto one of the 5 rating papers. The order of the specimens in the deck was randomized for each subject. The subjects were not informed whether the deck contains any counterfeit banknotes.

After the subjects finished rating of the specimens, they were asked what features in the whole open area of each banknote they were attending to, and what criteria they were using during the rating session. At the end of the session, the subjects were also asked which part of the faces of portraits, if any, they were attending to during the rating. The responses of the subjects were video recorded, and transcribed afterward.

Statements by subjects were reported by the open question method. When a statement was not clear, the exper-

imenter followed up to clarify what was meant by the statement, but no suggestions were made to lead the subject. Video recorded responses of subjects were transcribed literally, and then summarized as the keywords in Table 2 by one of the authors (OM).

Summarization of raw statements into selected keywords was done regardless of the context of the statements – whether they were mentioned positively or negatively.

Table 2: Keywords for the features in overall rating
of banknote genuineness

Keyword	Meaning and actual expressions
Background	Background other than the portrait.
Design	Design, arrangement, or combination of elements.
Detail	Fineness, high resolution.
Goniometric	Goniometric properties including gloss, raised intaglio lines.
Integrity	Overall integrity or conformity of elements.
Portrait	Intaglio portrait. Main figure of the banknote.
Photoreality	Photoreality of portraits and pictures.
Quality	Overall quality of printing.
Texture	Texture, pattern, shading, tone, contrast.
Wear	Wear and tear, fold, wrinkle.

3. Results

3.1 Rating of genuineness

Figure 3 shows the histogram of the category rating 5-level Likert scale on whether each banknote looks genuine. Each of 21 subjects made ratings of 17 banknotes, which comes to 357 ratings in total. Even though all of the specimens were actually genuine, only half of them were rated as "Strongly agree" and "Agree". A quarter of them were rated as "Neither agree nor disagree" and the remaining quarter were rated as "Disagree" and even "Strongly disagree".

Nominal values of 2, 1, 0, −1, −2 were first assigned to the 5 categories from "Strongly agree" to "Strongly disagree" of the raw rating data, respectively, and then an interval scale was constructed with Torgerson's law of category judgement, Condition D (Engeldrum, 2000), using the Colour Engineering Toolbox (Green and MacDonald, 2002), and the interval scale of "gen-
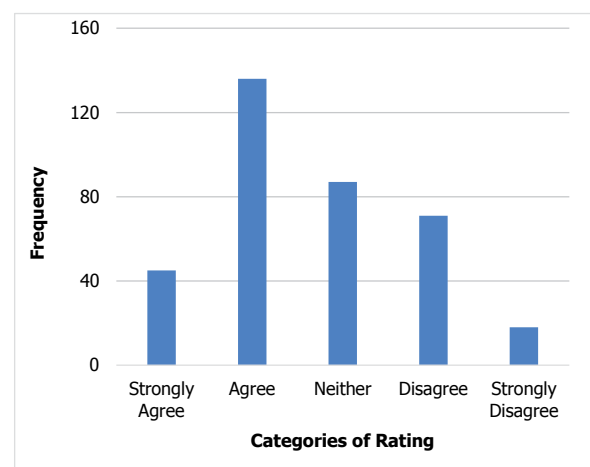

Figure 3: Histogram of category rating in 5-level Likert scale
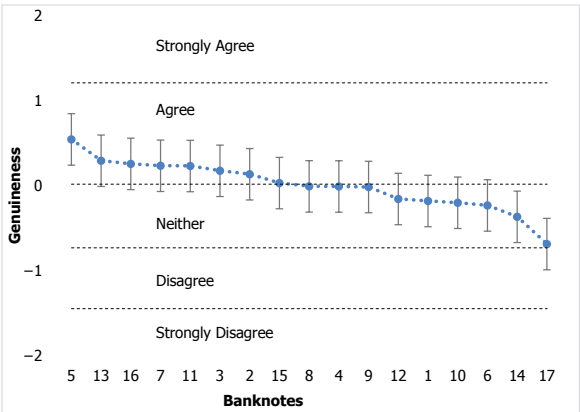*on whether each banknote looks genuine*

Figure 4: Interval scale of "genuineness" of the banknotes, where the error bars show the 95 % confidence intervals, and the horizontal lines show the borders between adjacent categories

uineness" of the banknotes was calculated as shown in Figure 4. The 95 % confidence intervals of the top 3 highly rated banknotes (5, 13, 16) did not overlap with those of the last lowly rated banknotes (14, 17).

3.2 Criteria of rating

Overall criteria of rating genuineness of banknotes were tallied as follows: The primary and secondary criteria were tallied separately, and each criterion was assigned 1
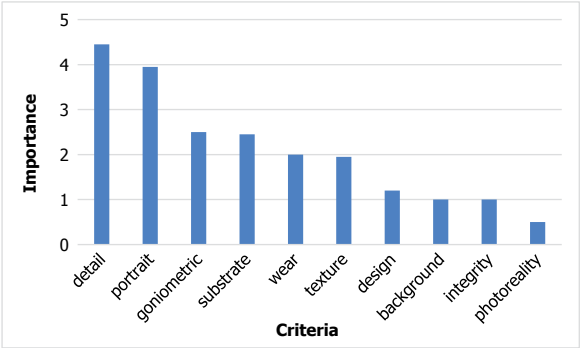
Figure 5: Importance of primary criteria in rating the genuineness of banknotes
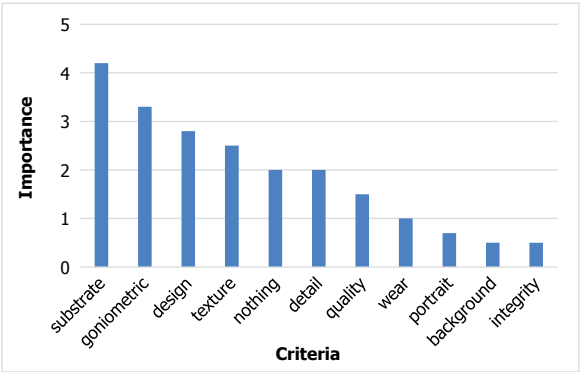
Figure 6: Importance of secondary criteria in rating the genuineness of banknotes
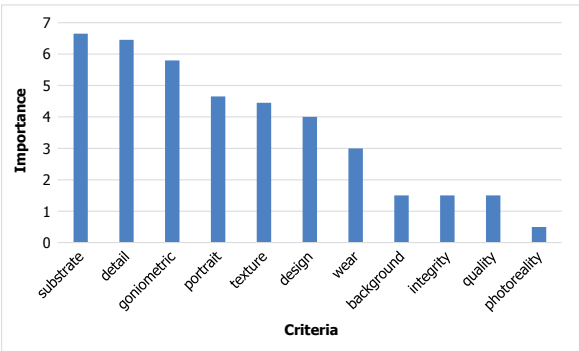
Figure 7: Summed importance of primary and secondary criteria in rating the genuineness of banknotes

point for each subject. When the subject stated his/her criterion of rating with an expression that contains multiple concepts across several keywords in Table 2, the assigned 1 point was divided to the keywords according to the importance of each keyword. For example, when a subject stated that the primary criterion was the conformity of portrait and background, the keywords "Integrity", "Portrait", and "Background" got points of 0.5, 0.25, and 0.25, respectively, for this subject. These points assigned for each subject were summed up for each keyword and are shown in Figure 5. The secondary criteria were also calculated in the same way, and are shown in Figure 6. When a subject had only primary criterion but no secondary criterion, the secondary criterion of this subject was counted as "Nothing". Figure 7 shows the histogram of the summed importance of the primary and secondary criteria.

Table 3: Additional keywords for the rating of individual banknote

Keyword	Meaning and actual expressions
Artifact	Artifacts, noise or errors in printing.
Color	Color of elements.
Complexity	Complexity or elaboration in configuration of elements.
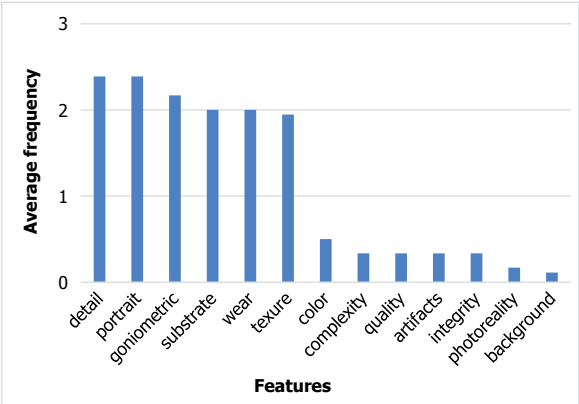
Figure 8: Histogram of features mentioned for highly rated banknotes individually

3.3 Comparison between highly and lowly rated banknotes

Features that were mentioned by subjects to each banknote were compared between highly rated banknotes (5, 13, 16) and lowly rated banknotes (14, 17). In counting features mentioned to individual banknotes, three new keywords in Table 3 were needed in addition to those
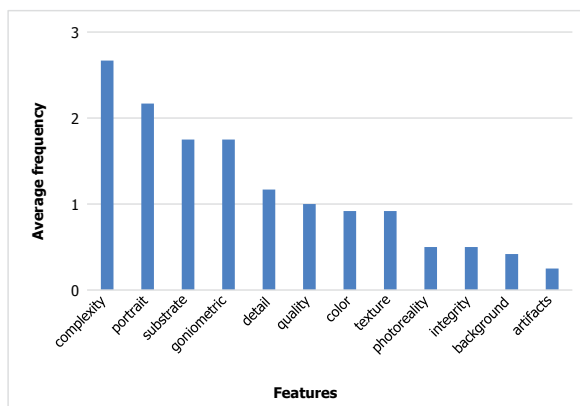

Figure 9: Histogram of features mentioned for lowly rated banknotes individually
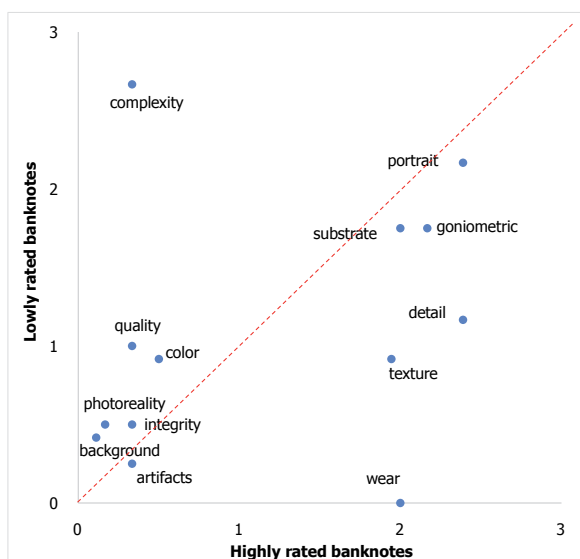

Figure 10: Scatter plot of the frequencies of features mentioned to highly and lowly rated banknotes

for overall criteria in Table 2. These additional keywords might be implicitly included in those in Table 2, but were not mentioned consciously for the overall rating of banknotes. For the rating of individual banknotes, these keywords were mentioned expressly and were not ignorable.

The features mentioned for each of highly rated banknotes were counted and averaged across all three banknotes as shown in Figure 8.

In the same way, features mentioned for each of lowly rated banknotes were counted and averaged across two banknotes as shown in Figure 9.

The histograms of Figure 8 and Figure 9 were merged as a scatter plot as Figure 10.

Figure 11 shows the importance of parts in the face of the portrait. Each subject answered which parts of the face, if any, she/he was attending to during the session. If a subject had any facial parts she/he attended, the subject earned one point of importance. When the subject answered more than one parts, the one point was divided to each part according to the importance of each part. For example, when the subject answered three parts and said that each part was equally important, each part earned 1/3 of point. When the subject didn't answer the degrees of importance of the parts explicitly, the experimenter estimated the degrees subjectively according to the verbal expressions by the subject. Seven subjects answered that they didn't have any part of the face to attend to, which were classified as "None" in Figure 11.
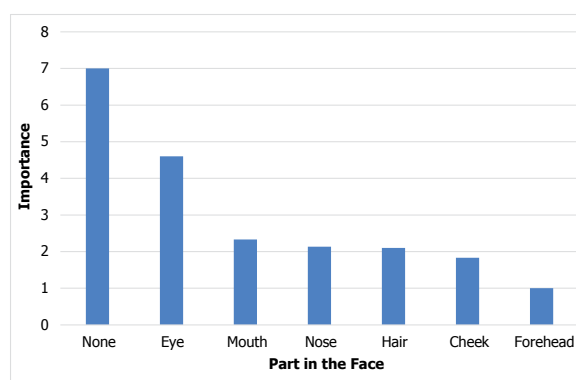

Figure 11: Importance of parts in the face of the portrait.

4. Discussion

As shown in Figure 3, the distribution of the histogram was skewed, and the peak of the histogram was at "Agree" and not at the center ("Neither"), which is natural because all the specimens were actually genuine banknotes. Even though the subjects didn't know whether the specimens contained counterfeits, a quarter of specimens were classified as counterfeits ("Disagree" and "Strongly Disagree"), and only a half of specimens were classified as genuine banknotes with confidence ("Strongly Agree" and "Agree"). The restriction of observable area (only on and around portraits) and perceptual modality (only with vision but without touch) might have decreased the genuineness of the genuine banknotes compared to the normal observation condition.

As shown in Figures 5–7, the importance of "Portrait" was ranked number 2 as a primary criterion and number 9 as a secondary criterion. The summed importance of "Portrait" was number 4 after all. On the other hand, the importance of "Detail" was larger than "Portrait" both as a primary and secondary criteria. "Substrate" and "Goniometric" were also ranked higher than "Portrait" in the summed importance. Even though the observable area was restricted only to around the portrait, the portrait itself didn't attract so much attention of the subjects. A possible cause of this result can be that it was too obvious to mention and the subjects just omitted to mention it even though they were aware of it. Another possible cause is that the portrait was not actually very important in judging the genuineness of banknotes. The latter possibility is discussed again later with the results of Figure 10 and Figure 11.

As shown in Figure 8, there was a clear difference between the more frequently mentioned features (from "Detail" to "Texture") and less frequently mentioned features (from "Color" to "Background") in highly rated banknotes. On the contrary in lowly rated banknotes, the difference of frequencies among features was gradual as shown in Figure 9. The clear dichotomous distribution of features for highly rated banknotes in Figure 8 suggests that the features that contribute to genuineness are limited and the relative importance among them are almost equal.

As shown in Figure 10, the features on and around the diagonal line of the graph are important in both highly and lowly rated banknotes in almost the same degree. Features in the upper right corner such as "Portrait", "Substrate", and "goniometric" are important for both highly and lowly rated banknotes. On the other hand, features in the lower left corner such as "Color", "Integrity", or "Artifacts" are not so important in neither highly and lowly rated banknotes. On the contrary, "Complexity" and "Wear" are far away from the diagonal line, which means that they were peculiarly important for lowly or highly rated note, respectively. Actually, "Complexity" was mentioned in a negative context for lowly rated banknotes, that is, the lack of complexity, excess simplicity, or poorness of configuration was des-

ignated to lowly rated banknotes. "Quality" was also mentioned more frequently to lowly rated banknotes in a negative context that the printing quality of those banknotes were poor. On the other hand, "Wear" was mentioned more frequently to highly rated banknotes than lowly rated banknotes, which means that the wear and tear of the highly rated banknotes were natural, and such natural damages did not harm the genuineness of the banknotes. On the contrary, reasonable and plausible wear and tear makes the banknotes look more genuine. The banknotes tested in the present study were polymer-substrate banknotes. The durability of polymer banknotes is known to be much longer than paper banknotes (Wilson, 1998). The fact that the feature "Wear" were rarely mentioned to lowly rated banknotes suggests that the intactness and flawlessness might have harmed the genuineness of those banknotes conversely.

As shown in Figure 11, one third of the subjects answered that they paid attention to no part of the face of the portrait even though the observable area was restricted only to on and around the portrait. Among the rest of the subjects, the part that attracted the strongest attention was the eye, and its importance was about twice of that of following four parts (mouth, nose, hair, cheek). Only one subject answered that the forehead was important. The fact that the eye was the most important is consistent with the conventional design policy in portrait engraving (Church and Setlakwe, 2004; de Heij, 2012). Since a third of the subjects didn't pay attention to any of the facial parts it might throw doubt on the conventional dogma that the peculiarity of facial perception gives a ground to use human portraits as the main feature in intaglio press. Further work should be carried out to investigate this, preferably with more subjects. As shown in Figure 10, "Portrait" was mentioned frequently both in highly and lowly rated banknotes when individual banknotes were reviewed. However, as in Figure 7, "Portrait" was ranked number 4 in importance when overall criteria were asked. There is a recent trend that the size of the portrait on a banknote is getting larger (de Heij, 2012; Board on Manufacturing and Engineering Design, 2007). Evidence-based verification of the effectiveness of human portraits as a security feature would be needed for further research.

5. Conclusions

Portraits are often considered to be one of the most important security features on banknotes. In this work, we investigated how important portraits actually are and what factors were contributing to the perceived genuineness of portraits on banknotes with a psychometric experiment. In the experiment, banknotes were presented to 21 subjects, who rated the genuineness of the banknotes. The results indicate that natural wear

and tear strengthen the perceived genuineness of the tested banknotes. Even though the inspection of the banknotes was restricted to on and around the portrait, the importance of the portrait was not high compared to other features, and a significant fraction of subjects answered that they paid no attention to any part of the face, which requires reflection and reconsideration of the use of human portraits as a security feature.

Acknowledgements

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Formatting print layouts with CSS3

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Abstract

Cascading Style Sheets (CSS) have already been the *de facto* standard for the visual representation of digital content for some time now. However, advanced functions intended for the formatting of print layouts have been included only recently. With CSS level 3, which is still under development, several new features have been added to the standard, such as, for example, the definition of marginalia, footnotes, running heads or the support for advanced micro-typographic settings like OpenType features. In theory, these new features could be the key to a significant simplification of cross-media publishing, based only on the use of XML or (X)HTML and CSS3. In this paper, the current status of implementation of CSS3 features for the formatting of XML-based print layouts is discussed and its current support by rendering engines analyzed. The results suggest that CSS3 can be used at present for the formatting of simply structured content, but not for visually or semantically complex print layouts.

Keywords: XML, Cascading Style Sheets, cross-media publishing, electronic publishing, rendering engine

1. Introduction and background

The more the publication of e-books or other digital content formats becomes firmly established, the more important effective procedures for multi-channel publishing become for publisher competitiveness (Kleinfeld, 2013; Ott, 2014, p. 3; Quin, 2014, p. 253). Of course, various computer-based technologies for professional typesetting have been around since the 1980s – such as TeX by Donald E. Knuth (1984), LaTeX by Leslie Lamport (1994), Standard Generalized Markup Language (SGML) by Charles F. Goldfarb (1990) or various desktop publishing systems ranging from Aldus PageMaker and QuarkXpress to Adobe InDesign, to name but a few. However, they were mainly intended to enable high-resolution or desktop printers to translate a pre-defined design into printed form (cf. Crawford, 1994, p. 101).

The eXtensible Markup Language (XML), on the other hand, designed in 1998 with the purpose to become the "future lingua franca for the exchange of structured data" (Bosak, 1998, p. 120), has a much stronger focus on principles like media and platform independence. It has therefore become a key technology for cross-media publishing, where information contained in one single source can, in principle, be published without manual intervention on different output channels in order to become a printed book, a website, an e-book

– or even an accessible document for handicapped users (cf. Nikolaus, 2010, p. 14).

However, in accordance with its media-independent approach, XML only describes the semantic structure of a document, not its layout. In order to specify a document's design, an additional stylesheet language is needed. Modern multi-channel publishing workflows automatically generate print layouts (along with various electronic products) by applying the eXtensible Stylesheet Language Formatting Objects (XSL-FO) to media independent (XML) data (Ott, 2014, p. 117; Quin, 2014, p. 253). However, XSL-FO has not become very popular within the publishing industry yet (Ott, 2014, p. 117; McKesson, 2012). Cascading Style Sheets (CSS), on the other hand, are extremely popular for the formatting of web content as well as e-books, although until now, they have barely been used in formatting of print layouts. While CSS has become a *de facto* standard for the styling of electronic documents, print layouts still have to be generated using different technology – this contradicts the basic concept to generate a coherent and truly homogeneous cross-media publishing workflow.

Nevertheless, an (albeit rather limited) *paged media* model has been added to CSS level 2 as early as 1998 – which

basically makes it possible to generate and format print layouts from HyperText Markup Language (HTML) or XML source documents using CSS as well (Ertel and Laborenz, 2014, p. 58; Harold and Means, 2004, p. 221; Lie and Day, 2005).

Since 1998 the CSS print layout functionality has been improved slowly but steadily by the World Wide Web Consortium (W3C). Thus, the current version CSS3 – with its modular design intended to simplify parallel development (Meyer, 2012) – comprises several CSS modules defining several new rules, functions, properties, values and selectors which can be used for the automatic generation of print layouts (Graham, 2014, p. 265; Quin, 2013, p. 261). Amongst others, CSS3 includes modules to:

- define and design multi-column layouts for elements in the *CSS Multi-column Layout Module* (W3C, 2011b),
- define color and opacity using different color models like RGB, HSL or CMYK in the *CSS Color Module Level 3* and *Level 4* (W3C, 2011a; W3C, 2014b), or
- make various micro-typographic settings – for instance in the *CSS Fonts Module Level 3* (W3C, 2013a) and the *CSS Text Module Level 3* (CSS3TEXT) (W3C, 2013d).

Apart from these more general CSS3 modules that can be used for other purposes as well (such as the formatting of digital content), CSS3 introduced several new modules that are of particular importance for formatting print layouts, such as:

- The *CSS Paged Media Module Level 3* (CSS3PAGE) describes a page model (or box model) for print layouts and defines rules, properties and special page selectors for the formatting of paged media (e.g. the definition of page size, orientation and margins) or the customization of headers and footers (size, styling and positioning). Furthermore, it allows for the positioning of content such as page counters in headers and footers (W3C, 2013c).
- The *CSS Generated Content for Paged Media Module* (CSS3GCPM) contains features to generate and to place content in special page areas automatically and to add, for instance, running heads, footnotes and cross-references to paged media (W3C, 2014d).
- The *CSS Fragmentation Module Level 3* (CSS3BREAK) includes properties to control pagination and defines fragmentation rules for page and text breaks which should be observed and applied when a static layout is generated (W3C, 2014c).

2. Methods

The objective of this paper was to explore how the new features of CSS3 can be used to render paged media layouts out of media independent data. In order to achieve this aim, a constructional approach was used: First, the structure, content and design of thirty textbooks and other non-fiction books (only Latin characters) with complex print layouts were analyzed to identify specific design elements that characterize paged media. Based on this analysis, a test document was developed to combine all these features into one single book. Next, a media independent XML file describing the content and structure of this test document and a CSS3 document containing the corresponding paged media formatting instructions were prepared. The content and layout files were validated (using both validation tools of the *<oXygen/>* XML editor and the W3C's online CSS Validation Service) to ensure the conform-

ity of the XML content file with the semantic language DocBook V5 and the CSS layout document with the specification of CSS3.

From these two files, a paged media PDF document was generated automatically using two different rendering engines: *YesLogic Prince v9 rev5.0* and *Antenna House Formatter V6.2 (evaluation version)*, in further text designated as PR and AH, respectively. At the time of the tests, these two renderers were considered to be the two major commercial tools that already support features of the CSS3 Paged Media Module (cf. Kleinfeld, 2013), while the Paged Media support of other programs and projects was supposed to be insufficient (Fellenz and Fischer, 2013). Finally, the generated PDF documents were analyzed and the conformity of the resulting paged media layout to the initial layout specification was tested.

3. Results

In contrast to previous CSS versions, CSS3 includes a wide range of new rules, properties, values and selectors to format print layouts with complex structures. The CSS3 modules support various new macro- and micro-typographic settings for print layouts and provide a formatting functionality for paged media that is comparable to professional typesetting software applications, such as the creation of sophisticated running heads and footnotes, the addition of marginalia,

the definition of baseline grids and floating images or the specification of advanced typographic settings for Open Type Fonts (OTF). Based on the nomenclature of classic layout processes, the new CSS3 features for print layouts can be categorized into six classes: *Page settings*, *Paragraph, Word and character formatting*, *Automatic content generation, Fragmentation options*, *Settings for printing and distribution*, and *Selectors*. For each of these categories, the following section will provide a brief overview

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of the new CSS3 features for formatting print layouts. Next, the results of the rendering tests will be presented in tabular form, followed by illustrative examples.

3.1 Page settings

Compared to CSS2.1, CSS3 provides several new rules, properties and values to define paged media. Beside the description of page sizes, page margins (controlling print space) and page orientation (W3C, 2013c), it is also possible to create and control baseline grids and snaps (Lie, 2015; W3C, 2014e) or to define other layout elements, such as pagination, column titles, footnotes or margin columns, and to describe their position on the page and their styling (Lie, 2015; W3C, 2013c; W3C, 2014d). Furthermore, CSS3 supports the usage of sample pages (W3C, 2013c).

Thus, CSS3 offer a functionality comparable to DTP applications when it comes to the formatting of paged layouts. Being style sheets for markup languages, however, CSS files have to be parsed and rendered by corresponding user agents. The new features are, thus, only applicable if these renderers support them (see also Götz and Nikolaus, 2013). Unfortunately, this could not always be taken for granted. When the test document was rendered by the professional typesetting applications PR and AH, the CSS style definitions for page size, page margins (including different margin settings for left and right pages), page orientation and the positioning of column titles and page numbers, respectively, were interpreted according to the specification (Table 1).

However, the rendering of column titles was differing: While PR rendered column titles according to the CSS specification, AH produced some unexpected results
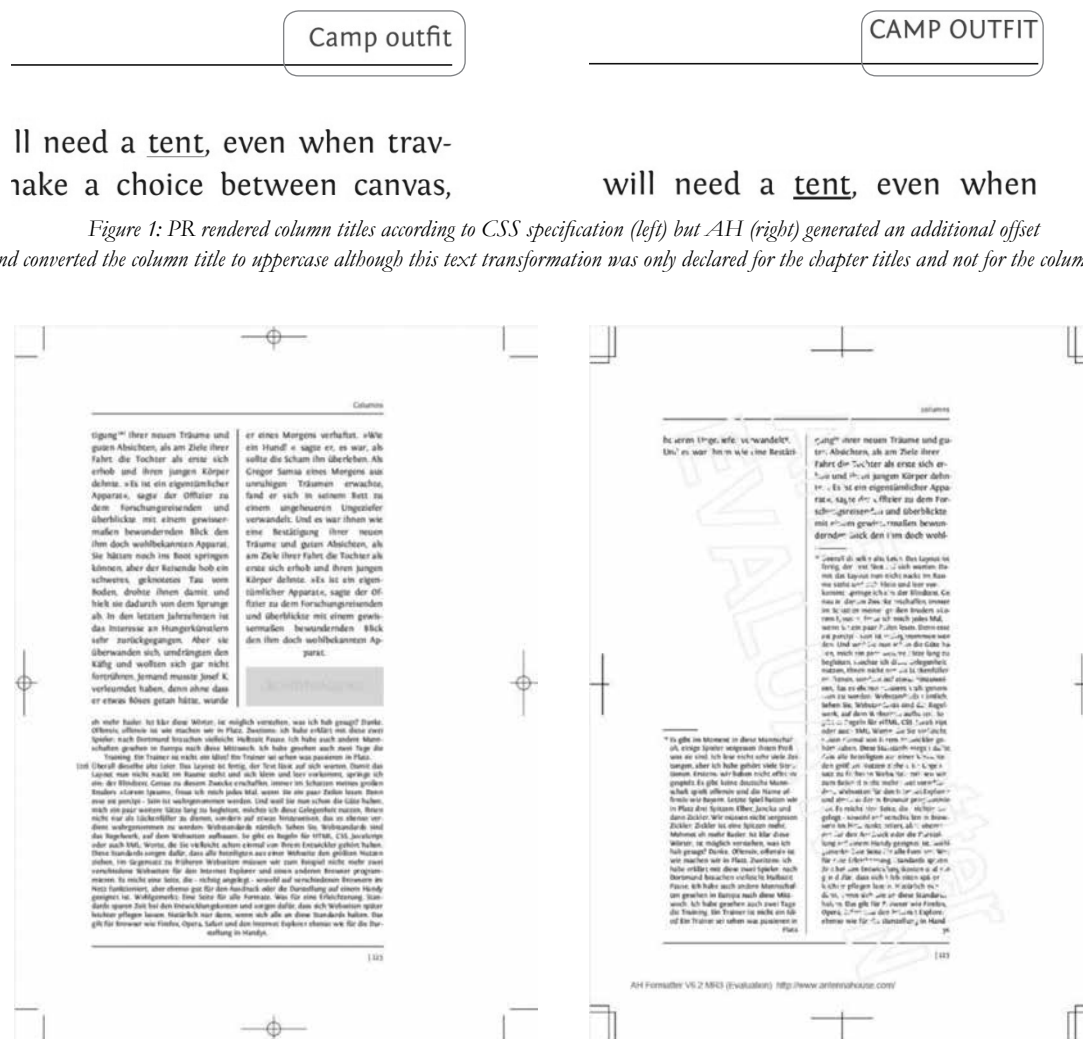

Figure 1: *PR rendered column titles according to CSS specification (left) but AH (right) generated an additional offset and converted the column title to uppercase although this text transformation was only declared for the chapter titles and not for the column titles*

Figure 2: *Rendering results of footnote styles by PR (left) and AH (right) for the CSS declaration that included a dividing line between main text and footnotes, a one column footnote area under the double-columned main text with a maximum height of 25 % of page size, and custom footnote markers and positioning*

when the column title was generated automatically from the chapter titles using the property `string-set` and the function `string()`. In this case, a text transformation to uppercase that was only intended for the chapter titles themselves was unintentionally propagated to the column title as well (Figure 1).

Table 1: Excerpt of test results for page settings, for more detailed descriptions cf. Götz (2014)

Analyzed and tested new features of CSS3 for page setting	PR	AH
Page size [f]	●	●
Orientation	●	●
Print space, margins, double page layout	●	●
Column title [f]	●	◓
Page number [f]	●	●
Footnote (notes, counter, area) [f]	◓	◓
Margin column [d]	○	○
Page template [d] and page selector	◓	◓
Baseline grid [d] and register accuracy	○	○

Legend: [f] format, [d] definition, ● full support, ◓ partial support, ○ no support

The rendering of footnotes was also heterogeneous (Figure 2). The styling of both footnote element and footnote call were consistent (full CSS support), as was the styling of footnote counters (although user-defined counters were only rendered if they were defined using `strings` but not when the `@count-style` rule was used). Changes of the `display` property of footnote elements (from `block` to `inline`) were ignored by both renderers. The styling of footnote markers was fully supported by AH but only partially by PR (footnote markers were always positioned outside of the print area, regardless of the CSS property settings). Custom changes of the footnote area were totally ignored by PR, which only used predefined formatting settings, while AH supported a few style settings like `background`, `border-clip` and text spacing; though it ignored the CSS properties for `height` and `width` of footnote area as well).

The rendering of marginalia did not comply with the CSS specification either, although renderer-specific workarounds to define such layout elements (and to fill them with content) could be found. However, none of these solutions proved to be fully satisfactory, as an alignment neither to baseline grids nor to corresponding elements in the main text could be realized.

Additional rendering problems could be found while working with page templates and page selectors. Page templates offer the opportunity to pre-define common page layouts; page selectors can be used to define varying layouts for the first page of a document or chapter, for blank pages or all left or right pages, respectively (`:first`, `:blank`, `:left`, and `:right`). In general, both the page template functionality and the page selectors were supported by both the PR and AH renderers; however, the pseudo class `:nth()` intendet to define a different styling for every fifth or ninth page and so on, was not.

3.2 Paragraph, word and character formatting

The CSS3 specification provides new features for the formatting of textual content. In addition to CSS1 and 2.1 properties such as `font-family`, `font-size`, `font-weight` and `font-style`, it is now possible, for instance, to specify `font-stretch` (e. g. condensed or semi-expanded font faces) or to use OpenType features like standard or historical ligatures and small and petite capitals, respectively, through `font-variant` and `font-feature-settings` (W3C, 2013a). As to justification, CSS3TEXT offers, for example, `text-justify` adding new sophisticated justification algorithms and `hanging-punctuation` specifying if a punctuation mark at the start or end of a text line should be rendered outside or inside the line box (W3C, 2013d). Moreover, multi-column layouts can be specified (W3C, 2011b); also, leaders for tables of contents, registers and the like are defined and formatted using the `leaders()` function (W3C, 2014d). Customized counters for lists, etc., can be declared (with `@counter-style` and `::marker`) and additional settings for the positioning, floating and the column span of figures and boxes are available (`float` properties like `top-bottom`, `column-span`, `float-defer-column`, `float-defer-line`, `float-offset`). Text can now be wrapped around other content (W3C, 2013b; Lie, 2014) and boxes can be embroidered with rounded corners or shadows (W3C, 2014a).

Just like the renderers' support for page settings, the results for paragraph, word and character formatting were equally mixed (Table 2). Only the `leaders()` function was fully supported by both rendering engines. As to the font settings, only the CSS3 `@font-face` rule (used to embed fonts into paged media) was supported by both PR and AH, while `font-stretch` and `font-variant` were not supported by either one.

The justification test showed that currently only `text-align-last` (used to specify the alignment of the last line of text of a paragraph) is partially supported by PR. AH, on the other hand, fully supported the text justification properties `hanging-punctuation` and `text-align-last` – but only partially supported the new `text-align` values and ignored the properties `font-kerning` and `text-justify` (though a proprietary version of the latter is available: `(-ah-)text-justify-trim`).

As for multiple column page layouts, the column properties `columns`, `column-rule` and `column-fill` can already

be used. The `column-span` settings, however, were ignored by PR if used for content that was generated by pseudo elements, and AH ignored `column-span: all` if it was used in the footnote area (instead, the columns in the footnote area always matched the layout of the main text columns, see Figure 2).

Table 2: Excerpt of test results for paragraph, word and character formatting, for more detailed descriptions cf. Götz (2014)

Analyzed and tested new features of CSS3 for paragraph, word and character formatting	PR	AH
Font settings	◒	◒
Justification	◒	◒
Columns	◒	◒
Depiction and decoration (e.g. text indent, text orientation, text decoration, text transform)	◒	◒
Leaders for register	●	●
Individual counter for e. g. lists	◒	◒
Figures and boxes	◒	◒

Legend: ● full support, ◒ partial support,

The `writing-mode` feature (`top-to-bottom`, `right-to-left` and `left-to-right`) was supported by both renderers. PR additionally recognized the new value `hanging` of `text-indent`, while AH supported `text-transform` without limitation. Other functions were only partially implemented (AH: `text-orientation`, `text-decoration-style` and `text-shadow`) or unsupported (PR: `text-orientation`, `text-transform`, `text-shadow` and `text-decoration` properties; AH: `text-indent: hanging`, `text-decoration-underline-position` and `text-decoration-skip`; both: `text-indent: each-line`). Again, PR and AH sometimes offered proprietary alternatives (YesLogic, 2015a; Antenna House, 2014).

The CSS styles to define individual counters are equally unknown to the renderers, although the pseudo element `::marker` can be used to customize predefined counters for lists, footnotes and the like.

In regard to the formatting of figures, CSS3 offers many new features, but only a few of them can already be used. The property `float`, to begin with, is supposed to control the alignment of figures on the page (*vertically:* `float: top | bottom | top-bottom | bottom-top`; *horizontally:* `float: inside | outside`). The properties `top`, `bottom`, `inside` and `outside` are currently supported by both AH and PR, whereas `top-bottom` and `bottom-top` (intended to define preferred alignments that can, however, be overridden by the renderers, if necessary) were not. The alignment in multi-column layouts can be controlled using `column-span`. Here, only the values

`none` and `all` were rendered correctly, while it was not possible to span an image across a specific number of columns using `integer` or `length` values. Both the new `float-defer-*` settings (which can be used to transfer a figure to another column or another page irrespective of its position in the original XML document) and the advanced new wrap configurations, `wrap-side` and `wrap-contrast` (Lie, 2014) or `clear-side` and `exclude-level` (W3C, 2013b), were not considered during the rendering process at all.

The performance of the renderers for CSS3 box model instructions – `border-image` to use bitmap images as border style patterns, `border-radius` to define rounded borders and `box-shadow` to attach shadows to an element (W3C, 2014a) was equally mixed. Border images were replaced by black solid borders by both PR and AH; `box-shadow` was only supported by AH, although the property was not interpreted according to CSS3 specification (box and content were converted to an image with low resolution and the RGB color mode was used, although CMYK colors had been defined throughout the document). The `border-radius-*` feature could be used according to specification, although PR did not accept the shorthand `border-radius` to define different radii for each corner; instead, the longhand terms such as `border-bottom-left-radius` had to be resorted to.

3.3 Automatically generated content

Automatically generated content, like paginations, column titles, footnotes, cross-references, tables of content or catchword indexes, is very important for effective cross-media publishing. Consequently, CSS3 offers various settings to generate paged media content automatically. Compared to previous CSS versions, CSS3 includes additional functionalities for:

- the automatic generation of paginations: `content: counter(page)` (W3C, 2013c),
- footnotes: the declaration `float: footnote` turns an element into a footnote; this conversion necessitates several background processes – the element has to be moved from the main text to the footnote area, a footnote marker has to be displayed before the element as well as a footnote call in the main text, and the footnote counter has to be incremented (W3C, 2014d; Lie, 2015),
- running headers and footers: the property `string-set` combined with `content: string()` is used to copy the textual content of an element into the header/footer or `position: running()` and `content: element()` to move an element including all of its substructures from the main text to the page margin boxes for headers and footers, respectively (W3C, 2014d),
- cross-references: `target-counter()` and `target-counters()` generate numbered cross-references and `target-text()` retrieves the text value of an element referred to using an URL (McKesson, 2012; Lie, 2015),

• bookmarks: CSS3 offers three properties to generate bookmarks: `bookmark-level` to define the hierarchy level of a bookmark in the bookmark structure, `bookmark-label` to declare the text which should be displayed to identify a bookmark entry and `bookmark-state` to specify the state of a bookmark hierarchy as open or closed – with open state bookmarks displaying the next level of bookmarks (W3C, 2014d; Lie, 2015).

Sophisticated as these new functions may be, there are still some features for automatic content creation left that the CSS3 specification does not include up to now: catchword indexes and tables of content. For the time being, this content has to be created semi-automatically using XSLT (XSL Transformations) and the CSS3 property for cross-references; for more details see Götz (2014).

Considering the features that are already included in the CSS3 specification, the test results show that only the automatic pagination and the definition of footnotes are currently supported satisfactorily by the renderers (Table 3); all other aforementioned functionalities for automatic content generation are only partially implemented. Column titles could be created using both methods mentioned above (`string-set: [<identifier> <content-list>];` and `content: string()` or `content: element()` and `position: running()`), but not all arguments intended to specify the mentioned content could be used by PR and AH (especially `first-except`, which allows for an empty header/footer on the page where a new column title is assigned, is currently unsupported).

As to the automatic generation of cross-references, the test shows that the `content` values `target-counter()` and `target-counters()` (to create dynamic paged cross-references that automatically adapt the pagination

Table 3: Excerpt of test results for generated content, for more detailed descriptions cf. Götz (2014)

Analyzed and tested new features of CSS3 for automatic generated content	PR	AH
Table of content [d]	◖	◖
Index [d]	◖	◖
Column title [d]	◔	◔
Page number [d]	●	●
Footnote [d]	●	●
`Content()`-function	◔	○
Cross-reference	◔	◔
Bookmarks	◔	◔

Legend: [d] definition, ● full support, ◖ support only in combination with an XSLT, ◔ partial support, ○ no support

to page size or layout changes) can be used by both rendering engines. The property `target-text()`, to generate customized textual references like "see chapter *(name of chapter), p. (page number)*", however, is currently only supported by AH.

On the other hand, the properties `bookmark-level` and `bookmark-state` for the generation of bookmarks were already fully supported. Bookmark labels were tagged correctly by both PR and AH when the text labels were hard-coded via `string`. PR also supported the `content()` function that can be used to define bookmark labels dynamically, but only without any argument (`content()`) or if the property `text` was used (`content(text)`) – other arguments like `before`, `after` or `first-letter` were unsupported. AH offered no support at all of the `content()` function – neither for the labeling of bookmarks nor in any other case.

3.4 Fragmentation options

To control the fragmentation of pages, columns and regions, CSS3 provides the properties `break-before` and `break-after`. These are similar to the CSS2.1 properties `page-break-before` and `page-break-after`, but new values, like `page`, `column` (inserting mandatory page and column breaks, respectively) and `recto` (adding page breaks so that the following page is a recto page) are added (W3C, 2014c). For in-text breaks, CSS3TEXT contains e.g. the properties `line-break` (fragmentation options for punctuations), `word-break` (breaking rules for letters) and `hyphens` (control of word splitting) (W3C, 2013d). In the CSS3GCPM module, the W3C also adds the property `footnote-policy`. This is important for fragmentation if a footnote call is located near the bottom of the print space so that there is not enough space to render the complete footnote body on the same page. With `footnote-policy`, it can be specified whether a page break should be inserted at the start of the line or before the corresponding paragraph, so that both reference and body of the footnote are displayed together on the same page (W3C, 2014d).

Although only about 20 % of the CSS3 fragmentation settings were supported in the test (Table 4), the rendering engines use proprietary methods to define breaking rules. For page breaks, the new properties `break-before/-after` were only supported by AH, but both rendering engines accepted the old CSS2.1 `page-break-before/-after` properties (limited to the CSS2.1 value set `always`, `avoid`, `left` and `right`). CSS3 line breaks were ignored by both PR and AH. AH supported CSS3 word fragmentation settings and PR as well as AH used proprietary commands for hyphenation (`prince-hyphenate-lines`, `prince-hyphenate-before`, `prince-hyphenate-after` (YesLogic, 2015a), see Figure 3. CSS3 page break settings for footnotes were ignored, but again, PR added a proprietary command named `prince-footnote-policy`.

Table 4: Excerpt of test results for fragmentation options, for more detailed descriptions cf. Götz (2014)

Analysed and tested new features of CSS3 for fragmentation options	PR	AH
Page, column and area fragmentation	○[1]	●
Hyphenation	◐[2]	◐[2]
Line break	○	○
Word break	○	●
Fragmentation settings for footnotes	○[3]	○

Legend: ● full support, ◐ partial support, ○ no support

[1] Instead of the CSS3 `break-before/-after` commands, the CSS2.1 properties `page-break-before/-after` could be used to define page breaks

[2] Proprietary functions to influence hyphenation: `prince-hyphenate-lines`, `prince-hyphenate-before`, `prince-hyphenate-after`

[3] Workaround to define fragmentation for footnotes with `prince-footnote-policy`

Achtung! Dieser Blindtext wird gerade durch 130 Millionen Rezeptoren Ihrer Netzhaut erfasst. Die Zellen werden dadurch in einen Erregungszustand versetzt, der sich über den Sehnerv in dem hinteren Teil Ihres Gehirns ausbreitet. Von dort aus überträgt sich die Erregung in Sekundenbruchteilen auch in andere Bereiche Ihres Grosshirns. Ihr Stirnlappen wird stimuliert. Von dort aus gehen jetzt Willensimpulse aus, die Ihr zentrales Nervensystem in konkrete Handlungen umsetzt. Kopf und Augen reagieren bereits. Sie folgen dem Text, nehmen die darin enthaltenen Informationen auf wie ein Schwamm. Nicht auszudenken, was mit Ihnen hätte passieren können, wenn dieser Blindtext durch einen echten Text ersetzt worden wäre.

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Figure 3: Two renderings showing the effect of a proprietary feature to influence hyphenation: due to the command `prince-hyphenate-lines: no-limit;` in the lower half, any number of lines ending with a hyphenation could follow one other, whereas in the upper half, the maximum number of hyphenations is 1 (`prince-hyphenate-lines:1;`)

3.5 Settings for printing and distribution

The new CSS3 features for printing and distribution include properties to switch between color spaces like RGB (W3C, 2011a) and CMYK (W3C, 2014b), to control image resolutions (W3C, 2012) and to define edge trim, corner marks and bleed (W3C, 2013c). These CSS3 functionalities were mostly supported in the test except for the definition of CMYK colors (Table 5). The rendering engine PR uses a proprietary command instead of the one specified by the W3C. Color manage-

Table 5: Excerpt of test results for printing and distribution settings, for more detailed descriptions cf. Götz (2014)

Analyzed and tested new features of CSS3 for settings for printing and distribution	PR	AH
Bleed [d]	●	●
Marks [d]	●	●
Color settings and color management	○[1]	●
Image resolution	◐	◐

Legend: [d] definition, ● full support, ◐ partial support, ○ no support

[1] PR uses the proprietary command `cmyk()` to define CMYK colors instead of the one specified by the W3C (`device-cmyk()`)
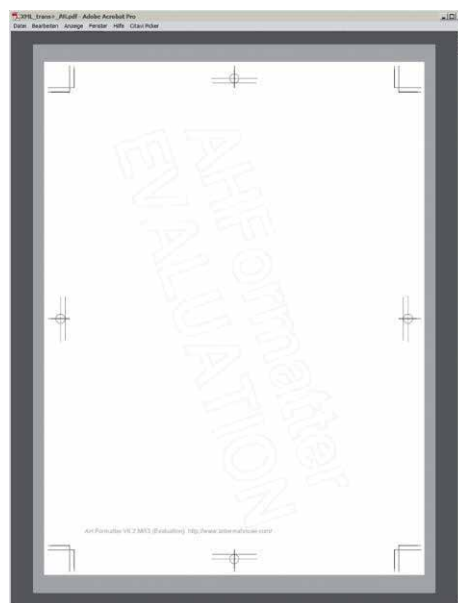

Figure 4: Rendering of bleed, marks and crops by PR (foreground) and AH (background); although the trimmed page size is identical, the untrimmed size differs, just as the visualization of marks and crops

ment of images, is only supported by AH. Both renderers also use different visualizations for crop marks and bleed (Figure 4).

3.6 Selectors

The CSS3 specification includes a wide range of new selectors to select and style elements separately. For instance, the new sibling selector `E ~ F` enables the selection of *all* following siblings of an element and not only the direct successor, which can be selected using `E + F`. The new pseudo class `:nth-child(n)` makes it possible to define styles e. g. for each odd table row with `tr:nth-child(odd) {…}`, and the pseudo element selector `::marker` to declare styles only for the marker, but not for the text, of a list with `li::marker {…}` (W3C, 2011c).

Fortunately, both rendering engines offer full support of all these new CSS3 selectors (Table 6), which facilitates the formatting of somewhat irregular but nonetheless recurring structures like, for instance, the odd-numbered rows of a table, which can now be addressed directly using `tr:nth-child(odd)` without recourse to inconvenient attribute definitions such as `<tr attr="odd">`.

This further improves the media-independent separation of content and layout between the XML file and the CSS document.

Table 6: Excerpt of test results for selectors, for more detailed descriptions cf. Götz (2014)

Analyzed and tested new selectors of CSS3	PR	AH
Attribute selectors	●	●
Pseudo class selectors	●	●
`::marker`, Pseudo element	●	●
`E ~ F`, Sibling selector	●	●

Legend: ● full support, ◑ partial support, ○ no support

4. Discussion

The aim of the present study was to test the current implementation status of CSS3 features that are needed for the formatting of XML-based print layouts in professional state-of-the-art rendering engines. In order to do this, a test document has been developed that contains the specific semantic elements of complex textbooks and other non-fiction books (only Latin characters). This book has been formatted using CSS3 and then rendered by the two state-of-the-art engines PR and AH.

The high potential of the new CSS3 features specification for a direct generation of print layouts from XML source documents becomes apparent if one considers the multitude of additional rules, functions, properties, values and selectors that have been described above. In principle, these new features could greatly enhance the efficiency of cross-media workflows. Even today, most digital publications such as websites, e-papers or e-books are using (X)HTML and CSS as source data formats to specify content and design (Quin, 2014). If print layouts could now be rendered from the same source documents as well, this would be another step towards a real single-source publishing, where a single media-independent file could be published on different channels just by exchanging the CSS. Double work and deviating processes for print layouts could thus be reduced.

This is not a mere future scenario, but is already becoming a reality: since 2013, for instance, the O'Reilly Media publishing house is developing HTMLBook, which is supposed to become an open, XHTML5-based standard for the authoring and production of both print and digital books (Kleinfeld, 2013). This initiative, however, is for the time being mainly focused on the semantic definition of a basic "book" structure (Kleinfeld, 2016) instead of the production of printed books. Whether this or other (X)HTML-based data formats are suited for the systematic editing, structuring and processing or typesetting data in a cross-media publishing workflow in conjunction with CSS3, needs

further analysis. However, it has already been stated that CSS as a technology to format XML documents for print is starting to come at age (Quin, 2014), that even XSL-FO processor vendors are moving to also support CSS (Graham, 2014) and that CSS will supplant XSL-FO within the next few years in the world's publishing houses (Kelly, 2015).

As for the situation today, the test results presented in this paper show that only less than a half of the new CSS3 features for print production are currently supported by *YesLogic Prince* and the *Antenna House Formatter*. This means that the test results are basically dissatisfying: for the time being, it cannot reasonably be expected that flawless CSS3 renderings of complex XML documents for print layout can be achieved with the available technology. As it is often the case with formal languages, the implementation of new language features into the rendering engines is unable to keep pace with the language's specification process (in the context of an automatic generation of accessible publications, cf. Nikolaus (2010)).

Furthermore, the test reveals fundamental differences between the rendering results of both engines. Not only that both support only a limited number of the new CSS3 features, but also, these feature subsets are not identical. Some features *are* supported by both renderers, but the rendering results are nonetheless different and the same CSS instruction thus results in differing print layouts. Besides, the analyses show that both renderers add non-standard, proprietary functionality to the definitions of the W3C CSS specification. While this may be helpful in some cases where complex print layouts might not have been rendered otherwise, the proprietary functions may require additional efforts and application testing. Because renderer-specific approaches do not validate against the W3C's CSS specification, it cannot be checked automatically and is not interchangeable with other XML rendering solutions. While this might not be a problem as long as the print production takes place in a controlled, in-house software environment,

it might not be suitable for a distributed production or print-on-demand solutions.

However, a continuous and dynamic development in the area of XML-formatting with CSS can certainly be observed; CSS is attracting many more resources and developers than XSL-FO today (Quin, 2014, p. 261). Compared to the time of testing, the *YesLogic Prince* renderer, for example, got a major update to version 10, which (according to the release notes) offers many new properties and features for the formatting of paged media with CSS3 (YesLogic, 2015b).

While the results presented in this paper do not allow any clear statements about the performance of other rendering engines, the two renderers tested here are certainly among the leading tools in this field. Therefore,

similar problems might be expected even if other tools are used for the XML-to-Print rendering, but this also calls for further study. A similar test might also be interesting for rendering engines like *pdfChip* by *callas software* (Callas Software, 2015) and *pdfreactor* by RealObjects (RealObjects GmbH, 2015), which are supposed to create high-quality PDF suited for printing directly from (X)HTML.

Finally, it needs to be mentioned that the test documents used here were based on the Latin writing system only, so that the suitability of CSS3 for the formatting of print layouts for ideographic languages with a different reading direction or for documents that use annotations for pronunciation or meaning (like the Japanese furigana; cf. Sampson (1990, p. 190)) have to be analyzed separately.

5. Conclusions

The possibility to generate and format both print and digital layouts using only XML (or HTML) and CSS3 could be the key to a significant simplification of cross-media publishing: the re-use or reprocessing of media-independent data in order to automatically generate websites, e-books, and well-designed and complex print layouts from the same media-independent data in a shorter time, with less effort and at reduced costs is an attractive prospect. The W3C standard CSS3 has the potential to make this vision come true. At present, however, our tests show that only few of the corre-

sponding paged media features are currently supported by the leading rendering engines. For the time being, CSS3 can already be used to generate works of fiction with a very simple semantic structure, but is not yet suited for the production of complex non-fiction and text books. Somewhat better results can be achieved by using non-standard, proprietary features of the respective rendering engines, thus adjusting the layout settings. But this, of course, contradicts the principle of a standards-compliant, media-independent and flexible production.

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Topicalities

Edited by Markéta Držková

Contents

News & more

The last news summary from drupa 2016 team

The start of drupa 2016 is approaching quickly. For the information on the fair itself please refer to the Events section. In the following text, we shortly introduce the summary of the report, which is tracking key economic and market developments in the global print industry, and three expert articles published since December 2015.

Third drupa Global Trends report

The report released in March 2016 analyses a global survey conducted in October 2015; this time, 892 printers and 355 suppliers took part (majority of which represented Europe and about one third other regions). The economic confidence in general is very similar to that reported a year ago, however, more diversified across regions and market sectors. The detailed picture resembles the previous one, but amplified; with the most positive numbers coming from North America and Functional and Packaging markets, whereas Publishing sector is the most cautious. A persistent warning is given by printer margins that decrease in all regions, and also by decreasing prices, with the exception of America and Africa. The investment plans remain positive in all sectors, with sheetfed digital presses on the top.

Expert articles in brief

Ron Gilboa in the 6th drupa 2016 expert article deals with 'The Digital Transformation of Industrial Printing'. He notes that the growth or decline in all market segments is dictated by consumer consumption and demand and thus highly dependent on the global economy and local consumer spending patterns. A growing desire for mass-customization favours innovative digital printing technologies, especially inkjet printing, now enabling deposition of a broad range of materials in a number of applications. The article goes through packaging, decorative printing, ceramics, textiles, laminates & wood, wallcoverings, glass, functional printing, membrane switches, 3D printing and printed electronics and give examples of available solutions.

touch **the future**
drupaexpert articles

The 7th one by Sophie Matthews-Paul, named simply 'Large format', cites several key vendors in the wide-format segment, which continues to grow. The author highlights practical benefits of wide-format ink-jet production and follows its spread from conventional markets to new, niche and speciality ones. Versatility enabled by effective workflow is often the same or more important than the speed, driving greater margins and profitability.

The current 'Digital versus traditional packaging print' situation is reviewed in the 8th expert article by Michael Seidl. Each of the fundamental market sectors – labels, flexible packaging, folding cartons and corrugated – has its own dynamics and characteristics. The label market was the first to adopt digital print technologies, followed by the other ones now, when relevant digital systems are becoming available. Besides traditional products, there is a range of special and innovative applications that creatively utilise the versatility of digital printing to follow the "micro-marketing" trend.

Live poll results from Digital Print for Packaging Europe 2015

Over 120 delegates from 16 countries and almost 80 companies, who participated the event in Berlin, Germany in December 2015, could take part in a poll through the mobile application and answer questions on their feelings about the future of digital print for packaging.

More than a half of them believes that the top brand owner motivation for adopting digital print technology is the customer engagement, while 25 % voted for cost-efficiency, 14 % for reducing risk on new product launches and the rest for workflow management, data capture or other.

The biggest business opportunity is seen in moving short print run jobs away from conventional presses (47 %), whereas for the complete replacement of conventional print by digital voted 11 %. The important opportunity lies also in customisation and personalisation (32 %).

With respect to substrates, flexibles (33 %) were identified as the biggest opportunity for digital print, followed by corrugated and cartons (both with 27 % of votes), and labels (13 %). In contrast, no one believes in rigid plastics and metal substrates.

Regarding the opportunity at various consumer markets, the poll returned this ranking: food (38 %) and beverage (31 %), pharmaceutical and medical with industrial (both 13 %), and cosmetics & personal care (6 %).

Customers are mostly expected to pay 10 %, or even 25 % extra (chosen by 44 % and 24 % of participants, respectively). The remaining votes were split between 0 % and 5 % extra.

As the main barriers, limiting the adoption of digital print, are seen costs (29 %), uncertainty (24 %), regulatory compliance issues (20 %), and the lack of partners (18 %).

The new partnership in print measurement & control systems

At the beginning of 2016, Q.I. Press Controls, established in optical measuring and control systems for web offset printing presses, has acquired INTRO International to expand into digital printing and the labelling and packaging market.

The QIPC-INTRO solutions for automatic print inspection consist of JetControl for missing jet and streaker detection, TagControl for reading variable printed barcodes, 2D codes or OCR tags, and DocControl, a modular image processing system, which in addition to misprint detection and reading of ID tags supports also object and print position check, color registration and printhead alignment control. The failures detected by print inspection systems or other sensors are processed by DocTracker, which subsequently controlls DocMarker, an ink-jet printer for marking void documents or for simple prints.

QIPC-INTRO PHT Print Traverses and PTU Print Towers enable ink-jet print integration to existing print or finishing lines either for monochrome or colour personalization, capable of very high speeds. Further, the QIPC-INTRO offers belt, casette or hybrid, as well as insulated and OEM IR dryers with intelligent energy management functions, designed for various customized applications.

Imprint-MIS version 18

The new version of Imprint-MIS launches in April 2016, with the overall extended functionality, redesigned Imprint Desktop, thin-client based Shop Floor Data Capture, enabling also to track the current position of every job, and SentinelNet for online machine monitoring to supply real time data on production times, materials used and costs for all presses and postpress equipment.

The system supports JDF integration by submitting jobs from the eXpert estimating module to prepress and press systems. Output JDF data with all job components can be exchanged using Hot Folders or HTTP.

Research & Development news

Open access pilot line for flexible OLED lighting

The PI-SCALE project is supported by the European Commission through the Photonics Public Private Partnership. The aim of the project is to accelerate the commercialisation of flexible organic light-emitting diodes lighting by creating a European-wide pilot line for testing and developing specific applications at an industrial scale. The consortium has 14 members and is coordinated by the Holst Centre.

A printed energy harvesting and storage circuit powered by ambient office lighting

The preparation and characterization of a one-step spray-coated carbon nanotube supercapacitor with aqueous NaCl electrolyte was reported by S. Tuukkanen et al. (Sci. Rep. 6, 22967, 2016). It was used in combination with printed organic photovoltaic module (detailed in P. Apilo et al. Prog. Photovoltaics 23, 918–928, 2015) harvesting an ambient light to power a printed electrochromic display. The fully charged supercapacitor was able to operate the display for 50 full ON-OFF cycles.

Medical application of screen-printed carbon electrodes

The screen-printed electrodes from Zensor Company (Taichung, Taiwan) were used by G. Tian et al. (Sci. Rep. 6, 23569, 2016) in the development of a novel indirect electrochemical detection method for the quantification of ethanol in human plasma. The performance of carbon screen-printed electrode was better than that of the Ag and Au ones. The method that employs disposable screen-printed carbon electrodes without modification and sample preparation procedure shows satisfactory correlation with the reference headspace gas chromatography method and could be applied to diagnose acute ethanol toxicity or ethanol-related death.

3D-printed guiding templates for improved osteosarcoma resection

Recently, computer-aided design (CAD) of guiding templates has been used effectively in several surgery applications. The objectives of the work of L. Ma et al. (Sci. Rep. 6, 23335, 2016) were to use CAD and 3D printing technique to design and fabricate, respectively, the patient-specific guiding templates for challenging precise osteosarcoma resection to reduce the operation time, blood loss, radiation exposure and incision size. The commercial bio-compatible MED610 material (Objet, Israel; now Stratasys) was used for fabrication of the 3D printed guiding templates.

Identification of print-related contaminants in food packaging

Since many other substances than photoinitiators only are used or formed during the print process, M.A. Lago and L.K. Ackerman (Food Addit. Contam. Part A Chem. Anal. Control Expo. Risk Assess. 33, 518–529, 2016) applied direct analysis in real-time high-resolution mass spectrometry, gas chromatography mass spectrometry and ultra-high-pressure liquid chromatography electrospray ionisation to detect and identify print-related molecules from the food-contact and print surfaces of three different food packages with under-cured prints. Over 100 compounds were tentatively identified or confirmed, including 35 print-related molecules, of which at least five are novel print contaminants such as 4-morpholin-4-yl-benzaldehyde or 3-phenyl-2-benzofuran-1(3H)-one.

Bookshelf

Fundamentals of Inkjet Printing: The Science of Inkjet and Droplets

The book guides the reader through the complete process of inkjet printing, explaining the principles as well as providing worked examples and case studies to ease the comprehension. Concise explanation of the content and the approach of the international author team is given by the editor, Stephen D. Hoath, in the preface: "The point of this new volume is to help explain quantitatively why fluids might behave the way they do under jetting, free flight, impact, spreading, coalescing, and drying conditions, by using scientific knowledge as gleaned from recent theoretical, numerical, and experimental research work." Appropriate theoretical tools are employed to make the processes involved more clear. The book should also represent a reference resource for those who will need to extend their understanding in this field further.

The text is organized into 16 chapters. The introductory one briefly presents continuous and drop-on-demand inkjet, surface tension and viscosity, dimensionless groups and length and time scales in inkjet printing. Next chapters explain the principles and factors that all influence how the fluid ink is jetted and then deposited. They start with fluid mechanics, discussing fluid properties, force, pressure, velocity and fluid dynamics in general as well as in inkjet systems, in order to help select a suitable regime for printing inks. 'Inkjet printheads' chapter overviews both thermal and piezoelectric printheads. The fourth chapter deals with the droplet formation itself. Following two chapters on polymers and colloid particles in ink formulations describe their essential properties and characterization methods. Jetting simulations, included in the seventh chapter, comprise 1D modelling, axisymmetric modelling and 3D simulation.

The volume continues with four chapters discussing the behaviour of droplets upon impact on a substrate surface and subsequent wetting and drying. First, the chapter named simply 'Drops on substrates' covers experimental observation of Newtonian drop impact on wettable surface, dimensional analysis and drop impact dynamics. The next one presents implications of drop coalescence on printed image formation and on functional and 3D printing, analysing the coalescence of inkjet-printed drops in various configurations up to 2D features and line printing. Further, described effects taking place during drying of droplets on surfaces include evaporation of single and mixed solvents, particle transport in drying droplets, leading to the coffee ring effect, and other effects observed for drying of complex fluids. Finally, the chapter dedicated to the simulation of drops on surfaces goes through continuum-based modelling of drop dynamics, challenging contact angle phenomena, diffuse-interface models and lattice Boltzmann simulations of drop dynamics.

Following chapters deal with a number of methods for inkjet printing process visualization and measurement as well as for characterization of inkjet fluids and surfaces, covering e.g. holographic methods, confocal microscopy or rheological measurement. In concluding chapters, selected inkjet printing applications and future directions for inkjet technology, including emerging solutions, are summarized.
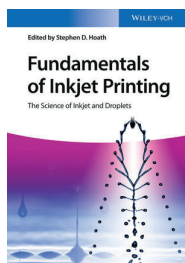
Fundamentals of Inkjet Printing:
The Science of Inkjet and Droplets
Editor: Stephen D. Hoath
Publisher: Wiley-VCH
1st ed., January 2016
ISBN: 978-3-527-33785-9
472 pages
Softcover
Available also as an eBook

Chipless RFID Sensors

*Authors: Nemai C. Karmakar,
Emran M. Amin, Jhantu K. Saha*

Publisher: Wiley
1st ed., February 2016
ISBN: 978-1118936009
272 pages
Hardcover
Also as an eBook

The low-cost, compact, printable and highly sensitive chipless RFID sensors are expected to replace optical barcodes and to play an important role in the Internet of Things. The authors of the book start with a concise introduction, RFID sensors literature review and an explanation of passive microwave design, followed by an overview of smart materials for temperature, humidity, pH, gas, strain, crack, light, and other sensing, and their characterization. The middle part deals with chipless RFID sensors for noninvasive partial discharge detection and localization, real-time environment monitoring, and multiparameter sensing. The final chapters present micro- and nanofabrication techniques, including printing, chipless RFID reader architecture, and several case studies.

Photonics
Volume 2: Nanophotonic Structures and Materials

Editor: David L. Andrews

Publisher: Wiley
1st ed., February 2015
ISBN: 978-1118225516
424 pages
Hardcover
Also as an eBook
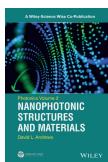
This volume discusses the basic physical principles, materials and structures in nanophotonics, which exploits light and matter interactions on the nanoscale. The content covers silicon and cavity photonics, metamaterials, quantum nanoplasmonics, dielectric photonic crystals, quantum dots, magnetic control of spin and thin-film molecular nanophotonics, light-harvesting materials, advances in metal oxide-based photoelectrochemical hydrogen production, and optical control of cold atoms and artificial electromagnetism.

Advances in Contact Angle, Wettability and Adhesion
Volume Two

After the first volume published in 2013, this volume includes more recent findings and also some additional topics, reflecting the significantly increased need to understand and control wetting behaviour. The progress is to a great extent associated with the development of surfaces exhibiting special properties (superhydrophobic, superhydrophilic, superoleophobic, superoleophilic, omniphobic, omniphilic), suitable for advanced applications. The content of the book is organized into three parts. The first one covers fundamental and general aspects. The second part, which is focused on wettability modification, includes the chapter on modification of paper/cellulose surfaces to control liquid wetting and adhesion. Finally, the third part brings three chapters on surface free energy and adhesion.
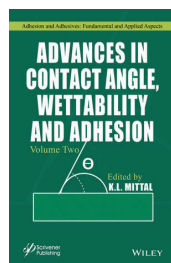
Advances in Contact Angle, Wettability and Adhesion
Volume Two
Editor: Kashmiri L. Mittal
Publisher: Wiley-Scrivener
1st ed., October 2015
ISBN: 978-1-119-11698-1
464 pages
Hardcover
Available also as an eBook

Surface Wetting:
Characterization, Contact Angle, and Fundamentals

The starting point for writing this book was disappointment experienced when the authors strived to understand how inks adhere on and release from different printing surfaces during the printing process with the objective to enhance the process and enable better ink and surface material designs. The motivation was to share some fundamental basic concepts, which the authors have learned, to improve the situation of unclear definitions or even controversies in surface science literature and lacking standardized measurement protocol.

The book is intended for all those who need to get into the field of surface science. After giving a background, contact angle measurements and surface characterization techniques are presented – determination of static contact angle, sliding angle, advancing and receding contact angle, and finally the Wilhelmy plate method. Next two chapters discuss wetting on flat and smooth surfaces and wetting on rough surfaces, respectively. Another two chapters answer the question what do contact angles measure and give an overview of terminologies and definitions. Then, various approaches to determine solid surface tension by contact angle and related issues are presented. The last chapter concludes the book with misconceptions in the Young's equation, promising concepts, outlook for surface characterization and guidelines for best practices.

Surface Wetting:
Characterization, Contact Angle, and Fundamentals
Authors: Kock-Yee Law, Hong Zhao
Publisher: Springer
1st ed., November 2015
ISBN: 978-3-319-25212-4
162 pages, 99 images
Hardcover
Available also as an eBook
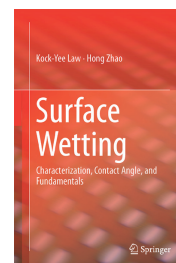
Digital Imaging Primer

Alan Parkin presents computers and their peripherals as modern tools for an ancient task of making pictures, to represent things seen or imagined. His book is intended for anyone interested in digital imaging, bringing the content which fills the gap between highly technical and superficial texts. Digital Imaging Primer with a lot of illustrations and examples explains the theory, technology, programs and practice to readers of any level. To make a full use of the exercises, only a simple scanner, digital camera, printer, and a PC with Microsoft Windows, Paint image editor and free QuickBASIC programming language are needed. Relevant code is supplied on CD.

The knowledge forming the basis of digital imaging is introduced in first four parts. They cover the sets, representation and arithmetic of numbers, the alphanumeric files and output, the coordinate, object, projection, lens and viewing geometry, the stereo projection and viewing, the auto-stereo imaging, the perception of space, the photometry, colorimetry and perception of brightness, hue, and saturation, and the complexity in digital imaging. The second half of the book describes practical imaging, from input through processing and storage to output and viewing, classified by bit-depth (1-bit, 4-bit, 8-bit and 24-bit imaging). In particular, there are explained transformations, including Fourier process, bitmap file structures, graphic editors, scanners, cameras, displays, and inkjet printers.

Digital Imaging Primer
Author: Alan Parkin
Publisher: Springer
1st ed., September 2015
ISBN: 978-3-540-85617-7
721 pages, 490 images
Hardcover
Available also as an eBook

Lean Management of Global Supply Chain

This book is published as Volume 12 of the Japanese Management and International Studies series, whose Editor-in Chief, Yasuhiro Monden, is the author of renowned book on Toyota Production System and many others. The process of the best global supply chain selection is explained in this volume through case studies, including Apple, BMW or Ikea. It is shown that reducing the total costs of global supply chain can be achieved by its organization considering causal relationships of the stage differences in market needs, product design architecture, and product life-cycle. Lean management of global supply chain management is covered in the first part and corresponding performance evaluation in the business operations in the second one. The third part deals with related topics in managerial and cost accounting and includes the chapter on measuring the performance of lean implementation at a commercial printing company.

Lean Management of Global Supply Chain
Editors: Yasuhiro Monden, Yoshiteru Minagawa
Publisher: World Scientific Publishing Co.
1st ed., October 2015
ISBN: 978-981-4630-70-2
312 pages
Hardcover
Available also as an eBook
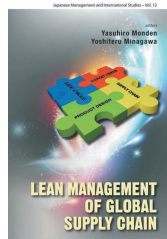
Beginning Scribus

Author: Robert White

Publisher: Apress
1st ed., November 2015
ISBN: 978-1484207239
352 pages
Softcover
Also as an eBook

After the introduction of a free page-layout program Scribus, the book describes working with text and images, and editing lines and shapes. Next, the colour management, preflight and documents export are explained. Enhancing the workflow with a free image editor GIMP, along with styles, templates and master pages in Scribus, is then presented. Finally, the exercises are provided.

Proceedings of the International Symposium on Research of Arts, Design and Humanities (ISRADH 2014)

Editors: Oskar H. Hassan, Shahriman Z. Abidin, Rusmadiah Anwar, Muhamad F. Kamaruzaman

Publisher: Springer
1st ed., September 2015
ISBN: 978-9812875297
556 pages
Hardcover
Also as an eBook

This volume features 56 papers, dealing e.g. with the implications of e-books on printed books, fine art reproduction by inkjet, production control in magazine printing or offset lithography print defects.

People of Print:
Innovative, Independent Design and Illustration

*Authors: Marcroy Smith, Andy Cooke*

Publisher:
Thames & Hudson
1st ed., April 2015
ISBN: 978-0500517819
336 pages, 452 images
Hardcover

The compendium combines in-depth interviews, print techniques, stories, references, and works and illustrations crafted by over fifty independent artists, designers, and illustrators.

Surface Modification of Biopolymers

Editors: Vijay K. Thakur, Amar S. Singha

Publisher: Wiley
1st ed., April 2015
ISBN: 978-1118669556
448 pages
Hardcover
Also as an eBook
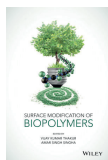
Biobased polymers are of a great interest due to the need for new and sustainable materials in a number of industries, not excluding pulp and paper industry. This informative and well-structured book reviews surface modification methods to enhance e.g. compatibility, flexibility, physicochemical properties, thermal stability, impact response, and rigidity of biopolymers, enabling to tailor and broaden their practical applicability. Among others, inkjet printing is utilised in biomedical applications.

Fundamentals of Conjugated Polymer Blends, Copolymers and Composites: Synthesis, Properties, and Applications

Editor: Parveen Saini

Publisher: Wiley-Scrivener
1st ed., May 2015
ISBN: 978-1118549490
800 pages
Hardcover
Also as an eBook
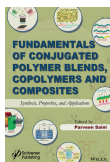
The contributions explore relevance, synthesis, properties, applications, and also drawbacks of individual conducting polymers, based on the state-of-the-art research across a broad range of topics in chemistry, processing, conducting composites, solar cells, thermoelectrics, batteries, supercapacitors, electromagnetic shielding, electrorheology, anti-corrosion, water purification, and sensing. A comprehensive understanding of the progress made so far should stimulate further discoveries in the field. The first part describes synthesis, properties and applications of multiphase systems in the form of blends, conjugated copolymers, composites or hybrids. Following three parts discuss energy harvesting and storage, environmental applications and conclude with sensing and responsive materials.

Pulp and Paper Industry:
Microbiological Issues in Papermaking
Chemicals
Energy Conservation

During past months, Elsevier has published three volumes of Pulp and Paper Industry, all written by Pratima Bajpai. The first two appeared together and cover microbiological issues and chemicals for papermaking. The third one now adds an overview of energy conservation possibilities.

In Microbiological Issues in Papermaking, the author at first presents a review of microorganism sources and various consequences of microbiological activity. A closed-loop process water system operating under neutral or alkaline conditions combined with an increased consumption of recycled fibres in modern paper mills results in higher microbiological activity, leading to decreased mill performance. The problems range from biofilm and spots or holes in paper products and microbiological growth in cellulose or additives through issues with odour and hygienic quality of the products to microbially influenced corrosion. Following chapters discuss the factors affecting biofilm development, types of microorganisms and their location on the machine, chemistry of deposits, and methods used for the analysis. Finally, the current methods and trends in biofilm (or more generally slime) prevention, treatment, and control are summarized.

The environmentally and economically driven changes in pulp and paper manufacture have substantially influenced also the papermaking speciality chemicals market. The Pulp and Paper Industry volume on Chemicals offers the in-depth, comprehensive overview of process and functional chemical additives and enzymes that are used in the papermaking, from pulp slurry through sheet formation to effluent disposal, along with their suppliers. Identified future trends include development of new chemicals and technologies for speciality papers, as well as functional and process chemicals market growth due to the increasing demand for recycled paper and technology innovation focusing on sustainable processes.

Pulp and Paper Industry: Energy Conservation discusses both available and emerging cost-effective, energy-efficient technologies and practices. Energy conservation measures for raw material preparation, chemical pulping, bleaching, chemical recovery, mechanical pulping, recovered fibre processing, and stock preparation and papermaking are presented together with corresponding qualitative and quantitative data. Various solutions mostly for drying, deinking and pulping, as well as several enzymatic treatments, are described among emerging technologies.

Pulp and Paper Industry:
Microbiological Issues
in Papermaking
1st ed., May 2015
ISBN: 978-0-12-803409-5
226 pages

Pulp and Paper Industry: Chemicals
1st ed., May 2015
ISBN: 978-0-12-803408-8
334 pages

Pulp and Paper Industry:
Energy Conservation
1st ed., February 2016
ISBN: 978-0-12-803411-8
290 pages

All volumes:
Author: Pratima Bajpai
Publisher: Elsevier
Hardcover
Available also as an eBook
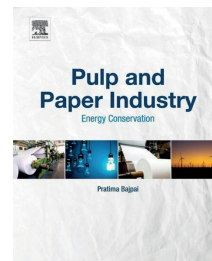
Bookshelf

Academic dissertations

Fully Printed Chipless RFID Tags towards Item-Level Tracking Applications

The dissertation systematically deals with the realization of low-cost printable chipless RFID tags intended to meet the growing demand for identification and tracking applications, expected to grow even further due to the Internet of Things. After the introduction, the second chapter presents the research on printed transmission lines and the investigation on paper substrates. Various types of transmission lines were printed and characterized by time domain and frequency domain measurements. The electrical properties were extracted and used to obtain corresponding lumped and distributed element models. The electrical properties of paper substrates were acquired as well. Then, the linearly-tapering method to design 50 Ω microstrip lines has been proposed. The third chapter explores tag antennas belonging to the most important components. To address the challenge to lower the fabrication cost without compromising the performance, typical tag antennas adopting the tapering method were designed. In addition, a novel bowtie antenna with square holes was suggested. According to the simulation results, both solutions allow to significantly reduce the material consumption. The bowtie antennas were inkjet-printed on various photopaper substrates. The process dependence simulations have shown that variations in line widths and thicknesses influence the antenna input resistance more than the antenna gain, radiation efficiency and read range. Following chapters discuss the ID generating circuits. An 8-bit time-domain based printable chipless RFID tag, consisting of a microstrip line and eight capacitors, was developed and inkjet-printed on photopaper substrates. A 10-bit frequency-domain based chipless RFID tag with ten configurable LC resonators was implemented on flexible printed circuit board by using toner transferring process. A more compact frequency domain tag with a configurable coplanar LC resonator was printed on low grade packaging paper substrates. The thesis is concluded by the discussion on the ultra-wide band technology and issues related to large coding capacity, compact size and configurability.

Doctoral thesis – Summary

Author:
Botao Shao

Speciality field:
Electronic and Computer Systems

Supervisor:
Lirong Zheng

Defended:
28 March 2014 at KTH Royal Institute of Technology / School of Information and Communication Technology Stockholm, Sweden

Contact:
botaoshao@gmail.com

Inkjet Printing: A Flexible Manufacturing of Functional Ceramic Coatings by Chemical Solution Deposition

This thesis explores the manufacturing of layered and patterned ceramic functional coatings when using drop-on-demand inkjet for ceramic oxide precursor deposition within chemical solution deposition process. The aim was to employ inkjet printing as a scalable and cost-effective technique to yield superconducting, magnetoresistive and other types of coatings. The relevance and general applications of functional ceramic oxides as well as the main features of two model systems studied in the thesis are introduced; namely, the copper, barium and yttrium mixed oxide ($YBa_2Cu_3O_{7-x}$) with an application in the production of superconducting tapes, and the lanthanum, strontium and manganese mixed oxide ($La_{0.7}Sr_{0.3}MnO_3$) showing a colossal magnetoresistance and a metal–insulator transition.

The technology of inkjet printing is reviewed, along with the influence of both ink and printing parameters on print quality. The thesis then describes the development, characterization and thermal treatments for the inks based on various ceramic oxides; the emphasis is put on morphological,

Doctoral thesis – Summary

Author:
Marta Vilardell Navarro

Speciality field:
Materials Science

Supervisors:
Susagna Ricart Miró
Xavier Granados García

Defended:
8 May 2014
at UAB / Department of Chemistry Barcelona, Spain

Contact:
mvilardell@icmab.es

structural and magnetic characterization. The physicochemical properties of the inks and the printhead actuation parameters were optimized to achieve desired drop formation and substrate wetting. Continuous layers and patterns of the superconducting $YBa_2Cu_3O_{7-x}$ were prepared, with film thickness controlled by modifying drop volume and the number of drops per unit area. Similarly, the magnetoresistive $La_{0.7}Sr_{0.3}MnO_3$ was successfully deposited and the manufacturing of a magnetoresistive device with high reproducibility by means of a predetermined design has been demonstrated. Prepared coatings and patterns were in depth characterized in terms of morphology, microstructure, magnetic and superconducting properties. The properties of obtained coatings are comparable with those of the layers prepared by conventional chemical deposition techniques, with the added value of an ability to produce patterned coatings of different thicknesses and shapes in a single pass. Finally, preliminary results in the upscaling of ceramic coated tapes are presented as a starting point for further technological development to longer lengths. The feasibility to implement the inkjet printing with the chemical solution deposition process to produce long lengths functional ceramic oxides on metallic tapes in continuous reel-to-reel systems has been demonstrated.

Doctoral thesis – Summary

Author:
Pentti Viluksela

Speciality field:
*Environmental Technology
within Process Industry*

Supervisor:
Olli Dahl

Defended:
*20 November 2015
at Aalto University / School of
Chemical Technology, Department
of Forest Products Technology
Espoo, Finland*

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pentti.viluksela@metropolia.fi

Environmental Engagement of Finnish Printing Companies

The aim of this thesis was to provide a comprehensive, up-to-date picture of the environmental activities of the Finnish printing industry, which was not available especially among small and micro enterprises, although they make up the majority of printing industry companies. The importance of environmental communication increases with the growing environmental awareness of customers and other parties; the influence of related activities of smaller companies on the image of the whole printing sector, facing the pressure from digital media, is not negligible. A review of various environmental characteristics, research, regulations, actions and tools related to the printing industry is given, followed by research design and results.

The study sample comprised all identifiable Finnish printing companies in the prepress, printing and finishing subsectors (not those in the publishing, advertising or packaging industry). Out of 970 companies in total, almost 84 % were micro enterprises of less than 10 employees. Basic company information, financial data and the information on the use of environmental and sustainability management tools were collected from secondary data sources (commercial databases, certification bodies, industry associations and authorities). The evaluation of the extent and quality of environmental communication was based on analysing the companies' websites (if existing). Less than 9 % of companies used at least one third-party certified environmental and sustainability tool and less than 15 % of companies provided some environmental information on their websites; moreover, the environmental web content was generally found to be unimpressive, with so called greenwashing on 58 websites. Novel calculation models combining the mentioned factors were developed to quantify the environmental engagement of individual companies. Companies operating in the printing were more environmentally active than prepress and finishing companies. There was no correlation with company profit and only moderate correlation with company turnover. On the other hand, over 80 % of the industry business volume originated from strongly or moderately environmentally engaged companies. It was concluded that environmental engagement of the larger Finnish printing companies is at a good level, but almost nonexistent among micro enterprises. Therefore, smaller companies should be supported, e.g. by industry organizations and larger companies of the supply chain, to implement suitable environmental and sustainability management tools and to improve their environmental communication.

Events

Specialty Papers Europe 2016

Manchester, United Kingdom
4–6 April 2016

The event, which is organized for papermakers, pulp manufacturers, machinery suppliers, specialty paper specialists and the like by Smithers Pira in partnership with TAPPI, is in its 8th year focused on active and intelligent functions on papers and food packaging, applications for microfibrillated cellulose in specialty papers, inkjet printing testing and demands on paper substrates, upscaling a new technology for the production of recyclable release paper without silicone, and bio-based barriers for grease resistance.

Some of the speakers shared their views related to the presented topics in pre-conference interviews. Per Svending (FiberLean) sees two main opportunities in commercial use of microfibrillated cellulose – to produce the same grade of paper at lower cost, and to be able to produce new grades of paper. Lionel Spack (Nestlé) expects the new coating for metal packaging, not containing bisphenol A, as the main challenge of upcoming years. He also stresses the life cycle assessment and consumer safety aspects as important factors when considering environmental performance of packaging. Ulla Forsström (VTT) presents the foam coating as suitable for hydrophilic substrates and low application amounts of chemicals, polymers and nanoscaled inorganic or organic materials. Chiara Medioli (Fedrigoni) points out that while new approaches for intelligent surfaces are certainly interesting, colour consistency across batches and geographies still keeps its importance and it may be worth to design reusable packaging.

LOPE-C 2016

Munich, Germany
5–7 April 2016

The program of this printed electronics industry event delivered by OE-A and Messe München combines the business, technical and scientific contributions, complemented by short courses on materials, devices and components, printing and pattering technologies, and wearables, as well as Start-up Forum for young entrepreneurs and investors. The key focus in 2016 is the marketability of technologies.

Each day starts with a plenary session, going through status and near future of printed organic electronics, OLED technology in automotive lighting, printed electronics materials, wearables, mainland China display industry technology, low-temperature organic and oxide transistors, and games. Technical program comprises twelve oral sessions on industry relevant applications. Scientific oral sessions cover the manufacturing of printed electronics devices, additive manufacturing, printing and patterning processes including the novel ones, progress in materials, circuit design and smart systems, photovoltaic devices, sensor systems and transistors.

SPIE Photonics Europe 2016

Brussels, Belgium
4–7 April 2016

The conference program, featuring more than 1,200 presentations, covers a number of cross-disciplinary topics like nanophotonics, metamaterials, graphene and 2D materials, organic photonics, photonics for solar energy systems, optical micro/nanometrology, lasers, optical sensing and detection, modeling and design, and also multimedia applications or image and video processing. Photonics Innovation Village offers a platform for startups and connections with funding organisations.

Dscoop 5 Tel Aviv 2016

Tel Aviv, Israel
5–8 April 2016

The 5th Digital Solutions Cooperative event for attendees from across Europe, the Middle East and Africa, active in labels and packaging, photo or commercial printing, will showcase the new HP solutions; the speakers will present the utilization of social networks and the lessons learned from successful startups to rapidly develop new products, markets, and sales strategies.

ExpoPrint Digital 2016

São Paulo
6–9 April 2016

Latin America digital printing fair is arranged so that its visitors can discover new equipment and close deals. All digital printing segments are covered, from digital publishing software, through web-to-print, on demand printing, variable data, direct mail and small runs, to outsourcing solutions, finishing, packaging or labels.

SustPack 2016

Chicago, IL, USA
11–13 April 2016

Smithers Pira and the Sustainable Packaging Coalition of GreenBlue partner for the second year to host the conference and exhibition on sustainability efforts in packaging design and materials management.

After the tours, workshops and meetings of the first day, the following program will present the approaches of leading brands, compostable packaging and recycling challenges, partnerships in sustainability solutions, transformation in the aluminum packaging industry, and how to keep packaging trash out of the water.

The London Book Fair 2016

London, UK
11–15 April 2016

The event encompassing all kinds of publishing innovations is, as usually, accompanied by a number of conferences and seminars, such as the Quantum, delivering a data-driven overview of the global publishing industry, forum on research & scholarly publishing, and the 31st International Publishers Congress, hosted here for the first time.

CPES2016

Oakville, Canada
19–20 April 2016

The Canada's Printable Wearable Flexible Electronics Symposium is held to inform the participants about emerging Canadian technologies and end user applications in the field. This year, the CPES Innovation Awards are launched to expand the CPES scope.

The program offers panel sessions with Canadian industry, networking events, keynotes, presentations and posters given by researchers and industry professionals. A number of leading innovative companies, institutes, and research centres will take active part.

Inkjet Ink Development Conference

Lausanne, Switzerland
13–14 April 2016

This new technical conference organized by the IMI Europe is aimed at inkjet ink developers across packaging, textiles, graphics, industrial and functional printing applications. Key inkjet industry suppliers and technology will be present.

Invited academy and industry experts will give talks on materials, equipment and techniques for digital printing ink development and manufacturing. Conference topics range from colorants, material dispersions, resins and polymers, photoinitiators, additives and other materials, through analytical equipment and techniques, processing equipment and technology, to jetting and surface behaviour, as well as application case studies.

The information relevant for ink development chemists, e.g. on creating stable dispersions, the impact of additives on formulation performance, raw material quality and consistency for manufacturing, will be provided. Further, the participants can learn on the challenges connected to metallic inks or pigments for food packaging printing, complying with the latest or forthcoming changes in legislations and recommendations by the competent authorities. Also, the speakers will clarify UV radiation curing and polymer degradation due to a flow-induced process in the printhead or due to a long-term mechanochemical process in the pump system, along with the possibility to reduce these effects using hyperbranched polymeric materials. Several methods for characterizing pigment properties will be discussed, as well as tools for drop visualisation, sample printing or print quality analysis, and experimental approaches to define surface tension and wetting, which are all essential for optimal inkjet results. Similarly, simulations of inkjet drop formation in complex rheological fluids can help to obtain satellite-free drops at higher speeds than it is possible with Newtonian fluids.

Two months later, the IMI Europe Inkjet Summer School 2016 will be held from 20 to 24 June at Print Media Academy in Heidelberg, Germany, offering the opportunity to gain a more detailed understanding of six inkjet printing topics from the basics through to advanced courses on inks, printheads and applications.

Printed Electronics Europe 2016

Berlin, Germany
27–28 April 2016

This global event focused on the commercialisation of printed, organic and flexible electronics aims to offer the latest insight into currently identified key areas of progress, which include structural and stretchable electronics, OLED displays and lighting, new materials, graphene, wearable technology, Internet of Things, sensors, automotive, energy harvesting and more. User needs and their experience with printed electronics will be shared.

In addition to the established conference and exhibition program, framed by the masterclasses, the IDTechEx Launchpad initiative will provide the opportunity for ten eligible researchers and young companies to demonstrate for free their state-of-the-art technologies in any of the related event topics – 3D printing, electric vehicles, energy harvesting, graphene, Internet of Things, printed electronics, sensors, or wearable technology.

48th Conference of the International Circle of Educational Institutes for Graphic Arts Technology and Management

Leipzig, Germany
29 May to 2 June 2016

This traditional gathering of the representatives of educational institutes that are focused on technology and management in the printing and allied industries from all over the world encompasses scientific as well as educational topics. On May 31st, the program includes also the election of the new President of the IC.

drupa 2016

Düsseldorf, Germany
31 May to 10 June 2016

This leading international trade show aims, as always, to encompass a broad range of innovative print and cross-media solutions, emerging technologies and industry applications. The latest developments of all kinds of printing technologies, various solutions and applications for the fast-growing areas of packaging production, functional and 3D printing, sustainable options across the supply chain, complying with green standards, and multichannel publishing, responding to the increasing requirements on customised, on demand content through big data, web-to-print, variable data printing and Internet-based tools, especially augmented reality and QR codes, all belong to the highlights for 2016.

The drupa app is available as the invaluable information and orientation tool, enabling the visitor to search online or offline the exhibitor and product database, navigate through an interactive hall map and show detailed information for all booths, as well as to retrieve the latest news.

The fair offers several special features. The six theme parks of the 2016 dip! – drupa innovation park in Hall 7.0, have been introduced a year ago in the News & more section of 1-2015. Being one of the focus themes, the printed electronics products and solutions, PEPSO, will be presented within dip! and in Hall 6. The 3D fab+print touchpoint in Hall 7a will present the state-of-the-art technology as well as vision and best-practice cases in the field of 3D additive production processes, dealing with the challenges, specialities and opportunities of 3D printing. The packaging touchpoint, placed in Hall 12, will show the best prototypes, the latest packaging design and production solutions, as well as concepts for the future. The main directions comprise the use of outstanding combinations of papers and finishing techniques, integration of electronic displays and sensors, and personalisation enabled by digital printing.

Trade fair visitors are welcome to participate in a complimentary conference program of drupa cube in Hall 6, with a mix of five sessions across the eleven days – reserved for keynotes, talks on business evolution, technology and highlighted innovations, and the invitation-only workshops.

Moreover, with the drupacity activities, the exhibition spreads into the city centre, selected hotels, shopping arcades and restaurants. The programme offering e.g. a 3D printer event programme or a rolling 3D laboratory is intended for exhibitors and visitors as well as for the citizens of Düsseldorf.

Archiving 2016

Washington, DC, USA
19–22 April 2016

Roger Easton and Keith Knox will give a keynote on 'Spectral imaging of manuscripts: Recovery of the past and preservation for the future'. The keynote named 'Implementing practices that lead to use or reuse of your collections' will be presented by Emily Gore. The technical program consists of sessions dealing with the advanced imaging techniques, asset management, preservation formats and frameworks, imaging standards, strategies and workflows, metadata standards, image color science and analysis, evaluation, dissemination, use, and impact of digital assets.

For the short course program, the Society for Imaging Science and Technology announced a number of new ones for this year, including 'Computational photography techniques for cultural heritage documentation and archiving', 'Program management for cultural heritage professionals', 'Spectral imaging – spectral capture and processing', 'Automatic cropping and deskewing', 'Four-light imaging', or 'Assessing formats for preservation'. On April 21st, tours will go to the Preservation Directorate at the Library of Congress, the National Archives and Records Administration Innovation Hub, and the National Gallery of Art Division of Imaging & Visual Services.

Serigrafia SIGN

 São Paulo, Brazil
3–6 May 2016

The 26th Latin America industry event will showcase machinery, equipment, products and services for screen printing, visual communications, signs, sublimation, digital printing, textile printing, promotional materials, gifts and customising.

 A co-located exhibition, FutureTEXTIL 2016, is dedicated to the digital textile printing technology, which is very successful at the Brazilian market. The latest trends will be presented at the 2nd Digital Textile Conference.

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Events – J. Print Media Technol. Res., 5(2016)1, 83–86

PePcon 2016

San Diego, California, USA
5–8 June 2016

The 7th annual Print + ePublishing conference, which is produced by the publisher of CreativePro, InDesignSecrets, and InDesign Magazine, offers e.g. talks on customising the content for each reader, typography for the screen, layout automation, fixes and tweaks of exported eBooks, or enhancing and publishing the mobile applications.

WAN-IFRA Events

In addition to the events detailed below, two workshops will be organized in Chennai, India – the first one on Excellence in Newspaper Printing (7–8 April 2016) and the second one on Digital Marketing Metrics, its understanding and using (18–19 April 2016); the Alternative Design & Story Forms workshop will take place in Kuala Lumpur, Malaysia (19–20 April 2016). News Design Conference in Bengaluru, India is scheduled to 16–17 May 2016.

Digital Media Europe 2016

Vienna, Austria
20–22 April 2016

This edition is focused on online reader revenue, effective advertising and content diversification. The European Digital Media Awards ceremony will be held on 20 April.

68th World News Media Congress 23rd World Editors Forum 26th World Advertising Forum

Cartagena, Colombia
12–14 June 2016

Traditionally, news media professionals will meet at this global event to discuss the management and business issues, new journalism initiatives and newsroom trends, as well as successful strategies for increasing advertising revenues from both digital and print media.

62nd Annual Pulp, Paper and Forest Industries Technical Conference

Austin, Texas, USA
19–23 June 2016

This five-day technical conference features papers, panel sessions, and tutorials on topics relating to pulp and paper engineering community. It is sponsored by the Pulp and paper industry committee (PPIC), operating within the Industry applications society of the Institute of Electrical and Electronics Engineers (IEEE). The objective of the committee is "To advance the theory and practice in the electrical field as related to the design and management of electrical systems within the pulp and paper industry."

The conference program is intended for engineers and maintenance professionals working in pulp, paper and forest industries, who can learn about changes in related practices, standards and codes, benefit from analysis of equipment upgrades in other plants, and acquire new skills. The last day is reserved for tutorial sessions.

High-Performance Graphics 2016

Dublin, Ireland
20–22 June 2016

This event is dedicated to the design of hardware architectures, programming systems and algorithms that increase performance in all areas of graphics, including animation and augmented reality. The program will be complemented by demonstrations of relevant prototypes and products.

The conference is this year co-located with the 27th Eurographics Symposium on Rendering – EGSR 2016, which will be held from 22 to 24 June 2016. In addition to the traditional EGSR papers track, the successful 'Experimental Ideas & Implementations' track, first offered last year, will be maintained to collect valuable submissions describing new ideas that have not yet been validated according to the high academic standard, or interesting implementation issues for known algorithms in industry-scale uses.

ZELLCHEMING-Expo 2016

Frankfurt am Main, Germany
28–30 June 2016

The event, combining the exhibition and congress with practice oriented panel discussions and expert lectures, brings an overview over the whole product range along the process chain of the pulp and paper industry as well as of fibre based materials, and offers other networking opportunities. 'Raw materials & fibres – the extended added value' were chosen as the main topic of the 2016 congress. The maximizing of wood products added value is seen as a great opportunity for the paper industry and the paper material to substantially contribute to the sustainable bio-based economy. The lectures within the Cellulose chemists' symposium will discuss the wood hemicelluloses, cationic pulp, the use of lignocellulosic residues, lignins, xylan and Agarose, and the production of carbon fibres, stimuli-responsive materials, novel thermoplastics and composite materials with improved mechanical properties and controlled water permeability.

Call for papers

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