J. Print Media Technol. Res. 8(2019)2
June–July 2019

2-2019

ISSN 2414-6250 (Online)
CODEN JPMTBI
UDC 665

Journal of Print and Media Technology Research

Scientific contributions

ISSN 2414-6250

Editor-in-Chief Gorazd Golob (Ljubljana)

Published by iarigai The International Association of Research Organizations for the Information, Media and Graphic Arts Industries
www.iarigai.org

J. Print Media Technol. Res. 8(2019)2
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ISSN 2414-6250 (Online)
A print version is available on-demand
ISSN 2223-8905 (Print)

Journal of Print and Media Technology Research

A PEER-REVIEWED QUARTERLY

PUBLISHED BY

The International Association of Research Organizations
for the Information, Media and Graphic Arts Industries
Magdalenenstrasse 2, D-64288 Darmstadt, Germany
http://www.iarigai.org
journal@iarigai.org

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Journal of Print and Media Technology Research

2-2019

June–July 2019

J. Print Media Technol. Res. 8(2019)2, 87–138

Journal of Print and Media Technology Research is listed in:

Emerging Sources Citation Index

Scopus

Index Copernicus International

PiraBase (by Smithers Pira)

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NSD – Norwegian Register for Scientific Journals, Series and Publishers

Printed in Slovenia by Collegium Graphicum, d. o. o. Ljubljana

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A letter from the Editor

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The second issue of the journal in 2019 is, somewhat unexpectedly and with some delay, published as a regular issue, again. Unfortunately, a special thematic edition will be released later this year. This time, three papers have been published to cover research and new achievements in a wide field.

The first original scientific paper deals with the problem of achieving good print quality, with special attention on the print register with modern roll-to-roll inkjet presses. These machines are already well-established in the market, and the author presents the mathematical model for the correction of the register, which is required to be performed due to the influence of the ink on the substrate and the deformations that occur during the printing process.

The second paper summarizes the study of the possibility of using sensitive dyes in a two-dimensional code for the production of smart packaging. The use of thermochromic, hydrochromic and photochromic dyes as sensors for irreversible detection of the exposure of the packaging to high temperatures, humidity and light are discussed. The starting points for further research on the use of modern inkjet printing techniques and new sensitive dyes are also given.

The third paper is devoted to image analysis and digital image processing, with an emphasis on edge detection in a computer-modulated 3D color image with established algorithms and the use of corresponding software, compared to the visual perception of observers. The topic will be interesting primarily for experts in the field of 3D modeling and printing.

In Topicalities the editor Markéta Držková (marketa.drzkova@jpmtr.org) summed up the news regarding Drupa 2020, which will be held in June next year, where we can again expect to see breakthrough achievements and future printing technologies. Furthermore, you will find short project presentatitons from our research areas under Horizon 2020, achievements of the European Federation for Print and Digital Communication Intergraf, and two highlights in the printing of conductive lines and graphene-based printed electronics.

Among the novelties of the library, an overview of new issues in the field of history of the press, classical photographs, materials, nanoparticles, and printed electronics is presented.

Three doctoral theses are also introduced. Martin Schmid successfully defended the thesis in the field of cognitive process control in the printing industry at the Technical University of Munich. The author has shown that, in the field of conventional technologies, by means of appropriate methods, it is possible to achieve substantially increased efficiency in material utilization and in the production management. The other presented thesis was defended by Colleen Erin Robertson at the University of North Carolina. She compared print vs. digital technology for students with low incidence disability and found the advantages or greater relevance of both print and digital technologies in different areas of teaching and learning. Jari Keskinen successfully defended the thesis on supercapacitors on flexible substrates at the Tampere University of Technology. Using roll-to-roll printing technology, he produced and demonstrated the use of supercapacitors on cardboard and polyethylene terephthalate substrate.

Among the announced events in the near future, I would highlight the 46th International iarigai Conference: Advances in Printing and Media Technology, which will be held in September in Stuttgart, however, many other international organizations and institutions also offer conferences, workshops, summer schools and other opportunities for presenting achievements, discussions and acquiring new knowledge.

I would expect that the upcoming iarigai Conference in Stuttgart will also be a milestone for the Journal of Print and Media Technology Research. For more than a year there have been discussions and coordination on the optimization of publishing activities of two major international organizations – the International Association of Research Organizations for Information, Media and Graphic Arts Industries and the International Circle of Educational Institutes for Graphic Arts Technology and Management. Both associations also publish scientific Journals, and both have also recognized the importance of publishing quality scientific papers in indexed Journals, that are highly ranked at international level. Up to now, co-operation and pooling of power in the publication of a joint Journal has already been agreed, with only a few details left to coordinate. Changes of the Editorial Board, the Scientific Advisory Board, and in the areas covered by the Journal will be revealed shortly. I am convinced that the Journal will become even more relevant to you as an interesting source of scientific papers, topicalities and also as a publication in which you would like to publish the results of your research work.

Ljubljana, July 2019

JPMTR 122 | 1904
DOI 10.14622/JPMTR-1904
UDC 005.31:774.8-021.465:004.356

Original scientific paper
Received: 2019-02-14
Accepted: 2019-05-16

A model for the prediction of print quality of a roll-to-roll inkjet press

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Abstract

In this paper, a simulation model for the web dynamics of a digital label printing machine is presented and an exemplary application from practice is shown to verify the model. The basis is an extended modeling of the web dynamics including thermal effects in order to calculate the dynamic behavior of the continuous web. It is shown how thermal excitation can be used to measure the transfer function of the web dynamics and the influence of web tension control systems. Furthermore, a post-processing algorithm is presented which links the output data of the web dynamics simulation with the behavior of the inkjet printing data path and thus simulates digital inkjet printing. The results can be used to explain both registration errors from color to color as well as color density fluctuations within a raster image printed by a single color. As a practical example, a digital inkjet printing machine is considered in the following, in which a periodic variation in the color impression of a raster or solid surface can be recognized in the printed image. The fluctuation period corresponds to one revolution of the rotary encoder, which serves as a trigger signal for the inkjet printheads. With the help of the simulation model for the web dynamics and the presented post-processing algorithm, the origin of the error can be understood. Measurement and simulation are compared to verify the model. If the amplitude and the phase angle of the encoder error are measured, the print quality can be ensured by compensating the error within the inkjet printing data path. This is shown both in the simulation and on the basis of measured data.

Keywords: web dynamics, register, thermal effects, digital printing, transfer function

1. Introduction and background

Due to the consolidation of the printing press market in recent years and the requirement to be able to print small runs economically, there is an obvious shift from conventional printing processes, such as offset and gravure printing, to digital printing technology, especially inkjet printing. This trend applies equally to roll-to-roll and sheet-fed printing presses.

This new technology creates additional requirements for the modeling of machine dynamics, which takes into account the special effects that play a role and are different from classic impact printing processes. In this paper, we limit the consideration to roll-to-roll (web) presses.

The longitudinal dynamics of the web fundamentally influence the printing process and the achievable print quality. As a first approximation, the longitudinal motion of the web can be decoupled from the transverse movement and movements perpendicular to the web's plane. For web presses, a plethora of publications dealing with the modeling of machine dynamics in the printing direction and the prediction of register and registration values exist. The first comprehensive process model was introduced in the 1970s in the pioneering work of Brandenburg (1971; 1976) and further developed by Whitworth and Harrison (1983). Further publications from various research groups around the world (Roisum, 1996; 1998; Wolfermann, 1995; Zitt, 2001; Galle, 2007; Yoshida, et. al, 2008; Schnabel, 2009) followed. Up to this day, this topic is of continued interest, as recent works show (Brandenburg, 2011; Göb, 2013; 2017; Seshadri, Pagilla and Lynch, 2013; Seshadri, Raul and Pagilla, 2014). The overall goal is always to most accurately control web tension, thereby optimizing the print quality. Overall, this increases productivity and reduces waste, which leads to the conservation of resources.

This paper presents a method for modeling and register simulation of roll-to-roll inkjet printing presses. In particular, it deals with the peculiarities of inkjet printing and presents a novel algorithm to calculate print quality from web dynamics simulations. The method is tested on a real case study. In this special case, it is considered how errors in the rotary encoder, which is used to clock the printheads, affect the print quality. In the process, simulation and measurement results are compared.

2. Methods and modeling

To model the web transport in longitudinal (printing) direction, the web is discretized into discrete web sections of the length l. Figure 1 shows a schematic of the control volume.

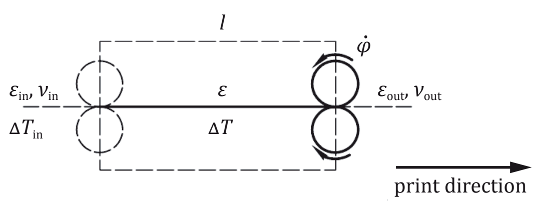


Figure 1: Schematic of the control volume for the derivation of the web transport equations where ε is strain, ν is material flow, T is temperature and φ is phase shift

The web is assumed to be homogeneous, only stressed in longitudinal direction, massless and have negligible bending stiffness. The thickness of the web t is added to the radius of the rollers transporting the web yielding an effective radius r_{eff}. The width of the web is w. The control volume is bounded by a roller at the beginning and the end of the web section. For each section, the roller on the right side of the section is used for the formulation of the equation of conservation of angular momentum. The inputs to the web section are the web speed and strain.

For the following equations, the index $_{in}$ denotes values belonging to the preceding web section and the index $_{out}$ denotes values belonging to the following web section. Variables without an index belong to the web section in question.

From the continuity equation, the equation

$$\frac{d}{dt}\left(\frac{l}{1+\varepsilon}\right) = \frac{v_{\mathrm{in}}}{1+\varepsilon_{\mathrm{in}}} - \frac{v_{\mathrm{out}}}{1+\varepsilon} \qquad [1]$$

can be developed to describe the transport of web material in and out of the control volume, where v_{in} is the material flow into the web section with strain ε_{in}, v_{out} is the material flow out of the web section, and ε is the material strain in the web section. The material law for the web can be linear elastic with an elastic modulus E (Hooke's Law) or viscoelastic, for instance, a Kelvin-Voigt-model (Markert, 2013) to determine stress σ, of the form

$$\sigma = E\varepsilon + R\dot{\varepsilon} + E\alpha_{\mathrm{T}}\Delta T \qquad [2]$$

which also incorporates the strain of the material due to temperature effects (thermal expansion coefficient α_T) and the viscosity R. For paper, material parameters have been collected by Niskanen (2012). Generally speaking, it may be necessary to obtain the correct material parameters from measurements for each special case.

The equation of conservation of angular momentum for the roller on the right side of each web section yields

$$\Theta\ddot{\varphi} + b\dot{\varphi} = M_{\mathrm{out}} - M + M_{\mathrm{drive}} + U\cos(\varphi + \delta) \qquad [3]$$

The terms in this equation describe the torques M stemming from the web

$$M_{\mathrm{out}} - M = (\sigma_{\mathrm{out}} - \sigma) \cdot w_{\mathrm{t}}\, r_{\mathrm{eff}} \qquad [4]$$

as well as a drive torque or friction torque M_{drive} as well as a sinusoidal unbalance torque with an amplitude U, phase shift φ and phase angle δ, at point w_t. The left-hand side of the equation is characterized by the moment of inertia of the roller Θ and a linear damping coefficient b, which corresponds to a viscous damping component in the bearings.

The transport equation for the temperature of the web can be approximated by

$$\frac{d\Delta T}{dt} + \frac{v_{\mathrm{in}} + v_{\mathrm{out}}}{2}\,\frac{\Delta T - \Delta T_{\mathrm{in}}}{l} = 0 \qquad [5]$$

using an average temperature for each section as the mean between the temperature of the web coming into the section ΔT_{in} and the temperature leaving the section ΔT. This completes the equations for the web dynamics including thermal effects.

The system of nonlinear differential equations is transferred to the MATLAB®/Simulink® environment for simulation in the time domain.

For an arbitrary web section, this set of equations can be placed into a subsystem block with defined inputs and outputs. For each web section, a simulation block is required in which only a few parameters differ, so that it is very easy to build up a complete model of the web dynamics of a printing press with dozens of rollers.

In addition to the equations presented above, each block is configured to provide information as to whether the Euler-Eytelwein adhesion condition (Eytelwein, 2011) is met at the present time, as well as the bearing load for the web-carrying roller.

The model is used to answer fundamental questions about web dynamics, for example to determine the expected natural frequencies and mode shapes of the overall system as a function of the substrate elasticity, or to assist in the dimensioning of the drive motors. For detailed investigations with a direct relation to the achievable print quality, it is however necessary to extend this purely mechanical model by a register calculation algorithm, which will be detailed in the next section.

3. Register calculation algorithm

Inkjet printing is a non-impact printing process (NIP), meaning a printing process without a fixed image carrying device (Kipphan, 2000). An inkjet printhead is comprised of a multitude of tiny nozzles for the jetting of minute ink drops, each of which is responsible for one image pixel perpendicular to the printing direction. To print an image, the substrate is moved relative to the stationary printhead, so the resolution in the printing direction is defined by the printing speed and the jetting frequency. In order to achieve the high resolution a required for high print quality in transverse direction, the nozzles in the printhead are staggered, as shown schematically in Figure 2 for a fictitious printhead with $m = 4$ nozzle rows and $n = 7$ nozzle columns. A real printhead is of course made up of many more nozzles. Due to the staggered construction, the printing of a line in the transverse direction results in the situation that not all nozzles print at the same time but with a time delay. For constant speed printing, this does not matter, but changes in printing speed can create a sort of inter-head registration error which manifests itself as a color density variation in print direction.

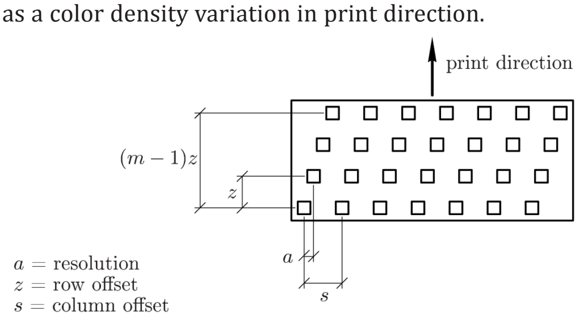


Figure 2: Schematic of the nozzle layout of an inkjet printhead

As a clock signal, a measuring system is required which accurately measures the current substrate speed. Typically, this signal is provided by a very accurate, high-resolution rotary encoder. Due to signal propagation times, program run times and especially the flight time of the drop from head to substrate, the time delay between measured web speed or position and real substrate position upon impact of the ink drop on the substrate is not negligible.

The difficulties become clear with a numerical example to illustrate the order of magnitude: at 1200 dpi (equivalent to 21 µm resolution) and a print speed of 1 m/s, the printheads have a clock rate of 47 kHz. This means that every 21 µs a drop is triggered. With a drop speed of 5 m/s and a distance from printhead to substrate of 1 mm, the drop flight time is 200 µs.

In order to calculate the register between two printed dots, it is necessary to know the current position of a printed dot. That is, a reference point printed at a certain position must be tracked on its way through the machine. The difference between the position of the n-th printhead and the position of the reference point at time $t_p(n)$ (at this time the n-th printhead sets a new point) results in the registration error denoted as $1/n$.

In order to determine the current position of the reference point within a certain web section, the data of the actual angular velocities of the rollers and strains of the web sections are needed, but these are known from numerical simulation. To illustrate the derivation of the necessary equation, the sketch in Figure 3 is used. It shows the web at time $t_p(n)$ moving under two consecutive printheads, the first of which printed the reference point at an earlier point in time.

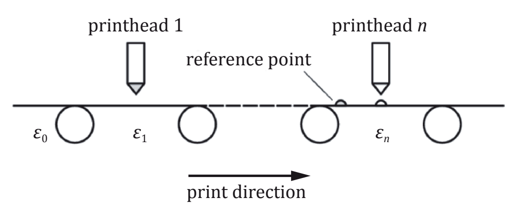


Figure 3: Sketch for the derivation of the point position

Let us consider section 1 with the corresponding strain ε_1. First, it is necessary to determine the strain-free material length $dx_{\text{unstrained}}$ that has been transported from section 0 to section 1 in the time period from t_1 to $\tilde{t}$. With the generally valid formulas $v = dx/dt$ and $\varepsilon = du/dx$ we can represent $dx_{\text{unstrained}}$ in the form

$$dx_{\text{unstrained}} = \frac{v_1(\tilde{t})}{1+\varepsilon_0(\tilde{t})} d\tilde{t} \qquad [6]$$

Integration then leads us to the strain-free length transported into the section

$$x_{\text{unstrained}}(t) = \int_{t_1}^{t} \frac{v_1(\tilde{t})}{1+\varepsilon_0(\tilde{t})} d\tilde{t} \qquad [7]$$

at the point in time t. The strain-free length $l_{\text{unstrained}}$ is the material length that was already present at the beginning between the printed point 1 and roller 1 at time t_1. The position of the point l_p at a point in time t taking into account the strain $\varepsilon_1(t)$ is then calculated by

$$l_{\text{p}} = (x_{\text{unstrained}}(t) + l_{\text{unstrained}})(1 + \varepsilon_1(t)) \quad [8]$$

At a second point in time t_2, point 1 has traversed the first web section where $x = l_1$. The formula for a generalized section i is thus

$$x_{\text{unstrained}}(t) = \int_{t_i}^{t} \frac{v_i(\tilde{t})}{1 + \varepsilon_{i-1}(\tilde{t})} d\tilde{t} \cdot (1 + \varepsilon_1(t)) + \sum_{l_i}^{l_{i-1}} l_j \quad [9]$$

wherein l_j are the lengths of the preceding web sections.

From the simulated encoder signal including the aforementioned time delay, the times are determined at which the web would have covered the distance from printhead 1 to printhead 2 without consideration of elongation effects. With these times, the difference between the location of point 1 at time t_2 and the location of the n-th printhead can be calculated – this is the registration error between the two points.

Algorithmically, this calculation was implemented as a MATLAB® script, with which a register prediction can be efficiently derived following a time-domain simulation of the web dynamics.

4. Results

The model just introduced is applied to an exemplary inkjet printing machine as shown schematically in Figure 4.

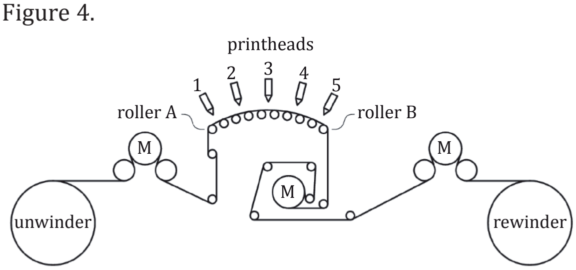


Figure 4: Schematic of a roll-to-roll inkjet printing press

The core of the machine is the digital printing unit with four process colors and white as a fifth color. The web is guided from an unwinder, past a web tensioning station over the so-called roller table, on which the substrate is guided over many small rollers past the printheads arranged one behind the other. The rotary encoder is mounted on the last roller of the roller table. The motors for web tension control are marked with M.

On the real machine, the web tension is measured on several rollers via flange-mounted force transducers. In the model, the web force sensors are integrated into each web section block as has been detailed in Section 2. In the model, the feedback control loop is closed via these virtual web force sensors. Overall, the model is made up of 31 discrete web sections.

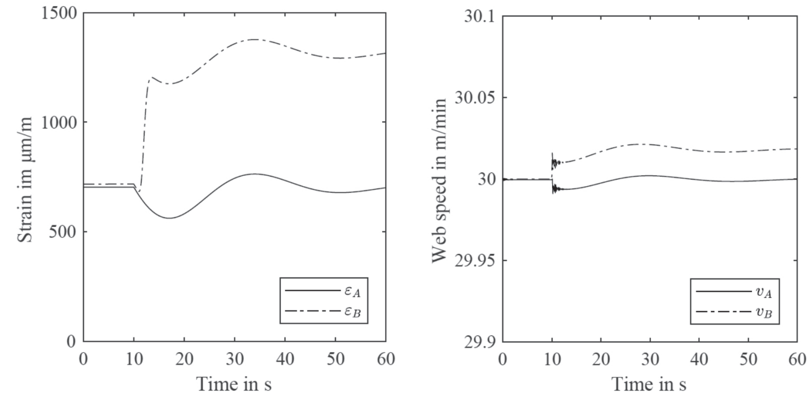
As a plausibility check, a simulation result leading to comprehensible effects in the register is shown. For this purpose, it is prudent to switch off all other disturbing factors in the simulation (for example imbalances, errors on the unwinder, errors in the control system) and only a temperature step is initiated.

If heat is coupled into the web between the printing of two colors, for example due to a drying process, this leads to thermal expansion of the web. The subsequent web sections must run faster to maintain a constant web tension. The corresponding intermediate results for a temperature step ΔT at time t = 10 s are shown in Figure 5. It can be seen that the speed difference is very small. Nonetheless, this tiny difference in speed is what will lead to undesirable effects in the register.

Let us consider the register between the reference color (printhead 1) and a printhead n behind the heat input, while using a rotary encoder on roller A to clock the printheads. After the temperature step the register settles to a new stationary value which linearly increases with the distance of the printheads to each other, since the encoder is specifying an incorrect (too slow) speed. In the simulation, the thermal strain after the temperature step $\alpha_T \Delta T$ = 600 µm/m and is effective for the register 1/3 over a length of 500 mm and for the register 1/5 over a length of 1000 mm, resulting in a stationary registration error of 300 µm and 600 µm, respectively. The result is shown in Figure 6a.

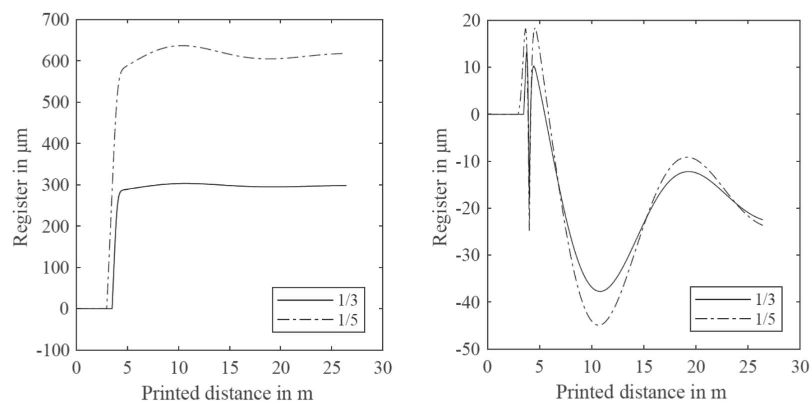
Using the rotary encoder on roller B for clocking the printheads results in a different picture. Regardless of the distance of the printheads to each other, after a transient phase, a static offset occurs which is much smaller (20 %). This is the case since the web is only subjected to a deviation between real speed and the speed detected by the rotary encoder on a short subsection of the web path. The transient process in the register due to the step in web temperature can be interpreted as a superposition of the differences in strain and velocity in Figure 5. The situation can be seen in the Figure 6b.

An interesting phenomenon can be observed in the model – the temperature step excites vibrations in the web motion. With this knowledge, a quasi-harmonic excitation can be induced into the system by means of a printed pattern, e.g. zebra crossing stripes. For



a) *b)*

Figure 5: Web strain (a) and speed (b) at roller A and roller B after subjection to a temperature step ΔT at time t = 10 s



a) *b)*

Figure 6: Calculated register after subjection to a temperature step ΔT at time t = 10 s using encoder on roller A (a) and roller B (b)

UV-curing inks, heat is introduced into the web when UV radiation activates the polymerization process and cross-linking enthalpy is released directly into the substrate. Thus, the thermal expansion of the web can vary greatly even over short distances.

In the case of the zebra crossing stripes, the thermal excitation frequency corresponds to the speed of the web. The system response can be measured, for example with the installed rotary encoders, allowing the calculation of a transfer function and thereby a com-

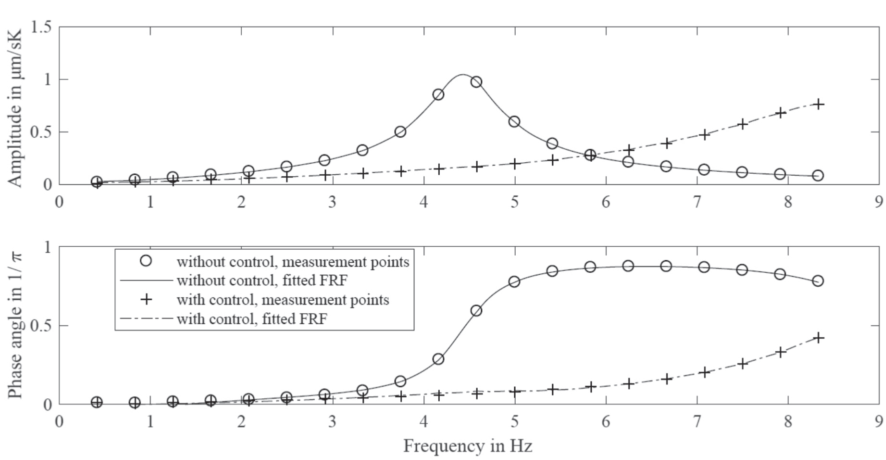


Figure 7: Transfer function gained through simulation of temperature excitation

parison of system behavior, e.g. with and without tension control. An example of such a test with simulated data is presented in Figure 7. The excitation is printed zebra crossing stripes with a width of 0.1 m and each measurement point corresponds to printing at a fixed web speed (from 5 m/min to 100 m/min). The fitted frequency response function (FRF) is calculated using the rational fraction polynomial method (Richardson and Formenti, 1982). It is evident that the web tension control within the digital printing unit is able to suppress the resonance at 4.4 Hz.

As explained in the Section 3, the image data path of an inkjet printing press uses the encoder signal as input on a web-guiding roller. Due to internal errors of the encoder (often referred to as the integral nonlinearity or INL of the encoder, e.g. in Carusone, Johns and Martin, 2012) as well as external errors due to eccentric mounting, the encoder signal is superimposed with a harmonic disturbance at constant speed.

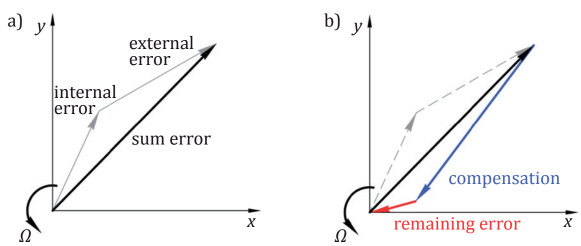


Figure 8: Superposition of internal and external rotary encoder errors (a), resulting residual error after compensation (b)

In the vector diagram (Figure 8a), the vector addition of internal and external encoder errors can be easily understood. Depending on the phase position of the two individual errors, a gain or attenuation of the amplitude of the sum error can result.

A faulty encoder signal suggests changes of the substrate speed, although it is constant in reality. As a result, the printheads are incorrectly triggered, which results in a registration error. This in turn is visible to the human observer as a periodic variation in the color impression of a raster or solid surface. This can be the case for the color-to-color register or the inter-head register described in Section 3. Both can be influenced by the encoder error due to the same effect. This influence can be measured and an exemplary measurement result is shown in Figure 9. For better recognition of the periodic component whose frequency corresponds to that of the rotary encoder, both the raw signal and a low-pass filtered signal are shown. The additional high-frequency disturbances in the raw signal have nothing to do with the harmonic encoder error.

The effect of the encoder error on the register can be understood using the proposed simulation methods. For this purpose, the simulated (ideal) encoder signal is corrupted with a harmonic disturbance and the inter-head register is considered. The distance between the first and the last row of nozzles according to Figure 2 is 12 mm for the printheads considered here.

If the sum error of the encoder can be measured in amplitude and phase, this error can be compensated in the image data path. The control electronics of the printheads then do not register the eccentricity of the encoder, which means that this error does not manifest itself in the register. Ideally, a signal with exactly the same amplitude and phase rotated by π is added. This would lead to perfect compensation of the error. Figure 8b schematically shows the addition of a non-ideal compensation value in the phase diagram (it is assumed that the determination of the amplitude is faulty by 10 % and the determination of the phase is wrong by 10°) and the residual error remaining as a

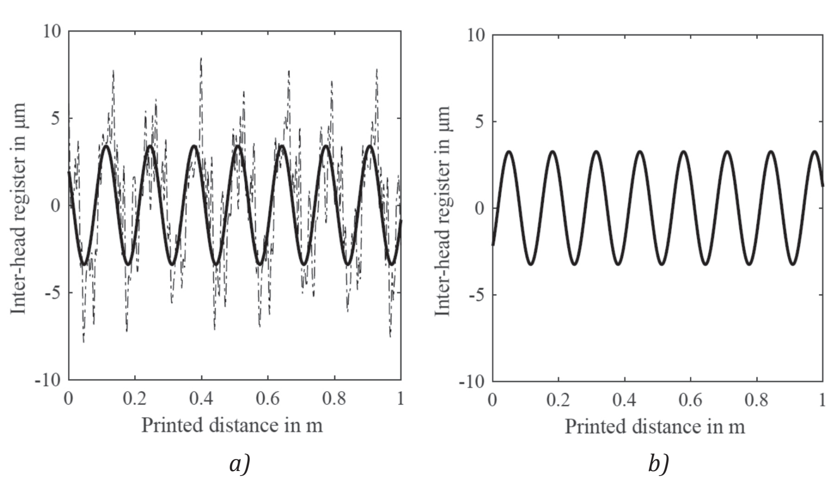


Figure 9: Inter-head register due to erroneous rotary encoder signal: (a) measurement, and (b) simulation

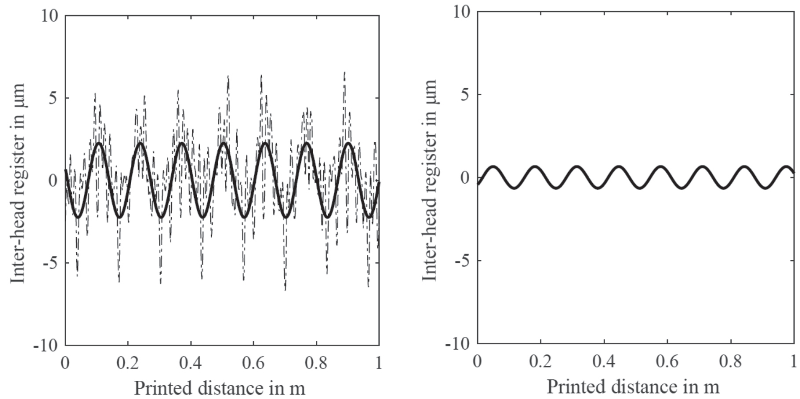


Figure 10: Inter-head register after compensation of erroneous rotary encoder signal: (a) measurement, and (b) simulation

result. It can be seen that especially a wrong phase information can quickly lead to incomplete compensation or even a deterioration of the result.

The effect of the compensation can be demonstrated both by simulation and measurement. The result is shown in Figure 10. In reality, a reduction of 33 % is achieved. The fact that the compensation does not work better can be explained by the fact that further errors, e.g. the geometric eccentricity of the rollers also contributes a considerable amount to the error. Theoretically, these errors could also be eliminated by the compensation by adding more harmonic components to the encoder signal beyond the measured encoder error. Trivially, the signal needed to compensate the error could be determined by trial-and-error.

In the simulation, the compensation achieves a reduction of 80 %, which can be easily understood due to the purposely erroneously entered amplitude and phase. It can be seen that the compensation is robust against small errors in the identified encoder signal of about 10 % in the amplitude and 10° in the phase.

5. Conclusions

A mathematical model of the longitudinal web dynamics was presented, capable of describing the dynamic behavior of the continuous web of a roll-to-roll press. Based on this model, a novel method was devised to track a printed point on its way through the machine, thus obtaining a calculation of the register. The method is suitable for constant printing speeds as well as transient processes. Simulation results were presented, demonstrating the functionality of the model. The possibility of using thermal expansion of the web to excite mechanical vibrations for the measurement of transfer functions was presented. It was shown in simulation and measurement how print quality can be optimized by the compensation of the harmonic encoder error within the image data path. The presented model with post-processing (point tracking algorithm to model the registration behavior) allows the impact of design changes of the printing press to be directly translated into print quality characteristics. These predictions ultimately save time and money in machine development and production.

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JPMTR 123 | 1901
DOI 10.14622/JPMTR-1901
UDC 621.798-027-035.67

Research paper
Received: 2019-01-09
Accepted: 2019-06-24

Smart packaging by the application of sensitive dyes

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Abstract

Smart packages can communicate with their users or other clients via the Internet of Things. By means of sensitive dyes implemented in an intelligent code, the code is able to report the history of critical environmental influences on the package and accordingly on the packed goods during the entire transport path. So all steps from manufacturing to delivery can be traced without any energy supply. Moreover, these intelligent codes are composed of different sensitive dyes in the form of dots. Each smart dot can change its colour from an inactive state into active states, in the form of colour gradations. Thus, a critical value of colour gradation can be defined as limitations that set the sensitive dot's state from inactive [0] to active [1]. Hence, static consumer or product information and dynamic information about environmental influences – e.g. water/moisture, temperature, UV-light, pressure, acids, etc., can be stored in one entire code. The use of various sensitive dyes also adds a significant anti-counterfeiting feature and a chemical fingerprint. The intelligent code can be cost-efficiently printed as a printable sensor. Furthermore, the intelligent code can be read and analysed by usual smart devices, e.g. smartphone, tablet, etc. – linked to a specific web server where the code can be compared with its original state, to indicate critical deviations. The foreground of this paper is the application of sensitive dyes (sensitive dyes are as well named as smart materials) in order to get information for comprehensive research. First, the printability of the sensitive dyes is examined as well as their reaction process and behaviour depending on technical parameters, e.g. viscosity. Second, their reaction processes and reaction times in dependence on different layer thicknesses based on various polyester screens and the remissions of the printed samples are analysed. Third, the characteristic wavelength changing of the sensitive dyes is shown, which will allow further investigations by a smartphone.

Keywords: smart materials, intelligent code, thermochromism, hydrochromism, photochromism

1. Introduction

Chromophores are the colour-bearing groups of molecules. They impart colour to a compound. They are often in organic solutions, where they have covalently unsaturated groups of conjugated π-bond systems, which are responsible for absorption in UV (100 nm to 380 nm) or visible/VIS (380 nm to 790 nm) spectral region (Latscha, Kazmaier and Klein, 2017). The chromophore structure of benzene (with a spectral bandwidth at 255 nm) is colourless, beyond visible wavelengths (Hesse, Meier and Zeeh, 2008). Many natural dyes like β-carotene (460 nm) in carrots and lycopene with a visible spectral bandwidth at 473 nm to 503 nm (Figure 1) in tomatoes have a large system of conjugated π-double bonds, which consist of alternating single and double bonds (Latscha, Kazmaier and Klein, 2017).

Some molecules have a small number of conjugated double bonds, which absorb non-visible radiation within a band of short-wavelength. If the number (n + 1) of conjugated double bonds of these molecules increases,

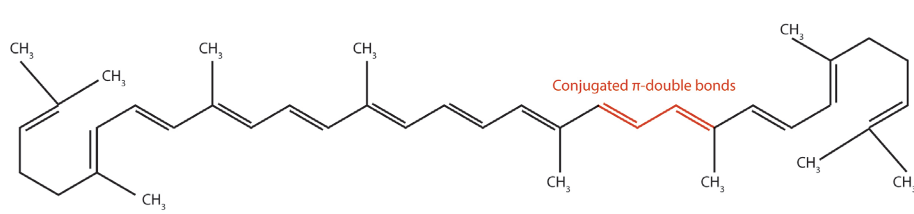


Figure 1: Lycopene

the absorption shifts to longer-wavelengths of VIS (Cranwell, Harwood and Moody, 2017). The particular energy of a wavelength defines the colour (Brown and Holme, 2015). Because of the absorption in the UV-VIS, the reflected light of the chromophore structures appears in a complementary colour (Herbst and Hunger, 1995). The intensity of colour increases by the number of delocalized electrons, shifts by absorption to longer wavelengths (bathochromic shifts) and needs lower frequency/energy. The gap between highest occupied molecular orbital – HOMO and lowest unoccupied molecular orbital – LUMO (HOMO–LUMO) energy is small (Engel and Reid, 2006). Shifting to shorter wavelengths (hypsochromic shifts) needs higher frequency/energy, because the gap between HOMO–LUMO is larger (Kalsi, 2005). Sensitive dyes change their absorption spectrum by light (photochromism), temperature (thermochromism), pH (acid-base/halochromism), water/humidity (hydrochromism), etc. – particular influences (stimuli) of the environment makes the dyes respond (Herbst and Hunger, 1995). During a stimulus-induced shift, these sensitive dyes change their colour, their index of refraction, and their volume (Bilgin and Backhaus, 2017a; Harvey, 2006). A well-known organic compound is spiropyran. Induced by heating and light irradiation it becomes coloured (Hunger, 2003). Hirshberg and Fischer (1954) observed the photochromic reaction of the spiropyran as the first ones in 1952. Hirshberg's vision was a photochemical memory model on the base of spiropyran: "Use of the phenomenon as a memory in a 'computer' as a 'high-speed memory' " (Hirshberg, 1956). This idea of a 'memory' can be extended through the use of printed autonomous sensors on a chemical basis, which records external influences. The use of sensitive dyes as printable sensors is a new field of application.

1.1 Smart packaging

With the Internet of Things (IoT), everything becomes smart and is connected to each other in an autonomous network to accomplish preassigned tasks (Ashton, 2009). For example, an object (e.g. a package) which is equipped with add-ons becomes intelligent when it includes an energy supply, printed electronics, sensors, integrated displays, audio input/output, communication technologies, programming code and more. There are various terminologies like smart, active and intelligent packages, with different definitions (Schaefer and Cheung, 2018):

1. Smart packaging: technologies with integrated functionalities, which can be chemical, electrical or kinetic.

2. Active packaging: subsidiary constituents enhance the performance of the package system, e.g. package material can absorb moisture, oxygen or it can eliminate bacterial contaminations.

3. Intelligent packaging: appearance is observed to detect temperature or humidity deviations.

There are many efficient and effective product applications of smart packages that can provide customers with information about conditions of the product, e.g. in the fields of medicine, pharmaceuticals, food, cosmetic, and more.

1.2 2D/3D code

Compared with smart packages, intelligent codes have a couple of benefits. One of these is the printability of sensors by using different sensitive inks. Another benefit is the cost-efficient printing of different sensitive dots inside a dot matrix code like an invented system of a QR code, (Denso ADC, n.d.; Hara, 2006; International Organization for Standardization, 2015). Moreover, by printing sensitive dots in different layer thicknesses, information about the intensity and duration of contamination (3D coding) can be displayed (Bilgin and Backhaus, 2017b). In this way, a modified QR code can contain both static and dynamic information if the code is extended for dynamic dots. For this application of dynamic dots, irreversible inks (sensitive dyes) are required, which change their colour from one state to another without changing back. By the definition of an upper and lower threshold, the states (inactive [0] or active [1]) of each sensitive dot can be defined.

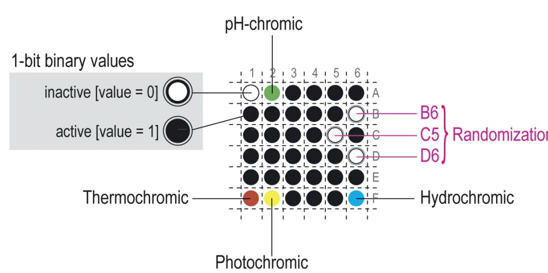


Figure 2: 1-bit binary values and randomized positions in a matrix

Furthermore, randomized allocation of the sensitive dots (Figure 2) can secure the code and gives it anti-counterfeited properties. Additionally, clusters of equal dots, which are at risk of partial contamination of one single cluster can be prevented (Bilgin and Backhaus, 2017a). Thus, static consumer or product information and dynamic information about environmental deviations, e.g. water/moisture, temperature, UV-light, pressure, acids, etc., can be stored inside an intelligent code.

1.3 Hardware and software

Smart devices such as smartphones, tablets, smart glasses, etc. are very popular in common use. They all are equipped with various helpful sensors. An impor-

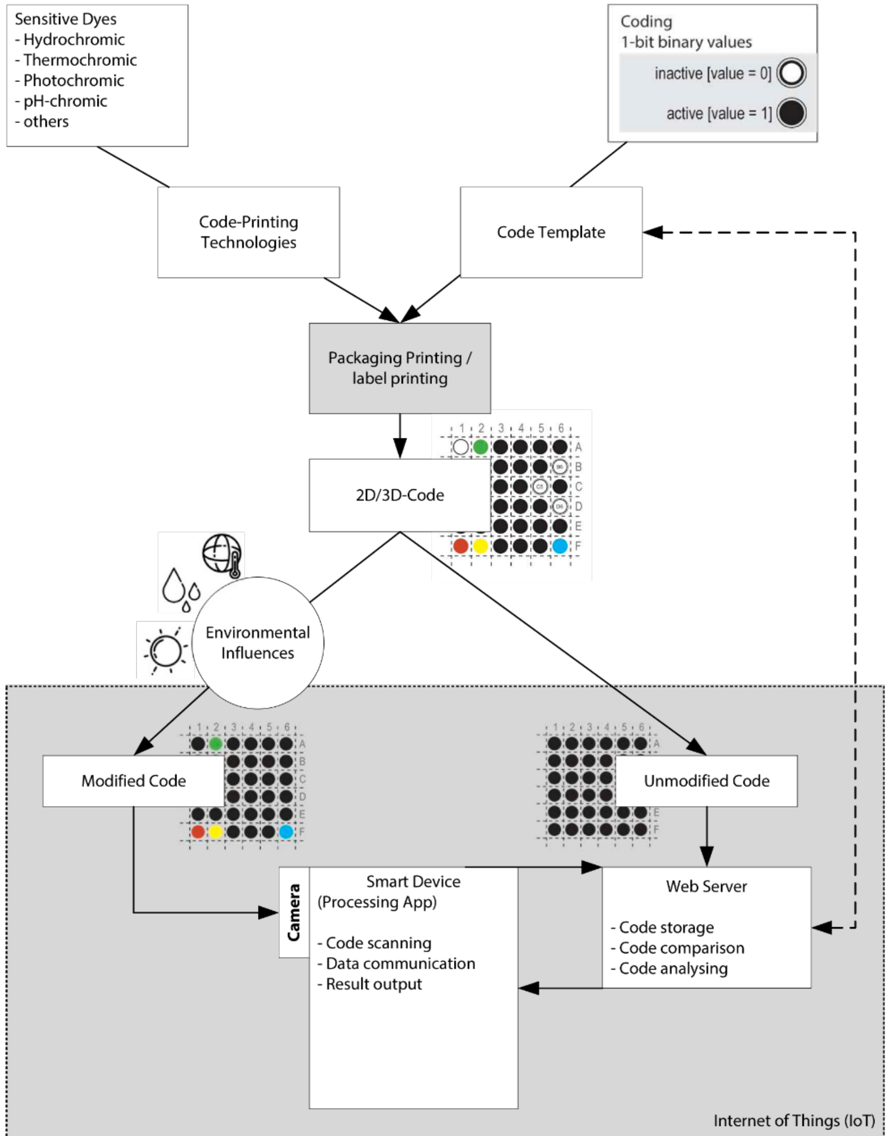


Figure 3: General concept of IoT based history tracing for packages

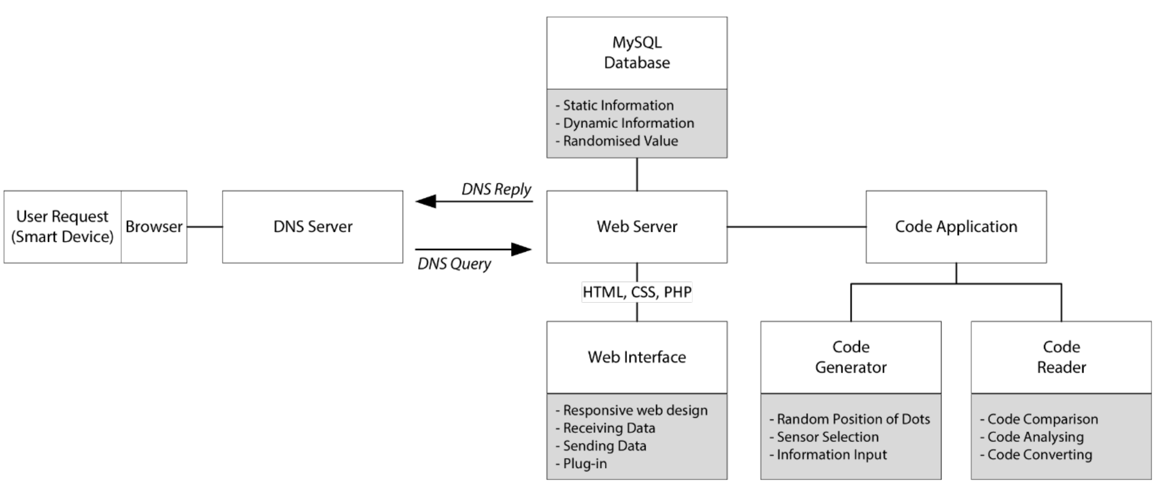


Figure 4: Software concept

tant component of smart devices is the CCD or CMOS image sensor. By means of the sensor, data (e.g. data of a QR code or intelligent code) can be read out and send bi-directionally via browser to a website on a secure web-server (Figure 3). Encrypted data exchange operates via web-server by a MySQL-database (Figure 4). The current state of the code will be transmitted and the package's history can be received via comparison with primary data. The server's web interface can be accessed by the web-browser via TCP/IP. Applications (Apps) are not necessary, because the browser directly accesses the web server via a web interface and domain address. The web interface based on HTML, CSS and PHP can be aligned by a responsive web-design to each screen resolution – independently of any hardware.

The aim of the work is to develop an overall concept for IoT-based history tracking for packages based on intelligent codes and sensitive dyes. Thus, the functionality (reaction process, viscosity and their characteristic wavelength for optical detection) and printability (screen-printed samples) of sensitive dyes were investigated for their future suitability as sensors inside intelligent codes in order to print self-developed sensitive colours. Firstly, the printability of various sensitive inks was investigated, in particular how process parameters of screen printing, such as different screens, can influence the sensitivity of sensitive inks. It was also determined, whether process parameters can influence the physiochemical properties of the dyes. Secondly, the reaction processes of the printed samples before and after contamination were analysed. Here, the coherence between different layer thicknesses and the individual reaction duration is reported. Third, the characteristic changes at distinct wavelengths (before and after contamination) of the various sensitive dyes were analysed, to detect material-specific limitations of their contrast after a colour change.

Currently, inkjet inks for laboratory application are under development (Bilgin and Backhaus, 2018). The inkjet inks are not included in the research covered in this paper.

2. Methods and materials

2.1 Equipment and instruments

All specimens were printed on a semiautomatic screen printer (SPS-Uniprint), by using different polyester mesh with thread counts: 140/cm, 100/cm, 71/cm, 54/cm; mesh angle: 45°; squeegee angle: 13.5°; printing speed: 116 mm/s; snap-off (distance between screen and substrate): 1.5 mm.

Rheological properties (viscous flow behaviour) of the smart materials were analysed by a rotational rheometer (Anton Paar Physica MCR 101) through a corresponding cone and plate measurement system (CP50-1); diameter: 50 mm; cone angle: 1°.

Technical printing results such as different layer thicknesses, volumes, surface structures, etc. were analysed by a confocal microscope (Keyence 3D Laser Scanning Confocal Microscope).

The colour changing behaviour (before and after an activation) of the smart materials were measured by a spectral-densitometer (TECHKON SpektroDens), in order to analyse their characteristical remission curves (spectral density). Technical parameters: polarising filter: off; illuminant: D50, 2° standard observer; measuring aperture: 3 mm.

Intelligent codes were captured through a reflex camera from Nikon (D7100); image sensor: 23.5 mm × 15.6 mm; the total number of pixels: 24.71 million pixels; file format NEF (RAW): 12 or 14 bit, lossless compressed; objective: AF-S 24/1,4G ED Nikkor.

Possible deviations were recorded in protocols to ensure the reproducibility of this experiment. The temperature and humidity throughout the research were controlled by an air conditioning system. The temperature was continuously 20 °C (±1 °C) and the relative humidity 55 % (±1 %). Measurement data are based on ten measurement repetitions.

Table 1: Material overview

Substrate	Multicolor Mirabell™, Chromo-duplex-carton with white and double-faced front and a grey pigmented back, from Papyrus Deutschland GmbH & Co. KG, with thickness: 0.340 mm, grammage: 250 g/m², suitable for screen, offset, and flexo printing
Inks (solvent-based)	Hydrochromic ink (LCR Hallcrest): black → transparent Thermochromic ink (Smarol): white → black Photochromic ink (Skyrad): transparent (light rosé) → dark blue
Additives for screen printing	Thinner: Ce-Jet® 090 (7101M000002) Retarder: VZ 2 (7102M000002)
Screen photo emulsion	FOTECOAT 1833 Stencil thickness below mesh: 6–7 µm

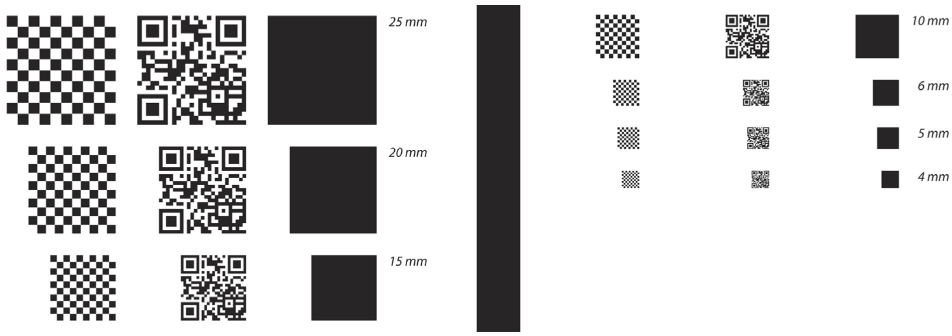


Figure 5: Test chart with different sizes of dots, dot distances, code fields and and other elements

2.2 Materials

The Table 1 lists the materials used in experimental setting. A uniform substrate was used throughout the study to analyse the reactivity of the sensitive materials under comparable conditions. The chemical characteristics of the sensitive materials were inquired, but no information about the functional components could be obtained. Thus, it can only be said that the dyes were embedded in a complex solvent. Therefore, in the future we will have to use materials we have developed ourselves. The additives are used for rheological investigations and the photo emulsion was used for making the stencil. Irreversible inks based on sensitive dyes are available for some printing technologies, e.g. flexo and screen printing. Because of this reason, general material tests were realised with screen-printed specimen.

2.3 Test chart

All experiments utilise one test chart shown in Figure 5. The test chart (DIN A3, 29.7 cm × 42.0 cm) consisted of different QR codes (Denso ADC, 1994; International Organization for Standardization, 2015) with different sizes of dots, fields and dot distances. The dots change their colour irreversibly by a particular influence. An intelligent code can be realized by means of dots printed by using different sensitive dyes. By means of the 'intelligent' dots, different environmental influences can permanently be detected and displayed on the test chart.

3. Results

3.1 Characteristic spectral reflectance

Before a smart device can reliably identify colour changes, it is necessary to analyse the behaviour of the sensitive dye by spectrophotometric methods. Especially the characteristic spectral reflectance bands are of importance. In Figure 6, remission curves are shown. The hydrochromic and thermochromic dyes show directly opposed reflections at all wavelengths. The contrast differences at these both inks are high enough to detect their current state. Thermochromic dye changes from white to black. On the contrary, the hydrochromic dye changes its colour from black to transparent. The change of the photochromic dye can be identified at two bands of the wavelength. On the one hand, the remission increases after a UV exposure at 450 nm to 475 nm (blue) and on the other hand, the remission decreases at 550 nm to 600 nm (yellow).

3.2 Difference in contrast of printed sensitive dyes

Entire QR-codes were printed with sensitive inks to analyse their colour-changing functionality and to reduce colour information to discrete binary information.

Figure 7 shows the screen-prints of different sensitive inks before (upper row) and after external influences (lower row). At these specimens, the contrast difference

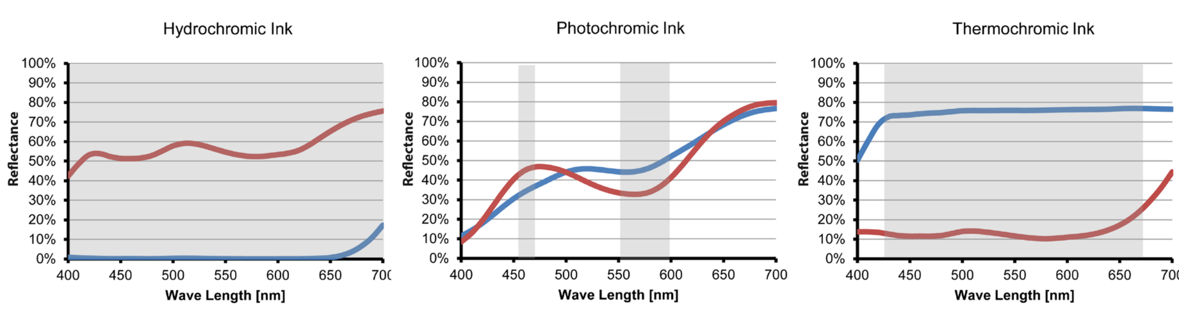


Figure 6: Remission curves and characteristic spectral bands of the sensitive inks; characteristic wavelengths that identify colour changes of sensitive dyes are grey marked

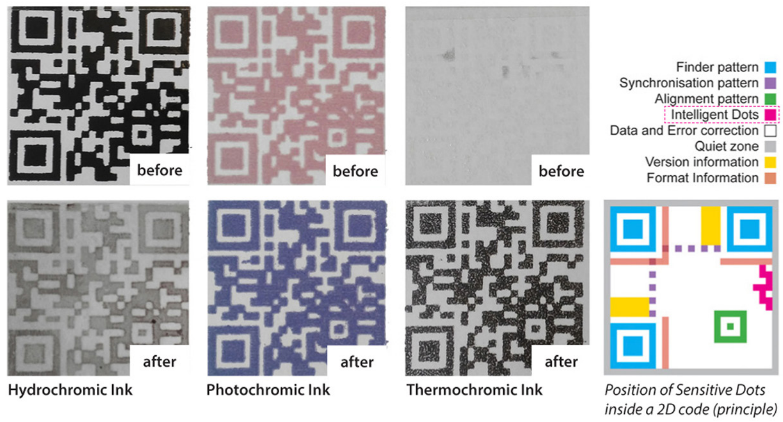


Figure 7: Sensitive dyes before / inactive (upper row) and after / active (lower row)

between all sensitive dyes after activation is high enough to be described by means of the CIE $L^*a^*b^*$ and the colour difference ΔE^*_{ab} (Table 2). Because an image capturing by means of a CMOS-camera could be error-prone, the transformation of the colour information would not be obvious if the colour contrast is not high enough.

Table 2: Measuremen[illegible]ive dye surfaces

	Hydrochromic before / after		Photochromic before / after		Thermochromic before / after	
R	24	135	173	87	184	69
G	24	136	133	88	184	68
B	24	132	137	132	184	67
L^*	10	57	62	36	75	28
a^*	0	−1	21	9	0	1
b^*	0	2	7	−27	0	1
ΔE^*_{ab}	48.3		35.4		45.9	

3.3 Flow behaviour

In this experiment, the flow behaviour of the inks with sensitive dyes was analysed (Figure 8). At shear rates higher than 1 s^{-1} (processing speed) they show a quasi-Newtonian flow behaviour.

The flow behaviour of the hydrochromic ink is shear thinning, between the shear rates from 2 s^{-1} to 20 s^{-1}. It exhibits in a Newtonian behaviour in observed intervals of shear rates 0.1 s^{-1} to 8.0 s^{-1}. Especially, the drying process of the ink is to examine. During the experiments with the hydrochromic ink, the screen several times clogged at low printing speed (116 mm/s). This maybe results from evaporating off the inks solvents. In order to prevent clogging, an alcohol-based screen-printing retarder (VZ 2) was added (20 volume percent). This addition of retarder reduced the ink's viscosity at about 0.3 Pa·s. The photochromic ink shows a slight shear thinning behaviour. The thermochromic ink exhibits a nearly Newtonian behaviour.

3.4 Reaction process

It was examined how technical parameters, e.g. full tone areas printed in various layer thicknesses can influence the behaviour of the thermochromic, hydrochromic and photochromic sensitive inks. The thermochromic ink was printed with a mesh thread count of 100/cm (theoretical ink volume: 21.1 cm^3/m^2). It reacts with different intensity to different levels of heat (Figure 9). The activation process of the ther-

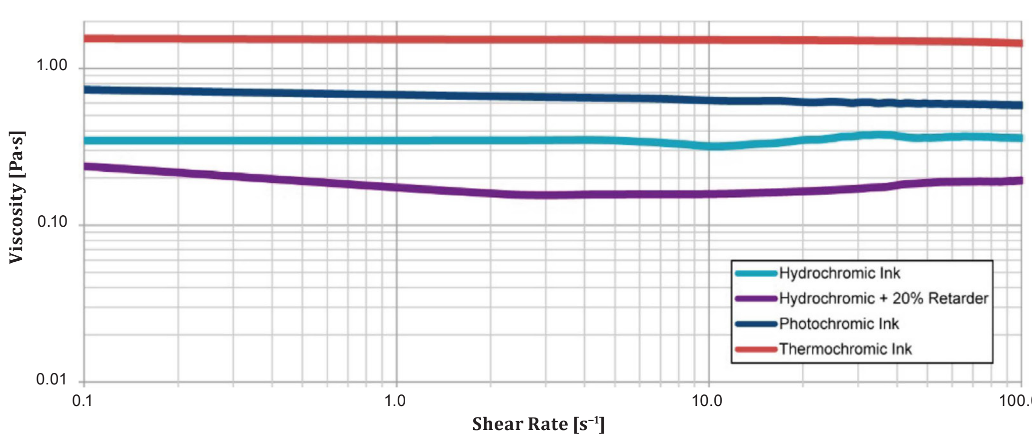


Figure 8: Viscosity of sensitive inks for screenprinting at 25 °C

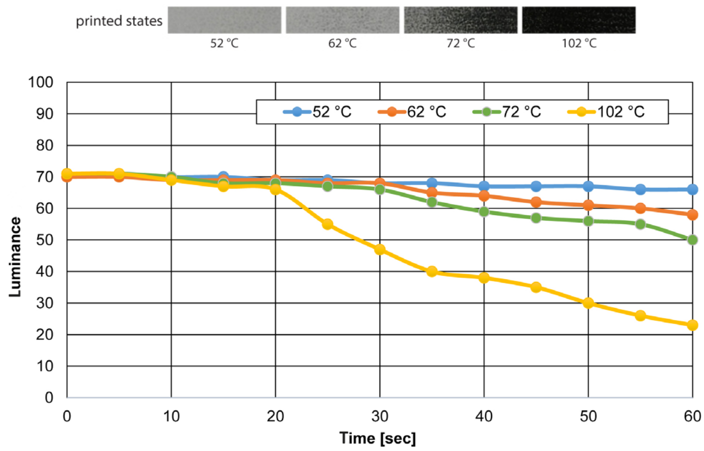
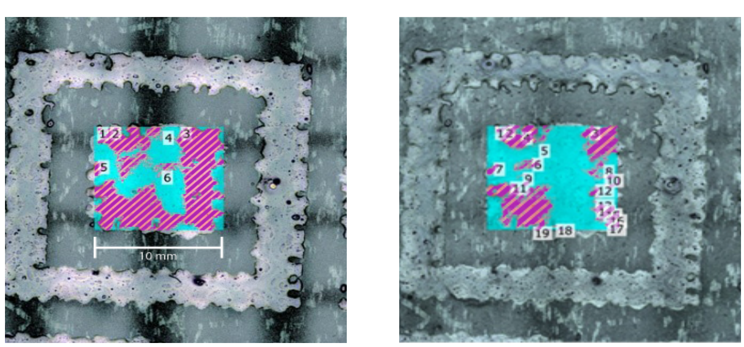


Figure 9: Luminance (L) as a function of heating (thermochromic ink)*

mochromic ink was carried out with a heating plate, which has a control precision of ±2 °C. The reaction process was recorded on video (Nikon D7100) in a preliminary study to define the reaction transitions of the thermochromic ink, presented in Figure 9, so that the measurements could be performed in the next step. After each activation step, the thermochromic ink surface was measured with a spectral densitometer. Up to 52 °C, the dye almost does not change. Above 52 °C, colour changes to black, the faster the higher the surrounding temperature is. The luminance (L^*) can be an indicator of the intensity (temperature and duration) of heat treatment. Depending on different temperature levels and treatment duration, the same L^* values can be reached. The recorded L^* values can give conclusions about the influence of the temperature in comparison with the reference. For example, the following statements can be given: the activated fields have different L^* values at different temperature ranges (normal states: 52 °C, 62 °C; activated states: 72 °C, 102 °C). Thus, exclusion can be made indirectly over the respective colour changes of the field over the degree of the heat impact. For example, the manipulation of a glued package closure, which was exposed to a certain temperature, can be visually represented.

Hydrochromic ink reacts to the presence of water or moisture and changes its colour from black to grey-transparent. In particular, it has been observed that the morphology of the printed dots changes due to water treatment. Investigations by means of a confocal laser microscope show smoothing effects of the surface and reduction of the volume. The surface of a printed dot (Figure 10) shows several peaks (high areas: magenta-dashed, Figure 10a) before water treatment. Treatment by water reduces a part of the peaks from 60 % to 30 % of the dot's area (Figure 10b). Simultaneously, the volume of the dot shrinks for about 45 %. Maybe the layer thickness of the printed dots is influenced by the reaction behaviour of the transferred hydrochromic ink.

The environmental influence of water (e.g. raindrops, humidity) can be verified through the hydrochromic ink. There is a complete colour change from black to transparent grey. Grayscale tones cannot be represented by hydrochromic ink, which indicates that it is not suitable for giving more accurate information about the degree of water influence. In particular, it would be necessary to use a hydrochromic ink, which presents moisture effects in different gradations, in



a) b)

Figure 10: Roughness peaks of a hydrochromic surface of dry sample (a), and after treatment with water (b) (Bilgin and Backhaus, 2017a)

order to provide information on the degree of exposure to moisture. This is currently being investigated in the development of improved hydrochromic ink.

The photochromic ink is a photosensitive compound. It changes its colour irreversibly from one state to another state, if it is induced with UV-light of particular wavelengths. Figure 11 shows printed photochromic samples (mesh thread count: 100/cm), exposed to direct daylight in a clear sky for one hour. In order to avoid changes in the lighting as far as possible, a sunny day without clouds was chosen (2017-07-21, 51° 14' 22.9'' N, 7° 09' 34.6'' E). The photos were captured every 10 s (360 pictures per hour) with a reflex camera (Nikon D7100) by the use of a stencil, which was moved and exposed every ten seconds. The samples were subsequently measured with a spectral densitometer, to analyse the grades of colour change in correlation to time. The activation process was based on continuous exposure of each square patch in the photochromic surface.

Besides the measurement by a spectral densitometer, the exposed samples (Figure 11) were captured by the Nikon D7100 camera. The images were taken in RAW format and opened in the Adobe Photoshop application (Adobe RGB, 1998) to determine the coordinates of the CIELAB colour space and the RGB values. It is possible to allocate the respective colour values from RBG or CIE $L^*a^*b^*$ to retrieve information about the intensity of changes caused by UV-light. Every photochromic sample at each stage of colouring has a specific colour value in RGB and CIE $L^*a^*b^*$. After exposing to daylight, the colour changes from a yellow colour to a yellow-blue colour at the first 30 min and becomes a very blue colour at about 60 min. This method of transferring colour impressions into characteristic values allows objectifying the results. This way the grade of colour changes or exceeding of limits etc. can be described by colour values. On the base of measuring this different colour values, a critical threshold can be defined. If this threshold is passed, warnings can be displayed.

This can be illustrated by the following example:

By dividing the measured values into three limit values, a traffic light system can be used to provide information about the respective influence of the light treatment. By sample measurements at initial state at 0 min: RGB: 208, 182, 166 / L^* = 80 ('everything okay'); after 30 min: RGB: 182, 172, 165 / L^* = 72 ('critical change warning') and after 60 min: RGB: 83, 105, 154 / L^* = 44 ('critical change'), it is possible to evaluate the range of a possible exceeding of the exposure to light. The references from Table 3 can be taken as a basis for imple-

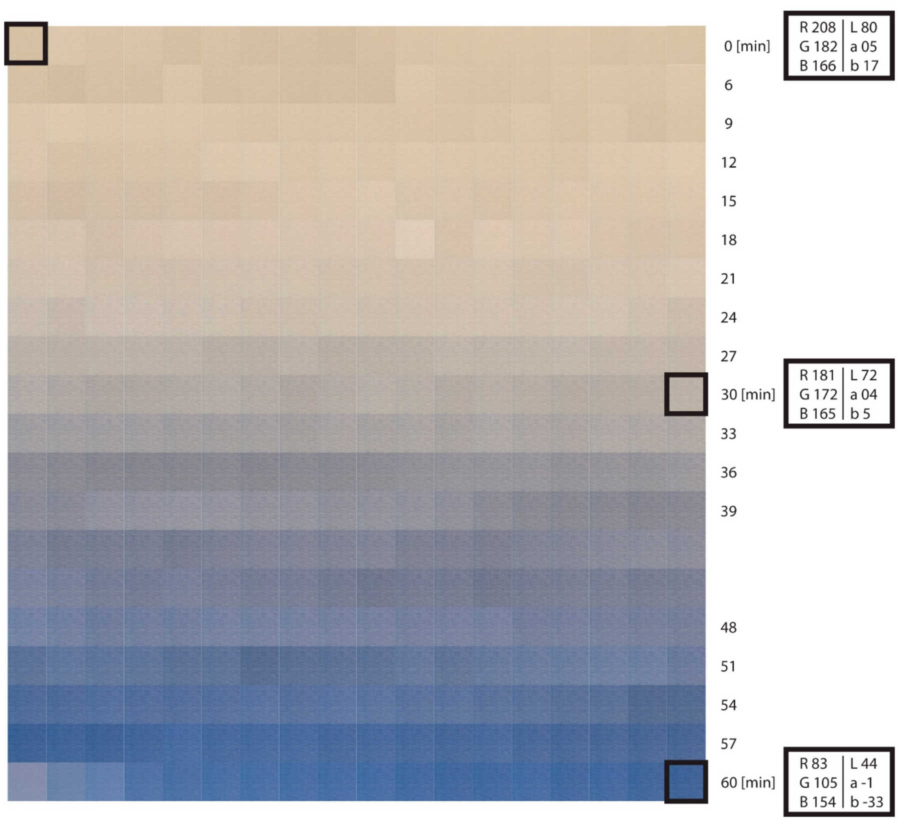


Figure 11: Photochromic samples exposed to sunlight

Table 3: Measurement data of photochromic surfaces; three fields from Figure 11 are grey marked

Min. of UV exposure	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60
R	208	210	214	209	218	216	211	209	202	188	181	168	148	147	141	120	28	113	96	88	83
G	182	195	200	193	204	201	196	196	190	178	172	163	146	146	143	125	132	124	110	105	105
B	166	166	174	167	178	178	173	179	174	168	165	160	157	151	156	145	157	156	147	149	154
L^*	80	80	82	80	84	83	81	81	79	74	72	68	62	61	60	53	56	52	46	44	44
a^*	5	4	4	5	4	5	5	4	4	4	4	2	3	1	1	1	2	0	0	0	−1
b^*	17	18	16	17	16	15	15	11	11	7	5	3	−6	−3	−8	−12	−15	−20	−24	−29	−33
ΔE^*_{ab}	0.0	8.6	8.6	7.0	9.6	8.0	6.8	6.5	5.8	7.6	9.6	13.8	22.9	21.3	25.2	32.9	48.8	38.3	44.4	48.8	48.1

menting statistical classifications. All ΔE^*_{ab} values were calculated from colour values of the sample in the initial state and after treatment.

Mainly UV-A radiation (315 nm to 400 nm) influences the photochromic specimen. The spectral analysis of the 'Federal Office for Radiation Protection – BfS' (BfS, n.d.) shows that UV-B (280 nm to 315 nm) has a very low influence because these wavelengths are regularly filtered by the atmosphere.

4. Conclusions

Irreversible sensitive dyes can be applied to a substrate as a component of printing inks. Treatment with heat, moisture or light causes dyes to change, e.g. their colours or their volume, respectively. This can be measured and – also gradually – described by means of colour values, e.g. shifting of the colour shade, expressed in CIE $L^*a^*b^*$ values or by a change of the layer thicknesses. Integrated into a matrix code, e.g. QR code, the sensitive dyes can provide information about the exposure of the substrate or package to changes in the environment. Modern smart devices are able to capture current colour information and to transfer the information to a web server for evaluation. Calculations, based on the comparison of initial color values with the current information after treatment provide numerical evaluation of the deviations.

The flow behaviour of the inks with sensitive dyes was analysed, whereby statements could be made regarding their specific characteristics and suitability for use in the printing process. The viscosity was measured to analyse the processability of the sensitive screen-printing inks, which were modified in further investigation. The functionalities of the sensitive dyes were examined with regard to their reactivity. The colour shift between at least two transitions was investigated. Thus, it was found that the hydrochromic ink can detect a direct influence of water, but there is no detection of a continuous influence of moisture.

Colour shift allows statements about the condition of the respective sensor. There are differences between the different photochromic, hydrochromic and thermochromic sensitive inks, expressed as the changes contrast of the colouring, the gradual colour shift and the measurement of the individual phases of the respective colour gradation.

Against this background, three priorities can be deduced for further R & D work:

- Development of inkjet inks with irreversible sensitive dyes for easier production of the codes in single step operation in comparison to screen-printing technique.
- Development of an application for measurement, transmission, and evaluation of the colour information by means of smart device and web server in the Internet of Things.
- Development of robust, data-based models for the reliable description and comparison of information retrieved as changes of sensitive dyes.

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JPMTR 124 | 1902
DOI 10.14622/JPMTR-1902
UDC 159.937:004.92-023.8

Research paper
Received: 2019-02-03
Accepted: 2019-07-09

The evaluation of rendered color shading using edge detection method

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Abstract

Color reproduction in 3D computer-generated scenes is affected by scene setting, object and camera properties, illumination and rendering technique. Regardless of controllable conditions in a computer-generated environment, the achievement of colorimetric accuracy is complex, it depends the most on hue, saturation, and lightness of the virtual object's color and has to be considered from different perspectives. Visual perception of object color and shading is also influenced by object form, usually defined by contours. The aim of this research was to introduce edge detection method for evaluation of rendered color shading and to define how participants perceptually match color shaded renderings with predefined and proposed edge detection representations. The testing objects were color renderings of shaded objects whose colors were defined with tiff textures in the test chamber consisting of four lights, camera, and an object with shadows. In the experimental part, different edge detection methods and color channel models were used on selected colors of color renderings. It was confirmed that color, light intensity and background influence the frequency of detected edge pixels. Moreover, it was established that visual evaluation is also affected by color, background and light intensity. When the results of the frequency of detected edges and visual evaluation were compared, it was demonstrated that edge detection can be a suitable supportive method for evaluation of rendered color shading.

Keywords: color rendering, scene settings, photometric lights, standard lights, visual perception

1. Introduction

The validation of static and dynamic meshes is usually performed with quality metrics techniques. Bulbul, et al. (2011), Corsini, et al. (2013), and Yildiz and Capin (2017) presented the development and the review of these methodologies. Yildiz and Capin (2017) further classified techniques in geometry-distance-based metrics and perceptually based metrics, i.e. model-based and image-based perceptual metrics. In perceptually based metrics computational models the algorithms are developed with consideration of human visual system. Many of these researches include contrast sensitivity function, moreover, studies also present visible difference predictor, visual equivalence detector, visual masking etc., where human perceptual phenomena of color are not separately studied. On the contrary, color is studied as a distinctive image characteristic by Bolin and Meyer (1998), where vision-based rendering model was introduced including cone fundamentals, cortex filtering, calculation of local contrast and chromatic aberration, by defining of opponent's contrast space and by using contrast sensitivity function filtering, masking transducer, spatial pooling and distance summation and resulting in just noticeable difference map. Albin, et al. (2002) used LLAB color space for perceptual metrics performed on color images. LLAB color space is a derivation of CIELAB 1976 color space, that in this particular study enabled chromatic adaptation, computation in CIELAB color parameters as lightness, hue and chroma, and prediction of color difference between two selected images rendered under different conditions. In the study of Albin, et al. (2002) perception of color was evaluated with three types of metrics: first, pixel by pixel and local distance map, second, by the comparison of two images with a global value and third, by recursive subdivision and the creation of adaptive distance map. Color as a perception of visual characteristic has been mainly analyzed in terms of color perception, color constancy, color management and color appearance. Studies of color appearance, variations of color parameters analysis (chromatic changes, background) and the introduction of CIECAM02 color appearance model in computer graphic were presented only occasionally (Fedorovskaya, de Ridder and Blommaert, 1997; Trèmeau, Nicolas and Dinet, 2008; Bratuž, et al., 2014).

After the human brain receives visual data from the retina, visual properties of objects such as depth, shape, color and motion are probably extracted in the first stages as color-shape information and depth-motion information. After that, properties are separated and processed as a single parameter (Čadík, 2004; Livingstone and Hubel, 1988). Color and form are basic information for an object's identification. In the striate cortex, edge detection (that renders possible identification of the form) is performed by three types of cortical cells that have different receptive field characteristic. First, simple cells are called edge detector, due to their responding to the luminance edge in the proper orientation; second, complex cells are responding to movement; and third, hyper complex cells are also called end-stopped cells (Hubel and Wiesel, 1959). Biederman (1987) reviewed the basis of perceptual recognition, studied contour-based perceptual categories more closely and presented the 'recognition-by-components'. In Biederman's research edges are detectable due to their five properties: curvature, co-linearity, symmetry, parallelism, and co-termination. Processing stages that allow object recognition are edge extraction followed by two steps detection of non-accidental properties and parsing at region of concavity. After determining components and matching them to object representation, object identification occurs. Objects are segmented into primitive components, i.e. symmetrical volumes as blocks, cylinders, spheres, etc. In his research, Biederman also discussed that surface characteristics such as color and texture are processed simultaneously as volume characteristic (edges, depth), however, color and texture, in his opinion, do not have primary role for mental representation of the objects.

On the contrary, contours are supposed to be crucial for objects identification, even when they are degraded in the collinear and smooth parts. Edges and their reinterpretation have also played an important role in computer graphic visualization, where contours-based and outline-based non-photorealistic renderings are one of the most frequently used techniques (Gooch, et al., 1999; Geng, 2010). Due to their ability to simplify details of objects by means of color, gradates, topological characteristic, they are more efficient for some purposes to communicate the information in comparison with photo-realistic rendering techniques (Gooch and Willemsen, 2001; Strothotte and Schlectweg, 2002).

Edge detection is a spatial operation that detects presence and location of edges defined by changes in image intensity and is one of the most important operations in image analysis and enhancement (Koschan and Abidi, 2005). In general, edge detection methods are based on two principles; first is searching for local minima and maxima of the first derivative and second by zero crossing of the second derivative of an image (Oskoei and Hu, 2010). These operations are to some extent sensitive to noise and spatial filtering methods, and are normally incorporated into algorithm (Marr and Hildreth, 1980; Deriche, 1990; Shen and Castan, 1992; Leclerc and Zucker, 1987; Miché and Debrie, 1995). Methods presented by Sobel (2014), Prewitt (Oskoei and Hu, 2010) and Roberts (Davis, 1975) are based on the first principle and are classified as fast and efficient methods being variously sensitive to noise. Laplacian of Gauss (LoG) is an efficient method combining Gaussian filtering with second derivatives, however, mostly applied is Canny method that combines both aforementioned principles and is also time-efficient, but sensitive to false edges that present themselves in shading or blurring (Koschan and Abidi, 2005; Basu, 2002; Canny, 1986). There is no general edge detection method for all applications and evaluation is still based on subjective judgment. A general rule to define quality edge detection is thin detected edges and no or little noise (Koschan and Abidi, 2005; Oskoei and Hu, 2010). Studies of contour formation in visualizations and analysis of color reproductions after image processing in computer graphics have not yet been firmly implemented (Fu, et al., 2018; Zhou, et al., 2017; Fiorucci, et al., 2017). Besides, a review of the literature revealed that edge detection has not yet been considered as a potential supportive method for evaluation of rendered color shading and also analysis of the results of edge detection by visual perception of rendered color representations is still unknown.

The aim of the research was to introduce an edge detection method as parallel or supportive method for evaluation of rendered color shading. Moreover, the goal was also to analyze the results of edge detection by visual perception of rendered color representations. To study shading in renderings, different edge detection algorithms were implemented and results, i.e. frequency of edge pixels, was analyzed in dependence of color channel models, the object and background color, and light settings. Consequently, a study of the definition of a probable perceptional connection was performed between: first, visual perception of object color and detected contours, and second, results of frequency of edge pixel occurrence of different colored objects and scene settings. The results of the research should open new possible methodologies in the field of evaluation of color renderings and 3D object's shading.

2. Methods

2.1 Scene setting

Scene was set up in 3ds Max software in a test chamber and consisted of two types of light (four standard lights simulating lamps with intensity 0.4, 0.6, 0.8 and 1, or four photometric lights physically determined with standard illuminant D65 and intensity 3000 lm and 4000 lm), two cameras, and one shaded object (Figure 1).

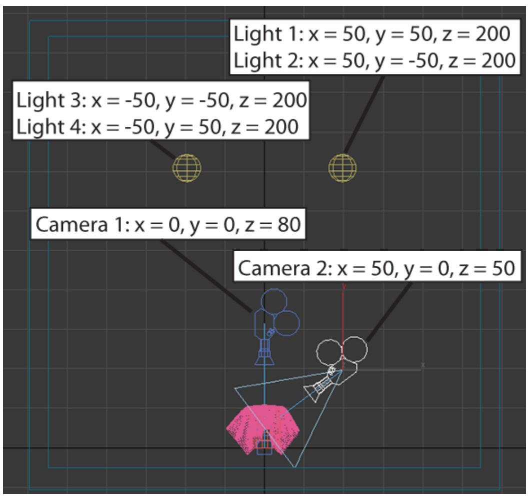

Figure 1: The positions of the lights and cameras (in cm), shown in x,z plane of virtual x,y,z space

Scene settings are presented in Table 1. Shadows were defined as raytraced. The scenes were rendered in mental ray render engine, i.e. production-quality rendering application based on ray-tracing technique. Other light and rendering settings were the default.

Table 1: The optimal conditions chosen for testing with mental ray render engine (Bratuž, Javoršek and Gabrijelčič Tomc, 2015)

Type of light	Light intensity	Gamma	Background
Standard	0.4	1.8, 2.0, 2.2	*R*, *G*, *B* = 255
(std.)	0.6	1.8, 2.0, 2.2	*R*, *G*, *B* = 200
	0.8	1.8, 2.0	*R*, *G*, *B* = 100
	0.8	2.2	*R*, *G*, *B* = 50
	1.0	1.8, 2.0, 2.2	*R*, *G*, *B* = 0
Photometric	3000 lm	1.8, 2.0, 2.2	*R*, *G*, *B* = 150
(pho.)	4000 lm	1.8, 2.0, 2.2	*R*, *G*, *B* = 50

Preliminary research was carried out to determine optimal conditions for color reproduction that are presented in Table 1. In that research, colorimetric accuracy of color reproduction of test chart colors illuminated with two types of virtual (digital) light sources and rendered with two rendering engines was analyzed (Bratuž, Javoršek and Gabrijelčič Tomc, 2015). Optimal conditions were established in terms of gamma values, illumination and background and those optimal conditions were further used in the presented research for analysis of edge detection and its potentials for the evaluation rendered color shading.

Position of lights and camera was defined with *x*, *y* and *z* coordinates (in cm) of central point. In total, four lights and two cameras (top view and side view) were positioned on the scene (Figure 1). The focus of cameras was defined by their targets, i.e. the position of the camera's focus point.

2.2 Selection of colors

In our research 15 colors were chosen from color test chart and tiff texture format was mapped on 3D object. Reference *R*, *G*, *B* values of chosen colors are presented in Table 2.

Table 2: Reference R, G, B values

Patch	*R*	*G*	*B*	Color
F17	31	17	38	dark violet
A39	5	26	15	dark green
A1	124	141	158	grey
H6	235	239	251	white
I18	205	2	3	saturated red
I10	97	191	15	saturated green
A2	8	16	139	saturated blue
M39	157	129	206	violet
C1	205	5	247	magenta
N4	231	228	2	saturated yellow
A14	155	43	151	saturated violet
H23	217	165	224	light pink
F30	130	229	206	light cyan
B23	233	112	205	pink
B27	130	32	33	dark red / brown

2.3 Edge detection

In order to evaluate rendered color shading, edge detection was performed in Matlab with four methods and consequently, the frequency of occurrence of edge pixels in relationship to non-edge pixels on an image was evaluated by calculating the percentage of detected edge pixels in comparison with all pixels on the image.

In general, edge function takes an intensity image $M = f(x,y)$, where x and y represents spatial coordinates and function f denotes intensity function, as its input and returns a binary image $BW = g(x,y)$, where x and y represent spatial coordinates and function $g = [0,1]$. The BW is of the same size as M, with ones where the function finds edges and zeroes elsewhere. Several methods are provided in Matlab: Sobel, Prewit and Roberts methods find edges using the appropriate (Sobel, Prewit or Roberts, accordingly) approximation to the derivative and they return edges at those points where the gradient of M is maximum. The Laplacian of Gaussian (LoG) method finds edges by looking for zero crossings after filtering M with a Laplacian of Gaussian filter. Canny method finds edges by looking for local maxima of the gradient of M. Gradient is calculated using the derivative of a Gaussian filter. This method uses two thresholds to detect strong and weak edges and includes weak edges in the output only if they are connected to strong edges. This method, therefore, less likely than others provide false information due to noise, and more likely detects true weak edges.

In our research, four methods for edge detection were used: Canny, Sobel, LoG, and Prewitt, abbreviated as C, S, L, and P in figures, respectively. Default Matlab parameters were used for all methods, thus threshold was set automatically for all methods. Direction for Sobel and Prewitt is set to 'both', default sigma parameter is set to '2' for LoG and 'sqrt(2)' for Canny (MathWorks, 2018). As edge detection is performed on intensity channel of an image M, three methods were used to calculate M (channel color model RGB, I, Y).

First, RGB, where color image was separated into three intensity images R, G, and B, edge detection was performed on each channel separately and results for each channel were merged into binary image BW (marked as rgb later on); Y channel of YIQ color space used by NTSC color TV system (marked as y), and I channel of 'hue, saturation, intensity' (HSI) color space (marked as i). Second, frequency of occurrence of edge pixels in relationship to non-edge pixels on an image was calculated as percentage of edge pixels in relation to all pixels in an image. Third, average frequency per color was also calculated. Frequency of edge pixels was discussed in dependence of object and background color, light settings, and color channel model (RGB, I, Y). Detailed numerical and visual inspections were additionally carried out for Canny and LoG algorithms, for dark green A39 and white H6 colors and on one representative topological part (detail) of the object.

2.4 Visual perception analysis

Next, a visual evaluation was carried out to determine whether results of edge detection match the visual perception of the observers when they are shown and asked to compare representations of contours of objects in the images (results of edge detection) and color images of objects that represent rendered color shading (Figure 2). The participants were asked to perceptually match color shaded renderings that consists of objects form, contours, color and tone transitions (color gradients) with predefined and proposed edge detection representations. 59 young observers (that voluntarily participated in the research), 45 women and 14 men, aged from 19 to 20 years, with normal sight and no color blindness reported. The participants' task was to correlate proper edge representations with rendered draped object colors: dark green (A39), light cyan (F30), white H6, red I18, and yellow N4 at standard light intensities 0.6 and 1. In test A, observers had to choose the optimal edge detection of a color rendering, to determine preferred edge detection algorithm between Canny (Crgb and Ci) and LoG (Lrgb and Ly). This task was performed merely to determine observers' preference.

In the second part of the analysis of visual perception (test B), observers had to match reference rendering with: first, matching edge detection image; second, edge detection image of the same color rendered in the scene with different background and light intensity, and third, edge detection image of different color, which had a high percentage of area covered with edges. With this test, the analysis of the actual visual correlation between rendered color and edge detection image and an investigation whether the observers tend to select the representation with the highest percentage of edge

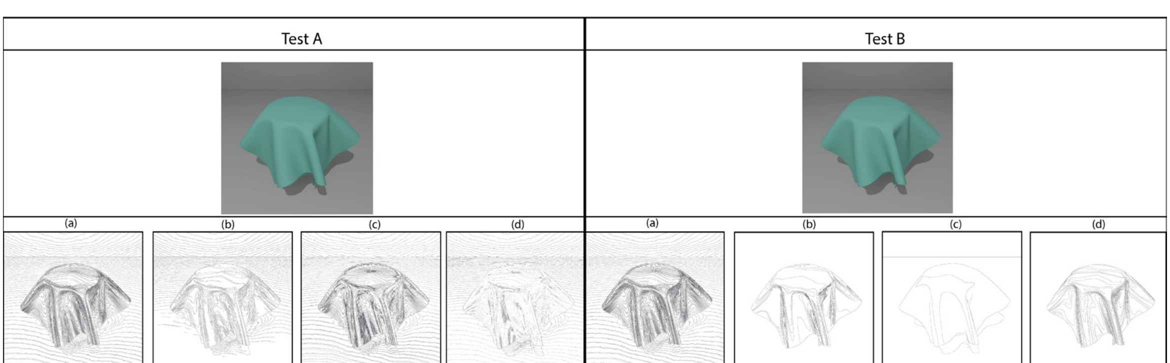

Figure 2: Test A and Test B with the images shown to the observers during visual perception analysis

detection regardless the color, background, and light intensity were carried out. For both tests, the visual analysis was performed in test room under controlled viewing conditions, where the images were presented on a 24'' monitor with the resolution of 1920 × 1200 pixels. Distance from the participants to the monitor was 60 cm. The participants were asked to observe the test images (presented in Figure 2, Test A and Test B) for 10 s (without interacting with them) and to choose the edge detection representation (naming the letter a, b, c, and d.). The question that was asked to the participant was: "Which of the four images showing edge detection (a, b, c, d) most accurately represents the rendering of the colored object?" The participants had time to rest between consecutive presentations of tests and when they were prepared, the next presentation was displayed.

3. Results and discussion

3.1 Results of edge detection

In Figures 3 to 8 results of edge detection frequency are shown for selected colors. In order, darker colors black F17, and dark green A39, brighter colors white H6, and light cyan F30, saturated red I18, and saturated yellow N4, were analyzed and frequency of edge pixels is shown (in %). To clarify, the names of applied edge detection functions and channel used are combined into name of method on the x axis.

For example, Crgb represents Canny edge detection algorithm applied on RGB channels. Abbreviations S, P, and L were used accordingly for other methods, meanwhile, rgb, i, and y stand for investigated channels.

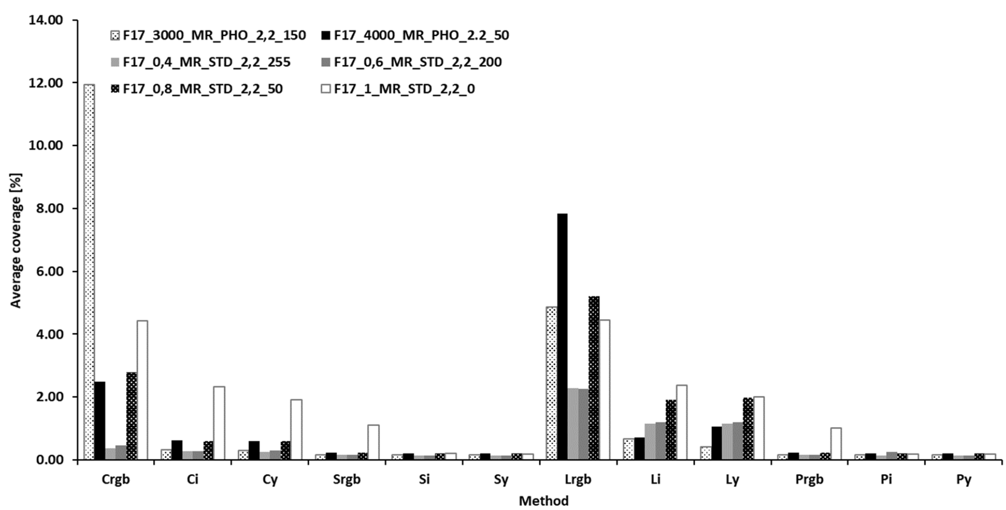

Figure 3: Edge detection frequency for rendered color black F17

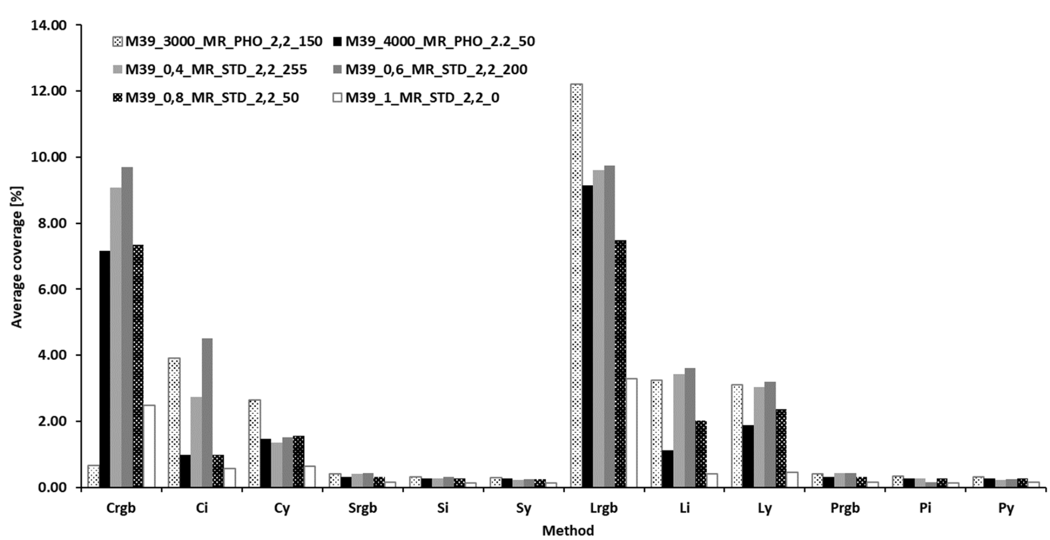

Figure 4: Edge detection frequency for rendered color dark green A39

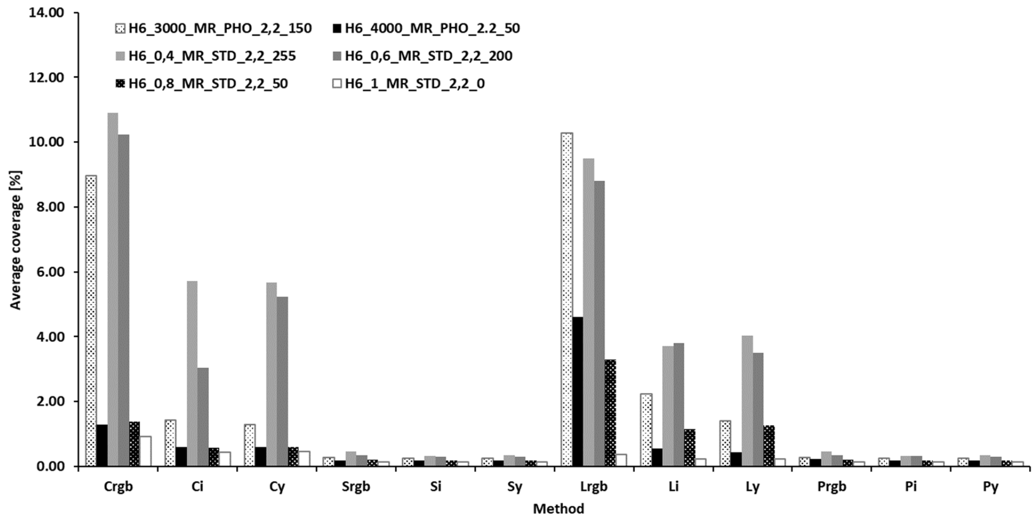

Figure 5: Edge detection frequency for rendered color white H6

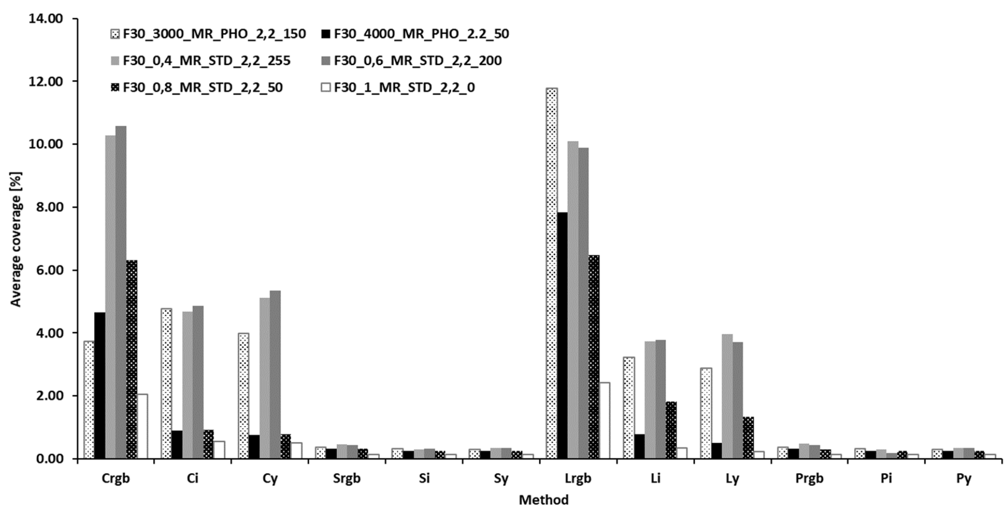

Figure 6: Edge detection frequency for rendered color light cyan F30

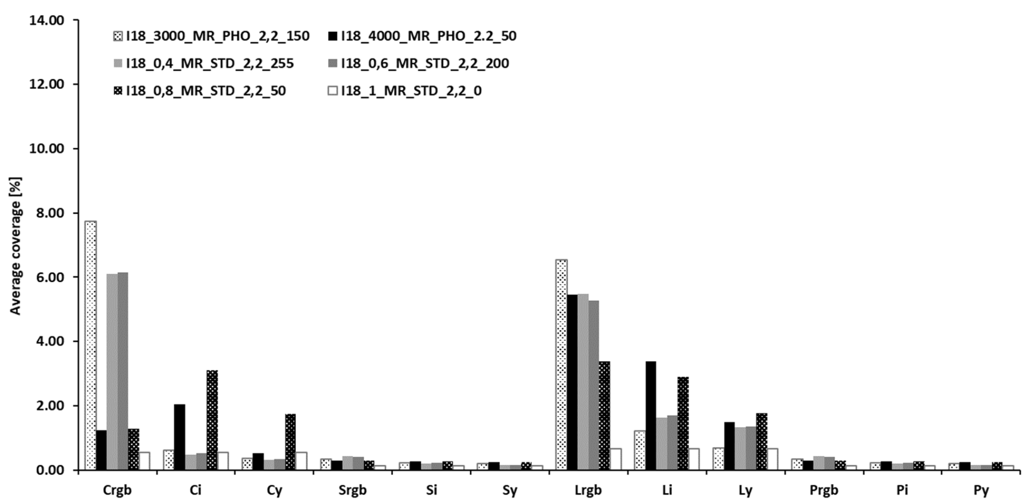

Figure 7: Edge detection frequency for rendered color red I18

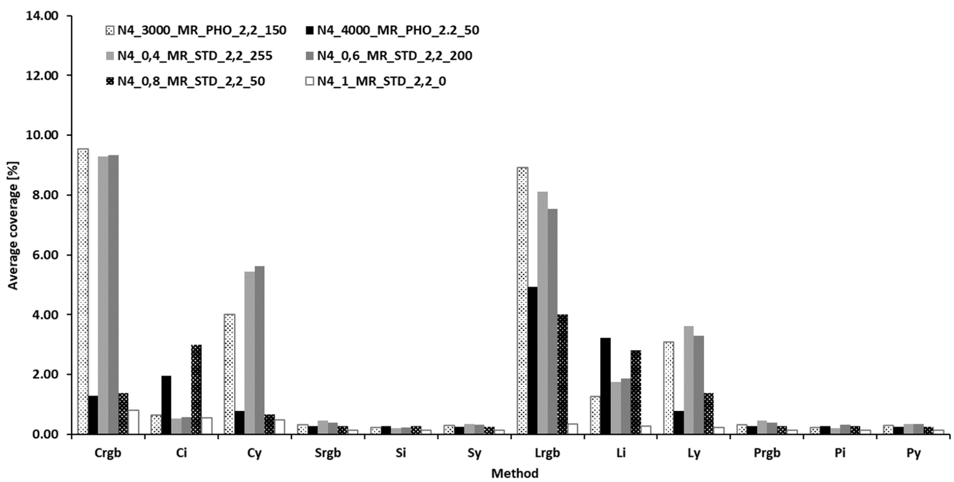

Figure 8: Edge detection frequency for rendered color yellow N4

3.1.1 The analysis of edge detection in dependence of color and illumination/background setting

The analysis of edge detection shows that frequency of edge pixels depends on hue, saturation, and lightness of colors. In general, numerical values of edge detection frequency are the highest for brighter colors (i.e. white H6, grey A1, light cyan F30, light pink H23) and the lowest for dark colors (i.e. black F17, dark green A39), as presented in Figures 3 to 8.

When considering the relation between color saturation and frequency of detected edges, it can be deduced that mainly less saturated and brighter colors (white H6, light cyan F30, pink B23, light pink H23) and colors as saturated green I10, violet M39, saturated red I18, magenta C1 and yellow N4 result in higher frequency of detected edges when the intensity of std. lights is 0.4 and 0.6 (background colors R, G, B = 255, and R, G, B = 200, accordingly) and the intensity of pho. light is 3000 lm (background color R, G, B = 150). On the contrary, dark saturated colors (grey A1, dark violet F17, violet A39, dark red/brown B27, saturated blue A2) had higher values of frequency for intensities 0.8 (background colors R, G, B = 50 and R, G, B = 100) for std. light and intensity 4000 lm for pho. light (background color R, G, B = 50). Those trends are present in all types of channel analysis (RGB, I and Y) and in all analyzed algorithms.

The deviations between results of lower (std. lights 0.4 and 0.6; pho. lights 3000 lm) and higher (std. lights 0.8, 1.0; pho. light 4000 lm) light intensities can be observed also when results of edge detection are evaluated on renderings with saturated colors and different hues. At lower light intensities saturated colors in the red and yellow region of RGB color space tend to have a higher frequency of detected edges than colors in blue, cyan and green region. Saturated colors magenta and especially violet have an ambiguous behavior, as, in dependence of lights intensity, they lean to results of both color groups: red–yellow and blue–green.

The results from Oskoei and Hu (2010) show that by use of Sobel and Prewitt algorithms, edge detectors that compute the first derivative captured only the most crucial contours to represent the renderings, regardless of the background/object color and light intensity. In our investigation, edge detection represents mainly the object's silhouette, i.e. the outer contours between the object and background and the shading could not be studied. Consequently, the further application of these algorithms was not useful, and the analysis continued with the Canny and LoG algorithms.

3.2 Visual and numerical analysis of edge detection of color samples dark green A39 and white H6

Detailed edge detection analysis was performed on two color samples: dark green A39 and white H6. As there was a distinct difference in-between the results of light intensities 0.4, 0.6 vs. 0.8, 1.0 for std. lights and 3000 lm vs. 4000 lm for pho. lights; both groups of samples and their results are discussed separately.

3.2.1 Light intensity of standard light 0.4 and 0.6, and photometric light 3000 lm

At light intensities, 0.4, 0.6 and 3000 lm, frequency of occurrence of edge pixels were lower for color dark green A39 (Figure 4) and higher for bright color white H6 (Figure 5). Differences in edge detection between two analyzed colors are lower in case of images generated with pho. lights and when edge detection is performed according to RGB channels (especially for color white H6). Frequency of detected edges is evidently higher in case it was performed on RGB channels in

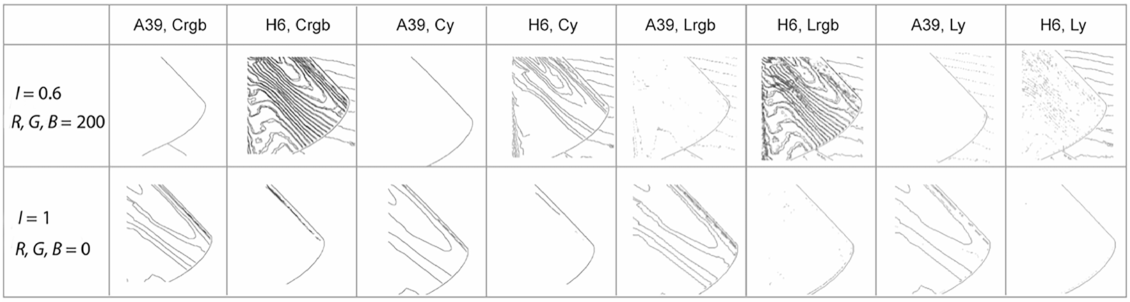

Figure 9: Detected edges for colors violet A39 and white H6 by use of Canny and LoG algorithms on RGB and Y channels, on the scenes with the background R, G, B = 200 and standard light at intensity I = 0.6 and on the scenes with the background R, G, B = 0 and standard light at intensity I = 1.0

comparison with the detection on channels I and Y. The comparison between Canny and LoG algorithm showed that the first has minor edge detection in case of color dark green A39, and stronger detection in case of bright color white H6, while the results of the LoG algorithm are just the opposite.

When the visual analysis was performed on processed images, it was found out that when performed on RGB, I and Y channels, the trend of edge detection is similar to both Canny and LoG algorithms. In Figure 9 a detail of an object is presented as edge detection with Canny and LoG algorithms for colors dark green A39 and white H6, according to RGB and Y channels and for the scenes with the background *R, G, B* = 200 and *R, G, B* = 0 illuminated with std. light at intensity 0.6 and 1.0.

3.2.2 Light intensity of standard light 0.8 and 1.0, and photometric light 4000 lm

Analysis of edge detection on renderings at higher light intensities (std. 0.8, 1.0 and pho. 4000 lm) in combination with dark background colors (*R, G, B* = 50 and *R, G, B* = 0) showed opposite results as in the case of scenes with brighter backgrounds and lower light intensities (Figure 9).

Numerical results of edge detection at these light intensities are in general higher for color dark green A39 (Figure 4), and lower for the bright color white H6 (Figure 5). Deviations between the numerical and visual representation of edge detection for both colors are negligible for the analysis of I and Y channels, meanwhile, the analysis of the RGB channels represent the more obvious difference between the results.

Besides, the differences between edge detection of two analyzed colors are lower for the scenes with higher light intensities and darker background *R, G, B* = 50 and *R, G, B* = 0 than it was demonstrated for the scenes with brighter background colors *R, G, B* = 150, *R, G, B* = 200 and *R, G, B* = 255.

Furthermore, the LoG algorithm resulted in a higher frequency of detected edges than the Canny algorithm (especially for the analysis according to RGB channels).

3.3 Visual perception analysis

In the first part of the visual analysis, different edge detection algorithms (Canny with RGB and I channels, marked as Crgb, Ci; and LoG with RGB and Y channels, marked as Lrgb, Ly) were tested and a number of observers that have chosen defined edge detection algorithm as the optimal representation of a color rendering were defined. In Figure 10 the numbers of answers that represent the observers' choice of an optimal edge detection algorithm for the images with object colors dark green A39, light cyan F30, white H6, saturated red I18 and saturated yellow N4 at std. light intensities 0.6 and 1.0 are presented.

Preliminary results of edge detection analysis show that when using the Canny algorithm with RGB values, the maximum frequency of detected edge pixels was obtained. It was followed by LoG algorithm performed on RGB channels and Canny and LoG algorithm performed on the Y channel. Visual analysis revealed the difference between results of testing on renderings with light intensity 0.6 (background *R, G, B* = 200) and 1.0 (background *R, G, B* = 0). In case of light intensity 1.0, Canny algorithm prevailed as a preferred solution for colors light cyan F30, white H6, saturated red I18 and saturated yellow N4, in the range from 23 % to 68 % (observers often chose Canny algorithm performed on RGB channels for colors cyan F30 and white H6, and Canny algorithm performed on I channel for colors red I18 and yellow N4). The exception is color dark green A39, where the difference between the results of Canny and LoG algorithms is smaller. The Canny algorithm performed on I channel was chosen by 38 % of observers, followed by LoG algorithm performed on RGB by 30 % of observers. When the light intensity was 0.6, the Canny algorithm performed on RGB and I channels was mainly chosen for bright colors light cyan F30 and

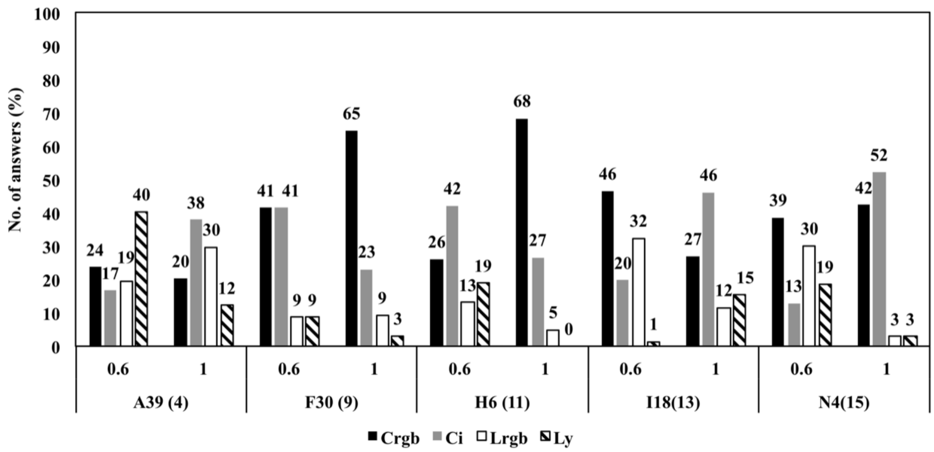

Figure 10: Results of perceptions in dependence of algorithm

white H6 (from 26 % to 41 %), meanwhile observers chose more equally between Canny (mainly Crgb) and LoG (Lrgb) algorithm for color saturated red I18 (Crgb = 46 %, Lrgb = 32 %) and color saturated yellow N4 (Crgb = 39 %, Lrgb = 30 %).

Again, the exception here was color dark green A39, were for the 40 % of observations the most appropriate was LoG algorithm performed on Y channel.

In addition, in the second part of analysis of visual perception users had to choose among images that represent proper edge detection image; first, edge detection image of the same color rendered in the scene with different background and light intensity, and second, edge detection image of different color which had a high portion of area covered with edges. The answers on both questions were considered as right, because we were interested in the perception of the colored object, regardless of the illumination and background.

In Figure 11 it can be observed that results again differ in dependence on tested colors. The percentage of wrong answers is high, from 29 % for the color light cyan F30 (light intensity 0.6) up to 73 % for the color saturated red I18 (light intensity 1.0).

Finding that observers have matched wrong edge detection image to color rendering is confirmed especially for the scenes with light intensity 1.0 (dark background *R*, *G*, *B* = 0) and saturated colors, i.e. saturated red I18 and saturated yellow N4 where the percentage of wrong answers was 59 % and 73 %, respectively. It can be presumed that observers gave wrong answers here due to their choice of edge detection images with a high frequency of detected edges (strong detection of

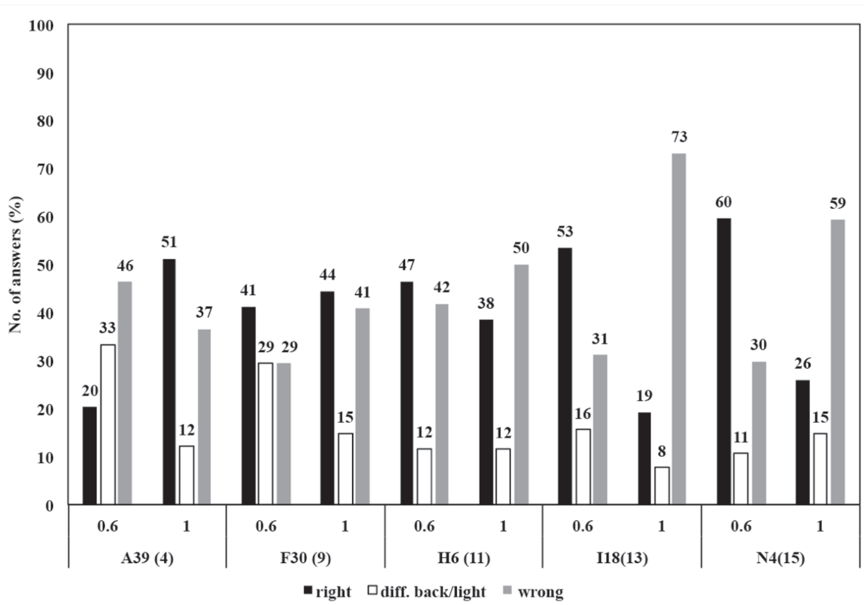

Figure 11: Results of perception in dependence of background and light intensity

shading), meanwhile, the algorithms usually detected a lower percentage of edges within these renderings. When all the right answers are summed up, results show that at light intensity 0.6, observers answered correctly for all colors with percentages from 53 % for the darkest color dark green A39 up to 70 % for light cyan F30 and 71 % for saturated yellow N4. By all means, these results do not confirm with full certainty there is a match between visual perception of contours (calculated with edge detection algorithms) and color objects, and that observations are strongly influenced by background and light setting. It can be deduced that when visual perception is considered, the use of edge detection processing could be plausible as an alternative method for evaluation of rendered color shading only for the rendered images at a combination of lower light intensities and bright background colors. Meanwhile, for the scenes rendered at higher light intensities and dark background, the application was not successful enough, due to observers' tendency for perceptual interpretation of dark shaded areas of rendered colors with a high frequency of edge pixel occurrence (regardless of the object's and background color and light intensity).

4. Conclusions

In the research, edge detection method and contour formation analysis was introduced on rendered color shading with an aim to define the relevance of the implementation of edge detection method in the color evaluation and its correlation with visual perception.

The analysis of the frequency of detected edge pixels on renderings shows that it depends on hue, saturation, and lightness of colors. The highest frequency was detected for brighter colors, whereas it was high for less saturated brighter colors and less saturated darker colors for lower lights' intensities and vice versa. Results of edge detection also depend on the hue and can be divided into two groups: red–yellow and blue–green.

Edge frequency obtained by Canny and LoG algorithm was adequate for further analysis and all analyzed color channels gave similar results. The highest frequency was achieved with the Canny algorithm performed on RGB channels and it was studied more closely. The visual assessment showed that there was no edge detection method favored by observers and that results depend on color and light intensity. Furthermore, the background also affects observers' judgment, which was proven in the second part of visual assessment.

Methods used in this study are a useful tool to assess color renderings and rendered color shading in computer reproductions of colors and provide new observations and a fresh point of view on the field of evaluation of contour visualizations and implementation of standardized image analysis in the workflow.

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TOPICALITIES

Edited by Markéta Držková

CONTENTS

News & more

Less than 12 months to drupa 2020

As of June 2019, the list of drupa 2020 exhibitors features about 14 hundred companies. The main product categories range from prepress, print, premedia and multichannel solutions, over post-press, converting, packaging, materials, equipment, services and infrastructure, up to future technologies, with six topics highlighted for this edition. For print products, it is their increasing fascination, with new enhancements and tactile impressions. In the worldwide-growing packaging production, innovations towards higher customisation and personalisation are made possible thanks to digitalisation. Another attractive direction is the application of functional printing technologies in smart packaging. Functional printing is also the highlight topic on its own, including printed electronics solutions for different industries and innovations in the textile printing sector. In 3D printing, the opportunities encompass its utilisation as a complement to other technologies as well as first-mover solutions. The future technologies highlight follows the developments in autonomous printing, cloud computing, the Internet of Things, robotics, big data, artificial intelligence and collaborative manufacturing, for example. Last but not least, the innovative processes and product solutions for industrial printing are in the focus, along with the progress in automation and robotics, new workflows and Industry 4.0.

Sixth drupa Global Trends report

The 6th edition of the drupa Global Trends Report from this April is based on the answers from 620 printers and 209 suppliers (a slight majority of which is from Europe) who participated the survey conducted in October 2018. The results show a stable condition of the global print industry as a whole, with conditions varying between regions and between markets. The worst numbers come from printers in Africa, reporting the net negative balance of economic confidence and decreased capital expenditure in 2018. On the contrary, the current economic situation was better than expected for suppliers in North America, Australia and Oceania. North America also reported positive net balances on all printer financial measures except substrate prices. Across markets, capital expenditure of functional printers was almost double than expected. The expected challenges are mainly related to politics and broader economic conditions.

Funding

In September 2019, the Horizon 2020 innovation action on Materials, manufacturing processes and devices for organic and large area electronics with total funding of 20 million EUR has the 2nd stage deadline; the first deadline was earlier this year in January, with 23 proposals submitted. The activities should include material development and improvement in terms of electrical performance, processability, stability and lifetime during device operation, as well as prototyping of advanced electronic products based on organic and large area electronics. Besides the economic and business outcomes, the projects should yield new products and improvements in

The year 2018 by Intergraf

Intergraf, the European Federation for Print and Digital Communication, has recently released its annual economic report based on the available data up to 2018. It again reviews the general economic situation as well as the situation in the European graphic industry and brings the reports on ink, paper, publishing, book, press, energy and postal markets and the value-added tax, complemented by the European print market review delivered by Smithers Pira and the reports from 14 countries.

Intergraf is also active in organising events and a number of EU affairs. In late December 2018, the project 'SPPRING: Skills for the Paper and Printing Industries' Next Generations' has started, funded by the EU with a budget of almost € 800 000. During the 18 months till June 2020, the consortium of project partners and experts from nine countries (Austria, Belgium, Estonia, France, Germany, Italy, Slovenia, the Netherlands and Portugal) coordinated by Intergraf is working to fulfil the defined objectives. The work packages, besides the administration, consist of the desk research on current education and training available and on current skills needs, assessment of future relevant education and training needs and their envisaged delivery pathways, identification of future relevant core and ancillary skills, and development of a sectors recruitment strategy complemented by a toolkit for recruitment campaigns, concluded with the recommendations for future training and education in the print and paper industry. The results of the research and the toolkit with social media activities, videos and interviews to demonstrate the paper and print industry job opportunities will be published at a conference in the final phase of the project.

A method for nano-scale printing of conductive lines developed by XTPL

Creating conductive lines with a width of as little as 100 nm is possible through a guided assembly of nanoparticles developed by the Poland-based company XTPL. According to the company website, the functionality of the XTPL additive manufacturing technology was confirmed in laboratory conditions in late 2015. After further development, in spring 2017, the line printing precision was improved below 100 nanometres and the XTPL printer prototype was completed. The prototype was presented at the 13th IDTechEx Printed Electronics Europe conference and exhibition, where the demonstrated ultra-fine resolution printing without the need of complex pre- or post-processing was recognised as a significant development for printed electronics manufacturing and won the Technical Development Manufacturing Award. This year, the patent application was published (patent is pending).

The claimed bottom-up method for forming wire structures upon a substrate comprises depositing the fluid containing electrically polarisable nanoparticles onto a substrate in the first step, applying an alternating electric field to the fluid on the wetted region, so that a plurality of the nanoparticles are assembled to form an elongate structure extending between the specially designed electrodes in the second step, and removing the fluid in the last step. During the step of applying the electric field, the separation between the two electrodes is increasing by moving the second electrode away from the first one; this way, the elongate structure is further extended towards the second electrode. The rate at which the length of the assembled structure is increasing is monitored and the properties of the alternating electric field are adjusted accordingly to ensure the desired performance. The method enables to produce a shape with the predetermined geometry.

environmental stability and charge carrier mobility, along with low water vapour and oxygen transmission rates.

On the other side of a budget scale, funding for PhD research on heterogeneous integration of photonic and electronic devices in microsystems at the University of Sheffield, visiting fellowship in printing and graphic arts at the Houghton Library (Harvard) and a number of PhD scholarships in print culture history across the world are available, for example. In addition, several prizes are awarded each year – such as those of the Society for Imaging Science and Technology, which include the Johann Gutenberg prize for the outstanding technical achievement in, or contribution to, printing technology and the Chester F. Carlson Award for the outstanding technical work that advances the state of the art in electrophotographic printing. Overall, many calls are related to research in the field of 3D printing and additive manufacturing.

Advances in graphene printed electronics

The work that is expected to assist a faster implementation of graphene into day-to-day products and technologies was published in December 2018 by K. Pan et al. (Nature Communications 9, 5197, 2018). The researchers based at The University of Manchester and the National Institute of Graphene, in cooperation with the UK's National Physical Laboratory, have elaborated the environmentally sustainable route of production of graphene ink suitable for screen-printing technology.

The liquid-phase exfoliation of graphite is considerably speeded up thanks to the use of the dihydrolevoglucosenone solvent, which is bio-based (produced from cellulose under the Cyrene brand), fully biodegradable and non-toxic; however, care must be taken due to the risk of serious eye irritation. Cyrene was identified as a high-performance solvent for the sustainable processing of graphene thanks to its optimum polarity and high viscosity in 2017 by H. J. Salavagione et al. (Green Chemistry 19, 2550, 2017). Besides its speed, the process presented by K. Pan et al. can provide a higher concentration of graphene ink, resulting in significant cost reduction for large-scale production. The lead author believes that this might be a significant step towards the commercialisation of printed graphene technology, which would be an evolution in the printed electronics industry.

For screen printing, the highly conductive graphene ink (10 $mg\,mL^{-1}$) stabilised by cellulose acetate butyrate was further concentrated to 70 $mg\,mL^{-1}$ via rotary evaporation. The printed layer achieved a high conductivity of $3.7 \times 10^4\,S\,m^{-1}$ (conductivity of the pristine exfoliated graphene ink after drying and compressing was $7.13 \times 10^4\,S\,m^{-1}$). This allowed producing flexible printed graphene antennas operational from MHz to tens of GHz, ranging from near-field communication over ultrahigh-frequency to ultra-wideband slot antennas. These can be used for wireless data communication in Internet of Things applications and provide radio-frequency energy harvesting for low-power electronics. In the article, a printed graphene-enabled battery-free wireless body temperature sensor, radio-frequency identification tags and energy harvesting system are demonstrated.

For researchers dealing with graphene, also the good practice guide 'Characterisation of the structure of graphene' written by the National Physical Laboratory in collaboration with the National Graphene Institute and available since November 2017 might be of interest.

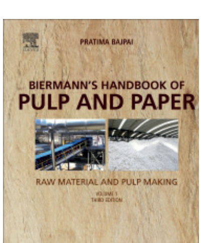
Bookshelf

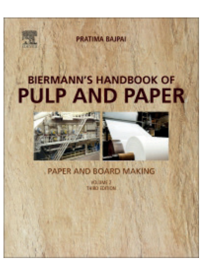
Biermann's Handbook of Pulp and Paper: Volume 1: Raw Material and Pulp Making Volume 2: Paper and Board Making

The first and second editions of this well-received book were written by Christopher J. Biermann under the titles of Essentials of Pulping and Papermaking (1993) and Handbook of Pulping and Papermaking (1996). The current edition is written by Pratima Bajpai, who is the author of the three volumes of Pulp and Paper Industry, among others, which were published in 2015–2016 and presented in the Bookshelf section of JPMTR 5(2016)1. The third edition of the Biermann's handbook is split into two volumes as it has been not only updated and revised but also largely extended in order to reflect the development during the last two decades. What remains unchanged is the intended audience; the handbook is designed as a comprehensive reference for industry and academia in the field.

The first volume opens with the introduction and fundamentals of wood and fibre, its growth and anatomy, detailing the anatomy of softwood, hardwood and wood fibre. The next four chapters present the properties of wood, wood-based products and chemicals, calculations of wood, paper and other materials, and nonwood fibre use in pulp and paper. The volume continues with the preparation of raw material, pulping fundamentals and calculations, production of dissolving grade pulp and pulp washing, cleaning, screening and fractionation. The following chapters then deal with kraft spent liquor recovery and alternative chemical recovery processes, pulp bleaching, hexenuronic acid removal, as well as bleaching and pulp properties calculations. The last chapters of this volume are dedicated to the purification of process water in closed-cycle mills, fibre from recycled paper and utilisation, pulp bioprocessing and forest biorefinery. The coverage of biotechnological methods is seen by the author as the distinguishing feature of this book.

The second volume first includes the refining and pulp characterisation, paper and its properties, stock preparation and additives for papermaking, followed by two chapters on paper manufacture (wet-end and dry-end operations). Next, it goes through the coating, paper and board grades, paper bioprocessing, papermaking chemistry, optical properties of paper and corrugated containers. Chapter 13 presents the basic concepts of printing and graphic arts. The next part then reviews the water circuits in the paper mill, discusses the environmental impact and provides metric and English units, along with unit analysis. The following chapters are focused on chemistry – the carbohydrate and polymer chemistry, colloid and surface chemistry, introductory chemistry reviews, as well as the analytical and coordinate chemistry. The remaining chapters of the handbook deal with the total quality management, hydraulics, process control, and several miscellaneous topics, such as corrosion, process simulation and bearings.



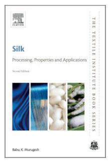


Author: Pratima Bajpai

Publisher: Elsevier
3rd ed., June 2018
ISBN: 978-0-12-814240-0 & 978-0-12-814238-7
668 & 576 pages
Softcover
Available also as an eBook

Silk: Processing, Properties and Applications

Author: K. Murugesh Babu

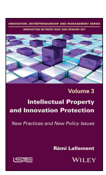


Publisher:
Woodhead Publishing
2^{nd} ed., December 2018
ISBN: 978-0081025406
272 pages, Softcover
Also as an eBook

The current edition of this book is updated to reflect the development in silk production and adds three new chapters that present non-mulberry silks, by-products of sericulture and silk industry, and also printing and finishing of silk fabrics. In general, printing on silk is specific thanks to a high number of colours. Besides traditional printing using the copper roller, the flat-bed screen printing is often a technique of choice. The author deals with printing inks and silk printing styles, namely the direct, discharge and resist ones. It is also pointed out that, in contrast to other fibres, the discharge printing is used for more than 50 % of printed silk articles, in spite of the lack of fastness due to the very poor fastness of the illuminant dyes. With this style, the fabric is first dyed and then printed with a colour-discharge paste. Transfer printing, printing with pigments, effect inks, natural dyes and other specialities are also included.

Intellectual Property and Innovation Protection: New Practices and New Policy Issues

Author: Rémi Lallement



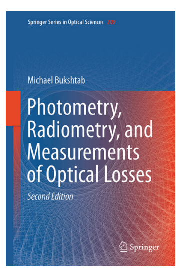
Publisher: Wiley-ISTE
1^{st} ed., November 2017
ISBN: 978-1786300706
170 pages
Hardcover
Also as an eBook

The book published as the third one of the Innovation Between Risk and Reward Set in Innovation, Entrepreneurship and Management Series argues in favour of a reform of the intellectual property rights system in order to drive the innovation. The

Photometry, Radiometry, and Measurements of Optical Losses

The second edition of this comprehensive reference from Springer Series in Optical Sciences has been throughout updated and expanded, with a new chapter on the spectroscopic interferometry. The first part explains the radiometric and photometric quantities and notions, describes the methods of photometric and radiometric measurements including the measurements of colour coordinates and indices and photometry of integrating spheres, deals with the radiometry of partially coherent radiation and then details the photometers and radiometers. This chapter discusses the optical design and absolute calibration of radiometers, attenuation and colour photometers and spectrophotometers – including the speciality applications of integrating spheres for optical calibrations and measurements – and also the photometric accuracy, along with the verification of linearity.

The chapters in the second part cover the conventional loss-measurement techniques, systems of multiple reflections with upgrades on techniques for enhancement of sensitivity and mitigation of fluorescence in Raman scattering, laser spectroscopy, measurements in passive resonators, determination of absorption losses, direct attenuation measurements and propagation losses in fibres and waveguides, followed by the new sections on Fourier-transform spectroscopic interferometry, high-dispersion interferometers for Brillouin spectroscopy, spectral measurements with frequency combs and time- and frequency-domain terahertz spectroscopy in the last, added chapter. The book also features an extensive list of references and index.



Author: Michael Bukshtab

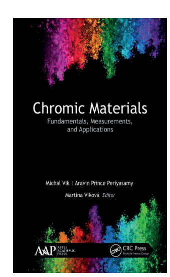
Publisher: Springer
2^{nd} ed., February 2019
ISBN: 978-981-10-7744-9
797 pages, 493 images
Hardcover
Available also as an eBook

Chromic Materials: Fundamentals, Measurements, and Applications

This new book provides the background necessary for the description of materials that dynamically change colour, namely the materials with photochromic, thermochromic, chemochromic, electrochromic and luminescent colourants, along with their applications and production. Further, it deals with their characterisation and available instrumentation for colorimetric, spectrophotometric, thermal and mechanical measurements. The last chapter then discusses the methods for fastness testing of chromic materials.

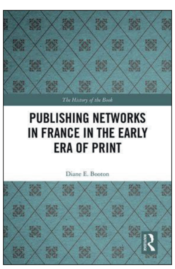
Authors: Michal Vik, Aravin Prince Periyasamy

Publisher: Apple Academic Press
1^{st} ed., September 2018
ISBN: 978-1-77188-680-2
440 pages, 273 images
Hardcover
Available also as an eBook



Publishing Networks in France in the Early Era of Print

The author of this book examining commercial and personal connections in the book trade in Paris and northwestern France in the later 15th and early 16th centuries draws on primary and archival sources, including those from in special collections, building on research into language and typographic developments in early modern Europe and the impact of the printed page on content and reception. First, five earliest Breton presses are surveyed in order to provide historical context, with the efforts allowing to improve the quality, which was initially low in comparison with professionally written manuscripts, and to tackle longer and more complex illustrated editions. The book demonstrates how the works of Breton poet Jean Meschinot were popularised by many publishers and studies the use, reuse, and adaptation of block illustrations, the role of booksellers in the marketing and distribution, the family and business ties of Bretons working in the Parisian book trade, as well as the buying habits of Breton book owners. It shows the connections of Paris, Caen, Angers, Rennes and Nantes through the trade in manuscripts and printed books, elucidating the role of trade networks in promoting and expanding cultural, religious and political knowledge.



Author: Diane E. Booton

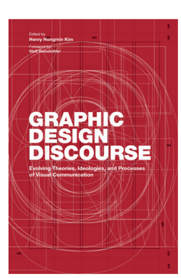
Publisher: Routledge
1st ed., April 2018
ISBN: 978-1-138-71253-9
252 pages, 41 images
Hardcover
Available also as an eBook

Graphic Design Discourse: Evolving Theories, Ideologies, and Processes of Visual Communication

This book intends to help practising designers, educators and students understand how to design in a singular, expressive way without forgoing clear and concise visual communication. To accomplish this goal, over 70 texts have been selected from more than 500 articles and books by philosophers, designers, architects, artists and critics and grouped into seven categories. The first one includes the manifestos of futurism and dada. The second group is split into a part with the works of René Descartes and Immanuel Kant and a part dealing with the Bauhaus and constructivism, among others. The third group discusses mainly typography, while the fourth postmodernism. The fifth group is again split into two parts, one on auteurs and authors and the other one on design ethics. The sixth group then deals with essential design and the seventh one with the structural process of design.

Editor: Henry Hongmin Kim

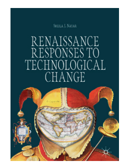
Publisher: Princeton Architectural Press
1st ed., December 2017
ISBN: 978-1-61689-639-3
480 pages, 18 images
Hardcover
Available also as an eBook



author analyses various aspects of the interaction between intellectual property rights and innovation activity, including the increasing significance of copyright and its effect on 3D printing on the one hand, and the risks of mass counterfeiting linked to the development of 3D printing on the other hand.

Renaissance Responses to Technological Change

Author: Sheila Nayar

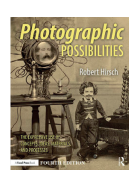


Publisher: Palgrave Macmillan
1st ed., October 2018
ISBN: 978-3319968988
366 pages, Hardcover
Also as an eBook

This study engages with the printing press, gunpowder, and the magnetic compass as the three transformative technologies for the early modern western European world, leading the revolutions in communication, warfare and navigation. In the first part, the author traces the culture of errata and analyses Rabelais's 'Gargantua and Pantagruel' and Cervantes's 'Don Quixote' through the typographic culture.

Photographic Possibilities: The Expressive Use of Equipment, Ideas, Materials, and Processes

Author: Robert Hirsch

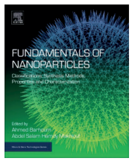


Publisher: Focal Press
4th ed., July 2017
ISBN: 978-1138213326
280 pages, 200 images
Hardcover
Also as an eBook

The new edition of this book, covering classic photographic processes and equipment together with a number of alternatives and special approaches, features the updated and revised technical data, as well as new sections on tri-colour gum prints from digital negatives, electrophotography and print-on-demand. The book presents the inspiring works by more than 150 contemporary artists.

Fundamentals of Nanoparticles: Classifications, Synthesis Methods, Properties and Characterization

Editors: Ahmed Barhoum, Abdel Salam Hamdy Makhlouf

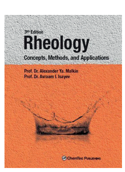


Publisher: Elsevier
1st ed., August 2018
ISBN: 978-0323512558
666 pages
Softcover
Also as an eBook

This comprehensive reference presents the topic in 20 chapters, contributed by more than 60 authors in total. One of the chapters is focused on engineered nanomaterials for the papermaking industry. It deals with nanocellulose, micro- and nanofillers for papermaking, electrospinning of paper-based nanofibres, organic nanoadditives for papermaking, processing of nanomaterials in papermaking, and nanofunctional paper. The use of 3D printing techniques is mentioned among the approaches to fabricate nanostructured polymer scaffolds for tissue engineering technology.

Rheology: Concepts, Methods, and Applications

Authors: Alexander Ya. Malkin, Avraam I. Isayev



Publisher: ChemTec Publishing
3rd ed., March 2017
ISBN: 978-1927885215
486 pages, Hardcover
Also as an eBook

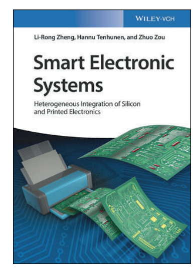
This book discusses viscoelasticity, the behaviour of liquids and solids, experimental characterisation methods and the applications of rheology, combining theoretical treatment with practical examples. The updates in the third edition include the new sections on the heterogeneity in flow, rheology of gels and highly concentrated emulsions and suspensions, the behaviour of nanocomposites and supramolecular solutions, deformation-induced anisotropy, and more.

Smart Electronic Systems: Heterogeneous Integration of Silicon and Printed Electronics

This book builds on recent research results, publications and theses in flexible and printed electronics for smart systems, and reflects the belief that the hybrid technology, integrating conventional silicon chips and printed large-area electronics, will be the most promising solution for future smart electronics systems. The first part, dedicated to materials and processes for printed electronics, introduces the topic, printing technologies and functional electronic inks, both conductive and semiconductive. The second part details the building blocks for printed electronics, namely the printed thin-film transistors and logic circuits, printed passive wireless sensors, printed RFID antennas and printed chipless RFID tags. Finally, the third part deals with the system integration for printed electronics, presenting the heterogeneous integration of silicon and printed electronics together with electrical performance and bendability of resulting heterogeneous interconnects, the plastic-based and paper-based humidity sensing systems for intelligent packaging and, as an example of a wearable healthcare device, three types of bio-patches. In addition, the last chapter discusses the life-cycle assessment for printed electronics.

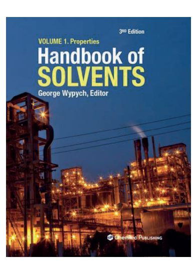
Authors: Li-Rong Zheng, Hannu Tenhunen, Zhuo Zou

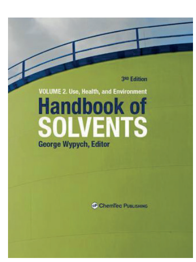
Publisher: Wiley-VCH
1st ed., January 2019
ISBN: 978-3-527-33895-5
296 pages
Hardcover
Available also as an eBook



Handbook of Solvents: Volume 1: Properties Volume 2: Use, Health, and Environment

The first volume of this exhaustive reference introduces fundamental principles and production of solvents and then elucidates individual aspects of their properties, which determine solvent selection in accordance with its intended use. It goes from simple characteristics and solubility parameters, over the swelling, solvent transport phenomena, mixed solvents and acid–base interactions, up to electronic and electrical effects, effects on chemical reactions and reactivity and other properties affected by solvents. The second volume presents solvent applications in various industries, including the printing and pulp and paper industries. It also discusses the methods of solvent analysis, residual solvents, environmental impact, toxicology and possible substitution of solvents, as well as new trends emerging in patents.





Editor: George Wypych

Publisher: ChemTec Publishing
3rd ed., March 2019
ISBN: 978-1-927885-38-3
& 978-1-927885-41-3
900 & 930 pages, 315 & 240 images
Hardcover
Available also as an eBook

Bookshelf

Academic dissertations

Cognitive Process Control to Improve the Resource Efficiency in the Printing Industry

Doctoral thesis – Summary

Author:
Martin Schmid

Speciality field:
Process Control

Supervisor:
Gunther Reinhart

Defended:
21 December 2017,
Technical University of Munich,
Department of Mechanical Engineering
Munich, Germany

Language:
German

Original title:
Kognitive Prozesssteuerung zur
Steigerung der Ressourceneffizienz
in der Druckindustrie

Contact:
schmid_martin82@web.de

The process control in printing is a complex issue due to a number of different influences and limitations in the measurement of output values. This thesis presents a control concept based on the analytic simulation model calculating the process output values and enabling a closed-loop control circuit. Because the ratio of the amount of ink on the paper and the optical density as the relevant quality criterion (the so-called ink efficiency) is an unknown parameter depending on various factors, a suitable adaptation mechanism was needed. It was achieved by a machine learning algorithm that fits the simulation model parameter according to the influences and machine condition.

The dissertation first describes the challenges for sustainable production, in particular in the printing industry, and provides the basics of offset lithography and colour control. Then it overviews the current state of knowledge in the areas of a colour density control, concepts for open-loop control, consideration of influencing factors, a model-based regulation, and printing process modelling, including the cognitive processes and known inking unit models. The following four chapters then in detail explain the concept for model-based control and the implementation of cognitive process control in the printing industry, present the subsequent validation of the proposed methodology on a web offset press and finally provide the technical and economic evaluation. The cognitive system utilises characteristic data records from past productions, which are preprocessed in order to clearly reflect the inking behaviour. The statistical analysis is used to take into account machine-related factors. The model parameters are estimated using a multilayer perceptron neural network. It was shown that the make-ready paper waste can be reduced by more than 40 % compared to the production controlled using the existing solutions, where the number of sheets with insufficient quality is higher.

The Comparative Effects of Print vs. Digital Technology on Comprehension of Functional Community Knowledge and On-Task Behavior for Students with Low Incidence Disability

Doctoral thesis – Summary

Author:
Colleen Erin Robertson

Speciality field:
Special Education

Supervisor:
Fred Spooner

Defended:
7 June 2018, University of North
Carolina at Charlotte
Charlotte, North Carolina, USA

Contact:
crobertson@coloradocollege.edu

This work provides the view on the interplay between print and digital technology seen from a specific perspective – in the context of education of students with low-incidence disabilities. The topic is not a matter of general importance, but the findings can be valuable for all involved in this particular area, helping educators to increase the quality of teaching and thus improve the post-school outcomes of students in question, significant for the quality of their life.

The study utilised the specially designed print and digital technology intervention package to teach functional community knowledge content and involved four high-school students with low-incidence disabilities and complex communication needs, two males and two females aged 17–19. Care was taken to ensure interobserver reliability and procedural fidelity. For all participants, the results indicated an improvement in comprehension. Based on the cumulative comparative data on the accuracy of answering three 'wh' comprehension questions (who, what, where), there was almost no difference between print and digital technology instruction across all four participants. The variation in scores across conditions indicated the viability of using both technologies for instructional purposes. In respect to digital technology, the author mentions numerous technological limitations and setbacks that occurred during the study. On the other hand, several benefits of digital technology instruction were identified, such as the ease of editing content based upon student need. When analysing the percentage of on-task behaviour, participants spent a greater percentage of time-on-task during print technology instructional sessions; opportunities to perform during digital instructional sessions were limited by the nature of the digital media and design of the intervention. According to the opinions of teaching staff, the students learned the best through print technology instruction; however, they were more motivated to participate in the digital technology instructional sessions. Both the teaching staff and participating students positively rated the use of the colour coding format.

Doctoral thesis – Summary

Supercapacitors on Flexible Substrates for Energy Autonomous Electronics

Author:
Jari Keskinen

Speciality field:
Electronics

Supervisor:
Donald Lupo

Defended:
*28 September 2018,
Tampere University of Technology,
Laboratory of Electronics and
Communications Engineering
Tampere, Finland*

Contact:
jari.keskinen@tuni.fi

The research presented in this thesis was aimed at the development of novel energy storage devices intended for wireless sensor networks and Internet of Things applications, among others. Such energy source should have a small size, a low price and often also a long lifetime. On the other hand, for applications of this kind, high power and low output resistance are not essential. These requirements can be met by printed supercapacitors. The manufacturing processes and materials were chosen to allow high-volume industrial production using either sheet-to-sheet or roll-to-roll printing processes and to utilise inexpensive and non-toxic components so that the supercapacitors could be easily recycled or incinerated with household waste.

The dissertation reviews the background, explaining the electrical energy storage in supercapacitors and their properties, along with materials used for their fabrication. Printing and other solution processing methods are also briefly mentioned. One chapter provides experimental details on the materials, layout and assembling process, and then describes the characterisation of electrical properties. In order to facilitate roll-to-roll printing and also to allow applications on curved surfaces, two types of flexible substrates were used – paperboard and polyethylene terephthalate foil. To improve their properties, the substrates were coated or laminated with other materials. As the current collector, the graphite ink was used, in some cases combined with the aluminium foil or silver ink. The electrodes were made of activated carbon with chitosan as a binder; in one case, also the printed polypyrrole electrodes were used. In most experiments, paper was used as the separator and aqueous sodium chloride as the electrolyte. The main part then presents and discusses the results in terms of the supercapacitor fabrication, functionality, lifetime, leakage current and self-discharge as influenced by the substrates, the properties of the current collector structure along with the achieved equivalent series resistance and corrosion issues, as well as the effects of electrode materials. Further, the advantages of a novel method for the fabrication of monolithic supercapacitors with electrical properties comparable to those of assembled supercapacitors are demonstrated. The achieved supercapacitor characteristics are summarised in the concluding chapter, proving the feasibility of the presented approach.

Events

NANOTEXNOLOGY 2019

Thessaloniki, Greece
29 June to 6 July 2019

Like each year, this large international event offers a rich programme in the field of nanotechnologies, organic electronics and nanomedicine, combining three conferences with the related exhibition, summer schools, business forum and matchmaking event. The plenary session features Mario Leclerc presenting 'Green chemistry for green energy', Sokrates Pantelides dealing with 'Novel nanomaterials' and Nicholas Peppas with 'Intelligent, recognitive, nanoscale systems for advanced therapeutic agent targeting and delivery'. The long list of contributions, which includes numerous keynotes and invited talks, covers a variety of interesting topics.

In 2019, there are seven new special workshops, namely the EU–USA workshop 'Sustainable nanofabrication & nanomanufacturing' and those focused on open innovation and standardisation for characterisation, modelling and manufacturing of materials, on in-line and real-time metrology and quality control for nano-manufacturing, on computational modelling of materials, devices and processes, on new business development and commercialisation, on women in nanoscience and technology, and on EU Projects.

FLEPS 2019

Glasgow, UK
7–10 July 2019

This year, the Institute of Electrical and Electronics Engineers organises for the first time the IEEE International Conference on Flexible and Printable Sensors and Systems (FLEPS 2019) as a forum to discuss and understand the advances in the flexible, printed and disposable sensor technology, enabled by the development of novel printable and solution processable nanomaterials as well as printing techniques and re-purposing the technologies developed for silicon-based planar electronics and solid-state sensors to meet the demands in this emerging field.

The announced keynotes include a review of the integration of oxides and fully printable organics for wearables and the Internet of Things by Arokia Nathan, discussing the critical design considerations and transistor operation in the different regimes, such as the deep sub-threshold regime or near-OFF state. Further, the keynote by Takao Someya deals with the recent progress and outlook of wearables using stretchable devices, in particular with the elastic electrode constructed of breathable nanoscale meshes used in a hypoallergenic electronic sensor as well as for in vitro characterisation. Finally, the keynote by Corne Rentrop discusses the available manufacturing techniques for hybrid printed electronics including the state-of-the-art printing steps and characterisation methods, with manufacturing examples of high-volume production prototypes at the Holst Centre pilot lines.

Printing for Functional Applications Summer School

Swansea, UK
9–11 July 2019

The established course introducing to printing electronics, sensors and functional materials is in 2019 organised by the Welsh Centre for Printing and Coating (WCPC) in association with icmPrint, the International Centre for Manufacture by Print. The sessions keep the proven format and are led by experts based at the Swansea University.

FuturePrint

São Paulo, Brazil
10–13 July 2019

After 28 successful years, Serigrafia SIGN FutureTEXTIL show has been transformed to this event, as another step to deliver more to its exhibitors and visitors while still tracking the evolution of printing and visual communication segments. The fair offers FuturePrint Forum lectures, presents silk-screen and sublimation solutions in action, and showcases the available options of textile digital printing and interior design in Future Têxtil and DecorPrint spaces.

CGDIP 2019
3rd International Conference on Computer Graphics and Digital Image Processing

Rome, Italy
25–27 July 2019

For its third edition, this conference covering computer graphics, images processing and computer vision, modelling and animation, visualisation, interaction and related foundations, including, e.g., perceptual aspects and hyperspectral imaging, returns to Europe.

SGIA Events

Over the course of the coming weeks, SGIA, the Specialty Graphic Imaging Association, organises in the USA a series of its Color Management Boot Camps, taking place in Illinois (Chicago, 9–11 July and 10–12 September), California (Irvine, 16–18 July, San Luis Obispo, 23–25 July, and Carson, 30 July to 1 August), Massachusetts (Wilmington, 10–12 September), and Colorado (Denver, 25–27 September). Further, graphic installers can register to the PDAA Master Certification Test (Kansas City, Missouri, 28–29 August).

In addition, anyone can join the free SGIA webinars. The current schedule includes these ones: Provide unique value to overcome price wars (2 July), Increase efficiency and profitability with production analytics (9 July), SGIA research report: measure your financial performance against your peers (16 July), Customization and personalization with UV for the retail market (23 July), Accelerate your sales pipeline (6 August), and Brands and PSPs: addressing expectations (13 August). The web archive with past webinars is also available.

XV Color Conference 2019

Macerata, Italy
5–7 September 2019

XV COLOR CONFERENCE
September 5th-7th 2019

This conference with the invited tutorial and scientific sessions in two parallel tracks – one in Italian and the other in English – is also a joint meeting with members of colour groups from Portugal, Great Britain, Spain, Sweden, Germany and Finland.

Unique 4+1

Leipzig, Germany
7–9 September 2019

This 'all-in-one' fair, launched in 2015, covers also printing technologies.

High-Performance Graphics 2019

High-Performance Graphics 2019
Strasbourg | July 8–10, 2019

Strasbourg, France
8–10 July 2019

After the previous two editions held in the USA and Canada, this conference for the research on performance-oriented graphics systems returns to Europe, again being partially co-located with the Eurographics Symposium on Rendering that is organised on 10–12 July also at the University of Strasbourg and this year celebrates its 30th anniversary. A new student scholarship program for funding travel and expenses to attend is introduced by the High-Performance Graphics conference together with Facebook Reality Labs. The 2019 keynote presenters include Steven Parker talking about NVIDIA RTX platform, Fabrice Neyret advising how to manage ultra-high complexity in real-time graphics, Luca Fascione reviewing modern movie rendering and changes made possible by ray tracing and, as the last one, Jaakko Lehtinen discussing a unique position of graphics research and arguing that tightly combining the power of modern machine-learning models with sophisticated graphics simulators in solving the longstanding problems of graphics research at the same time enables to make fundamental contributions to machine learning and artificial intelligence (this keynote is shared with the Eurographics Symposium on Rendering).

SIGGRAPH 2019

Los Angeles, California, USA
28 July to 1 August 2019

The 46th International Conference & Exhibition On Computer Graphics & Interactive Techniques offers a great variety of events to attend, including the oral and poster presentations of technical papers, as well as the expert talks and courses during all five days. There are also different examples showing the utilisation of 3D printing.

SPIE Optics & Photonics 2019

San Diego, California, USA
11–15 August 2019

The programme of this multidisciplinary optical sciences and technology meeting held in North America is structured into almost 70 conferences with about three thousand papers, complemented by the job fair, exhibition, numerous courses and special events. In connection to advances in print technologies and applications, it features the plenary talks on 'Technology progress on ink-jet printed display' by Lei Qian and 'From polymer fibrils and transport pathways to stretchable optoelectronic devices' by Elsa Reichmanis, as well as the invited papers dealing with the different printed high-performance thin-film transistors, direct printing of plasmonic micropatterns of gold and silver nanoparticles using precision photoreduction, and process, device design and bio-friendliness of printed organic photodetectors and light-emitting devices, among others.

Further, there are two sessions on printed sensors and integrated devices as a part of the Organic and hybrid sensors and bioelectronics conference, and various contributions across the other sessions. These include the thermoreflectance study of the thermal properties of printable metal nanoparticle ink influenced by sintering conditions, investigation of optimum viscosity and surface tension range for the stable inkjet printing of pixel patterns for quantum dot light-emitting diode, efficient interface engineering for high-performance fully printed thin-film transistors, a number of papers on 3D-printed components, and much more.

IC-MAST 2019
8th European Forum for Materials and Applications for Sensors and Transducers

Bratislava, Slovakia
2–5 September 2019

Under a slightly changed name, the eighth edition of this event previously known as the International Conference on Materials and Applications for Sensors and Transducers continues to follow the progress in actuators, applications, computational methods, fabrication technology, various kinds of materials and sensors, as well as materials simulation and sensor systems and applications. Among the already announced contributions, one presents the use of flexography for efficient production of nanobiosensors.

46th International iarigai Conference
Advances in Printing and Media Technology

Stuttgart, Germany
15–18 September 2019

This year, the annual iarigai research conference is hosted by the Hochschule der Medien of the University of Applied Science, the affiliation of the current President of iarigai. The claim for 2019 says ‘Print is Everywhere’, expressing the special attention paid to topics where printing technologies are used in innovative ways and the user often does not recognise that the product is printed. The announced keynote speakers are Sonja Mechling with a talk on ‘Digital transformation in the print media industry – how to drive the change?’ and Peter Sommer discussing ‘How to make money with digital print?’, as well as Joerg Hunsche and Robert Lindner, whose topics are yet to be specified. The sessions with scientific contributions then mostly run in two parallel tracks. On the last day, the industrial visits are offered.

Droplets 2019

Durham, UK
16–18 September 2019

The academic programme of the 4th International Conference on Droplets covers the topics ranging from the impact of liquid drops, wetting, coalescence and break-up, over aerosols, liquid crystals and complex fluids, modelling across time and length scales, emulsions and multiphase flow, evaporation, microfluidics and acoustofluidics, up to the textured, patterned and smart surfaces and inkjet printing – with invited keynote and contributed talks running in three parallel sessions, framed by plenary talks and complemented by two poster sessions.

WAN-IFRA Events

This summer, two educational events are offered in India: on native advertising and digital strategies in New Delhi (22–23 July) and then on newspaper design and redesign in Bangalore (19–20 August). News publishers can acquire digital marketing skills at the summit organised in Kuala Lumpur, Malaysia (7–8 August). The 2019 editions of two regular events follow. Digital Media Africa launched three years ago is held in Johannesburg, South Africa (11–12 September), with the awards ceremony on the first day. A week later, the 27th WAN-IFRA India conference takes place in Delhi (18–19 September). Finally, the eRev publishers network meeting is scheduled for 24–26 September in Copenhagen, Denmark.

ERA Events

The European Rotogravure Association holds its 2019 Annual Conference in Munich, Germany (16–17 September), with authorisation process for chromium trioxide and technological developments of the gravure process in focus. The ERA Basic Gravure Seminar organised in Germany at the Stuttgart Media University (25–27 September) is a hands-on introductory course that provides a practical overview of the whole gravure process (in English).

OLEDs World Summit

San Jose, California, USA
24–26 September 2019

The participants of this event dedicated solely to organic light-emitting diodes can this year learn about ‘The latest breakthrough of printing OLED technology for next generation premium TV’ on the first day and about ‘Super soluble noncrystallizable small molecules for vacuum deposited and printed OLEDs’ on the second one, among others.

FESPA Events

In the second half of summer, this year's FESPA Mexico exhibition takes place in Mexico City (22–24 August), featuring free seminars and textile workshops, the Printeriors showcase of digitally printed applications in interior decoration, and also the local vinyl car wrapping competition. Three weeks later, FESPA Africa 2019 is held in Johannesburg, South Africa (11–13 September), co-located with Sign Africa, Africa Print, Africa LED and the Modern Marketing events. The participants can attend several workshops and enter the Johannesburg Speed Wrap challenge.

FachPack 2019

Nuremberg, Germany
24–26 September 2019

The key theme of this packaging fair for 2019 is the environmentally friendly packaging – the recycled packaging, resource-conserving materials, reusable packaging and systems, and (new) environmentally friendly processes. This theme reflects in the booths of many exhibitors, within both presentation forums during all three days, at the special show 'Environmentally friendly premium packaging' and in the awards, like the German Packaging Award sustainability category.

Labelexpo Europe 2019

Brussels, Belgium
24–27 September 2019

In 2019, this show for label and package printing technologies returns to Europe and celebrates its 40th anniversary, offering label academy master classes in flexible packaging, inks and digital printing technology, among others.

1st International Circular Packaging Conference

Ljubljana, Slovenia
26–27 September 2019

This new conference is organised by the Pulp and Paper Institute in cooperation with the Faculty of Polymer Technology based in Slovenj Gradec and the Chamber of Commerce and Industry of Štajerska region. The aim of the conference is defined as to connect different stakeholders from academia, industry, design studios, brand owners and all involved in the packaging life cycle from idea to end of life stage. Sharing knowledge, good practices and ideas and making new connections is expected to assist in the transformation from linear to circular packaging supply chain with a holistic approach. The programme has not been announced yet, as the call for papers is still open. The topics range from the circular economy over innovative bio-based materials, optimised packaging design and supply chain, packaging printing and converting, packaging waste recycling, reusing and composting, up to consumer behaviour on the way to circular packaging and life-cycle analysis of the packaging.

Printing for Fabrication 2019
Materials, Applications, and Processes – the 35th International Conference on Digital Printing Technologies (NIP)

San Francisco, California, USA
29 September – 2 October 2019

Traditionally, this event starts with the short-course programme, in 2019 consisting of 15 two-hour classes at various levels. The new ones in the list deal with the software optimisation of print quality in industrial inkjet, fundamental transport phenomena of complex fluids and soft solids, drying and sintering effects, machine learning algorithms and applications in printing, and colour and appearance in 3D printing (this is the only one scheduled for the second day).

The technical part opens the keynote 'Conquering the challenges of new inkjet markets with MEMS printhead technology' by Martin Schoeppler, outlining some of the key areas. The second keynote scheduled for the afternoon is 'Printed textiles on demand: technology challenges meet creative opportunity' by Kerry Maquire King, addressing also customer expectations, the importance of product visualisation, colour management considerations and briefly the evaluation methods for printed textiles. On the third day, the keynote of Tsuyoshi Sekitani entitled 'Application of printed, stretchable electronics for monitoring brain activities' presents a successful development of a system combining a flexible, biocompatible and highly conductive electrode, a flexible thin-film amplifier to amplify very weak biosignals, a platform with a wireless communication function, and a signal processing technique for real-time visualisation of signals. The last keynote 'Fabricating beauty: the art and science of graphical 3D printing' by Philipp Urban surveys available technologies, covers challenges and solutions of the digital workflow and shows application areas. The sessions cover fundamental science and technology of inkjet, textile and nonwovens printing, 3D printing, materials and their interactions, printing biological materials, printed functionalities, printed electronics, security printing, healthcare applications, digital packaging, and also legal issues, standards and standardisation.

Journal of
Print and Media Technology
A PEER-REVIEWED QUARTERLY Research

ISSN 2414-6250 (Online)
ISSN 2223-8905 (Print)
CODEN JPMTBI
UDC 665

Call for papers

The Journal of Print and Media Technology Research is a peer-reviewed periodical, published quarterly by iarigai, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries.

JPMTR is listed in Emerging Sources Citation Index, Scopus, Index Copernicus International, PiraBase (by Smithers Pira), Paperbase (by Innventia and Centre Technique du Papier), NSD – Norwegian Register for Scientific Journals, Series and Publishers.

Authors are invited to prepare and submit complete, previously unpublished and original works, which are not under review in any other journals and/or conferences.

The journal will consider for publication papers on fundamental and applied aspects of at least, but not limited to, the following topics:

- **Printing technology and related processes**
  Conventional and special printing; Packaging; Fuel cells, batteries, sensors and other printed functionality; Printing on biomaterials; Textile and fabric printing; Printed decorations; 3D printing; Material science; Process control

- **Premedia technology and processes**
  Colour reproduction and colour management; Image and reproduction quality; Image carriers (physical and virtual); Workflow and management

- **Emerging media and future trends**
  Media industry developments; Developing media communications value systems; Online and mobile media development; Cross-media publishing

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  Environmental issues and sustainability; Consumer perception and media use; Social trends and their impact on media

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Journal of
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Vol. 8, 2019

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Scientific content

Introduction and background: Explain why it was necessary to carry out the research and the specific research question(s) you will answer. Start from more general issues and gradually focus on your research question(s). Describe relevant earlier research in the area and how your work is related to this.

Methods: Describe in detail how the research was carried out (e.g. study area, data collection, criteria, origin of analyzed material, sample size, number of measurements, equipment, data analysis, statistical methods and software used). All factors that could have affected the results need to be considered. Make sure that you comply with the ethical standards, with respect to the environmental protection, other authors and their published works, etc.

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Discussion: Answer your research questions (stated at the end of the introduction) and compare your new results with published data, as objectively as possible. Discuss their limitations and highlight your main findings. At the end of Discussion or in a separate section, emphasize your major conclusions, pointing out scientific contribution and the practical significance of your study.

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2-2019

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- Printing technology and related processes
- Premedia technology and processes
- Emerging media and future trends
- Social impacts

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