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To meet the need for a high quality scientific publishing platform in its field, the International Association of Research Organizations for the Information, Media and Graphic Arts Industries is publishing a quarterly peer-reviewed research journal.

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A letter from the Editor

Gorazd Golob
Editor-in-Chief
E-mail: gorazd.golob@jpmtr.org
journal@iarigai.org

Three papers in this issue were accepted for publication during the very last days of December 2017. The first one is a study and theoretical explanation of the unwanted effect of bulging-out shoulders in screen printing, often used printing technique in research and production of printed electronics and in industrial printing, where the dimensions and predictable thickness of the layer of functional ink is a necessary condition for a success of printing.

The second paper is an overview of the developments and use of alternative halftoning techniques adopted for improved sharpness and definition of a monochrome or colour printed reproduction of the originals with sharp edges and fine details. This review paper is mainly based on author's own research, publications and patents in the last decades, with a comparison and description of his findings as an alternative to established halftoning techniques from other authors and industrial vendors.

The research of possibilities for the use of RFID tags on relatively inexpensive dairy products is discussed in the third paper. Price and cost limitations on the consumer side were confirmed and consequently, the predictions regarding the wide use of RFID tags and other printed functionality on consumer packaging should be reconsidered in the future.

In the current Topicalities section, prepared by Associate Editor Markéta Držková (marketa.drzkova@jpmtr.org), an overview of the publications from CIE, Ghent Workgroup, and Fogra is introduced. The interesting topics from these reports are dealing with multispectral imaging, testing of LED lights, advances in PDF 2.0 workflow in print production and research report on abrasion test results. The short reviews of the newly published books cover 3D/4D printing, Internet of Things issues, advanced use of inkjet for printing with chemically reactive inks, and books on new materials for functional printing, on design and on a role of colour in modern life. Also, the new book on halftoning strategies is bringing additional information on the topic, presented in the scientific section.

Three interesting theses are introduced in the Topicalities Bookshelf. The thesis on a design of a newspaper defended at the University of Reading by Jasso J.J. Lamberg is bringing an overview of the concepts, processes, trends and the role of the designer in newspaper design and production. Carina Bronnbauer defended her thesis on printed dielectric mirrors at the University Erlangen-Nürnberg. The aim of her work was to develop an alternative production process for dielectric mirror stack usually prepared using vapour deposition processing and eventually employ it as a part of printed organic electronics devices. The third presented thesis was defended by Diogo José Horst at the Federal University of Technology

Paraná, Brasil. The aim of this thesis was a study of the properties and usability of vegetable resins in additive manufacturing, which was recognized as a challenge due to the use of natural bio-material, exposed to bacteria and pathogenic microorganisms, in 3D fused deposition modelling process.

A number of global events are presented in the final chapter of Topicalities, dedicated to different topics from computer vision, imaging, colour science and colour management to printed electronics, 3D printing, new materials, and publishing.

This short overview of the activities in our research field(s) is promising and encouraging. We are not limited only to traditional print and media technology research. Printing processes are nowadays used in many emerging technologies, not only in printed electronics and additive manufacturing. The use of printing technology in different ways and for different purposes, other than for printing books, periodicals or packaging, is calling for new design approach and for the use of new materials, methods, production technologies, as well as the use of final products and services. Thus, the scientific and research field of print and media technology is really wide, interdisciplinary and oriented to the future.

On the other side, the demand for qualified publishing channels in the scientific community, recognized in Web of Science, Scopus, and some other worldwide known indexing and abstracting systems, is constantly growing. The advantage of the Journal, indexed in ESCI and accepted by Scopus in comparison to any local Journal is evident. The call for quality papers for publication in the Journal is constantly open and we can expect publication of interesting research results in the future issues of the Journal of Print and Media Technology Research.

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Considerations on bulged-out print shoulders due to mesh depression and high 'emulsion over mesh' in screen printing

Gunter Hübner

Institut für Innovative Anwendungen der Drucktechnologien (IAD),
Hochschule der Medien,
Nobelstr. 10, 70569 Stuttgart, Germany

huebner@hdm-stuttgart.de

Abstract

In screen printing sometimes at the edges of an ink deposit that is wider than a few millimetres a phenomenon occurs, which can be described as an elevated edge or better as bulging-out shoulders. This can be a print quality issue if subsequent overprints need to be carried out. The shoulder bulge-out effect typically occurs if the stencil build-up is not well adapted to the targeted type of print pattern (e.g. fine lines vs. large solid tone areas). The effect is described in screen printing textbooks and some scientific articles but not yet tackled theoretically. As an approach, here a simple model, assuming a quasi-infinite line as the pattern to be printed is used. The model combines the elongation of the mesh caused by the mesh tension and the additional stress applied by the squeegee with material properties and calculates the depression of the mesh towards the substrate during the squeegee movement between the two edges of the stencil opening. The developed relationship ends up in an equation that is solved numerically by means of a look-up-table (LUT) approach. Graphs are derived that show the dependencies on print line width, stencil build-up, stresses applied and materials used.

Keywords: print quality, squeegee pressure, mesh elongation, ink deposition

1. Introduction

During recent years, screen printing is experiencing a kind of renaissance. It is increasingly regarded as a reliable, high-level quality prolific process. The focus is on medium to high volume functional and industrial printing. In industrial printing, the accuracy of the geometrical properties of the prints such as edge definition and surface smoothness is much more important, rather than colour matching as in graphic applications. One effect known in screen printing that will be investigated theoretically in this paper is the case where the bulging-out shoulders occur if the stencil build-up is not well adapted to the targeted feature sizes of the print (e.g. fine lines vs. large solid tone areas). The effect is described in handbooks (SEFAR, 2008), online guidebooks (Hobby, 1997) or scientific articles (Riemer, 1989). The stencil build-up, which is commonly called emulsion over mesh (EOM), can be one of the reasons for the shoulder bulge especially if the EOM is too high. Even though the stencil can be prepared in many different ways, the typical way is coating a liquid photosensitive emulsion onto the mesh or applying a so-called capillary film to the mesh. Both have advantages and disadvantages but with a capillary film, the control on the EOM is easier. Typically, experienced printers know which EOM-values achieve good printing results but theoretical background is missing. Figure 1 shows the situation (not drawn to scale) when the squeegee presses the printing form down onto the substrate. Here, the EOM is quite high and in the vicinity of the stencil-edge, the squeegee is not able to press down the mesh to touch the substrate, at all. Somewhere towards the centre of the print area, however, the squeegee pressure brings the mesh and the substrate into contact. Thus, at the edges, a higher amount of ink is squeezed through the mesh and deposited there in comparison to the centre of the printed area where the threads of the mesh touch the substrate. One of the targeted questions here is how the width of the printed line affects the bulge-out effect. Experienced printers estimate that if the width is about 2 mm or higher the likelihood of shoulder bulging-out significantly increases. This is confirmed by Riemer in his dissertation (Riemer, 1988) but not analysed further. Important to mention is that the snap-off distance does not play a role in this investigation as it is assumed that the squeegee pressure is high enough to press both of the stencil edges tightly down to the substrate.

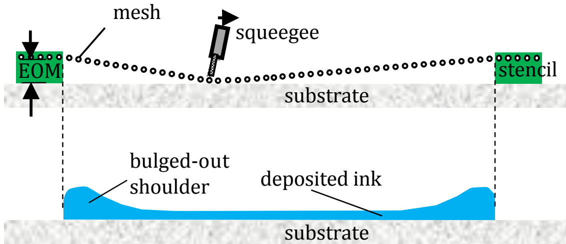

Figure 1: Shoulders bulge-out can occur at the edges of a printing area due to a very high EOM

In a former investigation at the same research institute (Willfahrt, Stephens and Hübner, 2011), the bulge-out effect could be proven quantitatively. According to Figure 2, a pronounced bulging effect can be seen for the 3-mm line (conductive track), whereas the smaller lines have a single peak, only. However, the maximum heights of the smaller lines are significantly larger than that of the 3-mm line.

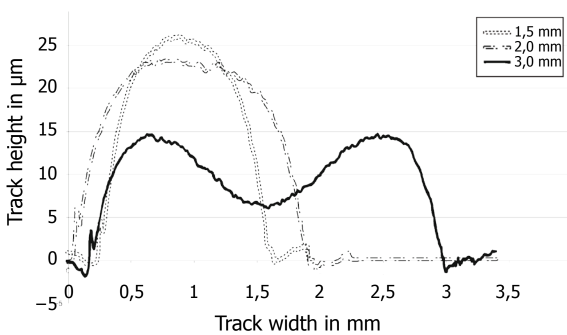

Figure 2: Cross section profile of three printed lines (conductive tracks), from Willfahrt, Stephens and Hübner (2011)

2. Research methods

2.1 Assumptions

During the printing process, the squeegee moves from left to right applying a certain vertical force, the squeegee pressure. The physical and geometrical properties will be idealised (e.g. the squeegee touches the mesh in a single infinitely small contact point) and it is assumed that a line with an infinite length (in squeegee-width direction) is printed. The dimensions in squeegee-width direction are much greater than the width of the printed line. This corresponds well to functional screen printing where mostly lines with conductive inks are printed. The length is up to 100 times the width of the line. The line widths typically are far below 5 mm.

If the printed line stretches in the squeegee movement direction, then it is supported by a high EOM all the time and the squeegee cannot “dive” too much towards the substrate. The investigation here therefore focuses on lines perpendicular to the squeegee movement. If larger solid tone areas are printed, the bulging can occur in both directions depending on the stiffness of the squeegee.

The mesh is regarded as flexible respectively limp. In this first approach, additional horizontal forces that may be caused by friction are neglected. It is obvious that the presence of ink lubricates the contact point.

2.2 Goal of the research

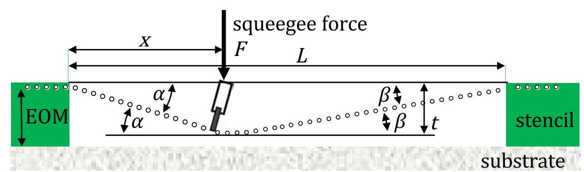

Figure 3: Geometrical dimensions and nomenclature of the problem

Introducing the geometrical properties according to Figure 3, the aim of the study is to find the following dependencies:

$$\alpha = f(F, x, L \text{ and mesh properties}) \quad [1]$$

and

$$t = f(F, x, L \text{ and mesh properties}) \quad [2]$$

Where F is the downward force exerted by the squeegee pressure, x the squeegee position, α and β the angles at the stencil edges and L the width of the printed feature. The depression of the mesh is called t.

The relevant mesh properties are the Young’s modulus E in Pa and the specific cross section A_q in mm^2/cm.

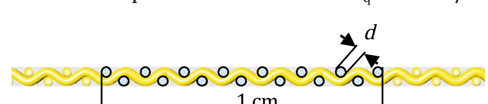

Figure 4: Specific cross section of a screen printing mesh

The specific cross section A_q (aka. SCS) according to Figure 4 is the cumulated area cross section of the threads in between 1 cm and represents a kind of strength parameter of the mesh. The higher the number, the more tension can be applied to the mesh.

$$A_q = n\frac{\pi d^2}{4} \quad [3]$$

with n = mesh fineness in threads per cm and d = thread diameter. The value of A_q typically is given in mm^2/cm.

2.3 Acting forces

The set-up can be regarded as a two dimensional problem in an x-z-plane. In y-direction, the printed feature is assumed to be infinite. The squeegee force F causes forces in the mesh called F_A on the left-hand side and F_B on the right-hand side. Thus, according to Figures 5 and 6, an equilibrium of forces can be found, represented by Equations [4] and [5].

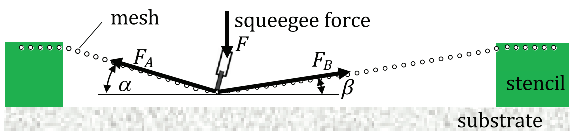

Figure 5: Acting forces

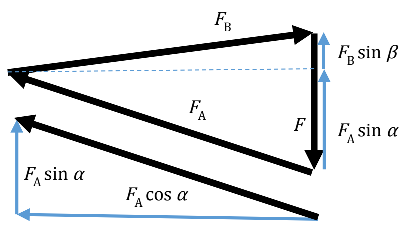

Figure 6: Equilibrium of forces

If the EOM is high enough, the mesh does not touch the substrate. Then the equilibrium of forces in vertical direction yields:

$$F = F_A \sin\alpha + F_B \sin\beta \qquad [4]$$

In addition, with neglected horizontal forces that may be caused by friction:

$$F_A \cos\alpha = F_B \cos\beta \qquad [5]$$

Thus, by combining [4] and [5]

$$F_A = \frac{F}{(\sin\alpha + \cos\alpha \tan\beta)} \qquad [6]$$

2.4 Elongation of the mesh

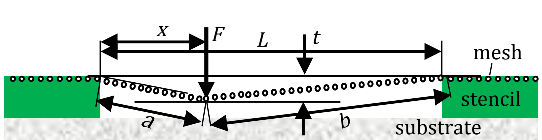

Figure 7: Elongation of the mesh

Due to the forces in the mesh caused by the squeegee force, according to Figure 7 an elongation of the mesh occurs: $a + b > L$. In dimensionless representation the elongation ε caused by the acting squeegee force is

$$\varepsilon = \frac{a + b - L}{L} \qquad [7]$$

Since the forces on the left- and right-hand side from the squeegee position are different, the elongation along the length L comprises of two parts:

$$\varepsilon_A = \frac{a - x}{x} \quad \text{and} \quad \varepsilon_B = \frac{b - (L - x)}{L - x}$$

thus

$$\varepsilon = \frac{\varepsilon_A x + \varepsilon_B (L - x)}{L} \qquad [8]$$

Some geometric considerations help to find relations between the depression of the mesh t and the angles α and β as well as a, b and x. The depression of the mesh t is (depending on the position x of the squeegee):

$$t = x \tan\alpha = (L - x) \tan\beta \quad \text{or} \quad \frac{\tan\alpha}{\tan\beta} = \frac{L - x}{x} \qquad [9]$$

The elongated lengths of the mesh then are $a = x/\cos\alpha$ and $b = (L - x)/\cos\beta$ such that finally:

$$\varepsilon_A = \frac{1}{\cos\alpha} - 1 \quad \text{and} \quad \varepsilon_B = \frac{1}{\cos\beta} - 1 \qquad [10]$$

2.5 Stresses

As long as we are in pure elastic behavior, there is the well-known relation between the stress (tension) and the elongation:

$$\sigma = E \cdot \varepsilon \qquad [11]$$

where E is the Young's Modulus of Elasticity, e.g. in N/mm^2. Thus, the mechanical stress σ = Force/Area in N/mm^2.

In screen printing, however, the mesh tension usually is given as force per unit length, i.e. in N/cm. Thus, let us call the stress per unit length Q in N/cm. According to Figure 8 the indices A and B mean the left- and right-hand side from the squeegee position.

Normally, not only the tension in the mesh due to stretching but also the squeegee line pressure is given in N/cm. Using the specific cross section A_q of a mesh in mm^2/cm (area per unit length), the stress can be written as:

$$\sigma = \frac{Q}{A_q} \quad \text{in} \quad \frac{N/cm}{mm^2/cm} \qquad [12]$$

Thus, left from squeegee position:

$$\varepsilon_A = \frac{\sigma_A}{E} = \frac{Q_A/A_q}{E} \qquad [13a]$$

and right from squeegee:

$$\varepsilon_B = \frac{\sigma_B}{E} = \frac{Q_B/A_q}{E} \qquad [13b]$$

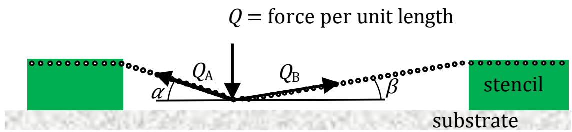

Figure 8: Forces per unit length

Now Equations [10], [13] and [6] can be combined (e.g. for left-hand side):

$$\frac{Q_A/A_q}{E} = \varepsilon_A = \frac{1}{\cos\alpha} - 1 \qquad [14]$$

and with

$$Q_A = \frac{Q}{(\sin\alpha + \cos\alpha \cdot \tan\beta)} \qquad [15]$$

thus yielding

$$\frac{Q}{A_q E} = \left(\frac{1}{\cos\alpha} - 1\right)(\sin\alpha + \cos\alpha \cdot \tan\beta) \qquad [16]$$

2.6 Non-dimensional representation

It is now helpful to introduce the relative position ξ of the squeegee:

$$\xi = \frac{x}{L}\ ;\ \text{with } 0 < \xi < 1 \qquad [17]$$

The final step is replacing $\tan\beta$ by a function of ξ and α. See Figure 7 for the geometric relations:

$$\frac{\tan\alpha}{\tan\beta} = \frac{1-\xi}{\xi} \quad \text{or} \quad \tan\beta = \frac{\xi}{1-\xi}\tan\alpha \qquad [18]$$

At last, the final formula can be derived by entering [15] into [13] and after some rearranging:

$$\frac{Q}{A_q E} = \frac{\tan\alpha - \sin\alpha}{1-\xi} \qquad [19]$$

2.7 Numerical approach – solving with a look-up table (LUT)

It is – at least to the knowledge of the author – impossible to solve the right hand side of the Equation [19] for α, which would be the aim of the calculations. The left-hand side, however, contains all well-known parameters that are preset and remain constant.

The squeegee pressure Q is ranging somewhere from 0.5 to 10 N/cm. For the Young's modulus values are e.g. E_{PET} = 4 500 N/mm^2 = 4.5 GPa and $E_{stainless}$ = 180 GPa. The specific cross section A_q is equal mesh count times single thread cross section, e.g. A_q = 0.058 mm^2/cm for a 380–14 mesh and A_q = 0.185 mm^2/cm for a 48–70 mesh. Since these three parameters are given machine settings or material properties, they can be regarded as constants. Therefore, a single, dimensionless constant K is introduced:

$$K = \frac{Q}{A_q E} \qquad [20]$$

On the contrary, the right-hand side of Equation [19] is a function of α and ξ only, so it can be written:

$$(\alpha, \xi) = \frac{\tan\alpha - \sin\alpha}{1-\xi} = K \qquad [21]$$

This function of α can be analysed using numerical methods. Thus, in an Excel-worksheet a table has been created for the function where in appropriate fine steps the values for α and ξ vary in ranges of $0 < \alpha < 90°$ and $0 < \xi < 1$, respectively.

This table can be used as a look-up table (LUT), in which for a given K and ξ the value for α is picked out easily. Interpolation techniques are used if the appropriate α-values cannot be read-out directly.

In Figure 9, the way to look up for α is shown. The value for $K = (Q/A_q E)$ is searched on the y-axis and on the x-axis the angle α can be looked up according to the relative position ξ in the set of curves in the plot.

As mentioned above, the actual value of K can vary in a quite large range. Besides the material (stainless steel or PET), the main influence comes from the mesh geometry.

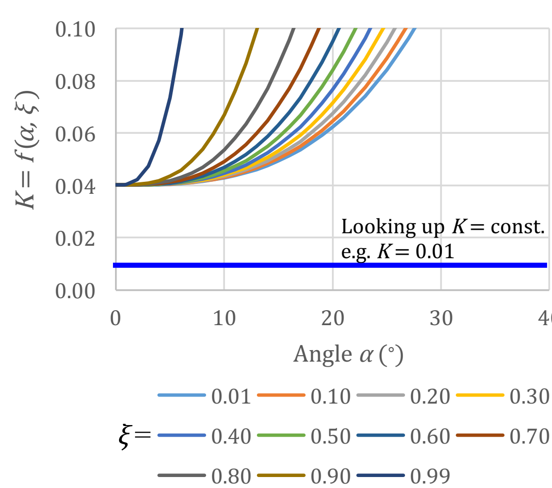

Figure 9: Set of curves for $K = f(\alpha, \xi)$

Table 1 shows some values for A_q (earlier in 2.7). The figures in the table are calculated from specifications found for PET-meshes from vendor SEFAR. Especially comparing the PET-meshes with the same n (e.g. 120 threads per cm) but with different thread diameters is interesting, since this lets one vary the A_q value by at least of a factor of 1.6.

Table 1: Specific cross section of the mesh regarding the fineness and diameter of the thread

Mesh *n–d*	A_q (mm²/cm)
48–70	0.185
110–34	0.099
110–40	0.138
120–31	0.091
120–34	0.109
120–40	0.151
150–27	0.086
150–34	0.136

2.8 First conclusions

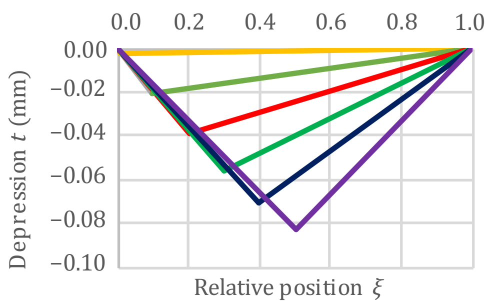

Figure 10: Depression t as function of ξ for different squeegee positions (setting: K = 0.044)

Using the appropriate values for K, Equation [21] can be evaluated using the LUT-method. Instead of having a single result for the depression e.g. as drawn in a kind of snapshot in Figure 3, Figure 10 shows a plot of subsequent snapshots during the squeegee movement from left to right.

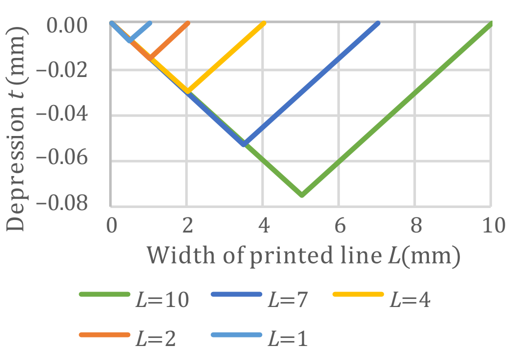

Figure 11: Dependence of t on line width L (mm) for ξ = 0.5

In the case of Figure 11 the influence of the width L of the printed feature is shown.

A typical value of the EOM is around 10 µm. In the case of Figure 11 at L > 1.6 mm the depression is large enough so that the mesh will touch the substrate. This theoretical finding corresponds with the observations described in the handbooks (SEFAR, 2008).

2.9 Influence of the mesh tension

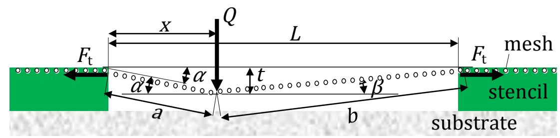

Figure 12: Forces overlaid by the tensioning of the mesh

For a good screen printing operation, the mesh must have an appropriate tension, typically applied in a mesh-stretching device. Thus, the length L is already a stretched length. The stress applied by the squeegee pressure described in the previous chapter is on top of that. If the mesh has an appropriate tension, represented in the drawing in Figure 12 by F_t (index t stands for tensioning), the elongation ε or the depression t is much less than without.

Thus, introducing the mesh tension per unit length $Q_t = F_t/L$ in N/cm and the stress $\sigma_t = Q_t/A_q$ it can be written – particularly for the left part (left from ξ):

$$\varepsilon_A = \frac{1}{\cos\alpha} - 1 = \frac{Q_A/A_q}{E} - \frac{Q_t/A_q}{E} \qquad [22]$$

and again, after some rearranging:

$$\frac{Q}{A_q E} = \frac{\tan\alpha - (Q_t/A_q)\sin\alpha}{1-\xi} \qquad [23]$$

Since the term $(Q_t/A_q)/E$ represents the elongation caused by the mesh tensioning it could be abbreviated with $\varepsilon_t = (Q_t/A_q)/E$

and finally:

$$K = \frac{Q}{A_q E} = \frac{\tan\alpha - (1-\varepsilon_t)\sin\alpha}{1-\xi} \qquad [24]$$

Using Equation [24], the given and constant value of ε_t can be introduced into the look-up table and with the procedure according to Figure 9, the angle α can be read out.

3. Results

The following result plots depict the depression t as a function of ξ where the lowermost points of the squeegee depression are interconnected in one single curve representing the lowermost point of the squeegee tip while passing over the distance L. Since the look-up still bears some impreciseness, interpolation methods had to be used. According to the geometric properties shown in Figure 12, the depression t is calculated with the modified Heron/Pythagoras relation according to

Equation [27] known from basic triangle calculations that can be found in formularies (e.g. Wikipedia, 2017). The needed distance a was calculated from the left-hand side of the squeegee position with

$$a = \frac{\xi L}{\cos \alpha} \qquad [25]$$

and the distance b from the right-hand side position respectively.

$$b = \frac{(1-\xi)L}{\cos \beta} \qquad [26]$$

$$t = \frac{1}{2L}\sqrt{2(a^2b^2 + a^2L^2 + b^2L^2) - (a^4 + b^4 + L^4)} \qquad [27]$$

The depression t is determined for 11 discrete values of ξ in steps of 0.1. The resulting curves are symmetric and reach a maximum in the middle position.

3.1 Varying the line width *L*

The most important parameter for this investigation is the width of the printed line (with infinite length).

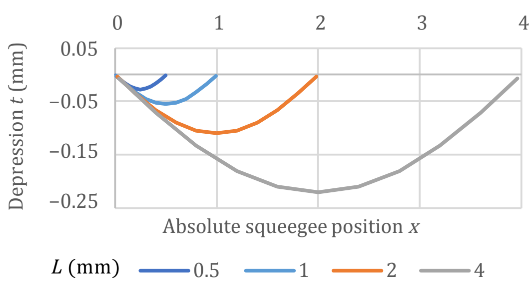

Figure 13: Depression t as a function of the squeegee position x for different line widths L; with settings: PET, squeegee pressure Q = 5 N/cm, mesh tension Q_t = 20 N/cm

Figures 13 and 14 show in different representations that the depression is strongly dependent on the length L of the printed feature. It is very likely that with typical values of the EOM, the mesh starts touching the substrate if the printed feature is wider than 1 mm.

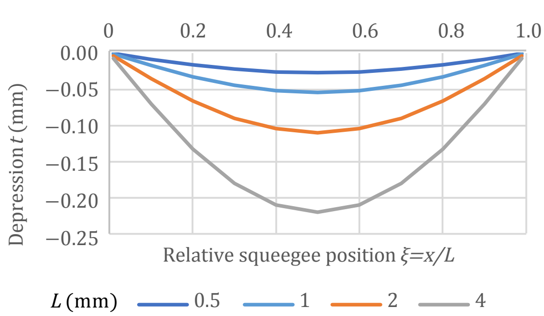

Figure 14: Depression t as a function of the relative squeegee position ξ for different line widths L; with settings: PET, squeegee pressure Q = 5 N/cm, mesh tension Q_t = 20 N/cm

3.2 Varying the mesh tension

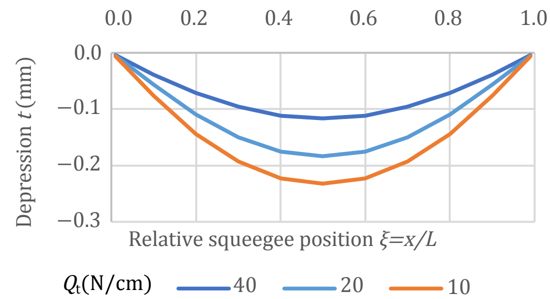

Figure 15: Depression t as a function of the relative squeegee position ξ, by varying the mesh tension with settings: PET, L = 2 mm, squeegee pressure Q = 10 N/cm

In Figure 15 the result plot is shown when varying the mesh tension Q_t. It is obvious that with higher mesh tension the depression decreases. Thus, in practical observations the bulging-out effect can be minimised if screens with high mesh tension are used.

Another way of avoiding the bulging-out effect is using stainless steel instead of PET. Figure 16 depicts the result with exactly the same settings as in Figure 15 except using stainless steel mesh instead of PET.

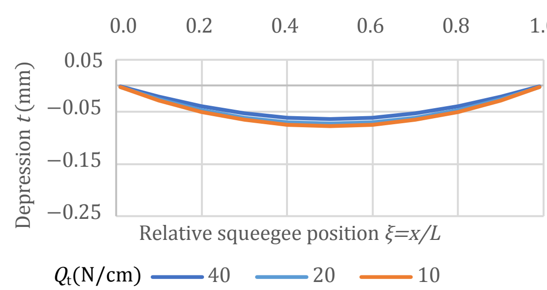

Figure 16: Depression t as a function of the relative squeegee position ξ; with the same parameter settings, as in Figure 15 except stainless steel instead of PET

3.3 Varying the squeegee pressure

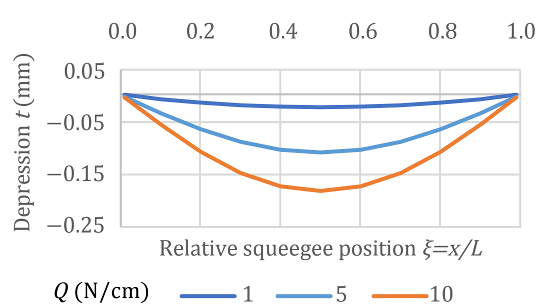

Figure 17: Depression t as a function of the relative squeegee position ξ, by varying the squeegee pressure Q; with settings: PET, L = 2 mm, mesh tension Q_t = 20 N/cm

The graphs in Figures 17 and 18 show the influence of the squeegee pressure Q on the depression t, again the first plot for PET, the latter for stainless steel (same scale of the y axis). Since the effect of Q and Q_t superimpose each other, the plots look very similar.

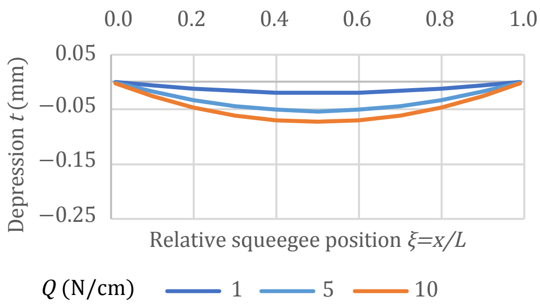

Figure 18: Depression t as a function of the relative squeegee position ξ, by varying the squeegee pressure Q (1, 5 or 10 N/cm); with same parameter settings, as in Figure 17 except stainless steel instead of PET

4. Conclusions

It could be shown that with some simple assumptions the depression that a screen printing mesh is undergoing during the squeegee movement over the given width of an infinite printing line under the impact of the squeegee pressure can be calculated theoretically. The theoretical results correspond to measurements done in previous projects (Willfahrt, Stephens and Hübner, 2011). In other experiments, where it was tried to provoke the bulging-out effect it was almost impossible to observe elevated edges.

It seemed that the ink showed thixotropic behavior and levelled quite well after printing and before drying. These experiments should be repeated with an ink showing no thixotropy at all.

In future, the simple theory might be broadened by introducing influences of horizontal forces (friction between squeegee and mesh). Furthermore, a certain bending stiffness (especially for stainless steel) may be assumed, but it would complicate the calculations significantly.

In the calculations done here, the approach in which the x-z-plane provides the image feature width and depth having infinite length in the y-direction parallel to the squeegee extension represents the worst case with maximum depression of the mesh. Any stencil material before or behind the observed x-z-plane would support the squeegee and decrease the depression.

Table of symbols

α, β = squeegee deflection angles at edges (left and right hand side of squeegee)

t = mesh depression in mm

L = width of the printed feature in mm

E = Young's modulus of elasticity in N/mm^2 or in Pa

A_q = specific cross section of the mesh in mm^2/cm

x = squeegee position ($0 < x < L$)

$\xi = \frac{x}{L}$ = relative squeegee position in dimensionless representation with $0 < \xi < 1$

F = vertical squeegee force in N

F_A, F_B = forces in mesh in N (A = left and B = right hand side of squeegee)

a, b = elongated lengths of the mesh (left and right hand side of squeegee) in mm

ε = relative elongation, ε_A left and ε_B right hand side of the squeegee

ε_t = mesh elongation caused by the stretching in %

ε_q = mesh elongation caused by the squeegee pressure in %

$K = \frac{F_q}{A_q E}$ = dimensionless constant

Q = squeegee pressure in N/cm

Q_t = mesh tension in N/cm

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Optimal image encoding for hard copy production and method of its efficiency estimation

Yuri V. Kuznetsov[1] *and Andrey A. Schadenko*[2]

[1] St. Petersburg State Institute of Cinema and Television, Ul. Pravdy 13, St. Petersburg, 191119, Russian Federation — yurivk@mail.ru
[2] St. Petersburg State University of Industrial Technology and Design, Ul. Jumbula 13, St. Petersburg, 191180, Russian Federation — violin_2004@mail.ru

Abstract

Unlike in a soft copy generating, the multilevel pictorial data are, after capturing by camera or scanner, once again encoded in prepress to get the output signal governing the halftone printing in bi-level, "ink – no ink" fashion. Criteria of such encoding optimization are comprised in the transfer through physical plate making and press communication channel onto a print with as much as possible of original image data perceivable for a viewer. It undermines the providing of mutual conformity for parameters of a source image and channel, as well as for properties of an output print and vision. On the background of the screening developments overview for the last half a century, the paper presents: discussion of tone spatial dispersion in halftoning and accompanying contour and fine detail distortion; such distortion corrections and the method of quantitative estimation of their efficiency; principles of an image optimal encoding in prepress and their implementation in the High Definition Halftone Printing (HDHP); including results of testing and promotion issues of its practical application; and disclosed approach potential with the spatial dispersion adaptive to an arbitrary contour. Samples of test images and fragmentary photographs from illustrative print trails and jobs using HDHP are also presented. On this basis, the paper pretends to disclose some mainstream aspects bypassed in the most of other publications on halftoning.

Keywords: image data encoding, halftone dot, printing, adaptive halftoning, image sharpness, print definition

1. Background

1.1 Fifty years of electronic screening developments

In the sixties and early seventies of last century, the halftone transparencies were used to be exposed in electronic scanners through contact screens. Instead of being strongly connected just with the tone value signal, the halftone dot area was very dependent on collateral factors of the film chemical treatment due to the use of photomechanical screening effect in super contrast, lith-type photosensitive layers (Zernov, 1969). So, besides of contact screens eliminating, the halftone dot formation somewhere in the optical channel of a recorder, i.e. prior to or during the exposure onto conventional film or the, so-called, "electronic screening" providing the robust connection between the signal and resulting tone value was rather urgent. Putting aside some previous patent publications, the fifty years of electronic screening developments can be counted from October 1968 when the first remarkable technical report named "Electronic Halftones" authored by researchers from RCA Graphic Laboratory has appeared in IEEE Spectrum (Hallows and Klensch, 1968). They have generated the halftone on the faceplate of high-resolution CRT, with 110 lpi image being applicable for exposing on a photo plate. The dots of variable area were drawn by means of the electron beam spiral sub-movement under control of a tone signal. In spite of the actual use of a pulse-width modulation, they named this kind of halftones generating as amplitude modulated (AM) to disclose in the same paper the alternative method of such an image formation by the variable placement of fixed size dots and to call it frequency modulated (FM).

The first electronically halftoned color prints were next year distributed in ten thousand copies at the Moscow "Inpoligraphmash'69" exhibition by the Graphic Laboratory of Leningrad Bonch-Bruevich Institute of Electric Communication (Exhibition pamphlet, 1969).

Sharp image of variable area dot was formed on a faceplate of the special CRT by an electron beam cross section modulation (Kuznetsov and Uzilevskey, 1976). Such dot was then exposed onto a film fixed on rotated drum of a scanner. Photograph of one of those pictures with the dots random displacement avoiding moiré is given in Figure 1. Dots of variable area were also electronically formed in PDI scanners of the seventies with the use of galvanic mirrors or diaphragms (Moe, et al., 1973).

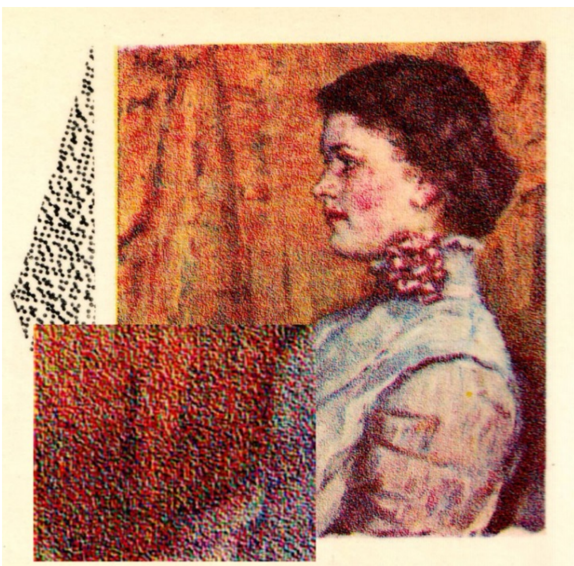


Figure 1: Copy of one of the first color prints produced with electronic screening the halftone transparencies and with avoiding moiré by using non-periodic dots placement (Exhibition pamphlet, 1969)

In spite of their use along with the digital color processing and image scaling, all these dot formation methods, as well as electromechanical engraving of that time, have provided the continuous dot area variation and relate to the analog electronic screening techniques.

“Digital” halftoning was at a full scale commercially implemented with the laser parallel exposing of six microdots onto a film in Chromograph 300 ER of Dr. Ing. R. Hell company in 1972 (Gast, 1973). The halftone dots were formed there from discrete elements within the matrix, which in the simplest case could comprise a screen period. So, in addition to an analog to digital conversion at an image capturing stage, the pictorial data were once again spatially sampled, at least, with a screen frequency while its tone range was a second time quantized according to a finite amount of dots in an “alphabet” defined by said matrix dimensions. As result of this new encoding, the output bit map was produced to control the film exposure in “on–off” fashion.

Figure 2 illustrates the mutual location of four discrete spatial periods within such a matrix (36 × 36 microdots unit area) for the screen with an angle of about 71.6 degrees with rational tangent of 3/1. The abbreviations commonly used nowadays (lpi, spi, ppi, dpi) of spatial frequencies, inverse to three of these periods, are also marked on this picture. The spot function period includes here ten halftone dots. In some further developments such period was extended to a “supercell” with many hundred dots thereby allowing for approximation of rational tangents, which with sufficient accuracy correspond to the “conventional” screen angles of 15° and 30° having irrational tangents.

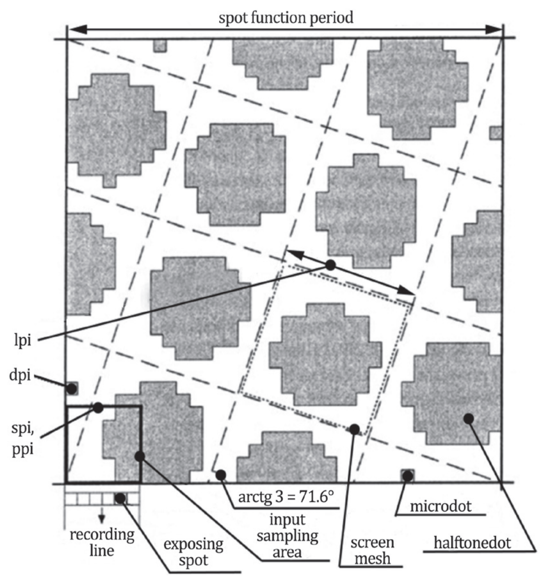
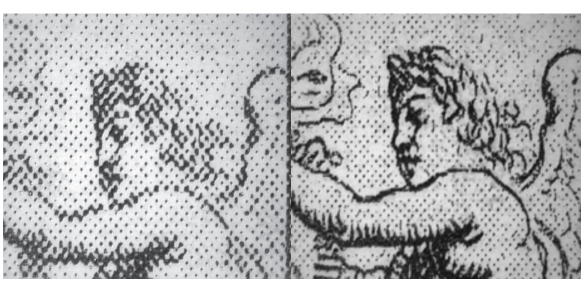


Figure 2: Mutual location of discrete spatial periods within the 36 × 36 microdots unit area for a screen angle of about 71.6 degrees at tangent 3 in Chromograph 300 ER, adopted from Gast (1972)

Due to the limited digital facilities of that time, the tone signal was presented in this machine by the six digits, i.e. by the halftone “alphabet” comprising just $2^6 = 64$ symbols. So, the visible steps could appear instead of continuous tone (CT) variation. That’s why the halftone symbols of adjacent levels were stochastically mixed at transitions to get rid of such quantization noise (Koll, 1972). This principle of error diffusion was later on expanded from 1/64 to 1/2 part of tone range with the use of just two symbols from the halftone “alphabet” comprising the fixed sized dot and blank (Floyd and Steinberg, 1976). Following this mathematically elegant error diffusion approach, the screening developments have then declined to stochastic or FM halftones generating. The great number of publications was devoted to make their irregular structure homogenous with applying of the, so-called, “blue”, “green” masks and other means (Ulichney, 1987; Lau and Arce, 2001). Nevertheless, they were lacking printability due to ignoring the basic physical issues of a plate–ink–substrate interaction (Kouznetsov and Alexandrov, 1999).

Use of a dot with a minimal available area within a whole tone range makes the resulting tone value very sensitive to printing tolerances. (It is easily evidenced by the attempt to print a 50 % tint comprising the chessboard location of minimal dots and blanks.) As result, they were just partially implemented in the ink jet and, so-called, hybrid halftoning. Effective tone range of the latter is expanded by modulating the amount of a fixed minimal size dots/blanks in the highlights or the darkest areas while using the usual dot area variation for the most part of the said range. Such kind of screen frequency auxiliary variation was earlier also met in photomechanical Respi screens of the '60s and in digital screening of K-separation in Chromograph 300 ER.

As far as it is concerned of conventional, AM digital screening, the certain improvements there were also done. Reduction of the dot gain and ink waste was achieved, for example, by the use of perforated or "concentric" dots providing lower adhesion in their inner area. However, all these developments were mostly related to the replacement of an optical, photomechanical screening by its electronic version, to some extent bypassing the drastic print image deterioration followed at the end of 19^{th} century with introducing the screening itself instead of the previous manual engraving (Figure 3). Improvement of print image quality can be achieved using the so-called, adaptive screening methods, like high definition halftone printing (HDHP), directed to engraver skills restoration in the modern electronic prepress (detailed in Chapters 4.3–4.5).



a) b)

Figure 3: Enlarged fragments of halftones produced with the use of: conventional ABC screening (a); HDHP technique imitating the manual engraver skills (b), Kuznetsov (2017)

1.2 Overview of image reproduction process

In the light of communication theory, the prepress processing of a picture comprises its optimal encoding by the criteria of a picture data transmitting onto a print through the physical plate making and press communication channels, keeping as much as possible of a source image data which can be perceived by a viewer. Such encoding undermines the mutual conformity for parameters of original image, as well as for properties of output print and human visual system (HVS).

Representative example of such conformity providing is in the empirically found and traditionally used non-orthogonal, 45 degrees screen orientation on a black and white (b/w) print and that for the black ink on a multicolor one. It takes into account the angular anisotropies inherent in these three basic components. The first of them is in the statistics of contours orientation distribution on images, replicas of a visually perceived world where, due to gravitation, the vertical and horizontal contours prevail over the inclined ones. The other one relates to transmitting channel and is comprised in 1.41 greater spatial frequency response of its orthogonal screen grid for diagonal lines as compared with that for vertical and horizontal directions. The third anisotropy is, at last, in about the same degree less vision frequency response in diagonal direction (Grudzinsky, Tsukkerman and Shostatsky, 1976; Kuznetsov, 1998a).

However, unlike TV and pictorial data compression solutions, the printing technology doesn't completely satisfy such principle in some other important relations. For example, it uses the same quantization scale or dynamic range per color separation without taking into account the specifics both of an image local area content and vision.

Such a fact is schematically illustrated (Figure 4). Three basic components (source, channel, user/receiver) are shown there streamed by the image data flow with the first of these components being of the greatest width while that of the channel, with inherent hindrances and band pass limit, the narrowest.

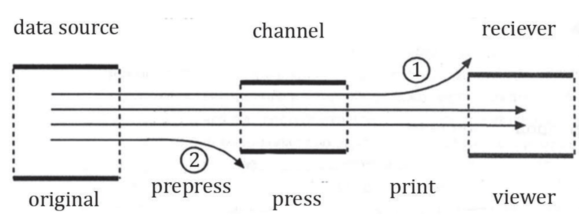


Figure 4: Data flow in halftone print production

Arrow 1 in Figure 4 indicates the image data which, in spite of being, in fact, present on a print copy, can't be visually perceived by a viewer. In digital prepress of today it is formally pretended to reproduce (to transmit through the printing channel) any detail of an image and, for example, the quarter of millimeter thick line in as much as 16 million colors (256^3). The fact is that the eye can scarcely tell if such a line is somewhat darker or lighter, and whether it is green, cyan or gray is ignored. Such luxury of color interpretation isn't available for the most of other, such as color TV, imaging techniques making them possible just by providing the necessary conformity between the properties of an output data and facilities of an end user. Arrow 2 designates, on the other hand, the data of original image which would be perceived on a print but were lost at the prepress stage. It is related to the contour and fine detail distortion accompanying the tone measure spatial dispersion inherent in the CT original transform to the bi-level (ink / no ink) output signal.

Such losses are illustrated by the enlarged fragment of a halftone print in Figure 3a. The same reproduction of manually engraved picture in Figure 3b is free of them. The original (not shown in Figure 3) consists of engravings and shades of print dots variations (mezzotint) at a stationary image area. Meanwhile, instead of the scattered halftone dots, the engraver uses exclusively the solid lines for contours and fine details imitating the average brightness of a local area by varying just the width of these lines. That allows him to reproduce the image content with as much as possible geometric accuracy.

So, the fundamental objective of image encoding in screening is comprised in more effective use of the imaging system resources by shortening the gap between printing process resolution and halftone image definition with exploring the elements of artificial intellect taken, by analogy, from the work of engraver.

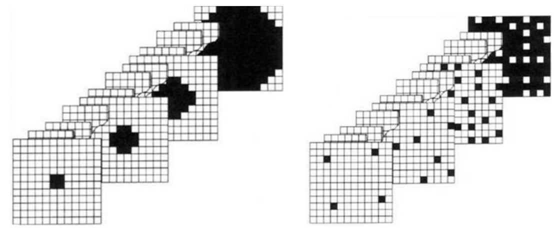
Practically approved, disclosed in several our patents and herein below described the HDHP technique is adaptive to local tone value gradient. It imitates the mentioned engraver skills to increase the halftone definition. Moreover, the reproduction system recourses are there completely used for standalone thin stripes with their accuracy inherent just in the line work (LW) kind of printing.

2. Introduction

2.1 Determination of tone spatial dispersion

Unlike some other imaging applications such as, for example, soft copy creating, the image data are at least twice encoded in printing. Its initial presentation by multilevel, predominantly 8-bit samples (256 levels) per color separation is quite sufficient for computer or TV display.

However, the set of such samples should be transformed into a bitmap to control the print output in a bi-level fashion. This new encoding is performed with the spatial image sampling at a screen ruling frequency and the use of sampled values quantization by an “alphabet” of finite size halftone symbols available in a raster image processor (RIP) or printer driver (Figure 5).



a) b)

Figure 5: Symbols of halftone dot “alphabets” with clustered (a) and diffused (b) distribution of microdots within a screen period, adopted from Kuznetsov (2016b)

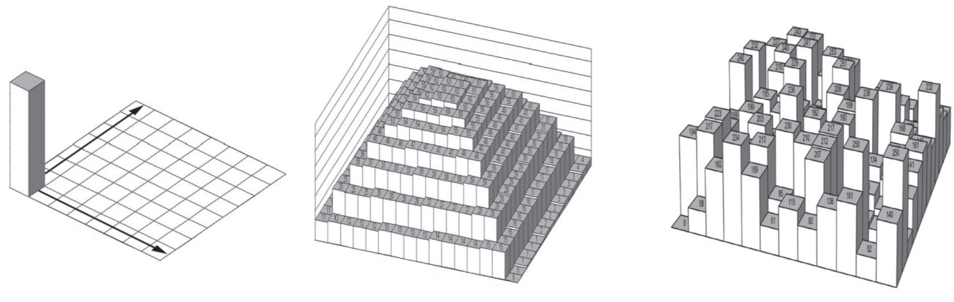
Such “halftoning procedure” is accompanied by the multilevel tone measure dispersion over screen mesh period as illustrated in Figure 6. The area of 16 × 16 microdots is formally required at the output for ascertain inking each of them according to one of 256 input levels. Such selective marking is provided by the so called “spot” function using a “screen hill” (Figure 6b), diffused (Figure 6c) or directional microdots weights distribution. Their horizontal threshold slices produce the symbols of halftone dot “alphabets” shown in Figure 5. Tile geometries are further discussed in Chapter 4.3.

As shown in Table 1, the dispersion parameters, such as margins of its spatial bounds, continuity, linearity, discreteness, and direction (geometry), strongly correlate to related properties of a halftone structure or an image itself. Bounds of dispersion define, for example, the print screen period (ruling) finally affecting an image sharpness and definition.

Table 1: Parameters of tone scale spatial dispersion and properties of a thereby produced halftone structure

Dispersion parameter	Halftone structure property
spatial bounds	screen period (definition)
continuity	AM, FM (stochastic)
linearity	tone response curve
discreteness	number of gray levels
direction	form of print element, screen geometry

The illustrative examples of Figure 5 relate to the beforehand defined dispersion by the use of corresponding weight or spot functions. However, in error diffusion and in some of the locally adaptive techniques, which provide the dispersion “on-fly”, such spatial period does, nevertheless, exist being defined by the input pixel code length. Eight-bit length requires, for example, the margins of, at least, 16 × 16 microdots for adequate presentation of one of $2^8 = 256$ quantization levels on a copy. Moreover, the input image file metric mostly relates to visually uniform optical densities or CIELAB values, which are in logarithmic or cubic degree relationship to the absorbance (tone value) on



a) b) c)

Figure 6: Spatial dispersion of the multiple values of an input image sample (a) between the screen mesh microdots with the use of a clustered (b) and random (c) distribution of their weights, adopted from Kuznetsov (2016b)

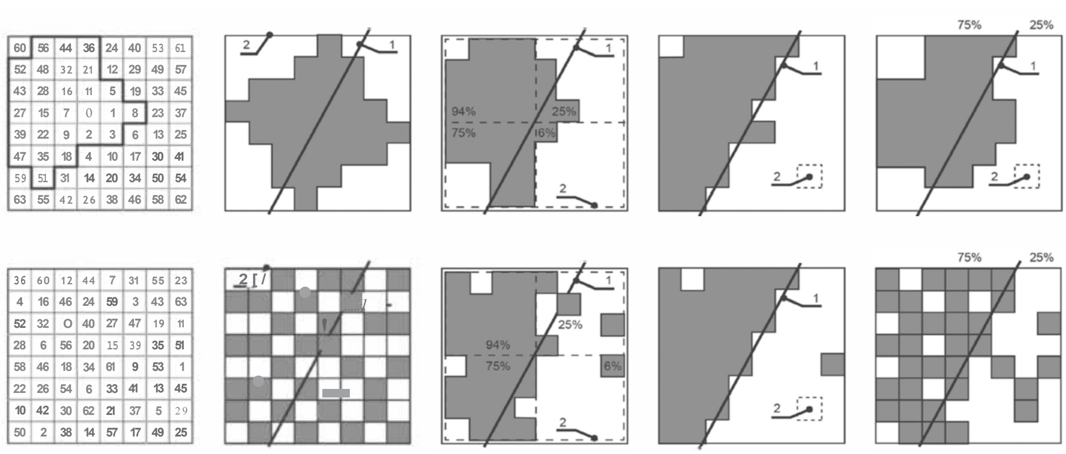
a print. That's why the dispersed quantization scale should be in rather strong non-linear connection to that of the input file, requiring, once again, the excess of dispersion discreteness. So, the print output resolution has to significantly exceed the scan frequency of an image input.

2.2 Image detail distortion in screening and its correction

Figure 7 shows the reproduction variants for border **1** sharply separating on CT original the dark (from the left) and light (from the right) areas altogether corresponding to a single screen mesh of a print copy. The greatest distortion happens when the original sampling area **2** is equal to such a mesh (period of halftone), i.e. at the so-called screening factor (SF) of 1.0. Because of this area, half division on black and white the tone value comprises 50 % for the whole screen period and the border sharpness is greatly lost as shown in Figure 7b.

In more realistic scale this effect is demonstrated in Figure 8b for letters **Q** and **n** as fragments of a CT original (Figure 8a).

The upper parts of Figure 7c and Figure 8d relate to the twice higher image capture resolution when SF = 2.0. Within each quarter of a screen mesh, the microdots are assembled here under control of four different input values, i.e. with the use of just parts of halftone symbols. The form of such "partial" dots somewhat better matches the contour geometry. The same degree of contour accuracy improvement, but with the use of a quarterly fewer amount of input samples at SF = 1.0, is demonstrated by Figure 8e. As indicated on the upper part of Figure 7a the dots are here shifted toward the darker side of a contour at a distance dependent on its contrast (Moe, et al., 1978; Ershov, et al., 1990). Joint effect of SF = 2.0 and such displacement is illustrated in Figure 8f where just the part of a dot is displaced on a border. It is interesting to notice that, instead of contour destroying (Figure 8b), these dots are them-



a) b) c) d) e)

*Figure 7: Print copies of sharp transition, with border **1** dividing dark (left) and light (right) areas on a CT original with the use of monotonous (upper) and random (lower) microdot weights distribution within a screen mesh (a) at: SF = 1.0 (b) and SF = 2.0 (c); SF = 8.0 for full (d) and intermediate (e) contrast (75 % to 25 %) values*

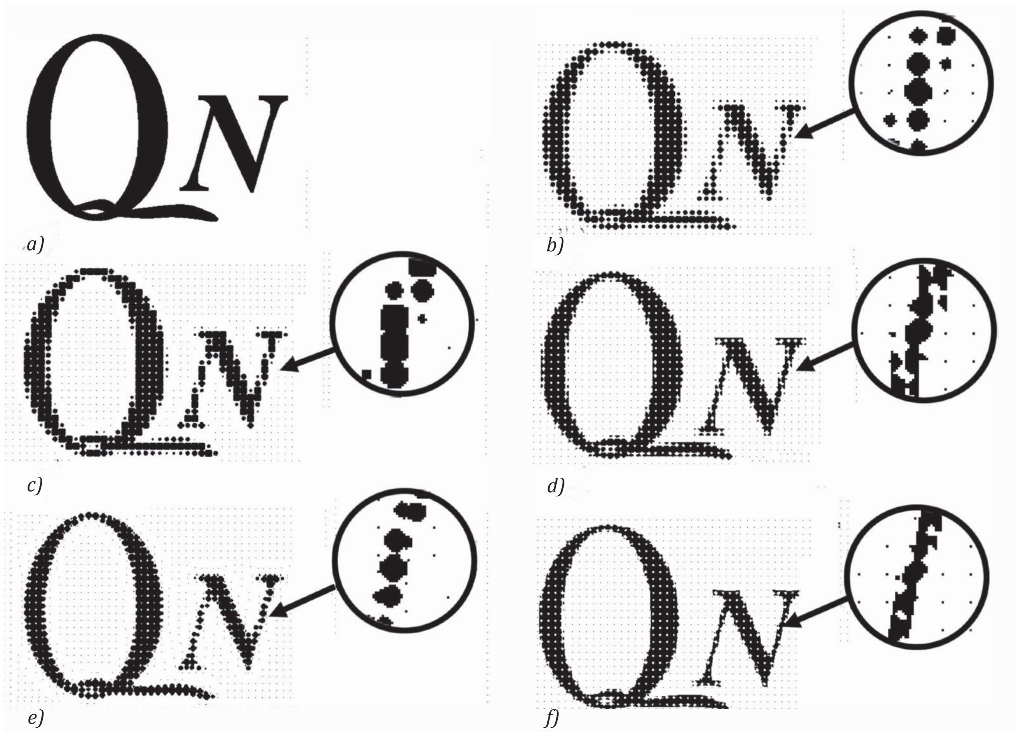


Figure 8: The distortion variants of a continuous tone original detail (a); on a print: at SF = 1.0 (b); with the use of unsharp masking at SF = 1.0 (c); at SF = 2.0 (d); with dots displacement at SF = 1.0 (e); with displacement and SF = 2.0 (f)

selves divided into parts each of them made to adjoin the nearest side of a border. Such effect is seen within the smaller opening of letter **Q** in Figure 8f.

Further increase of SF up to 8.0 improves the geometric accuracy on a print for the b/w border of full contrast to the level of LW as shown in Figure 7d. As far as the LW image doesn't need halftoning at all, the printer deals with it as a Boolean repeater in a "fine scan/fine print" mode. However, the most of the CT original contours are of some lower contrast. Figure 7e demonstrates that the eight times increase of a scan frequency, i.e. the ultimate SF value of 8.0 doesn't help so much. In spite of sharpness on original the scattered dots and blanks of reproduced transition tone values (in this example of 75 % and 25 %) are, nevertheless, formed at each side. Moreover, it was shown that the use of SF values greater of 2.0 results in specific losses of textures (Schadenko and Kuznetsov, 2009).

According to one of "halftoning myths" (Kuznetsov, 2016; 2017), the above kind of distortion can be corrected not in screening procedure itself but by the previous high-frequency filtration of an input multilevel data. However, as demonstrated by an example in Figure 8c, the unsharp masking (USM), except of increasing the local contrast, doesn't at all improve geometric accuracy of a detail.

3. Halftone definition and sharpness estimation

3.1 Investigation of the halftoning effect on image quality

Resulting amount of ink transferred to a print and, hence, the basic quality aspects of the latter such as color, tone rendition, definition, sharpness, etc. are fundamentally dependent on halftone dots area, form and geometry of placement. That's why the screening comprises the actual, cornerstone R&D issue of illustrative printing and a lot of currently available, announced or upcoming, patented and trademarked screening techniques focus on their practical use. In such situation the demand arises for correct, quantitative comparison of their efficiency (Kuznetsov, 1999).

The generalized approach to the halftone print quality evaluation was formulated on the basis of comparing not the original and its halftone copy themselves but the image metaphors of the both produced with the use of HVS model (Nilsson and Kruse, 1999). Such approach embraces the whole set of a halftone print quality parameters. In our research, it was, however, purposeful to divide this set into two groups with the first of them including parameters characterizing: color, contrast, tone range, number and distribution of gray levels, etc. Along with the visual estimation, such quality indices can be quantitatively and separately measured on a test wedges by a colorimeter and densitometer with plotting the tone reproduction curve, color gamut, tone deviation, etc.

Our research was focused on estimation of the second group of parameters, such as definition and sharpness. They are responsible for the high spatial frequency content of an image and thereby for the accuracy of its fine details. The definition is commonly estimated by the overall amount of smallest details which can be potentially reproduced on a print. Sharpness characterizes, on the other hand, the border quality independent on detail dimensions. The ISO standard 12647-1 (International Organization for Standardization, 2013) recommends, for example, to measure dot sharpness on a halftone transparency by the inverse of its edge fringe width. Such a fringe is schematically illustrated on a "photograph" (Figure 9b) of an "ideal" original b/w transition of Figure 9a.

a) b) c)

Figure 9: The "ideal" stripe (a) and its copies on a photograph (b) and on a halftone print (c)

More adequately the sharpness evaluation is provided when, beside the width, the gradient of optical density within a fringe is also taken into account. It explains, for example, in today obsolete process, the practical use of dots optical density up to 5.0, in spite of about 1.0 being sufficient to protect the sensitive layer in offset plate making (Kuznetsov, 1998b).

Modulation Transfer Function (MTF) is commonly used in modeling the frequency response of an imaging system. Micro photometric measuring across the variable spatial frequency bar pattern is applied, for example, in photography, to verify the modeled MTF and experimental data correlation. However, such measurement isn't applicable for halftone print of such a pattern (Figure 9c) because of its bi-level nature being formally similar to that on an original in Figure 9a. The only difference is that, instead of straight lines, the structure of print version comprises the scattered halftone dots or just parts thereof filling both the pattern stripes and blanks in a different, illustrated, for an example, in Figures 7 and 8, being dependent on specific screening algorithm or of its settings. Therefore, the facility of certain halftoning to preserve the sharpness is mostly judged visually. The objective visual comparison meets, meanwhile, the difficulty of keeping non-changed the multiple of other imaging conditions. The slightest parameters variation in color, gradation and the like may affect the expert judgment of sharpness and vice versa. So, there is the need for a quantitative method allowing for evaluation the influence of various imaging parameters (volume of a scanned/input image data, printer resolution, type of printing, etc.) and settings (screen and dot geometry, screen ruling and angle, screening algorithm, etc.) on a halftone quality. It is also desirable to get such estimation at the different spatial frequencies and contrasts of details, as well as, along the whole chain of reproduction stages. Such an attempt was undertaken by Kitakubo and Hoshino (1997) with analysis of frequency spectra calculated for the differences between the input multilevel samples and averaged sums of bits on a print copy.

3.2 The method of a detail distortion quantitative evaluation

We have proposed to directly measure the norm of error for quantitative estimation of the fine detail distortion involved by screening (Kuznetsov and Zheludev, 2008). This value is found by superimposing the bitmaps of an original test pattern and its halftone copy with calculating the normalized sum of bits (microdots) changing their polarity (from black to white and from white to black) as result of halftoning. That allows for defining the screening efficiency factor (SEF) as

$$\mathrm{SEF} = 1 - 0.5\left(\frac{\sum_{i=1}^{M}\sum_{j=1}^{N}\left|A_{ij} - B_{ij}\right|}{\sum_{i=1}^{M}\sum_{j=1}^{N}A_{ij}}\right) \qquad [1]$$

where A_{ij} and B_{ij} are the bi-level values in original **A** and screened **B** pattern bitmaps (Figure 10), while M and N denote the numbers of their lines and columns.

In this approach, the initial test with resolution pattern of full or intermediate contrast is concerned as a detail of a CT original. With high-resolution bitmap **A** of a test pattern (Figure 10a) being formed this method emulates the following prepress procedures:

- coarsely scanning and encoding the test at prescribed resolution (SF) to provide the input gray level ("byte-map") file (Figure 10b);
- creating the metaphor of a PostScript file at predetermined tone value percent for white and black on a print (Figure 10c);
- screening the PS file by the investigated method to get the bitmap **B** of a halftone (Figure 10d).

Superposition of initial **A** and final **B** bitmaps shows in Figure 10e the bits, which have changed their polarity as result of screening, and allows for calculation the SEF according to Equation 1.

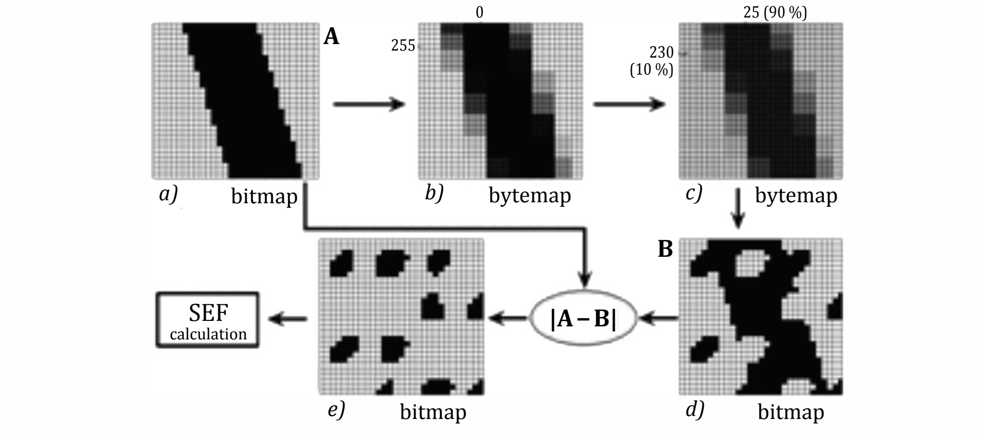


Figure 10: Steps sequence of resolution test pattern processing for the SEF calculation

It should be noticed that, even if the extreme input values of 0 and 255 are prescribed for "black" and "white" in a test pattern file, the intermediate, gray ones indicated in Figure 10b nevertheless appear at boundaries due to aperture distortion of scanning or, in other words, because of tone value averaging over a sampling area. When the picture is further prepared for printing the new meanings should be assigned to its black and white. They relate, in this example, to 10 % and 90 % ultimate areas of halftone dots available for a certain given kind of print job (Figure 10c).

For testing this method the MATLAB functions were used to create the resolution test patterns at 3600 dpi, to screen them with analytically defined spot functions, to calculate and plot the SEF curves. Test image formation, scanning, and encoding were emulated in Photoshop. When plotted along pattern periodicity the graphs of such a factor (Figure 11) comprise some equivalent of MTFs and allow for comparing the various screening methods efficiency in the relation to high frequency image content reproduction.

Presence of peaks on curves of Figure 11a is explained by the interference of a pattern and screen frequencies. These peaks almost disappear due to integral nature of SEF calculation when the concentric test stripes are used instead of the vertical ones (Figure 11b).

The SEF value is normalized in such a way that its zero meaning corresponds to some virtual, negative presentation of a test (Figure 12c) when all the input bits are reversed. The 0.5 SEF value takes place when half of an input test pattern bits has changed their sign thus producing, instead of stripes, the uniform tint as, for example, shown in Figure 12b. So, all the SEF meanings lower than 0.5 are non-representative. The SEF = 1.0 relates, on the other hand, to facsimile reproduction

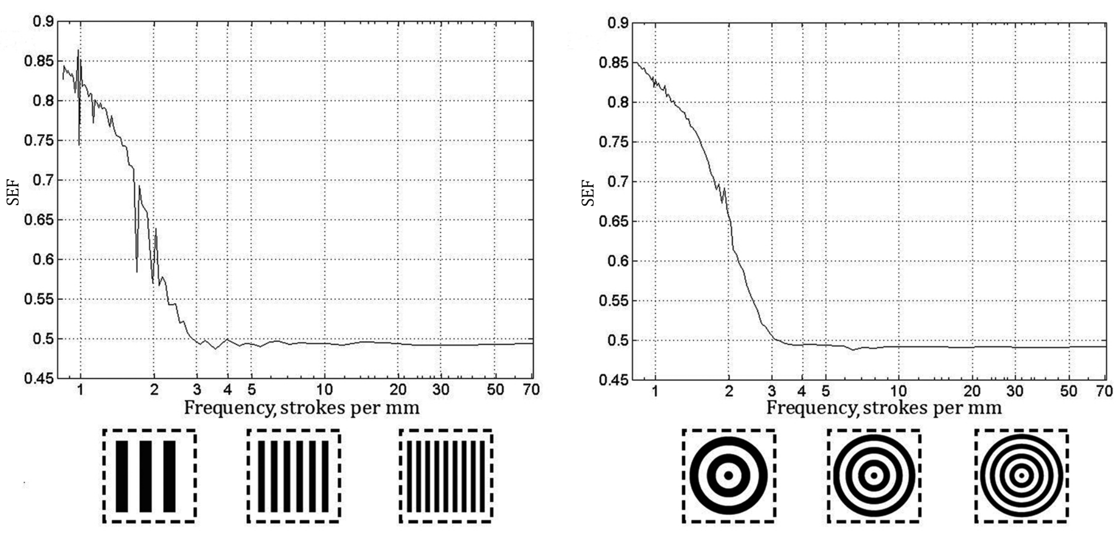


Figure 11: The SEF plotted along the resolution test pattern frequencies for two of its geometries: parallel (a) and concentric (b)

of a pattern with all input pixels remaining unchanged (Figure 12a). It takes place for the test of full contrast scanned at maximal SF, i.e. at as high resolution as that of the printer (fine-scan/fine-print mode) and assigning to its white and black levels correspondingly the halftone dot of 0 % and ink solid (100 %) tone values. With no screening in such case, the dot generator works as a repeater and the upper SEF curve in Figure 13 comes parallel to the abscissa.

a) b) c)

Figure 12: Halftone copies of the input test pattern at SEF: 1.0 (a); 0.5 (b); and 0.0 (c)

3.3 Efficiency of screening with its settings variation

The curves in Figures 13 to 15 adequately show the different effect of SF, screen ruling, and stripes contrast on the test pattern distortion. Figure 16 demonstrates the rather strong reciprocity effect for SF and screen ruling when reduction of the former is compensated by the increase of the latter and vice versa. The curve plotted for SF = 2.0 and screen ruling of 20 lines/cm comes very close to that calculated for half SF (SF = 1.0) but doubled (40 lines/cm) ruling.

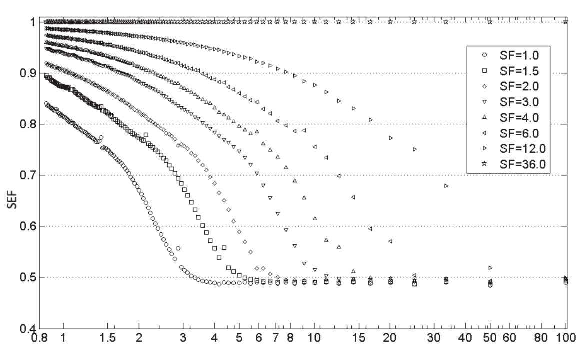


Figure 13: SEF at different SF values for test of a full contrast and screen ruling of 40 lines/cm

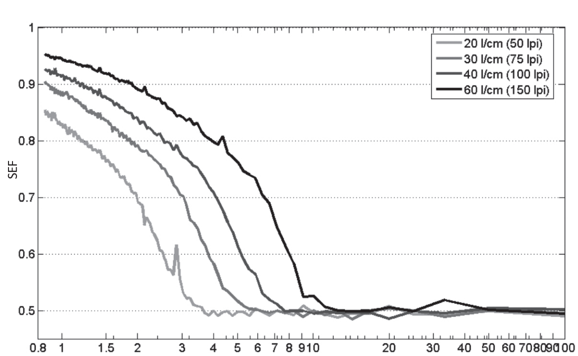


Figure 14: SEF for different screen rulings at SF of 2.0

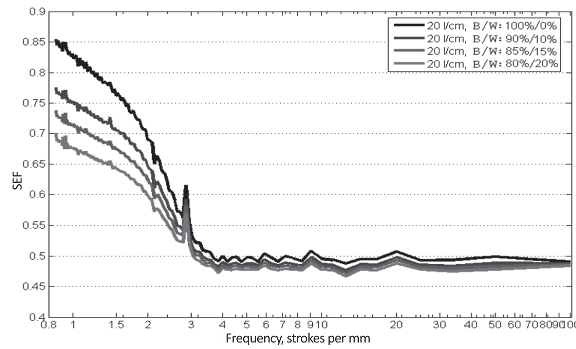


Figure 15: SEF for different contrasts of the input test at screen ruling of 20 lines/cm and SF = 2.0

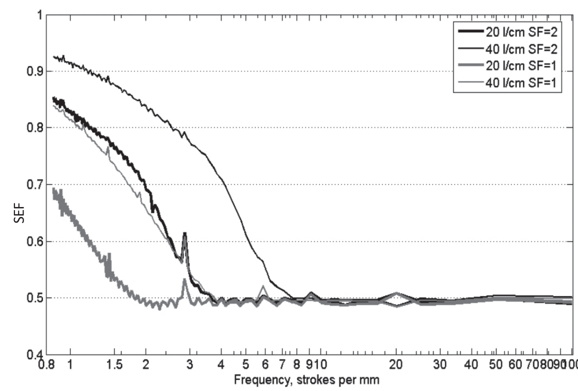


Figure 16: Proximity of two middle SEF curves illustrates the reciprocity effect of screen ruling and SF

In spite of the use at the last step of some idealistic image copy, the method allows, nevertheless, for objective, quantitative estimation of frequency response for various screening techniques unlike the visual comparing the realistic halftones or their enlarged fragments in Figures 7 and 8. Moreover, the use of high resolution scanned test of a halftone transparency, plate or print may help to estimate the share of distortion involved by the additional low pass filtration inherent in the further technology stages. For screen printing, it makes, for example, possible to detect the effect of a mesh and stencil parameters on an image sharpness and definition. Similarly, the effects of anilox roller parameters can be estimated in flexography. At last, the method should be helpful for evaluation of the halftoning facilities of a digital printer whose screening algorithm is concealed in its closed architecture.

4. Adaptive screening research

4.1 Tone value dependent processing

As it was already mentioned, the issues of tone (color) rendition and of contour accuracy are mostly independently concerned in the imaging science. Screening comprises, however, the unique kind of an image transform with inherent conflict of providing both tonal and spatial resolution. The tradeoff is solved in reproduction practice on behalf of the first of these requirements, i.e. by preserving the tone value range between 3–5 % and 95–97 % for all the variety of practically used screen frequencies (International Organization for Standardization, 2013; Kouznetsov, 1999; Kuznetsov, 2016).

At such a condition, the screen ruling depends on the absolute minimal size of a dot steadily available for given type of job, i.e. for the particular kind of print stock, ink, plate, equipment, etc. Providing such dot over a print sheet within a run is therefore fundamental for the optimal adjustment of substrate-plate-ink system. Altogether it is worthwhile to notice, that the ink solid densities, used in wide practice to indicate the match to some standard conditions, are just the secondary factors of a proper press setting.

To provide both as much as possible amount of steps within the gray range and uniformity of vast stationary areas the optimal geometry of a dot form transformation was empirically found in over a century of halftone printing use. However, some of the lately suggested digital screening techniques, being aimed to achieve a certain novel image quality, failed to be practical because of ignoring said long term experience. The non-periodic, “screenless” photomechanic halftones, provided, for example, in collotype printing of the past, were renewed by digital techniques of last decades under the names of FM, dither, stochastic, error diffusion, etc. In spite of providing the greater spatial frequency response than regular, periodic ones, they have found limited application because of putting aside the practically approved priority of tone rendition and printability requirements. As result, the concept was just partially implemented, for example, in the already mentioned hybrid halftones. In terms of adaptive screening approach such a way of modifying the algorithm over an image area can be referred to *tone value* dependent ones. Similarly, the printing element form variation along a gray scale from, for example, round in highlights to elliptical in middle tones, etc., is also *tone* dependent.

4.2 Tone gradient dependent screening

In early period of electronic screening developments, the other, *tone value gradient* dependent approach was suggested for screening distortions correction. Local image nature is evaluated in the closest vicinity of a processed pixel by a differential operator to form the parameter for dynamic, over a picture area, algorithm readjustment. The first examples of such control were comprised in the halftone dots or their parts displacement toward the darker side of a contour eliminating its stepwise serration in analogue electronic halftones of P.D.I. scanner of the '70s (Moe, et al., 1978; Hunt, 2004) and in its digital version (Ershov, et al., 1990). Modifying the form of dots (their elongation matching the contour direction) was also suggested (Hammerin and Kruse, 1994).

However, the eternal conflict of providing both tonal and spatial resolution to a greater extent withdrawn by the increase of a screen ruling on detail borders with taking into account the acceptability of accompanying gray scale reduction.

Screens sequence of the stepwise square root of two higher rulings was used for this purpose at the first step of our developments (Kuznetsov, et al., 1978). Such kind of solution is similar in its approach to adaptive differential pulse code modulation where the dynamic mutual exchange of a sampling rate and quantization scale is explored. With a signal gradient increase the samples of shorter bits length and, hence, of a fewer quantization scale are used to get the higher frequency response. However, the effects of data compression are limited there by spending extra bits to indicate the actual bit length of a current sample for decoder. This is no problem for halftoning where the results of both spatial sampling and value quantization are finally presented by a single bitmap.

Our first experiments have shown that the abrupt changing of frequency, as well as of any other screen parameter, along the contour of gradually fading contrast is distinct for a viewer. To get rid of the stepwise, noisy change of an image structure we proposed to seamlessly blend the screens of different ruling in each other (Kuznetsov and Nishnianidze, 1982; Kuznetsov, Kogan and Nishnianidze, 1982). It is performed by dividing the current tone value S in two parts S_1 and S_2 in proportion depending on the local image area content estimated as its busyness q:

$$S = (1 - q)\, S_1 + q\, S_2 \qquad [2]$$

The first part S_1 may control any kind of a basic, practically approved algorithm providing the appropriate printability and tone rendition for the stationary, low spatial frequency image area. The S_2 part relates to fine detail and governs the screen functions of higher ruling but of shorter quantization scale (symbols “alphabet”).

Busyness parameter q characterizes, in general, the share of high frequencies within the local image area comprised of a processed pixel and its neighboring ones. It can be estimated, for example, with the use of Fast Fourier Transfrom (FFT) or by the sum of difference modules in all pixels pairs of such area. As our experience has shown, the maximal tone value difference module among these pairs does also quite satisfactorily present q. Later versions of disclosing this method in HP patents name the same parameter as activity index (Bradburn, Hoffman and Lin, 1999).

In this approach the contour geometry improvement was, however, dependent on the excess of an input data captured from original, i.e. at SF much greater than commonly used 2.0 and, hence, at many times larger image file volumes.

4.3 High definition halftone printing (HDHP)

In our further development there was proposed to use the set of auxiliary functions having constant, about twice higher frequency than a basic screen (Kuznetsov, 1998b). Relying on typical "coarse-scan/fine-print" mode (SF = 2.0) it can formally just double the halftone print definition. However, the variety of about a thousand dots (tiles) in their "alphabet" (Figure 17) allows for much greater geometric accuracy of contours and fine details as shown in Figure 18.

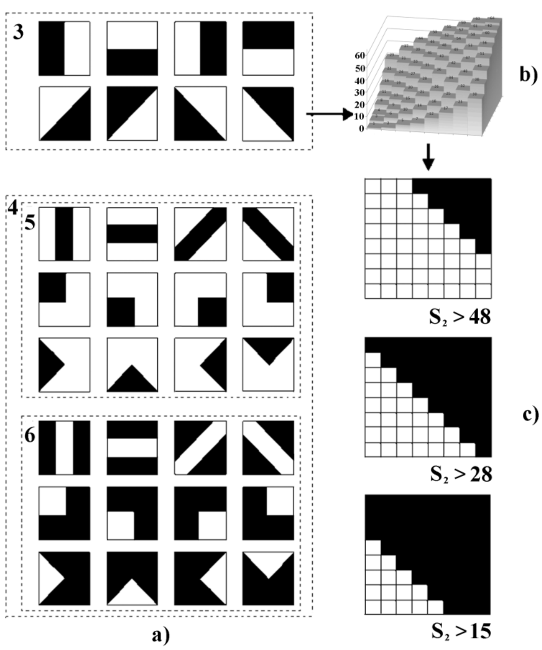


Figure 17: Tile geometries (a) with their first (3) and second (4) pluralities, the latter subdivided into the subsets (5) and (6); auxiliary spot function (b) for one of geometries; tiles (c) produced by this function for three tone values S_2 (Kuznetsov, 2017)

To properly identify the auxiliary function within a set and extract the tile closely matching a reproduced detail or contour geometry the pattern recognition technique is used in the vicinity of a processed input pixel. Each input sample of non-stationary image area is jointly presented within the screen mesh by such a tile and conventional dot or its part in proportion defined by the busyness factor q. This mixture is illustrated by Figure 19 for the contour of intermediate contrast sharply separating the original areas of 75 % and 25 % tone value, i.e. having q = 0.5.

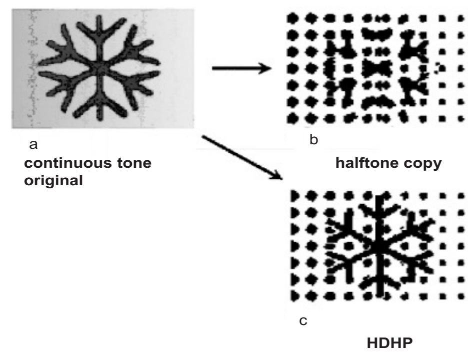


Figure 18: The fine detail (a) of CT original and its halftone copies in conventional (b) and adaptive screening (c) at SF = 2.0, adopted from Kuznetsov (2016b)

Share of tiles use increases with q growth up to 1.0 resulting in precise matching the geometry of a detail as was shown in Figure 18c. Such a mixture is, on the other hand, gradually replaced by the conventional dots of 50 % tone value when the contrast is fading along a contour with its complete dissolving in uniform background of 50 % value where q = 0.

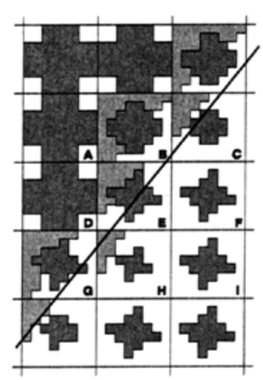


Figure 19: The mixture of tiles (lighter) and halftone dots (darker) for contour of intermediate contrast sharply separating on an original the areas of 75 % and 25 % value (SF = 1), adopted from Kuznetsov (2016b)

As it became clear from further experiments, the issues of seamless blending of different dot structures can be also concerned in different way for the boundary and standalone thin line, i.e. for the double tone jump within an input sample area **E** indicated in Figure 20. The constrained use of tiles instead of dots isn't visually caught here. That allows for reproducing such line by the ink solid (Figure 20d) instead of the mixture of tiles and dots (Figure 20c). On the other hand, the gradual contrast fading along such a line can be quite satisfactorily compensated simply by the line width reduction.

As follows from engraver practice, the 0.1 mm thick gray line (Figure 20b) doesn't need screening at all and can be printed by solid, for example, with half of its initial width to preserve the average grayness of an area (Figure 20d).

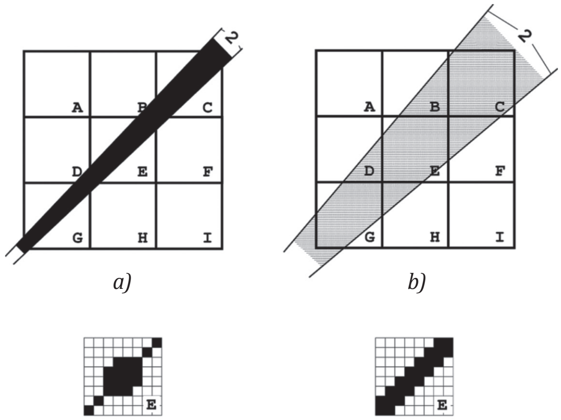


*Figure 20: Thin black (a) and wider gray (b) lines producing the same tone value for each of **A**–**I** sampling areas due to reflectance averaging at the CT original input; halftone copies of these lines for the processed **E** area in previous (c) and current (d) HDHP versions, adopted from Kuznetsov (2016b)*

The set of auxiliary screen functions was for this purpose divided in two groups with subdividing the second of them in two subsets (shown in Figure 17a) allowing for the selective use of tiles of different geometry and polarity (Kuznetsov and Volneikin, 2011). As result, the standalone thin lines are reproduced by the latest HDHP version with the complete use of a printer resolution.

4.4 Discussion on HDHP testing in traditional and digital printing

Selective distribution of the imaging system resources over a picture, taking into account its local area content as described above allows for the mutual exchange of printing system facilities in relation of tone/color rendition and contour/fine detail graphic accuracy, i.e. with tonal and spatial resolutions adaptively replacing each other. This new way to form and place the print elements was realized as the computer program. Meanwhile, the absence of iterative procedures in algorithm facilitates to implement it in a RIP or in a hardware halftone dot generator. The technology was named HDHP and tested in lithography, flexography, screen printing, toner based and ink jet digital printing.

The results of experimental printing of the tests and realistic images as well as of the commercial jobs with the use of adaptively halftoned image files have vividly shown the following advantages:

- twice higher definition at any screen ruling used for the stationary image area;
- reproduction of black or white thin lines by the ink solid or clean paper instead of the scattered or partial dots in any other kind of halftoning;
- higher appearance of contrast and color gamut accompanying the increase of image sharpness and definition;
- these quality improvements at a standard volume of input data and without any special requirements to ink, plate, paper or their interaction in printing.

Figure 21 illustrates the higher frequency response, as compared to halftoning in Harlequin RIP, by the SEF curves produced with the use of the above described method of screening efficiency estimation. Two lower curves for Harlequin regular and diffused screening almost coincide. It may indicate the use of the latter for a random spot function of the same size as for the former with the both of them similar to those shown in Figures 5 and 6.

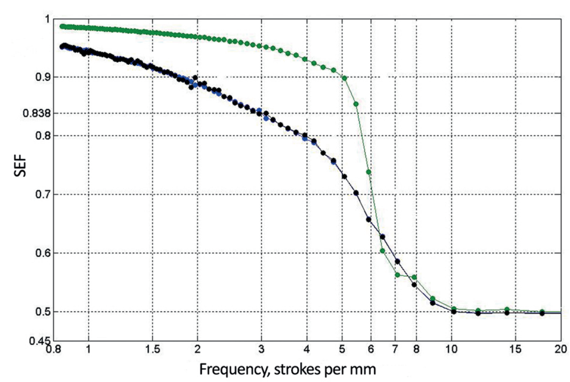


Figure 21: Frequency curves for SEF: HDHP at SF = 2.0 and 150 lpi (upper); two lower (almost coinciding) for Harlequin regular (150 lpi) and for diffused screening

Over a dozen pictures of different content were printed on same sheet in about 1000 copies at standard printing conditions on offset press KBA Rapida 130. The pictures were positioned in pairs allowing for quality comparison of Scitex Class Screening 175 lpi and HDHP. The latter has used as its basic the screen of the former. So, the stationary image area in each pair has had exactly the same tone and color thereby providing the correct conditions for visual comparison of sharpness and definition (Figure 22).

Quality improvement is more evident for pictures containing the greater amount of fine detail and textures and, as well, for gravure in Figure 23. The same periodic screen was also used for whole stationary area but HDHP just for the left part of an image.

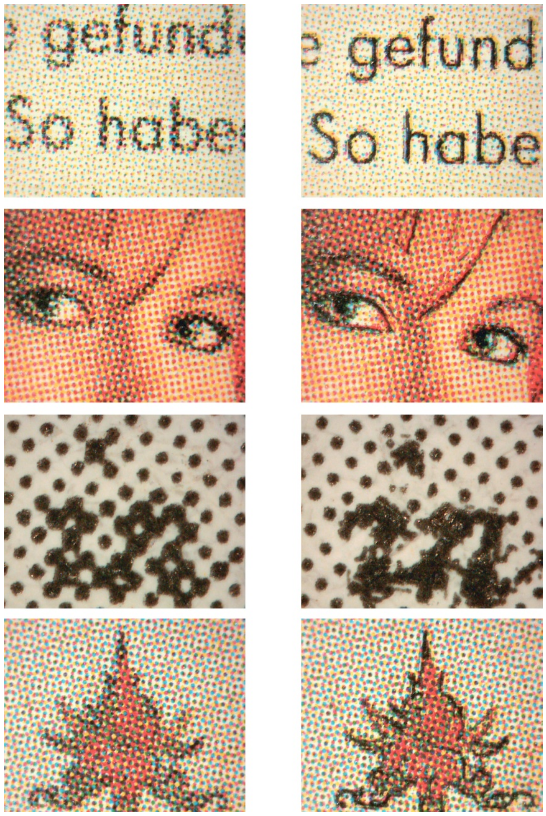


Figure 22: Fragmentary microphotographs of 4-color halftone prints produced at 175 lpi and SF of 2.0 with the use of Scitex Class Screening (left) and HDHP (right), Kuznetsov (2016b)

As it is seen on the enlarged fragment of Figure 23, its HDHP processed left part contains, to the contrary to its right part, the print elements (dots, lines and blanks) much smaller of minimal printable ones conventionally used in the halftone range settings (from 3–5 % to 95–97 %). Being present in output HDHP signal, such elements, nevertheless, doesn't have effect on resulting printability due to such dots/lines loss and blanks filling just once again increasing the contour fidelity.

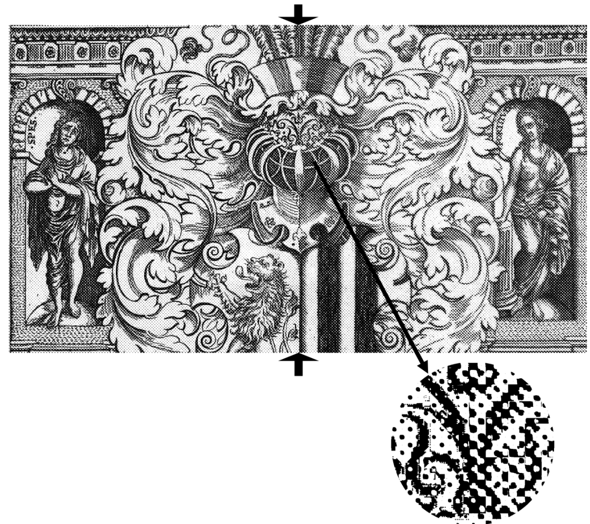


Figure 23: Halftone image of gravure with the use of HDHP (left part) and just of the same basic, conventional spot function (right part), Kuznetsov (2016b)

The rate of improvement increases when the image spatial frequencies are predominantly located in the wave band positioned between the frequencies of a screen and of twice higher input sampling. It is also dependent on the reproduction scale for its effect on the degree and distribution of auxiliary functions use. The special software option was developed to display this use by a histogram in our research (Figure 24). Such kind of visualization can also be useful for the semantic analysis of high frequency image content or to characterize the specific of creating some piece of art, e.g. gravure.

Another print trial has allowed for comparing the HDHP of 175 lpi with the Agfa ABS (175 lpi) and hybrid Agfa Sublima (210 lpi, 240 lpi) technologies. Microphotographs in Figure 25 vividly illustrate the higher sharpness and definition with HDHP at 175 lpi than that of, intended for the same purpose, hybrid screening at as much as 240 lpi.

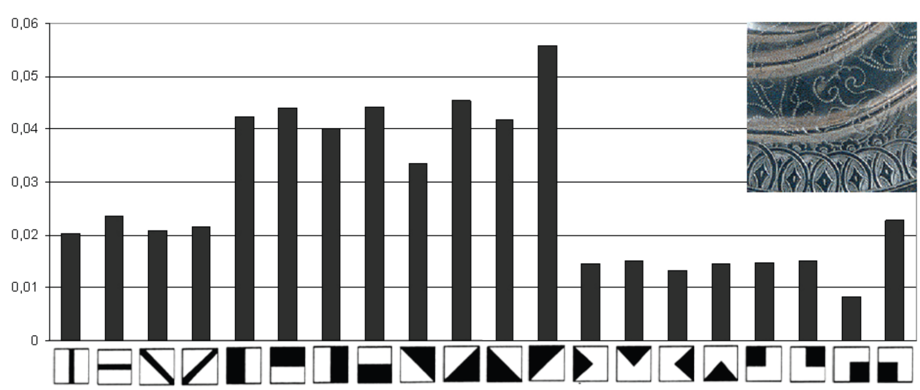


Figure 24: Distribution of various geometry tiles use in adaptive halftoning of the image fragment

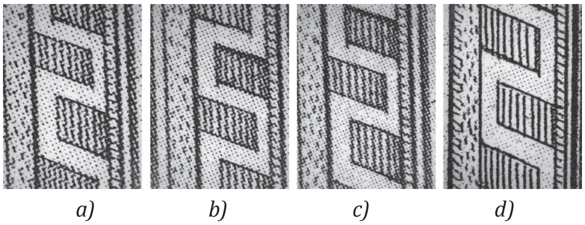


Figure 25: Photographs of halftones produced at SF of 2.0 with the use of (a) Agfa ABS (175 lpi), (b) hybrid Agfa Sublima (210 lpi), (c) hybrid Agfa Sublima (240 lpi) and (d) HDHP (175 lpi), Kuznetsov (2016b)

Advantages were especially evident for the screen printing in various combinations of its relatively low rulings (85 lpi and 100 lpi) with the meshes of 240 and 300 threads/inch on different substrates. The flexography tests have shown rather excessive increase of sharpness which, however, can be easily compensated by the HDHP settings control.

For testing in digital printing the special file was prepared with resolution grids and realistic images. One of its parts is the EPS file produced according the scheme in Figure 27 while the other one is the source TIFF to be halftoned in a printer default mode. The both parts were output on the same sheet.

The lack of resolution is inherent in digital printing (600 dpi against 2 400–5 400 dpi of filmsetters, platesetters). So, a lot of effort was spent and solutions patented for the screening techniques enhancement providing the appropriate screen ruling of digitally printed halftones. Shortage of quantization scale at high rulings was compensated there by the increase of addressability (Kishida, 1991), use of multi clustered screen functions (Kang, 1995), multilevel screening (Jin, et al., 2015) and other means of expanding the halftone dots "alphabet". With such solutions concealed within a printer driver the results we have got for the most of over a dozen tested machines were looking surprisingly good. Some examples are shown in Figure 26.

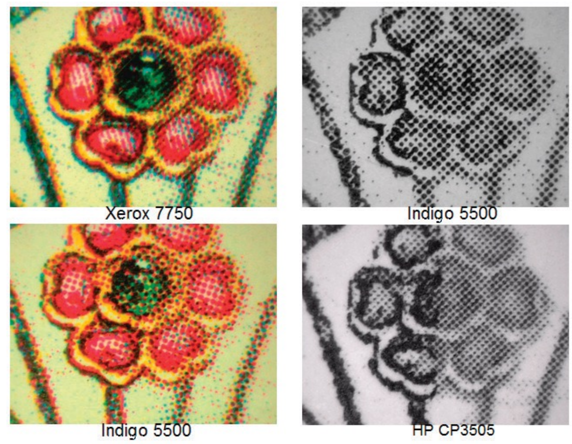


Figure 26: Seamlessly divided fragment of the test file outputs: in a printer default mode (right parts of each image); with use of HDHP (left parts), Kuznetsov (2016b)

4.5 HDHP use in prepress environment and further developments

The latest version of HDHP program creates the according to Equation 2 modified CT file for a stationary image area and the LW mask (bitmap) of tiles for contours and thin lines, the both being then combined in EPS or TIFF file. After EPS file interpretation, the RIP creates a halftone bitmap for CT component and combines it in overprint mode with the LW mask (Figure 27).

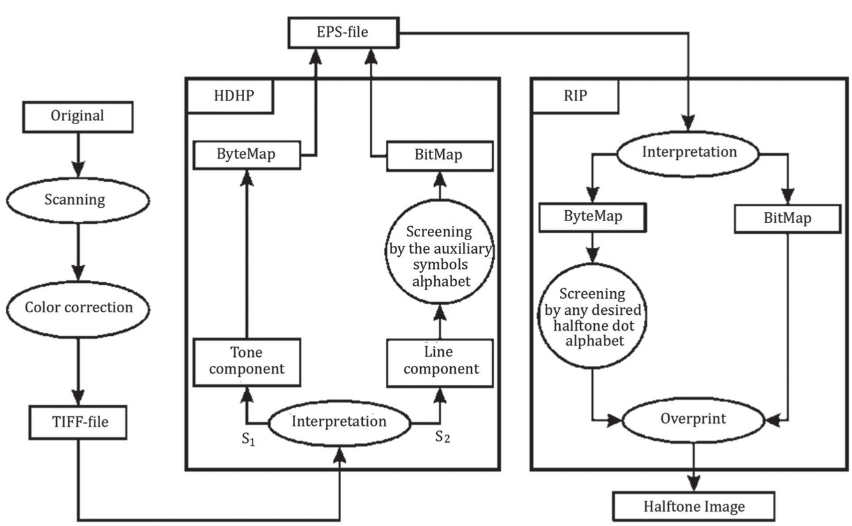


Figure 27: HDHP within the prepress workflow

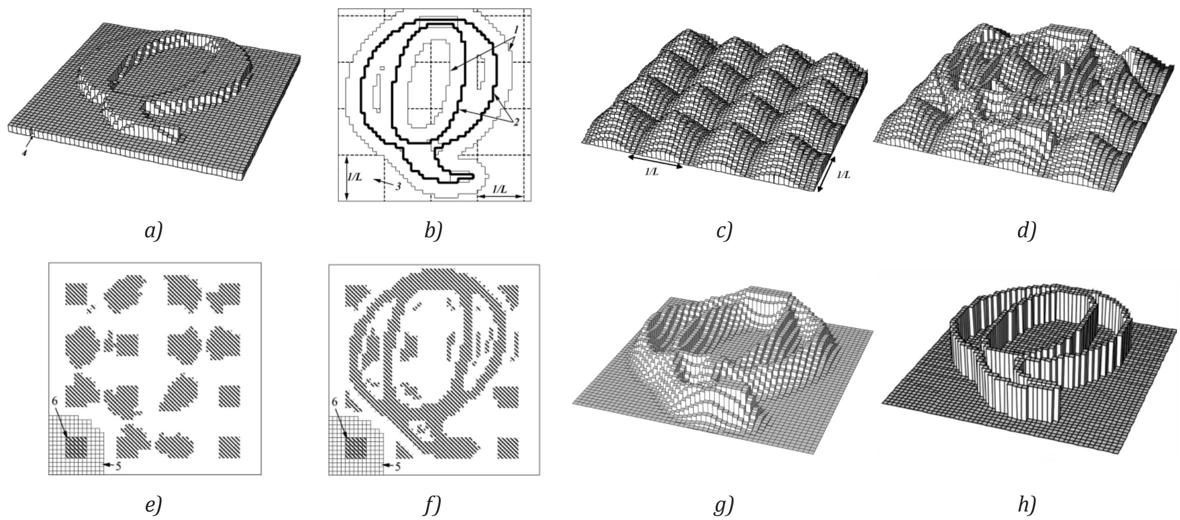


*Figure 28: Halftoning adaptive to arbitrary contour: multilevel fine scan of a dark detail on gray background (a); its scheme (b) designating the margins **1** of tone value dispersion, "trace of contour" **2** and period **3** of a basic screen function shown on (c); resulting screen function (d); halftones (e) and (f) produced correspondingly with the use of functions (c) and (d); auxiliary function (g) generated adaptively to arbitrary contour with the use of its "trace" signal (h) within margins **1** of (b), Kuznetsov and Shadenko (2005)*

This way of operating allows for exactly the same tone and color rendition as provided by a RIP or customer profiles for the stationary area. Moreover, the parts processed in the HDHP mode and in some conventional manner can be seamlessly divided in any area of an image thereby providing the facility of absolutely correct visual comparison of a reproduction quality.

With the on-line use of this HDHP version, the films were output and the number of art books was produced in four color production runs without any additional adjustments of printing conditions or requirements to printing consumables. Some color images seamlessly combining two screening techniques were also published in graphic technical magazines.

Relying on the standard volume of an input image data at SF = 2.0, i.e. in coarse-scan/fine-print mode the HDHP twice increases the halftone definition and improves the quality of standalone lines. However, the printing process resolution still stays about five times higher. For more completely use of this reserve, the fine-scan/fine-print mode with about hundred times larger input image file is required. With taking into account the constant increase of data storage facilities, computation/transmitting speeds and in view of permanently growing requirements to print image quality the processing of such files doesn't nowadays look as problematic as at times of beginning the adaptive screening research.

Instead of operating with the predominantly given set of finite size weight matrices, we have proposed the quantization scale spatial dispersion adaptive to an arbitrary contour as the way to more effective use of the "excessive" volume of an input image data as shown in Figure 28 (Kuznetsov and Shadenko, 2005).

Auxiliary screen function (Figure 28g) can be "on-fly" produced on the basis of the contour "trace or path" signal (Figure 28h) within the margins **1** designated in Figure 28b. This signal is created by the differential operator dealing with the high-resolution input data and that's why it is completely representative for the image high spatial frequency content. With such a signal being formed the input data can be downsampled at over a 100 times compression ratio. So, the combination of downsampled "byte map" and of contour trace signal bitmap may comprise the basis for the file format to be effectively used in fine-scan/fine-print way of a hardcopy production.

5. Conclusions

Basic quality parameters of a graphic arts product are fundamentally dependent on printing element area, form and geometry of placement. So, the screening stays among the most actual issues of illustrative printing. Conflict of tonal and spatial resolution, inherent in this procedure, is solved on behalf of keeping the first of them constant for all the variety of screen frequencies. Their choice depends, in its turn, on the available minimal size of a halftone dot. Providing it over the print sheet within a run is the basic criteria of halftone printing optimal adjustment.

Spatial dispersion of tone measure requires the great excess of a printer resolution over screen ruling which comprises, at the same time, the reserve for print quality improvement. The specific of an HVS should be exploited for more effective use of such resource.

The optimal geometry of a screen and halftone dot, as well as, the way of a dot form variation was empirically found in over a century of halftone printing. The number of later suggested solutions failed to be practical because of the ignoring long-term industry experiences. The need exists in a quantitative method allowing for objective evaluation of screening effect on a print quality. Traditional methods of its estimation incompletely satisfy these purposes due to bi-level nature of halftones. Proposed SEF criteria allow for comparing various screening techniques with the use of its frequency response curves.

Imaging system resources are effectively explored within the tone gradient dependent approach, where the stationary area is presented by some traditional, basic screen, while the set of auxiliary functions of higher frequency provides the dots (tiles) matching the form of detail boundaries.

It is useful to differentiate the way of processing the single and double sharp tone transitions in tone gradient dependent screening.

Relying on the “coarse-scan/fine-print” mode the current HDHP version provides the accuracy of standalone narrow stripes at the level of a printer resolution. However, the further halftone definition increase is limited there due to the lack of a higher frequency input image data.

Instead of operating by predominantly given set of spot functions the better use of an input data excess in “fine-scan/fine-print” system can be provided by the “on-fly” dispersion of tone measure adaptive to the arbitrary contour.

Down-sampled byte map for image stationary part and bitmap for contour trace signal can be combined in the compact file format of such a system.

Results of research and industrial approbation allow foreseeing the adaptive techniques of HDHP kind as “by default” prepress image processing procedures, i.e. as the widespread norm of graphic arts technology.

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The possibilities of RFID and NFC tag implementation in dairy segment

Tina Žurbi

University of Ljubljana, Faculty of Natural Sciences and Engineering,
Department of Textiles, Graphic Arts and Design,
Snežniška ulica 5, SI-1000 Ljubljana

tina.zurbi@gmail.com

Abstract

With the help of printed electronics, the product-consumer relationship can be further evolved and explored, thus enabling the building of a deeper emotional connection. The growing implementation of online connectivity – Internet of things, is one of the important driving factors for the printed electronics market. The goal of our study was to estimate implementation options of printed electronics into the packaging of dairy products according to the type of packaging with considering the approximation of the cost per unit. Knowing that the dairy segment is mainly a commodity, we assume this implementation will have a big influence on the product price. Our research showed that the added value in the commodity segment is too low to be able to cover the cost of implementation of the RFID tag. Printed electronics and, generally speaking, smart packaging has found its place in a segment where a need for security elements or the product is higher priced and the extra cost of a tag does not represent a high burden. There is a great potential in the packaging of pharmaceutical and cosmetic products, where the product's identity is key. There is also a potential in a food segment where food safety is crucial; these are nutritional products for children, for example, baby milk. The main obstacles of printed electronics and smart labels, in general, are in the high unit price per product because the uses are mostly carried out on luxury goods and those are smaller in quantities. Taking it into consideration the printed electronics providers cannot achieve large quantity productions and therefore lowering of price because the economy of scale is insufficient. Until there are no implantations in the segments where the quantities are high, the RFID tag has lesser chance to get its price lowered.

Keywords: smart packaging, consumer interaction, aseptic packaging, food packaging

1. Introduction

Printed electronics (PE) enables the implementation of new types of packaging and product features outside classic static printing technologies. This allows the owner of the brands, manufacturer or retailer to stimulate and persuade the consumer in the purchase activity. The longer the potential consumer is in the emotional phase, the actual purchase is more likely to happen (Achar, et al., 2016). Printed electronics enables to gain the customer attention and keep him in a deeper connection with the product. At the same time, the use of PE enables communication directly to the consumer in real time; for example, it can offer customized solutions, discounts and promotional prizes. The expanding collection of connected things and the growth of Internet of things (IoT) is showing a need for new technology and development of PE. According to the new report, PE was valued at USD 3.13 billion in 2015 and is expected to reach USD 12.10 billion by 2022, at a compound annual growth rate (CAGR) of 22.38 % between 2016 and 2022 (MarketsandMarkets, 2016). By increasing the volume of the economy, the price of PE will drop, and this will ensure its broader use.

Most common usage of PE on the packaging is the use of radio-frequency identification (RFID) tags and sensors for inventory management, tracing in logistics, and monitoring of temperature regime. The PE usage in the marketing, advertising and point of sale is strongly oriented into the usage of near-field communication (NFC) tags. The PE is also essential to promote customer loyalty and retention. Many consumers carry many loyalty cards, and with PE this becomes economical and at the same time feasible to turn them into smart cards. They can store data and enable wireless interaction. When a consumer enters the store, makes it easier to communicate promotions and other features that make it possible to adjust shopping experience. At the same time, from a producer or trade point of view, PE are also crucial, as the applicable technologies provide security against counterfeiters and fraudsters (Vanderroost, et al., 2014). Communication possibilities are not yet introduced in commodity goods due to yet not analyzed reasons – which are the basic goals of this study.

The advantages of using RFID technology in retail are obvious, as vendors can monitor their goods throughout the store and thus have instant information, in a case when a product on the shelf is running out. This greatly enhances the precision of the inventory and reduces the management of stocks. It is also possible to maintain lower inventory and at the same time to manage purchasing statistics, thereby simultaneously reducing costs (Kaur, et al., 2011; Swedberg, 2013). The cost, on the other hand, is also dramatically reduced by the more effective anti-theft protection offered by the aforementioned system. The payment process itself at the end of the purchase is much faster, as there is no need to scan each product separately. Moreover, the purchase can be simultaneously added to the buyers account during the purchase time and is displayed on the shopping cart.

Looking at the implementation of RFID and NFC tag, we looked also on the main differences. The RFID is a one-way process in the discussed field since information is transmitted from an encrypted memory chip (known as a “smart tag”) via the antenna to the RFID reader itself. Active RFID tags contain an energy source so they can emit a signal up to 100 meters, but passive RFID tags do not have their own power source and a RFID reader activates them. This allows them to be used for short reading domains, up to 10 meters. Passive RFID tag uses one of three frequency ranges; low frequency (LF), high frequency (HF), and ultra-high frequency (UHF). The NFC operates as a passive RFID HF tag. High-frequency NFC reads smart tags and also has a read-write mode like RFID. If comparing RFID and NFC, last mentioned has the advantage of exceeding the RFID’s one-way limitation (reading only information on a chip, not able to write new information) with two-way communication: card emulation or peer-to-peer (P2P) communication. For example, a smartphone that has the ability to use NFC technology, and today most of them have this feature, can also transfer information back and forth to another device which has an NFC protocol – e.g. contactless payment is an example of the way the cards emulate.

Due to the rise of PE use in packaging on general and the possibility of prolonging consumer interaction, we analyzed the possibility of implementing an RFID and NFC tags in the food-packaging segment, more precisely in the dairy segment. This segment was selected because of its specifics being in lower added value segment where the increasing of the costs can be more influential than in case of products with higher added value, like non-commodity products, mainly as indulgent, premium, bio-products, alcoholic beverages, and in general higher-priced products, like chocolate, coffee, cheese and champagne.

We made an approximated financial estimation of the implementation and analyzed its impact on the product. In this paper, we present the main possibilities of implementation of RFID and NFC tags on three different types of product with different types of packaging and we investigated what kind of technical and financial effects can this application bring.

2. Methodology

2.1 Information collection and analysis

In order to get an outlook on the possible implementation of PE, in our case RFID and NFC tags, we looked upon the different types of temperature control policies, and took three different types of packaging and products, where we decided on the products with different added values, for which the quantities are higher and the types of packaging are widely used in the region (even in Europe). The products of interest were a long-life product (UHT milk), a fresh product (yogurt) and a frozen product (ice cream). The price analysis was performed on a general assumption of population size and dairy production data in Slovenia. Because the production costs information is a trade secret, we made estimation according to publicly known data. To estimate production costs (EPC), we calculated the average shelf price (ASP) collected on the field and online retail stores, deducted it with the current average market price (AMP) of the main ingredient, i.e. milk, and average retail margins (ARM):

$$EPC = ASP - AMP - ARM \quad [1]$$

We used this calculation knowing that the milk consists of 100 % percentage of the main ingredient, in yogurt little less and in ice cream the difference from 100 % has only minor effect – while this is a product with higher added value, consequently there is less impact on the final result. The implementation options were reviewed according to the type of packaging and an indicative calculation to consider what it means regarding the approximation of the cost per unit. Knowing that the dairy segment is mainly in a commodity sector and with that lower added value, we assumed that implementation of an RFID tag will have a big influence on the production price. The implementation possibilities were examined from the packaging structure point of view, considering also the packaging manufacturing process where the process itself can influence the tag functionality.

According to the three types of products and packaging, i.e. long-life milk, fresh yogurt and ice cream, we examined the technical possibilities and cost-effectiveness of the RFID or NFC tag application. Long-life milk has, for the purpose of the safety, also a layer of aluminum, which may cause interference in the signal when the tag is read. According to different providers, these problems are solved with an added secure protective layer on the back or in the last layer of the tag; this either prevents or reduces the interference. Fresh products do not need aluminum layer and there are no such restrictions. However, taking in consideration that the products are filled in a relatively wet environment, the problems may also occur when the tag is in contact with water, but this is only in case when the tag is applied to the outside of the packaging and is actually exposed to external influences. There are possible solutions to this, adding protection layers to the tag, and this may partially or fully solve the wet environment problem. In the case of a long-life and fresh product, the application would be most suitable on the top of the layer of paper, so the tag is protected against the water with a layer of polyethylene. In the case of ice cream, or frozen products, in general, the problem is that low temperatures needed for maintaining the cold regime of frozen products must be less than −18 °C, mostly on average below −24 °C. The currently known RFID technology is ensuring the tags are in full operational in no less than −22 °C.

2.2 Monitoring a typical dairy product – a long-life, fresh and frozen product

A typical process of dairy product tracking and different temperature regimes needed according to the type of product were examined to see to possible solution for implementation of a smart element. In the production of milk and dairy products, all input materials, from raw materials (milk) to all packaging components (paper, caps, foils), need to be traced. Our interest was to see how the traceability of the finished product is carried out. Mostly the production is tracked by using the GS1-128 and EAN-13 code. When the primary packaging is filled, packaging also receives a printed date of production, and on the pallet, the series or batch of the production is also indicated. The pallets are transported to storage under a proper cooling regime and from there transported to the buyer and their successful delivery is recorded. When handling a food product that needs to be cooled, special care must be taken to ensure that the cold chain is not interrupted. Modern refrigerating and freezing transports already have computer-controlled systems, whereby the controller can easily find out what was happening with the product. In the event of system failure or prolonged power failure, the stored products are carefully inspected and usually eliminated from the sale. If the products are left in unfavorable conditions, their temperature rises and microorganisms have better conditions for development and growth. Consumers perceive the development of microorganisms as a process of deterioration, changing the taste, smell and consistency; in short, the product becomes different from the customer expectations. In respect to the cold chain principle and the appropriate storage conditions there are two cooling modes that ensure food safety and quality. For fresh products, the temperature of the cooling must not rise above +8 °C, and when we have frozen products, the temperature must not be above −18 °C.

2.3 Packaging structure

2.3.1 Long-life and fresh product

For long-life product, we examined the aseptic packaging, which basic structure is composed of 6 layers (Tetra Pak, n.d.). From inside out they follow as:

- layer 1 – polyethylene (closes the package at the side facing the contents, liquid);
- layer 2 – polyethylene (connecting the first layer of polyethylene and aluminum, layer 1 and 3);
- layer 3 – aluminum (oxygen and light barrier);
- layer 4 – polyethylene (connecting layer 3 and 5);
- layer 5 – paper, which is the carrier of the strength and stability of the package and at the same time the print media;
- layer 6 – polyethylene (last outside layer protects against external moisture in the production process).

The paper layer is the most important for the hardness of the package and is also the surface that determines the print quality. The polyethylene protects the packaging against external moisture and allows the paper to be laminated on a layer of aluminum. The aluminum protects the product against oxygen and light to maintain its nutritional value and taste at daily temperature. The aseptic package differs from the fresh package in aluminum layer, which is oxygen and air barrier and not needed for shorter shelf life products. However, taking recycling into account, the packaging producers are working on the development of new aseptic packaging without the aluminum layer, replacing it with other high-barrier materials. For example, first mentioned was the use of Toppan GL film – a transparent high-barrier film with the same degree of barrier performance as that of aluminum foil (Steeman, 2014).

2.3.2 Frozen product

The packaging of ice cream cup, so-called thin-walled packaging made of polypropylene is made on the principle of “in-mold” technology. Namely, with the help of a robot, a label is inserted into the tool during the process of plastic injection; in our example a cup and a lid. The label is made from the same material as the injected mold, so it is a perfect fusion of both materials and the temperatures in the process are exceed the temperature of 200 °C.

2.4 Restrictions of printed RFID tags

There are some restrictions of printed RFID tags. The operating frequency of printed antennas can reach a HF (13.56 MHz) and even an UHF (433–960 MHz) range that meets the requirements that the RFID tag can operate. However, the current problems that hinder the development of the printed market of RFID tags lie in the printing of transistors that could replace the microchip, because the printed transistors can only operate at a very low frequency, which is incompatible with the working frequency of the testers (Kaur, et al., 2011). In addition, only hundreds of transistors are printed based on current printing techniques, while about 10 000 integrated transistors are required in a normal RFID tag. When it comes to dairy products, the problem of water occurs as the functionality could be lost if water is in contact directly with metal parts of the tag. The higher the frequency of a tag, the more problems arise in the RFID system, these can accrue and finally cause that the tag has lower ability to be read. In general, passive UHF tags are intended for use on dielectric materials (non-conductive), such as cardboard, non-carbonic plastics and general non-metallic surfaces typical for use in logistics or production (Stark, 2011).

When used on or near metallic or metallic-dielectric material, signal disturbance can be generated. To reduce the interference, the non-conducting material (spacer) is added between the label and the substance; this significantly reduces the interference. It can be also solved if we place the tag physically away from the metal surface, and in packaging, this is neither practical nor possible (Roberti, 2012).

In the case of multilayer packaging, which has an aluminum layer in its composition, the tags on the inner part are protected, this way we can avoid the disturbance of the signal during the tag reading. In the case of an unprotected back layer of the tag, the reading signal is caught between the layer of aluminum and the tag, so the tag can transmit a poor signal or even not emit. For example, metal can reject RF energy from the tag, which greatly reduces the powering of the antenna, thus preventing good communication with the reader. When we are thinking how to implement the tag we have to consider sustainability and recycling issues as well. It is difficult to separate and recover multilayered packaging, even without RFID tags, besides the fact that it represents a more energy intensive process. At developing packaging equipped with RFID tags, packaging designer should design products that are fit for recycling, and make it easier to separate out potential contaminants (Pullman and Boyd, 2017). Even if RFID tags have no impact on the recycling process, they do have an impact on the processing costs and/or the quality of products, material loss and the recovery rate (Schindler, et al., 2012). According to Benton (2017), acting policy director at environmental thinktank Green Alliance, the main challenge is in ensuring that new inks and NFC chips do not contaminate the recycling process, or enable a reuse loop. Inks are a major reason for down cycling, and NFC chips are essentially unrecyclable as they contain too little metal to separately collect but contain too much metal to not mess up traditional plastics, glass or paper recycling streams. Benton also pointed out the need for communication between packaging designers and recycling bodies, to ensure the products are suitable for recycling; to design the packaging in a way that the potential contaminants could be easier to separate out. To tackle the recyclability issue, the NFC tag producer, ThinFilm, is avoiding the use of silicon in its tags, and they instead invested in a new method of printing on to recyclable strips of thin steel, of a thickness of a human hair (Pullman and Boyd, 2017).

3. Results

In the results we will show first the economical surroundings and the primary elements for monitoring typical dairy products – a long-life, a fresh and a frozen product, following the differences in the packaging structure for all three type of products, ending with the application of RFID and NFC tags.

3.1 Products and their economical surroundings

For estimation of the production and packaging cost, the average shelf price was reduced for the average retail margin and main ingredient – milk. The price of milk was taken from the August 2017 and was indicated at 0.31 euro per liter (SURS, 2017). We have to take into consideration that the milk price differs according to the fluctuation of the milk market during seasons and demand. The average margins in Slovenia are approximately 30 % and they vary according to the different segments (Križnik, 2012). In Table 1 data is collected for average shelf prices of 1 l packaging, reduced for the average margin and for the cost of the main ingredient, milk.

Table 1: Average shelf prices of selected products, net price, and price reduced for the cost of milk

Products	Average shelf price of 1 l (in euro)*	Net price (reducing the average shelf price for 30 % margin, in euro)	Production and packaging cost (net price reduced by milk price, in euro)
Long-life milk	0.80	0.62	0.31
Yogurt	1.70	1.31	1.00
Ice cream	4.50	3.46	3.15

* Information gathered with the research of the prices in the retails in Slovenia.

3.2 The possible applications of RFID and NFC tags

The product tracking in loading and transporting process is easy, and existing systems are well implemented using barcodes GS1-128 and EAN-13. The main cause of misplaced product or shipment is usually a human error when products can be loaded onto another truck or remain in the warehouse.

At the moment, human error is also the only direct economic reason for the introduction of the RFID or NFC tracking system, because it is not enough that only one user is equipped with the aforementioned technology, but it is recommended that the whole chain would be included in the system; manufacturers, logistic transport companies, and final customers. The connected supply chain can contribute to rationalization and can offer a lot of transparency and, most importantly, quick access to information. The contribution would be even greater if the system would be introduced at the point of sale itself and would replace existing barcodes with RFID or NFC technology.

Going a step further, your intelligent refrigerator could detect when the product needs to be replaced with a new one. The most recommended and optimal implementation of the RFID or NFC tag is directly in the packaging and in the case of long-life and fresh product directly between the layers. This requires the cooperation of the packaging provider, the RFID or NFC technology provider and the manufacturer of the product. Currently, the cost of RFID and NFC tags per unit of product for primary goods (commodity goods) is too high to have enough impact and have enough advantages of their use.

3.2.1 Application on the long-life and fresh products

The possible application of an RFID or NFC tag on long-life milk and fresh products were reviewed together while there is a difference in only one layer when it comes to packaging structure – long-life product has additional layer of aluminum.

If we look at our three cases, we are interested in the approximation of the application cost. For the approximation of the tag price, we needed a yearly quantity of tags. When we talked to different manufacturers and RFID technology providers, nobody wanted to explicitly quote the prices, because the price is highly dependent on long-term cooperation, possibilities for implementation, and cooperation with the packaging provider. In fact, it was important to them what kind of business model is behind and for what purpose the tag is used. It is interesting that technological solutions exist; the problem is an economy of scale and thus high price. As we have already said from a hypothetical point of view, passive RFID tag costs roughly 0.10 euros (depends on the specific characteristic or needs) when talking about the quantity of more than 10 million tags per year according to Zorlu (2017), vice president and head of sales for industry segment at Smartrac. For easier estimation of the RFID or NFC tag quantities, we took the production quantities in the Slovenia in 2016 and divided them with three major Slovenian manufactures of dairy products.

This way we came up with an estimation of the production quantities and the possible tag order, in long-life milk, which is around 40 million, and yogurt with estimation quantities below 10 million (SURS, 2017b).

Table 2: Percentage of RFID and NCF tags cost per 1 l unit on the selected products

Products	Tag cost of net price per 1 l unit (in %)	Tag cost of production and packaging costs per 1 l unit (in %)
Long-life milk	16.1	32.3
Yogurt	7.6	10.0
Ice cream	2.9	3.2

In Table 2 the percentage of a tag cost per 1 l unit and current net (or production and packaging) costs for the selected products are shown. From the standpoint of 1 l long-life milk, the cost of a tag represents more than 16 % of the cost of the net price and more than 32 % of the cost of the production and packaging. From the point of view of 1 l of fresh yogurt, the tag cost is approximately 10 % of the production and packaging costs. We did not take into account the cost of research for the implementation of a tag in the packaging, as well as the additional costs of investment in the marketing. A question arises whether the manufacture will be willing to pay at a higher price, which this in milk represents the increase of 17.5 % price, and in yogurt 7.6 % and in ice cream 2.8 % (Table 3) and the answer is no, because the benefits of using the new technologies are yet not well explored from all parties involved to bring the proper return on the investment.

For price comparison, according Kantola, et al. (2009), Coca Cola said that they would not consider using RFID tags until the price decreased to 0.01 dollar per tag (approx. 0.0085 euro), so even big manufacturers concluded that the price of RFID should be much lower.

It would be necessary that the packaging supplier and the tag provider join forces and by increasing the volume of production, they could jointly act on the market and thus offer already final solutions to the consumer. This could bring the acceleration of usage and drop of tag cost. New smart technologies in the low added value segment are difficult to enter, despite the fact that large volumes are provided, and large volumes are lacking in the segment of luxury goods where added value is high.

3.2.2 Application on the frozen product

Unfortunately, we did not get the data for ice cream, but according to the consumption, we can assume that its numbers are even lower. In the case of ice cream, the value added is higher for the mentioned product, and therefore the price of the tag per unit is much smaller, i.e. just above 3 % of the production and packaging costs. However, according to the information from the tag provider (Zorlu, 2017), this normally works in temperature higher than −22 °C, and these products are stored at lower temperatures, which excludes the possibility of use of a tag in frozen goods segment. The tag can be placed on the outside of the packaging and due to temperature fluctuation, the moisture condensation can appear, which additionally makes the use impossible; or we should use tags with a water protection layer, which only further increases the costs. In the market, there are RFID tags specifically for in-mold technology, i.e. Diobond RFID (Inotec, 2017), which consist of a label and UHF inputs. Due to special surface treatment, they are highly resistant to wear, UV light, cleaning agents, weak acids, and chemicals and also higher in price. The tag is attached to the lid or cup during the injection process so that its surface remains smooth. This means that dirt or moisture cannot get under the label, which is essential. This solution is suitable for identifying returnable buckets, which could possibly be used in larger fillings (e.g. 10 liters) such as milk or sour cream for the catering industry, where the pack sizes are larger and can bear the costs.

4. Conclusions

Looking at the growth forecast of PE, a very high growth (MarketsandMarkets, 2016), more than 20 % per year is predicted. The question is in which segment this will become the reality. For commodity goods, like dairy segment, consumers are very price sensitive so that manufacturers cannot hold up to 17 % increase in costs if we look upon long-life product where the quantities are substantial for the lower tag price. Based on our research the added value in the commodity segment is too low to be able to cover the cost of implementation of the tag only for the marketing use, as prolonging the connection with the consumer. Furthermore, many supermarket chains use dairy products, mainly milk, as a dump product to attract customers. This is also the reasons why we do not see uses in the dairy or on general commodity food sector. If we look further from the consumer point of view, the dairy segment already has a very well structured product monitoring (EU region). We see a potential of RFID or NFC tags use for optimization of logistics process to ensure the tracking of different temperature regimes and at the same time to simplify the traceability process. While this means the

Table 3: Price structure of selected products with implemented tag

Products	Cost of the product (production, packaging, milk and tag cost in euro)	Cost of the product with 30 % margin (in euro)	Difference in price to the average shelf price (in %)
Long-life milk	0.72	0.94	17.5
Yogurt	1.41	1.83	7.6
Ice cream	3.56	4.63	2.8

need of reorganizing and building a system where all parties will be involved – from the producer of packaging, filling machine, manufacturer, logistic company and retailer to consumer – the direct cost effect is harder to predict, but packaging companies are already tackling this issue.

In our opinion, even if we are in a commodity business, the dairy segment has its differences while here security is still and a very important factor and consumers wish to know about the origin of the product (i.e. traceability). The cost of a tag in comparison to the benefits should bring the positive effect even if it is more than 0.01 dollar per unit as in Coca Cola case. In our opinion, it could hold up to 0.05 dollar per unit (depends on added value; it means milk consequently less, yogurt more), which is still the half of current tag cost.

Printed electronics and, generally speaking, smart packaging has found its place in a segment where security is key or the product is higher priced and the extra cost of a tag does not represent such a burden. By using smart packaging and thus also PE, there is a great potential in the packaging of pharmaceutical, cosmetic products, where the product's identity is key and also added value much higher. In addition, the aforementioned technology is already used by recognized brands of beverages, clothing, and toys in order to protect their products from counterfeiters while at the same time allowing for greater connectivity with the consumer. There is also a potential in a food segment where food safety is crucial; these are nutritional products for children, for example, baby milk. The main problem of PE and smart labels is generally in the high unit price per product. The current uses of RFID are mostly carried out on luxury goods and those are smaller in quantities. Taking it into consideration, the PE providers cannot achieve large quantity productions and therefore lowering the price because the economy of scale is insufficient. Until there are no implementations in the segments where the quantities are high, the RFID tag has lesser chance to get its price lowered. We found ourselves in a circle and good long-term partnership between producers, packaging and smart solution providers can bring a quicker lowering of the cost of an RFID tag and from this widespread use also in a segment more sensitive to the cost increase.

Acknowledgment

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TOPICALITIES

Edited by Markéta Držková

CONTENTS

News & more

The 2017 Publications from CIE

Besides organising the CIE Tutorial and Practical Workshop on LED Lamp and Luminaire Testing to CIE S 025 in Switzerland in May (see the Events section in 6(2017)1) and CIE 2017 Midterm Meeting in South Korea later in October, the International Commission on Illumination released several publications in 2017. Those more relevant to the field of print and media technology are presented in the following text. The others include for example the technical reports CIE 222:2017 and CIE 227:2017 dealing with different aspects of lighting in buildings.

CIE 223:2017 – Multispectral Image Formats

This technical report was prepared by the Multispectral Imaging committee, which works under CIE Division 8, Image Technology, and was established to address the issues related to colour imaging applications that employ cameras capable of capturing more than three channels or bands of wavelengths. In search of a common format for the exchange of multispectral images, this document presents the study, development and recommendation of encoding techniques and data formats, along with their testing and evaluation. Only 2D multispectral images are considered. The report introduces fundamentals, the multispectral image model and encoding, requirements for multispectral image formats, and four candidate formats, namely JPEG 2000, Spectral Binary File Format, Natural Vision Multispectral Image Metadata Format, i.e. XML schema (NVXML), and Multispectral Image File Format AIX. Further, three example applications utilising different types of cameras with 6, 10 and 120 bands, respectively, are provided. Finally, the formats presented in the report, as well as other formats and metadata, are compared. The Annex provides the specifications of all the above-mentioned formats except for the first one.

CIE 224:2017 – CIE 2017 Colour Fidelity Index for accurate scientific use

Prepared by the corresponding committee (Colour Fidelity Index) formed under Division 1, Colour and Vision, this technical report first introduces the background and clarifies the purpose of a colour fidelity index, as well as the terminology used within the report. Next, the limitations and inaccuracies in the calculation of the CIE general colour rendering index (R_a) are identified, considering the current status of science and technology especially with respect to the solid-state light sources. Then the development of recommended improvements for the colour rendering index calculation is described. Further, the comparisons of resulting general colour fidelity index values of spectral power distributions with their corresponding general colour rendering index values are made. Finally, the calculation procedure for the general colour fidelity index (R_f) and special colour fidelity indices ($R_{f,i}$) is detailed. The report concludes with recommendations and remarks. The Annex lists spectral radiance factors for the 99 test-colour samples and explains the methods for visualising the colour shifts of the samples and for creating 1 nm interval tables for the data. The corresponding Excel calculation tools and data are available at the CIE website.

Ghent Workgroup Activities in 2017

In the course of the year, GWG welcomed several new members, e.g. the Stuttgart Media University. Several companies achieved the Ghent Workgroup PDF Preflight Certification and the new Ghent PDF Output Suite Version 5.0 (presented in the News & more section of 5(2016)4) was successfully employed to verify the process in various commercial workflows. In spring months, the worldwide survey on PDF workflows was conducted to gain the information about the current situation in the industry, tracking the change since a similar survey conducted in 2008.

In May, the workshops on packaging prepress were organised, followed by one of the Ghent Workgroup meetings. During these months, GWG offers a series of free-to-attend webinars. They are scheduled from November 2017 until February 2018. The first webinar provided a general introduction to the Ghent Workgroup mission and the best practices for PDF workflows; the topics of the next seven are briefly introduced further. The recordings of past webinars are available on the GWG website for all who couldn't attend or want to get back to some details.

9 Reasons to Preflight

For those who don't preflight their PDF's, Didier Haazen summarises why PDF preflight is so important and explains key essentials behind certain PDF features or prefight checks.

PDF 2.0 standards – what's new?

In this webinar, Dietrich von Seggern presents the new features of PDF 2.0 that are relevant for prepress and print and outlines the current state of PDF/X-6 standard, which will be based on the new PDF version.

Although the real-life implementation of these new standards in prepress workflows won't come immediately, it shouldn't take too long, as the main RIP and digital front end vendors took part in PDF 2.0 development.

GWG 2017 PDF Survey Results

In the fourth webinar from the current GWG series, David van Driessche examines the interesting results of the above-mentioned survey, which attracted more than a 1 000 respondents.

PDF and PDF/X-plus

In this one Didier Haazen gives more details on the role of PDF and its importance for the industry, explaining the fundamental differences between individual PDF standards and what they are intended for, as well as the added value of the Ghent Workgroup approach.

How the Ghent PDF Output Suite can help you to check your output workflow?

This webinar is focused on the latest Ghent PDF Output Suite version. Stephan Jaeggi shows how exactly it should be used for checking and improving a PDF output workflow. He explains what can be tested, clarifies the structure of the test patches as well as the amalgamated pages, and advises on the results evaluation.

Processing Steps

The ISO 19593-1 standard is still under development, however, the related GWG specification is available since May 2016 (see the News & more section in 5(2016)4). Lieven Plettinck and Steve Carter in this session outline the key concepts and present corresponding product features.

PDF for Packaging: The missing piece?

David Zwang concludes the webinar series by summing up the progress made in the development of a standardized framework for PDF, supporting the needs of the whole graphic chain, including packaging.

CIE 225:2017 – Optical Measurement of High-Power LEDs

The first of 2017 technical reports prepared within Division 2, Physical Measurement of Light and Radiation, was elaborated by the respective committee. The aim is to provide a method for reproducible and reliable characterisation of high-power light-emitting diodes under DC operation. The results strongly depend on thermal conditions; therefore, it is critical to accurately set the required junction temperature of a diode and keep it stable during the optical measurement. The recommended approach is specified after the introductory part of the report, followed by measurement setups, namely the optical bench, goniophotometer or gonioradiometer, and integrating sphere. The next part deals with photometric, radiometric and colorimetric measurements employing different instruments. The remaining two chapters discuss the calculation of thermal resistance and measurement uncertainties. In five sections of the Annex, the alternative method for setting junction temperatures, extrapolation of forward voltage, characteristics of high-power light-emitting diodes, instrumentation, and calibration standards are provided.

CIE 226:2017 – High-Speed Testing Methods for LEDs

This technical report prepared by the committee of the same name is the second one from Division 2 published in 2017 and addresses specific requirements for measurements on light-emitting diode packages and chips, different in comparison with conventional light sources. Both of these two reports are intended to extend the scope of the technical report on Measurement of LEDs (CIE 127:2007) and complement each other. While the first one provides the measurement methods for laboratories, this one deals with the optical measurement of LEDs and high-power LEDs on a wafer and at a product level in the production environment. Pulse methods are used due to the absence of a heat sink. The document describes the factors that influence the LED performance, pulsed operating conditions, industrial high-speed testing of LED devices, and high-speed testing of LED chips on a wafer. The remaining chapters discuss the correlation between measurements on different levels, conversion of values obtained at rated operation conditions and real operating conditions, measurement uncertainty, and traceability. Thermal management of LED applications is in the Annex.

Recent Fogra Research Report on Abrasion Test Results

The aim of the study on 'Ink cohesion phenomena and possibilities for their standardized evaluation' was to determine the importance of various material parameters on the abrasion test results across different testers and test conditions. While the project involved specimens printed by all techniques, the main part consisted in the testing of 60 sheet-fed offset printed specimens under 35 test conditions using the prüfbau Quartant, IGT RT 4, Danilee Sutherland 2000 and James Heal Midi-Martindale abrasion testers. All results of the abrasion tests were visually evaluated and ranked by several persons, as well as investigated by means of an image analysis system, the prüfbau Print target. In case of the Quartant abrasion test results, the samples were investigated also by means of scanning density measurement, colour measurement under diffuse illumination, and scanner-based image analysis employing the PTS DOMAS system. No reliable correlation between the quantitative optical methods and the visual evaluations was found during the analysis; therefore, the planned multi-dimensional correlation approach couldn't be applied.

Bookshelf

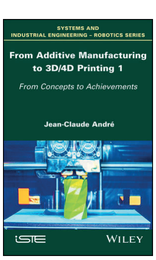
From Additive Manufacturing to 3D/4D Printing 1 & 2: From Concepts to Achievements Current Techniques, Improvements and their Limitations

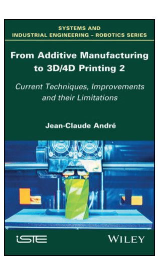
The author of this edition shares his considerable experience, looking through the entire history and discussing various and diverse applications and future outlook of an area where a truly multidisciplinary approach is a must. Thanks to the versatility based on a possibility to employ a number of different principles, experimental setups and conditions, the 3D process can be tailored for all kinds of materials and uses. The outputs can range from highly personalised to industrially produced on a large-scale, with a creative or strictly functional design, as a hobby or for a sophisticated purpose, in sizes from nanometres to decametres. Besides covering all these aspects, the author emphasises also the related social and cultural changes, economy, the role of creativity in research and alike. While the index includes only a few general entries in both volumes, the books are extensively referenced throughout all parts, and where applicable, the text is complemented by numerous illustrations.

The first volume has two parts, starting with the one giving selected significant examples, such as military, spatial and other transport applications, mechanical parts, spare parts and toys, or applications in arts, restoration, medicine and science, and then dealing with the integration of additive manufacturing technologies into society, analysing the economic market, principal application niches, growth and innovation dynamics, etc. The second part brings an overview of 3D processes, machines and materials, presenting stereolithography, a process of wire fusion, sheet or powder glueing process, and powder fusion (sintering), i.e. the majority of current technologies, with the history from 1984 up to now.

In the second volume, organised into three parts, the author explores the limits and current trends in further development. The first part tackles incremental innovations, such as non-layered stereolithography, optical-quality surface finish, cold-cast metal 3D printing, and coloured objects, where some are close to real application, while the others still not advancing beyond the stage of academic interest. Two chapters of the next part are dedicated to microfluidics and to 3D nanomanufacturing, 3D microelectronics and microrobotics. Finally, the third part asks 'How should we go that one step further?' It starts with the favoured spheres of innovation and the conditions for achieving success, continuing with a debate on essential prerequisites to move forward, which include e.g. the management of research, stimulating engagement, diversity within the team, creativity's place, responsibility, and freedom.

The third volume, titled Breakthrough Innovations: Programmable Material, 4D Printing and Bio-printing, will be presented in one of the following issues.





From Additive Manufacturing to 3D/4D Printing 1 & 2:
From Concepts to Achievements
Current Techniques, Improvements and their Limitations
Author: Jean-Claude Andre
Publisher: Wiley
1st ed., November 2017
ISBN: 978-1-786-30119-2 & 978-1-786-30120-8
354 & 350 pages, Hardcover
Available also as an eBook

Standards, Quality Control, and Measurement Sciences in 3D Printing and Additive Manufacturing

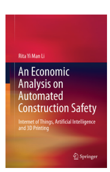
Authors: Chee K. Chua, Chee H. Wong, Wai Y. Yeong

Publisher: Academic Press
1st ed., June 2017
ISBN: 978-0128134894
268 pages, Softcover
Also as an eBook

To foster design and production of safe, reliable and quality 3D-printed products, this book provides the roadmap on additive manufacturing standards as well as on the related measurement sciences and discusses the quality management framework, software and data format, process control and modelling, characterisation and qualification of materials, equipment qualification, and finally the benchmarking.

An Economic Analysis on Automated Construction Safety: Internet of Things, Artificial Intelligence and 3D Printing

Author: Rita Y. M. Li



Publisher: Springer
1st ed., August 2017
ISBN: 978-9811057700
173 pages, 116 images
Hardcover
Also as an eBook

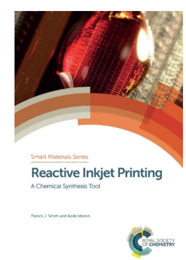
The innovative applications of various information technologies to increase the safety in the construction industry comprise not only robots, building information modelling and software engineering, but also virtual reality and smart working environments using the Internet of Things. Their analyses in this book are based on the literature, big data and real-life examples from different parts of the world, either already working or being in a stage of planning or a proposal, which are complemented by viewpoints of different stakeholders gained by interviews. The results provide the insight into costs, benefits, perspectives and impacts.

Reactive Inkjet Printing: A Chemical Synthesis Tool

This book presents the technique that extends the range of materials which can be patterned by inkjet beyond the materials formulated into ink, enabling to form layers or 3D structures e.g. from systems otherwise needing additives to be inkjet-printable, impairing their desired functionality. Reactive inkjet printing involves dispensing a reactant that chemically reacts either with a material present on the substrate or with a second reactant, benefiting from the ability to dispense different inks in a controlled manner.

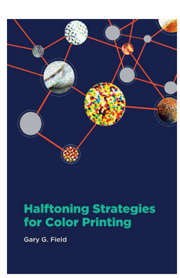
The first four chapters provide the necessary background. After a brief introduction to the concept of reactive inkjet printing and inkjet printing as such, the process of patterning surfaces using inkjet printed droplets is described, including a deposited droplet lifetime, spreading on a surface, phase change, and interaction of multiple droplets. Next, diffusion and advection mechanisms and resulting mixing and reactions in impacting and coalescing droplet are discussed. Unwanted reactions of polymers during the inkjet printing process are also explained. The following chapters present the current research in a broad range of disciplines utilising the reactive inkjet printing, namely silicon solar cell fabrication, oxidation of conducting polymers, self-assembled nanoparticles and quantum dots synthesis, dental applications, silk-based enzyme-powered micro-rockets, additive manufacturing, printing of metals, and tissue engineering.

Reactive Inkjet Printing: A Chemical Synthesis Tool
Editors: Patrick J. Smith, Aoife Morrin
Publisher: Royal Society of Chemistry
1st ed., November 2017
ISBN: 978-1-78262-767-8
284 pages
Hardcover
Available also as an eBook



Halftoning Strategies for Color Printing

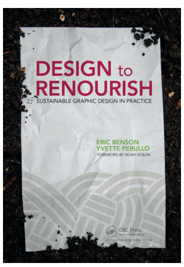
Nowadays, the technology made possible to use a plenty of different halftone structures to achieve the desired colour reproduction; however, the optimal screening choice is not straightforward and decisions still must be made, as different situations require individual solutions, considering the particular printing process and its resolution, substrate properties, original images and desired print quality. The four main sections go through the historical and artistic approaches to tonal rendition, photomechanical halftoning for a four-colour process, halftoning requirements of individual printing techniques, and digital halftoning options.



Halftoning Strategies for Color Printing
Author: Gary G. Field
Publisher: Graphic Communication Institute at Cal Poly
1st ed., February 2017
ISBN: 978-0-9886739-1-5
88 pages
Softcover

Design to Renourish: Sustainable Graphic Design in Practice

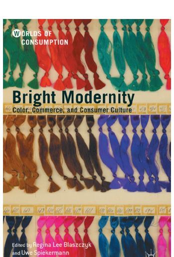
To help graphic designers to create sustainable print and digital work, this book shows how to integrate sustainability into their workflow through strategy, systems thinking and client engagement, while considering also business implications. Getting beyond just selecting recycled paper requires to learn and consider the impacts of material and vendor choices. Providing a practical approach to incorporation of sustainable practices throughout the graphic design process, Design to Renourish fills the gap in literature where is a little information on sustainable practices specific to graphic design. The possibility to adopt the sustainable systems methodology is demonstrated through ten case studies with real-life examples of completed projects. It is shown not only how to avoid the unintended negative consequences of design work, but also how design responsibility can make a positive impact. Besides the careful choice of resources used for production, the level of sustainability can be raised thanks to the messages conveyed.



Design to Renourish: Sustainable Graphic Design in Practice
Authors: Eric Benson, Yvette Perullo
Publisher: Focal Press
1st ed., October 2016
ISBN: 978-1-138-91661-6
156 pages
Softcover
Available also as an eBook

Bright Modernity: Color, Commerce, and Consumer Culture

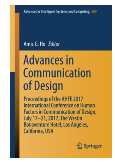
Dealing with the impact of colour on modern Western consumer societies, the book shows that colour is crucial for attracting our attention. After the introductory chapter, surveying a connection between colour and consumption and its environmental impacts, the content is organised into four parts. The first one describes the history starting with the success of dye industry in the second half of the 19th century and colour in education. The second part deals with gender and colour, discussing the gender history of colour and the perception of pink colour, the close connection of the language of fashionable colour and the variety of new dye products, as well as the relationship between coloured goods and colour science. The third part explores colour inventions affecting visual culture – colour printing, movies, and also residential electric lighting. The last part is dedicated to colour management practices in American and European industries, including the coordinated development of leather colours, and also to the significance of colour and trend forecasting in the fashion industry.



Bright Modernity:
Color, Commerce, and Consumer Culture
Editors: Regina L. Blaszczyk, Uwe Spiekermann
Publisher: Palgrave Macmillan
1st ed., August 2017
ISBN: 978-3-319-50744-6
287 pages, 39 images
Hardcover
Available also as an eBook

Advances in Communication of Design

Editor: Amic G. Ho

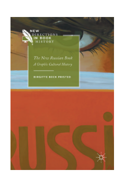


Publisher: Springer
1st ed., June 2017
ISBN: 978-3319604763
153 pages, 55 images
Softcover
Also as an eBook

The Proceedings of the AHFE 2017 International Conference on Human Factors in Communication of Design present the papers in two parts on methodologies and applications, respectively. The first one opens with a paper entitled 'Humanistic teaching pedagogy in typographic communication design' contributed by the editor and further covers e.g. sound patterns, reverse image searches, methods for business communication auditing, campaign websites design, check-in advertising, and generalization of new media. The second part describes the Calligraphy Practice app development and deals with smart device-based notifications, challenges of online meal-ordering platforms, a weak ontology for new media studies, consistency of visual information in web design, and ways to reduce the awareness conflict between users and designers.

The New Russian Book: A Graphic Cultural History

Author: Birgitte B. Pristed

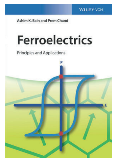


Publisher:
Palgrave Macmillan
1st ed., August 2017
ISBN: 978-3319507071
343 pages, Hardcover
Also as an eBook

This book is based on studies of the author who analysed a broad variety of book covers and compared the Western and Soviet book cultures. It first overviews the Russian book design from the Soviet period to the present, then discusses the changing values in a visual representation of literature, and finally introduces three generations of Russian book designers.

Ferroelectrics: Principles and Applications

Authors: Ashim K. Bain, Prem Chand

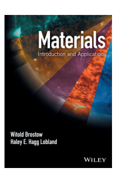


Publisher: Wiley
1st ed., June 2017
ISBN: 978-3527342143
328 pages
Hardcover
Also as an eBook

This reference builds upon hundreds of recent publications on piezoelectric and ferroelectric materials. First, it summarises dielectric properties of materials, introducing energy band in crystals, Fermi–Dirac distribution function, polarisation of dielectrics, dielectrics breakdown, and other basics, and outlines phonons and phase transitions, i.e. microscopic properties. Then, pyroelectricity and piezoelectricity are explained, including piezoelectric materials applications. The main part of the book consists of the chapters on ferroelectricity and ferroelectric ceramics, presenting various types of these materials and their applications in transistors, electro-optic and photorefractive devices, and more.

Materials: Introduction and Applications

Authors/Editors: Witold Brostow, Haley E. Hagg Lobland



Publisher: Wiley
1st ed., October 2016
ISBN: 978-0470523797
480 pages
Hardcover
Also as an eBook

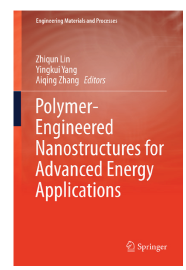
This well-written and comprehensive textbook presents intermolecular forces, thermodynamics and phase diagrams, crystal structures, non-crystalline and porous structures, metals, ceramics, organic raw materials, polymers, composites, biomaterials, liquid crystals and smart materials, their rheological, mechanical, thermophysical, electronic, magnetic, colour and optical properties, surface behaviour and tribology, and materials recycling, sustainability, testing and standards.

Polymer-Engineered Nanostructures for Advanced Energy Applications

Contributed by 50 experts and well supported by hundreds of references and figures, this book summarises the progress in the field of nanostructured polymer materials for advanced energy applications and their unique properties. The applications encompass photovoltaics, fuel cells, thermoelectrics, piezoelectrics, ferroelectrics, batteries, supercapacitors, photocatalysis, and hydrogen generation and storage.

The first part provides an overview of optimal synthesis and processing techniques for nanostructures engineering. Namely, it deals with the polymer-mediated electrospinning for ceramic fibres, the use of polymer microbeads for various metal, semiconductor and polymer nanostructures, the top-down strategies for metal-containing polymers, and various methods for porous polymer materials, structure-tailored polymer photonic crystals, and nanostructured polymeric materials with stimuli-responsive features. The remaining two parts are dedicated to the energy storage and conversion applications, respectively. For example, one chapter within the latter one discusses the means to control the solid-state orientation of conjugated polymers, which can be on a large scale effectively implemented into various organic electronic devices by printing.

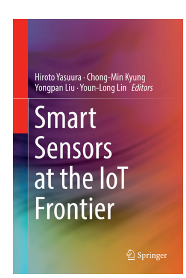
Polymer-Engineered Nanostructures
for Advanced Energy Applications
Editors: Zhiqun Lin, Yingkui Yang, Aiqing Zhang
Publisher: Springer
1st ed., June 2017
ISBN: 978-3-319-57002-0
701 pages, 382 images
Hardcover
Available also as an eBook



Smart Sensors at the IoT Frontier

The aim of this book is to provide current engineering aspects of the Internet of Things, covering materials, processes, circuits, software design, big data domains and measurement methods, especially with respect to smart sensing. The main content consists of contributions of 13 authors or author teams. After smart devices and sensing technology for the Internet of Things presented in the first two parts, the last part provides examples of selected systems and applications. These include LED spectrophotometry, air quality and event detection system, road conditions and events collecting, sensing and visualization in agriculture, learning analytics for eBook-based educational big data in higher education, discussing also security and privacy issues connected to the Internet of Things.

Smart Sensors at the IoT Frontier
*Editors: Hiroto Yasuura, Chong-Min Kyung,
Yongpan Liu, Youn-Long Lin*
Publisher: Springer
1st ed., May 2017
ISBN: 978-3-319-55344-3
378 pages, 252 images
Hardcover
Available also as an eBook



Bookshelf

Academic dissertations

Clothing the Paper: On the State of Newspaper Design, Redesigns, and Art Directors' Perspectives in Contemporary Quality and Popular Newspapers

While originally focused on genre differences between quality and popular newspapers, the aims of the project have evolved to deal with the contemporary newspaper design as a whole, with the reconceptualisation of this topic as an additional research goal. Newspapers, genres, redesigns and identified gaps in related knowledge are introduced and then further detailed in the literature review, which also discusses possible ways to conceptualise newspaper design. The resulting approach involves a naturalistic perspective, the use of metaphors and anthropomorphising. To answer the four research questions on the current state of newspaper design, the way the art directors see newspaper design, redesigns are conducted, and design knowledge is controlled, the research design combines quantitative means and qualitative interviews. A quantitative content analysis of British and Finnish newspapers was used to examine the design of quality and popular newspapers, revealing design features that function as genre markers and showing differences in their use in the UK and Finland. In case of interviews, the results enlighten the use of design features for conveying the newspaper character or creating desired moods on the page, redesign processes, factors influencing redesigns, redesigns implementation and measures actually used for it by today's newspapers, how successful they are, and more. The final chapter contrasts the uniformity of quality newspapers and the variety common for the popular ones, corresponding to the amount of visual energy. It concludes that the redesign processes are inherently different in quality and popular newspapers and stresses the art director's role in redesigns. It also points out the tension between the design guidelines and creativity in the daily production of the newspaper. Finally, the thesis proposes that imagined newspaper personalities can be seen as problem-solving mechanisms in design processes and thus distinct from brands.

Doctoral thesis – Summary

Author:
Jasso J.J. Lamberg

Speciality field:
Graphic Communication

Supervisors:
Andy Goodwyn
Mary Dyson

Degree Conferral:
29 February 2016,
University of Reading, Department of Typography & Graphic Communication
Reading, United Kingdom

Contact:
jasso@comdesres.com

Printed Dielectric Mirrors and Their Application in Organic Electronics

Dealing with a less-common topic within the area of organic electronics, this thesis explored the possibility to fully print dielectric mirrors. Based on interference at thin dielectric layers, they reflect light in a selected wavelength regime, while being almost transparent in other wavelength regions. The aim of the work was to move from expensive physical vapour deposition processing techniques to printing, making them easily scalable. Eventually, they were integrated into printed organic electronics to achieve enhanced functionality without substantially impairing device transparency. After the brief summary of the necessary background, the experimental details are given. In order to deposit layers with nanometre thicknesses on a large scale, mainly doctor blading and spray coating techniques were employed; in some cases, spin coating was required. Materials, device architectures, degradation studies and characterisation methods are specified as well. The core of the dissertation comprises the chapters describing the research on printed dielectric mirrors fabrication and incorporation into solar cells and organic light-emitting diodes. All experiments are well documented, with

Doctoral thesis – Summary

Author:
Carina Bronnbauer

Speciality field:
Materials Science and Engineering

Supervisor:
Christoph Brabec

Defended:
30 March 2017, Friedrich-Alexander-University Erlangen-Nürnberg, Faculty of Engineering
Erlangen, Germany

Contact:
carina.bronnbauer@schott.com

careful simulation and characterisation of the key aspects; for example, an agreement between experimentally determined transmittance spectra and simulated ones was investigated. Similarly, theoretical simulations were applied to optimise the design in case of the more complex tasks, saving material and time in experimental studies. It was shown that the colour, transparency and optical bandwidth of printed dielectric mirrors can be adjusted by changing the layer thickness, material characteristics and the number of double layers. With respect to ink variations, the use of polymer-nanocomposite inks proved highly promising results, allowing to produce very smooth and homogenous layers with various refractive indices. High stability of the fabricated dielectric mirrors was verified through degradation studies involving humidity, light and temperature treatment for over a month. Interestingly, a dielectric mirror stack shows significantly better stability than the corresponding single layers. Separate processing of the solar cell and the dielectric mirror enabled to independently determine how the dielectric mirror affects the final device performance. The increase in photocurrent ranged from 5 % to 45 % depending on a number of factors, e.g. the angle of light incidence and the number of dielectric layers. The integration of a dielectric mirror is recommended in case of thin photoactive layers as well as for photoactive materials with a broad absorption spectrum; in addition, it can be used to modify the device colour, e.g., of perovskite solar cells. The novel device architecture of semi-transparent organic light-emitting diodes and dielectric mirrors allowed guiding the emitted light into a preferred direction. Moreover, colour changing effects, at least at one side of the full device stack, could be achieved by switching the diode on and off.

Doctoral thesis – Summary

Author:
Diogo José Horst

Speciality field:
Production Engineering

Supervisor:
Sergio Mazurek Tebcherani

Defended:
29 May 2017, Federal University of Technology Paraná, PPGEP Ponta Grossa, Paraná, Brasil

Language:
Portuguese

Contact:
diogohorst@hotmail.com

Investigation of the Bioactivity and Thermo-Mechanical Properties of Vegetable Resins and Its Processability in Additive Manufacturing (3D)

Combining the research in two prospective areas, this thesis aimed to analyse the bioactivity of the plant resins against the proliferation of selected pathogenic microorganisms and also to characterise physico-mechanical and thermal properties of these resins in order to verify their applicability in 3D printing, specifically in fused deposition modelling. The bioactivity of the studied vegetable resins, namely the resins of *Stirax benzoin*, *Commiphora myrrha*, and *Boswellia papyrifera*, was determined through the in vitro susceptibility tests using the agar diffusion methodology. The tested microorganisms included *Candida albicans* yeast and three bacteria – *Escherichia coli*, *Pseudomonas aeruginosa*, and *Staphylococcus aureus*. The filaments were made by hot-melt extrusion and 3D printed. Materials were characterised using ultraviolet-visible spectroscopy, Fourier transform infrared spectroscopy, X-ray diffraction, scanning electron microscopy, and differential scanning calorimetry; tensile and compressive strength properties were also tested. In accordance with the literature, it was verified that during the test period the resins under study inhibited the growth of all tested microorganisms, showing a bacteriostatic activity. The use of the automatic cell counting in ImageJ software proved to provide fast and accurate evaluation of bacterial growth, with the possibility to visualise and evaluate also the respective zones of inhibition (halo) created between the resin discs and the pathogenic microorganisms through applying suitable filters. After 48 hours, the mean diameter of the zone of inhibition was in a range of approximately 1–5 mm. With respect to material processing, the tested vegetable resins exhibited suitable characteristics for extrusion and fused deposition modelling at temperatures below 100 °C. Based on thermal analysis, the thermal behaviour of all tested resins is resembling that of semicrystalline polymers, however, each of them has specific characteristics.

Events

VISIGRAPP 2018
13th International Joint Conference on Computer Vision, Imaging and Computer Graphics Theory and Applications

Funchal, Madeira, Portugal
27–29 January 2018

Starting from the 12th edition held last year, this international three-day event comprises four conferences that are focused on theory and applications of computer vision (VISAPP), computer graphics (GRAPP), information visualisation (IVAPP), and human–computer interaction (HUCAPP). In 2018, the programme offers panel discussions, keynotes, technical contributions, mostly divided into six tracks, and also numerous poster presentations.

The two panels are aimed at solved problems, trends, and challenges in vision, visualisation, graphics and interaction, and the benefits of participation in R&D projects. Among the four keynote presenters there are Falk Schreiber dealing with the methodology and applications of the so-called immersive analytics in the life sciences, Catherine Pelachaud with modelling the interaction between humans and Embodied Conversational Agents, Carol O'Sullivan discussing the challenges related to the achievement of plausible perception of physical interactions in mixed reality, and Alexander Bronstein presenting the approach employing geometry tools and deep learning in increasing the accuracy of 3D shape processing problems.

SPIE Applications of 3D Printing 2018

San Francisco, California, USA
27 January to 1 February 2018

Photonics West is a large technical event featuring several plenary presentations, more than 5000 technical contributions, over 70 courses and various networking opportunities, complemented by two exhibitions. The papers on 3D printing, fabrication and manufacturing are highlighted within a dedicated application track.

A number of contributions deal with optics 3D printed by means of different techniques. For example, 3D-printed freeform lenses for random illuminations utilise a modified ink-jet printing technology that uses UV-curable polymer, enabling to achieve subwavelength surface roughness without any post-processing. Another approach is based on laser 3D processing, applied e.g. for high-throughput 3D printing of customised imaging lens without the layer stair-stepping effect and for preparation of functionalised optics. Other papers explore all-inkjet-printed frequency-controlled phased array antennas with multi-angle receiving, dual-mode mobile phone microscope in a form of a 3D-printed clip-on module, 3D-printed phantoms for various biomedical applications, and many more.

Color 2018

San Diego, California, USA
13–16 January 2018

This conference hosted by Printing Industries of America and SGIA (Specialty Graphic Imaging Association) starts on Saturday with a pre-conference afternoon session on the colour management basics, which is free to all registered attendees.

The keynotes include the discussion of the psychology behind colour, design and interaction by David M. Hogue, the design and illustration expertise shared by Brian Yap, the roles of colour and motion in visual communication by Dan Boyarski, and different aspects of brand colour consistency examined by Barry Sanel and Lisa Price. Topics of the Print & Production track cover various uses of G7 specifications, benchmarking and troubleshooting of devices, Apple's new colour space, practical colour management issues, expanded gamut separation and printing, and also the techniques and options for reducing ink consumption. The Brand & Design track deals e.g. with remote proofing and augmented reality included on the packaging, while the Emerging Technology one with optical brighteners and metallic dry inks. The remaining two tracks are dedicated to standards and technology of conference sponsors.

3D Printing Electronics Conference

Eindhoven, Netherlands
23 January 2018

In 2018 this event's programme offers lectures on in-mould electronics, hybrid printed electronics on 3D objects, 3D electronics dimensional control and process assembly, and others.

EFI Connect 2018

Las Vegas, Nevada, USA
23–26 January 2018

This large users' conference offers over 200 sessions for beginner, intermediate and advanced users coming from packaging, commercial, publication and in-plant printers worldwide. Showcasing new technology and product advances, it covers EFI solutions in areas ranging from management information systems, enterprise resource planning and web-to-print, over Fiery servers and software, up to Jetrion presses for digital label printing and other inkjet printers. The sessions advise not only on how to use the individual products but also on how to efficiently combine them to increase the added value, supported by the success stories presented by other users.

C!Print

Lyon, France
6–8 February 2018

C!Print again combines the tradeshow with round tables, thematic guided tours, demonstration areas, technical trainings and workshops. This year, a new area is dedicated to the sign, display and digital markets. The Plug&Play experimentation space features live production as well as demonstrations in three unique pop-up spaces where all visitors can imagine their own projects.

High Security Printing EMEA

Warsaw, Poland
19–21 February 2018

The Polish edition of this Reconnaissance event starts with two pre-conference seminars – one dealing with the three key components to effective counterfeit deterrence, i.e. banknote design and integration, public

EI 2018 – IS&T International Symposium on Electronic Imaging

Burlingame, California, USA
28 January to 1 February 2018

The 2018 event comprises 18 technical conferences and 24 joint sessions in the following topic areas: human perception and cognition for emerging technologies, image capture systems, image reproduction and material appearance, document processing and media security, image and video processing, quality and systems, virtual and augmented reality, 3D and stereoscopic systems, real-time image and video, and web and mobile imaging and visualization.

The plenary lectures feature Greg Corrado exploring the impact of modern machine learning and deep neural networks on imaging and the field of computer vision, Avideh Zahkor presenting fast, automated 3D modelling of buildings and other GPS denied environments based on 3D reality capture, and Ronald T. Azuma discussing what is necessary for achieving ubiquitous, consumer augmented reality systems with a potential to replace current smartphone technology. The list of keynotes consists of almost 30 talks. Those presented within joint sessions include 'Experiencing mixed reality using the Microsoft HoloLens' by Kevin Matherson, 'Computer vision and deep learning applied to simulations and imaging of galaxies and the evolving universe' by Joel Primack, 'Real-time capture of people and environments for immersive computing' by Shahram Izadi, and 'Advances in automotive image sensors' by Boyd Fowler with Johannes Solhusvik.

Further, the rich technical programme is traditionally complemented by the short courses, IS&T awards and the EI Scientist of the Year award presentation, the industry exhibit, the Demonstration Session where the hardware and software presented in papers are shown, and other networking events.

IMI Inkjet Printing Conference 2018

San Diego, California, USA
7–9 February 2018

While the core content of this conference is represented by reports on the latest commercially available inkjet printing technology with its applications and markets, as well as corresponding software, materials and other supplies, the programme also features talks on development in areas less familiar to most of the printers. As a few examples, the lectures discussing printed and flexible hybrid electronics, technological advances in 3D printing including voxel-scale design and engineering, and industrial fabrication of layer stacks on non-flat surfaces can be mentioned. The conference follows the co-located events scheduled on 6–7 February, which include 2018 editions of IMI Conferences on Digital Packaging, Security Printing, and Understanding Inkjet Ink. Their participants can learn e.g. about the smart packaging value proposition and innovations in security inks. Complemented by the IMI Inkjet Academy providing the theory of inkjet technology, all mentioned events together combine within the IMI Digital Print Week 2018.

This American event is a counterpart of the inkjet conferences organised by a sister company IMI Europe, which currently offers the Inkjet Winter Workshop on 22–26 January 2018 in Valencia, Spain.

Nano tech / 3D Printing 2018

Tokyo, Japan
14–16 February 2018

During the Nano tech exhibition, a number of seminar sessions can be attended within the main programme and three tracks of the Seeds&Needs Seminars. While some are in Japanese only, the others are in English or with simultaneous interpretation. These include the contributions dealing with cellulose nanofibres, graphene and materials informatics, among others; all of them are scheduled within the corresponding dedicated symposia.

Other events are held in the same days and organised as a part of the co-located Converting technology exhibition. These include the Printable Electronics and Neo Functional Material seminars, which reflects that the converting industry has expanded to produce semiconductor components, electronics, and aerospace-related items.

6th Colour Management Symposium

Munich, Germany
28 February to 1 March 2018

The symposium motto in 2018 is "Colour communication in scale and multicolour printing – CMYK++". This year, the 25 Years ICC Anniversary Evening Event is the highlight of the programme, celebrating a quarter century of the International Color Consortium. A part of this evening is the keynote of Chris Lilley focused on the colour management of images and video on the Internet and presenting the latest news from the Color on the Web Community Group on CSS Color Module Level 4, SDR and HDR (Standard and High Dynamic Range, respectively), and wide gamut displays. Then, The Color Quiz Night follows.

The programme has seven thematic blocks. First, the brand colour management is in the focus, with managing spot colours from design to print using CxF/X-4 and the state of multi-channel process colour support in PDF, followed by PDF/X in multicolour workflows and extended colour gamut printing prerequisites and benefits, discussing various aspects of cross-process colour communication. The next block presents some real-world implementations of expanded colour gamut in packaging. The fourth one then deals with the printing workflows utilising high-speed inkjet and the machines and software tools available. The second day starts with colour accuracy for both hard- and soft-proofing, presenting also the Cloud Proofing service. Then, the presentations examining the added value of inline spectral colour measurement for process control and digital press benchmarking are scheduled. The final session is reserved for quality evaluation in advanced applications, including 3D printing. At the symposium, the new Fogra Media Wedge Multicolour will be presented for the first time, available at the discounted price.

education and law enforcement, and the other presenting real-life cases of the various methods used for altering, tampering with and counterfeiting of passports and ID documents. The next two days of presentations encompass contributions on currency and identity documents, currency developments and features, production and print, cash management and processing, developments in national eID and ePassports, features for travel and ID documents, authentication and border controls, and other innovations. These include e.g. the new banknote series in Norway, foil features for banknotes, statistics and development of holograms on banknotes, new developments for wiping solution treatment, novel diffractive features based on pulsed laser technology, and the published downstream circulation impact of a change to the polymer.

Inside 3D Printing

Düsseldorf, Germany
21–22 February 2018

The Düsseldorf edition of this event offers several tens of presentations in three tracks, panel discussions, and keynotes. This year, the so far announced plenary talks include the business drivers to 3D printing adoption and opportunities for value creation by Phil Reeves, the discussion on what prevents 3D printing from becoming mainstream manufacturing technology by Thierry Rayna, additive manufacturing as a key digital transformation driver towards a digital factory by Nikolai Zaepernick, and the new simulation-based hatching strategies for powder-bed metal additive manufacturing by Vasily Ploshikhin.

The other 2018 Inside 3D printing events are organised by the Rising Media in Singapore (6–7 February), then in Sydney (9–11 May), São Paulo (11–12 June), Seoul (27–29 June), later in New York (30–31 October), and, finally, the last one for 2018 in Mumbai (19–20 December).

LOPE-C 2018

Munich, Germany
13–15 March 2018

This event for the printed electronics industry combines the trade fair with the programme of business, technical and scientific conferences, starting each day with a plenary session. On the first day, also the short courses are offered. In 2018, they cover perovskite and organic photovoltaic materials, printed electronic and hybrid systems, printing and patterning, biosensors platforms, and roll-to-roll printed sensors for automotive and mobile. With respect to business, the Start-up Forum brings the chance to present the ideas and innovations to investors.

13th Paints Symposium

Athens, Greece
15–16 March 2018

This forum for the coatings industry presents the research results and technology of paints, varnishes and inks. This year, the programme includes the lectures dealing with the microfibrillated cellulose as a coatings additive, current approaches to quantitative surface roughness characterisation, new advancements in artificial weathering testing, printing with carbon nanohybrids, development of water-based conductive gravure inks, and more.

Digiday Publishing Summit

Vail, Colorado, USA
21–23 March 2018

The theme of this event for publishing executives is Building for Sustainability, stressing the need for strategy in all aspects of publishing. Besides that, also practical issues are examined, such as the page load time reduction.

SPIE Smart Structures / Nondestructive Evaluation 2018

Denver, Colorado, USA
4–8 March 2018

The 25th edition of this SPIE symposium features hundreds of technical presentations in 10 parallel conferences, including the new one tracking the progress towards Industry 4.0, live demonstrations of the latest capabilities and applications of electroactive polymers, as well as the course dedicated to the actuators, sensors and devices based on these materials.

With respect to printing technology, mostly the current trends and outlook for 3D printing are in focus, including suitable printers and materials ranging from reprocessable thermosets over highly stretchable hydrogels to microvascular materials for sacrificial templates, as well as characterisation methods. Among various 3D printing applications, for example, the military components, sensors, and different wearable medical devices are covered. The fully inkjet-printed dielectric elastomer actuator with 5 μm thick silicone membrane is also represented.

TAGA 2018 Annual Technical Conference

Baltimore, Maryland, USA
18–21 March 2018

In 2018, this traditional event organised by the Technical Association of the Graphic Arts is stepping into its 70th edition, preserving the proven format.

High-quality publications of active student members can compete in the Harvey Levenson Undergraduate Student Paper Award and the Dusty Rhodes Graduate Student Paper Award. In addition, institutions with an active TAGA student chapter can participate in the Helmut Kipphan Student Publication Competition by submitting a student publication that presents a collection of student research and excels in technical content, print quality and design. All students are also encouraged to submit abstracts for regular presentation at the Annual Technical Conference.

The keynote speakers are Joe Webb, Ken Fleisher, Kate Smith, and Tim Luong, however, the topics have not been announced yet. The list of technical papers to date again covers a wide range of topics from the field of graphic arts and printing. The studies of the conventional printing problems examine e.g. optimal tone reproduction curves for colour printing and what papermaking factors affect lateral web position, while in case of electronic publications, the impact of white space on user experience is evaluated for tablet editions of magazines. Materials and devices are represented for example by the new anti-alteration ink, controllable LED illumination, and the colour viewing system compatible with ISO 3664 standard. Contributions dealing with characterisation and measurement include the comparison of TAPPI brightness and other brightness indices, visual and numerical evaluation of metallic inks, spectrophotometers for measuring samples with optical brightener additives, statistical process control of colour, and more. The emerging trends are covered e.g. by papers describing the development of molecular switches for piezoelectric inkjet, harnessing computer intelligence for rapid makeready, and pioneer examples incorporating NFC into the smart packaging. Yet another type of findings brings the study on employers' expectations of graduates technical and managerial competencies.

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

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UDC 665

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

Vol. 7, 2018

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