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Contents

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Consumer perception of printed point-of-purchase displays

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Abstract

Hedonic shopping value is built with consumers' fantasies, feelings and fun, and it is more subjective than the utilitarian value, which stems from task completion. From the hedonic point of view, it is important to create positive associations and please the consumer. The hedonic aspect of shopping influences satisfaction with the retailer and positive word of mouth, which have an important role in building store loyalty.

Brand owners (BO) communicate their values through multiple platforms, including point-of-purchase (POP) displays. The material choices of the platform must be in line with the message of the BO. It is therefore of interest to know what kinds of mental impressions the consumers gain and attach to POP displays when the material used or the printing method is changed. Getting the message right is very important for building the right kind of image and for stressing the hedonic shopping value.

In this study, we use the experience map to get a better understanding of the hedonic shopping value associated to a selection of (POP) displays. The experience map is used for visualising how the consumers associate different mental impressions with POP display samples and which visual parameters characterise the same samples. Seven samples of POP displays of sweets selling racks were chosen for the study, of which six were printed by inkjet and one by offset. Six different board samples were used, including one sample of corrugated board.

The results indicate that an experience map is well suited to evaluating the mental and visual attributes of the POP displays. Moreover, the experience map can be used to gain a better understanding of hedonic shopping value. Material choices had a clear effect on the mental attributes evoked by the samples. With the right material choices, the inkjet print quality is a good enough substitute for the offset print quality in sweets selling racks and communicating the message of the BO in the desired way. In this case, the consumers preferred the white background in delivering the message of fresh, berried (rich in berries) and delicious sweets over the brown background. The brown background was associated with an ecological image but at the same time it was experienced as fusty (stale) and cheap.

Keywords: consumer experience, experience map, hedonic shopping value, inkjet, POP displays, user experience, substrate selection

1. Introduction and background

A large number, up to 70 %, of retail purchases are unplanned, and some product categories, such as hedonic goods like chocolate, are very likely to be purchased on impulse (Inman, Winer and Ferraro, 2009). In-store communication and point-of-purchase (POP) marketing are much researched areas and they are increasing their share in the marketing expenditure (e.g. Ailawadi, Neslin, and Gedenk, 2001; Areni, Duhan and Kiecker, 1999; Beatty and Ferrell, 1998; Chandon et al., 2009; Jansson, Bonton and Marlow 2003; Sigurdsson, Engilbertsson and Foxall, 2010; Wilkinson, Mason and Paksoy, 1982).

The time to catch the consumers' attention in the store is very short. Hoyer (1984) observed that in a grocery store, it takes an average of 13 seconds from entering the aisle to completing the decision. Furthermore, approximately 4.5 seconds of the time taken is devoted to the chosen brand. Thus, the first communication objective in POP marketing is to catch the attention for the purpose of differentiation. Other objectives are reminding consumers of marketing communications stimuli, providing information about product attributes, creating an image of positive associations, and persuading consumer to impulse buying (Sigurdsson, Engilbertsson and Foxall, 2010). In-store POP displays are one marketing technique to immediately catch the consumer's eye and increase sales.

Our research focuses on creating positive associations with the displays of sweets selling racks produced by

inkjet printing. Digital printing of packaging provides new possibilities for packaging customisation due to cost-effective short runs, on-demand production, and suitability for versatile packaging surfaces (Ewing, 2004). It offers new potential for targeted promotions. Currently, this technology is at an early stage, regardless of its history, which goes back to the 1940s. The idea in digital printing is its comprehensive nature: it is not just printing, but handling a broad service concept that incurporates customised printing as one part of the entity. The trend of tailoring packaging for specific consumer groups, events, and regions is a major opportunity in the printing market (Heilmann and Antikainen, 2009). Inkjet printing has not been widely used in packaging applications. Hence, it is not yet known how the end-users perceive and accept inkjet quality in packaging solutions.

1.1 Utilitarian and hedonic shopping value

The shopping experience can be evaluated based on two dimensions representing how valuable the time spent on shopping was. Utilitarian shopping value reflects *the instrumental benefits* of shopping, whereas the hedonic shopping value is more tied to *the experiential benefits* (Babin, Darden and Griffin, 1994; Babin and Darden, 1995). Utilitarian shopping value has been described as the acquisition of products or services in an efficient manner and it reflects a more task-oriented, cognitive, and non-emotional outcome of shopping. The hedonic part is more subjective than the utilitarian value and stems more from consumers' fantasies, feelings, and fun than from task completion (Babin, Darden and Griffin, 1994; Holbrook and Hirschman, 1982). Jones, Reynolds and Arnold (2006) showed that utilitarian and hedonic shopping values can have different effects on retail outcome variables.

The building blocks of utilitarian shopping value, such as good variety and assortment, as well as the availability of inventoried merchandise, provide a minimum threshold for competition, but not enough for building store loyalty. The hedonic aspect of shopping has more influence on the satisfaction with the retailer, positive word of mouth, and on repatronage anticipation, which have a vital role in building loyalty (Jones, Reynolds and Arnold, 2006).

Babin, Darden and Griffin (1994) have developed a two-dimensional scale of personal shopping value, including both utilitarian and hedonic dimensions. The scale consists of several statements concerning either utilitarian or hedonic aspects of the shopping trip, which are evaluated using a five-point Likert scale (strongly disagree - strongly agree). Without major modifications, the scale has been used, for example, in studying consumers' perceptions of hedonic and utilitarian shopping value associated with general merchandisers, relationships between hedonic and utilitarian shopping value and retail outcome variables, and between inter-activity dimensions and perceived consumption value in e-commerce (Carpenter, 2008; Carpenter and Moore, 2009; Jones, Reynolds and Arnold, 2006; Yoo, Lee and Parka, 2010).

1.2 The effect of point-of-purchase displays on shopping experience

The communication objectives of POP displays can also be divided into utilitarian and hedonic parts, based on the shopping value they reflect, as presented in Table 1.

Table 1: The division of communication objectives of POP displays into utilitarian shopping value and hedonic shopping value. Adapted from (Babin, Darden and Griffin, 1994; Sigurdsson, Engilbertsson and Foxall, 2010)

Communication objectives of POP marketing	
Utilarian shopping value: Task-related and rational	Hedonic shopping value: Entertainment and emotional worth
▪ Catch consumers' attention; ▪ Reminding of marketing communications stimuli; ▪ Giving information about product attributes	▪ Creating positive associations; ▪ Persuading to impulse buying

Earlier research on POP displays has mainly concentrated on their effects on increasing sales, and the main focus has been on the utilitarian aspects of shopping. The findings from the studies are ambivalent. Wilkinson, Mason and Paksoy (1982) found that changes in product display and price reductions appear to increase unit sales of supermarket products more than newspaper advertising does. On the other hand, in the in-store experiment of Sigurdsson, Engilbertsson and Foxall (2010), the POP display did not increase relative sales of the target brand. They suggest that the POP display as a stand-alone marketing communication channel has unreliable effects on increasing sales. The study of Areni, Duhan and Kiecker, (1999) showed that POP displays of wines can actually cause a decrease in sales of the featured brand due to reorganising products within the store. Chandon et al. (2009) studied the effect of the number and position of shelf facings on brand attention and evaluation. They concluded that the number of shelf facings, as well as shelf position, has an influence on visual attention. However, the attention gains do not always improve the brand evaluation.

The different aspects of shopping value have mainly been studied at store level, although differences can be expected to exist between product categories and their marketing messages and methods (e.g. Babin and Darden, 1995; Carpenter and Moore, 2009). Earlier studies on associations and aesthetic responses deal with the design attributes of the product or package (e.g. Veryzer and Hutchinson, 1998; Creusen and Schoormans, 2005; Garber, 1995). Jansson, Bonton and Mar-

low (2003) have also studied the impact of the design attributes 'unity', 'proportion', and 'focal point' on consumer aesthetic responses to POP displays. In addition to these aspects, there has been very little discussion on the hedonic value of POP displays in the literature.

1.3 Research objectives

The current study focuses specifically on the hedonic part of shopping and on creating positive associations with the POP displays of sweets selling racks produced by inkjet printing. As we are, at the same time, studying consumer acceptance of inkjet-printed POP displays, we are concentrating on rather small differences, mainly based on material choices.

The first objective of this study was to *define the experience map* for sweets selling racks printed using offset and inkjet printing, in order to identify the hedonic value associated with the product category and its marketing material. The experience map illustrates how subjective attributes like mental impressions and visual attributes are associated with the samples under study. This research methodology is also presented in a study by Mensonen, Aikala and Laine (2010). In addition, we wanted to find out *whether the inkjet quality is perceived as a good enough substitute for offset* in order to use all the possibilities that inkjet provides for the brand owner. The underlying goal is to answer the question, *is it possible to strengthen the desired associations created by the POP displays with the right material choices*?

2. Materials and methods

The study was focused on the selling racks of sweets boxes (Figure 1b). Six different substrates were printed with an Océ Arizona 350GT flatbed inkjet printer, which uses piezoelectric printing technology. The printer uses UV-curable inks, the drop size which can be varied from 6 to 42 picolitres using OcéVariaDot imaging technology. The inks are dried with a UV-curing lamp. The sample set was completed with the reference sample, which was printed by offset. The samples and their characteristics are presented in Table 2. The L* (luminance), C_{ab}* (chroma), and h_{ab}* (hue) values of the CIELAB colour space were measured from the printed background (inside the letter "o" of the word sm**o**othie) of the poster, and the gloss was measured from the left eye of the panda (Figure 1a).

The Gretag Macbeth SpectroEye was used in the measurements of L*, C_{ab}*, and h_{ab}* values with settings of illuminant D50 and the CIE 1931 2º Standard Observer. A Zehntner ZLR 1050 was used in gloss measurements, with a measuring angle of 20º. Figure 1a shows the layout of the poster. Sample 6 differed from the others as it was printed on single-faced corrugated board. The sample is presented in Figure 2.

a)

b)

Figure 1: a) On the left: The layout of the test poster. The arrows indicate the measuring points. b) On the right: The sweets selling racks

Table 2: The characteristics of the samples

Sample	1	2	3	4	5	6	7
Description	Top and bottom side white. Ink jet.	Top side white, bottom side brown. Ink jet.	Top and bottom side brown. Ink jet.	Top side white, bottom side brown. Ink jet.	Top and bottom side brown. Ink jet.	Brown single faced corrugated board. Ink jet.	Top and bottom side white. Offset. (ref.)
Lightness L*	91	87	59	84	62	54	95
Chroma C_{ab}*	15	16	27	14	25	26	14
Hue angle h_{ab}*	101	100	70	97	73	67	96
Gloss % (20°)	2.9	2.3	1.7	2.1	1.6	1.3	3.8

Figure 2: The single-faced corrugated board (sample 6)

Information on the mental impressions connected with the POP displays and their perceived magnitudes was collected in three stages, involving altogether 61 professionals or consumers. First, 25 persons with professional interest in media but with different backgrounds gave their opinion of the mental impressions evoked by the selling racks. There were more than 70 different impressions given. Mental impressions were grouped based on their similarity, and five groups were found. The mental impressions in three groups described the sample set in a very similar manner to the brand owner's description of the product, and some of the impressions were exactly the same. The mental impressions in the other two groups resembled more of the professionals' thoughts of the product than impressions. The final set of mental impressions was complemented with the impressions of the brand and the product given by the brand owner of the sweets. By regrouping and removing overlapping mental impressions, thirteen impressions were chosen for closer study. The impressions were generated using the Finnish language, and for this paper the chosen ones were translated into English. A short description was added to impressions that couldn't be translated one-to-one. The chosen mental impressions were: ***natural***, ***delicious***, ***fresh***, childlike, ***brisk*** (referring to being lively), fusty (referring to being dull and stale), ecological, cheap, **berried** (referring to being rich in berries), foreign, relaxed, pleasant, and bright. The images shown in bold above were given by the brand owner, images in italics were given by both the brand owner and the professionals, and the remaining images were given by the professionals. The magnitudes of images were evaluated by a consumer panel of 25 people.

The visual quality of the samples was evaluated against four criteria: lightness, colourfulness, gloss, and sharpness. The visual assessment was made by a panel of 11 printing experts. The test persons were given the instructions presented in Table 3. A similar methodology has been used before, in a study by Mensonen, Aikala and Laine (2010).

Principal component analysis (PCA) and attribute mapping were used to create an experience map for the visualisation and interpretation of the results. The original data consisted of a total of 17 observations (assessments of the 4 visual attributes and 13 mental impressions) of each sample.

The locations of the samples were mapped from the 17-dimensional space of the original scales to the plane of the first two principal component axes. This reduced the redundancy in the original data (arising from the correlations between the original scales) and allowed the most significant perceived differences between the samples to be illustrated on a 2-dimensional graph. The principal components are calculated as linear combinations of the original variables so that the maximum amount of variance in the data is explained by the minimum number of principal components.

By mapping the samples and also the original visual and mental impression scales to the principal component axes, the visual perceptions and mental impressions evoked by the samples can be visualised and interpreted, as shown in the next section. Jackson (2003) describes principal component analysis in detail.

Table 3: Instructions for the test persons

Criteria	Instructions
Lightness	Lightness refers to the perceived amount of light reflected by the sample, relative to the light incident on the sample. A sample with higher lightness appears to reflect more light than a sample with lower lightness.
Colourfulness	Colourfulness refers to the perceived purity of chromatic colours. For instance, an intense pure red sample has a higher colourfulness than a greyish subdued red sample.
Gloss	Gloss refers to the specular (mirror-like) reflection of ambient light from the surface of the sample. In highly glossy samples, this specular reflection is stronger than in less glossy samples and can mask the surface colour of the sample (making it hard to see the text and pictures in a magazine, for example) when viewed from a certain angle.
Sharpness	Sharpness refers to the perceived clarity of edges and the visual resolution of small details in a sample. In a sample with higher sharpness, small details in pictures are easier to discern and the edges of objects in pictures appear to be more distinctly defined than in a sample of lower sharpness, for instance.

3. Results

3.1 Visual evaluation

The visual attribute profiles presented in Figure 3 indicate considerable differences between the POP display samples in all of the four evaluated visual attributes. In this sample set, the attributes colourfulness and lightness had a close correlation. Perceived sharpness and gloss also had a relatively high correlation with one another across the samples (with sample 5 slightly deviating from this trend with its relatively higher sharpness, as compared to its own level of perceived gloss), but did not follow the pattern of colourfulness and lightness for all samples. For instance, sample 3 had a relatively high sharpness and gloss but low colourfulness and lightness, as opposed to sample 2, which had very similar levels of perceived lightness and gloss to sample 3 but considerably higher colourfulness and lightness.

The raw data from the evaluation of each of the four visual attributes of the samples consisted of an integer from 0 (the smallest magnitude of the given visual attribute among the POP display samples, as evaluated by the given observer) to 24 (the largest magnitude of the given attribute among the samples, as evaluated by the given observer) for each observation of each sample. Visualisation based on principal component analysis of the variance in evaluations across the 11 observers in the visual evaluation panel revealed outlier observations by 2 observers. The observations by these two observers were excluded from the analysis. Hence, the results in Figure 3 were derived from the evaluations of the 9 remaining observers.

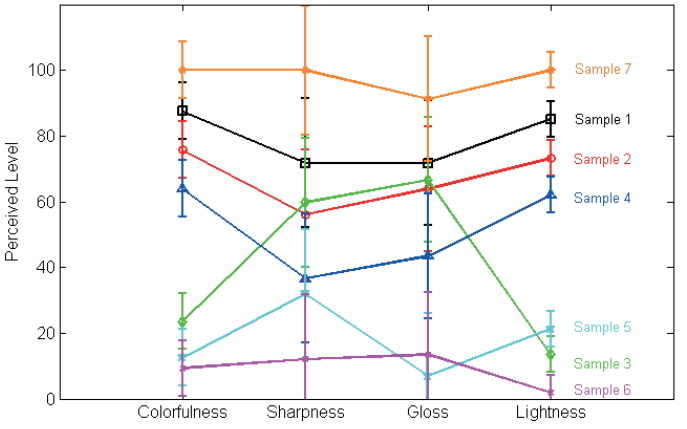

Figure 3: Visual attribute profiles for the seven POP display samples

The scale value for each sample on each visual attribute scale was calculated as the average of individual observations. The scale values were further mapped to a range from 0 to 100 by dividing by 24 and multiplying by 100. Thus, e.g., a sample judged as having the largest magnitude of a given attribute by all observers would receive a scale value of 100. The visual attribute profiles for the seven POP display samples are plotted in Figure 3. The error bars in the figure indicate the least significant difference (LSD, see Meilgaard, Civille and Carr, 1999) between the scale values at 95 % confidence level. When the difference between the scale values of two samples is larger than the LSD value (when the data point corresponding to the scale value of a sample does not lie within the error bars of the other sample in the graph), the difference can be considered to be statistically significant.

3.2 Mental impression

Figure 4 shows an example of the mental impressions associated with the samples. The mental impression magnitude scales, comprising all the 13 mental impressions studied for the 7 POP display samples, are plotted in Figure A1 in the Appendix. The results indicate considerable differences in the mental impressions evoked by the samples. Correlations between some mental impresssion magnitudes are also evident, as presented in Figure 4.

For instance, the scales for the mental impressions "brisk" and "fresh" are very similar to one another, and the Pearson's correlation coefficient for these two scales, $r = 0.995$, indicates very strong linear correlation. The raw data from the mental impressions assessment task consisted of an integer between 0 and 100 for each subjective assessment of the strength of a given mental impression associated with the given POP display sample by the given observer. Analysis of the variation in assessments between the subjects did not reveal any clear outliers or distinct clusters of observers. The 13 mental impression scales were calculated as the averages across assessments of all 25 subjects. The error bars indicate the 95 % confidence intervals for the mean value.

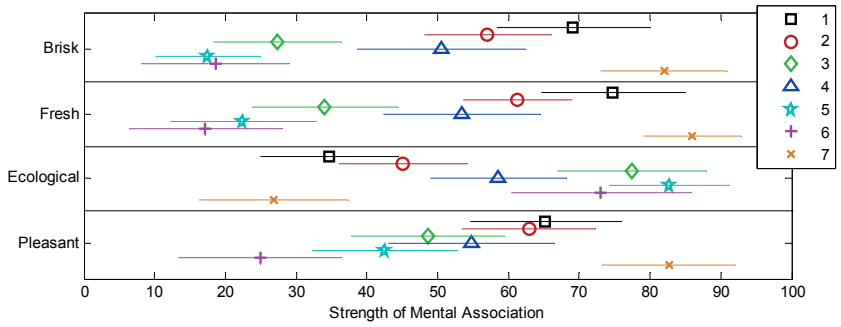

Figure 4: Four of the thirteen mental association scales for the seven POP samples. See Appendix for a graph of all 13 mental association scales

3.3 Experience map

An experience mapping approach, based on principal component analysis (PCA) and attribute mapping, was used to further analyse and visualise the perceived differences between the POP display samples and the relationships between different visual attributes and mental impressions. The visual attribute scales and the mental impression scales were normalised across the samples and combined in a single data matrix. PCA was used to calculate the principal components of this 17-dimensional space (4 visual attributes + 13 mental impresssions). The locations of the samples were mapped from the original 17-dimensional space onto the space of the principal component axes. Roughly 85 % of the variance in the data between the POP display samples can be explained by the first principal component. Together, the first two principal components account for approximately 93 % of the variance between the samples, representing the vast majority of perceived differences between the samples.

Figure 5 shows the locations of the 7 POP display samples on the plane of the first two principal components. The vectors in the graph indicate the relative contributions of the 17 original variables (visual attributes and mental impressions) to the first two principal components.

The approximately horizontal direction of the graph differentiates the samples mainly according to their perceived lightness and colourfulness, with the close correlation between these two attributes shown by their vectors pointing in the same direction. Samples 7 and 1 had the highest colourfulness and lightness and also rated high in association with mental impressions such as fresh, berried, delicious, brisk, and childlike. Negatively correlated with these attributes were the impressions of being fusty, cheap, and ecological (environ-mentally friendly).

The latter impressions were most strongly associated with samples 3, 5, and 6. Gloss and sharpness further differentiated between the samples in a top-right to bottom-left direction in the graph, and contributed to their pleasantness (as did colourfulness and lightness). Relaxed, shown in a smaller point size in Figure 5, was the only attribute for which there were no statistically significant differences between any of the samples at 95 % confidence level.

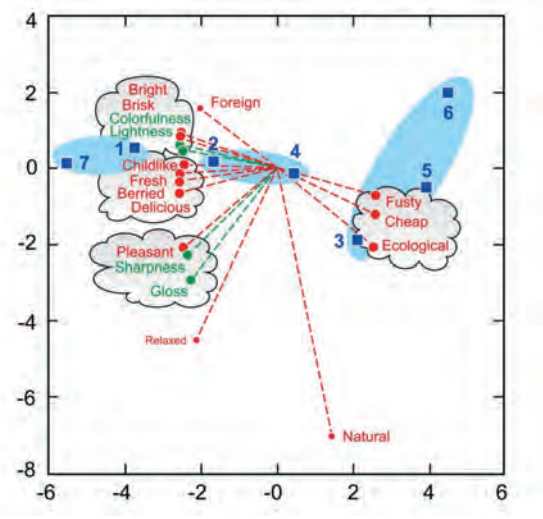

Figure 5: The POP display samples (blue numbers) and the visual attribute (green) and mental association (red) vectors plotted on the plane of principal components 1 and 2

A MANOVA analysis indicated that the mental association evaluation results were significantly different at a 95 % confidence level between all pairs of samples except for the following pairs of samples: samples 1 and 7, samples 2 and 4, samples 3 and 5, samples 3 and 6, and samples 5 and 6. Three groups of samples can thus be distinguished in such a way that the mental impressions are different between the samples of different groups but do not differ significantly between the samples within the group. The first group comprises samples 1 and 7, the second group of samples 2 and 4, and the third group of samples 3, 5, and 6. A MANOVA analysis for the visual evaluation based on the four visual attributes, on the other hand, indicated statistically significant differences between all samples.

This suggests that while some of the samples evoked similar mental impressions, none of them appeared visually identical to another sample on close inspection.

4. Discussion

The results show that, among the studied POP display samples, the large perceived differences in the visual attributes of colourfulness and lightness were further perceptually differentiated between some of the samples (mainly samples 3, 5 and 6) by sharpness and gloss. Sharpness and gloss can also explain some of the variance in pleasantness between the samples, beyond the contribution of the colourfulness and lightness variation to the differences in pleasantness. A part of this pleasantness variation between the samples is independent of the variation in the strength of other mental images, such as the image of being ecological.

Based on the results, the samples printed on brown board (samples 3, 5, and 6) are found to be fusty, cheap, and ecological in consumer evaluation. In earlier studies, ecological packaging has been defined as "minimizing the impact of packaging materials" (Vernuccio, Cozzolino and Michelini 2010; Prendergast and Pitt, 1996; Bone and Corey, 1992). From a material point of view, this means reduced use of materials and packaging material that is ecological or certified, and it can be recycled (Vernuccio, Cozzolino and Michelini, 2010). This can be interpreted as using less processed materials, which means that the shade of the board is brownish like wood fibres or greyish like recycled fibres. Reduced use of materials also includes a reduced amount of ink, which means less colourful images.

The ecological impression in the case of these POP displays for sweets selling racks is strongly related to cheapness and fustiness, which is not the message that the BO wishes to deliver. Hence, care needs to be taken when aiming at an ecological image of the product. Environmentally conscious consumers can be receptive to ecological signs, but the message should not be misleading. Treated poorly, "green" consumers might not only switch brands, but might take others with them as well (Shrum, McCarty and Lowrey, 1995). In this case, the brand owner's desired images (bright, brisk, fresh, berried, and delicious) are close to the reference sample printed on white board with offset (sample 7) and the sample printed on white board with inkjet (sample 1). The chosen materials give the product brisk and bright images. Based on the results, it is recommended to keep the material choices in line with the present state and not to make any radical changes towards materials with a brownish colour.

The results obtained show that there is no significant difference in the measured mental impressions of samples 1 and 7, but in visual attributes there is. This means that the difference is visible although it does not appear to be of importance in practice, with regard to the mental impressions. Thus, it may be concluded that the quality of the inkjet-printed sample (sample 1) is good enough to replace the sample printed by offset (sample 7). Hence, the ability of inkjet printing for personalisation could very well be used to attract the attention of consumers. In addition, through the use of inkjet printing, the POP displays could be printed in as small quantities as needed, and in this way surprise consumers by varying, for example, the display information, colours used, and layout.

From the viewpoint of hedonic shopping value, it is important to create positive associations and please the consumer. The results indicate that the experience map is a useful tool for visualising the interdependence of mental associations, as well as the correlation between mental associations and samples studied. Consumer experience of POP displays can be guided in different directions through material choices. In this study, the material choice had a significantly larger effect on the user experience than the choice of printing method. The link between experienced hedonic shopping value and buying decision was not within the scope of this study but would be an interesting direction for future research.

5. Conclusions

The experience map was used in this study to test the suitability of the method for evaluating hedonic shopping value and the correct marketing messages, through the evaluation of POP displays for sweets selling racks. Seven POP displays were chosen for the study to obtain variability of materials and printing methods.

For the brand owner, it was important to receive information both on the effect of changing the board material used for the POP display and on the potential for replacing the offset printing method with inkjet printing.

Based on the results, the experience map is suitable for giving information on the hedonic shopping value. It could be used to gain more information on the mental impressions associated with the POP displays as well as on the interconnection between the mental impressions and visual attributes. The results show that, with the correct material choice, the inkjet printed POP display was experienced in a very similar manner to the offset printed POP display, even though the samples were visually perceived as different. The results also pointed out the importance of material choice when aiming at certain mental images being associated with the product.

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Appendix A

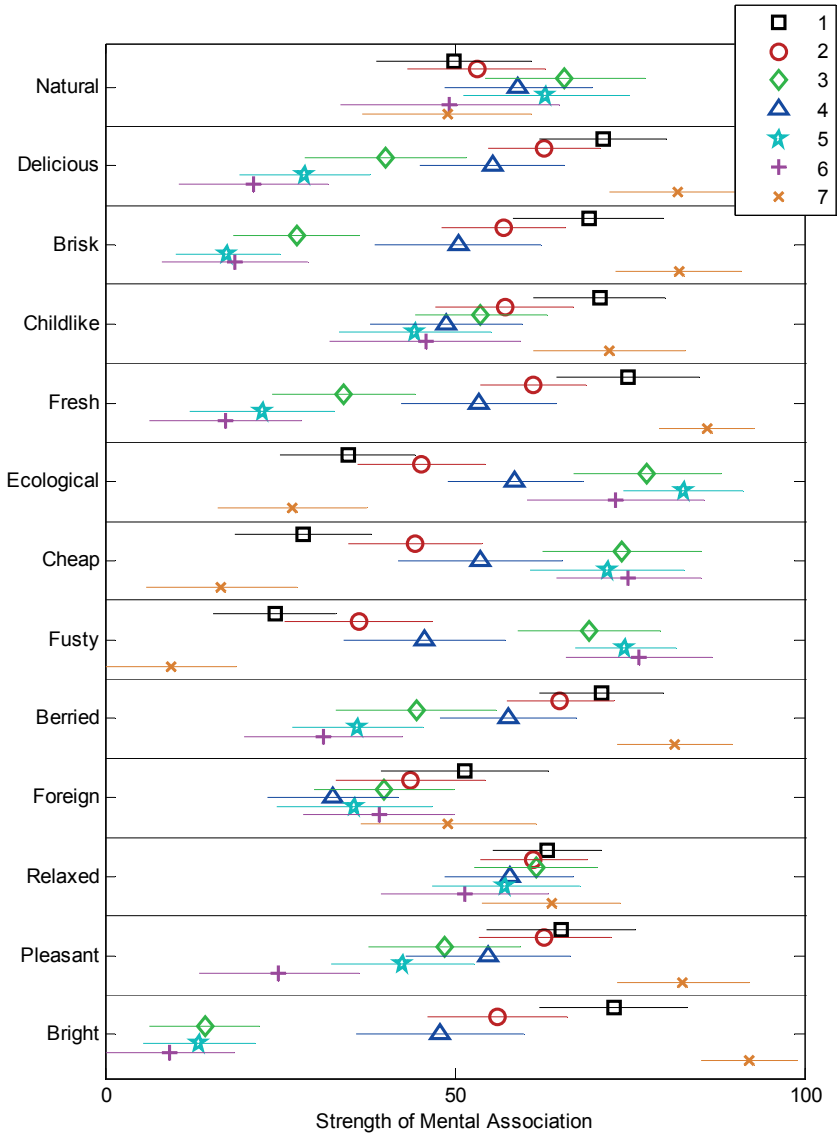

Figure A1: All 13 mental association scales for the seven POP samples

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Local television content production: process structures and climate impacts - a case study

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Abstract

The business environment in which media companies exist today is rapidly changing. If they have not done so already, media companies need to position themselves to this ongoing change and find their place in the new media landscape. However, this could also mean a good opportunity to optimize work processes on different levels. In order to meet these opportunities, as well as being proactive when it comes to environmental performance, we first need to understand the current structure of media companies, for example when it comes to work processes.

The aim of this study is to identify and analyze the process structure and the potential climate impact of the content production of the local television station TV4 Gävle/Dalarna in Sweden. The study objectives are:

- to identify the major editorial and marketing processes and to visualize the two workflows in order to discover how the processes could be optimized and how this in turn may affect the environmental impact.
- to assess the carbon footprint of the content production of the local television station and to identify the major reasons for this climate change impact.

Two main methods were used - semi-structured interviews and carbon footprint assessment.

The editorial part of the workflow is centered on broadcasting news at certain times. A total of nine process steps were identified in the editorial workflow. The largest amount of person hours can be found in the process steps of content production and content editing. Work is done in order to meet the deadlines which come every time there is a broadcast. This fact puts special demands on the personnel, such as an ability to manage stress and short deadlines, and an ability to handle the technical equipment in one-person teams. There is a total of seven process steps on the marketing side, two of which are located outside of the local television station.

A large part of the carbon footprint from the TV4 Gävle / Dalarna content production is caused by business trips by car. The editorial department makes most of the business trips, but the marketing department is also responsible for some of the trips. The total carbon footprint from the television production is estimated to 52 tons of CO_2 eq/year, including the employees' trips to and from the workplace. The trips to and from work is the second largest contributor to the carbon footprint. When considering the impact per viewer, the result is 0.35 kg of CO_2 eq/viewer and year.

Judging from today's situation, the efficiency on the editorial side is very good. However, it might still be fruitful to consider the travelling practices in order to improve the overall environmental performance.

Keywords: carbon footprint, environmental impact, LCA, media, television, workflow structure

1. Introduction and background

The business environment in which media companies exist today is rapidly changing. "For at least these past couple of decades traditional media industries have been deeply engaged in a relentless process of change and adaptation" (Hultén et al., 2010). According to Hultén et al. (2010), this process consists of responses to new technologies and to changes in the business operations of media firms, of which the most important are ownership consolidations and the present recession. Stand-alone media firms are being merged and transformed into even bigger conglomerates and chains of multimedia corporations, often publicly traded and often international (Hultén et al., 2010). According to Achtenhagen and Raviola (2007), organizational structures at media companies will become even more complex in the future, due to these consolidations and changes in the media landscape. At a time where many media companies struggle with their financial performance, it might be worthwhile for them to review their organizational practices in order to improve performances (Achtenhagen and Raviola, 2007).

Different incentives to facilitate environmental improvements are also likely to become more common, and a proactive media company needs to consider and act upon its environmental performance (Teljas et al., 2007). Globally, the entertainment and media sectors account for a couple of percent of the total greenhouse gas emissions (Malmodin et al., 2010).

If they have not done so already, media companies need to position themselves to this ongoing change and find their place in the new media landscape. However, this could also mean a good opportunity to optimize work processes on different levels. In order to meet these opportunities, as well as being proactive when it comes to environmental performance, we first need to understand the current structure of media companies, for example when it comes to work processes.

Several studies on the environmental impacts of media products have been undertaken during the past years, both on the printed and electronic versions of printed media and on broadcasted media such as television (Gard and Keoleian, 2003; Kronqvist et al., 2010; Moberg et al., 2010; Moberg et al., 2011; Reichart and Hischier, 2008; Toffel and Horvath, 2004; Crosbie, 2008). Crosbie, for example, takes a closer look at the television from the perspective of a consumer electronics product. Crosbie encourages an improvement in the energy efficiency of current consumer electronics on the market but does not address the issue of the service infrastructures which support their use, or the development of new technologies.

Reichart and Hischier (2003) analyze and compare the environmental impact associated with reading an online and a printed newspaper with a television broadcast. The environmental impact was assessed using lifecycle assessment (LCA). According to Reichart and Hischier key drivers of the environmental impact for both online newspapers and television broadcast were energy consumption and power generation. "Not only do the manufacturing of the products and their use have an environmental impact, but so does the use of the necessary infrastructure, that is, energy consumption of the telephone network or data transfer via Internet. Printing of online information also turned out to be important" (Reichart and Hischier, 2003). They conclude that reading a printed newspaper causes significant environmental impact relative to watching the television news or reading the online newspaper.

The British Broadcasting Company, the BBC, have done some extensive work on their environmental impact. In 2011, the BBC published a white-paper in collaboration with Cranfield University, which estimates the carbon footprint of two different ways of watching television: using broadcast digital terrestrial television (DTT) and video-on demand (VOD) over the internet. The study compares the two distribution methods and the corresponding consumer equipment, using life cycle assessment (LCA). "The main results showed that broadcast DTT have a smaller carbon footprint per viewer-hour than VOD for average sized audiences, but not with small audiences or for homes using an aerial amplifier" (Chandaria et al., 2011). The largest environmental impact from watching television is from the consumer equipment, according to the study by the BBC. The consumer equipment amounts to 76 percent of the carbon footprint for digital terrestrial television. The results were sensitive to the amount of viewers per display. If the number of viewers per display was doubled, the carbon footprint was reduced by 44 percent for digital terrestrial television. Content production at the BBC generates 10 tons of CO_2 equivalents in average per hour of program produced, according to Chandaria et al. (2011), but this number varies greatly depending on the channel and program genre. The uncertainty factor is 30 percent.

To some extent, the work at a local television station is similar to a regular office. In 2011, Gaidajis and Angelakoglou published a screening life cycle study of an office in a more general sense. It states that the use of energy was the key factor affecting most of the impact categories examined. "This finding is in conformity with the general consensus that the service sector should focus on the reduction of energy consumption in order to improve its environmental performance. Indicatively, in 11 out of 15 impact categories, energy consumption dominated the results" (Gaidajis and Angelakoglou, 2011).

Kronqvist et al. (2010) note that the editorial work processes involved when producing media content also contribute to the environmental impact. However, in most of the studies mentioned above, focus is on media product systems, while the content production part has not been studied as extensively. Work processes in editorial newsrooms have been examined from a research perspective in earlier research. Sabelström Möller (2001) is the most relevant for this case study, because of her study of workflows. Sabelström Möller's research focuses mainly on the workflow of different types of content with regard to different publishing channels, especially printed versus electronic products and services within newspaper companies.

Two case studies of editorial processes and environmental impact were published recently, one with focus on a local newspaper and the other on a monthly magazine (Picha and Moberg, 2011; Picha et al., 2012). Pursuing change in a media company brings an opportunity to optimizing processes and being proactive when it comes to the environmental performance of the company. In order to finding ways to optimize processes and make other improvements, we need to understand the current structure of media companies. Consequently, more research in this field is needed in order to get a good understanding of the structure, work processes and possible improvement options regarding the reduction of environmental impact.

2. Aims and objectives

In order to benefit from the opportunities which are results of the ongoing process of change and adaptation in the media landscape, as well as being proactive when it comes to environmental performance, we need to understand the current structure of media companies, for example when it comes to work processes. The aim of this study is to identify and analyze the process structure and the potential climate change impact of the content production of the local television station TV4 Gävle / Dalarna in Sweden. The study objectives are:

- to identify the major editorial and marketing processes and to visualize the two workflows in order to discover how the processes could be optimized and how this in turn may affect the environmental impact.
- to assess the carbon footprint of the content production of the local television station and to identify the major reasons for this potential climate change impact.

In this case study, we have not looked at the environmental impact of the distribution of content to the user, nor the end-user equipment for watching television. Instead, the focus of this study is the environmental impact from the work processes involved in the content production and at the marketing department of a local television station.

We have investigated the editorial processes in connection to their place in the company structure, and not paid any special attention to the actual television content.

3. Methods

3.1 Methods used

In this study, two main research methods were used - semi-structured interviews and carbon footprint assessment using the life cycle assessment (LCA) methodology for climate impacts. The main purpose of the semi-structured interviews was to identify the process steps involved in the editorial content production. Another purpose of the interviews was to understand the situation in which this local television station exists, and what challenges it is faced with, both on a daily basis and on a more structural level.

3.2 Semi-structured interviews: Process assessment

The interviews were undertaken with the Editorial Manager of the local television station TV4 Gävle/Dalarna and the Marketing Manager at the same television station during March 2011. The interviewees were asked to describe the work organization at the television station, by telling and drawing a flow chart on a large piece of paper. During this descriptive exercise, additional questions were posed connected to the work processes, conditions and challenges. As part of the study, the corresponding author participated at a regular morning meeting and talked in general terms with the rest of the reporters.

The interviews resulted in an overview of the process steps and how they act together to form a content production process where the end product is content ready for distribution from the local television station. The information gained from the interviews was analyzed, using the computer based process modeling program AI0 WIN (Knowledge Based Systems, 2012).

When the overview of the process steps was completed, environmental data was collected for each of the process steps. For each process step, the following environmentally related parameters were considered:

- person hours;
- travel (distance, amount of people, mode);
- computer hours for laptops;
- computer hours for stationary computers;
- use of office material;
- use of other equipment;
- electricity use;
- transport of goods;
- use of delivery firms.

3.3 Life cycle assessment: Carbon footprint

Life cycle assessment (LCA) was used to assess the environmental performance of TV4 Gävle / Dalarna during one year. LCA is an environmental assessment method for considering various potential environmental impacts, including resources used, throughout the whole life cycle of a product or a service, including raw material acquisition, production, use, and disposal or recycling (Baumann and Tillman, 2004). In this particular study, the focus was on greenhouse gas emissions (the carbon footprint). The ReCiPe impact assessment method (Goedkoop et al., 2009) as implemented in the SimaPro LCA software (developed by Pré) was applied to assess the potential climate change impact in the study.

In life cycle assessments, the functional unit plays an important role in the modeling specification since it relates the input and output flows to the function of the product system under study. In some cases, several products are the outcome of one process. In this case the environmental impacts of this process need to be allocated between the products. When there are several products resulting from one process, the allocation may be avoided through so called system expansion. This can be done by including the potential avoidance of the additional products provided, e.g. when waste treatment through incineration is additionally providing electricity and heat. The same amount of electricity and heat can be assumed to be avoided, thus subtracting the environmental impacts related to production of electricity and heat from another source. An allocation problem may also be solved by so called partitioning, when the weight, the monetary value or the use time of the products are used as basis for allocation. See for example Baumann and Tillman (2004) and Finnveden et al. (2009) for more details on the method.

4. System description and data inventory

4.1 The studied company

Today, about 86 percent of the Swedish population watches television on an average day. In 2010, 47 percent of the total population watched the commercial television channel TV4 on an average day, including TV4's specialized channels TV4Plus, TV400, and TV4Fakta. The same percentage (47 percent) watched any of the Public Service television channels on an average day (Nordicom, 2011).

The Swedish television channel TV4 was founded as recently as in 1991, when the monopoly of the government owned Swedish public service television was lifted (Hadenius et al., 2008). The owners of TV4 was at that time the industry related Wallenberg-group, the book publishing company Natur & Kultur and the Farmers' bank, Jordbrukarnas Föreningsbank. The channel started broadcasting in 1992 and was fully built out in 1993 (Hadenius et al., 2008). By creating its first commercial television station TV4 Sweden had conformed to the structure of the media market in the rest of Europe (Hedman, 2008). Today, TV4 is owned to 100 percent by the Swedish Bonnier group (Hultén, 2010).

The digitization of the television broadcasting in Sweden changed the structure of the Swedish media channels completely. With digital television, there is room for more channels in the television network, and there are no longer only the public service television and the channel TV4 which can be watched by "everyone" across Sweden. The analogue terrestrial network was closed down in 2007 (Hadenius et al., 2008).

The year 2007 also meant a breakthrough for watching television over the Internet (Hedman, 2008). According to Hedman, web-television can be seen as evidence of the ongoing convergence of the media market, and brings new opportunities to offer interactive content which is independent of broadcasting time. As a result, new actors on the market, such as newspaper companies and user generated content, will challenge the traditional television companies.

According to Hadenius et al. (2008), 27 percent of all Swedish journalists work with radio or television broadcasting. About 40 percent of the total amount of journalists live and work in the Swedish capital of Stockholm. During recent years, there has been a dramatic change on the work market for journalists. There is an increasing demand for "multi-reporters", the professional identity of journalists is less strong, and the work itself has become less individualistic (Hadenius et al., 2008).

4.2 TV4 Gävle/Dalarna

One way of describing the local television station in this study, is to say that it exists in relation to a number of entities. First and foremost it exists in relation to its viewers in its geographic area. The personnel aim at satisfying their viewers, and in the community, and to what the viewers think of them. Closely connected to the

viewers are the advertisers, which are another entity and an important factor when it comes to the economic survival of the local television station.

The third entity, to which this local television station has an important relation, is the government owned Swedish public service television, which has an office in the same town. The local TV4 station closely follows what is broadcasted on the public local news, and measures itself in relation to that. The fourth entity in this general structure is the main office of TV4, located in the Swedish capital, Stockholm. Crucial decisions are made in Stockholm, and the actual broadcasting is technically done from Stockholm as well. This fact is also affecting the thoughts and actions of the personnel working at the TV4 Gävle/Dalarna (personal interview in March 2011).

When asked about their environmental impact on a general level, the personnel at the local television station had the opinion that they travel much by car in order to report on news events in their geographic area. The area covered by this local television station consists of parts of two Swedish provinces: Dalarna, 29 086 km², with an estimated television-watching population of 267 000 people, and Gästrikland, 18 191 km², where 151 000 people are estimated to watch the local television station (SCB, 2011).

TV4 Gävle/ Dalarna broadcast approximately 28.5 minutes per day on weekdays. They broadcast four times 4.5 minutes in the mornings and 10.5 minutes in the evenings. The remainder of the broadcasting time is filled with national content transmitted from the central office in Stockholm. A total of 12 people (full-time employee equivalents, FTE) worked at TV4 Gävle / Dalarna in 2010 when the first interviews in this research project were done. In 2011 there were a total of 14 FTE. There are offices in the cities of Falun (3 FTE) and Gävle (11 FTE). Of these 14 people, 6 people belong to the marketing department and 8 people belong to the editorial department, including the management group. The personnel at the local television station do not consider themselves to be particularly environmentally conscious, but some of them have the opinion that they would like to become better at thinking about the environment. At the same time, the office in Gävle is very small. It consists of nine people, which gives the employees the impression that the environmental impact "couldn't be so large" (personal interview in March 2011).

4.3 System studied

This study investigates the structure of the editorial and marketing processes at a Swedish local television station, TV4 Gävle/Dalarna. By editorial processes we mean all work steps included in producing editorial content ready to broadcast, but not including the technical side of broadcasting. The actual production of the television commercials is not done at the local television station and therefore not included in the study of work processes. The central computer systems as well as the actual broadcasting are located at the headquarters in Stockholm, and not the local television station. Therefore this part of the process is not included in this study.

Figure 1: The geographical area of Dalarna and Gästrikland, where TV4 Gävle / Dalarna is broadcast

For the assessment of the carbon footprint of the content production, a similar system is studied, i.e. all the processes related to producing editorial and marketing content, including administration. Using a life cycle perspective all the upstream and the downstream processes are included, e.g. the manufacturing of electronic devices used and the waste handling of the office waste. In some cases this has not been possible due to lack of data. This is described later in the inventory section. The function provided by the system studied is television content. This function can be presented in different functional units. Three functional units were considered in the study:

- content produced during one year;
- content for one viewer during one year;
- content for one hour of broadcast.

In this study the environmental data was collected and analyzed for the following activities:

- electricity, heating and cooling in the offices;
- business trips;
- trips to and from the office;
- electronic equipment used for work;
- office paper used in the working process;
- goods transportation;
- water consumption in the office:
- waste utilization.

4.4 Data inventory

4.4.1 Data sources

Specific company data for the carbon footprint assessment was collected mainly by personal communication with the Head of Environmental affairs at TV4. Additionally, information concerning heat and water consumption, and waste utilization in the offices was gathered from the premises' owners (personal interviews with Vi Förenade, 2012; Fastighetssnabben, 2012) and data concerning office paper delivery from the Lyreco company (Lyreco, 2012). It was not possible to collect all the data for only 2010 specifically. Consequently some 2011 data was also used. The size of the offices was the same both these years and the number of employees was 2 FTE higher in 2011. We have assumed that this is a feasible estimation.

All the upstream processes were included in the analysis, such as production of electricity, heating and cooling, manufacturing of transport vehicles, road infrastructure, fuel production and emissions from the vehicles operation; manufacturing of the electronic devices, their transportation to the user and their final disposal; production of office paper, its transportation and then recycling, including the avoided production; emissions from and resources for the waste utilization.

The assessment was made for the editorial department and the marketing department separately. Some data was related to both departments, for example electricity, heating and water consumption. In those cases, the environmental impact was allocated based on the number of FTE. Below, the data for each activity is presented shortly. Data gathered, database processes used as well as references are all provided in the Appendix (pages 230-232).

TV4 Gävle/Dalarna produces local news and has a total broadcast time of about 120 hours/year, excluding commercials. Some of the material is reused during the day, but it was not possible to find out the exact amount in hours of the repeating material, since it is never reused completely, but always edited and mixed with new material. Commercials are produced externally and their production and broadcasting were not included in the assessment. As described in section 4.2 the number of viewers is estimated to be 151 000 persons (SCB, 2011).

4.4.2 Electricity, heating and cooling consumed in the offices

Energy use in the offices includes electricity, heating and cooling. Heating of the offices is provided through district heating; cooling through cooling machines run on electricity. For production of electricity generic Ecoinvent data for Swedish conditions were used (Frischknecht et al., 2007) and for heat production specific Swedish data were used for the heating mix (Svensk Fjärvärme, 2006).

4.4.3 Business trips

Business trips cover the personnel's travels for work reasons. The personnel travels are made by car or train only. For the environmental assessment of business trips the generic Ecoinvent data as implemented in SimaPro 7.3 was used. For the trips by car the data set for the average European fleet of 2010 cars was used. The manufacturing and final disposal of a car, diesel and petrol fuel production, road infrastructure and emissions from a car operation were covered (Spielmann et al., 2007; Jungbluth, 2007). For the trips by train, the generic data for a high speed train in German conditions were used (Spielmann et al., 2007), but the electricity mix was substituted by the Swedish mix (Frischknecht et al., 2007). The data covers manufacturing, maintenance and utilization of a train, necessary infrastructure and operation of the train.

4.4.4 Trips to and from the office

The trips to and from the office include the trips of the personnel by car and by bus. Generic Ecoinvent data was used, covering the manufacturing and final disposal of the vehicles, the road infrastructure, the fuel production and the emissions from operation (Spielmann et al., 2007; Jungbluth, 2007). There is an uncertainty of allocation concerning these data, since the trips to and from the office could be allocated to other activities, and this was not taken into account when gathering data.

4.4.5 Electronic equipment used for work

The electronic equipment in the offices includes desktop and laptop computers, screens, servers, printers, video cameras, mobile phones and television sets. Data for the number and type of the electronic devices in the Falun office was missing, so the assumption was made that the same types of devices are used in both offices and the number of devices was calculated in relation to the number of FTEs and number of devices and FTEs in Gävle. The generic Ecoinvent data was used to assess the environmental impacts of desktop computers, laptop computers, screens, printers and servers, covering the resource extraction for their production, manufacturing and final disposal (Hischier et al., 2007). The final disposal data set was modified in order to include the recycling and recovery of valuable metals (Hischier et al., 2007; Classen et al., 2009). The background data for the mobile phones was based on Bergelin (2008), covering the manufacturing, transportation and end-of-life of the device and excluding the user phase, assuming that the phones are charged in the office, so that the electricity consumption is included in the total office energy consumption. The analysis of the television sets was based on Fraunhofer IZM and PE Europe (2007) including manufacturing, transportation and end-of-life disposal. The video cameras were not included in the assessment due to lack of data.

4.4.6 Office paper used in the working process

Manufacturing of the office paper was assessed using generic Ecoinvent data (Hischier, 2007), covering the average European wood-free uncoated paper production and transportation to the regional storage.

4.4.7 Goods transportation

In this part, the transportation of electronic equipment and office paper to the office was considered. Based on the Ecoinvent data (Hischier et al., 2007) and communication with Madeleine Bergrahm at HP (2011), the distances and means of transportation for electronic equipment were defined in the following way:

- desktop computers, screens, printers, servers and 50 percent of the laptops are transported by boat from Shanghai, China to Rotterdam in the Netherlands;
- 50 percent of laptops are transported by airplane from Shanghai in China to Rotterdam in the Netherlands;
- Desktop computers, screens, printers, servers and laptops are transported by truck from Rotterdam to Stockholm.

The data concerning the distances and means of office paper transportation was collected from the company Lyreco (2012). The paper is transported from the storage in Bankeryd to Stockholm by truck and then from Stockholm to Falun and Gävle by truck. The generic Eco-invent data as implemented in SimaPro 7.3 was used for transportation by truck, boat and plane (Spielmann et al., 2007; Jungbluth, 2007), covering the resource extraction, manufacturing of a vehicle, their maintenance and end-of-life, fuel production, necessary infrastructure and emissions from the vehicle operation.

4.4.8 Water consumption in the office

For the water consumption, generic Ecoinvent data (Althaus et al., 2007) as implemented in SimaPro 7.3 was used. The data covers the infrastructure and energy use for water treatment and transportation to the end user.

4.4.9 Waste management

The management of the various types of waste from the office was considered in this part. According to the information from the building owner in Falun (Fastighetssnabben, 2012) the organic waste from the office is sent to composting and other municipal solid waste is sent to incineration.

The same types of waste treatment were assumed for the Gävle office and the amounts were calculated based on the Falun data per FTE. For the assessment of these processes, the data from the ORWARE model (Björklund, 1998) as implemented in Arushanyan et al. (2012) was used, covering the emissions from the waste management processes as well as its benefits, such as biogas production from composting and heat and electricity recovery from incineration.

The data for the paper waste and its treatment was incomplete. Therefore it was assumed that the amount of paper waste is equal to the amount of paper bought to the office.

It was assumed that 95 percent of the waste goes to recycling and 5 percent goes to incineration. The data for incineration was taken from the ORWARE model (Björklund, 1998) as implemented in Arushanyan et al. (2012) taking into account the emissions from the process and the benefit of energy recovery. Generic Ecoinvent data as implemented in SimaPro 7.3 was used for the paper recycling process with the addition of the benefit of recycling, through system expansion including avoided newsprint production from virgin fibre (Hischier, 2007).

There was no data for the electronic waste from the office, so the amount was assumed based on the amount of electronic equipment used in the office and its life span (IVF, 2007). For the final disposal of the electronic equipment generic Ecoinvent data was used, but modified in order to include the recycling and recovery of valuable metals and corresponding avoided production from virgin sources (Hischier et al., 2007; Classen et al.).

5. Results

5.1 Process structure analysis

As a result of the interviews, a number of process steps were identified and described, according to the principles of the computer processing modeling program AI0 WIN used in this study. The results show that the two departments at TV4 Gävle/Dalarna are strictly separated, also when it comes to the personnel. As an example, the staff at the two departments seldom eats lunch or takes coffee breaks together. The editorial department works with the news content, and the marketing department with the television commercials. This separation serves a purpose, since it is important that the two sides are not influencing each other, thereby affecting the trustworthiness of the editorial content. The editorial content production must follow the general publishing rules, which among other things state that journalistic content should be independent and free from any commercial interests (Hadenius et al., 2008). Since the two departments at the local television station are so divi-

ded, two different process structure analyses were made in this study, in order to illustrate the two separate work flows.

5.2 Process structure of the editorial department

The editorial part of the workflow is centered on broadcasting news at certain times, and the workflow is quite repetitive. A total of nine process steps were identified in the editorial workflow:

1. Preparations and broadcast at 6:30.
   Preparations such as writing telegrams for the earliest broadcast at 6:30 and sending over moving images to the Stockholm headquarters of TV4;
2. Preparations and broadcast at 7:30;
3. Preparations and broadcast at 8:30;
4. Preparations and broadcast at 9:30;
5. Updating the web, handing over to the day team;
6. Preparing and planning content, meeting, writing planning lists, morning meeting with reporters;
7. Producing content, such as looking for background information, traveling to interviews, interviewing and recording, traveling back;
8. Editing the content, sending off the content to Stockholm for the broadcast at 18:30 and updating the web. Some material can be used later, and some is handed over to the evening reporter;
9. Writing telegrams, updating the web, preparing for the broadcast at 22:00 and for tomorrow morning's broadcast.

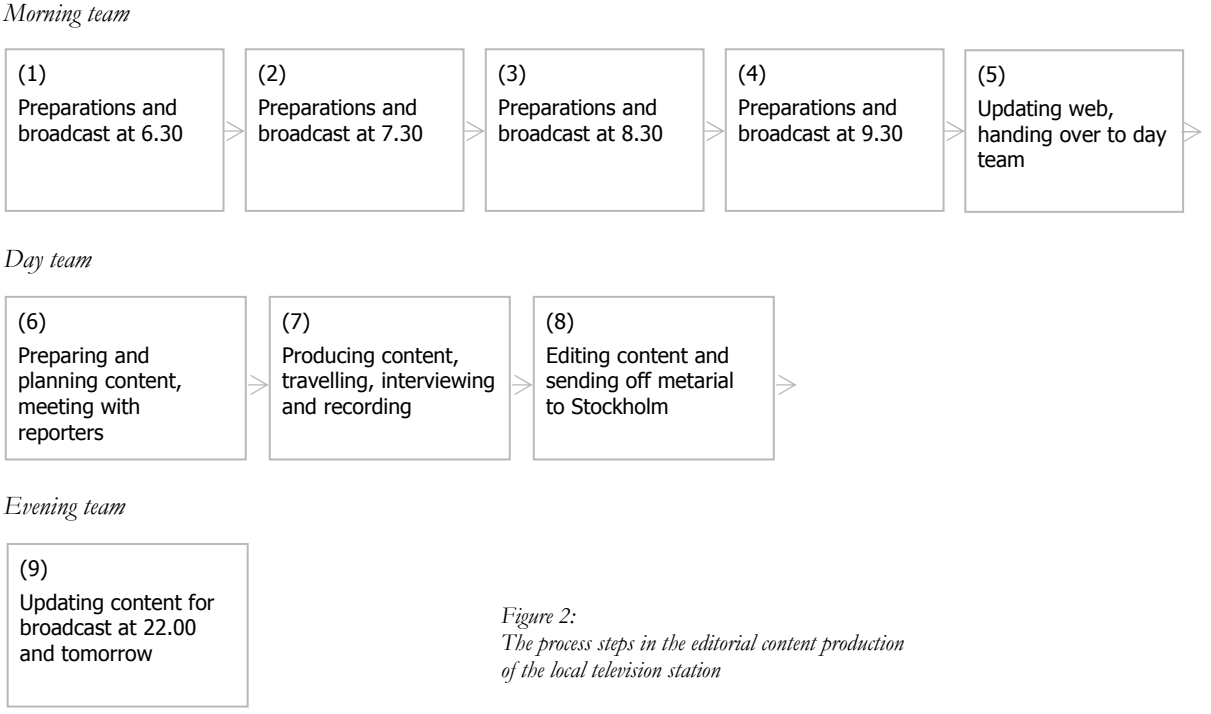


Figure 2:
The process steps in the editorial content production of the local television station

When looking at the time spent on the different process steps, the largest amount of person hours can be found in the process steps 7 and 8 - content production and editing the content. Most reporters work during the office hours when these process steps take place.

It takes more than twice as much time to edit the content than it actually takes to record it, including travel, interviews and recording sound and images. A considerable amount of time is also spent preparing and planning the content, approximately the same amount of time as the producing of content. In general, speed is of essence at a local television station. Work is done in order to meet the deadlines which come every time there is a broadcast. This fact puts special demands on the personnel, such as an ability to manage stress and short deadlines, and an ability to handle the technical equipment. According to interviews with the Editorial Manager of the local television station, the work processes at the station were radically changed a few years ago, when all reporters had to become "multi-reporters", which means that they multi-task and work as photographers, sound technicians and reporters at the same time. The change was pursued in a quite forceful way, where management bought new equipment suited for one-person-teams, and the personnel had to choose between learning how to use this new equipment or leave the company.

As a result, however, all reporters who work at the local television station today are very skilled and professional when it comes to using the television equipment, according to the Manager.

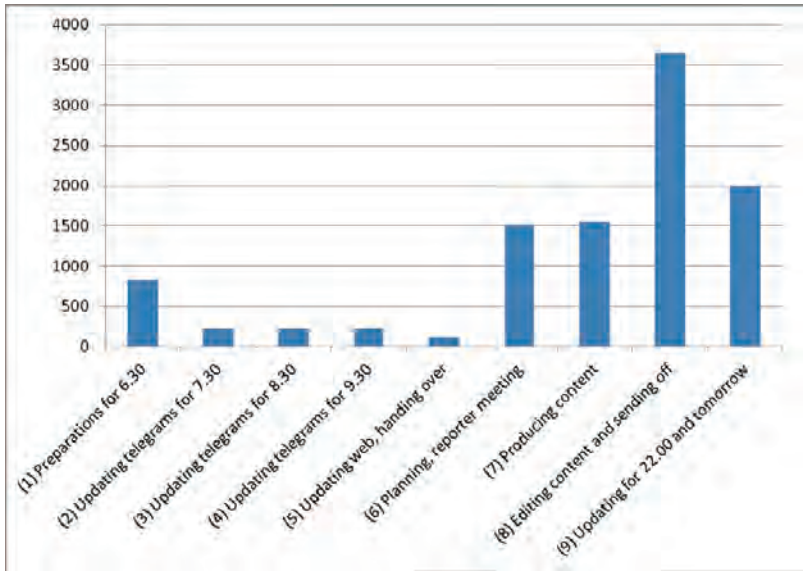


Figure 3: Person hours spent in the different process steps in 2011

5.3 Process analysis of the marketing department

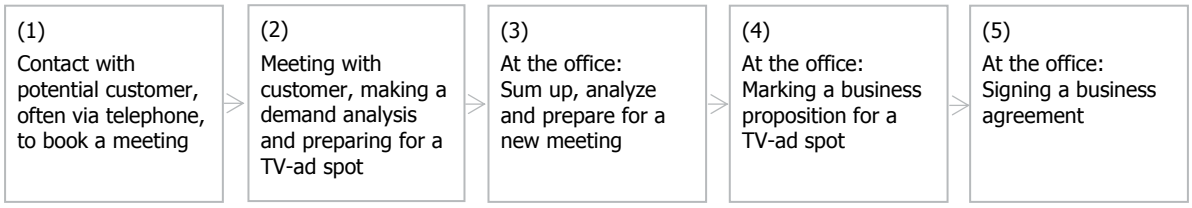
The marketing department at the local television station shares the same office as the editorial staff, but the two departments work separated from each other. The marketing department works in parallel with customer relations and with producers of television commercials, which is often done by separate production companies. Figure 4 illustrates that there are a total of seven process step on the marketing side, of which two are located outside of the local television station. The process steps are as follows:

1. Contact with potential customer, often via telephone, to book a meeting;
2. Meeting with customer, making a demand analysis, and preparing for a television commercial spot;
3. At the office: Sum up, analyze and prepare for a new meeting;
4. At the office: Making a business proposition for a television commercial spot;
5. At the office: Signing a business agreement;
6. Externally: Production process - producing the actual commercial at an external production company;
7. Traffic: Central planning and administration for ad spots and ad material, and evaluation.

Figure 5 illustrates that most person hours are spent on meeting with customers, making demand analyses and preparing for television commercial spots, and business agreements (process step 2 and 5).

Process step 2 also includes all the travel.

Work process at the marketing department:



External processes:

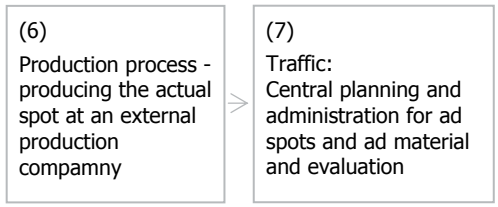


Figure 4:
Process steps in the marketing department at the local television station

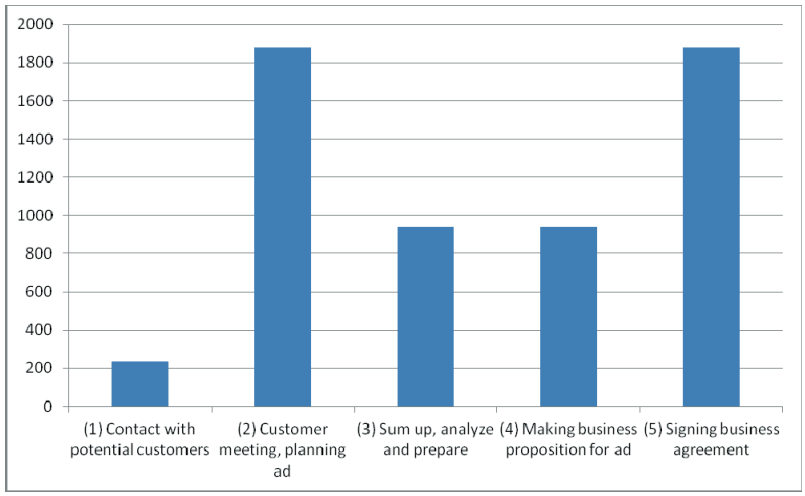


Figure 5: Person hours at the marketing department in 2011, divided up on the process steps, excluding the external process steps

5.4 Other environmental parameters

When looking at the travel habits at TV4 Gävle/Dalarna, there are mainly two work processes that involve travelling. These are content production (process 7) on the editorial side and customer meetings (process 2) on the marketing side. The average daily travel distance is 260 km for the editorial side and 230 km for the marketing side.

When it comes to computer use, the television station uses both stationary computers and laptops. The marketing department has mainly laptops, and the same is true for the Editorial Manager, while the television reporters use stationary computers for writing and editing. The laptops are used approximately 84 600 hours per year, while the stationary computers are used approximately 60 700 hours per year.

At the television station, there is not really a need to use delivery firms, and goods are not transported anywhere except for the weekly fruit basket provided by TV4 to its personnel.

5.5 Carbon footprint

The results of the assessment show that the total carbon footprint from the television content production activities is 52 tons of CO_2 eq/year (see Figure 6). The carbon footprint from the editorial department is higher than from the marketing department. As described earlier, the number of employees at the marketing activities is lower than the number of employees on the editorial side. But even when calculated per employee, the carbon footprint from the editorial activities is still slightly higher: 4.2 tons of CO_2 eq/FTE compared to 3.1 tons of CO_2 eq/FTE from marketing activities.

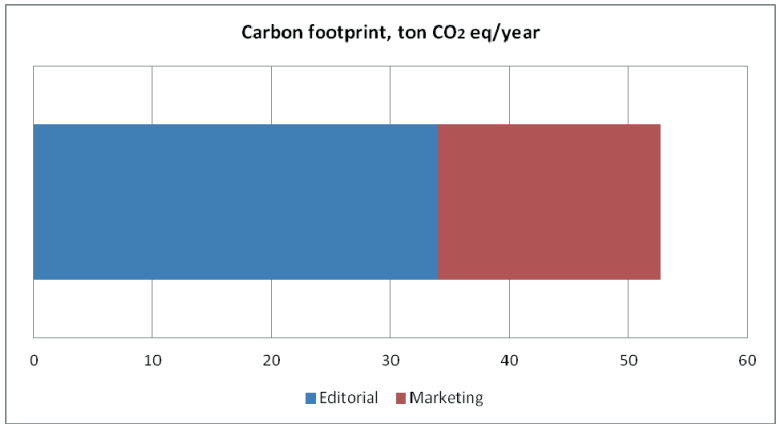


Figure 6: Greenhouse gas emissions (carbon dioxide equivalents) associated with the editorial content production and marketing during one year

The three functional units estimated in this study are: content production for one year, one hour of broadcast and one viewer during a year. The carbon footprint per hour of broadcast is 437 kg CO_2 eq. and, if considering the impact per viewer, the result is 0.35 kg CO_2 eq/viewer and year. Figure 7 demonstrates which activities that give rise to carbon footprint in the editorial and marketing departments.

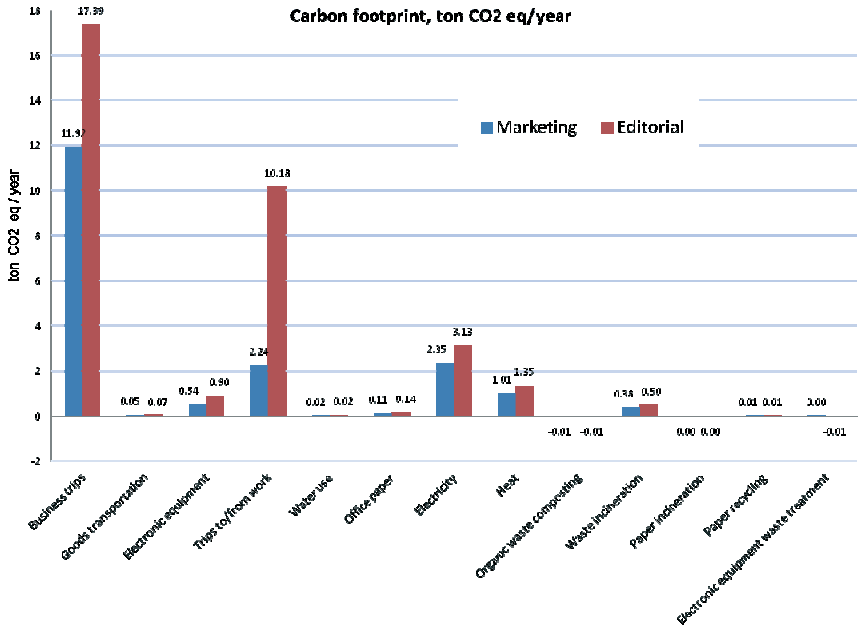


Figure 7: The greenhouse gas emissions (carbon dioxide equivalents) associated with the various activities of editorial content production and marketing during a year

The results of the study show that the climate change potential from the TV4 Gävle / Dalarna content production is originated mainly by the business trips (56 % of the total carbon footprint), most of which are by car. The business trips are a major factor both for editorial and marketing departments, but overall the carbon footprint of the business trips is larger for the editorial department. This can be explained by the number of trips for reporting on news events and a rather high number of trips by the management team (70 trips per year).

Furthermore, trips by the personnel to and from the office are also important (24 percent of the total carbon footprint). In this case, there is a larger difference between the editorial and marketing departments. The editorial personnel uses cars three times as much as marketing personnel if accounted per FTE. However, some of the personnel usually take the bus instead of the car. Such a high difference in car use for trips to and from the office might be explained by the different distances from home to the office.

The other significant contributors to the carbon footprint are electricity, heating and office equipment. The greenhouse gas emissions from the electricity production are originated by the coal incineration, which is part of the Swedish electricity mix. For the heat production, oil and coal burned in the district heating plant incineration, which are part of the Swedish mix used in the assessment, are the reasons for the carbon footprint. The main contribution to the carbon footprint from the electronic equipment comes from manufacturing of desktop computers and screens. However, travel-related greenhouse gas emissions dominate over-all, since the coal and oil content in the Swedish electricity and district heating mixes are not high, and the number of electronic devices used in the TV4 offices is rather low. Some activities in this study have a so-called negative carbon footprint, even though the values are small. These are the waste treatment processes, such as composting, paper incineration and electronic waste recycling. The results are negative due to the benefits of the waste treatment - biogas production from composting, energy recovery from the paper incineration and metal recovery from the electronic waste recycling. These benefits are awarded by including the avoided virgin production of the same benefits.

Paper recycling, on the other hand, still produces greenhouse gas emissions despite of the benefit of the secondary material production. This is due to the emissions caused by the recycling process.

6. Discussion

In this study, we have presented the work processes of the editorial and marketing departments at TV4 Gävle / Dalarna. A total of nine work processes were identified in the editorial department. Most of the person hours were spent producing content in the afternoon, as well as editing and sending off material to Stockholm. A total of seven work processes were identified in the marketing department, of which two are located externally.

Today, all reporters who work at the local television station work in one-person-teams. This implies that one reporter can perform an interview while at the same time record sound and images. Before the reorganization, a team could consist of one reporter, one photographer and one sound technician. However, some aspects that might be lacking in today's work environment are long term planning, evaluations and archiving already broadcasted material. These aspects were not mentioned by the Editorial Manager and the Marketing Manager at the interviews regarding the process structure.

The total carbon footprint from the TV4 content production is estimated to be 52 tons of CO_2 eq/year. This result is company specific and highly dependent on the type of activity. For example the carbon footprint of the content production of a Swedish monthly magazine with focus on interior design, studied by Picha et al. (2012), is lower and constitutes 23 tons of CO_2 eq/year. Compared to an ordinary small office studied by Gaidajis and Angelakoglou, (2011) the impact of the TV4 Dalarna office is 10 times higher. But, the number of people working in the office is significantly lower and no business trips are considered. Also, the trips to and from work are included in the study of TV4.

When looking at the carbon footprint of television content production, it is smaller than for example from BBC production (Chandaria, 2011), constituting 437 kg CO_2 eq/hour of broadcast compared to the 5 000 kg CO_2 eq/hour of broadcast from the BBC. This can be explained by the fact that TV4 Gävle/Dalarna is producing local television, while the BBC works on a national and international level. Different types of television content will give rise to varying carbon footprints, for example depending on the work methods and quality level. Furthermore, the electricity mix in the United Kingdom has a larger carbon footprint than the Swedish electricity mix, which would also affect the overall footprint.

If we were to exclude the carbon footprint from trips to and from the offices, the impact per viewer of the content production at TV4 Gävle/Dalarna constitutes 0.27 kg CO_2 eq/year. As a comparison, the impact from the content production of a Swedish monthly magazine is assessed to be 0.21 kg CO_2 eq/year per reader (Picha et al., 2012). While one reader of a printed magazine studied by Kronquist et al. (2010) generates 1 kg CO_2 equivalents during one year, of which 0.16 kg CO_2 eq come from content production. It is not really possible to compare these various media products, since the content and the number of media consumers are so different. However, the numbers indicate that in this case the carbon footprint per reader is similar.

The carbon footprint assessment shows that the main reasons for the climate change potential are business travel by car, which falls in line with the expectations of the employees, who mentioned that travelling might be the biggest environmental issue related to their work. Business travels also come up among the main reasons for the potential climate change in other studies of media content production (Picha and Moberg, 2011; Picha et al., 2012). The trips to and from work appear to be a significant issue when it comes to the TV4 Gävle/Dalarna editorial and marketing activities. The reason for the relatively high carbon footprint from the trips to and from work might be the location of the office, when many people live outside the town and have to travel long distances every day. This issue was also addressed in Picha and Moberg (2011) where travel to and from the office was the major reason for potential environmental impact when included in the assessment. In Picha and Moberg (2011), travel to and from the office was not part of the reference case as the uncertainties on allocation between different purposes for the travel is large. The trips could be assumed to also be used for other activities on the way to and from work (driving children to school, shopping, etc).

In the current study all the greenhouse gas emissions related to the travel to and from work were allocated to the television content production and this could be decreased if allocation had been done to other activities. This is also a question of system boundaries. In many studies, trips to and from the work place are not considered part of the scope when assessing the environmental aspects of the production at the work place. Since it may be a major factor in the case of media content production, it is good to at least consider it when the target group of the study is the company itself.

At TV4 Gävle/Dalarna, the carbon footprint from the business trips is high compared to other studies on media content production. For example, in the study on a interior design magazine done by Picha et al. (2012) the greenhouse gas emissions from the business trips were four times lower than in this study if calculated per FTE. The office of the magazine studied is situated in the Swedish capital Stockholm, where public transportation is well developed. On the other hand, a local television reporter in a rural area might need to travel by car in most cases. Also, many hours of content production for an interior design magazine is probably made without much travel, while the editorial staff of a local television station might have to travel every day and to various locations in order to make interviews.

The results of the study indicate that as the television content production activities involve a considerable amount of travelling, it can be recommended that TV4 rethink their travelling behavior. The company uses mainly petrol cars, so a substitution to "green" cars would reduce the greenhouse gas emissions significantly. Better efficiency in car use, such as combining several trips into one or one car used by several people (pool cars) would be another possible solution. Using other means of transportation, e.g. train, when possible, would also

contribute to the carbon footprint reduction. Furthermore, encouraging employees who live fairly close to the television station to e.g. take the bicycle to work would also have an effect.

In this study, only the climate change impact category was considered. If we were to look at other impact categories such as ecotoxicity or metal depletion, we might get different results. Picha and Moberg (2011) for example showed that the business trips and the manufacturing of the electronic devices were the major reason for the impacts in most of the studied impact categories.

The electronic waste treatment is an uncertain issue and the case assumed here involved recycling of all the major recyclable parts, which is not always the case. Part of the electronic equipment might be disposed of through incineration or landfill, which may increase the carbon footprint. However, the end of life of electronic equipment is more likely to have other major environmental impacts.

When looking at the editorial content production, the work method of multi-tasking could be an explanation to why the person hours are comparatively low on the recording side, while higher on the editing side. Another explanation could be that some news items do not need any special recording, since it consists of previously recorded images or a photograph and a new speaker text.

Judging from today's situation, the efficiency on the editorial side is very good. However, the marketing department might want to aim at increasing the time spent on contacting potential customers, since the time spent on that process step is relatively low compared to other activities. The efficiency in the whole system might result in that the business trips in our study appear to be larger than they really are. However, it might still be fruitful to consider the travelling practices in order to improve their overall environmental performance of TV4 Gävle/Dalarna. Especially the business trips made in order to participate in different meetings might be possible to reduce with the help of technical solutions for meetings at a distance. Combining several trips to meetings is another solution which most likely would give a positive effect on the overall climate impact. Thus, travelling seems to be an area where media companies in general can make environmental improvements.

At least this is an area worth taking a closer look at, when heading for the future.

7. Conclusions

In this study we have identified and analyzed the process structure and the environmental impact of the local television station TV4 Gävle/Dalarna. We have looked at the content production, not including transmission or consumption of content. We have:

- Identified the major editorial and marketing processes and visualized the two workflows in order to discover how the processes can be optimized and how this in turn may affect the environmental impact;
- Assessed the carbon footprint of the content production of the local television station and identified the major reasons for this climate change impact.

The results show that the two departments at the television station are strictly separated, also when it comes to the personnel. The editorial part of the workflow is centered on broadcasting news at certain times. A total of nine process steps were identified in the editorial workflow. The largest amount of person hours can be found in the process steps of content production and editing the content. Work is done in order to meet the deadlines which come every time there is a broadcast. This fact puts special demands on the personnel, such as an ability to manage stress and short deadlines, and an ability to handle the technical equipment in one-person teams.

The marketing department works in parallel with customer relations and with producers of television commercials, which is often done by separate production companies. There are a total of seven process step on the marketing side, of which two are located outside of the local television station.

Our main conclusions are:

- Judging from today's situation, the efficiency on the editorial side is very good;
- The main contribution to the overall carbon footprint comes from business trips;
- The efficiency in the whole system might result in that the business trips in our study appear to be larger than they really are. However, it might still be fruitful to consider the travelling practices in order to improve the overall environmental performance.

Acknowledgments

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List of abbreviations

CO_2 eq: Carbon dioxide equivalents

DTT: Digital terrestrial television

FTE: Full time employee

LCA: Life cycle assessment

VOD: Video-on-demand

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Marketing Manager, March 2011

Head of Environmental Affairs at the TV4 Headquarters, May 2012

Head of "Vi Förenade" Jan-Olov Karlsson Fält, March and April 2012

Customer manager at "Fastighetssnabben" William Eriksson, April 2012

Customer service of Lyreco (www.lyreco.se), April 2012

Madeleine Bergrahm at HP, Hewlett Packard, August 2011

Appendix

Overview of the system used for the Life Cycle Assessment made in this study.

	Amount		Unit	Reference	Background data reference
	marketing	editorial			
Sub-system: energy and water consumption					
Electricity	23 144.1	30 858.8	kWh/year	Head of Environmental Affairs at the TV4 Headquarters, May 2012; Vi Förenade, 2012; Fastighetssnabben, 2012. Commonly used by editorial and marketing departments, allocated based on the number of FTEs	Frischknecht et al., 2007
Heating	17 785.7	23 714.3	kWh/year	Head of Environmental Affairs at the TV4 Headquarters, May 2012; Vi Förenade, 2012; Fastighetssnabben, 2012. Commonly used by editorial and marketing departments, allocated based on the number of FTEs	Svensk Fjärrvärme, 2006
Cooling	included in electricity			Vi Förenade, 2012; Fastighetssnabben, 2012	
Water	51 428.6	68 571.4	kg/year	Vi Förenade, 2012; Fastighetssnabben, 2012. Commonly used by editorial and marketing departments, allocated based on the number of FTEs	Althaus et al., 2007
Sub-system: business trips					
Trips by train	2 250	6 300	km/year	Head of Environmental Affairs at the TV4 Headquarters	Spielmann et al., 2007; Frischknecht et al., 2007
Trips by car (petrol)	64 860	9 4200	km/year	Head of Environmental Affairs at the TV4 Headquarters	Spielmann et al., 2007; Jungbluth, 2007
Trips by car (diesel)	1 322.2	1 924	km/year	Head of Environmental Affairs at the TV4 Headquarters	Spielmann et al., 2007; Jungbluth, 2007
Sub-system: trips from/to office					
Trips by car (petrol)	6 500	25 700	km/year	Head of Environmental Affairs at the TV4 Headquarters	Spielmann et al., 2007; Jungbluth, 2007
Trips by car (diesel)	6 500	25 700	km/year	Head of Environmental Affairs at the TV4 Headquarters	Spielmann et al., 2007; Jungbluth, 2007
Trips by bus		12 500	km/year	Head of Environmental Affairs at the TV4 Headquarters	Spielmann et al., 2007; Jungbluth, 2007
Sub-system: electronic equipment					
Desktop	0	7	pieces	Head of Environmental Affairs at the TV4 Headquarters	Hischier et al., 2007
use life	6.6		years	IVF, 2007	
Laptop	5	4	pieces	Head of Environmental Affairs at the TV4 Headquarters	Hischier et al., 2007
use life	5.6		years	IVF, 2007	
LCD screen	5	5	pieces	Head of Environmental Affairs at the TV4 Headquarters	Hischier et al., 2007
use life	6.6		years	IVF, 2007	
TV-set		2	pieces	Head of Environmental Affairs at the TV4 Headquarters	Hischier et al., 2007
use life	5		years	Frauhofer, 2007	

	Amount		Unit	Reference	Background data reference
	marketing	editorial			
Sub-system: electronic equipment (continued)					
Mobile phone		9	pieces	Head of Environmental Affairs at the TV4 Headquarters	Hischier et al., 2007
use life	3		years	Bergelin, 2008	
Server	0.9	1.1	pieces	Head of Environmental Affairs at the TV4 Headquarters. Commonly used by editorial and marketing departments, allocated based on the number of FTEs	Hischier et al., 2007
use life	5		years	own assumption	
Printer	0.9	1.1	pieces	Head of Environmental Affairs at the TV4 Headquarters. Commonly used by editorial and marketing departments, allocated based on the number of FTEs	Hischier et al., 2007
use life	5		years	own assumption	
Sub-system: office materials					
Office paper	81.1	96.6	kg	Head of Environmental Affairs at the TV4 Headquarters. Commonly used by editorial and marketing departments, allocated based on the number of FTEs	Hischier, 2007
Sub-system: goods transportation					
Office paper transportation (truck)	26.9	35.9	m^6/year	Lyreco, 2012; Head of Environmental Affairs at the TV4 Headquarters. Commonly used by editorial	Spielmann et al., 2007; Jungbluth, 2007
Office paper transportation (van)	16.1	21.4	m^6/year	Lyreco, 2012; Head of Environmental Affairs at the TV4 Headquarters. Commonly used by editorial	Spielmann et al., 2007; Jungbluth, 2007
Electronic equipment transportation (ship)	207.0	502.2	m^6/year	Hischier et al., 2007; Sea rates, 2012	Spielmann et al., 2007; Jungbluth, 2007
Electronic equipment transportation (lorry)	15.8	34.8	m^6/year	Hischier et al., 2007; Google maps, 2012	Spielmann et al., 2007; Jungbluth, 2007
Electronic equipment transportation (airplane)	10.4	8.3	m^6/year	HP, 2011; World airport codes, 2011	Spielmann et al., 2007; Jungbluth, 2007
Sub-system: waste utilization					
Paper recycling	77.0	91.8	kg/year	own assumption: 95 % of the paper used in the office	Hischier, 2007
Paper incineration	4.1	4.8	kg/year	own assumption: 5 % of the paper used in the office	Björklund, 1998; Arushanyan et al., 2012
Electronic equipment recycling				own assumption: number of equipment used in the office split on their respective use times	Hischier et al., 2007; Classen et al., 2009
Desktop	0	1.1	pieces/year		

	Amount		Unit	Reference	Background data reference
	marketing	editorial			
Sub-system: waste utilization (continued)					
Laptop	0.9	0.7	pieces/year		
LCD screen	0.8	0.8	pieces/year		
Server	0.2	0.2	pieces/year		
Printer	0.2	0.2	pieces/year		
Organic waste composting	1 337	1 782	kg/year	Vi Förenade, 2012; Fastighetssnabben, 2012. Own assumption on waste weight/volume relationship	Björklund, 1998; Arushanyan et al., 2012
Municipal solid waste incineration (CHP)	1 337	1 782	kg/year	Vi Förenade, 2012; Fastighetssnabben, 2012. Own assumption on waste weight /volume relationship	Björklund, 1998; Arushanyan et al., 2012

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Evaluation of a simple approach for color gamut boundary determination of a point cloud

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Abstract

The color gamut of a printing device is commonly used to give information about the printing quality of a system. Various algorithms for determining the color gamut boundary based on a point cloud have been developed previously. These differ from each other in some aspects.

In this paper a new method for color boundary determination and assessment is presented. In this approach we vary the parameters needed for determination according to the characteristics of the input data. In this way we achieve optimal computation of the color gamut boundary. Different parameters are analyzed, quantified and combined to reach the best accuracy of the color gamut boundary.

Our method is implemented in Microsoft Excel© using Visual Basic. Color gamuts can be visualized in both three- and two-dimensional space and analyzed according to their color volume and the reproducibility of spot colors. Exemplarily, the capacity of the Color Gamut Calculator is shown for the lithographic printing process. A complex analysis of the color gamut can be readily achieved, and the tool is easy to apply in the graphic arts industry or in R&D.

Keywords: color reproduction, color gamut boundary determination, color point cloud, gamut volume, concavity, convexity, color gamut descriptor

1. Introduction

The color gamut is an appropriate criterion to describe the quality of printing systems. The quality of a color output device can be expressed in detail by (a) the visualization of the color gamut in a two- or three-dimensional color space, (b) the gamut volume or the number of reproducible colors and (c) the representability of spot colors.

In this paper, a new method for color gamut boundary determination and assessment is presented. This point-based model works with a simple triangulation method by making use of an octahedron as an auxiliary object. The refinement of the triangulation is chosen according to the input data points.

A tessellated sphere with a defined number of grid points is constructed, starting with an octahedron. The grid is projected onto the point cloud via an Euclidean distance approach. These steps lead to a color gamut boundary that depends on the characteristics of the input data.

The paper analyzes the quality of our method and examines different parameters which can influence the accuracy of the generated color gamut boundary. Additionally, we indicate a way of combining parameters for reaching the best results in the computation process.

Based on the criteria mentioned above, our Microsoft Excel© tool "Color Gamut Calculator" allows color gamut boundary determination based on any number of color values in the CIELAB color space. A comprehensive assessment of the quality of color output devices can, therefore, be achieved. The color gamut boundary can be visualized in a three- or two-dimensional space and analyzed according to the volume and reproducibility of spot colors.

The paper goes on to assess a standard lithographic printing process according to the quality criteria established (3D and 2D visualization, color gamut volume and representability of spot colors). These experimental

results can be gathered to compare this approach with other color gamut algorithms. The proposed method is a simple way to determine the color gamut boundary of an arbitrary point cloud. It shows good results in the experiments presented here. Furthermore, the implemented algorithm is suitable for assessing the quality of color output devices in industries as well as in R&D.

2. State of the art

Different algorithms exist for carrying out color gamut boundary determination. Hardeberg and Schmitt (1997) classified previously developed methods into two groups: physical and empirical models. Physical models consider physical or chemical properties of the output devices by using the Neugebauer equation (Mahy, 1997; Kang, 1997) or the Kubelka-Munk equation (Berns, 1993; Meyer, 1993), or by combining the Neugebauer and the Yule-Nielsen approach (Balasubramanian, 1999). Empirical models require ICC profiles (Hung, 1993; Balasubramanian, 1994) or spectrophotometrically measured color values (Stone et al., 1988; Bolte, 1992). Our method is an empirical model based on a set of color points.

A simple approximation for determining the outside points of a point cloud is the convex hull algorithm. Barber et al. (1996) adopted the quick hull algorithm, a modified convex hull algorithm, to optimize the original approach. Combined with a Delaunay Triangulation, this algorithm achieves direct triangulation of a point cloud without needing an auxiliary object. Hardeberg and Schmitt (1997) applied inner and surrounding structures to eliminate problems with the Delaunay Triangulation. This approach helps to avoid errors provoked by mirrored triangles which can occur during subsequent color space transformation. The verification of mirrored triangles is another step in determining the color gamut boundary and requires further effort. Balasubramanian and Dalal (1997) modified the convex hull algorithm, adding a pre-step to give the point cloud a more convex shape before generating the convex hull. Cholewo and Love (1999) utilized the alpha-shape algorithm developed by Edelbrunner and Mücke (1994) to generate the color gamut. The alpha-shape algorithm is closely related to the Delaunay Triangulation. Cholewo and Love (1999) pointed out that the quality of computation depends on the selection of the α parameter.

Giesen et al. (2005) performed a direct triangulation of a point cloud by using a so-called complex flow method (Giesen and John, 2003). This method is an appropriate alternative to the Delaunay Triangulation algorithm.

Following Bakke et al. (2008), the method presented in this paper applies triangulation by using an auxiliary object. Our proposed method uses an octahedron whose vertices are converted to spherical coordinates. Depending on the input data, different levels of triangulation can be chosen. This ensures that the risk of underestimation or overestimation is low.

In our method the grid points of the generated and tesselated sphere are projected onto the point cloud by computing the Euclidean distance between grid points and color points. Several approaches exist that use the segment maxima method for this process. This method integrates adjacent color points to generate the surface (Morovic and Luo, 1997, cited in Bakke et al., 2008), decomposing the point cloud into segments and using the maximum of any segment for building the gamut surface. Empty segments are interpolated depending on the adjacent segments. Bakke et al. (2008) combined the segment maxima method with a modified convex hull algorithm to replace the interpolation algorithm. In our method, the outlying color points are determined without the segment maxima method. The triangulation of the sphere is kept during the projection process, so a new triangulation is not needed. In our method, no transformation between different color spaces is necessary, so no triangles are mirrored.

Some authors have also outlined ideas for the computation of the gamut volume. Balasubramanian and Dalal (1997) created tetrahedra between the edges of the surface points and the center of the point cloud. This method requires that the tetrahedra do not overlap, but cases of concave surface areas overlapping cannot be avoided. So we propose to accumulate two-dimensional slices of the color gamut to number the gamut volume. In addition, the gamut is defined by the quantity of reproducible colors.

Regarding the approach of Balasubramanian and Dalal (1997), Guyler (2007) summed up the volumes of all tetrahedra which belong to the alpha-shape. In this case a center point is not needed for calculating the color gamut volume. They used these values for volumes to compare different gamuts in percentages.

Willert et al. (2004) also used two-dimensional slices to calculate the color gamut volume. They created a color gamut by mixing cyan, magenta and yellow in any amount from 0 % to 100 % each. These vertices are visualized in the CIELAB space.

As in our method, the connecting lines are proved if they contain the given L* value. In this way slices are created and areas summarized.

3. Method

Our method for color gamut boundary determination starts with a cloud of color points C_P in a threedimensional space. Any number of color values can be used: these are spectrophotometrically measured and converted to CIELAB. A sphere is constructed enclosing a set of color points C_P. The minimum radius of the sphere r_S equals the distance between the center point C and color point P_f furthest from the center point.

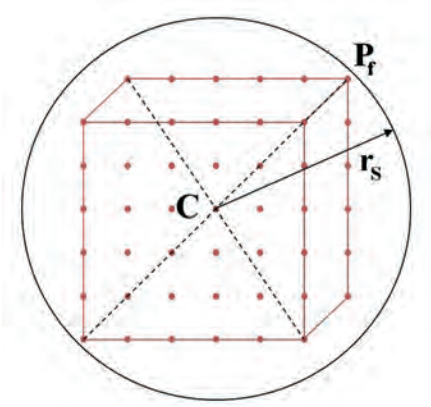

Figure 1: Model of color points, e.g. forming a cube surrounded by a sphere

This ensures that all color points are located within the sphere (cf. Figure 1). An octahedron is then created with vertices P_1 to P_6 located on the constructed sphere (cf. Figure 2). The geometry of the octahedron is, therefore, specified by the shape of the point set or the radius of the sphere, as described above. The triangulation of the octahedron surface can be refined at different levels.

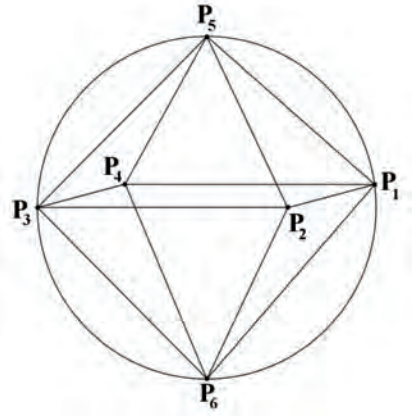

Figure 2: Model of a sphere formed on an octahedron

Depending on the level of triangulation different quantities of points A_S and triangles A_ST of the sphere are generated (cf. Equations [1] and [2]):

$$A_{ST} = 8 \cdot 4^k \quad [1]$$

$$A_S = 4^k + 2 \quad [2]$$

where:

A_{ST}: number of triangles on the octahedron/sphere
k: level of triangulation; $k = [1, 2, 3]$
A_S: number of points on the octahedron/sphere

Next, the vertices of the octahedron are projected onto the surface of the sphere. During this process the triangulation persists. The vertex coordinates of the octahedron are converted from Cartesian into spherical coordinates. A tesselated sphere with points and triangles occurs (cf. Figure 3).

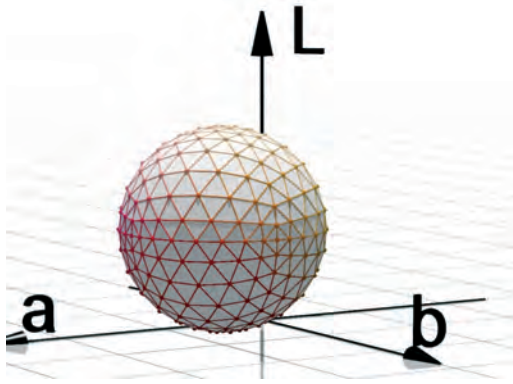

Figure 3: Model of a tesselated sphere

The vertices of the sphere P_{S1} to P_{Sn} are projected onto the points of the point cloud P_{C1} to P_{Cn}. In this process for any vertex of the sphere the color point with the smallest Euclidean distance is found (cf. Figure 4). The projection leads to new positions for the edges of the triangles forming the surface of the color gamut.

A color point may be related to more than one vertex of the sphere, or to put it the other way round, several vertices of the sphere may coincide at a single color point. In this case the three vertices cannot create a triangle (cf. Figure 4). These invalid triangles are not kept for further determination, because they have no influence on the construction of the color gamut boundary.

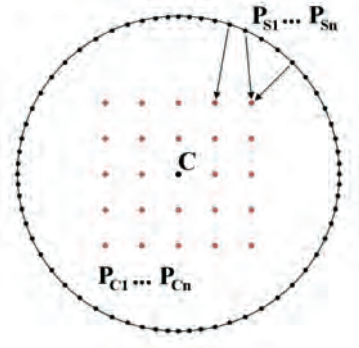

Figure 4: Projection of the spherical vertices P_{S1} to P_{Sn} onto color points P_{C1} to P_{Cn}

4. Verification

4.1 Earlier methods

As in previous methods (cf. Table 1), the accuracy of the color gamut boundary depends on parameters specified during the process of determination. Our method is compared here with previously presented ones which are able to compute both convex and concave surfaces.

In this section our method is investigated extensively with regard to the parameters that influence the quality of the determination. This procedure indicates how to combine parameters to get the best computational results.

4.2 Cube as a test object

A cube with a side length of 50 units and equally positioned color points is utilized as a test object. This object is suitable for testing the accuracy of the generated color gamut boundary, because it has a regular shape. Inaccuracy in the visualized color gamut will clearly indicate mistakes in the computation.

Table 1: Parameters influencing the accuracy of color gamut boundary determination. Previous methods in comparison to our method

Cholewo and Love (1999)	**Giesen et al. (2005)**	**Bakke et al. (2008)**	**This approach**
α parameter (Alpha shape)	Orbit of grid points (Complex Flow Algorithm)	Number of segments and γ value for the interpolation of empty segments (segment maxima method)	Number and distance of sphere points (Euclidean distance approach)

4.3 Parameters

The quality of computation depends on several parameters, which will be defined in advance: (a) number of points on the tesselated sphere A_S, (b) number of triangles on the sphere A_{ST}, (c) distance between points on the sphere ΔE_S and (d) radius of the sphere r_S.

Characteristics of the color point set also influence the accuracy of computation: (e) number of color points A_P and (f) distance between color points ΔE_P.

4.4 Evaluation of computational quality

The accuracy of the color gamut boundary can be specified by the number of points found on the surface (cf. Equation [3]):

$$A_{PoB}\,\% = \frac{A_{fPoB}}{A_{PoB}} \cdot 100\ \% \qquad [3]$$

where:

$A_{fPoB}\,\%$: percentage of color points found on the color gamut boundary [%]

A_{PoB}: number of color points on the color gamut boundary

A_{fPoB}: number of color points on the color gamut boundary as found.

The best quality of computation will be achieved if each point of the color gamut boundary is found:

$$A_{fPoB}\,\% = 100 \qquad [4]$$

The influence of every relevant parameter should be considered. Parameters are isolated to show their individual influence. The percentage of color points found as points lying on the color gamut boundary $A_{fPoB}\,\%$ will be used as a measure of quality.

4.4.1 Influence of the number of points and triangles on the sphere

As described in section 3, triangles and points of the tesselated sphere are generated starting with an octahedron. The number of points A_S and the number of traingles on the sphere A_{ST} depend on the chosen level of triangulation.

Maximum accuracy of computation is achieved if the tessellation of the sphere will be as rich or richer in detail as the surface of the color point cloud:

$$\Delta E_P \geq \Delta E_S \qquad [5]$$

where:

ΔE_S: distance between vertices of the sphere

ΔE_P: distance between color points

To check the correlation in Equation [5] a cube with a side length of 50 units and variable distance $\measuredangle E_P$ is applied. The sphere is tesselated into 2 048 triangles A_{ST} = 2 048. As a result the greatest distance between the vertices of the sphere $\measuredangle E_S$ is 5.4681 units.

The point cloud is generated for three cases with different ratios between the point distances $\measuredangle E_P$ and $\measuredangle E_S$. The results are shown in Table 2 and the gamuts are illustrated in Figure 5.

Table 2: Quality of computation using different point distances between ΔE_S and ΔE_P

		Point cloud		Sphere	Results	
Case No.	Ratio ΔE_P to ΔE_S	Distance between color points, ΔE_P	Num. of color points at the boundary, A_{PoB}	Distance between sphere points, ΔE_S	Number of color points at the boundary as found, A_{fPoB}	Percentage of color points found, A_{fPoB} %
1)	$\Delta E_P > \Delta E_S$	25.0	26	5.4681	26	100.0
2)	$\Delta E_P = \Delta E_S$	5.4681	488	5.4681	488	100.0
3)	$\Delta E_P < \Delta E_S$	2.5	2 402	5.4681	858	35.72

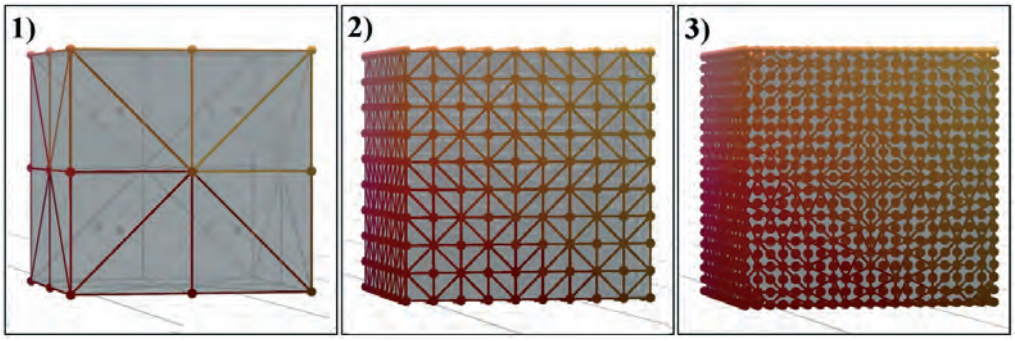

Figure 5: Comparison between color gamut boundaries using different point distances between ΔE_P and ΔE_S (cf. Table 2, case No. 1, 2 and 3)

The statement in Equation [5] can be confirmed. Maximum quality of computation will be reached if the distance between vertices of the sphere ΔE_S is smaller or equal to the distance between the color points ΔE_P.

4.4.2 Influence of the stretching factor

In our method a stretching factor f_S allows enlargement of the radius of the tesselated sphere and reduction of the curvature of the sphere (details in section 4.3.3). The point-to-point distance changes in accordance with the stretching factor (Kruskal, 1964):

$$\Delta E_{S2} = \Delta E_{S1} \cdot f_S \qquad [6]$$

where:

ΔE_{S2}: distance between vertices of sphere No. 2
f_S: stretching factor
ΔE_{S1}: distance between vertices of sphere No. 1

Centric extension of the tesselated sphere induces a less detailed tesselation. The results in Table 3 and Figure 6 show a better quality of computation in case No. 1. In this case the smallest stretching factor is adopted.

Table 3: Quality of computation using different stretching factors f_S

	Point cloud			Sphere		Results	
Case No.	Number of color points, A_P	Distance between color points, ΔE_P	Number of color points at the boundary, A_{PoB}	Stretching factor, f_S	Number of sphere points, A_{ST}	Number of color points at the boundary as found, A_{fPoB}	Percentage of color points found, A_{fPoB} %
1)	2 331	5	602	1	2 048	602	100.0
2)	2 331	5	602	2	2 048	314	52.159

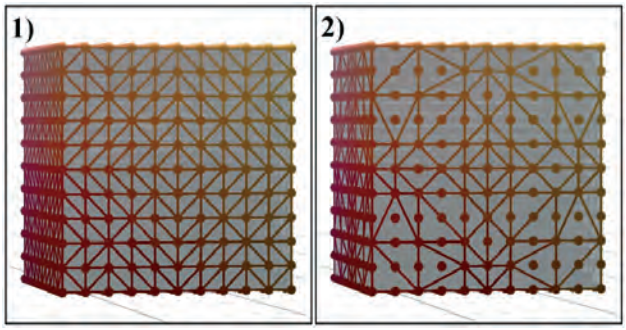

Figure 6:
Comparison of color gamut boundaries using different stretching factors f_S (cf. Table 3, case No. 1 and 2)

4.4.3 Influence of the curvature of the sphere

To investigate the influence of the curvature of the sphere two cases are analyzed. The stretching factor f_S and the number of triangles A_{ST} are chosen in mutual opposition, so that the distance between vertices of the sphere $\measuredangle E_S$ is equal in both cases. In this way the parameter "curvature" is isolated and can be observed. Table 4 shows greater accuracy for the larger stretching factor (case No. 2).

Table 4: Quality of computation using different curvatures of the sphere ($\measuredangle E_P$ = 5 units)

	Point cloud			Sphere		Results	
Case No.	Number of color points, A_P	Distance between color points, ΔE_P	Number of color points at the boundary, A_{PoB}	Stretching factor, f_S	Number of sphere points, A_{ST}	Number of color points at the boundary as found, A_{fPoB}	Percentage of color points found, A_{fPoB} %
1)	2 331	5	602	1	512	210	34.884
2)	2 331	5	602	2	2 048	314	52.159

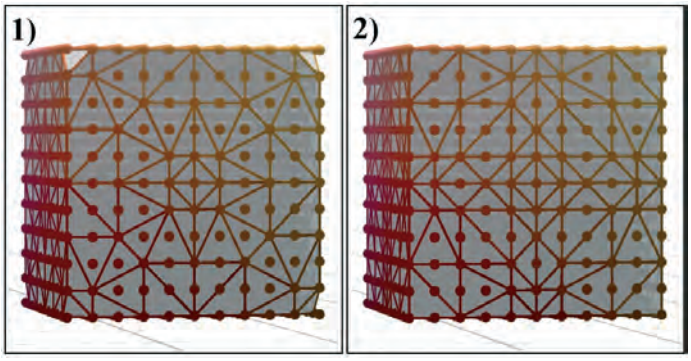

Figure 7: Comparison of the color gamut boundaries using different curvatures of the sphere ($\measuredangle E_P$ = 5 units) (cf. Table 4, case no. 1 and 2)

If the distance between color points is enlarged to ΔE_P = 10 units, the improvement will be about 5 % (Tab. 5 and Fig. 8). In general, the accuracy of the gamut boundary is then better. This is a result of the relationship between ΔE_P and ΔE_S. In conclusion, a better quality of computation can be achieved if the curvature of the sphere is smaller.

Table 5: Quality of computation using different curvatures of the sphere ($\measuredangle E_P$ = 10 units)

	Point cloud			Sphere		Results	
Case No.	Number of color points, A_P	Distance between color points, ΔE_P	Number of color points at the boundary, A_{PoB}	Stretching factor, f_S	Number of sphere points, A_{ST}	Numb. of color points at the boundary as found, A_{fPoB}	Percentage of color points found, A_{fPoB} %
1)	431	10	161	1	512	144	89.441
2)	431	10	161	2	2 048	152	94.410

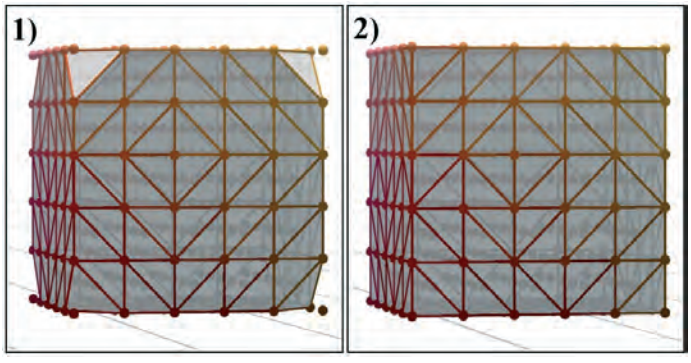

Figure 8: Comparison of the color gamut boundaries using different curvatures of the sphere ($\measuredangle E_P$ = 10 units) (cf. Table 5, case No. 1 and 2)

4.4.4 Influence of concave and convex shape of the point cloud

The influence of the concavity and convexity of the color point cloud will be analyzed in this section. For this purpose one side of the cube is shifted in the direction of a*.

Strength of curvature is defined by height *h* as amplitude of a sine curve (Equation [7]).

$$f_{vi} = h \cdot \sin\left(\frac{i \cdot \Delta E_P}{a} \cdot \pi\right) \quad [7]$$

where:

f_{Vi}: factor for moving
h: maximum height
i: control variable [0…a/ΔE_P]
ΔE_p: distance between color points
a: side length of the object

The curvature of the point cloud is also defined by the equation of the circular segment (Equation [8]).

As a result, the radius r_C of a sphere describing the curvature of the point cloud can be computed as follows:

$$r_c = \frac{4 \cdot h^2 + a^2}{8 \cdot h} \quad [8]$$

where:

r_C: radius of the circle building the curvature of the point cloud
h: height of the circular segment
a: side length of the segment (in this case: side length of the cube)

The following tables indicate the quality of computation for different levels of convexity (cf. Table 6) and concavity of the point cloud (cf. Table 7).

Table 6: Quality of computation using different convex curvatures of the point cloud

	Point cloud				Sphere		Results	
Case No.	Number of color points, A_P	Distance between color points, ΔE_P	Number of color points at the boundary, A_{PoB}	Height of the circular segment, h	Stretch. factor, f_S	Number of sphere points, A_{ST}	Number of color points at the boundary as found, A_{fPoB}	Percentage of color points found, A_{fPoB} %
1)	2 331	5	602	1	2	2 048	326	54.153
2)	2 331	5	602	2	2	2 048	328	54.485
3)	2 331	5	602	3	2	2 048	334	55.482
4)	2 331	5	602	1	1	512	216	35.880
5)	2 331	5	602	2	1	512	216	35.880
6)	2 331	5	602	3	1	512	216	35.880

Table 7: Quality of computation using different concavities of the point cloud

	Point cloud				Sphere		Results	
Case No.	Number of color points, A_P	Distance between color points, ΔE_P	Number of color points at the boundary, A_{PoB}	Height of the circular segment, h	Stretch. factor, f_S	Number of sphere points, A_{ST}	Number of color points at the boundary as found, A_{fPoB}	Percentage of color points found, A_{fPoB} %
1)	2 331	5	602	1	2	2 048	308	51.163
2)	2 331	5	602	2	2	2 048	308	51.163
3)	2 331	5	602	3	2	2 048	298	49.502
4)	2 331	5	602	1	1	512	210	34.883
5)	2 331	5	602	2	1	512	210	34.883
6)	2 331	5	602	3	1	512	210	34.883

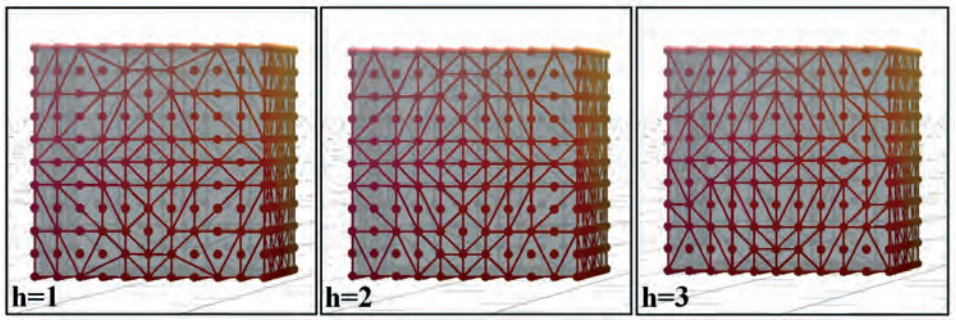

Figure 9: Quality of computation using different convex curvatures of the point cloud (cf. Table 6, case No. 1 to 3)

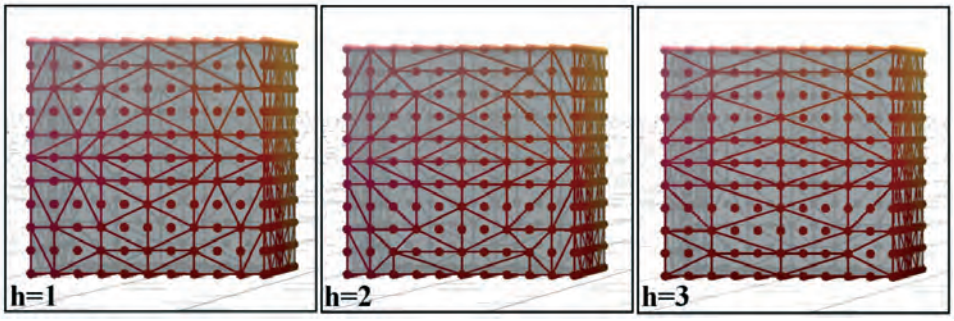

Figure 10: Quality of computation using different concave curvatures of the point cloud (cf. Table 7, case No. 1 to 3)

Taking Table 6 and Table 7 into consideration, it is obvious that convex surface areas can be captured better than concave structures. Increasing convexity induces a better quality of computation. Conversely, increasing concavity of the point cloud induces a lower quality of computation.

The convexity and concavity of the point set for the levels of h=1, h=2 and h=3 is shown in Figure 9 and Figure 10. In the following diagram we will consider the influence of concave structures in detail by using another model (Figure 11).

Table 8 shows the accuracy of the gamut shape generated for three different concave curvatures: $h=0$, $h\approx4$ and $h\approx8$ units. The curvature of the point cloud r_{P2} with $h\approx4$ is equal to the curvature of the tesselated sphere with a radius $r_{S2}=88$ units, and the curvature of the point cloud r_{P1} with $h\approx8$ units is equal to the curvature of the tesselated sphere with a radius $r_{S1}=44$ units (cf. Figure 11, Equation [8]).

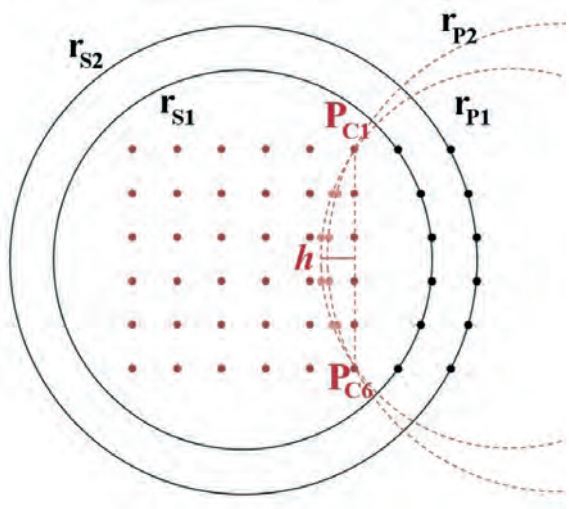

Figure 11: 2D model for revealing the correlation between the concave curvature of the point cloud (r_{P1} and r_{P2}) and the curvature of the sphere (r_{S1} and r_{S2})

Table 8: Correlation between the concave curvature of the point cloud and the curvature of the sphere

Sphere	**Point cloud**	**Color points found**					
Radius of the sphere, r_S	Height of the circular segment, h	P_{C1}	P_{C2}	P_{C3}	P_{C4}	P_{C5}	P_{C6}
44	0	x	x	x	x	x	x
44	4	x	x	x	x	x	x
44	8	x	x	o	o	x	x
88	0	x	x	x	x	x	x
88	4	x	o	o	o	o	x
88	8	x	o	o	o	o	x
x: Point of the cloud is found; o: Point of the cloud is not found							

Taking a steep curvature of the sphere ($r_{S1}=44$ units) and a slight curvature of the point cloud ($h=0$ or $h\approx4$ units), all the points in this case study are found.

If the curvatures are equal, the quality of computation will decrease. Low curvature of the sphere (r_{S2}=88 units) will induce a low quality of computation - i.e. if the curvature of the point cloud is $h\approx4$ or $h\approx8$ units. The results in section 4.4.2 confirm this statement: small curvature of the sphere (f_S=2) gives best quality of computation if a set of color points without curvature ($h=0$) is used. Accordingly, optimal computation quality is achieved by:

$$r_s < r_c \qquad [9]$$

where:

r_s: radius of the sphere
r_c: radius of the circular segment building the point cloud

4.5 Results

Regarding the case studies mentioned in section 4.4, we conclude that the distance between the points of the sphere ΔE_S should be lower than or identical with the distance between the color points ΔE_P. This induces a number of vertices and triangles on the sphere. The curvature of the sphere, defined by the stretching factor f_S, should be steeper than the curvature of the color point cloud. The relationship between the distances ΔE_S and ΔE_P may not be affected. These requirements and characteristics lead to higher computational quality within this method and optimize the accuracy of the color gamut boundary determined by it.

4.6 Further test objects

In this section cuboids with different side lengths are applied as test objects.

This additional case study should prove that the parameters concluded in section 4.5 do not depend on this specific test object used there.

For the analysis, the sides of the test objects (cf. Table 9) are shifted in the direction of a*, b* and L*, where a concave curvature is formed in the direction of positive values and a convex curvature in the direction of negative values.

Table 9: Characteristics of test objects

Cuboid No.	Length towards L*	a*	b*	Distance between color points, ΔE_P
1	100	50	50	25
2	96	36	36	12

Case No. 1 and 2 in Table 10 (cuboid No. 1) achieve maximum computation quality. Even taking a strong curvature of the sphere optimal quality is reached.

For determination of case No. 3 to 9 cuboid No. 2 is used. The relation between the sides of this cuboid is 3:1:1. Optimum computation quality is achieved here with the test objects of case No. 3 and 5. If the requirements shown in section 4.4 are ignored, computational quality will decrease markedly, with a mere 44.595 % of the points of the color gamut boundary found (case No. 4).

Table 10: Quality of computation using cuboids

Case No.	Point cloud: Number of color points, A_P	Dist. of color points, ΔE_P	Num. of color points at boundary, A_{PoB}	Height of circular segment, h	Sphere: Stretch. factor, f_S	Num. of sphere points, A_{ST}	Dist. of sphere points, ΔE_S	Results: Num. of color points at boundary as found, A_{fPoB}	Pct. of color points found, A_{fPoB} %
1)	61	25	42	0	1	512	10.76	42	100.0
2)	61	25	42	0	2	512	21.51	42	100.0
3)	216	12	148	0	1	512	10.76	116	78.378
4)	216	12	148	0	2	512	21.51	66	44.595
5)	216	12	148	0	2	2048	10.98	116	78.378
6)	216	12	148	1	1	512	10.26	108	72.973
7)	216	12	148	1	2	2048	13.92	102	68.919
8)	216	12	148	2	1	512	10.75	102	68.919
9)	216	12	148	2	2	2048	13.92	88	59.459

If the curvature of the color point set *h* increases, the quality of computation will generally drop (case No. 6, 7 and 8). This is most evident in case No. 9, where r_s=110 units, r_c=577 units (direction L*) and r_c=82 units (direction a* and b*). The reason for the loss of quality is the smaller radius of the color points r_P in comparison to the radius of the sphere r_S.

The requirements for optimum quality as described in section 4.4 are in this case not achieved.

5. Color Gamut Calculator

5.1 Three-dimensional visualization

Based on our method as described in section 3, we have implemented a Microsoft Excel© application using Visual Basic for color gamut boundary determination. The tool generates the color gamut boundary by using an arbitrary data set of color points in the CIELAB color space. Moreover, the tool can visualize the gene-

rated color gamut and can give information about color gamut volume (section 5.2) and the representability of spot colors (section 5.3). As a result, a comprehensive assessment of the quality of a printing device is possible. The "Color Gamut Calculator" creates an input file as required for the 3D modeling application POVray©. With this program the generated color gamut can be visualized in three-dimensional space. The input file includes all information about edges, triangles and the point cloud. The gamut can be observed in different perspectives.

5.2 Volume of the color gamut

5.2.1 Calculation principles

Gamut volume is commonly defined by the quantity of distinguishable colors. To achieve this conversion different steps are necessary: The generated color gamut is first subdivided into slices in steps of $\Delta L = 1$. The area of each cut is computed and summed up. The summation results in a mass of $\Delta E = 1$ cubes.

The volume of a color gamut is given by the quantity of colors that can be placed within the color gamut as spheres with a diameter of $\Delta E = 1$. This value defines an average number of colors that can be distinguished as different colors. Kerschbaumer (2008) realized that colors with a color distance ΔE between 0.7 and 1.5 can only be recognized by experts.

Equal sized spheres stacked with maximum density fill approximately 74 percent of a volume (Szpiro, 2003). So we utilize a multiplicator f_V to convert the volume into a quantity of colors (cf. Equations [10] to[14] and Figure 12).

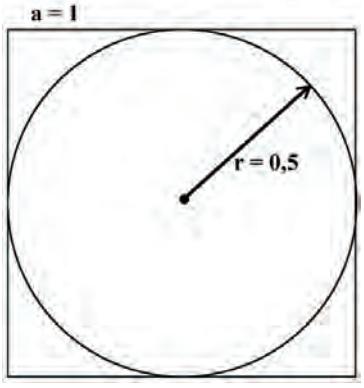

Figure 12: Model of a circle (r=0.5) surrounded by a rectangle (a=1)

$$V_C = a^3 \quad [10]$$

$$V_{C,a=1} = (1)^3 = 1 \quad [11]$$

where:

V_C: volume of cube
a: side length of cube
$V_{C,a=1}$: volume of cube with side length $a=1$

$$V_S = \frac{4}{3} \cdot \pi \cdot r^3 \quad [12]$$

$$V_{S,r=0.5} = \frac{4}{3} \cdot \pi \cdot \left(\frac{1}{2}\right)^3 \quad [13]$$

where:

V_S: volume of sphere
r: radius of sphere
$V_{S,r=0.5}$: volume of sphere with radius $r = 0.5$

$$f_V = \frac{V_{C,a=1}}{V_{S,r=0.5}} \cdot \frac{\pi}{3 \cdot \sqrt{2}} = \sqrt{2} \quad [14]$$

where:

f_V: volume factor

5.2.2 Color gamut slices

The color gamut is subdivided into slices each $\Delta L = 1$ step. For this purpose the intersections between the plane at lightness L_x and an edge of the surface traingles defined by *Point A* and *Point B* have to be computed. Hence, each intersection point at plane L_x (cf. Figure 13) whose position fulfills the following requirement will be found (cf. Equation [15]):

$$((L_{Point\,A} \leq L_x) \wedge (L_{Point\,B} \geq L_x)) \dot{\vee} ((L_{Point\,A} \geq L_x) \wedge (L_{Point\,B} \leq L_x)) \quad [15]$$

where:

L_{PointA}: lightness L*of *Point A*
L_X: lightness L* and position for generating a slice
L_{PointB}: lightness L* of *Point B*

The points of intersection form an area in the slice at lightness L_x in the two-dimensional space. (cf. Figure 13).

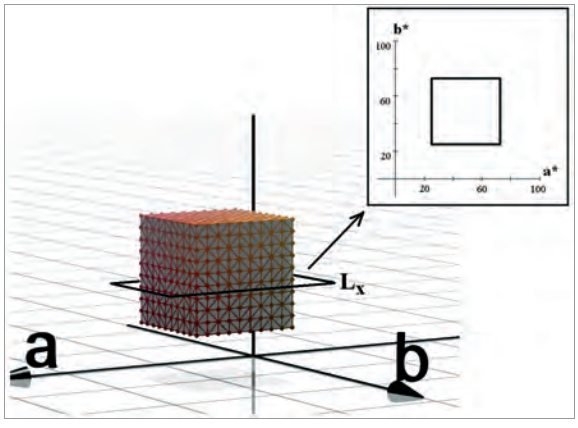

Figure 13: Gamut slice of test object (section 4.1) at lightness L_X

$$p_{L_x} = \begin{pmatrix} L_x \\ 0 \\ 0 \end{pmatrix} + \mu \cdot \begin{pmatrix} 0 \\ 1 \\ 0 \end{pmatrix} + \nu \cdot \begin{pmatrix} 0 \\ 0 \\ 1 \end{pmatrix} \quad [16]$$

$$S_{Point\,A,Point\,B} = \begin{pmatrix} L_{point\,A} \\ a_{point\,A} \\ b_{point\,A} \end{pmatrix} + \lambda \cdot \begin{pmatrix} L_{point\,B} - L_{Point\,A} \\ a_{point\,B} - a_{point\,A} \\ b_{point\,B} - b_{Point\,A} \end{pmatrix} \quad [17]$$

$$P_{Intersection} = \begin{pmatrix} L_x \\ \mu \\ \nu \end{pmatrix} \quad [18]$$

where:

p_{Lx}: plane at L_x
L_x: lightness L* at position x
$s_{PointA,PointB}$: straight line between *Point A* and *Point B*
$P_{Intersection}$: point of intersection
L_{PointA}, a_{PointA}, b_{PointA}: coordinates of *Point A*
L_{PointB}, a_{PointB}, b_{PointB}: coordinates of *Point B*
λ, μ, ν: factors for creating a straight line or plane

5.3 Representability of spot colors

To evaluate if a spot color is representable by a printing device, its three-dimensional position in relation to the color gamut boundary has to be observed.

Thus the two-dimensional slice created by a* and b* coordinates of the color gamut is observed at the position L_x (L*-coordinate of the color in question).

Exemplarily, Figure 14 shows the two-dimensional slice at L_x = 25.4 given by the L* value of the color Pantone© Violet C (*L** 25.4, *a** 47.5, *b** -68.0).

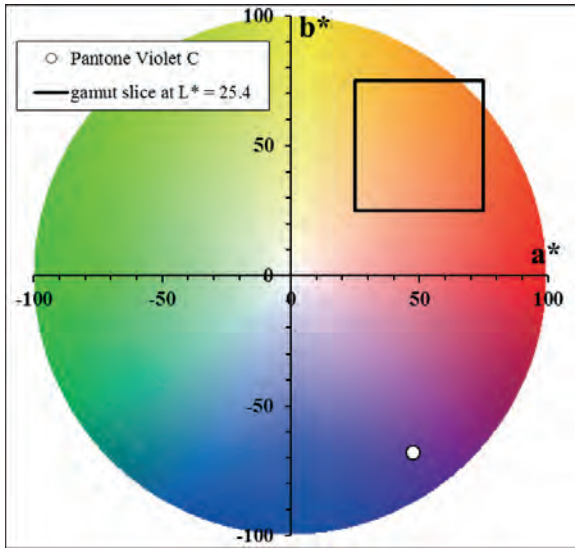

Figure 14:
Two-dimensional visualization of the color gamut slice at lightness L=25.4; spot color Pantone© Violet C (L* 25.4, a* 47.5, b* -68.0)*

6. Color gamut determination and assessment of the lithographic printing process (ISO12647-2)

6.1 Basis for determination

In this section the "Color Gamut Calculator" is used for determining and assessing the color gamut boundary of the lithographic printing process (ISO 12647-1).

The 1 485 testing patches of the ECI2002 test chart serve as an input data sample for the evaluation of the "Color Gamut Calculator". This set of color point values will be used for the determination of the color gamut boundary of the lithographic printing process.

6.2 Parameters of the determination

Following our proposed method (cf. chapter 3), the point set is first analyzed and parameters estimated. So the center point of the point cloud is located at *L** = 52.412, *a** = 2.505 and *b** = 23.605. The greatest distance between center point and color points is found, so that the radius of the sphere r_s = 84 units is given. By using the minimum radius (stretching factor f_S =1) and maximum triangulation (2 048 triangles generated) the most detailed determination can be obtained.

6.3 Three-dimensional visualization

The color gamut boundary consisting of color points and triangles can be visualized (cf. Figure 15).

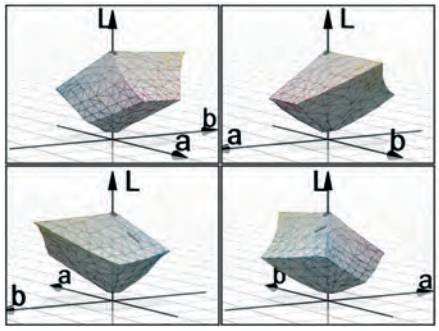

Figure 15:
Three-dimensional visualization of the color gamut boundary (ISO 12647-2) using our Color Gamut Calculator

6.4 Volume of the color gamut

The "Color Gamut Calculator" computes a color gamut volume of 383 825 cubes with side length a =1. This amounts to 542 463 distinguishable colors (ΔE =1).

6.5 Two-dimensional visualization

In this investigation, slices of the color gamut are generated in steps of ΔL.

Exemplarily, five slices with the L* value of 20, 30, 40, 50 and 60 units are shown in Figure 16.

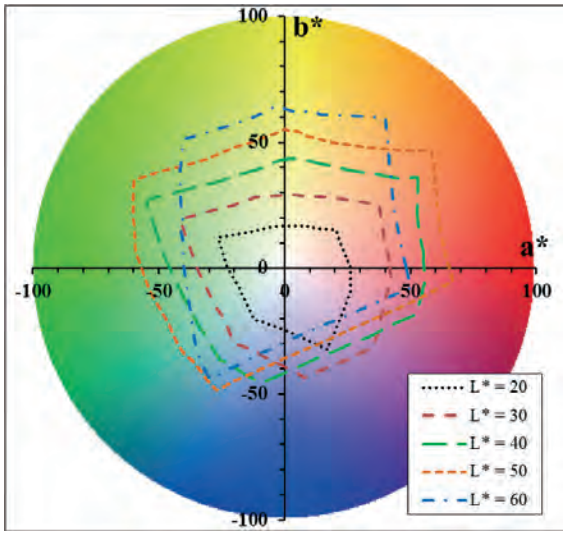

Figure 16: Standard lithographic color gamut ISO 12647-2 visualized in two-dimensional space; slices from L=20 to L*=60 in steps of 10 units*

6.6 Spot colors

For demonstrations, the color value Pantone© Violet C (*L** 25.4, *a** 47.5, *b** -68.0) is chosen to test whether the color is representable by the standard lithographic printing process. The slice of the color gamut boundary at *L** 25.4 and the location of the spot color are visualized in the two-dimensional space (cf. Figure 17).

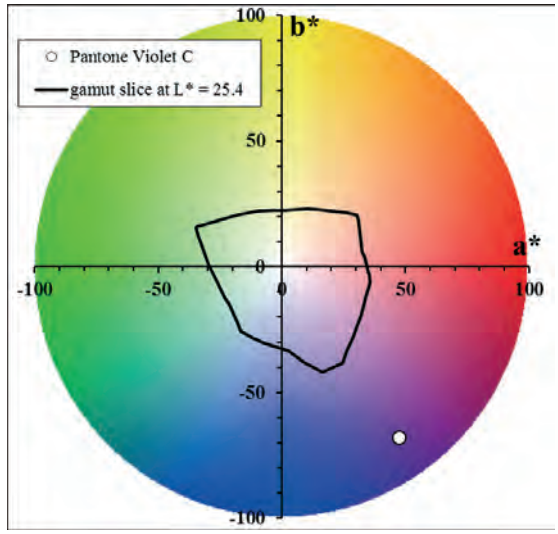

Figure 17: Pantone© color Violet C in relation to the standard lithographic color gamut (ISO 12647-2) visualized in two-dimensional space; visualized slice at L=25.4*

7. Conclusions and future work

The "Color Gamut Calculator" implemented here allows good color gamut boundary determination and assessment. The determination process starts with a comprehensive analysis of the input data. In comparison with previous methods we adapt the accuracy of the computation to the requirements given by the input data, so overestimated or underestimated results can be avoided. As shown in section 4, the accuracy of the generated gamut surface is influenced by different computational parameters and input data characteristics. If the influence of the parameters is taken into account, the quality of computation will be good. But there are limits with regard to the visualization of concave areas.

We will continue our work to solve the existing problem of determining concave point sets. We suspect potential for improvement by integrating a further iteration step. Comprehensive comparison of our approach with others will help in assessing the quality of computation. Future work will be devoted to this task.

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Model for calculation of design and electrical parameters of thermoelectric generators

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Abstract

Energy harvesting - the conversion of ambient energy into electrical energy - is a frequently used term nowadays. Several conversion principles are available, e. g., photovoltaics, wind power and water power. Less known are thermoelectric generators (TEG) although they were already studied actively during and after the world wars in the 20th century (Caltech Material Science, n. d.). In this work, the authors present a mathematical model for the calculation of input or output parameters of printed thermoelectric generators. The model is strongly related to existing models (Freunek et al., 2009; Rowe, 1995; Glatz et al., 2006) for conventionally produced TEGs as well as for printed TEGs. Thermal effects as investigated by Freunek et al. (2009; 2010) could be included. In order to demonstrate the benefit of the model, two examples of calculations are presented. The parameters of the materials are derived from existing printing inks reported elsewhere (Chen et al., 2011; Wuesten and Potje-Kamloth, 2008; Zhang et al., 2010; Liu et al., 2011; Bubnova et al., 2011). The printing settings are chosen based on feasibility and convenience.

Keywords: screen printing, thermoelectric generator, energy harvesting, modelling

1. Introduction and background

A thermoelectric generator (TEG) allows the direct conversion of thermal energy into electrical energy. This effect was found by the physicist Thomas Johann Seebeck in the beginning of the 19th century. Jean Peltier discovered the reverse effect, the generation of a hot and a cold side by applying an electric current. British physicist William Thomson found the effect of absorption or evolution of heat along a current-carrying conductor, when its two ends are kept at different temperatures (Kumar, 2004). The Seebeck, Peltier and Thomson effects are subsumed under the notion thermoelectric effect.

The principle of converting heat into electricity is illustrated in Figure 1. Two dissimilar materials (leg 1 and leg 2) are electrically connected. If the junction and the open ends of this thermocouple are kept at different temperatures, a thermoelectric voltage V_{oc} can be measured. The Seebeck effect was initially observed for metals, but also semiconductors show thermoelectric properties. Using semiconductors, the different leg materials are indicated by the terms n-type or p-type materials, since the leg materials are subdivided in two classes according to the concentration of the majority charge carriers (electrons in n-type and 'holes' in p-type materials respectively).

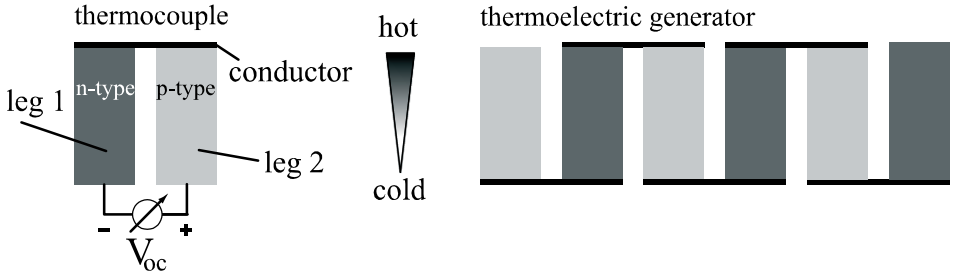


Figure 1: Schematic illustration of a thermocouple. Two dissimilar materials are electrically connected. If a temperature gradient is applied, a thermoelectric voltage can be measured. A thermoelectric generator is a series connection of single thermocouples

Since the thermoelectric voltage V_{oc} is very small (some to some tens of μV), a series connection of single thermocouples (TC) is applied to constitute a TEG. High costs of around 30 $/Watt (Hendricks and Choate, 2006) of conventionally produced TEGs encourage researchers to find a less expensive production procedure that could be realized by the printing of the whole generator or at least some parts of it.

Generally, there are two different layouts of printed TEGs, the coplanar and the vertical design (Glatz, 2008). In this paper only the vertical design is considered.

According to Figure 2 a) the fully printed TEG consists of at least five layers (Willfahrt et al., 2011).

Printing TEGs implies that the lengths of the thermocouples are identical and that the gaps between the thermoelectric legs are filled with electrical and thermal insulating material. It is further assumed that the edge length a of the square shaped apertures in the insulating layer and the distance d between the apertures are equal in both directions. The depth of the apertures l is equal for both thermoelectric legs, since it is determined by the thickness of the printed insulating layer.

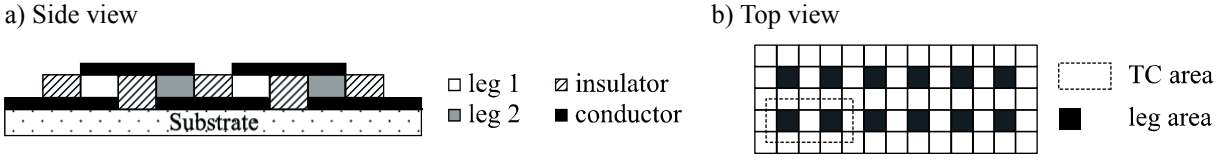


Figure 2: a) Schematic illustration of a vertically printed TEG. b) The area of a thermocouple is determined by eight congruent parts (=area of one thermoelectric leg). Using printing technologies the design parameters can be changed easily

2. Methods

On the basis of Michael Freunek's doctoral thesis (Freunek, 2010) a mathematical model for the optimization of thermoelectric generators was established. Unlike Freunek, the authors of this paper include additional input variables, namely the geometric and material properties of the thermal coupling and thermoelectric layers. Two different approaches to the optimization of the printed TEGs are presented:

a) The optimized geometric properties of the TEG are calculated depending on the required electrical performance, a reasonable temperature difference and the given parameters of the thermoelectric materials (electrical resistivity and thermal conductivity) and of the thermal coupling layers to heat source and heat sink, as shown in Table 1.

b) The optimization of electrical parameters depending on parameters given by the printing process, as shown in Table 2.

Table 1: Optimized design parameters

Given parameters	Voltage at the load V_{load}, power at the load P_{load}, load resistance R_{load}, electric current I, temperatures T_0 and T_1, thermal resistance $K_c^*+K_h^*$ of coupling layers for area A^*
Calculated parameters	Leg length l, number of TCs m, cross-sectional area of a leg A_{leg}, total area of TEG A_g, thermal resistance of TEG K_g, thermal resistance K_c+K_h of coupling layers of area A_g

Table 2: Optimized electrical parameters

Given parameters	Leg length l, leg area A_{leg}, total area of TEG A_g, temperatures T_0 and T_1
Calculated parameters	Number of TCs m, ohmic resistance TEG R_g, ohmic resistance of load R_{load}, voltage at load V_{load}, electric current I, power at load P_{load}, thermal resistance K_c+K_h

3. Results

In this section the required equations will be established. Many of them are well understood and reported elsewhere (Rowe, 1995; Freunek, 2010). For the interested reader these equations are listed in the Appendix.

The equations adapted to the printing process are explicitly mentioned. In the following, uniform cross-sectional areas $A_n = A_p = A_{leg}$ as well as uniform lengths $l_n = l_p = l$ are assumed.

3.1 Power output of printed TEGs without thermal effects

The Seebeck coefficient S is a non-linear function of the temperature depending on the material and its lattice structure. For small temperature differences S may be considered constant and independent of temperature (Appendix, [A1]). The open circuit voltage V_{oc} of a TEG is proportional to the number of serially

connected thermocouples m (Appendix, [A2]). The total area of a TEG A_g is determined by the number of thermocouples m, a factor 8 - see Figure 2 b) - and the area of a single thermoelectric leg A_{leg} (Appendix, [A3]). Maximum power transfer to the load requires $R_{load} = R_g$. This means that half of the generated power is transferred to the load.

$$P_{load} = \frac{(mS_{tc}\Delta T_g)^2}{4m(\rho_n + \rho_p)\frac{l}{A_{leg}}} = m\frac{(S_{tc}\Delta T_g)^2}{4(\rho_n + \rho_p)}\frac{A_{leg}}{l} \qquad [1]$$

The ohmic resistances of the conductors are neglected because they are small compared to the resistances of the thermoelectric materials. In order to keep the model simple, the contact resistances will also be neglected.

Thus, the total resistance R_g (Appendix, [A5]) is governed by the resistivity of the leg materials ρ_n and ρ_p, the number of thermocouples m and the geometric parameters of the legs. In conclusion it can be said that the power output P_{out} depends linearly on the cross-sectional area of the legs A_{leg} under the assumption that the number of thermocouples m, the length of the legs l (= depth of the cavities in the insulator) and the temperature difference are fixed.

3.2 Optimized TEG model including thermal effects

In the previous section the flow of heat, the thermal coupling, the Joule heating, the Peltier effect and the Thomson effect were not considered. Recent publications on the performance analysis of thermo-electric systems consider only some of them or use numerical methods.

In his work, Freunek established energy balance equations, which include all the above-mentioned effects. He applied a Taylor expansion to solve the equations analytically.

Fortunately, only the Peltier effect and the heat flow through the TEG have significant impact on the result and therefore only these effects have to be considered (Freunek, 2010). Thus, Freunek's results enable the analytical optimization of printed TEGs. The temperature difference $\Delta T = T_1 - T_0$ between heat source (T_1) and heat sink (T_0) differs from the temperature difference ΔT_g in the thermoelectric legs (Appendix, [A13]). Mainly the thermal resistances K_h, K_c and K_g (thermal conductor attached to the heat source, thermal conductor attached to the heat sink and thermoelectric legs respectively) determine the temperature difference, as shown in Figure 3.

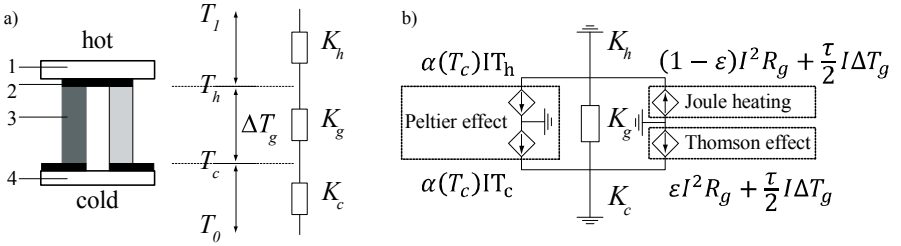
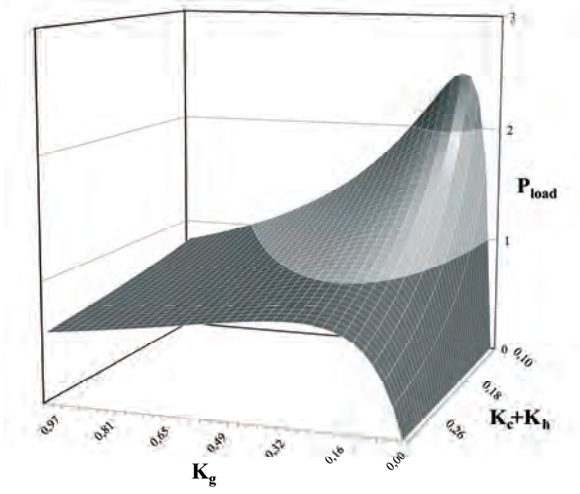


Figure 3: a) Schematic illustration and equivalent circuit diagram of the thermal resistances in a thermoelectric generator. 1) Thermal conductor attached to the heat source with corresponding thermal resistance K_h; 2) Electrical conductor; 3) Thermoelectric legs with thermal resistance K_g; 4) Thermal conductor attached to the heat sink with corresponding thermal resistance K_c. The temperature difference ΔT (=T_1-T_0) between heat source and heat sink differs from the temperature difference ΔT_g in the thermoelectric legs. b) Contribution of Peltier effect and Thomson effect as well as Joule heating to the thermal behaviour of a TEG (Freunek et al., 2009)



Freunek introduced the effective resistance R_{eff} that implies the thermal contact resistance K_c+K_h as well as the resistance of all thermocouples K_g (Appendix, [A14]).

As shown in Figure 4, the power transfer to the load for a given value of K_c+K_h is maximized by an appropriate value of K_g. The optimized power output is derived from (Appendix, [A19]) and (Appendix, [A18]).

$$P_{load,opt} = \frac{\Delta T^2}{4}\frac{1}{(K_c + K_h)}\frac{Z}{(1+\sqrt{1+ZT_0})^2} \qquad [2]$$

Figure 4:
Diagram of the power transferred to the load as a function of K_c+K_h and K_g. Arbitrary data without units

This corresponds to the intuitive expectation that small values of the thermal resistance K_c+K_h result in a high power output.

The effective resistance R_{eff} includes a correction factor containing the dimensionless figure of merit ZT_0 (Appendix, [A20]).

The thermal resistance K_g of the thermoelectric generator is the quotient of the thermal resistance of a thermocouple K_{tc} and the number of TCs m.

$$K_g = \frac{K_{tc}}{m} = \frac{l}{m\,A_{leg}} \frac{1}{\lambda_n + \lambda_p} \qquad [3]$$

(*Freunek, 2010*)

According to (Appendix, [A3]) K_c+K_h in series connection may be expressed as:

$$K_c + K_h = \frac{1}{A_g}\left(\frac{l_c}{\lambda_c} + \frac{l_h}{\lambda_h}\right) = \frac{1}{m\,8\,A_{leg}}\left(\frac{l_c}{\lambda_c} + \frac{l_h}{\lambda_h}\right) \qquad [4]$$

If compound materials are used as a substrate and if the influence of conductive paste should be included, thermal conductivities may be unknown. In this case experimentally obtained values K_C^*+K_h^* could be used instead of the thermal conductivities as long as the area A^* is known to which these values refer to.

$$K_c + K_h = (K_c^* + K_h^*)\frac{A^*}{A_g} = (K_c^* + K_h^*)\frac{A^*}{m\,8\,A_{leg}} \qquad [5]$$

Unlike Freunek (2010) the combined thermal resistance of $K_c + K_h$ is not a fixed parameter but depends on the scalable area A_g of the TEG.

With [3] and [4] in (Appendix, [A19]) the length of the legs can be calculated to:

$$l = \frac{1}{8}\sqrt{1+ZT_0}\,(\lambda_n + \lambda_p)\,(\frac{l_c}{\lambda_c} + \frac{l_h}{\lambda_h}) \qquad [6]$$

or if the thermal resistance K_c^*+K_h^* for an area A^* is known:

$$l = \frac{1}{8}\sqrt{1+ZT_0}\,(\lambda_n + \lambda_p)\,(K_c^* + K_h^*)\,A^* \qquad [7]$$

In case of maximum power transfer (R_{load}=R_{eff}) (Appendix, [A24]) the number of TCs is:

$$m = \frac{2\,V_{load}}{S_{tc}\,\Delta T}\,\frac{\sqrt{1+ZT_0}+1}{\sqrt{1+ZT_0}} \qquad [8]$$

Appendix, [A11]) and [8] inserted in (Appendix, [A20]) allow calculating the cross-sectional area of the legs Al_e.

$$A_{leg} = \frac{2V_{load}}{S_{tc}\Delta T}\,\frac{\sqrt{1+ZT_0}+1}{\sqrt{1+ZT_0}}\,\frac{l}{R_{load}}(\rho_n + \rho_p)\sqrt{1+ZT_0} = \frac{V_{load}}{R_{load}}\,\frac{2l}{S_{tc}\Delta T}(\rho_n + \rho_p)(\sqrt{1+ZT_0}+1) \qquad [9]$$

(Appendix, [A14]) may be transformed into:

$$P_{out,max} = (S\,\Delta T)^2\left(\frac{K_g}{K_c + K_h + K_g}\right)^2 \frac{1}{4\,R_{load}} = \frac{(mS_{tc}\,\Delta T)^2}{4\,R_{load}}\left(\frac{\sqrt{1+ZT_0}}{\sqrt{1+ZT_0}+1}\right)^2 = \frac{(V_{load})^2}{R_{load}} \qquad [10]$$

4. Discussion

4.1 TEG design depending on electrical requirements of the application

Based on the equations for the thermoelectric voltage and the power transfer in section 3.2 the optimized design parameters for printed TEGs are calculated analytically. With this model it is possible to choose the input data, e. g., the voltage requirement of a given load, the load resistance, the electrical power needed by the load or the current in the electrical circuit comprising of the TEG, and the load. For the calculation only two of the aforementioned electrical parameters are required since the others are interdependent parameters.

Besides, additional parameters, e. g. the thermal conductivities, the electrical resistivities and the Seebeck co-efficients of the used materials as well as the temperature difference must be known.

Table 3 shows a set of thermoelectric materials reported elsewhere. All materials are printable but differ in the required process parameters. The bismuth containing epoxy inks need thermal treatment in vacuum at high temperatures. These materials, however, are not appropriate for printed TEG on PET. Thus, polymer substrate with a higher melting point like PA 66 has to be used.

To achieve a required voltage at the load and maximum power transfer the design parameters m, l, A_{leg} and A_g are determined by [8], [6] or [7], [9] and (Appendix, [A3]).

Table 3: Thermoelectric materials for printed TEGs reported in literature

Materials	S (μV K^{-1})	ρ (Ohm cm)	λ (W m^{-1} K^{-1})
Nickel (Ni)	-19 (1)	2.5 x 10^{-2} (2)	90.7 (1)
TTF-TCNQ	-18 (3) - - 48 (1)	1 x 10^{-3}(4)	0.34 (3)- 1 (1)
PEDOT:PSS	20 - 30 (6)	2-3.3 x 10^{-3}	0.17 (7)- 0.2
PEDOT:tosylate	40 (8)	3.3 x 10^{-3} (8)	~ 0.35 (8)
n-type Bi_2Te_3 /Epoxy	-159 (5)	12.5 x 10^{-2} (5)	0.48 (5)
p-type $Bi_2Sb_{1.5}Te_3$ /Epoxy	272 (5)	6.9 x 10^{-2} (5)	0.52 (5)
PET/PA 66	-	-	0.24 (9)/0.24 (10)

(1) (Wuesten and Potje-Kamloth, 2008); (2) (Creative Materials, 1994); (3) (Itahara et al., 2009); (4) (Salameh, 2005); (5) (Chen et al., 2011); (6) (Zhang et al., 2010); (7) (Liu et al., 2011); (8) (Bubnova et al., 2011); (9) (Osswald and Hernández-Ortiz, 2006); (10) (Crawford, 1998 cited in Algaer, 2010).

A specific example of an optimized TEG according to the introduced mathematical model is shown in Table 4.

The comparison of the optimized value of K_c+K_h and the thermal resistance of PA 66 foil shows that it is feasible to achieve the required thermal resistance.

If the cross-sectional area of the legs is changed, it has to be ensured that the total resistance of the conductors is smaller than the total resistance of the legs. The total resistance of the conductors only depends on the layer thickness and the resistivity, but not on the conductor's cross-sectional area. In contrast, the total resistance of the legs depends on their cross-sectional area.

$$2\frac{\rho_c}{d} << \frac{(\rho_n + \rho_p)\, l}{A_{leg}} \qquad [11]$$

Table 4: Optimized design parameters using Bi_2Te_3/Epoxy and $Bi_2Sb_{1.5}Te_3$/Epoxy

Input parameters		Output parameters	
Voltage V_{load}	0.5 V	Length of the legs l	101 μm
Power P_{load}	1 mW	Number of TCs m	1536
Resistance R_{load}	250 Ohm	Cross-sectional area A_{leg}	1.23 mm^2
Current I	2 m A	Total area A_g	150.7 cm^2
Lower temperature T_0	27 °C	Thermal resistance K_g	0.0539 KW^{-1}
Upper temperature T_1	30 °C	Thermal resistance K_c +K_h	0.0551 KW^{-1}
Thermal resistance Kc^* + Kh^* for A^* = 1 cm^2	8 KW^{-1}	Thermal resistance of PA 66 thickness = 200 μm, A = A_g	0.0553 KW^{-1}

4.2 Optimization of electrical parameters depending on the printing process

In an experimental situation, the leg length l, the uniform cross-sectional area A_{leg} and the total cross-sectional area of the TEG A_g may be given. According to equation [6] the thermal interfacing materials connecting the TEG to the heat source and the heat sink respectively have to fulfil the condition:

$$\left(\frac{l_c}{\lambda_c} + \frac{l_h}{\lambda_h}\right) = \frac{8\, l}{\sqrt{1 + ZT_0}\,(\lambda_p + \lambda_n)} \qquad [12]$$

Following [7] alternatively the experimentally optimized values K_C^*+K_h^* could be used instead of the thermal conductivities under the assumption that the corresponding area A^* is given:

$$(K_c^* + K_h^*)\, A^* = \frac{8\, l}{\sqrt{1 + ZT_0}\,(\lambda_n + \lambda_p)} \qquad [13]$$

Equation [12] shows that the optimal thicknesses of the substrate and of the electrical insulating material covering the legs depend on their thermal conductivities.

Further it is shown that they are not independent from each other. In order to fulfil the requirements for thermal optimization the usage of a compound material including a metal foil as a substrate makes sense. The thermal resistance of that compound material is smaller than that of bulk polymer foil, e.g. PA 66. This implies also a smaller thermal resistance of the whole TEG.

Equation (Appendix, [A3]) provides the number of thermocouples m:

$$m = \frac{A_g}{A_{tc}} = \frac{A_g}{8\, A_{leg}} \qquad [14]$$

The calculated number of thermocouples m in (Appendix, [A24]) results in the voltage at the load:

$$V_{load} = \frac{A_g}{8\,A_{leg}} \frac{S_{tc}\,\Delta T}{2} \frac{\sqrt{1+ZT_0}}{\sqrt{1+ZT_0}+1} \qquad [15]$$

Additionally, the internal resistance of the TEG can now be calculated by using equation (Appendix, [A11]).

$$R_g = m\,(\rho_n + \rho_p)\frac{l}{A_{leg}} = (\rho_n + \rho_p)\frac{l\,A_g}{8\,A_{leg}^{\,2}} \qquad [16]$$

Applying equation (Appendix, [20]), the adjusted resistance of the load R_{load} can be calculated:

$$R_{load} = R_{eff} = R_g\sqrt{1+ZT_0} \qquad [17]$$

(Freunek, 2010)

The current at the load (Appendix, [A25]) results in the maximum electrical power:

$$P_{\text{load,opt}} = V_{load}\;I = \frac{V_{load}^{\,2}}{R_{load}} \qquad [18]$$

The leg length l is the most significant parameter for several reasons. It determines the distance between the hot and the cold side of the TEG but it also governs its ohmic resistance. Additionally the flexibility of thin TEGs is depending on the thickness of the whole compound.

Even though screen printing is capable of depositing an ink layer thickness of some hundred micrometres the aspect ratio of l and A_{leg} is critical in terms of filling the cavities.

Results of an example calculation for input parameters addressing issues of screen printing are given in Table 5.

Table 5: Optimized electrical parameters using TTF-TCNQ (S=-48μVK^{-1}, ρ=1x10^{-3} Ohm cm, λ=0.35Wm^{-1}K^{-1}) and PEDOT:tosylate (S=40μVK^{-1}, ρ=3.3x10^{-3} Ohm cm, λ=0.34 Wm^{-1}K^{-1})

Input parameters		Output parameters	
Leg length l	200 μm	Number of TCs m	1 875
Area of the legs A_{leg}	1 mm²	Ohmic resistance of TEG R_g	16.1 Ohm
Area of the TEG A_g	150 cm²	Ohmic resistance of load R_{load}	16.7 Ohm
Lower temperature T_0	27 °C	Voltage at load V_{load}	0.126 V
Upper temperature T_1	30 °C	Electric current I	6.6 mA
		Power at load P_{load}	0.95 mW
		Thermal resistance K_c+K_h	0.1413 KW^{-1}
		Thermal resistance of PET Thickness =200 μm, A = A_g	0.1472 KW^{-1}

The number of thermocouples is determined by equation [8] and the cross-sectional area is given by [9].

The geometric parameters of the TEG ([6], [7], [9]) have to be checked against its printability. Using equation [12] the thermal resistance K_c^*+K_h^* for a given area A^* may be calculated. According to (Appendix, [A18]) and Figure 4 it is obviously advisable to keep K_c+K_h smaller than the result calculated by (Appendix, [A19]), if K_g is determined by geometric parameters.

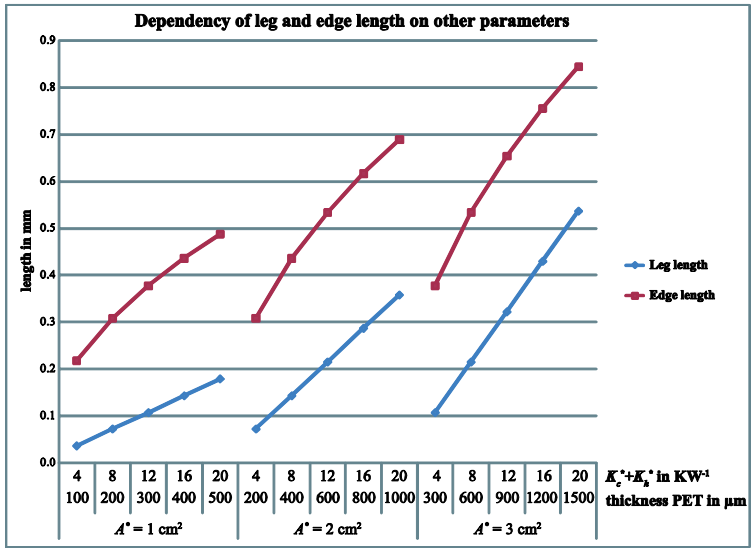


Figure 5: Diagram of the geometric parameters leg and edge length (a and l) depending on the thermal resistance K_c^*+K_h^*, the corresponding area A^* and the equivalent thickness of the PET substrate. The calculation is based on the thermoelectric materials TTF-TCNQ and PEDOT:tosylate

According to Figure 5, a compromise has to be found between the printable geometric parameters (leg length l and edge length a) and the thermal parameters of the calculated TEG. The thickness of the PET substrate has to be chosen according to equation [A26]. From a printers point of view it is convenient to start from an edge length of around 500 µm, since the corresponding leg length starts from around 200 µm (see Figure 5, $K_c^*+K_b^*=20\,\mathrm{KW}^{-1}$; $A^*=1\mathrm{cm}^2$). The thicker the substrate and the corresponding area A^* gets, the more both geometric parameters grow. Although screen printing is able to deposit thick ink films on the substrate, this is the limiting factor if the ink layer thickness is to be accomplished with only one print pass.

5. Conclusions

The developed model allows the calculation of independent parameters characterizing a (printed) thermoelectric generator at known performance requirements and at an assumed temperature difference. The most important part is the calculation of the geometric dimensions of the TEG at a given material combination in order to achieve maximum thermo-electric power output. The power adjustment may be realized considering the supply voltage and the power requirements of a load. But, alternatively, also the resistance of the load or the electric current through the load may be given. The required number of thermo-couples, the optimized length of the legs, the cross-sectional area of the legs as well as the total area of the TEG can be calculated. The second approach allows calculating the load at the TEG for given properties of the thermoelectric materials and under the geometric restrictions of the printing method. The TEG is coupled to the heat source/sink through the thermal resistance K_c+K_b. These parameters have significant influence on the performance of the TEG. On one hand, the length of the legs l has to be matched on the thermal resistances according to equations [6] and [7]. On the other hand, l has a significant impact on the internal resistance of the generator (Appendix, [A11]), on the effective resistance introduced by Freunek (2010) and on the optimal load resistance R_{load}.

In this work, the thermal resistance of the insulating layer was neglected. But it could be implemented in the calculation by introducing an additional parameter $\lambda_{insulator}$ e. g. in [3]. The influence of the thermal resistance of the insulator material depends on the structure of this layer.

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List of symbols and abbreviations

a	edge length of aperture in insulating layer
A^*	area for which the combined thermal resistance Kc^*+Kb^* is known
A_g	cross-sectional area of the thermoelectric generator
A_{leg}	cross-sectional area of a leg
A_n	cross-sectional area of n-leg
A_p	cross-sectional area of p-leg
A_{tc}	cross-sectional area of a thermocouple
d	distance between the apertures in the insulating layer
I	electric current
K_c	thermal resistance between the thermoelectric generator and the heat sink
$K_c^*+K_b^*$	thermal resistance of the coupling layers for area A^*
K_c+K_b	thermal resistance of the coupling layers of area A_g
K_g	thermal resistance of the thermoelectric generator
K_b	thermal resistance between the thermoelectric generator and the heat source
K_{tc}	thermal resistance of a thermocouple
l	length of the aperture in the insulating layer
l_n	length of n-leg
l_p	length of p-leg
m	number of thermocouples
P_{load}	power at the load
$P_{load,opt}$	maximum electrical power at the load
R_{eff}	effective resistance
R_g	ohmic resistance of the thermoelectric generator
R_{load}	load resistance
S	Seebeck coefficient
S_{tc}	Seebeck coefficient of a thermocouple
T_0	temperature of the heat sink
T_1	temperature of the heat source
TC	thermocouple
V_{load}	voltage at the load

V_{oc}	open circuit voltage
ZT_0	dimensionless figure of merit
ΔT_g	temperature difference across the thermoelectric generator
λ	thermal conductivity
$\lambda_{insulator}$	thermal conductivity of insulating material
λ_n	thermal conductivity of n-material
λ_p	thermal conductivity of p-material
ϱ	electrical resistivity
ϱ_n	electrical resistivity of n-material
ϱ_p	electrical resistivity of p-material
ΔT	temperature difference of heat source and heat sink
TTF-TCNQ	tetrathiofulvalene 7,7,8,8,-tetracyano-quinodimethan
TEG	thermoelectric generator
PEDOT	poly(3,4-ethylenedioxythiophene)
PET	polyethylene terephthalate
PA 66	polyamide

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Appendix

Equations

The open circuit voltage of a thermoelectric device is:

$$V_{oc,tc} = (S_A - S_B)(T_h - T_c) = S_{tc}\Delta T_g \quad [A1]$$

S_A and S_B are the Seebeck coefficients of two dissimilar Materials A and B. $S_{tc} = S_A - S_B$ is the Seebeck coefficient of the thermocouple (TC) comprising of A and B. $\Delta T = T_h - T_c$ is the temperature difference between the ends of the TC. The open circuit voltage V_{oc} of a TEG is proportional to the number of serially connected thermocouples m

$$V_{oc} = S\Delta T_g = m\, S_{tc}\Delta T_g \quad [A2]$$

The total area of a TEG A_g is determined by m and the eightfold area of a leg A_{leg}

$$A_g = m\, A_{tc} = m\, 8A_{leg} \quad [A3]$$

TEGs can be considered as ideal voltage sources with an internal resistance R_g which is governed by the electrical resistances of the thermoelectric materials and the conductors. If a load is connected to the TEG and thus a current I flows the voltage drop $\Delta V = R_g I$ at R_g reduces V_{oc} to the voltage at the load V_{load}

$$V_{load} = m\, S_{tc}\Delta T_g - R_g I \quad [A4]$$

The resistance of a single thermocouple R_{tc} and the number of thermocouples m determine R_g. R_{tc} is the sum of the leg's resistances R_n and R_p as well as the conductor's resistances R_{ch} (hot side) and R_{cc} (cold side), which include also the contact resistances

$$R_g = m\, R_{tc} = m(R_n + R_p + R_{cc} + R_{ch}) \quad [A5]$$

The current results from Ohm's Law

$$I = \frac{V_{oc}}{R_g + R_{load}} = \frac{m\, S_{tc}\Delta T_g}{R_g + R_{load}} \quad [A6]$$

The voltage at the load equals the voltage drop at R_{load}

$$V_{load} = V_{oc}\frac{R_{load}}{R_g + R_{load}} = mS_{tc}\Delta T_g \frac{R_{load}}{R_g + R_{load}} \quad [A7]$$

The electrical power at the load

$$P_{load} = I^2 R_{load} = \left(\frac{m\, S_{tc}\Delta T_g}{R_g + R_{load}}\right)^2 R_{load} = (mS_{tc}\Delta T)^2 \cdot \frac{R_{load}}{(R_g + R_{load})^2} \quad [A8]$$

Using the matching condition $R_{load} = R_g$ equations [A7] and [A8] can be simplified to [A9] and [A10]

$$V_{load} = \frac{V_{oc}}{2} = \frac{m\, S_{tc}\Delta T_g}{2} \quad [A9]$$

$$P_{out} = \frac{(m\, S_{tc}\Delta T_g)^2}{4R_{load}} = \frac{(m\, S_{tc}\Delta T_g)^2}{4R_g} \quad [A10]$$

The total resistance R_g is assumed to be governed by the electrical resistivity of the leg materials ρ_n and ρ_p and the number and geometric parameters of the legs

$$R_g = m\,(R_n + R_p) = m\,(\rho_n \frac{l_n}{A_n} + \rho_p \frac{l_p}{A_p}) = m\,(\rho_n + \rho_p)\frac{l}{A_{leg}} \quad [A11]$$

The relationship between the temperature difference at the legs ΔT_g and the temperature difference between heat source and heat sink ΔT (see Figure 3) is

$$\Delta T_g = \frac{\Delta T}{1 + \frac{K_c + K_h}{K_g} + \frac{S^2(K_c T_1 + K_h T_0)}{R_g + R_{load}}} \quad \text{(Freunek, 2010) [A12]}$$

Assuming a small temperature difference ΔT

$$T_1 = T_0 + \Delta T \approx T_0$$ (Freunek, 2010) [16]

[A12] simplifies to

$$\Delta T_g \approx \frac{\Delta T}{\frac{K_g + K_c + K_h}{K_g} + \frac{S^2 T_0 (K_c + K_h)}{R_g + R_{load}}}$$ (Freunek, 2010) [A13]

Freunek introduces the effective resistance R_{eff} that implies the thermal contact resistances K_h and $K_c$as well as the resistance of all thermocouples K_g

$$R_{eff} \approx R_g + S^2 K_g T_0 \frac{K_c + K_h}{K_c + K_h + K_g}$$ (Freunek, 2010) [A14]

For maximum power transfer $R_{load} = R_{eff}$

$$P_{\text{load,opt}} = (S\Delta T)^2 \left(\frac{K_g}{K_g + K_c + K_h} \right)^2 \frac{1}{4R_{eff}}$$ (Freunek, 2010) [A15]

With the figure of merit Z

$$Z = \frac{S^2 \cdot K_g}{R_g}$$ (Freunek, 2010) [A16]

equation [A14] can be transformed to

$$R_{eff} \approx R_g (1 + ZT_0 \frac{K_c + K_h}{K_c + K_h + K_g})$$ (Freunek, 2010) [A17]

The dimensionless figure of merit ZT is the product of Z with the average temperature T, which is approximated with T_0.

$$\mathrm{P}_{\text{load, opt}} = \frac{\Delta T^2 Z}{4} \frac{K_g}{(K_c + K_h + K_g)^2} \frac{1}{(1 + ZT_0 \frac{K_c + K_h}{K_c + K_h + K_g})}$$ (Freunek, 2010) [A18]

In its mathematical structure the quotient containing only the thermal resistances has the same structure as the one for maximizing the resistance of the load R_{load}. So, it is possible to optimize the power at the load in respect to the thermal resistance K_g of the TEG, if K_c+K_h is determined by the geometric and the material parameters

$$K_{g,Popt} = (K_c + K_h)\sqrt{1 + ZT_0}$$ (Freunek, 2010) [A19]

With [A19] in [A17] R_{load} can be simplified to

$$R_{load} = R_{effPopt} = R_g \sqrt{1 + ZT_0}$$ (Freunek, 2010) [A20]

The temperature difference at the TEG results from [A19] and [A20] in [A13]

$$\Delta T_g = \frac{1}{2} \Delta T$$ (Freunek, 2010) [A21]

The following calculations take into account the application specific requirements regarding the supply voltage V_{load} at the load and the power output P_{load} delivered to the load for instance.

Because the lengths and cross-sectional areas of the thermoelectric legs area assumed to be equal for both legs, the figure of merit can be expressed only by thermal and electrical properties

$$Z = (m\, S_{tc})^2 \frac{\frac{l}{m\, A_{leg}} \frac{1}{\lambda_n + \lambda_p}}{\frac{m\, l}{A_{leg}} (\rho_n + \rho_p)} = S_{tc}^{\,2} \cdot \frac{1}{(\rho_n + \rho_p)(\lambda_n + \lambda_p)}$$ (Freunek, 2010) [A22]

According to [A7] the voltage at the load V_{load} is

$$V_{load} = m S_{tc} \Delta T_g \frac{R_{load}}{R_{load} + R_g} = S \Delta T_g \frac{R_{load}}{R_{load} + R_g}$$ [A23]

$$V_{load} = \frac{S\Delta T}{2} \cdot \frac{\sqrt{1 + ZT_0}}{\sqrt{1 + ZT_0} + 1} = \frac{m\, S_{tc} \Delta T}{2} \cdot \frac{\sqrt{1 + ZT_0}}{\sqrt{1 + ZT_0} + 1}$$ [A24]

The current results from

$$I = \frac{V_{load}}{R_{load}} \qquad [A25]$$

If thermal effects are considered a correction factor is necessary (compare the equations [A20], [A24], [10] with the equations [A8], [A9], [A10]). This factor depends on the dimensionless figure of merit ZT_0 and represents mainly the influence of the Peltier effect. According to equation [A20] R_{load} is higher than estimated in equation [A14]. This also leads to a higher power output.

Thickness of the PET substrate results from

$$K_{PET} = \frac{l_{PET}}{A_{PET}} \frac{1}{\lambda_{PET}} \qquad [A26]$$

Topicalities

Edited by Raša Urbas

Contents

News & more

Entering a new realm of professionalism

The new system of digital laser printing has introduced the entry-level black and white production device which will be able to handle monthly peak volumes of up to 1.5 million A4 prints. Highlights are its affordability, extraordinarily high print resolution and outstanding media flexibility as well as a tone curve utility that comes with the printer, maxed out paper capacity and professional finishing options.

The fully integrated media catalogue enables operators to define their media profiles, which are stored in a library and can be easily picked up from the printer driver. In addition the scheduler function gives a detailed overview of jobs in the queue and indicates the paper needed and the amount still in the tray. One of the features is also the tone curve utility; this tool can change RIP adjustments such as screening and tone curves.

The bizhub PRO 951 (product of Konica Minolta) holds up to 9 000 sheets of paper and enriches printouts with finishing options like stapling for up to 100 sheets, booklet making and z-folding as well as post insertion, GBC punching and automatic ring binding.

Thanks to a graphical user interface bizhub PRO 951 is easy to operate with touch screen access and a richness of printer drivers for enhanced compatibility. Its high productivity (55 A3 pages/min) and impressive media flexibility (duplex printing is possible with up to 300 g/m^2 paper) provide extremely short turnround times.

Cyrel-Fast-Round systems

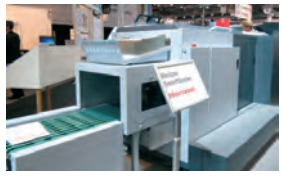
Flexographic market is now richer for jet another novelty - round sleeve making system. The system is the latest in the portfolio of sheet photopolymer products and workflows, launched by Cyrel® FAST by DuPont™

The round system is distinguished by small footprint and high throughput combined with remarkable productivity and quality. This novelty is the only sleeve-making system that uses dry, thermal technology to process high quality photopolymer sleeves, thus eliminating all solvents and aqueous solutions from the plate room.

The processor delivers high sleeve quality and uniformity, and along with the complementary exposure and post exposure units (Cyrel® FAST round EX 1450 an LF 1450) is part of a complete sleeve making system. Maximum sleeve size which can be produced by this system is 145 x 99 cm. The new round system produces a finished sleeve without the use of washout solvents or liquids of any kind.

Eliminating the traditional folding or cutting

Close technical cooperation between HP Indigo and Horizon offered new market solution which eliminates traditional folding and cutting. Novelty named SmartStacker possesses a cutting system which is fully automatically controlled and supports management through JDF-protocol data. With the use of rotary knife sheets are catted longitudinal, in header and footer as well as at the back.



The SmartStacker slits a B2-size sheet into a maximum of 28 individual sheets, with seven slits in one direction and four in the other. Slit sheets can be either offset or straight stacked for different applications. The system is compatible with papers of different grammages (from 65 to 400 g/m^2) and different formats (from 330 x 550 mm to maximum 530 x 760 mm).

The new SmartStacker is capable of operating as an independent system or as an integrated part in the existing production lines for perforation or folding.

Characterization of particle size distribution

The Cilas Nano DS Dual Light Scattering Particle Size Analyzer features a technology that makes nano particle characterization more accurate.

The Nano DS is the only nano particle size analyzer to combine static light scattering and dynamic light scattering technologies into a single optical system. This revolutionary technology provides the best accuracy, repeatability and resolution over the entire range of 0.3 nm to 10 microns.

Inks for solvent based wide format printers

Portfolio of inks for wide format printers has been extended with two new Streamline inks - ESL HPQ and Ultima HPQ from Sun Chemical. Both ink ranges have been designed for use in solvent based wide format printers due to the fact that they have excellent adhesion to very wide range of media which is commonly used in the sign and graphic markets.

Streamline ESL HPQ and Streamline Ultima HPQ are distinguished by color shade and strength. They ensure high quality of prints and good adhesion to different printing media.

In addition to mentioned inks Sun Chemical has also introduced new multipurpose system SunUno Solimax for surface and reverse print applications on a number of commonly used flexible packaging substrates. Ink system is suitable for flexographic and rotogravure print processes and provides shelf stand out and high quality packaging.

New inks are intended for surface printing and adhesive lamination for various end-use applications - lidding materials, medical laminates and food packaging (low migration properties). Solimax is compatible with both solvent free and solvent based lamination technologies. Inks could be used for thrust external surfaces of the package, as well as the surface after printing subsequently protected by a plastic film.

iPad as an additional monitor

With a simple application your iPad can be connected to your computer and used as an additional monitor.

There are several iPad applications on the market for additional monitor, as AirDisplay, iScreen and Air Doc Viewer.

Some solutions can pair iPads to laptop via WiFi or without it. In this case iPad can take advantage of three things: additional monitor, monitor extension or as a mirror image. The application works both on Mac as well as Windows.

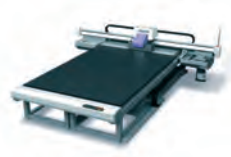
It is environmentally friendly, with no solvents to handle, store or recycle and no drying equipment. In addition, the new design saves space and requires no expensive plate room construction.

This powerful combination of digital and thermal plate technologies enables the rapid production of high quality sleeves. LAMs (laser ablation mask) based digital imaging and rapid-access, dry thermal processing ensures that a single sleeve can be produced in well under an hour. When operating in the 'pipeline mode', the round system will continually produce 3-6 round seamless photopolymer sleeves per hour, making it the ideal just-in-time sleeve making system for the packaging market.

Round sleeves are capable of high tone reproduction, high screen rulings, fine text and linework and open reverses; resulting in flexography of outstanding quality.

New UV-LED flatbed inkjet printer

New wide format printer JFX500-2131 is distinguished mainly by improved technology of UV-LED curing, which ensures the stability of prints at low curing energies. Equipped with a large-size flatbed (2.100 x 3.100 mm), direct printing on a great range of materials with a height of up to 100 mm is possible, using the speed of 60 m^2/h. compared to a conventional UV technology due to lower treating temperature more sensitive substrates could be used.



Unique head control technology has achieved highly detailed printing which even enables printing of 2 pt characters. Beautiful gradations using variable dots, which enable better printing results with reducer granular appearance, can be achieved.

Thanks to the improved LED technology almost no VOCs are generated by UV curing printing by which environmentally-friendly and energy-saving prints could be made.

Easier and more affordable 3D printing

The Z Corporation introduced two new devices for 3D printing - Zprinter 150 and ZPrinter 250. The first printer belongs to so-called "business quality" category according to the classification of the manufacturer, and the second has earned the title of "cheapest and most affordable" multicolor 3D printer.

The advantages of the printers are compact size which allow them to be installed almost anywhere. Both printers are easy to use and have high 300 x 450 dpi resolution and the lowest industry cost of operation - cost per print.

Main advantage of this 3D printers is their speed of printing which is 20 mm per hour. The dimension of the minimum replicable element is 0.4 mm and the maximum size of a model is 236 x 185 x 127 mm. A key advantage of this printer is the support of simultaneous printing with multiple colors.

The printers feature an automatic tuning, automatic loading of supplies, the level of self-control of consumables level and status of the job. When in opertion, devices do not make any noise and do not pollute the environment.

EcoPaperLoop: A new Central Europe project to improve collection and product design

We are alll aware that the paper is a precious raw material which shall not be wasted. Knowing the fact that too much of it is lost for different reasons (improper collection systems, improper design of a graphic or packaging product etc.) the new european project EcoPaperLoop was approved. The project partners from Italy, Germany, Poland, Hungary and Slovenia will share their ideas and represent the solutions on this topic.

The main goal of this project which will run until end of 2014 is to improve quality of paper for recycling. On the first meeting in Milan partners agreed upon strategies and concepts for the different parts of the projects. They plan to increase the awareness among all members of the paper chain - publishers and printers, designers, packaging users and print buyers as well as converters and local public administrations.

According to the project coordinator Graziano Elegir from Milan's Innovhub-SSI this project has the potential to boost the way we engineer products for easy recycling after collection and it will on the other hand identify the best collection strategies for given regions.

In Central Europe regions paper for recycling is a major resource. However, the paper recycling rates are still highly inhomogeneous. Since paper for recycling is not only recycled in the country where it is produced, some essential features such as ecodesign and eco-collection concepts must be developed at transnational level to increase the sustainability of the paper loop.

EcoPaperLoop contributes to the Lisbon strategic objective for Sustainable Production and Consumption (SCP/SIP) by improving end-of-life recycling performances of paper-based products. This will lead to a decrease of energy and water demands for the production of new paper products while guaranteeing organic carbon storage by recycling a renewable material. This project is co-funded by the European Union/European Regional Development Fund (ERDF) and the local project partners.

Inkjet iPrint Compact printer

One among many Impika novelties iPrint Compact presents new continuous feed inkjet printer. Designed for meeting transactional, transpromo and direct mail markets for different applications, it can be operated either by document printing service providers, in-house print services, or by printers looking for the best compromise.

System assures prints 2-up duplex in 600 x 600 dpi at 76 m/min within a single-frame (one print tower only) with a footprint among the smallest on the market (below 10 sq/m). With those features this printer in a single print tower and turns the iPrint range in the largest and most comprehensive print offering on the market.

In order to meet the requirements of volume production printing the iPrint Compact uses Impika's piezo DOD inkjet technology. The iPrint Compact is designed for monthly volumes between 2 and 10 million A4 sides per month, with the ability to absorb daily production peaks of over 1 million A4 sides. On the digital front end side, Impika AFP/IPDS iController manages full variable data printing.

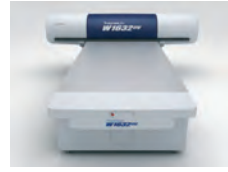
Entry-level digital color production

The Linoprint C 751 is the series for entry-level digital color production. With remarkable image quality and an exceptional range of functions, it offers the best specifications and reliability in its class. The Linoprint C 751 boasts cost-effective production for very short runs and variable data, workflow integration via the Prinect Digital Print Manager and print speeds of up to 75 A4 pages per minute (65 pages as an option) on media up to 300 gsm. The oil-free PxP toner ensures optimum image quality.

The reliability, flexibility and straightforward operation of the digital print system produce results similar to those achieved in offset. A comprehensive media library for automating the media settings delivers high-quality results in a fast production workflow. The system also supports a broad range of automated postpress solutions. Last but not least, operators can exchange many components quickly and easily themselves, thereby maximizing the productive time of the Heidelberg Linoprint C 751.

New inkjet solutions

Drupa introduced two new inkjet products Jet W1632 UV for signage and Jet L350 UV for label printing by Screen.



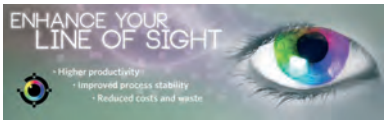
The web-fed Jet L350 UV is a single-pass UV inkjet label printing system which offers a linear speed of up to 50 m/min, and can accommodate media, including film and foil, up to 350 mm wide. To provide a wider color gamut often required for labels and packs, the Truepress Jet L350 UV also supports unique high-definition inks and Screen's owns proprietary high-resolution screening.

On the other hand the Jet W1632 UV flatbed device has been targeted at point-of-purchase and graphic display applications. With a production speed of 94 m^2 per hour, the wide-format machine is capable of printing on boards of up to 1.600 x 3.200 mm and 50 mm thick. It supports the use of light cyan and light magenta and by that enables the achievement of photographic quality for front- and back-lit display applications.

CTP plate monitoring

Production of top quality plates without monitoring by operators is now possible. New management system enables alerting in times when attention is needed, regardless of producer's location. Kodak's Inteligent Prepress Manager 2.0 (iPM 2.0) provides full and monitoring of up to five plate production lines.

Its powerful features enable flexibility and control to manage prepress operations from anywhere and at any time, driving improved efficiency and profitability.



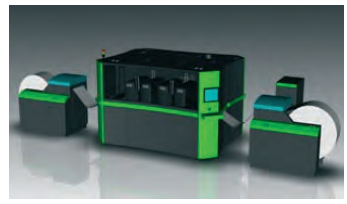
iPM 2.0 is a monitoring solution with enhanced features and mobile connectivity, offering users more control over their CTP and plate line systems for added productivity, monitoring and faster problem resolution. The system is available for commercial printing, publishing and packaging professionals.

Utilizing the mobile functionality of the solution, users can take advantage of 24/7 access to their prepress systems, allowing for the ultimate flexibility of managing production and monitoring performance of the plate production line from any location.

Featured business continuity module enables minimization of interruptions and safeguard critical operations. Users are by that assured that, in the case of any problem, their CTP system can be restored quickly.

Intelligent Prepress Manager 2.0 is already available for the Kodak Magnus 800 Platesetter and VLF Platesetter, Kodak Trendsetter 800 Platesetter and new Trendsetter 1600 Platesetter. Support for additional Kodak CTP devices will be introduced by the end of 2012.

It takes full advantage of the printer's performances in terms of speed, output and printing quality through the dynamic ICC color profile management.



This printer presents an ideal solution for print shops offering variable data customization in the transactional and direct marketing trades who wish to benefit without any risk from a high volume inkjet solution at a moderate investment cost.

With the iPrint Compact it is possible, for example, to start with a monochrome solution, for black overprinting of pre-printed stocks (pinless or pinfed) and evolve to a full color process through the onsite installation of additional printheads.

As for other iPrint models, the iPrint Compact benefits from a smart counting device, that differentiates the print cost between monochrome and full-color pages excluding the blank pages from the counting.

The iPrint Compact is compatible with all Impika water based inks, pigment or dye, as well as with the new HD inks, also well adapted for transpromotional and transactional applications. HD inks enable the use of uncoated low cost (<700 €/ton) and lower weight papers with unrivalled print quality. HD inks accelerate the return on investment through highly competitive print costs per page. Flexible and versatile, the iPrint Compact supports a wide range of out-puts, including books, newspapers, brochures, specification sheets, manuals,etc.

Wide format printers

Recently two new solution for wide format printing have been introduced by Lynx Europe: UV flatbad printer 250FB-UV and roll-fed printer 320 PQ.

The Lynx 320PQ is a super-wide format printer (3.20 m print width) which uses exclusively organic inks based on sustainable raw materials. The key base ingredient of these organic inks is ethyl lactate obtained from maize, amongst other sources.

This new generation of inks enables a wide range of tints to be created while retaining all the benefits of hard solvent inks, in particular high UV and scratch resistance. By using Spectra Polaris printheads, we achieve print speeds of up to 48 m^2/h and maximum resolutions of 1 600 DPI. In addition, this device provides a number of special tools to simplify production, such as a skip white function and wave system, and an advanced infrared drying technology.

The 250FB-UV can print in draft mode up to 54 m^2 an hour. This drops to 28 m^2 an hour in high-quality operation of 720 x 1.200 dpi. Using Fujifilm Dimatix Spectra Polaris printheads, the machine can print onto media that includes board, foam and metal.

The 250FB-UV will enable small and medium-sized signmakers to offer high-quality output at fast production speeds.

The company is also showcasing its Lynx 320PQ super-wide 3.2 m format roll printer which offers print speeds of up to 96 m^2 an hour.

New RIP software solutions

The latest version 7.10 of RIP software solutions, Productionserver, Filmgate, Proofgate and Photogate, are available now in a new version 7.10. It provides new features and modules such as the 1-Bit-TIFF-Input Module (1BITM), In-RIP-Trapping Module (TRAPM), and the versatile GamutViewer. Supporting a wide range of new printers and measuring devices the area of application of Productionserver RIP software has been extended again. In addition, the Adobe PDF Print Engine 2.6 (APPE) now is also available for screen workflows.

The optional *1-Bit-TIFF-Input Module* provides a simple and reliable method for processing incoming 1-bit TIFF-files to create halftone proofs and to de-screen input data for form impositioning proofs and thereby test (prior to print) documents to avoid incompatible artwork.

The system's accurate color proofs allows detection of color shifts. This solution presents an optimal solution for packaging industry, but also for pre-press workflows in other areas.

In-RIP-trapping module eliminates registration error, boundary-lines flashes of image elements that can occur (due to mechanical inaccuracies) when sequentially printing different color elements. In-RIP trapping enables overprinting or under filling of adjacent image elements.

Gamut Viewer enables 2- and 3-D comparisons of different color spaces. It can be launched from the Profiler Module (PFM)/ Profiler Suite (PFS) or via the software's menu options. The viewer allows comparison of up to five ICC profiles in 2D, with a reference or standard color space, and defines the largest gamut for print-run workflow when using various printers. Additionally, GamutViewer allows comparison of up to two ICC profiles in 3-D and rotate the view to see details and possible problems.

It also provides many more convenient functions of which one highlight is absolutely the function for illustrating motives as a 3D point cloud that shows the parts of the motive lying inside and outside of the color space. The Profiler Module/Profiler Suite enables the view of calculated profile and allows its comparison with the embedded MIM combination profiles in or other reference profiles. ColorGATE GamutViewer is now available for all Productionserver 7.10 products, Photogate 7.10, and Proofgate 7.10.

Version 7.10 also performs screen-data format interpolations; confidence strip placement options and size and distance data. ColorGATE RIP software Productionserver 7.10 already supports the measuring devices: Barbieri Spectropad, Mutoh SpectroVue VM-10 and X-Rite i1Pro2. It provides driver support for many common printers.

UV flexo press for food packaging

Nuova Guide has introduced an M5 Digital Flexo 3.0 (430 mm) eight-color press with three die-cutting units. The technology displays a new converting section with undisclosed "revolutionary" technologies to improve the specific productivity of self-adhesive labels.

M5 Digital Flexo 3.0 displays GIDUE HD Cameras (PrintTutor), which read the printed image on each print unit, and automatically adjust the print pressure, register and density, while the waste is less than 20 m.

Advanced system of paper wrapping

Manufacturer of mailing and fulfillment solutions launched a new developed paper wrapping system - the Buhrs 5000. The system has been engineered and tested to the highest specifications for achieving high quality poly and paper wrapping.

Within the new Buhrs 5000 wrapping and inkjetting are combined inline. The inkjet options range from monochrome addressing to fully personalized variable data and images printing in full color; all at a speed of up to 30.000 packages per hour. These new developments address the growing demand for paper wrapping.

Originally, paper wrapping was seen as an ecological equivalent of poly wrapping, however, it is now increasingly seen as a replacement for the traditional envelope, especially in the high volume mail segment for Direct Mail, Transactional and Transpromotional mail. The new system also has the ability to produce inline self-mailers with inserts.

New multilayered board

Korsnäs Artisan is a high-white multilayered board made of 100 % virgin fiber and available from 270 to 390 g/m^2. It is distinguished with a silky jet matte finish. It is aimed for luxury packaging market - printers of beauty, healthcare, fashion and high-end confectionery products (the board is approved for contact with food). Its physical properties allow blind or hot foil printing.

Another beneficial factor is board's environmental credentials. Board's construction and coating enable it´s light weight (approximately 20 g/m^2 on the overall weight of the board is saved) still keeping strength and durability properties. With this carbon footprint is reduced because the number of needed pallets for transportation and storage is lower. The Artisan board is also recycleable and made out of compostable ingredients.

Desktop SEM solution

The ASPEX EXpress^x is fast integrated desktop SEM solution. It is suitable for academic and commercial applications that require rapid, automated particle counting and detection. EXpress^x microscope provides precision and accuracy in identifying and characterizing quality issues enabling informed decisions.

OmegaMax™ technology offers maximized solid angle which is the optimized EDX system. For high efficiency EDX system detector features larger, closer and multiple silicon drift detectors.

By integrating sensor modules directly into the EXpress^x product platform, the system provides more than 3x the solid angle using the same sensor size. The direct integration of EDX detectors into the specimen chamber also accommodates the integration of up to four sensors in a range of sizes (from 5 mm^2 to 30 mm^2), offering up to 25x performance gains.

Cleaner and faster exchange of colors on press

New clean and lean inking system for flexo and UVflexo has been introduced on the market. The Nilpeter Clean INKING™ system is based on a docter chamber system with a unique design optimizing inking for the flexo printing unit. The design enables both low and high degree of filling for short and long runs. The inking chamber features very simple cleaning, works both with and without ink-pump, thus reducing handling and setup time and waste.

Camera operated squidge regulates the ink level. For the 100 mm chamber width minimum volumes of 0.042 and maximum of 0.44 liters can be used. On printing systems with 410 mm width volumes are much higher - from 0.2 liters to 2.0 liters. So the system is suitable for color management in both the small print and as large print runs.

The design ensures a perfect, consistent inking at varying speeds. Fully automated adjustments are performed by seven servo motors per print unit. The operator has no need for touching the printing units for adjustments, while print quality and set-ups are digitalized and fully automated in a closed-loop, digitally controlled print unit.

39th International research conference

The 39th annual iarigai International Research Conference was held in Ljubljana, Slovenia, from 9 to 12 September, hosted by the Faculty of Natural Sciences and Engineering. This year, the conference was attended by around 100 participants from 20 different countries.

The scientific contents of the iarigai research conferences are traditionally broad in scope, covering research into such diverse fields as ink-paper interaction, color reproduction, packaging and interactive media. The 2012 conference had a strong focus on printed electronics and functional printing. Two keynote presentations, one invited lecture, and eight of the presented papers were addressing the challenges of printing electronics on different surfaces. The invited lecture by Miran Mozetič had the title "Recognition of pigments in organic matrices". The keynote presentations by Marta Klanjšek Gunde and Nikola Peřinka addressed material science in graphic communication and photoacoustic measurements of conductive layers, respectively.

A second emerging focus area at the conference was the impact and use of non-printed digital media and the attitudes and expectations of consumers to the changing media landscape. In this emerging multidisciplinary scientific field, the conference offered two keynote lectures and eleven peer-reviewed presentations. The keynote presentations by Helene Juhola and Kristiina Markkula discussed research cooperation between industry and academia related to emerging media and studies of media user behavior, respectively.

Although the two focus areas mentioned here captured much attention at the conference, the main body of the presentations was still centered on the problems and challenges of achieving quality and productivity in the printing process. In addition to the focus areas, conference sessions were held on flexography, offset and gravure printing, materials, text and image processing, packaging, and productivity. All in all, the conference provided an excellent overview of the current international state and the main problem issues of print and media technology research today.

The award for the best conference presentation was won by Natalia Lumby for the second year in a row. This year, her presentation bore the title "Linking physical print and digital media: opportunities and challenges of quick response codes in the face of mobile visual search technology".

The full manuscripts of all the presentations given at the 2012 iarigai International Research Conference will be published in volume 39 of the Advances in Printing and Media Technology. The book can be ordered at www.iarigai.org.

The 2012 conference was expertly and splendidly arranged by the Faculty of Natural Sciences and Engineering at the University of Ljubljana in cooperation with iarigai. In addition to the smoothly run scientific sessions, the organizers provided an enjoyable social program and an interesting industrial visit to the Savatech company in Kranj. The next iarigai research conference will be hosted by the Chemnitz University of Technology in September 2013.

Bookshelf

Advances in Printing and Media Technology, Vol. XXXIX

What, how and when to print - and when not to

This volume contains the research contributions presented at the 39th iarigai International Research Conference, Ljubljana, Slovenia, September 2012. It also includes the non-reviewed manuscripts of the keynote and invited lectures. The editors and publisher hope that readers will find the contents of these proceedings informative and interesting.

Printing has been defined as the art of rapidly and accurately placing "stuff on stuff". By habit and centuries old tradition, we are used to thinking of printing as a technology for putting ink on paper. But, nowadays, the technologies and methods for efficiently and on an industrial scale placing other substances on other substrates are increasingly capturing the attention of researchers and industry alike.

Printed electronics and functional printing are strongly in focus in this volume. A second emerging area is the impact and use of non-printed digital media and the attitudes and expectations of consumers to the changing media landscape.

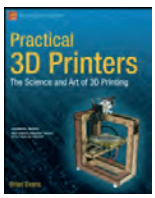
Are the venerable iarigai conferences, so rich on traditions, moving away from print research, then? Certainly not. The main body of papers is still centered on the problems and challenges of achieving quality and productivity in the printing process. But printing technology and science are now being applied in new and exciting areas. At the same time, traditional printed products are encountering competition and potential extensions in the digital realm. These developments open up new intriguing and important fields of research that certainly will be reflected in further volumes of the Advances …

Advances in Printing and Media Technology, Vol. XXXIX
Editors: Nils Enlund and Mladen Lovreček
Publisher: IARIGAI, Darmstadt, 2012
ISBN 978-3-9812704-5-7; ISSN 225-6067
348 pages
280 x 195 mm
Hardcover

Practical 3D Printers:

The Science and Art of 3D Printing

Practical 3D Printers takes you beyond building the printer to calibrating it, customizing it, and creating amazing models with it, including 3D printed text, a warship model, a robot body, windup toys, and arcade-inspired alien invaders. The author presents various types of popular 3D printers, presents their customization and calibration, as well as how to design and create models to put a specific printer to work. In addition to the theoretical part bonus projects for building, including windup walkers, faceted vases for the home, and a handful of useful upgrades for improving 3D printer are included.



Practical 3D Printers
Author: Brian Evans
Publisher: Apress (2012)
ISBN 978-1430243922
332 pages
190 mm x 234 mm
Paperback

Applications of Organic and Printed Electronics

A Technology-Enabled Revolution
(Integrated Circuits and Systems)

Editor: Eugenio Cantatore

Springer (2012)
ISBN 978-1461431596
192 pages
Hardcover

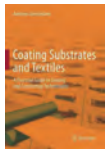
The book focuses on various "substrate independent, large throughput" technologies - techniques that are able to build electronics on cheap, low cost, flexible and temperature sensitive substrates, like PEN or other plastic foils, and using inexpensive and large throughput methods like printing. It presents a comprehensive landscape of new applications enabled by substrate independent, high throughput electronic technologies and their business potential. It explains the differences between innovation in technology and in products. It also provides the reader with a clear understanding of the technology and the research challenges in the field.

Book is divided in two parts - the first devoted to applications where the most important selling point is large area and the second devoted to applications where cost reduction is the main factor.

Coating Substrates and Textiles

A Practical Guide to Coating and Laminating Technologies

Andreas Giessmann



Springer (2012)
ISBN 978-3642291593
256 pages
Hardcover

Content of this work covers presentation of coating industry and its latest demands on coating facility. It also presents an overview of the technical capabilities of substrate coating, enabling the practitioner to design and implement new products.

Detailed topics present preparation of pastes and substrate coating, as well as key characteristics and applications of different plastisols and additives. Furthermore, the author goes into detail on various air pollution control procedures and economic issues of asset valuation.

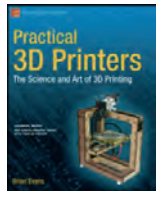
Measuring Colour

(Wiley-IS&T Series in Imaging Science and Technology)

The measurement of color is of major importance in many commercial applications (textile, paint, foodstuff industries) as well as in the lighting, paper, printing, cosmetic, plastics, glass, chemical, photographic, television, transport and communication industries etc.

Authors R. Hunt and M. Pointer have presented a new edition of measuring color building upon the success of earlier editions. New chapters in this book on color rendering of light sources, colorimetry with digital cameras, factors affecting the appearance of colored objects, and an examination of new color appearance models are based on the most current International Commission on Illumination (CIE) recommendations.

The authors approach color measurement as more than engineering and instrumentation, but also include physiological and psychological perspectives of the human observer. A sampling of topics includes relations between color stimuli, light sources, metamerism and color constancy, RGB colorimetry, colorant mixtures, and models of color appearance for stimuli of different sizes. Subject treatment is thorough and the text is well-supported by detailed illustrations. The book includes many worked examples, and a series of Appendices which provides the numerical data needed in many colorimetric calculations.



Measuring Colour
Authors: Robert W. Hunt, Michael R. Pointer
Publisher: John Wiley & Sons, Inc., 4th edition (2011)
ISBN 978-1119975373
492 pages
175 mm x 252 mm
Hardcover

Typographic Design: Form and Communication

Typographic design has been a field in constant motion since Gutenberg Staying abreast of recent developments in the field is imperative for both design professionals and students. Thoroughly updated to maintain its relevancy in today's digital world this 5th edition of Typographic Design continues to provide a comprehensive overview of the fundamental information for effective typographic-design practice.

Book offers detailed coverage of such essential topics as the anatomy of letters and type families, typographic syntax and communication, design aesthetics, and designing for legibility. It includes four pictorial timelines that illustrate the evolution of typography and writing within the context of world events - from the origins of writing more than 5 000 years ago to contemporary typographic applications.

Features in this new edition include a new chapter that analyzes typography on screen, new case studies featuring typographic design in books, information graphics, web design, and environmental design and new designer profiles that reveal innovative typographic design processes.

Typographic Design
Authors: Rob Carter, Ben Day, Philip B. Meggs
Publisher: John Wiley & Sons, Inc.,
5th edition (2011)
ISBN 978-0470648216
368 pages
213 x 280 mm
Paperback

Events

40th International research conference of iarigai

Digitalization of Print - Exchanging Ideas Across Generations

Chemnitz, Germany
8 to 11 September 2013

The conference series Advances in Printing and Media Technology has a long successful tradition. The 40th anniversary of the International research conference of iarigai will take place in Chemnitz, Germany, from September 8 to 11, 2013. In parallel, the 5th Printing Future Days will be held, a biannual conference for junior scientists and PhD students. This joint event will be hosted by the Department of Digital Printing and Imaging Technology of the Institute for Print and Media Technology of the Chemnitz University of Technology.

Both conferences address a wide and international audience in the field of printing, graphic arts, and media industry. Renowned senior scientists as well as a new generation of junior scientists and PhD students are invited to discuss latest research topics under the general title "Digitalization of Print - Exchanging Ideas Across Generations". The general concept of combining two conferences inspires the entire project: In a combined keynote session, leaders from the industry and experts in the related scientific fields will present current key issues of the Print and Media Industry, followed by a joint panel discussion. The poster session of the Printing Future Days enables attendees of iarigai conference to have a look on scientific results of the new generation of scientists. Furthermore, a versatile social program including a joint conference dinner, gives additional opportunities for the communication across generations.

With a wide range of subjects being covered interested scientists are encouraged to submit their proposals. Due to the scientific strength of the Chemnitz University of Technology on new technologies applying print, printed functionalities and flexible electronics, these topics are focused on the conference. However, contributions are not limited to these topics. All submissions related to the wider field of media and graphic arts will be considered. More detailed fields of contributions will cover topics of Color Image Printing, Packaging Printing, Applications and Functional Printing.

iarigai and the Chemnitz University of Technology are inviting all interested experts, and scientists to become a part of this unique international conference!

More information is available on www.iarigai-chemnitz.org.

Asia Coat & Ink Show 2012

Mumbai, India
7 to 9 December 2012

Event organized every second year creates a platform to bring all printing ink manufacturers, the suppliers of raw materials, machine manufacturers, quality control equipment manufacturers, and others together. Beside the exhibition the international conference and technical workshops will also be held.

11th Printpack India 2013

Noida, India
23 to 28 February 2013

PRINTPACK INDIA 2013 is one of the Asia's biggest exhibitions, where not only Indian companies but world's majors into printing and allied machinery mark their presence. It is a unique platform for the industry showcasing today's as well as tomorrow's technology and equipment.

Visitors profile includes top management, managers, and technical staff, small and medium entrepreneurs, not only from different parts of the country but also from SAARC, USA, South Asian Countries, Europe & Middle East.

PRINTPACK INDIA 2013 will cater to complete market supply for the printing, packaging and media. The event will provide a panoramic view of the Indian Graphic Arts Industry. The exhibition will not only be a stimulus but also a growth motor for the industry. It will leave an indelible print on the printing & packaging industry, globally.

Print UV

Las Vegas, California, USA
3 to 6 March 2013

The Print UV Conference is the all-in-one conference event for commercial, packaging or specialty printers of the UV printing industry. Attendees meet annually in Las Vegas to network, engage with printers and leading suppliers, uncover new ideas and growth opportunities, dive deep into core UV processes with experts from multiple fields and hear case studies from successful UV print initiatives around the world.

This peer-oriented, sixth in a row intimate event is geared to be exciting and relevant to attendees who are looking to accelerate their profits with UV printing.

IPX India

Mumbai, India
13 to 15 December 2012

IPX India represents an exciting international business platform for the Indian pulp and paper industry. The event features not only the highest-level quality exhibition but also an adjacent top level technical conference and business oriented seminars.

Event will host suppliers of machinery, equipment, accessories and raw materials for the pulp, paper and allied industries.

IPX India is being organized by Adforum, world's leading organizer of exhibitions for the pulp and paper industry.

ABSRC 2013 Venice Advances in Business-Related Scientific Research Conference)

Venice, Italy
20 to 22 March 2013

ABSRC is an important international gathering of business and business-related sciences scholars and educators which will take place in Venice, Italy. In addition to scientific papers, the focus will be on various best practices and solutions, which are important for business-related policies and activities at the individual, organizational, group, network, local, regional, national, international, and global level.

10th Pan European High Security Printing Conference

Prague, Czech Republic
12 to 14 February 2013

This annual event focuses on government-specified and issued documents. These include currency, fiduciary documents, excise stamps, ID cards, e-passports, visas, vehicle documents and licenses, with a particular emphasis on banknotes and emerging technologies for ID and travel documents.

Running in tandem with the event is a trade exhibition of over 40 exhibitors working in the currency, e-passport, smart card, authentication and related industries.

drupa remains in a four-year cycle

In spite of indications that the drupa committee was considering essential changes for the next event, invoked by the changing market, latest decisions confirmed only some of them.

The key intention was to shift the world's most important trade fair for the print and media industry from four to a three year cycle, altering it with two other compatible events - K-Messe and Interpack From the standpoint of the Düsseldorf Trade Fair this sounds reasonable, but already the first informal news caused strong reactions, both from other graphic trade exhibition organizers, as well as the manufacturers and providers. The entire community is used to the four-year cycle, while all development programs are adapted to follow this traditional sequence.

However, the length of the next exhibition wil be reduced from full two weeks to 11 days. Therefore, the next drupa will remain in 2016, as previously planned, taking place in Dusseldorf from 31 May to 10 June.

At the same time, the drupa committee introduced some personal changes related to this event. Claus Bolza-Schunemann, CEO of Koenig & Bauer AG. was unanimously appointed as the chairman of drupa 2016. Manuel Mataré, long time director of drupa, is withdrawing from his position and will gradually hand over his responsibilities to Ms. Sabine Geldermann, who was appointed as his successor.

digi:media 2013 canceled

Although planned and widely announced for April 2013, this annual event - trade fair for commercial publishing & digital printing - is definitely canceled.

Even though the international supply sector explicitly welcomed the innovative concept of digi:media, the indications are that in the present format and design the show would not truly mirror the sector. It was a difficult decision for the Düsseldorf Trade Fair, which will explore possibilities whether and to what extent individual elements of the 'content' part can and will be realized in the future.

Tissue World Barcelona

Barcelona, Spain
18 to 21 March 2013

The original Tissue World, which began in Nice in 1993 and is now held in Barcelona. It is "the big one" in the Tissue World series and is supported by two somewhat smaller regional events. These are Tissue World Asia in Shanghai targeting the Asian market and Tissue world Americas in Miami mainly focusing on the American markets.

Tissue World is clearly the leading global event series covering soft hygienic tissue products. Tissue World 2013 will include a technical conference covering new developments for manufacturers and converters of soft hygienic tissue paper

This event offers tissue makers, converters and suppliers an unique experience and opportunity for meeting, idea exchange and learning. It is truly a global event with visitors end exhibitors coming from all over the world and average attendance around 2 000 visitors from 80-90 countries.

D PES Digital Printers & Engravers & Signage Expo

Guangzhou, China
25 to 28 February 2013

D·PES Digital Printers & Engravers & Signage Expo is organized by Guangzhou D·PES United Network Technology Co., Ltd., co-organized by China Industrial Digital Printing Technology Union and China Engraving Equipment Industry Union, aiming at boost the healthy development of digital printing, engraving and signage professional show. From 2012, the show is held in Guangzhou every spring.

As a cutting-edge in the global printing, engraving and signage expo, the D·PES Expo professionally presents an integrated and mature making system, assembling a variety of hi-end products in professional printing, engraving equipment, inks and signage, etc.

It showcases the most advanced technology, equipment and consumables in the sign industry. The exhibits including: digital printing equipment, digital engraving equipment, digital printing consumables, laser engraving equipment and printing& engraving related accessories, signage, board, light boxes and display equipment and so forth.

D·PES Digital Printers & Engravers Exhibition can be rated as a top event in printing and engraving industry. Professionals said that this exhibition is not merely a good chance to bring forward new ideas and display new technologies, new processes and new equipment, but also a barometer that reflects the industry trends.

Graphispag.digital: 2013

Barcelona, Spain
17 to 20 April 2013

Organized in collaboration with the Graphispack Association, graphispag.digital: 2013 will present the latest development in graphic applications which will offer new business opportunities.

New digital printing equipment, hybrid technologies, web-to-print, augmented reality, printed electronics and 3D printing will grab the attention of over 18 000 visitors expected to attend. The show will also feature new materials and substrates, as well as improvements in the finish and customization of printed products.

The show will coincide with another event - Sonimagfoto & Multimedia exhibition. This alliance was created in 2011 when Sonimagfoto & Multimedia was held together with Graphispag, reinforcing the range of exhibits and increasing commercial synergies.

At this edition, Sonimagfoto & Multimedia will feature products and services for image capture, storage, editing, processing and output; multimedia audio and video systems; accessories and consumables; equipment for studios and professional photographers; image services and Photo Art.

Photography exhibits, seminars, courses, workshops, conferences and multimedia demonstrations for imaging professionals and enthusiasts will add important cultural, educational and technological features to this traditional event.

TAGA's 65th Annual Technical Conference 2013

Portland, USA
3 to 6 February 2013

TAGA's annual technical conference is the only international conference for the graphic arts that features technical papers on research straight from the laboratory, studies from the pressroom, and software and systems engineering papers.

65th TAGA's Technical Conference agenda will deliver to the educators, researchers and developers new information in pressroom management, paper and ink technologies, prepress, micro technology and graphic arts.

Event is mainly intended to managers of printing companies, pressroom equipment manufacturers, front-end systems, publishers, as well as manufacturers of ink, paper, and other consumables.

Graphics of the Americas

Orlando, Florida, USA
21 to 23 February 2013

Graphics of the Americas (GOA) is an annual combined exposition and education event. This year's event will be held in February 2013 in Orlando, Florida.

With worldwide attendance, GOA is a unique event that attracts an average audience of 9 800 printers, designers, and creative professionals from over 90 countries. The diverse attendance provides international networking at its best.

GOA's combined expo & conference provides attendees and exhibitors with a venue that addresses the needs of both end-users and printers, with a one-of-a-kind showcase for the convergence of knowledge, products and technology. Not only does GOA provide an excellent educational program with select bilingual sessions, it also provides hands-on training labs and vendor tutorials right on the show floor. In addition, GOA provides a world-class educational program with select bilingual sessions.

Sino-Pack 2013 Packaging Material, Supplies & Machines

Guangzhou, China
4 to 6 March 2013

Sino-Pack is a premier international trade event for the packaging industry. The event will discover the latest materials and supplies for packaging, as well as the newest technologies to make it more efficient and ecofriendly.

Sino-Pack will attract people from food, chemicals, cosmetics, pharmaceuticals, beverage, plastic, packaging and printing industries, trading companies, government bodies, trade associations and other corporate end users with a comprehensive display of packaging materials, equipment and machinery, plastic packaging products, measurement, testing, control, labeling and printing systems, professional's services and general industrial machinery.

SinoCorrugated

Shanghai, China
8 to 11 April 2013

SinoCorrugated is one of the world's largest business platforms for the global corrugated manufacturing industry. This event not only showcases the latest global corrugated equipment and consumables on the market, but it also helps carton box manufacturers to make informed purchasing decisions by alerting them to new products, the latest techonlogiy developments and emerging market trends.

Carton box manufacturers can also gain valuable new insights to inform their purchasing decisions. There will be an abundance of choice in terms of the equipment and technologies on-site. SinoCorrugated is the business platform on which buyers and exhibitors can communicate and network directly and freely.

The events will co-host the international Image & Print World congress, where world experts will talk about the innovations and trends that are reinventing the graphic communication industry. Conferences, round table debates and success stories will offer knowledge and experience to help companies find a better position on a continually changing market and, thereby, respond to the needs of new clients.

The sessions will combine technical contents with their application in business, to help increase competitiveness and improve companies' results. It will be a congress, in which experts will talk about business solutions for imaging and printing.

The key topics at Image & Print World will be: Full process color management; Digital Publishing; Multiple Media Printing; Shoot and Create; Social Media: News Business Opportunities; How to innovate: Distribution & Retail + Web to Print and Global Printing Industry Overview.

In addition to the Congress, graphispag.digital: will host presentations and seminars promoted by sector organizations and companies. Another highlight will be Design Corner featuring conferences on the current situation of graphic design and the presentation of best practices, as well as a networking and exhibition area.

graphispag.digital: will also be repeating the daily Youth Sessions - aimed at groups of students at graphic arts and design schools - that offer practical information on visiting the show, detecting trends and finding the main new products presented by exhibitors. The show will also host the "Marco de Oro Awards" that recognize the best screen printing, pad printing or digital printing work on any substrate using these techniques alone or in combination with other printing systems, carried out in Spain during 2011 or 2012.

5th Printing Future Days

International Scientific Conference for Junior Scientists and PhD Students

Digitalization of Print - Exchanging Ideas Across Generations

The Department of Digital Printing and Imaging Technology of Chemnitz University of Technology is proud to announce the Printing Future Days which will be held in Chemnitz, Germany, for the fifth time in 10 years, from September 10 to 12, 2013. The conference will be combined with the worldwide renowned and well established International research conference of iarigai which celebrates its 40th anniversary. These are two high level international events in one week hosted by the Chemnitz University of Technology, Germany. Both conferences are entitled "Digitalization of Print - Exchanging Ideas Across Generations".

The idea of the Printing Future Days is to provide an international platform for junior scientist and PhD students to gain first conference experiences. Under the auspices of iarigai this conference is held biannually since 2005. The Printing Future Days bring together scientists, representtatives of the industry and interested listeners. The collaboration of students, the industry as a potential employer or suppliers and the lecturers is being fostered. Thus, the Printing Future Days is a conference on which the future generation of engineers and managers is gathering.

To support and encourage young people and universities with low financial appropriations, the Printing Future Days are free of participation fees for students and PhD students.

Present topics of the Printing Future Days are in general related to the Graphic Arts but are also driven by the research of universities and institutions covering topics such as Digital Fabrication Technologies, Printed Functionalities and Printed Electronics.

In view of the Printing Future Days 2013, the organizers assume that approximately 60 junior scientists and PhD students will present their works. All in all they expect, as in previous years, more than 100 attendees. They hope to increase the quota of international students from Western Europe, the USA, and Korea. Working groups from these countries to whom Chemnitz keeps a close contact are planning to send students to the conference again in 2013. Beyond that, the focus will be on the integration of German universities of applied sciences and corresponding educational institutions in Europe. Special attention will be given to the following topics:

- Color Image Printing,
- Packaging Printing,
- Applications and
- Functional Printing.

The submitted papers will be reviewed by internationally renowned senior scientists and then grouped into the categories focal paper, oral presentation and interactive paper. In different parts of the program they will merge the two conferences to form special events. Furthermore, the joint conference dinner will give additional opportunities for contact across generations.

The organizers are looking forward to the 5th Printing Future Days and the 40th International research conference of iarigai and they welcome you in Chemnitz in September 2013.

More information and details for submission of papers are available on www.printingfuturedays.com.

AppForum PODi

Las Vegas, California, USA
28 to 30 January 2013

The AppForum is the only digital printing conference hosted by PODi, the support organization for digital print industry. It represents a uniquely unbiased view of the newest, most profitable applications. AppForum concentrates on a rich program featuring presentations by peers and practitioners who are succeeding with relevant direct marketing strategies, integrated cross-media, collateral management services, cloud technology, digital packaging and variable data printing.

This three day event offers educational sessions - presented by real users, not vendors - focused on breaking technology and ideas to use right now to grow profits with digital print solutions.

The AppForum is small and intimate event, attended mostly by decision makers moving the industry forward. Topics of this new forum will introduce the ways of finding new money, show how to be more successful with digital print solutions and it will offer quality networking and community.

Middle East Coatings Show

Cairo, Egypt
26 to 28 February 2013

The Middle East Coatings Show is the largest dedicated coatings event in the Middle East and Gulf Region for raw materials suppliers and equipment manufacturers for the coatings industry.

Egypt is emerging as a promising avenue for the global paints and coatings companies to explore due to a large potential, yet untapped. A population of approximately 79 million but paint consumption of only 23.000 t stands testimony to this. The paints and coatings industry depends largely on the growth of the construction industry in the GCC. With major investments made by governments of the GCC States, the paints and coatings sector is expected to pick up and steadily grow from the lows experienced during the global economic slowdown. The governments of GCC states are investing heavily on basic infrastructure and projects that were put on hold during the recession; these are now being actively executed. This proves a major boost to paints and coatings manufacturers.

European Coatings Show

Nuremberg, Germany
19 to 21 March 2013

From 18 to 21 March 2013, engineers, developers and decision-makers will meet again at the exhibition for the paint and coatings industry to update on the latest developments in the production of high-grade and competitive coatings and paints.

The European Coatings Show plus Adhesives, Sealants, Construction Chemicals is the leading exhibition for the international coating and paint industry, organized every two years. The exhibitors will have the opportunity to source information on the production of coatings, paints, sealants, construction chemicals and adhesives. The European Coatings show will be accompanied with a congress.

International Audience Conference

Paris, France
21 to 22 February 2013

The key to success in the new Industry's environment is audience growth. Efficient publishers understand the need of diving into the market, connecting with & engaging their audiences.

The conference program will take a close look at the most innovative cases within the industry and will also bring in inspiration from outside the industry. Main key topics are Listening to the market, Producing right content at the right time for the right audience, Engagement and communities, New audience development opportunities with social media and Turning occasionnal readers into loyal customers.

Printing Summit 2013

Hamburg, Germany
19 to 20 March 2013

Following on the success of its previous editions, the Printing Summit will offer during two days an array of international speakers which will bring participants up-to-date on a variety of important topics including: Printing process innovations, Designing for success, Business and innovation, Less energy, less emissions and The power of print.

Digital Media Europe 2013

London, United Kingdom
15 to 17 April 2013

DME13 in London will offer digital media networking and insight. The event's success stems from the quality of its program - with speakers in 2012 including Arthur O. Sulzberger Jr, chairman of the New York Times, and Andrew Miller, CEO of Guardian Group.

IC Conference 2013

Toronto, Canada
2 to 6 June 2013

The 45th Conference of the International Circle of Educational Institutes for Graphic Arts, Technology and Management (IC) will be hosted by Ryerson University in Toronto, Canada.

Ryerson University is home to Canada's School of Graphic Communications Management, featuring full prepress, offset, flexo and digital printing labs, finishing, material testing and simulation facilities. The program is home to over 500 undergraduate students and 20 faculty, instructors and staff.

Hosted in multicultural Toronto, Canada's largest city and the center of the Canadian graphic arts industry, the conference promises to be stimulating and enjoyable. Beside the academic sessions, organizers will offer attendees a visit of nearby Niagara Falls and industry tours as well as visits to local Toronto attractions.

The Call for Papers has recently been issued. Researchers from IC member organizations, as well as from other universities, research institutes and industry are invited to submit results of their research for presentation at the conference. The scope of the conference encompasses scientific and educational topics from the fields of Graphic Arts Technology, Management and Communication, in a wider sense. According to the organizers abstracts from students and new members are especially welcome. More information is available on www.ic2013ryerson.ca.

European Extractables and Leachables Conference 2012

Vienna, Austria
12 to 13 December 2012

Extractables and Leachables conference, taking place in Vienna, Austria, features a comprehensive representation of best practice examples in pharmaceutical packaging, as well as the latest regulatory and working group updates, analytical chemist perspectives and recent technical innovations presented by top experts from pharmaceutical companies and materials suppliers.

INFO*FLEX 2013

San Diego, California
29 to 30 April December 2013

Every year for the last 31 years, the INFO*FLEX show represents the opportunity for printers, converters, and package buyers to network, learn about the newest trends and technologies and offer possibilities for new solutions. More than 1 600 experts attend this event.

Different fields of graphic industry like prepress, tag and label, corrugated, folding carton, flexible packaging, digital printing, or inks and coatings presented at INFO*FLEX exhibition offer close insight in the latest developments.

Guidelines for authors

Authors are encouraged to submit complete, original and previously unpublished scientific or technical research works, which are not under review in any other journals and/or conferences. Significantly expanded and updated versions of conference presentations may also be considered for publication. In addition, the journal will publish reviews as well as opinions and reflections in a special section.

Submissions for the journal are accepted at any time. Papers will be considered for publishing if meeting the general criteria and ethic standards of the scientific publication. When preparing a manuscript for JPMRT, please strictly comply with the journal guidelines, as well as with the ethic aspects. The Editorial Board retains the right to reject without comment or explanation manuscripts that are not prepared in accordance with these guidelines and/or if the appropriate level required for scientific publishing cannot be attained.

A - General

The text should be cohesive, logically organized, and thus easy to follow by someone with common knowledge in the field . Do not include information that is not relevant to your research question(s) stated in the introduction.

Only contributions submitted in English will be considered for publication. If English is not your native language, please arrange for the text to be reviewed by a technical editor with skills in English and scientific communication. Maintain a consistent style with regard to spelling (either UK or US English, but never both), punctuation, nomenclature, symbols etc. Make sure that you are using proper English scientific terms.

Do not copy substantial parts of your previous publications and do not submit the same manuscript to more than one journal at a time. Clearly distinguish your original results and ideas from those of other authors and from your earlier publications - provide citations whenever relevant. For more details on ethics in scientific publication, please consult:

http:// www.elsevier.com/ethicguidelines.

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B - Structure of the manuscript

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