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A Study on Subjective Evaluation of Printed Launch Vehicle Lift-Off View Colour Photographs and Pattern Quantification of Perceived Image Quality Attributes

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Abstract

Quantification of subjectivity is essential to have a consistent quality in prints for further analysis of rocket lift-off view printed images. An experimental mathematical model has been derived to quantify the human visual response vis a vis print process controls in rocket lift-off view sequence photography. Subjective evaluation data of eight professional printing technicians was collected using pairwise comparison. They gave 16 kinds of evaluations for each print. Their data consistency was checked by the process clustering of the subjects and qualified for taking as a quantification model for the analysis of perception in print quality. After trying multi variant analysis and judgmental analysis, it was found that the problem is fuzzy in nature and involves multiple linkages and hence human like response is required. Hence, neural network model was selected which works on a simplistic non-linear weighted averages attached to inputs projected from dynamic modification of the target to reach the target output. The interdependency in the factor analysis output is linked up in a feed forward neural network. The 16th attribute of the data evaluation (overall preference) parameter is taken as output. The inter linkages of the possible explanation from the contributors of the remaining parameters is explained by the performance of the neural network. The positive correlation of the factors confirms the data with that of the nationally acclaimed professional colour printing laboratory expert's opinion.

Keywords: Printed Launch, Perceived image .

Introduction

The object of this study are the still sequence printed photographs of launch vehicle at exact lift-off moment. They are the visual documented proof of the launch mission performance given for publication to Indian Press / Scientific establishments / scientific exhibitions, etc., These special network still sequencing cameras are operated using remote controlling (relay logic) from about 8 Km. away from the control centre during every major Launch Mission, at Satish Dhawan Space Centre .SHAR (ISRO-Dept.of Space), Sriharikota.

During the initial lift-off of a rocket, due to flame exhaust from the main rocket motor and also from the strap-on booster rocket motors at the sides, smoke emerges at a fast pace, raises along with flame and acts as added **reflectors of flame-light over the rocket with multiple reflections.** The speed and direction of wind at that lift-off moment causes **uneven illumination** with **strong density variation** in the photographed scene negative. This dynamic brightness range makes the rocket lift-off view photograph printing a complex task, because the printer has to evaluate the optimum compromise in finalizing his technical settings along with his printing experience to get both the rocket surface details and the details about the flame . The printer has to determine the correct exposure, filters for color correction , correct print paper grade ,etc., at every density point, unlike other normal printing works. It has always been a challenging job for the printing technicians to bring-out a perfect rocket lift-off view color print with all the desired Image Quality Attributes. (IQA)

Quantification of image quality attributes (IQAs) is confounded by the inherent subjectivity of human judgement, and the fact that human perception is a complex mixture of psychology, physiology, and environment. In spite of these difficulties, the need for quantitative image analysis of printed Rocket lift-off view still exists. In general, it is important to maintain a correlation between measured attributes and the human visual response.

The evaluation of perceived image quality in launch vehicle lift-off view color prints is a

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complex task due to its subjectivity (fuzziness of human senses) and dimensionality.

Investigation into Important Image Quality Attributes.(IQAs)

Generally, for a normally exposed scene negative (single source illumination / uniform brightness), which is within acceptable brightness range, the perceived quality of its color print is influenced by a number of different image quality attributes.(IQAs)

Out of the following 15 Image Quality Attributes (IQAs) taken into this study (as to the Kazuhiko Tanaka,Michio Sugeno [1] evaluation model) many of them are similar and have common denominators. This allows them to be grouped within more general Image Quality Attributes to reduce the dimensionality and create a more manageable evaluation of Image Quality. These include lightness[10,11], sharpness [6,7,8,16,17], blur[12], contrast [6,7,10,13], details [7,10,13,14,16], naturalness [4], color [5,13,14], hue [10,15], chroma [10], saturation [13], color rendition [5,12], gloss [6,7], color reproduction [18], color shift [7,17], effective resolution [5], skin color [14], paper roughness [17], paper whiteness [17,21], perceived grey value [16], structural changes [16], structural properties within printing technicians [16], colorfulness proportional to the original [22], correctness of lightness [22].

1. The **Colour** IQA (ImageQualityAttribute) contains aspects related to colour such as hue, saturation, and color reproduction, except lightness. Colour is a sensation. It is the result of the perception of light by our Human Visual System.
2. The **Lightness** IQA is considered so perceptually important that it is beneficial to separate it from the colour IQA.[11]. A common definition of lightness is the visual sensation by which the area where the visual stimulus is presented appears to emit more or less light in proportion to that emitted by similarly illuminated areas perceived as a "white" stimulus [3]. Variations in lightness ranges from "light" to "dark".
3. The **Contrast** IQA can be described as the perceived magnitude of visually meaningful differences, global and local, in lightness and chromaticity within the image. Contrast is a difficult IQA since there are many different definitions of contrast.[25,26,27,59].

Contrast

Contrast is a difficult IQA since there are many different definitions of contrast. Michelson[28] defined contrast as $\frac{I_{\max} - I_{\min}}{I_{\max} + I_{\min}}$,

where $I_{\max}$ and $I_{\min}$ represent the highest and lowest luminance. In Webter, contrast is defined as $\frac{I - I_b}{I_b}$,

Where I represents the luminance of features, and I_b is the background luminance. Root mean square (RMS) contrast is another common way to define contrast. $RMS = \left[\frac{1}{N-1}\sum_{i=1}^{n}\left(x_i - \bar{x}\right)^2\right]^{1/2}$

where , **x**i is a normalized gray level value, and $\bar{x}$ is the mean normalized gray level. Contrast can also be defined as the visual property that makes an object distinguishable. This definition is useful to express the readability of prints. Another definition of contrast is the lightness ratio between two areas in an image. Fedorovskaya [1,4] defined contrast as an integrated impression of differences in lightness, or lightness variation observed within the whole picture[23]. Keelan [1,11] defined contrast in the context of colour and tone reproduction, as the relationship between the original scene lightness perceived by the photographer and the final image (reproduced) lightness perceived by the observer[11]. Contrast is clearly difficult to define, and its definition changes according to application. Even so, the literature distinctly presents some common characteristics of contrast.

4. The **Sharpness** IQA is related to the clarity of details and definition of the image. **Cavides** and **Oberti** [1], related the perception of sharpness to the clarity of details of an image. similar thinking was established by **Bouzit** and **MacDonald** [1], IQAs that are suitable to group within the sharpness QA are diverse and many, including sharpness [6,7,8,16,17], details [7,10,13,14,16], blur[12], line quality[5,20], and effective resolution [5].

5. The **Artifacts** IQA contribute to degradation of the quality of an image [24]. Random variations in brightness and colour change perceived within a small region and change in structural properties results in perceived discontinuity.{non-uniform light or dark lines across the print [9,19]}

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6. The **Physical** IQA is important because the other IQA's cannot account for Physical IQA's such as paper roughness, grade and gloss level. Literature study reveals [1], these physical IQA's to be very important for the overall Image Quality and therefore they should be accounted for in the evaluation of Image Quality.

Relations Among Image Quality Attributes

IQA's are not necessarily independent, and in order to calculate overall Image Quality , it is important to know which IQAs influence other IQAs and the magnitude of their influence. Literature reveals[1], many of the relationships among IQAs. Colour can be linked to a number of other attributes including Contrast [24,25]. Colour differences can also be linked to different artifacts. Sharpness can result in halo artifacts caused by colour differences [11]. Colour can also occur due to changes in lightness, creating relations to sharpness and artifacts. Lightness can be linked to Contrast [23,25,32] but also to artifacts. Contrast has been said linked to colour [1,24,25] and lightness [1,23,25,32]. It can be linked to sharpness as well [1,32,33,34], since an increase in contrast generally increases sharpness [1,33].

Sharpness has also been linked with colour [1,13,30,31], artifacts [1,11] and contrast [1,32,33,34]. Artifacts can be related to a number of IQAs. The relations for artifacts will change according to the different artifacts evaluated. Among the physical IQAs, many relations can be found. For example, Paper characteristics can be influence colour[1,21] and artifacts {as lack of smoothness[1,17]}, while paper coating can affect artifacts(for example, lack of uniformity[1,7].Usually tradeoffs exist among the different issues that require compromises. The selection of IQAs can be based on different aspects, such as technological issues or perception. IQAs based solely on technological issues might not be suitable to evaluate perceived IQA, and vice versa. The basis upon which IQAs have been selected also affects the evaluation of IQAs, whether subjective or objective evaluation methods are used. For subjective evaluation, the complexity of the IQAs determines the required expertise level of the observer. For objective evaluation, some IQAs might be specially designed for measuring devices, while others are intended for IQ metrics. In this subjective study the evaluators are all experts in rocket lift-off colour printing.

Review of Earlier Literature on Printed Colour Image Quality Evaluation Models

In a rare work in this field**, Mishina** [2], first derived an equation of color-printing image evaluation from subjectively evaluated data by **multiple regression analysis**, where representations of material, color balance, and feeling of roughness were selected as predictor variables. **Norberg** et al [1] , evaluated overall image print quality as well as color rendition, sharpness, contrast, detail rendition in highlight and shadow areas, and paper gloss as important attributes. **Lindberg** , **Gast** and **Tse**[1], studied the following attributes as essentials for a good color photographic print reproduction: Overall quality, sharpness, contrast, tone quality, detail highlights, detail shadow, gloss level, gloss variation, color shift, color rendition, and patchiness. In 1980 **Sawyer**[1], investigated the influence of sharpness and graininess on perceived image quality as well as their combined influence on printed color images. In 1982 **Bartleson** [1], showed results in which the worst quality attributes tended to determine the quality, and the change in other quality attributes would not increase quality of a color print. This framework has the advantage of representing strengths and weakness of a given system by a relatively small number of quality attributes. Because of this advantage and the framework's perpetual considerations, this was videly adapted by several researchers. **Dalal** et al's [1] , document appearance characterization system had some drawbacks. Since the evaluation is carried out mostly by experts, the results are influenced by the subjectivity of the expert. The system of print evaluation was not suitable to nonexperts due to its complexity, because the quality attributes are associated with known printing problems and technological issues. In 1999 **Natale-Hoffman** et al. [1] , investigated the relationship between color rendition in uniformity as preference. This was considered by the authors as a step towards predicting preference without depending on human observers. **Morovic** and **Sun**[1], based an photo-printing model where the quality attributes were chosen based on answers from observers, resulting in more general printing quality attributes. This was totally different from the evaluating approach of **Dalal et al** [1] , This system of evaluating printed color images does not directly account for the contrast attribute, which has been regarded as an important quality measure by other researchers. **Keelan** [1], first identified important quality attributes, then found the relationship between a subjective scale (based on just noticeable differences) and an objective metric. In cases where multiple quality attributes influence the quality of an

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image, Keelan's approach found the influence of each quality attribute to overall image quality. He adapted multivariate formalism as a tool to combine the influence of each attribute and obtain a value for overall image quality. Quality attributes used in Keelan's model were assumed to be independent, which is different from the attributes used by others. The advantage of keelan's model is that quality attributes do not influence eachother and can be easily combined to achieve an overall image quality-value which is not straightforward for dependent quality attributes. However the disadvantage is that it might be very difficult to identify independent quality attributes. **Engeldrum** [1], focused on building an image quality **mathematical model** with image quality circle. **Cavids** and **Oberti** [1], gave importance to sharpness attribute. **Bouzit** , **Macdonald** and **Fedorvskaya** [1], also tried for better understanding of color printing mechanism, using mathematical quantitative tools. **Kazuhiko Tanaka** and **Michio Sugeno** [2] constructed a mathematical model suitable for subjective evaluation of color printing. They build it on the idea of fuzzy measures, where we do not have to assume additivity and independence among predictor variables. However, the human evaluation process with respect to reproduced images in which an evaluator subjectively selects the most preferable reproduction can be considered essentially fuzzy, as such evaluations can be influenced by particular colors such as skin color or sky blue. Fidelity to the original is not always important to its reproduction. They framed their evaluation model using CHOQUET's Integral -2.

Suppose there are three evaluation itsm s_1, s_2 and s_3. Let $K = \{s_1, s_2, s_3\}$, $h : K \to [0, \infty)$ be a function giving the evaluation score for each item. In the case of $h(s_1) = a_1 \le h(s_2) = a_2 \le h(s_3) = a_3$, we have

$$(C)\int hd_{\mu} = a_1\mu(K) + (a_2 - a_1)\mu(\{s_2, s_3\}) + (a_3 - a_2)\mu(\{s_3\}) = C$$

Where μ represents the fuzzy measure.

The desired subjective evaluation model is obtained if we can determine the fuzzy measure μ so that the result C is close enough to the actual overall evaluation E.

Let $x = (x_1, \ldots\ldots, x_7) \in R^7$ denote the fuzzy measure μ, where $x_1 = \mu(K), x_1 = \mu(\{s_1\}), \ldots\ldots, x_4 = (\{s_1, s_2\}), x_5 = \mu(\{s_2, s_3\})$, $x_6 = \mu(\{s_3, s_1\})$. The fuzzy measure we seek is the 'x' minimizes. $f(X) = \sum_j (E_j - C_j)^2$

Under the following constraints :

$$x_1 \leqq x_4, \quad x_1 \leqq x_5, \quad x_2 \leqq x_4, \quad x_2 \leqq x_6, \quad x_3 \leqq x_5,$$
$$x_3 \leqq x_5, \quad x_4 \leqq x_7, \quad x_5 \leqq x_7, \quad x_6 \leqq x_7, \quad \text{and} \quad \theta \leqq x_1,$$

Where θ is the zero vector.

This problem is of quadratic programming. It can be solved by applying the Lemke Method.

"This present study is aimed to get an better understanding of rocket lift -off view printing mechanism with 1) Dynamic brightness range variation and 2) Sudden surge of colour temperatures and 3) About the quantitative structural evaluation characteristics of the 8 printing technicians of Technical Photographic Facility (TPF/Range Instrumentation /Range Operations/Sathish Dhawan Space Centre/ISRO/DOS/Sriharikota) in estimating the perceived image quality of such dynamic brightness range prints through subjective evaluation of various image quality attributes".

Generation of Pair-Wise Comparision Data

20 Lift-off view prints were made from 4 original negatives ,containing rocket, smoke and flame. 5 prints from each negative with little technical variations while printing were made. Subjective evaluation data of 8 professional printers who regularly print the dynamic range rocket **Lift-off** view negatives at Technical Photo-Lab, Satish Dhawan Space Centre, Sriharikota were collected. They gave their scores for pair-wise comparisons. The sub-evaluation items (quality attributes) were selected as typical words that these 8 printers frequently use in expressing their evaluations of such dynamic range colour prints. A total of **5120** observations were obtained in pairwise comparisons given to these eight experts. The pair-wise comparison contained the following scheme of attribute evaluation with a corresponding answer to the following:

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Attributes:
Image quality Attribute description

1. Which print displays more 3-dimentional feeling?
2. Which print displays more transparent feeling?
3. Which print displays more feeling of metallic surface?
4. Which print displays more feeling of fine texture?
5. Which print displays more feeling of volume?
6. Which print has more contrast?
7. Which print displays more feeling of sharpness?
8. Which print is more blue?
9. Which print is more reddish?
10. Which print is more yellowish
11. Which print is vivid(exactly truthful), fresh in color
12. Which print displays more details in lighter part
13. Which print displays more details in darker part
14. Which print is away from muddiness
15. Which print is bright as a whole
16. Which print do You Like Better? Comparison of prints are made as to the popular

Lacure's Scale Comparison

Minus 2marks and minus 1mark(left) -- 0 marks for balanced -- plus 1mark and plus 2marks for (right). The individual scores are added for each attribute against each expert. The final data has been generated for analysis.

Analysis of Subjective Evaluated Data

Data obtained from eight subjects for fifteen attributes is quantified as already described in the experimental setup. Since the print quality is perceptional, the subjects were first tried with communal analysis for the benefit of the understanding the general trending in print quality perception. The data consistency was checked by the process clustering of the subjects. It was found that 87.5% of the subjects are always clustering together in presenting their perception of the given attributes. Thus this data can be taken into a quantification model for the analysis of perception in print quality. The proposed model is evaluated through cluster analysis of samples obtained. The entire data has been segmented with clusters of individual expertise of 8 printing experts. Cluster analysis has been carried out with a view to observe any possible perception clustering even though within the cluster similarity level in varying from 84.18 to 39. 85. This is represented in annexture-4. When principle component analysis has been carried-out it was observed that except for evaluator- KMR, all other experts evaluators are falling within a band. The components assessed are suited in state variables, of the model relocated, as seen from the annexture- 5. After trying multi variant analysis and judgmental analysis , it is found that the problem is fuzzy and involves multiple inter linkages and hence human like response is required from the model. Hence a neural network model was selected.

Quantification of Subjective Evaluated Data Using Neural Network

Neural networks works on a simplistic non-linear weighted averages attached to inputs projected from dynamic modification of target to reach the targeted output. This gives a pattern for an attribute and a mapping towards the desired optimum output. This is possible as neural networks generally get trained with different input output combinations and network will be used at a later stage to arrive an optimum output for the variations in input attributes. In this work measurements of an output attribute is highly subjective, which is mapped from the process control parameters. For the best print output, optimized process control inputs are needed to be selected. Neural network gives the optimum process parametric combination from the subjective measurements of the pre-print.

Attribute No.	Attribute Name	Relationship with other Attributes Sure / Not Sure
1	3-dimentional feeling	3, 4, 5 surely, but 6 (not sure)
2	Transparent feeling	14, 15, surely, but 11 (not sure)
3	Metallic (rocket) surface feeling	1, 5, surely
4	Feeling of fine texture	1, 2, 7, surely, but 5 (not sure)
5	Feeling of volume	1, 3, 4, 6, surely, but 7 (not sure)
6	More contra st	12, 13, 15, surely, but 1 (not sure)
7	Feeling of sharpness	1, 6, 12,13, 15, surely, but 2, 7 (not sure)
8	Is more blue	9, 10, 11, 14, 15, surely, but 2 (not sure)
9	Is more reddish	8,10, 11, 14,15, surely, but 2 (not sure)
10	Is more yello wish	8, 9, 11, 14, 15, surely, but 2 (not sure)
11	Is vivid (exactly/ truthful) fresh in color	8, 9, 10, 14, 15, surely
12	Displays details in lighter part	6, 13, surely, but 2, 7, 15 (not sure)
13	Displays details in darker part	6, 12, surely, but 2, 7, 15 (not sure)
14	Is away from muddiness	1, 2, 6, 8, 9,10, 11, 15, surely but, 5, 7 (not sure)
15	Is bright as a whole	2 ,6, 7 ,8 ,9, 10, 11, surely but, 12,13 (not sure)
16	Do You like better	1,2,3,4,5,6,7,8,9,10,11,12,13,14,15 surely.

According to famous **Michio Sugeno**(2), factor analysis of the experimental attribute measurement of the prints is carried out through this neural network, represent:

P-factor: 1,5,6, 11 concerns physical and space representation

T-factor: 2,7,14,15 concerns transparency, sharpness, and clarity of appearance

Q-factor: 3,4,12 concerns representation of material constituting the main object (rocket) with flame in a reproduced picture.

Michio sugeno(2), has left out the color combinatory of 8,9 and 10 attributes, which is given a factor name of C-factor from this work. This C-facor will come into picture while analyzing the print attributes of dynamic high color temperature events, such as rocket lift off. Attributes 8,9 and 10 give the color temperature perception of the rocket lift off. The result of attribute 9 of negative correlation with its factor attributes, the factor is not fuzzy but is sure of determining high rocket plume color temperature.

The different factors so arrived at are further given to nationally acclaimed printing expert (GM, operations M/s. PRASAD Film laboratories, Chennai), to consolidate the interdependency of contributing factors. With slight variation in opinion, the inter dependent factors arrived are as below:

Discussion and Conclusion

This interdependency in the factor analysis output is linked up in a feed forward neural network. The 16th attribute (Which print they liked better for having all merits for year perfect rocket lift of view print) is taken as output. The Inter linkages of the possible explanation from the contributors of the remaining parameters is explained by the performance of the neural network (R^2). The positive correlation of the factors confirms the data with that of the expert opinion. The factors 9 , 10 and factor 13 are showing up negative correlation in neural network, which indicates that component interdependency of the expert is at variance.

Conclusion

1. There is an interdependency for factors/ observations for all the parameters chosen in the model.
2. There is a positive correlation for all these interdependencies, except for attributes nos. 9,10 and 13.
3. It establishes that there is a negative connectivity between attributes 9 and 10 (more reddish and more yellow in print perception) .
4. Details in the dark area (factor attribute no. 13) are less perceptible than details in the lighter area
5. Details in the darker area are negatively correlated in perception which is NATURAL.

This also validates the configuration of our model.

References

[1] Marius Pedersen,Nicolos Bonnier,Jon Yngoe Hardeberg,Fritz Albergtsen. "**Attributes of image quality for color prints.**" J. of electronic Imaging. 19(1), 011016 (Jan – Mar.2010)SPIE and IS & T.

[2] Kayuhiko Tanaka, Michio Sugeno. "**A study on subjective Evaluations of Printed color Images**." International Journal for Approximate reasoning, Vol.5. No> 3 pp. 213-222 (1991).

[3] G. Wyszecki and W.S. Styles, "**color science, concepts and methods, quantitative Data and Formulae**, 2nd edition, Wiley Interscience,Derby, UK (2000).

[4] E.A. Fedorovskaya, F.J.J. Blommaert, and H.de Ridder, " **Perceptual quality of color images of natural scenes transformed in CIELUV color space**," in Color Imaging Conf., IS&T/SID, pp.37-40 (1993).

[5] E.N. Dalal,D.R. Rasmussen, F. Nakaya, P.A.Crean, and M.Sato, " **Evaluating the overall image quality of hardcopy output**," in Image Processing, Image Quality, Image Capture, System Conf., IS&T,pp. 169-173 (1998).

[6] S. Lindberg, "**Perceptual determinants of print quality**," Ph.D. Thesis, Stockholm University (2004).

[7] O.Norberg, P.Westin, S. Lindberg, M. Klaman, and L. Eidenvall," **A comparison of print quality between digital, offset and flexographic printing presses performed on different paper qualities**," in International Conf. on Digital Production Printing and Industrial Applications, IS&T, pp.380 – 385 (2001).

[8] S. Bouzit and L. MacDonald, " **Colour difference metrics and image sharpness**" in 8th Color Imaging Conference, pp. 262 – 267, IS&T/SID (2000).

[9] C.Cui. D. Cao. and S. Love, " **Measuring visual threshold of inkjet banding**, " in Image Processing, Image Quality, Image Capture, Systems Conf., pp. 84 – 89, IS&T (2001).

[10] J. Morovic and P.Sun, **" Visual differences in colour reproduction and their colorimetric correlates**." in 10th Color Imaging Conf., pp. 251 – 255, IS&T/SID (2002).

[11] B.W. Keelan, "**Handbook of Image Quality: Characterization and Prediction**," Marcel Dekker, New York (2002).

[12] G.Gast and M.K. Tse, " **A report on a subjective print quality survey conducted at NIP16**. " in NIP17: International Conference on Digital Printing Technologies, pp. 723 – 727, IS&T (2001).

[13] N. Bonnier, F.Schmitt, H.Brettel, and S.Berche, " **Evaluation of spatial gamut mapping algorithms**, " in 14th Color Imaging conference. Vol. 14, pp. 56 – 61, IS&T/SID (2006).

[14] J.Y. Hardeberg, E. Bando,and M. Pederson, " **Evaluating Colour image difference metrics for gamut-mapped images**, " Coloration Technol. 124(4), 243 – 253 (2008).

[15] G. Hong and M.R. Luo, " **New algorithm for calculating perceived colour difference of images**, " Imaging science. J. 54(2), 86 – 91 (2006).

[16] F. Nilsson and B. Kruse, **" Objective quality measures of halftone images**," in NIP 13: International Conf.on Digital Printing, pp. 353 – 357, IS&T (1997).

[17] M. Klaman, " **Aspects on colour rendering, Colour prediction colour control in printed media**, " Ph.D. thesis, Stockholm University (2002). Digital Printing Technologies, IS&T, pp. 147 – 152 (1996).

[18] K. Miyata, N. Tsumura, H. Haneishi, and Y. Miyake, " **Subjective image quality for multi-level error diffusion and its objective evaluation method**, " J. Imaging Sci. Technol. 43(2), 170 – 177 (1999).

[19] Y. Bang, Z. Pizlo, and J.P. Allebach, " **Perception based hardcopy banding metric**," in NIP21: International Conf. on Digital Printing Technologies, pp. 745 -750, IS&T (2005).

[20] M.K. Tse and A.H. Klein, " **Automated print quality analysis in inkjet printing**: **Case study using commercially available media**, " in Recent Progress in Ink Jet Technologies II, pp. 515 -519, Society for Imaging Science, Springfield, VA (1999).

[21] M. Klaman, " **The influence of paper whiteness and other parameters on the creating of ICC-profiles for digital colour printers and conventional offset presses**," in IARIGAI: Advances in Printing Science and Technology-Advances in Digital Printing, Vol. 6, Munich, Germany (1999).

[22] R.W.G. Hunt, "**The Reproduction of color in Photography, Printing and Television**", Fountain, Tolsworth, UK (1987)

[23] E.A. Fedorovskaya, " **Image quality as a problem of computational vision,** " in Image

Processing, Image Quality, Image Capture, System Conf., IS&T, pp. 22-28 (2003).

[24] K. Topfer, B. Keelan, S. O'Dell, and R. Cookingham, " **Preference in image quality modeling**, " in Image Processing, Image Quality, Image Capture, System Conference. pp. 60-64, IS&T (2002).

[25] M. Pederson, A. Rizzi, J.Y.Hardeberg, and G. Simone, " **Evaluation of Contrast measures in relation to observers perceived contrast**, " in CGIV 2008- Fourth European Conf. on Color in Graphics, Imaging and Vision, pp. 253 – 256, IS&T (2008).

[26] A. Rizzi, G. Simone, and R. Cordone, " **A modified algorithm for perceived contrast in digital images**, " in CGIV 2008- Fourth European Conf. on Color in Graphics, Imaging and Vision, pp. 249 – 252, IS&T (2008).

[27] E. Peli, " **Contrast in complex images**," J. Opt.Soc. Am.A 7,2032– 2040 (1990)

[28] A. Michelson, " **Studies in Optics**". University of Chicago Press (1927)

[29] P.Whittle, " **The psychophysics of contrast brightness**," in Lightness, Brightness, and Transparency,pp.35 -110,Lawrence Erlbaum Associates, Hillsdale,NJ (1994).

[30] S.Y. Choi, M.R. Luo, and M.R. Pointer, " **Modeling image naturalness**," in CGIV 2008- Fourth European conf. on color in Graphics, Imaging and vision, pp. 126 – 131, IS&T (2008).

[31] J.Radun, T. Leisti, J.Hakkinen,H.Ojanen,J.-L. Olives, T. Vuori, and G. Nyman, " **Content and quality: Interpretation-based estimation of image quality**," ACM Trans.Appl.Percept $(4), 1-15 (2008).

[32] A.J. Calabria and M.D. Fairchild, " **Perceived image contrast and observer preference:I. The effects of lightness,chroma,and sharpness manipulations on contrast perception**," J. Imaging science Technology. 47, 479 – 493 (2003).

[33] G.M. Johnson and M.D. Fairchild, " **Sharpness rules** , " in 8th Color Imaging Conf., pp. 24- 30, IS&T/SID (2000).

[34] P.G.J. Barten, " **Evaluation of Subjective image quality with the square-root integral method**, " J. Opt. Soc. Am. A 7, 2024-2031 (1990).

[35] Pirkko Oittinen,Raisa Halonen,Anna Kokkonen,Tuomas Leisti,Gote Nyman, Tuomas Eerola,Lasse Lensu, Heikki Kalviainen,Risto Ritala,Johannes Pulla, Marja Mettanen. Finland. Universities of Helsinki, Univesity of Lappeenranta, University of Tampere, " **Framework for modeling visual printed image quality from the paper perspective**, " Image Quality and System Performance V, SPIE-IS&T Electronic Imaging,Vol. 6808,68080L, (2008).

[36] **P.G. Engeldrum,** " Image quality modeling: **Where are we** ?" in Image processing, Image quality, Image capture, System conf., pp.251 – 297, IS&T/SID (2002).