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Study of an Intelligible and Quantitative Index to Clarify Required Gloss Impression

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Abstract

This study focused on suggesting an intelligible index for evaluating gloss degrees of printed images. Psychophysical evaluation of image-perceptibility, which is a feature for describing gloss appearance, was performed for various kinds of paper surfaces. Additionally, cluster analysis was performed for classifying the evaluated values. As results, we found that image-perceptibility on printed images and paper can be classified into 4 main categories, and we quantitatively clarified that a set of 3 main types of paper and a mirror finished acrylic board can be the intelligible index for describing gloss degrees of printed images. Furthermore, a range, in which observers cannot recognize differences of image-perceptibility, has been shown, and this result is expected to be a useful guide for determining conditions of printers from gloss quality point of view.

1. Introduction

Preferred gloss degree of a printed image depends on feelings of clients who ordered the printings. Printing operators change conditions of the printer or select another printer when reducing gloss difference between some samples is required by their clients. However, sometimes the changing cannot make observers feel the change of gloss even if it could change glossiness of the image.

We assumed that it would be valuable on such a situation if there is an intelligible and quantitative index to show the impression of gloss. Various paper surfaces were expected to be suitable for the index because paper's appearance is always compared with printed images and can be observed as a standard. We also assumed that clarifying a range, in which observers cannot recognize difference of gloss appearance, is valuable as well because such a range expected to be a good guide for printing operators who select printer's condition for each client.

Although glossiness is commonly used as a physical value to describe gloss degrees, relation between measured glossiness value and impression of gloss appearance is vague. Sone et. al. reported the correlation between subjective evaluated value of gloss appearance and glossiness [1,2]. However, their subjective value was difficult to be reproduced, and it was not easy to connect their results with impression of gloss appearance. Hence, we newly performed subjective evaluation here in order to create an intelligible and quantitative index to describe gloss appearance.

A proper term to express gloss appearance was needed for the subjective evaluation we planned. Sone et. al. indicated that gloss appearance of typical printed images can be expressed as "gloss perception" and "clarity (distinctness of image)," and both of them should be evaluated to describe gloss appearance [1]. The former can be interpreted as "luster," and the latter expression can be interpreted as "'distinctness of outline of reflected image' or 'image-clarity.'" However, impressions perceived from those terms were not always the same among several persons. We assumed that reconsidering and selecting the most proper term to express gloss appearance was also needed.

2. Objective

The objective of this study was to suggest an intelligible and quantitative index for evaluating gloss degrees of printed images. The index should be shown based on quantitative procedure. Therefore, we planned to achieve this objective by three outcomes as follows; First: to show gloss degree of typical paper surface quantitatively based on the appearance perceived by observers. Second: to show the gloss range that makes observers "definitely" feel difference. Third: to show the usefulness of the index by visualization of capability range of several printers.

3. Methods

All the subjective evaluations were regarded as analytical tests [3,4] hence they were performed with a few subjects. The number of subjects should be more than 5 [4], and our condition satisfied it. All the subjects were specialists of gloss appearance evaluation.

3-1. Defining a term to express gloss

This definition is based on the evaluation with semantic differential method performed in advance for several expressions relating to gloss appearance. As a result, the term: "image-clarity" was selected for expressing gloss appearance on paper or a printed image. However, the subjects were taught that "image-clarity" in this evaluation was defined as "distinctness of outline of reflected images, and it doesn't include color reproducibility of reflected images." This definition is different from the generally known definition of image-clarity. Therefore, we changed the term: image-clarity, whose definition was unique in this study, into "image-perceptibility" eventually.

3-2. Defining Standard Samples

The subjective evaluation was performed with magnitude estimation method. The number of subjects was 18. The samples were several acrylic boards with different surface roughness. White paper was attached on the back side of each acrylic board, and all acrylic boards looked white. Every presented sample size was 100 × 100 mm^2 and it had a white frame with 25 mm width. The presented size was determined to be larger than 10 degrees of visual angle. Image-perceptibility value of mirror finished surface of acrylic boards was defined as 100. The subjects estimated numerical value of image-perceptibility for every sample by comparing samples with the mirror surface of acrylic board. The evaluation was conducted in a light booth. The subjects observed the reflected images of the fluorescents installed in the light booth, and they evaluated distinctness of the outline of reflected images on samples (Fig. 1). The subjects were allowed to observe samples without fixing them since they needed to observe from several angles in order to perceive reflected light, but observation distance was around 300 mm. This evaluation was performed twice. Finally, evaluated values by 6 subjects, whose difference of the evaluated values for the same sample was small, were selected and averaged.

As a result, the acrylic board samples obtained values of image-perceptibility and became capable to be used as standard samples for when additional subjective evaluations would be performed.

Five of the acrylic board samples were selected as standard samples, followed by the 6 subjects above evaluated 9 kinds of paper surfaces. In the end, the 5 acrylic boards and the 6 types of paper used in this procedure were selected as the standard samples for the next procedure explained in section 3-3. The defined image-perceptibility value of each standard sample was the mean of the values evaluated by the above 6 subjects.

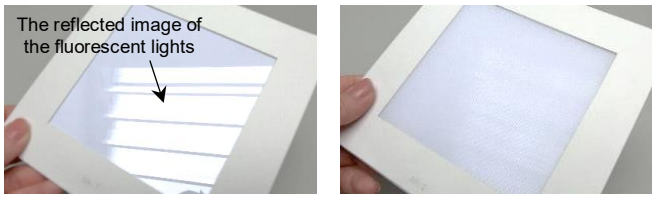


Figure 1. *Examples of samples when the evaluation for defining standard samples was performed. Left: The mirror finished acrylic board whose image-perceptibility was defined as 100. Right: An example of another sample.*

3-3. Evaluation of Various Paper Surface

The psychophysical evaluation was conducted with magnitude estimation method again. Subjects could compare the samples with the 11 standard samples explained in section 3-2. The evaluation was performed with minimum number of subjects, because the way with comparison with the standard samples had been expected to reduce evaluation errors. The number of subjects were 5 and all of them practiced evaluation in advance.

The samples were surfaces of 24 types of white paper and 6 acrylic boards with different roughness. The size of the acrylic samples had frames and their sizes were the same as the standard samples. The paper samples didn't have frames, but the presented sizes were the same as that of standard samples: 100 × 100 mm^2. Subjects arranged samples in order of image-perceptibility degree until they were convinced. Based on the several standard samples, which already had evaluated values, subjects estimated value of image-perceptibility for each sample. The basic criterion of evaluation was the same as section 3-2. Additionally, when it was difficult to distinguish difference between plural samples, a metal rod with mirror finished surface was contacted to the samples and reflected images of the metal rod was referred to (Fig. 2). The evaluation was basically performed twice but 11 samples were evaluated only once because of a temporal restriction. However, it is expected that there is no serious problem because the 11 samples were evaluated lastly after the subjects got used enough to evaluating.

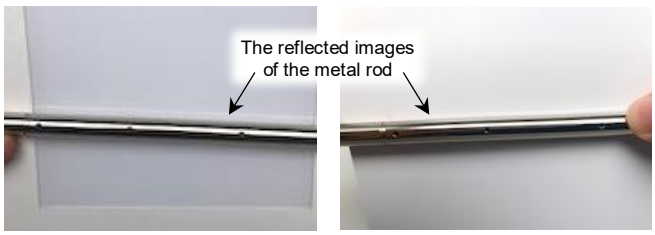


Figure 2. *Examples of samples when the evaluation for various paper surface was performed. When it's difficult to distinguish the difference between samples, the reflected images of the metal rod with mirror surface was referred to.*

3-4. Cluster Analysis

Cluster analysis with Ward's method was performed using almost all image-perceptibility values obtained by the evaluation in section 3-2 and 3-3. The data relating to the standard sample, whose value of image-perceptibility was 100, were excepted from the analysis as outliers. The amount of total analyzed data was 400 ([30 samples + 10 standard-samples] × twice evaluation × 5 subjects). Most of them were obtained by twice evaluation but some of them were obtained by only once evaluation. The 11 samples evaluated only once in the procedure of section 3-3. Besides, each standard sample had only one value. In such cases, the 2nd evaluated value was regarded as the same as the 1st evaluated value. The amount of data obtained by actual evaluation was 255 ([19 samples × twice evaluation + 11 samples × once evaluation] × 5 subjects + 10 standard-samples).

3-5. Comparison of Printed Images

Image-perceptibility of solid images printed by 7 models of electrophotography printers and an offset printer were evaluated with magnitude estimation method. Subjects were the same as those who performed evaluation in section 3-3. One sample had one color of yellow, black, red, green or blue. Samples of the electrophotography printers were printed on 3 types of paper: uncoated paper (mondi, image-perceptibility value was 1.7), gloss-coated paper (POD Gloss Coat, image-perceptibility value was 14) and cast coated paper (Esprit Coat C, image-perceptibility value was 63). Samples of the offset printer were printed on other 2 types of paper: uncoated paper (recycled wood-free paper, image-perceptibility value was 1.2) and gloss-coated paper (coated paper, image-perceptibility was 24.2). The size of presented images was 100 × 100 mm^2. The samples were divided into several sets of 15 to 40 samples, and the evaluation was conducted for each set. Each sample set included all colors to avoid that subjects' judges would be changed depending on colors. It was desirable that each sample set included samples of several printers randomly but realizing such a condition and including all colors into the sample set at the same time was difficult. Therefore, we gave priority to mixing all colors in each sample set, and the sample sets were divided by printer kinds. The names of printers were hidden instead.

Other conditions regarding this subjective evaluation were the same as that explained in the section 3-3.

We had expected that a set of the standard samples would be a more intelligible index for gloss evaluation than glossiness. Hence, glossiness (60° of measurement angle) of all samples was also measured in order to confirm the usefulness of the index. Glossiness was measured by UNI GLOSS 60A (KONICA MINOLTA).

4. Results and Discussion

4-1. Proposing an Index Based on Cluster Analysis

First, the number of clusters were determined based on the calculated dendrogram. The number of clusters was 4. Next, considering sensations that the subjects felt during the evaluation, the clusters were additionally divided into 9.

Fig. 3 shows the result of cluster analysis based on Ward's method. The length of branches corresponds to the distance between each cluster. The distance was significantly long when the number of clusters were under 4. Therefore, we interpreted that dividing into 4 clusters was statistically the most suitable. The numbers on left side in fig. 3 are the sample numbers, which are shown in table 1. According to the samples' paper type and the cluster labels in table 1, it can be seen that image-perceptibility level could be statistically

divided into the following 4 major regions: “uncoated paper level,” “gloss-coated paper level,” “cast-coated paper level” and “the middle of gloss and cast coated paper levels.” Therefore, we expected that the 3 types of paper, which are “uncoated paper”, “gloss-coated paper” and “cast-coated paper,” and mirror finished acrylic board should be standards to express gloss appearance, and we proposed that a set of them should be used as an intelligible and quantitative index. However, we also proposed that the standard paper or the standard acrylic board must be white in itself or look white by attached paper on their backsides, and all of them must have evaluated values of image-perceptibility. The image-perceptibility value of the mirror finished acrylic board was defined as 100 in section 3-2. The values to describe the 4 major regions, which means gloss appearance of paper, were proposed based on the results on table 1. The values were as follows; uncoated paper level: 0 - 11, gloss-coated paper level: 11 – 29, the middle of gloss and cast coated paper levels: 29 – 55 and cast-coated paper level: 55 or more (the upper limit of cast-coated paper level is unknown because it has not been measured in this study). The above image-perceptibility values of borders between adjacent regions were the mean of the maximum of the cluster in lower value region and the minimum of the cluster in higher value region. Although there is possibility that image-perceptibility values of the borders will be changed after more evaluation data will be added, the change is expected to be small enough because the evaluations in this study satisfied the minimal required conditions for reducing errors. In other words, the evaluated values of standards based on paper appearance, which give quantitative values to the index for gloss evaluation, are allowed to be obtained in another new evaluation conducted in the same procedure as our experiment. In that case, subjects must be specialists or regarded as specialists by practicing in advance. Moreover, the required minimum number of subjects is 5 but the number can be increased.

It had been expected that observers didn’t feel difference between samples when their values of image-perceptibility were in the same cluster, and it was certainly difficult to distinguish the difference in a such case even if the number of clusters was only 4. However, it was possible for the subjects to perceive the difference when the difference of image-perceptibility values was greater than approximately 5. Considering the result, we additionally divided the clusters into 9 small clusters. Fig. 4 shows the evaluated values of image-perceptibility in each small cluster. When the number of clusters was 9, in the especially important region from “uncoated paper level” to “gloss-coated paper level,” the intervals between cluster borders were approximately 5, and it was consistent with the fact that the subjects could not feel difference when the gap was within 5. Therefore, it was concluded that the intervals of the 9 small clusters showed the ranges, in which observers cannot feel difference of image-perceptibility, and observers definitely feel difference when the image-perceptibility value changed greater than the width of the intervals. Relating to the region from “the middle of gloss and cast coated paper levels” to “cast coated paper level,” the intervals between borders of the small clusters were wider than those on the uncoated or gloss-coated level regions. It would mean that the range, in which observers cannot feel difference, was wider in higher image-perceptibility regions. However, the amount of data in the high image-perceptibility regions was less than them in uncoated or gloss-coated paper level regions, and consequently there is possibility that the intervals between each border in the high image-perceptibility region don’t correspond to the true range, in which observers cannot feel difference. It would be desirable to verify it by adding data in the future.

Table 1: Image-perceptibility value of each paper sample.

Cluster (*1)	I.P. (*2)	Paper Type	Sample No./ Paper Name (*3)
α	0	Acrylic Board	37 / Acrylic Board No.3（Standard)
α	0.5	Uncoated Paper	6 / OK Prince Eco Green
α	0.6	Uncoated Paper	24 / Steinbeis Classic 80
α	0.8	Uncoated Paper	34 / HMT (Standard)
α	1.2	Uncoated Paper	25 / Brilliant White 300
α	1.2	Uncoated Paper	30 / Recycled Wood-free Paper (Formal name is unknown)
α	1.4	Uncoated Paper	7 / Kinmari-V
α	1.4	Uncoated Paper	11 / White A Prince
α	1.6	Matte Coated Paper	3 / New Age
α	1.7	Uncoated Paper	32 / J-Paper (Standard)
α	1.7	Uncoated Paper	33 / mondi (Standard)
α	1.7	Matte Coated Paper	5 / Sanmat
α	1.7	Matte Coated Paper	9 / b7 bulky
α	1.8	Uncoated Paper	20 / Domter Copy 201b
α	2.6	Matte Coated Paper	8 / OK TopKote Mat N
α	2.6	Uncoated Paper	12 / Kisyū-Jōshitsu: 紀州上質
α	5.6	Matte Coated Paper	29 / Matte Paper (Formal name is unknown)
α	7.8	Uncoated Paper	26 / Ensocoat 330
α	8	Uncoated Paper	27 / Ensocoat 2s 270
β	14	Gloss Coated Paper	35 / POD Gloss Coat (Standard)
β	16.2	Gloss Coated Paper	21 / Digital Gloss Cover
β	17.8	Gloss Coated Paper	22 / Magnostar Gloss 350
β	17.9	Gloss Coated Paper	2 / Aurora Coat
β	18.8	Gloss Coated Paper	4 / OK TopKote +
β	19.1	Gloss Coated Paper	13 / OK Art Post + : OK特アートポスト＋
β	20.1	Gloss Coated Paper	1 / Raichō Coart: 雷鳥コート
β	21	Gloss Coated Paper	36 / OK TopKote (Standard)
β	21.2	Acrylic Board	18 / Acrylic board sample No.27
β	21.8	Gloss Coated Paper	23 / CoatedGlossy135
β	24.2	Gloss Coated Paper	28 / Coated Paper (Formal name is unknown)
β	25	Acrylic Board	38 / Acrylic Board No.20 (Standard)
γ	32.6	Acrylic Board	15 / Acrylic Board No.19 (Standard)
γ	32.9	Acrylic Board	16 / Acrylic Board No.26 (Standard)
γ	36.9	Acrylic Board	17 / Acrylic Board No.2 (Standard)
γ	46	Acrylic Board	39 / Acrylic Board No.18 (Standard)
δ	63	Cast Coated Paper	31 / Esprit Coat C (Standard)
δ	63.1	Cast Coated Paper	10 / Esprit Coat C
δ	68.2	Acrylic Board	14 / Acrylic Board No.12 (Standard)
δ	69.5	Acrylic Board	25 / Acrylic Board No.25 (Standard)
δ	73	Acrylic Board	17 / Acrylic Board No.17 (Standard)

*1) The written characters show each cluster when the number of clusters was 4.
*2) I.P. is evaluated value of Image-Perceptibility.
*3) A name in original language is written when formal translation is unknown.

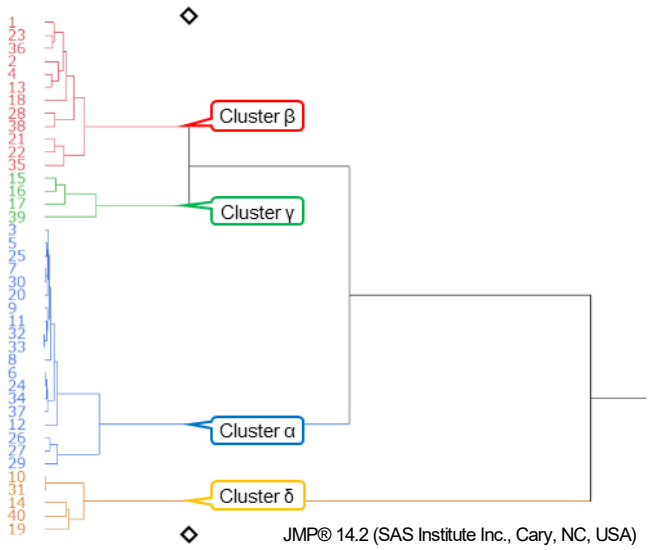


Figure 3. *Result of the cluster analysis. The length of branches corresponds to the distance between clusters. The numbers on left side shows the sample numbers shown in table 1.*

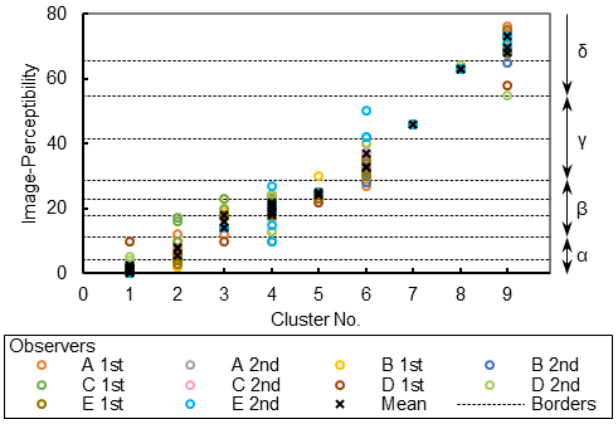


Figure 4. *The evaluated values of Image-perceptibility in each small cluster when the number of clusters was 9. The broken lines show the borders between adjacent clusters. Gloss appearance in region α, β, γ and δ are as follows; α: uncoated paper level, β: gloss coated paper level, γ: the middle of gloss and cast coated paper levels and δ: cast coated paper level.*

4-2. Usefulness of the Proposed Index

Fig. 5 shows the evaluated values of image-perceptibility and their positions on the clusters. α, β and δ in fig. 5 show the region based on the index that we proposed in section 4-1, and they mean the region of "uncoated level," "gloss-coated level" and "cast-coated level" respectively. By using the index, it was clarified that all electrophotography printers used in this experiment were not capable to produce uncoated level image-perceptibility even when the images were printed on uncoated paper. Most of their image-perceptibility were gloss-coated level independent of paper types. Image-perceptibility produced by printer 1, 2 and 3 (fig. 5) exceeded the upper limit of gloss-coated paper level when their images were printed on cast-coated paper, but they didn't reach cast-coated paper level. This result indicates that difference of gloss appearance between on images and on paper are definitely perceived in many cases that images printed on paper except for on gloss-coated paper.

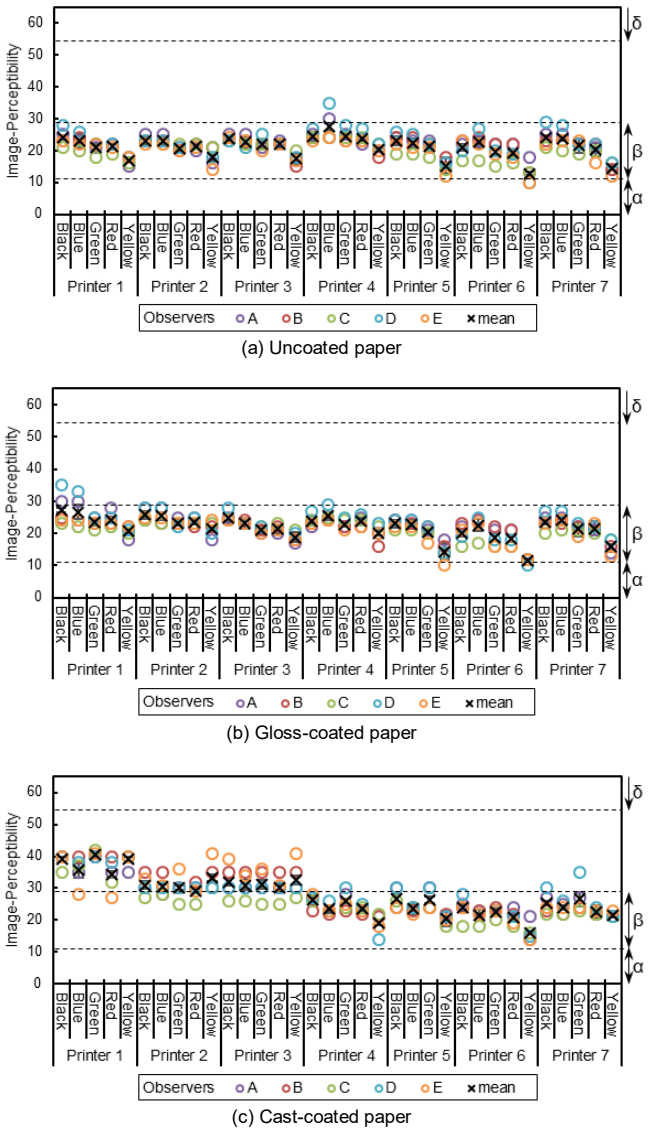


Figure 5. *The evaluated values of image-perceptibility and their positions on the clusters. α, β and δ are the region based on the index that we proposed in section 4-1, and they mean the region of "uncoated level," "gloss-coated level" and "cast-coated level" respectively. (a): A result on uncoated paper (mondi). (b): A result on gloss-coated paper (POD Gloss Coat). (c): A result on cast-coated paper (Esprit Coat C).*

Fig. 6 (a) shows the relation between image-perceptibility and glossiness (60° of measurement angle) of images printed on uncoated paper (mondi) by the 7 electrophotography printers. The error bars show standard errors on the subjective evaluation. There were many cases that differences of image-perceptibility were smaller than the standard errors or the width of small clusters, which are the 9 clusters mentioned in section 4-1, even if glossiness were different. The width of small clusters in region of uncoated paper level or gloss-coated paper level can be standards to know the range, which makes observers definitely feel difference of image-perceptibility. Therefore, the result shown on Fig. 6 (a) means that difference of glossiness, which is commonly used for evaluating gloss level, does not always corresponds to appearance difference. Furthermore, it was indicated that lower lightness colors tended to

be perceived higher image-perceptibility even if glossiness values were the same.

Fig. 6 (b) and (c) show the relation between image-perceptibility and glossiness of images printed by the offset printer. (b) shows the results of images on gloss-coated paper (coated paper, formal name is unknown) and (c) shows the results of images on uncoated paper (recycled wood-free paper, formal name is unknown). All image-perceptibility values were obtained in region α or β, which were the same region as that of the paper surface. It means that the offset printer was capable to reproduce image-perceptibility, which was close to the paper. In particular, fig. 6 (b) shows that perceived gloss appearance of all images except yellow were equivalent even though glossiness of the samples were different. Only the difference of image-perceptibility between the yellow sample and others on gloss-coated paper would be perceived by observers because the difference was greater than the intervals between small clusters' borders.

Above all results had been empirically expected before image-perceptibility concept was suggested. However, it had been difficult to connect evaluated gloss features with perceived impression without an index like what we suggested. Therefore, we concluded that the proposed index made it possible to describe what we empirically expected, and that the index is useful on gloss appearance evaluation.

Moreover, the procedure to create the index has been improved compared to the past study [1,2]. The reason is that the procedure of this study was based on magnitude estimation method, and it allowed adding other samples after first subjective evaluation. That would be an important advantage for maintaining or improving accuracy of quantitative values given for the index. However, the method would require more subjects than the method in the past study (method of paired comparisons [1,2]) to obtain accurate evaluated values, and it can be disadvantage from the accuracy point of view. Nevertheless, the above advantage helps to improve the accuracy and its effect is expected to exceed affection of the disadvantage.

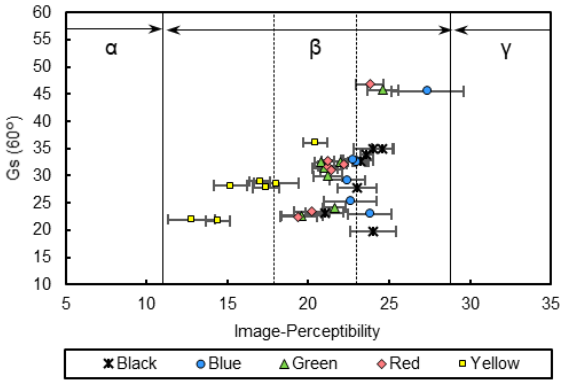
Conclusions

Image-perceptibility has been defined as follows; "distinctness of outline of reflected images, and it doesn't include color reproducibility of reflected images." Image-perceptibility means impression perceived from gloss appearance.

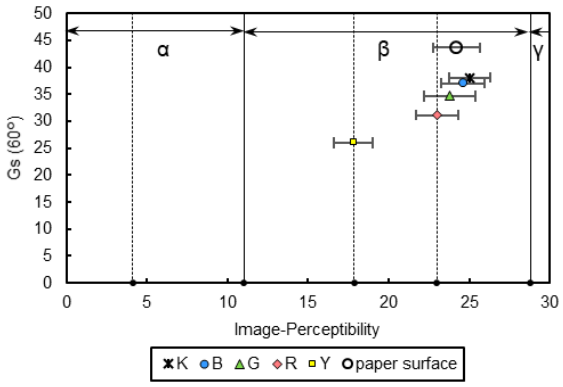
Gloss degrees of the paper surfaces were shown quantitatively based on image-perceptibility perceived by observers. It was statistically shown that image-perceptibility degrees of printed images and paper can be divided into 4 main clusters based on 3 types of major paper appearances, and a set of them and mirror finished acrylic board appearance can be the intelligible and quantitative index for evaluating gloss degree of printed images. The all quantitative values describing the index are based on the definition: image-perceptibility value of mirror finished acrylic board surface is 100.

The gloss range, which makes observers "definitely" feel gloss difference, was quantitatively shown on the scale of image-perceptibility. Relating to the range in higher image-perceptibility regions, verification by adding data would be required in the future.

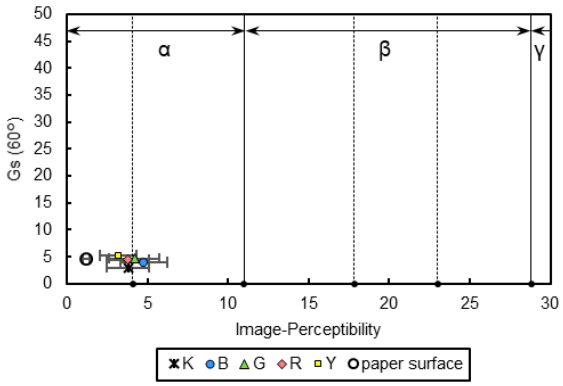
The usefulness of the index by visualizing capability range of several printers has been shown. We concluded that the proposed index can be used when observers require to judge whether gloss appearance of a printed image is approximately the same as that of the paper. Moreover, the information of range, in which observer cannot feel difference, can be additional standard in case that gloss difference between some images need to be evaluated in detail. These index and standard are expected to be useful guides for determining printer's conditions regarding gloss.



(a) Images printed on uncoated paper by electro photography printers



(b) Images printed on gloss-coated paper by the offset printer



(c) Images printed on uncoated paper by the offset printer

Figure 6. *The relation between evaluated image-perceptibility value and glossiness (60° of measurement angle). α, β and γ are the region based on the index that we proposed in section 4-1, and they mean the region of "uncoated paper level," "gloss-coated paper level" and "the middle of gloss and cast coated paper levels" respectively. (a): Results of the images printed on uncoated paper (mondi) by electrophotography printers. (b): Results of the image printed on gloss-coated paper (coated paper, formal name is unknown) by the offset printer. (c): Results of the image printed on uncoated paper (recycled wood-free paper, formal name is unknown) by the offset printer.*

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