Identification technology of paper
-Authenticity detection using multiple feature quantities-

Takahisa Nakano, Nobuki Nemoto, Takeo Miki; Power and Industrial Systems Research and Development Center, Toshiba Corporation; Kawasaki, Japan

Abstract
Counterfeiting ID cards and negotiable securities such as bills and gift certificates are always repeated. To improve performance of detection for authenticity, development of new technology that combines sensor technology and encoding techniques for security information are required. There are many reports to confirm printing regions for security documents, however, methods to detect features of paper media are rarely studied We have developed a method for detecting the authenticity of paper by optically sensing the characteristics of uniformity, brightness, color values, gloss and near-infrared absorption properties. Using multiple features, the separation boundary in a multidimensional feature space is determined. We report results of separation abilities of twenty kinds of paper media based on a multidimensional analysis.

Introduction
Many security items are equipped in security documents such as ID cards or bills to discriminate authenticity. For example, the fluorescence, the magnetic, the watermark, the hologram, the intaglio print, and the micro character print are already become popular as security items. These security items are effective, .however, there is a possibility that the authenticity using these popular security items and unjust paper materials that are brought from outside of authorities To prevent such authenticity , detection technologies that distinguish a forgeries with a non-destructive inspection of for paper media are required.

The papers are different in appearance and senses of touch for each material that relate to their properties such as durability, print-proof and forgery prevention. Persons can distinguish the difference of materials by their five physical senses. For instance, the color, the brightness and the gloss are sensed by their sight, sounds are sensed for hearing, and the roughness of surface is sensed for sense of touch. If some physical quantities can represent the human senses papers can be classified and identified by its feature quantities.

In this paper, we describe methods to extract and selected effective feature quantities for paper classification, and explain a multidimensional analysis using the plural feature quantities to classify paper media. By using this method, a specific kind of paper is separated from other paper media. We also report evaluation results by using twenty kinds of paper.

Principles
As same as other classification problems, the multidimensional analysis has higher classification performance compared with the one-dimensional analysis. For example, as shown in Figure1(a)(b), it is difficult to separate distributions of feature quantities, because the distribution is piled by the three distributions in the one dimension. However as shown in Figure1(c), a separation of three groups becomes easy by getting the distribution of the two dimension. Considering the multidimensional distribution, we will select the effective feature quantities to classify kinds of paper,

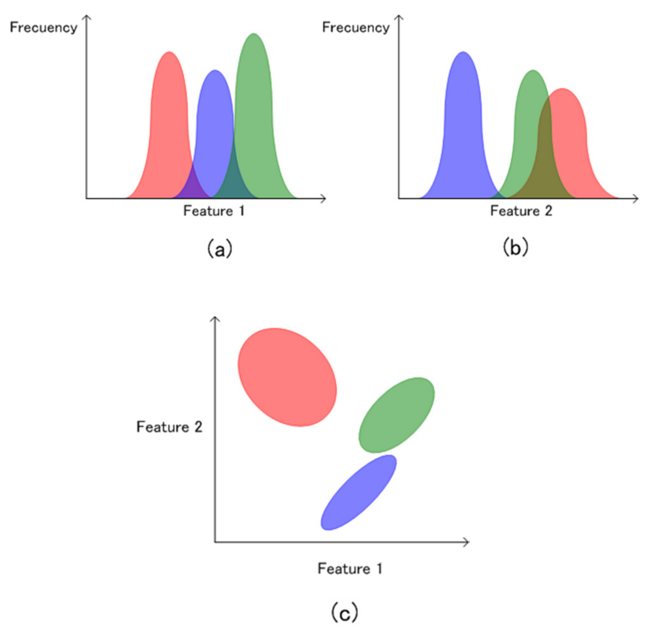

Figure 1. Basic ideas of multidimensional analysis *(a)1-demensional distribution of Feature1, (b)1-demensional distribution of Feature2, (c)2-demensional distribution of Feature1 and Feature2*

Methods

Selection of the feature quantity
When we select the feature quantities, we have to get the features from more than one viewpoint. At first, we describe human senses for materials of papers to judges the same kind of paper. Feature quantities equivalent to the feel of a material about paper media are extracted as shown in in Table1. If we can

represent the feature quantities equivalent to these in the physical quantities, we can represent the feel of a material in a numerical value. We selected “brightness”, “color”, “glossiness” set by Japanese Industrial Standards (JIS) as the feature quantities (Table2). The brightness is represented by L* of Munsell color system L*a*b* as the numerical value. The color is represented by c* of Munsell color system L*c*h*.

Table 1 Features corresponding to sense

Feature quantity	Descriptions for feels of a material
Brightness	Black, White
Color	Chroma, Hue, Vividness
Glossiness	Surface nature, Fascinating, Ratio of direct reflection ingredient
Fluorescence	Fluorescent emission, Fluorescence increasing white
Hardness	Thickness, Sound, Impoverishment
Strength	Thickness, Sound, Impoverishment
Smoothness	Coarse, Unevenness

Table 2 Selected feature quantities

Feature quantity	Definition	Standard
Brightness	Attributes of the sight based of the strength of the light rising from a face.	JIS Z8105
Color	Attributes of the sight based of the strength of the chromatic degree of perception color from a face.	JIS Z8105
Glossiness	Ratio of direct reflection ingredient	JIS Z8105

The structure and the length of fibers in the paper are one of the feature quantities from the viewpoint of the production process of papers. Those features have an influence to roughness or unevenness of the paper. We have selected the "uniformity" representing the structure and the length of fibers in the paper as one of the feature quantities. The uniformity is the feature quantity picked out from a pattern of paper fiber structures and the length that has high correlation as the texture feature. The uniformity is defined as the moment for inertia of angle for the gray level co-occurrence matrix. The gray level co-occurrence matrix is the matrix which makes an element of the probability P=(i,j) that the density of the point that only fixed displacement $\delta=(r,\theta)$ is away from the point of the density i is j. When the contract of the picture element is N, the gray level co-occurrence matrix is the matrix of the size in N x N. For example, in the case r=1, θ=90°, and N=4, it shows that there are a lot of pairs of small difference of density so that the numerical value concentrates on the center diagonal of the gray level co-occurrence matrix (Figure 2) [7] [8].

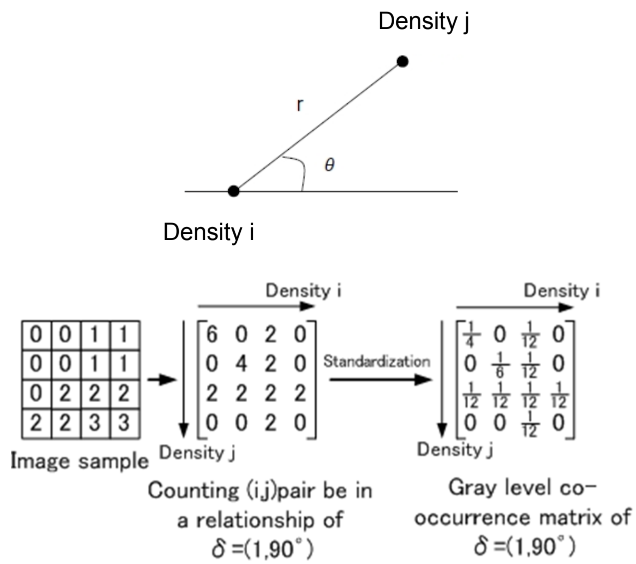

Figure 2. *The Uniformity described by fray level co-occurrence matrix [7] [8]*

In addition, there are absorption characteristics of the wavelength for the paper as a feature quantity from the viewpoint of component analysis. Figure 3 shows an example of absorption characteristics of the paper. There are the differences in absorption characteristics depending on paper around 1480nm in a near infrared band. We have selected the ratio of absorption of this band as the "near-infrared absorption characteristics".

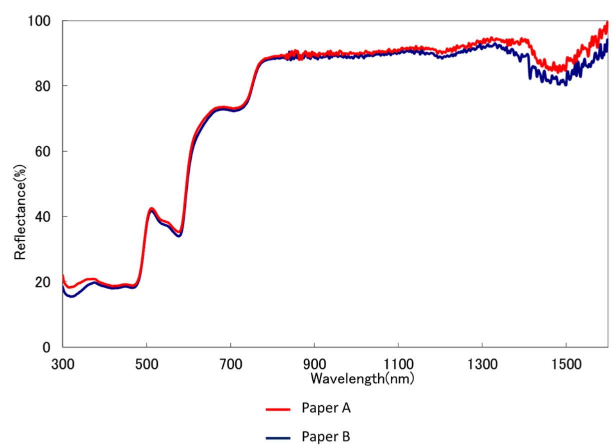

Figure 3. *Schematic illustration for the absorption characteristic of paper*

Multidimensional analysis method

Using the selected feature quantities, multidimensional analysis is applied to classify papers. Each feature quantity is normalized in 1.0 by using averages, and stored their frequencies in the multidimensional histogram. Calculated the positive classification ratio using a discrimination analysis method [8], degrees of separation for different kinds of paper are calculated at the positive classification ratio of 100%. We use standard deviation (σ) between the distribution of the object paper (True) and the resemblance paper (False) as the degree of separation. The distance of two distributions is represented as the degree of separation by the standard deviation (σ), and the smallest value for plural distance values calculated for combinations of two distributions (see Figure 4). The degree of separation indicates the probability of the separation boundary from which the object paper and other paper are separated. The degree of a separation D is calculated by the following calculating equations.

$$\sigma_T = \sqrt{\frac{\sum_{i=1}^{n_T}(\overrightarrow{x_{Ti}} - \overrightarrow{\mu_T})^2}{n_T}} \quad (1)$$

$$\sigma_F = \sqrt{\frac{\sum_{i=1}^{n_F}(\overrightarrow{x_{Fi}} - \overrightarrow{\mu_F})^2}{n_F}} \quad (2)$$

$$D = \frac{L_{TF}}{\sigma_T + \sigma_F} \quad (3)$$

σ_T : Standard deviation of the feature quantities of the object paper

σ_F : Standard deviation of the feature quantities of other paper

n_T : Data count of the feature quantities of the object paper

n_F : Data count of the feature quantities of other paper

μ_T : Average of the feature quantities of the object paper

μ_F : Average of the feature quantities of other paper

L_{TF} : Distance between μ_T and μ_F

A possibility that both of them can be separate becomes so high that the degree of separation D is big.

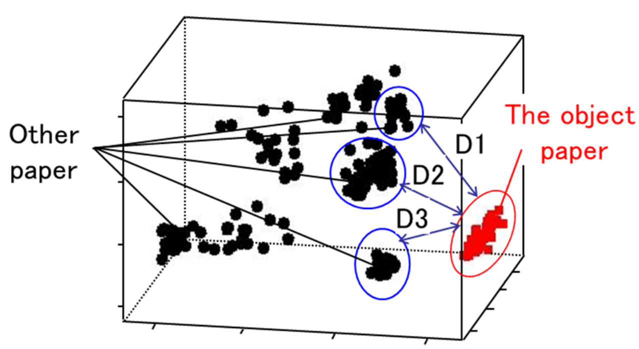

Figure 4. *Definition of the degree of separation*

Evaluations

Paper separating evaluation using measurement equipment

We acquired experimental data for the respective feature quantities by using various kinds of measurement equipment. Twenty kinds of paper including specific ID cards, xerographic papers, the paper from which ID cards are copied in xerographic paper, and 6 kinds of Japanese paper are used for experiments.

Table 3 shows feature quantities and measurement equipment that measure each feature. We have measured L* as the brightness, c* as the color, direct reflection ratio as the glossiness. We have calculated uniformity from a paper pattern of a reflective picture of near-infrared band, and absorption ratio of the desired wavelength from spectral properties as the near-infrared absorption characteristics.

Table 3 Feature quantities and Measurement equipment

Feature quantity	Measurement equipment
Brightness	Spectrophotometer (KONICA MINOLTA CM-503d)
Color	Spectrophotometer (KONICA MINOLTA CM-503d)
Glossiness	Gloss meter (KONICA MINOLTA GM-268)
Uniformity	CCD area camera
Near-infrared absorption characteristics	UV/Vis/NIR Spectrophotometer (JASCO V-570)

We have defined a plain color area of the ID card as the object paper (True) and other papers are defined as False. Table 4 shows, degrees of separation by using three features. Using combinations of the brightness, color and the near-infrared absorption characteristics, the degree of separation has been the highest value, D = 5.91 σ (Figure 5). According to the results, we can estimate abilities of separation between true and false papers as more than 99.99% of probability.

Table 4 Results of evaluate of the degree of separation

Feature1	Feature2	Feature3	Positive classification ratio(%)	Degree of separation(σ)
Uniformity	Brightness	Color	100	1.43
		Glossiness	100	1.71
		Near-infrared absorption characteristics	100	1.70
	Color	Glossiness	100	1.74
		Near-infrared absorption characteristics	100	2.25
	Glossiness	Near-infrared absorption characteristics	96.7	-
Brightness	Color	Glossiness	100	4.97
		Near-infrared absorption characteristics	100	5.91
	Glossiness	Near-infrared absorption characteristics	100	1.92
Color	Glossiness	Near-infrared absorption characteristics	100	5.00

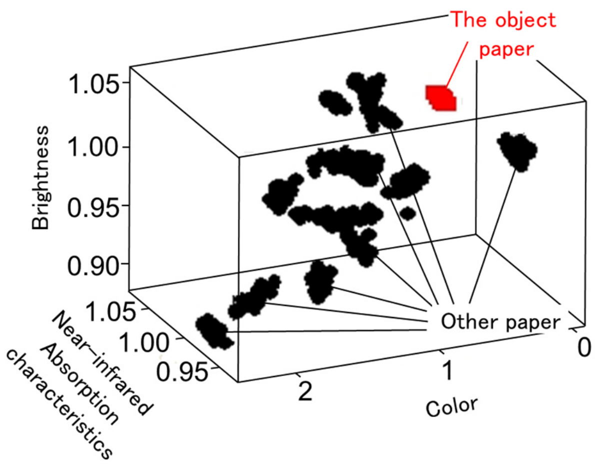

Figure 5. The result of paper separating evaluation

We confirm the method to a printed area of ID card. We have defined a printed area of the ID card as the object paper (True) and other papers are defined as False. Table 5 shows results of the degree of separation. As a result, when we have analyzed at three dimensions using the brightness, glossiness and the near-infrared absorption characteristics, the degree of separation has been the highest value, D = 1.29σ. The degree of separation became low because selected features are not designed for printing but paper materials.

Table 5 Results of the degree of separation

Feature1	Feature2	Feature3	Positive classification ratio(%)	Degree of separation(σ)
Uniformity	Brightness	Color	97.0	-
		Glossiness	96.3	-
		Near-infrared absorption characteristics	100	0.96
	Color	Glossiness	92.8	-
		Near-infrared absorption characteristics	99.8	-
	Glossiness	Near-infrared absorption characteristics	91.1	-
Brightness	Color	Glossiness	95.0	-
		Near-infrared absorption characteristics	98.7	-
	Glossiness	Near-infrared absorption characteristics	100	1.29
Color	Glossiness	Near-infrared absorption characteristics	98.5	-

Paper separating evaluation using optical devices

We design a sensing module that consists of various optical devices corresponding to the above-mentioned measurement equipment. Figure 6 shows the construction of the optical devices which measures feature quantities of the paper. Brightness and color are measured by using white LED lights and RGB color photodiode sensors. Glossiness is measured by using white LED lights and silicon photodiode sensors. Uniformity is measured by using near-infrared LED (940nm) lights and a CMOS monochrome area sensor. We have measured near-infrared absorption characteristics using near-infrared LED (1450nm) lights and an InGaAs sensor.

We have defined a plain color area of the ID card as the object paper (True) and other papers are defined as False to evaluate the degree of separation (see Table 6).

As a result, when we have analyzed at two dimensions using the brightness and glossiness, the degree of separation has been the highest value, D = 3.82σ (Figure7.). The degree of separation is smaller than a case using measurement equipment, however we can estimate abilities of separation between true and false papers as more than 99.99% of probability**.** The degree of separation with the three-dimensional analysis became low because the standard deviation of the feature quantities besides the brightness and the glossiness has become big. The standard deviation becomes big because the characteristics of devices have been fallen more than a case using measurement equipment.

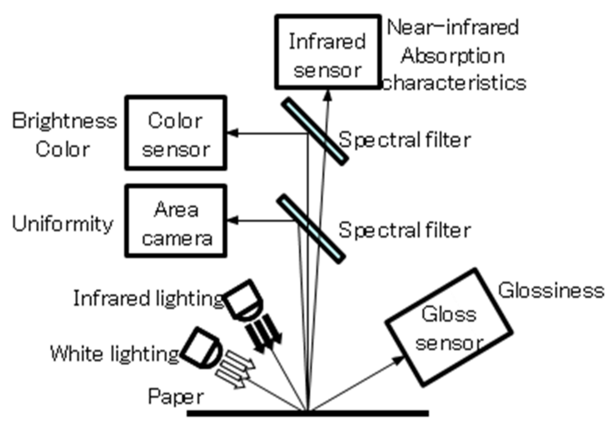

Figure 6. *Schematic illustration for the paper separating evaluation using optical devices*

Table 6 Results of evaluate of the degree of separation

Feature1	Feature2	Positive classification ratio(%)	Degree of separation(σ)
Uniformity	Brightness	100	0.54

	Color	98.7	-
	Glossiness	97.0	-
	Near-infrared absorption characteristics	80.0	-
Brightness	Color	100	3.10
	Glossiness	100	3.82
	Near-infrared absorption characteristics	100	2.16
Color	Glossiness	100	3.10
	Near-infrared absorption characteristics	99.6	-
Glossiness	Near-infrared absorption characteristics	97.0	-

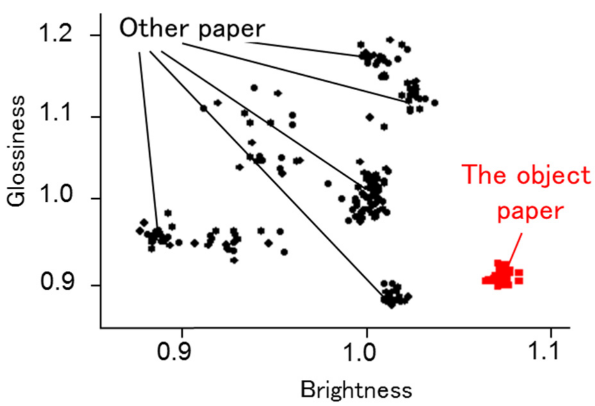

Figure 7. *Schematic illustration for the result of paper separating evaluation*

In addition, we have evaluated by the system which illuminates RGB 3-color LEDs are from the individual direction instead of white LED as the illumination of extracting the brightness and the color (see Table7).

As a result, when we have analyzed at two dimensions using the brightness and glossiness being not different from the occasion using white LED, the degree of separation has been the highest value, D = 2.41σ, but it has been fallen more than a case using white LED. The degree of separation became low because color shading on the work has occurred by using RGB 3-color LEDs illuminated from the different direction.

Table 7 Results of evaluate of the degree of separation

Feature1	Feature2	Positive classification ratio(%)	Degree of separation(σ)
Uniformity	Brightness	100	0.46
	Color	72.2	-
	Glossiness	99.6	-
	Near-infrared absorption characteristics	80.0	-
Brightness	Color	100	0.56
	Glossiness	100	2.41
	Near-infrared absorption characteristics	100	1.88
Color	Glossiness	99.6	-
	Near-infrared absorption characteristics	79.6	-
Glossiness	Near-infrared absorption characteristics	100	2.11

Conclusions

We have selected plural feature quantities from various viewpoints and developed the method for detecting the authenticity of paper by the multidimensional analysis of the feature quantities. Then we have confirmed that a kind of the specific ID card can be separated from 20 kinds of paper by more than 99.99 % of probability. Our approach enables to detect authenticity of the paper being a base for ID card and can improve security levels of ID cards. The next our goals are (1) developing the detection system that can handle not only paper areas but also printed areas and (2) developing the process of total security systems after the detection system.

References

[1] Hiroshi Hara, Standardization Paper (Japanese Standards Association, Tokyo, 1992) pg.238-242.

[2] Tsutomu Matsumoto, "Research and Development Trends and Challenges of Artifact metric", 11th Information Security Symposium, Briefing paper 1, pg.16-19(2009)

[3] Takahisa Nakano et al. "Light Detecting Device" Japan Patent P2011051437 (2011.03.09)

[4] Takahisa Nakano et al. "Light Detecting Device" Japan Patent P2011183897 (2011.08.25)

[5] Takahisa Nakano et al. "Personal Authentication Media Issuing Apparatus" Japan Patent P2012055008 (2012.03.12)

[6] JISZ8105 Glossary of colour terms: 1048 glossiness, 2070 CIE1976L*a*b* colour space, 2071 CIE1976a,b chroma, 3010 brightness, 3021 chromaticness, www.jisc.go.jp

[7] Shinichi Murakami, Image Processing Technology (Tokyo Denki University Publisher, Tokyo, 1996) pg.88-89.

[8] Hideyuki Tamura, Introduction to Computer Image Processing (Soken Publisher, Tokyo, 1985) pg.68, 135-136.

[9] Naotake Natori et al. "Light Detecting Device" Japan Patent P2010115567 (2011.05.19)

[10] NATIONAL RESEARCH COUNCIL, Is That Real? (National Academy of Sciences, Washington DC, 2006)

Biography

Takahisa Nakano received his B.S. in Electrical engineering from Chiba University in 1992. He joined Toshiba Corporation in 1992 and now engages in development of security printing technologies in Power and Industrial Systems Research and Development Center.