

Detection of transition of red colours on *Nishiki-e* printings from colour-corrected digital images

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Nishiki-e (Japanese traditional polychrome woodblock print) is one of the leading products of colour culture in Japan. We tried to detect a new vivid red colour that is used on *Nishiki-e* printings in 1860s explosively. Red colours of 2,561 *Nishiki-e* printings made from 1751 to 1934 were analysed. These printings are owned by National Museum of Japanese History (Japan), and digital images have taken by a digital imaging system with a GretagMacbeth ColorChecker chart since 2003. We developed an automatic extraction software program of the ColorChecker image and a *Nishiki-e* image. The RGB-CIEXYZ conversion matrix of each image for colour correction was calculated from the extracted colour chart image. From colour-corrected CIELAB images, strong red colours ($0^\circ \leq h \leq 50^\circ$, $C^* \geq 20$) were extracted, and frequency of use of hue and chroma was visualised as a histogram. It is clearly observed that the use of new vivid red colour ($h \approx 10^\circ \sim 20^\circ$, $C^* \geq 50$) was occurred in 1869. This is one of effective applications on digital archiving of coloured museum materials.

Received 04 November 2014; revised 22 January 2015; accepted 26 January 2015

Published online: 27 April 2015

Introduction

Nishiki-e is Japanese polychrome woodblock print of the *Ukiyo-e* school. *Nishiki-e* was first produced by *Harunobu Suzuki* in 1760s and had made to 1910s. *Nishiki-e* is one of the leading products of colour culture in Japan. Inexpensive dyes were mainly used on *Nishiki-e* as colorants because *Nishiki-e* printings were mass-produced and were sold at low prices. They are interesting problems to identify these colorants and to reveal an area and a period that each colorant was used.

National Museum of Japanese History (Japan) has thousands of *Nishiki-e* printings as a collection of the museum. Digital colour imaging of *Nishiki-e* printings and colour-correction of the images has been continuously executed for condition recording of the printings and for utilisation as resources for Japanese history research.

In this paper, analysis of red colours in colour-corrected *Nishiki-e* images is described. It is known that a new vivid red colour was used on *Nishiki-e* printings in 1860s explosively. 2,561 colour-corrected *Nishiki-e* images were investigated. Red colours of each image were extracted and represented as a hue histogram and a chroma histogram. Serialised histograms of the images clearly indicated that hue of red colours was changed in 1869.

Recording and colour correction of *Nishiki-e* images

Since 2003, *Nishiki-e* printings owned by National Museum of Japanese History (Japan) have been taken using a digital imaging system [1] for condition recording of the printings and for utilisation as resources for Japanese history research (Figure 1). Each printing was illuminated uniformly by a flash xenon lamp and was taken with a colour chart (GretagMacbeth ColorChecker).



Figure 1: *Nishiki-e* digital imaging system.

Table 1 shows specifications of two digital imaging systems. The first generation system was used until 2008, 4,258 *Nishiki-e* images were taken by this system. Since 2009, the second generation system has used. Devices were replaced, but fundamental structure is the same. In this paper, taken images by the first generation system were used for analysis.

	First generation system	Second generation system
Digital still camera unit		
Body	Mamiya RZ67 ProII	Sony DSLR-A900
Lens	Mamiya SEKOR Z 50mm F4.5W	Sony 100mm f/2.8 Macro Lens
Image sensor	Kodak DCS Proback Plus (CCD)	Built-in CMOS sensor
Pixels	4072 × 4072	6048 × 4032
Colour depth	36 bits (RGB 12 bits)	36 bits (RGB 12 bits)
Flash xenon lamp unit		
Lamp	COMET CLX-25 mini	Broncolor Litos
Power supply	COMET CB-2400	Broncolor Sense A2
White point	$[x, y] = [0.3312, 0.3446]$	<i>not yet measured</i>
Colour temperature	5555K	5500K

Table 1: Specifications of the first and second generation digital imaging systems.

We developed an automatic extraction software program of a colour chart image and a *Nishiki-e* image [2] as show in Figure 2. Both the colour chart and a *Nishiki-e* printing are put on a uniform grey sheet, and the colour chart has a black frame. The colour chart in every taken image has similar size. Using these facts, automatic extraction of the colour chart from every taken image was succeeded. By the combination of binarisation and labelling algorithm, extractions of the colour chart were available from 3,648 of 4,258 (~85.7%) taken images. In case that an extraction was failed, the use of template matching was slow but effective. On the other hand, automatic extraction of the *Nishiki-e* image was not easy. Some *Nishiki-e* printings were combined and automatic separation was impossible. For example, in Figure 3(a), a set of three printings are combined in a line. To separate every printing automatically, every seam between adjacent printings have to be detected computationally. Manually separated images of every printing are shown in Figure 3(b). From 4,258 taken images, 978 (~23.0%) *Nishiki-e* images were manually extracted.



Figure 2: Automatic extraction of the colour chart and a *Nishiki-e* image: (a) original image; (b) binary image for detection of the colour chart; (c) detected position of the chart; (d) detection of every colour chip in the chart; (e) colour-corrected image; (f) image that the chart is masked; (g) binary image for detection of a *Nishiki-e* image; (h) detected position of the *Nishiki-e* image and (i) extracted *Nishiki-e* image.



Figure 3: Example of combined Nishiki-e printings and their separation: (a) combined Nishiki-e printings and (b) manually separated images of the printings.

The RGB-CIEXYZ conversion matrix [3] of each image for colour correction was calculated from the extracted colour chart image. Colour-corrected images had CIEXYZ colour values. For colour analysis under a uniform colour space, images which have CIELAB colour values were made from them. The average of ΔE_{ab} between measured CIELAB value and estimated CIELAB value of each colour chip in the colour chart in every color-corrected image was about 2.83.

Hue and chroma analysis of red colours on *Nishiki-e* images

It is known that a new vivid red colour was used on *Nishiki-e* printings in 1860s explosively. Such printings were called *Akae* (red paintings) and caught on with the public as a symbol of the new period¹ [4-5].

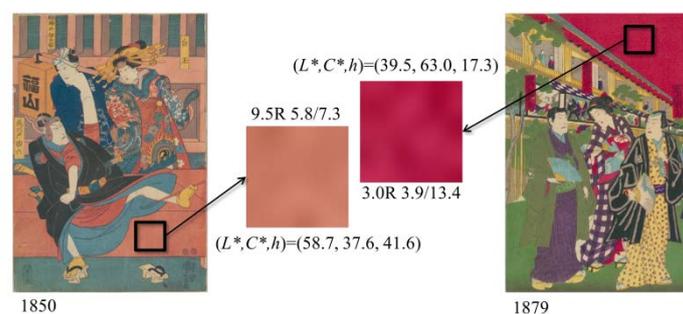


Figure 4: Comparison of old (left) and new (right) red colours.

¹ The 19th century of Japan was revolutionary period. In 1868, Tokugawa Shogunate came to an end and Meiji government was established.

In Figure 4, the left-hand image shows a *Nishiki-e* which was printed in 1850, and the right-hand image shows an *Akae* which was printed in 1879. Different red colours are used in these two printings. It is noted that the old red colour has yellowish red hue ($\sim 10R$ Munsell Hue) and moderate chroma (~ 8 Munsell Chroma). On the other hand, new red colour has red hue ($\sim 2.5R$ Munsell Hue) and strong chroma (~ 14 Munsell Chroma).

	Number of records		Number of images	
	Total	Creation year available	Total	Creation year available
Included in <i>Nishiki-e</i> database	2,340	2,012	---	---
Images already taken	2,172	1,870	3,093	2,709
Red colours are included (0.2% relative area and over)	---	---	---	2,561

Table 2: Number of *Nishiki-e* images as analysis object.

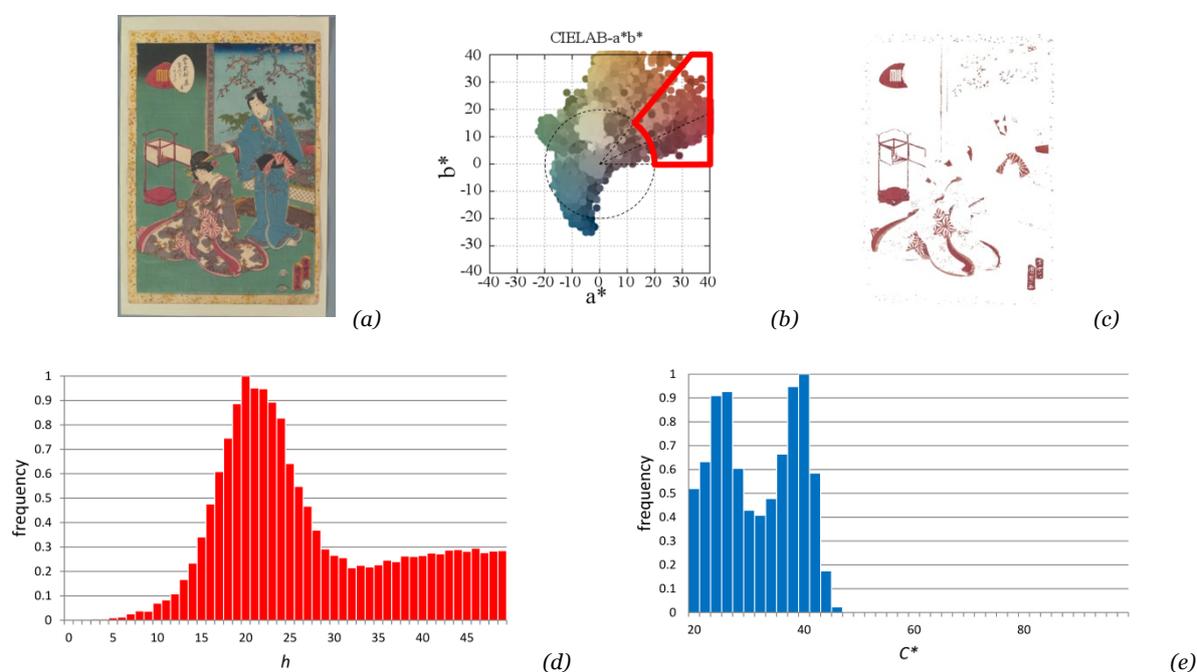


Figure 5: Extraction of red colour information from a *Nishiki-e* image: (a) *Nishiki-e* image; (b) colour distribution; (c) extracted red; (d) hue histogram of red and (e) chroma histogram of red.

We analysed 2,561 colour-corrected images of *Nishiki-e* printings made from 1751 to 1934 to detect the transition of red colours quantitatively. These printings were chosen from *Nishiki-e* database provided by National Museum of Japanese History [6]. The database contains detailed information of selected *Nishiki-e* printings which are owned by the museum and have value for *Nishiki-e* research. The database has 2,340 records. One record may have information of a set of 2 or more *Nishiki-e* printings. Number of records which have creation year information is 2,012. 2,709 images in 1,870 records are already taken by the first generation imaging system. Furthermore, 2,561 images have 0.2% and over red colour area. Table 2 shows a summary of the number of *Nishiki-e* images as analysis objects.

From a *Nishiki-e* printing (Figure 5(a)), strong red colours ($0^\circ \leq h \leq 50^\circ$, $C^* \geq 20$, Figure 5(b)) were extracted (Figure 5(c)), and frequency of use of red hues and chroma were visualised as a hue histogram (Figure 5(d)) and a chroma histogram (Figure 5(e)).

Figures 6(a) and 6(b) are graphs of vertically serialised histograms. Every horizontal monochrome line in the graphs expresses one histogram. Maximum frequency value of every histogram is normalised to 1, and frequency value from 0 to 1 is expressed by greyscale such that black is 0 and white is 1. (However, frequency value 1 is indicated as red.) Histograms are vertically serialised in order of the creation year. From Figure 6(a), it is observed that h of extracted red in most images before 1869 is greater than 25° , and small h ($<25^\circ$) red colours are occurred after 1869. From Figure 6(b), it is observed that C^* of extracted red in most images before 1869 is less than 50, and large C^* (>50) red colours are dominant after 1869.

The existence of new red colour after 1869 is clearly observed. However, it seems that 1869 is not the first occurrence year of new red colour. Small h images are also observed before 1869.

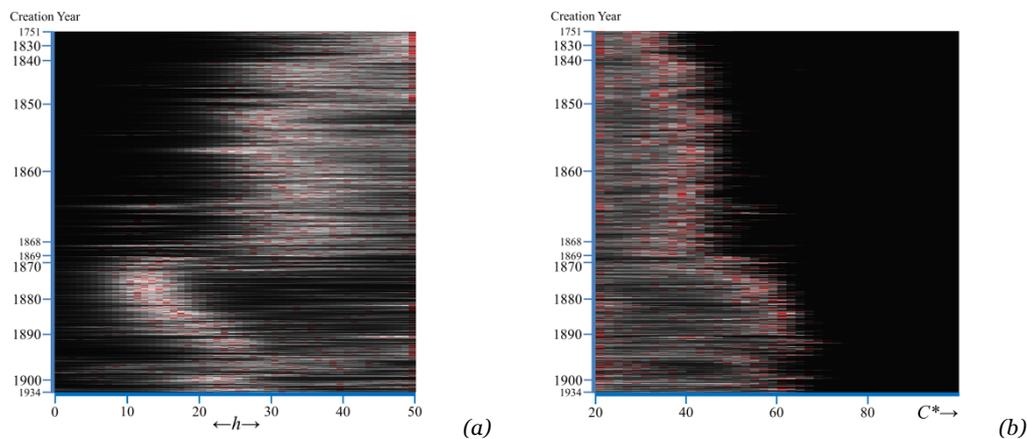


Figure 6: Vertically serialised histograms of 2,561 *Nishiki-e* images: (a) serialised chroma histograms and (b) serialised chroma histograms.

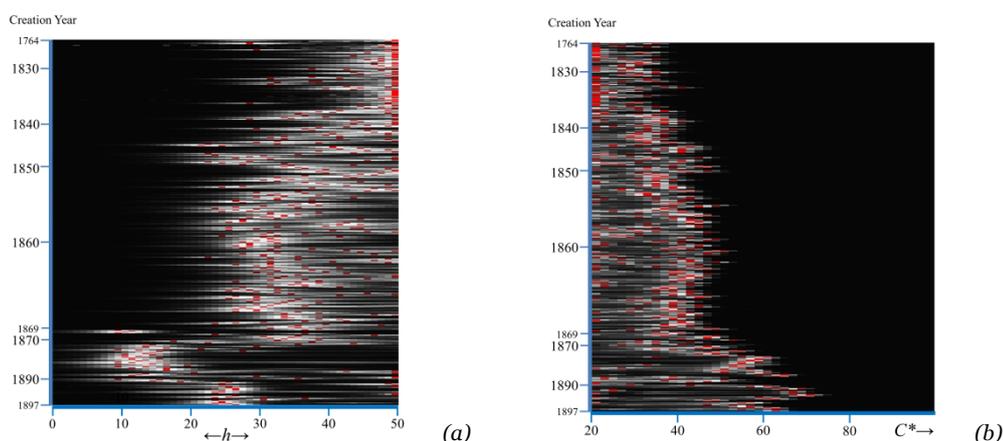


Figure 7: Vertically serialised histograms of 479 *Nishiki-e* images: (a) serialised chroma histograms and (b) serialised chroma histograms.

We should note that creation year is not always the same as printed year. Some kinds of *Nishiki-e* were reprinted for a long period. Creation year of a *Nishiki-e* printing can be known from several marks on the printing, but it is very difficult to know actual year of the printing.

Printed years of *Nishiki-e* printings that were made for advertisement of a new play can be precisely specified. We chose 479 printings that printed year can be specified from 2,561 printings and made the graphs again (Figure 7). In Figure 7(a), it is clearly observed that small h ($\sim 10^\circ$ - 20°) images are first occurred from 1869.

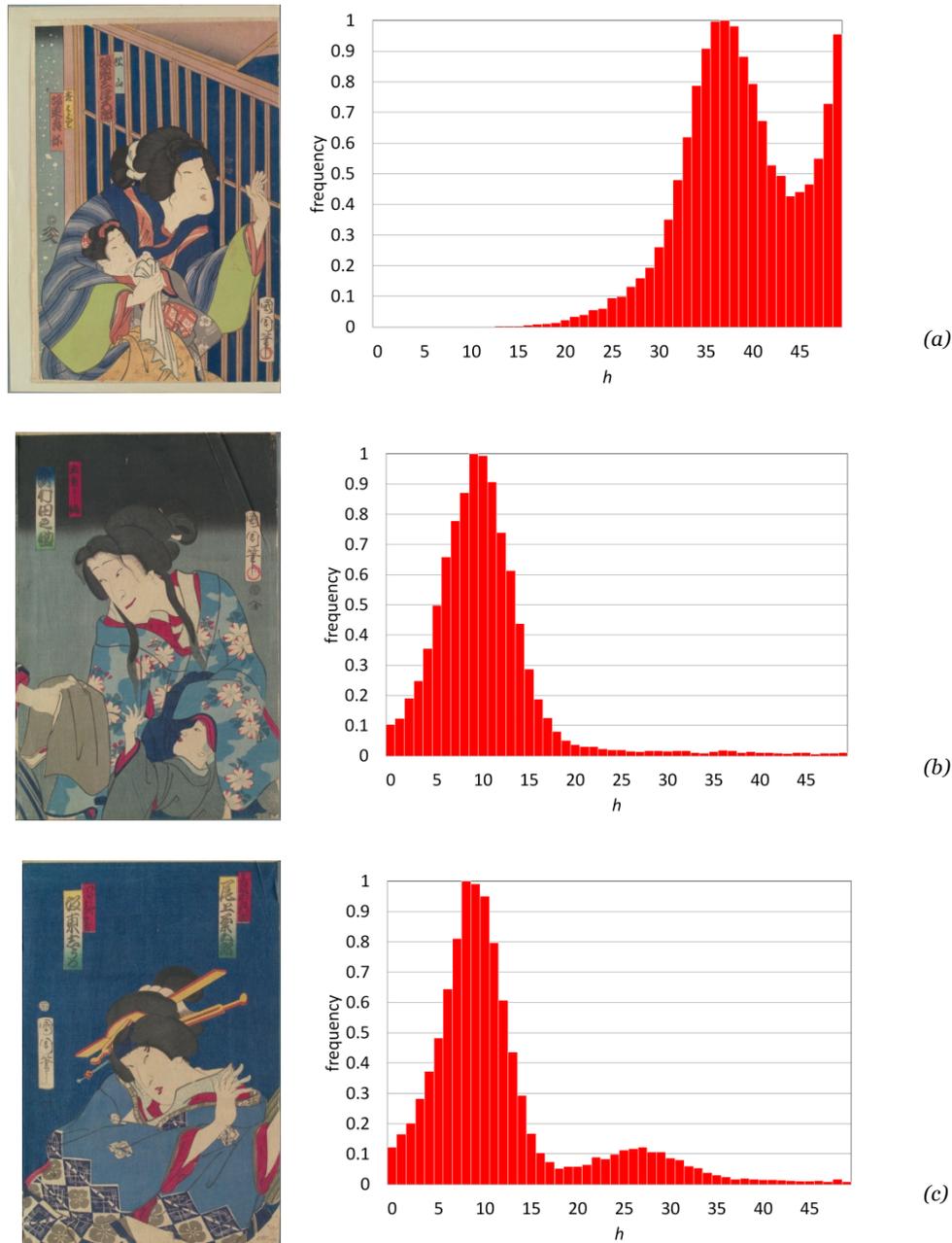


Figure 8: *Nishiki-e* printings of a scene in a play in early 1869 and their hue histograms: (a) “*Nezumi Komon Kuku no Iroage*” at Nakamura-za, started from March 13th 1869 and its hue histogram; (b) “*Kōshoku Shikishima Monogatari*” at Morita-za, started from April 30th, 1869 and its hue histogram; (c) “*Hototogisu Amayo no Minogasa*” at Nakamura-za, started from May 28th, 1869 and its hue histogram.

Figure 8 shows *Nishiki-e* printings of a new play started in early 1869 that we analysed. It is expected that new red colour was first used in April or May 1869. Existence and start-of use of new red colour was testified quantitatively and precisely.

Conclusions

Transition of red colours on *Nishiki-e* Printings could be clearly detected from colour-corrected digital *Nishiki-e* images. Colour information cannot be used for identification of materials directly, but from quantitative analysis from large number of material data, meaningful result can be deduced. This is one of effective applications on digital archiving of coloured museum materials.

Books about the history of *Nishiki-e* said that the new vivid red colorant was imported from overseas in 1860s and was used in Akae [4-5]. It is very probable that the new red colour we detected is caused by the new red colorant.

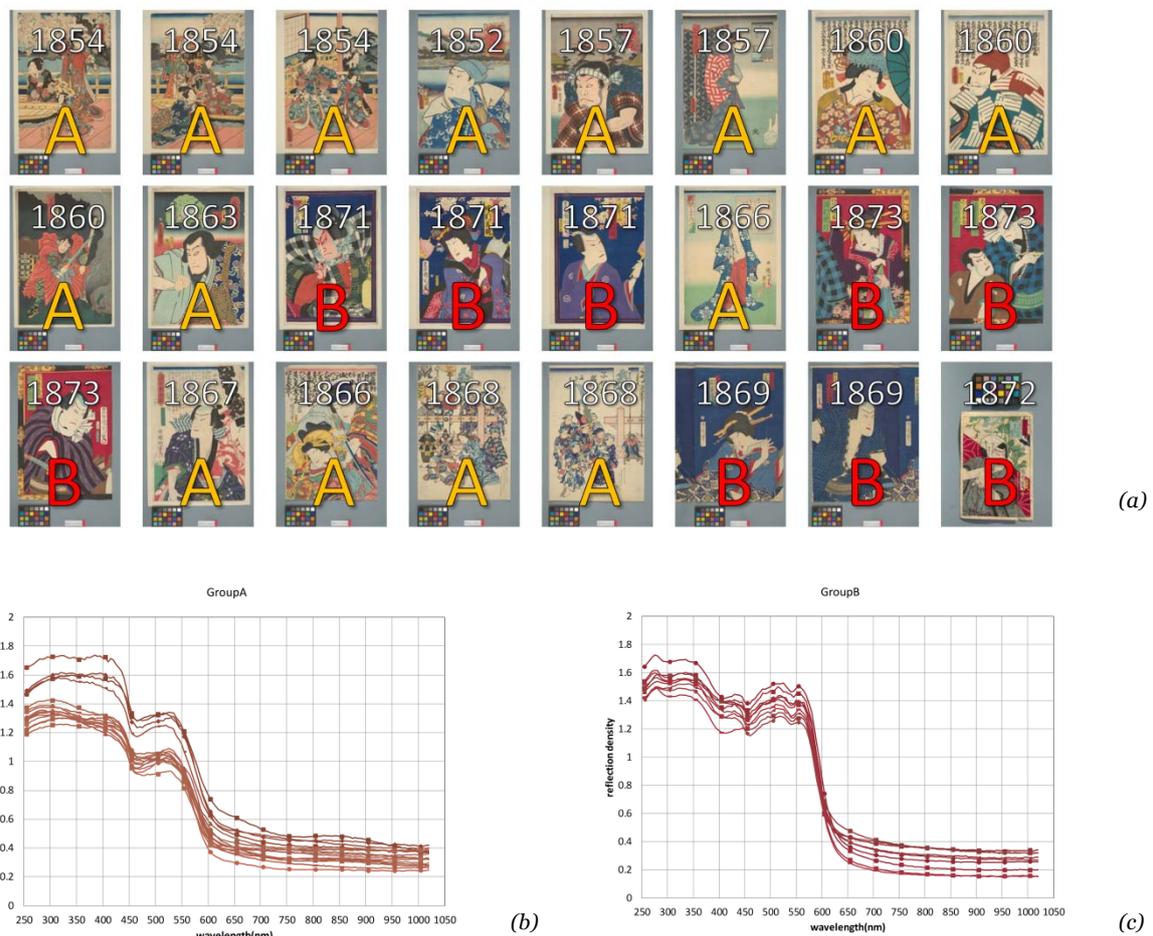


Figure 9: Spectral reflection density of old red and new red: (a) 24 samples for spectral measurement of red and its group; (b) Spectral reflection density of Group A (old red, 1852-1868) and (c) Spectral reflection density of Group B (new red, 1869-1871).

Existence of the new red colorants can be verified by spectral measurement [7]. Figure 9 shows that the comparison of spectral reflection density curves of two groups. The Group A consists of 13 *Nishiki-e* printings made from 1852 to 1868. The Group B consists of 9 printings made from 1869 to 1873. Spectral curves that are included in same group are similar each other, but spectral curves of the Group A and Group B images are not similar. The difference of shape of curve indicates the difference of colorants. This suggests that the new red colorant was used in the *Nishiki-e* printings of Group B.

It is said that the new red colorant is a kind of aniline dye [4-5]. However, it is quite doubtful. It is not similar to Mauve or other aniline dyes. It is said that the word 'aniline dye' was used as the same meaning of '(chemically) synthetic dye' at the 19th century in Japan [8].

Recently, a possibility of the use of a kind of anthraquinone-based dye is proposed [9-10]. Cochineal, lac, rose madder, synthetic alizarin, etc. are candidates of the new red colorant. Identification of the new red colorant is our future work. More precise analysis for identification of red and other colorants on *Nishiki-e* printings is ongoing at National Museum of Japanese History.

It is also interesting to reveal the relationship between the start of the use of the new red colorants and the start of import from overseas. However, the exact beginning year of import is unknown because there are hardly any records of import in the 19th of Japan. We will continue the research on it.

Acknowledgement

The authors are thankful to Dr Jun'ichi Ōkubo of National Museum of Japanese History who is an expert of *Nishiki-e* printings. We also thank Ms Yoshiko Shimadzu of National Museum of Japanese History who provided information about several kinds of colorants.

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