Spectral Image Acquisition of Icons

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Abstract

We present a novel technique for artwork image acquisition to obtain the spectral image simultaneously at the wavelength area from 400nm to 1700 nm. The imaging system consists of two line scanning based spectral cameras that are imaging the same line and the object is moved line by line. We performed the experiments with cultural historical icons. We show the results of the analysis and our preliminary findings.

Introduction

The accurate spectral imaging of cultural historical artifacts is becoming more and more important. Spectral imaging makes it possible to obtain the spectral color in visible wavelength area of the electromagnetic radiation or also in infrared (IR) or in ultraviolet (UV) area. Spectral imaging can be used to eliminate the effect of illumination, since absolute spectral reflectance can be obtained as independent on the illumination. The spectral image in visible wavelength area can be used to calculate color coordinates, for example RGB-representations of the artworks under wanted illuminations [1], it can be used to accurately analyse the used colors, such as pigments, in an object, and it can be also used to filter the image for optimal color characterizations on different display devices [2]. Spectral image in UV- and IR-area can be used to analyse the object in more detail.

Spectral imaging can be done, for example, by line scanning based imaging systems, Liguid Crystal Tunable Filter based (LCTF) systems, Acousto Optical Tunable Filter (AOTF) based systems, or by interference filter based spectral imaging systems [3]. All of these systems are non-touching, and external illumination is needed to illuminate the object. The measured spectral data is converted to absolute spectral radiance by measuring the reference white under the used illumination and in the same position and geometry where the actual imaging is done.

The spectral imaging systems above are for certain wavelength area, i.e. they are for visible light, from 400 to 700nm or from 400 to 1000nm or from 900 to 1700nm, for example. If we need the spectral image for vider spectral area, for example, from 400 to 1700nm, the separate camera systems are needed. If these camera systems are used separately, we need to change the camera to take separate spectral images from the object. There are interference filters for the wide spectral area, but sensor needs to be separate for visual and IR-area, for example.

In this study, we present a novel technique for artwork image acquisition to obtain the spectral image simultaneously at the wavelength area from 400nm to 1700 nm. We performed the experiments with cultural historical icons. We also show the results of the analysis and our preliminary findings.

Spectral Imaging System

Our spectral image acquisition system consists of two ImSpector [4] type spectral cameras that are measuring one line at the time, and the linear stages are moving the object line by line [5]. The experimental setup is shown in Figure 1. The upper spectral camera's measuring area is between 400-1000 nm and lower spectral camera's measuring area is between 950-1700 nm. The cameras are measuring exactly the same line during the measurements. The size of CCD in 400-1000 nm spectral camera is 1600 x 1200 pixels, from which 1600 pixels are used in spatial domain. In 950-1700nm spectral camera, the CCD is 320 x 256 pixels, from which 320 pixels are used in spatial comain. The CCD-arrays of the cameras are different, and therefore, the postprocessing of the spectral image from both cameras is needed. The measurement geometry 45/0 is used and the lightsource is Gretag Macbeth SpectralLight III, that illuminates the object by simulated D65 illumination. After the measurement, the black image and white reference reflectance are used to convert the measured data to spectral reflectance. The object is attached to linear stages that move the sample line by line. Vertical movement is related to measurement line and the horizontal movement is used to acquire high resolution spectral images by imaging the object slice by slice.

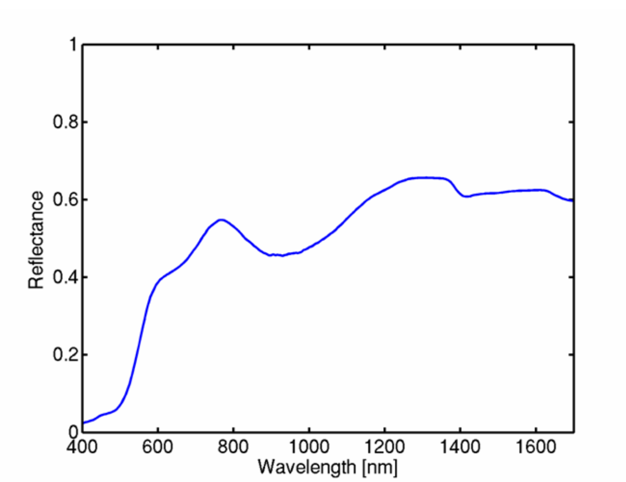
Experiments

We performed the experiments with religious icons that have origin in the 18th century. The spectral images were acquired by the spectral imaging system shown in Figure 1. Some example spectra from one spectral image are shown in Figure 2, in which the reflectance spectra as a function of the wavelength from 400 to 1700 nm are shown.

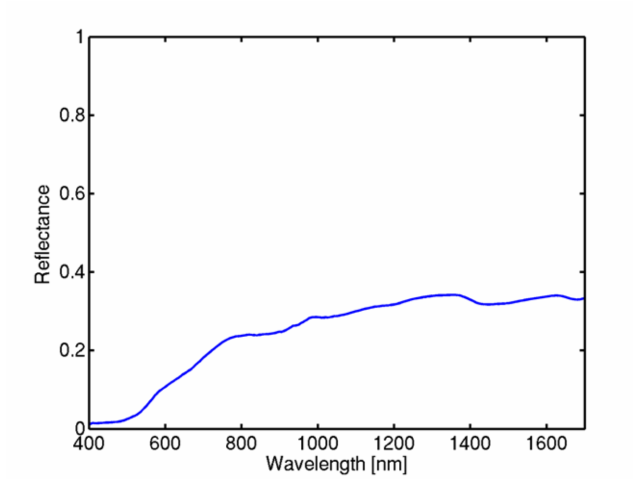
The measured data was converted to RGB-image with D65-illumination, to show the colors of the spectral image by computer display. The measured data was analysed by Principal Component Analysis (PCA) method.

Figure 3 a) shows the converted RGB-image of the spectrally measured icon. Figure 3 b) shows the result of the Principal Component Analysis (PCA) at the wavelength area from 950nm to 1700nm, in which the shown 3rd eigenimage shows interesting information that is visualized in Figure 3 c).

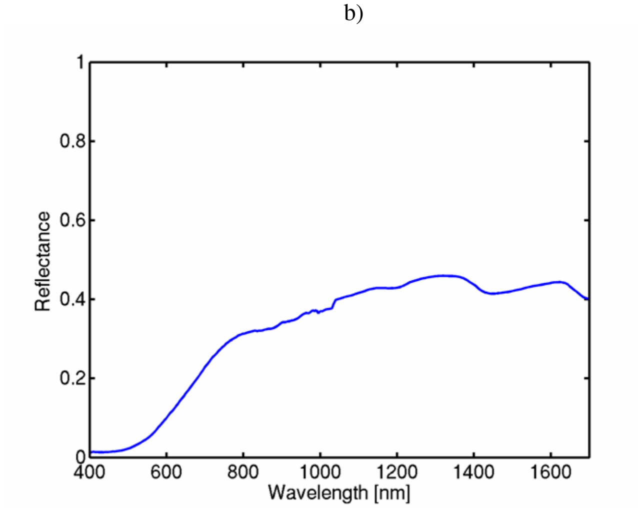
Figure 1. Two spectral cameras combined to measure the same line. Upper spectral camera is measuring at 400nm - 1000 nm and lower spectral camera at 950-1700 nm. Linear stages are moving the object.



a)



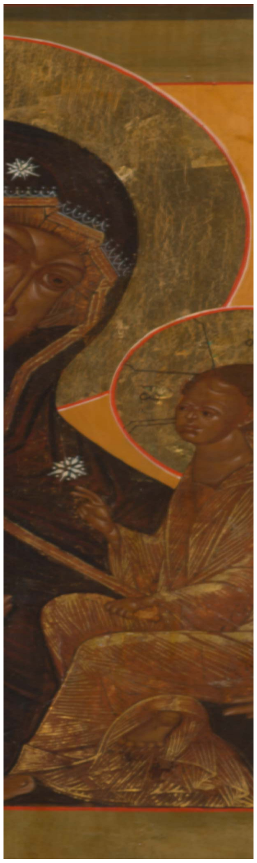
b)



c)

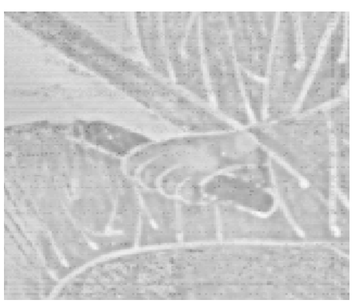
***Figure 2**. Example spectra of an icon at the wavelength range from 400nm to 1700nm.*

Another result from the measurements is shown in Figure 4, in which the Figure 4 a) shows the converted RGB-image of the spectrally measured icon, Figure 4 b) shows the result of the Principal Component Analysis (PCA) at the wavelength area from 950nm to 1700nm, in which the shown 1st eigenimage shows interesting information that is visualized in Figure 4 c). Also the cracks can be seen clearly from the infrared region eigenimage.



a)

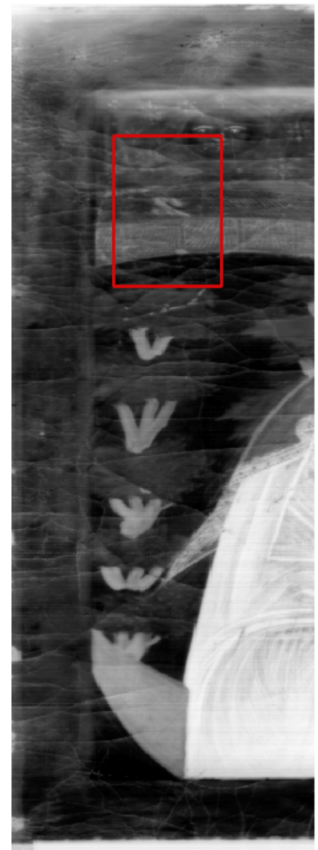
b)



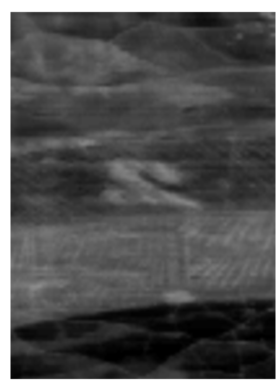
c)

Figure 3. *a) Spectral image of an icon converted to RGB-image, 1680 x 320 pixels, b) the 3rd eigenimage of the PCA calculated from the infrared range from 950nm to 1700nm, c) details that can be observed clearly from the infrared PCA information, but unseen from the RGB-image.*

a)



b)



c)

Figure 4. *a) Spectral image of an icon converted to RGB-image, 1248 x 266 pixels, b) the 1st eigenimage of the PCA calculated from the infrared range from 950nm to 1700nm, c) details that can be observed clearly from the infrared PCA information, but unseen from the RGB-image.*

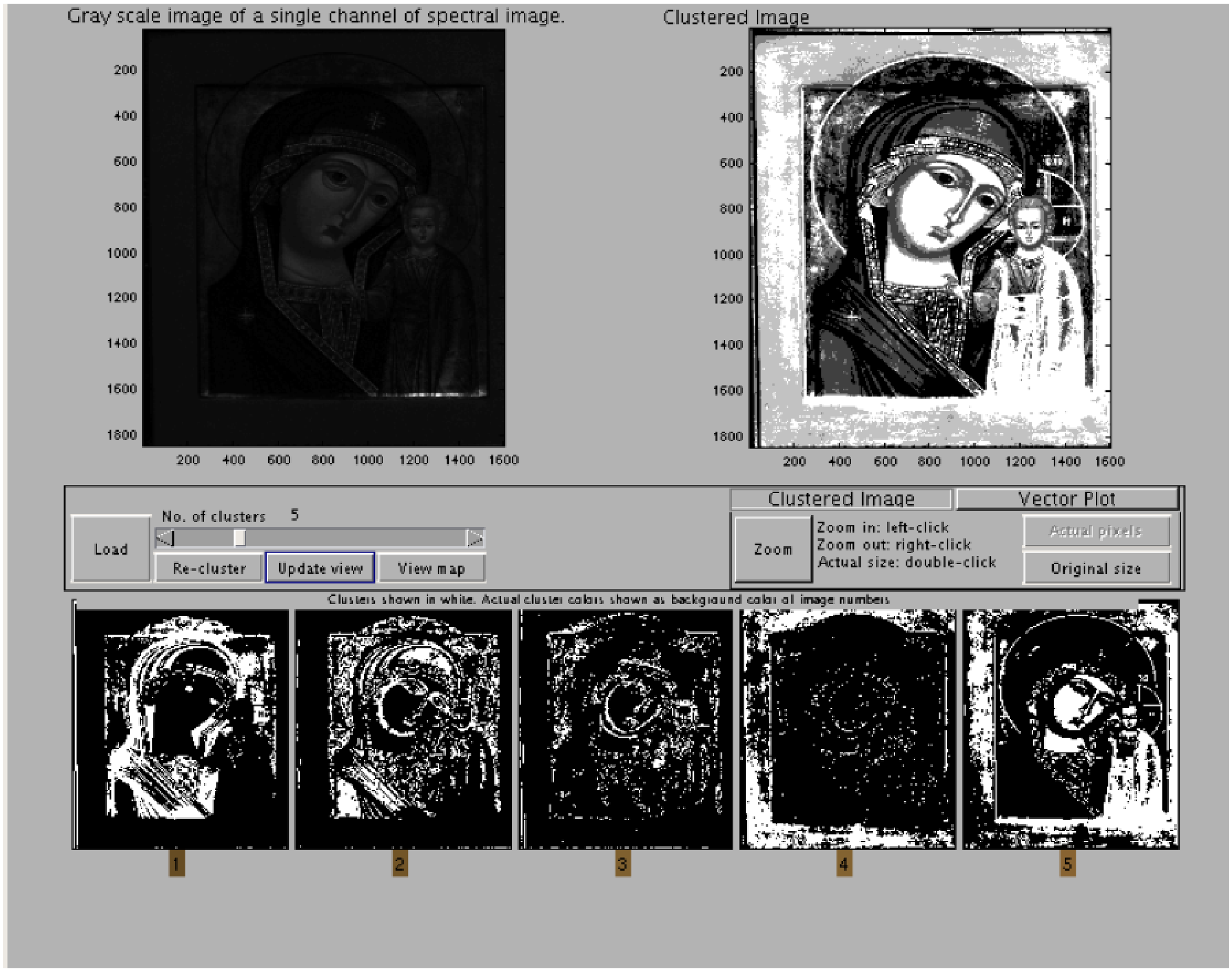


Figure 5. *Developed graphical user interface for spectral image clustering.*

We also developed an user interface for clustering the spectral image into regions. In clustering, the Self-Organizing Map (SOM), was used. Figure 5 shows the screenshot from the developed graphical user interface and the clustering results for one icon.

Conclusions

In conclusion, we have presented a novel spectral imaging system for artwork imaging that measures simultaneously spectral information from 400nm to 1700 nm. This system has advantages in image acquisition in archiving cultural historical artifacts such as artworks since it can store the wide range spectral information from the object simultaneously. This spectral information has many interesting applications, the accurate spectral information in the visible range can be used in spectral based color reproduction applications and the infrared range can be used in artwork analysis in which the visible spectral information is not enough.

References

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Author Biography

Markku Hauta-Kasari received his MSc in computer science from the University of Kuopio, Finland, in 1994 and his PhD in information processing from the Lappeenranta University of Technology, Finland, in 1999. Since 1999 he has been working in research and teaching positions at the Department of Computer Science and Statistics, University of Joensuu, Finland. He is a Docent in spectral imaging and spectral image analysis at the University of Joensuu. Since 2003, he has been the Director of InFotonics Center Joensuu research center at the University of Joensuu. His research interest include spectral color research, pattern recognition and computer vision. He is a member of the Optical Society of America, Optical Society of Japan, and Pattern Recognition Society of Finland, and the committee member of the International Committee for Imaging Science (ICIS). He is a past chairman of the Pattern Recognition Society of Finland.