

Comparative study on the resolution effect difference between hardcopy (printed image) and softcopy (displayed image)

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Abstract

The advance in imaging system of digital camera and display are remarkable recently. One of important factors of the imaging system is pixel number of camera area sensor and display. The pixel number of digital camera such as 36MPixels (D800, Nikon corp.) has been on the market, and in some cameras, low pass filter is removed for high resolution. Concerning display, 4 K display (3840x2160 pixels) is already on market, and 8K display (7680x4320 pixels) is planned to sell in near future.

It is recognized that the image quality increases according to the increase of the pixel number of input and output devices. Image quality has controlled by various factors such as color, sharpness, gradation, depth feeling, texture feeling and so on. From the view point of resolution, the studies on the effect are not enough. In this report, to understand the effect of resolution to hardcopy and softcopy, concerning perspective image, image quality in general and depth feeling, and concerning the still life image, image quality in general and texture feeling are subjectively investigated respectively.

Softcopy of 4 K display is used. Concerning the pixel number, image data of 3840 x 2160pixel (which is named 4K), 1920 x 1080pixel (2K), 960 x 480 pixel (1K) and 480 x 240 pixel (0.5K) are prepared and subjectively estimated. Hardcopy is also nearly same data are prepared. Image quality, depth feeling and texture feeling increases as pixel number increase on the whole.

Introduction

Pixel number of image is very important factor of image quality and the pixel number of display and digital camera is specially increasing. High-resolution display which has 4 times pixels of full high vision has been launched [1] and in near future 16 times pixel number of full high vision display is also scheduled, and they are called 4K and 8K display, respectively. The 4K display has 3840 x 2160pixel. Concerning digital camera, the pixel number of its image sensor increases and optical low pass filter on its sensor is removed for high resolution image capturing in some type camera [2].

The increase of pixel number of their devices is thought to have effect of improve image quality. According to the advertisements of 4K display, it can express high quality image as beautifulness, details, reality and more. But its influence of pixel number increase on image quality is not studied enough. As another important technology for image reproduction, there is hardcopy. The comparison of these technologies is interesting point in high resolution age.

In this study, concerning the display, image quality of 4 cases of image pixel number ranging from 3840x2160 pixels to 480x240

pixels are examined by subjective estimation. In addition to image quality, depth feeling and texture feeling which are factors of image quality are also estimated. The estimation is carried out at two typical distances of pixel recognizable distance and unrecognizable distance. In the pixel recognizable distance, as the increase of pixel number, it is found that image quality increases. Concerning the hardcopy [3], the image quality of 4 cases of image pixel number is examined by subjective estimation. The image quality increases as the pixel number increases.

Experimental

Two images are prepared by captured by digital camera (Canon EOS D600D). These images are shown in Figs. 1 and 2. Image quality and depth feeling is subjectively estimated on Fig. 1 and image quality and texture feeling is also subjectively estimated on Fig. 2.



Fig. 1 Image for subjective estimation of image quality and depth feeling.

<Softcopy>

The display used in this experiment is 4K display (Toshiba Regza 55X3), which display area is 1210mmx680mm and pixel number is 3840x2160 pixels. The size of one unit pixel is 0.315mm x 0.315mm and one unit is composed of RGB strips. Concerning the pixel number, maximum pixel number is 3840 x 2160pixel and is named as 4K, and 1920 x 1080pixel, 960 x 480 pixel and 480 x 240 pixel are named as 2K, 1K and 0.5K respectively in this report. Original image is resized from 4K to 2K, 1K and 0.5K by bi-cubic processing.

Subjective estimation is carried out at two distances. The distances are determined from the visibility of the Landolt ring gap



Fig. 2 Image for subjective estimation of image quality and texture feeling.

as the person of vision 1.0 can recognize the pixel size of RGB unit of the 4K display. The size of the pixel composed of RGB cell is 0.315mm x 0.315mm. So, the observation distances are obtained as 105cm as the limit of recognition for vision 1.0.

Subjective estimation is carried out by 25 persons of wide range of age 10-60 years. The image of 4K, 1K and 0.5K image is estimated subjectively compared with 2K which is full high vision image (1920x1080 pixels) respectively as 5 levels of better, rather better, same, rather worse, worse. It is considered that more stable results are obtained by comparing with our familiar full high vision image (2K).

<Hardcopy>

Every image is printed on the semi-glossy paper with the size 297mm x 420mm by Canon iPF6460 printer. Two types of subjective estimation are carried out with more than 10 students of the department of imaging science and technology, Chulalongkorn University. Subjective estimation method is 5 stages estimation.

Results and Discussions

<Softcopy>

Subjectively estimated values of image quality and depth feeling of Fig.1 are shown in Figs. 3 and 4, which show the results at the observation distance 1.05m and 2.10m, respectively. It is found that the values of image quality and depth feeling increases as the resolution of image increases in both observation distances. At the longer distance of 2.10m, the change against the resolution is less than shorter distance 1.05m, and especially, it is found that the difference between 2K and 4K is very small.

Concerning Fig. 2, subjectively estimated values of image quality and texture feeling are shown in Figs. 5 and 6, which show the results at the observation distance 1.05m and 2.10m, respectively. Similarly it is found that the values of image quality and texture feeling increases as the resolution of image increases in both observation distances. At the longer distance of 2.10m, it shows same tendency of image quality and depth feeling as: the change against the resolution is less than shorter distance, and

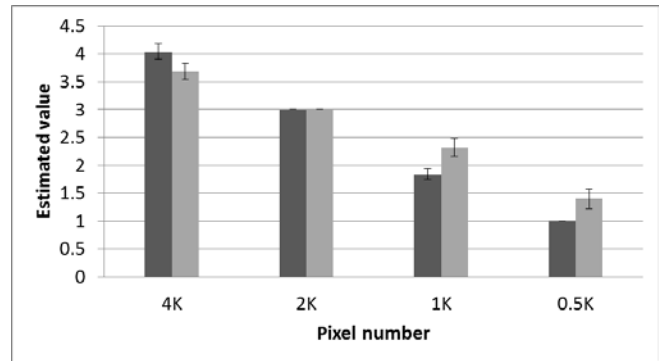


Fig. 3 Estimated values of image quality (dark grey bar) and depth feeling (light grey bar) of Fig. 1 at 1.05m. Error bar means standard deviation.

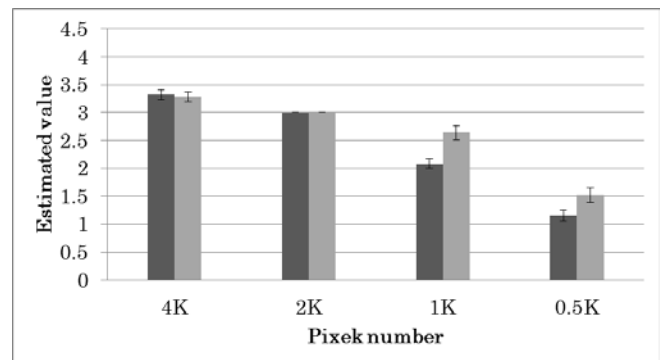


Fig. 4 Estimated values of image quality (dark grey bar) and depth feeling (light grey bar) of Fig. 1 at 2.1m.

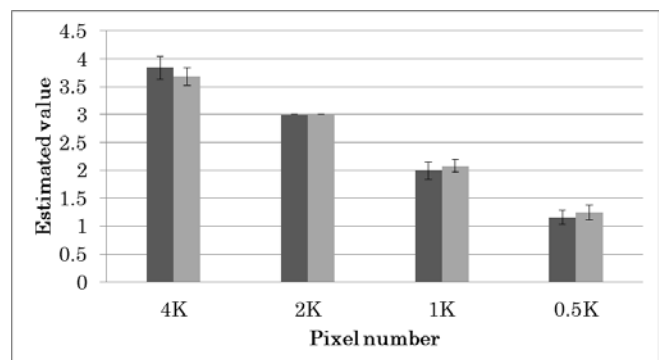


Fig. 5 Estimated values of Image quality (dark grey bar) and texture feeling (light grey bar) of Fig. 2 at 1.05m.

especially, it is also found that the difference between 2K and 4K is very small. Resolution dependence of subjectively estimated results is summarized as the results increase as the resolution increases. This is mainly considered from the reason that the detail of the image is expressed and definition degree which is one of important factor of image quality increases. It is said that the clues for depth feeling are line perspective, diminishing size and overlapping, and that that for texture feeling is color, and light reflection. The recognition of clue of depth feeling and texture feeling becomes easier as the resolution increases.

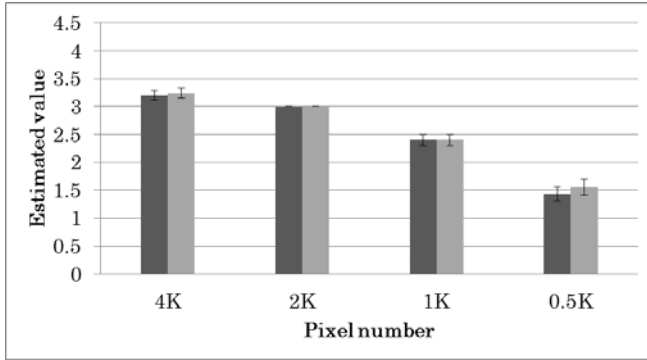


Fig. 6 Estimated values of Image quality (dark grey bar) and texture feeling (light grey bar) of Fig. 2 at 2.1m.

Concerning the reason that the estimated values of 4K and 2K are not so different at the observation distance 2.1m in Figs. 4 and 6, it is considered that the observers of vision 1.0 can distinguish the pixel 0.315mm x0.315mm of the display at 1.05m, but at the observation distance 2.1m it is difficult to distinguish the pixel, so the difference between 2K and 4K is little.

It is obtained that the correlation between image quality and texture feeling dependence on resolution is good in Fig. 2, on the other hand, it is found that the value of depth feeling decrease gradually compared with image quality in Fig. 1. Image quality is controlled generally by various factor, however the depth feeling is controlled by restricted factors such as line perspective, size and so on.

< Hardcopy>

The subjective estimation results of Figs. 1 and 2 are shown in Figs. 7 to 10. It is found that estimated every values of image quality, depth feeling and texture increase as the pixels numbers/resolution increases. Concerning the pixel number, it is found that their every estimated values increases from 0.5K (0.3 Mpixels) to 2K (4.5 Mpixels). Compared with 4K (4.5 Mpixels) and 4K (18 Mpixels), the average of the estimated values increases, however the difference between them decreases. It is considered that their images approaches to the resolution limit of human eye.

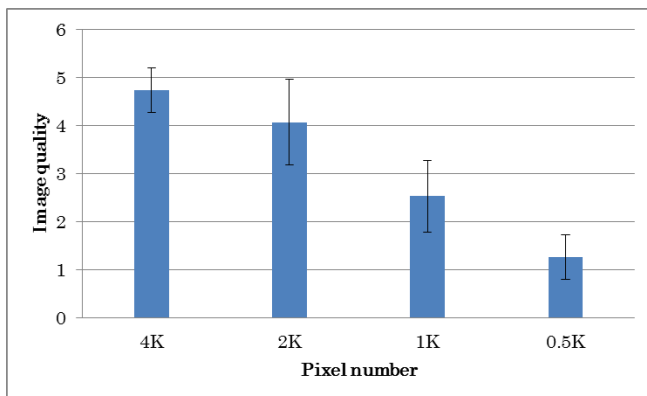


Fig. 7 Estimated value of image quality of hard copy of Fig. 1.

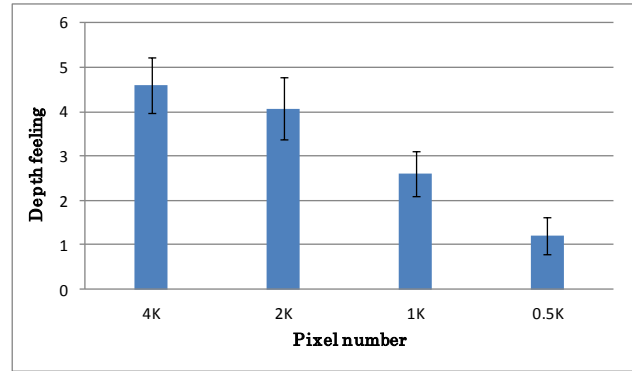


Fig. 8 Estimated value of depth feeling of Fig. 1 hard copy.

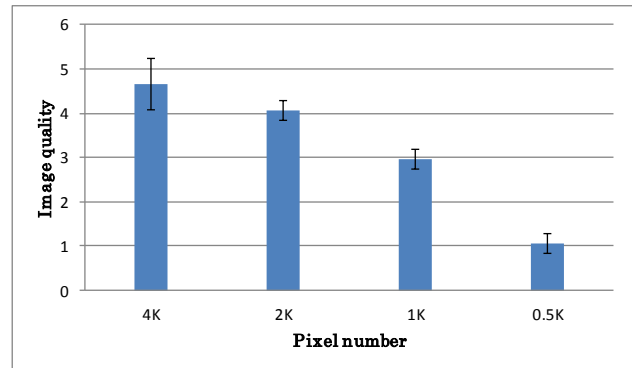


Fig. 9 Estimated value of image quality of Fig. 2 hard copy.

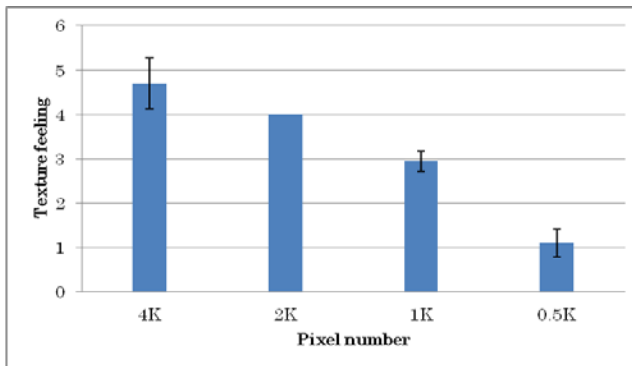


Fig. 10 Estimated value of texture feeling of Fig. 2 hard copy.

Concerning the depth feeling, it said that we feel depth even in the two dimensional images and that our visual system recognizes the depth from the clues of linear perspective, overlapping forms, diminishing size and so on. [4, 5] The depth feeling is one of important factors for image quality and our visual system perceives independently in the early stage of image vision. [6] Concerning the texture feeling, it is also important factor of image quality and we feel the texture from the surface reflection characteristic and refined structure of material in our brain. [7] So, it is proposed that the image quality, depth feeling and texture feeling are improved as the resolution of the image increases, because we can recognize the clues of depth feeling and texture feeling more easily.

Comparison between the dependences of softcopy and hardcopy

Concerning softcopy (4K display), image quality and depth feeling are estimated at two observation distances of 1.05 m and 2.1 m and the results are shown in Figs. 3 and 4. As for 4 K display, it is found that the estimated value of image quality and so on increase as the resolutions increase within the range that pixel is distinguished by vision. On the other hand, as for hardcopy, it is found that the estimated values of image quality and so on increase as the resolution increases as shown in Fig. 7 and 8 [3].

It is considered that printed materials are able to be watched at the arbitrary distance and position. On the other hand, we usually watch display at the fixed distance.

The 4 K display has enough resolution for ordinary watching distance, so it is proposed that one of possible application of 4K display is to enjoy or appreciate high quality photo image with arbitrary distance in addition to moving picture enjoyment.

Conclusions

At the two different observation distances, subjective estimation of image quality, depth feeling and texture feeling are carried out on two type images of line perspective image of Fig. 1 and texture image of Fig. 2. It is found that the estimated value of image quality and so on increase as the resolutions increase within the range that pixel is distinguished by vision.

Concerning the hardcopy, the subjectively estimated values of its image quality, depth feeling and texture feeling increase as its resolution increases. It is proposed that the factors such as linear perspective, overlapping forms and so on influenced to the depth feeling and texture feeling are recognized clearly as the resolution increases.

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Author Biography

Yasushi Hoshino (IS&T Fellow) is Professor at Tokyo Denki University. He gained Bs., Ms. and Dr. degree from the University of Tokyo, 1970, 1972, and 1984 respectively. After he gained Ms. Degree, he joined Electrical Communication Laboratories of NTT and joined the developing of first LED printer, high speed laser printer, color-laser printer by using ultra elliptical laser beam scanning, photo-induced toning technology and ion flow printing. He moved to Nippon Institute of Technology on 1994 and worked there till 2013, and then moved to Tokyo Denki University and also become visiting Professor of Chulalongkorn University Thailand since 2013. His recent interests are image quality estimation, image processing and electrostatic applications. (E-mail: hoshino@im.dendai.ac.jp)