

# On-Demand Pixel Arrangement for Flat Panel Displays

Mutsumi Kimura and Akihiko Tsunoya, Ryukoku University, Department of Electronics and Informatics, Otsu, Shiga, Japan

## Abstract

A new idea, on-demand pixel arrangement for flat panel displays, is presented. First, the human characteristic of sight sense is reviewed, and the visual features of display images are evaluated. It is found that the request for information displays depends on who sees and what is seen. Next, the pixel arrangements in information displays are explained. Finally, the system and examples of the on-demand pixel arrangement are shown.

## Introduction

Advantages of digital fabrication are: acquisition of high performance, creation of new application, improvement of fabrication efficiency such as high throughput, low cost, low emission, etc. Especially in this presentation, customization is also an important advantage of digital fabrication. Wide variety of products and free choice by customers can be attained.

Classifications of digital fabrication are : digital printing such as ink-jet, electrophotographic and gravure, direct writing such as laser, ion and electron beam, mechanical scanning, etc. In particular, ink-jet is actively applied to fabrication processes for flat panel displays. Using ink-jet, organic thin-film transistors have been developed,<sup>1</sup> alignment layer can be deposited,<sup>2</sup> liquid crystal may be filled into display panel, color filter<sup>3</sup> and organic light emitting diodes<sup>4</sup> are under mass production.

In our laboratory, we have been designing novel displays using organic light emitting diodes by ink-jet.<sup>5</sup> On the other hand, we have also been analyzing relationship between pixel arrangements in information displays and picture quality by considering human characteristic of sight sense. We have obtained interesting results<sup>6</sup> and proposed a novel pixel arrangement.<sup>7</sup>

In this presentation, first, we will review the human characteristic of sight sense. Next, we will evaluate the visual features of display images. After that, we will explain the pixel arrangements in information displays. Finally, we will present a new idea, on-demand pixel arrangement for flat panel displays.

## Human Characteristic of Sight Sense

### Color Resolution and Color Sensitivity

It is clarified that there are differences in color resolution of human sight between red, green and blue. The cone receptors in the human retina are shown in Fig. 1.<sup>8</sup> There are more than 10 times fewer blue cones relative to red and green cones. Furthermore, there are differences in this relationship among individuals. Therefore, the blue pixels can be reduced in pixel arrangements in information displays. Furthermore, how suitably the blue pixels are reduced depends on individuals.

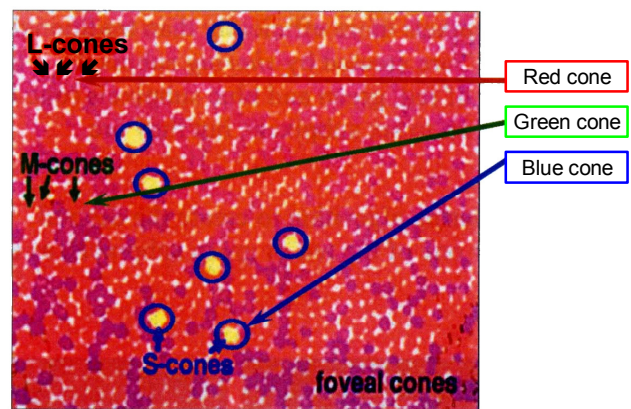


Figure 1. Cone receptors in the human retina.

Moreover, it is also known that there are differences in color sensitivity among races. For example, while the Occidentals prefer yellowish, the Orientals prefer bluish, which is proven by lighting in Western and Japanese hotels. Furthermore, there are also differences in this preference among individuals.

## Color Blind and Weak Sight

It is said that more than 5% of males are color blind, and color blind and weak sight are due to both internal and external causes. Therefore, they are not idiosyncratic, and their request should be considered universal design when information displays are designed.

The sensitivity and vision of the color blind and weak sight are shown in Fig. 2. Although there are many types of the color blind and weak sight, here are the deuteranope type of the color blind and cataract symptom of the weak sight. It is found that their sensitivity and vision are quite different from the normal ones.

## Visual Features of Display Images

Display images are classified into 2 types: text letters and natural images. Use frequency of the text letters and natural images depends on applications such as computer monitors, video displays and mobile viewers. The text letters and natural image are shown in Fig. 3. Their contour lines are enhanced and extracted, and the histograms about their directions are compared. It is reasonably found that the text letters mainly consist of horizontal, vertical and 45° tilted lines. On the other hand, the natural image includes all directions of contour lines. It is so even if the natural image contains an artificial object as shown in Fig. 3. This is because the artificial object is not located at just horizontal and vertical directions.



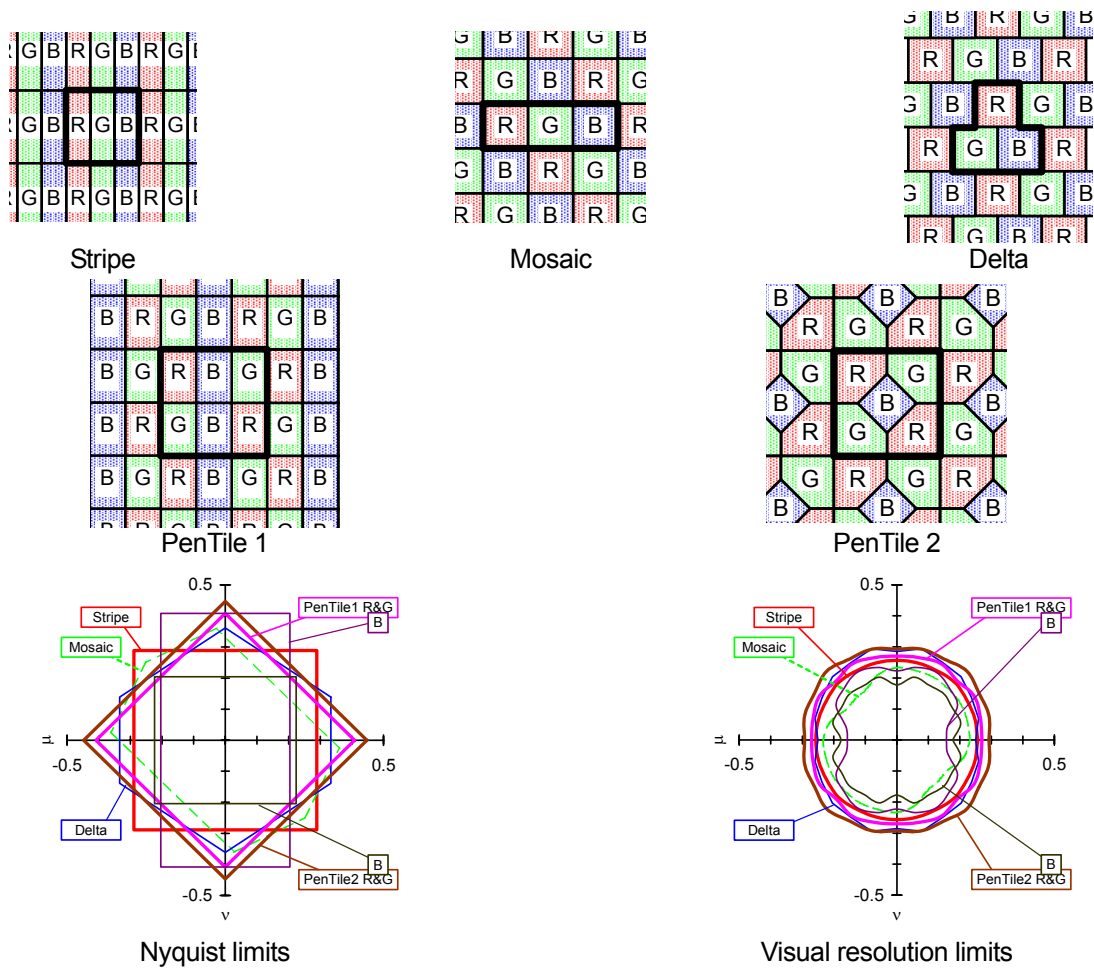


Figure 4. Overall views, Nyquist limits and visual resolution limits for the pixel arrangements.

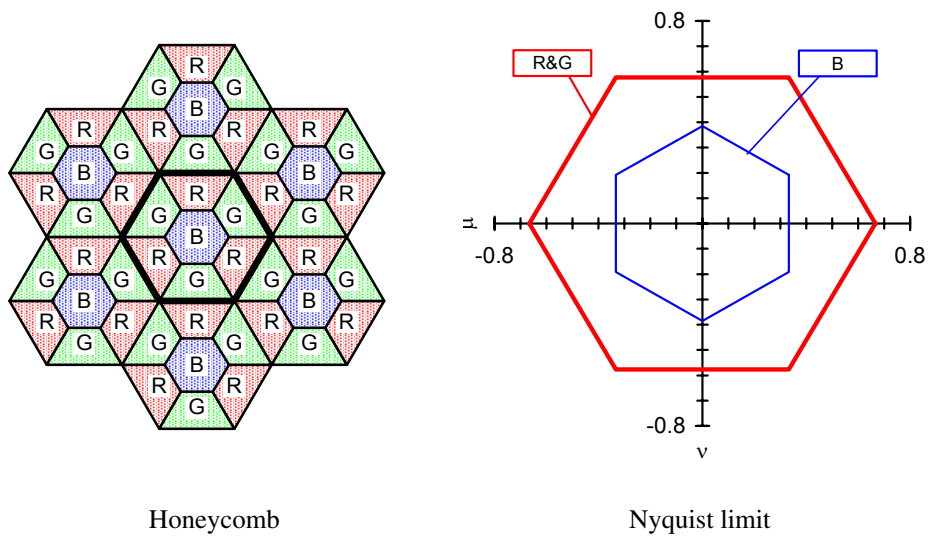


Figure 5. Overall view and Nyquist limit for the honeycomb arrangement



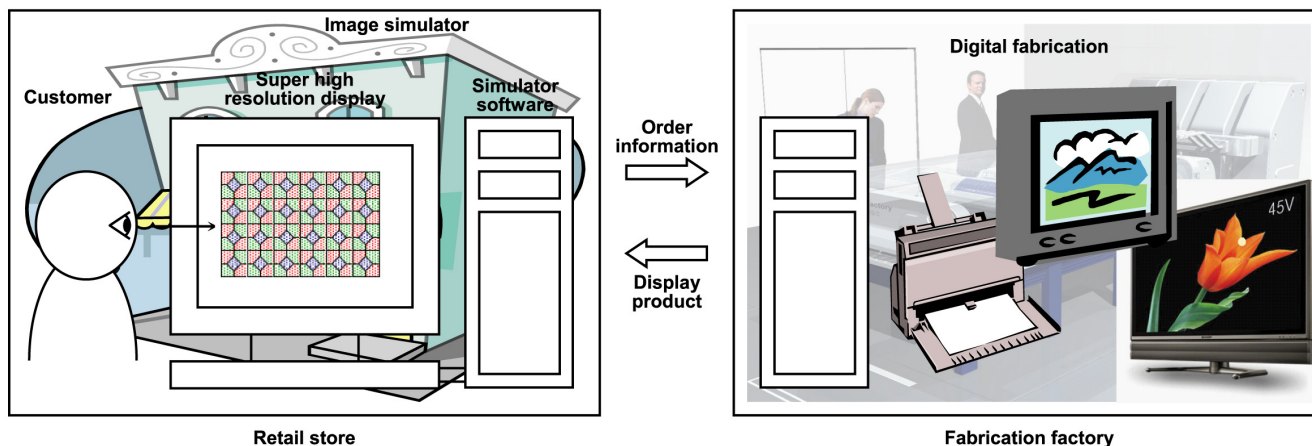


Figure 6. Order system of the on-demand pixel arrangement.

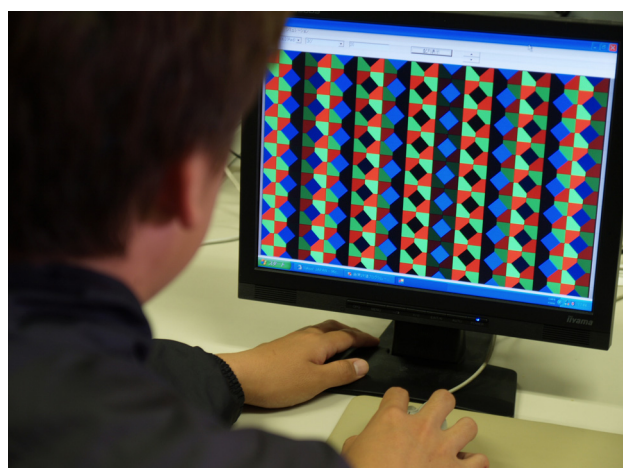


Figure 7. Actual example of the image simulator.

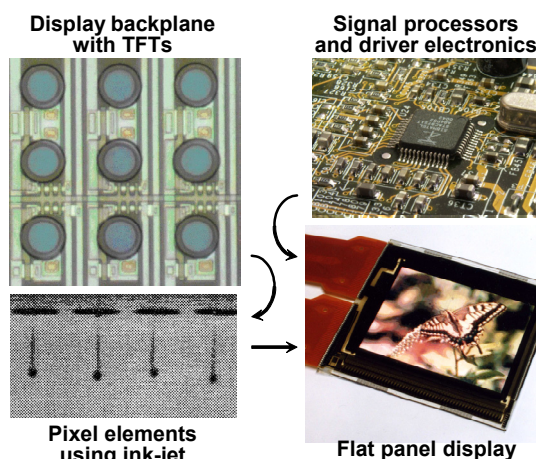


Figure 8. Concrete example of the digital fabrication for the on-demand pixel arrangement.

## On-Demand Pixel Arrangement for Flat Panel Displays

As written above, the request for information displays depends on who sees and what is seen. Moreover, each pixel arrangement has each feature. Therefore, we are led to a new idea, on-demand pixel arrangement for flat panel displays.

The order system of the on-demand pixel arrangement is shown in Fig. 6. First, a customer can chose a pixel arrangement including the area ratio between the color sub-pixels, etc. using an image simulator, which consists of a simulator software and super high resolution display and can simulate any kinds of display images. The actual example of the image simulator in our laboratory is shown in Fig. 7. After the pixel arrangement has been chosen, order information is transferred to the fabrication factory. A flat panel display with the on-demand pixel arrangement is produced using digital fabrication and finally delivered to the customers.

The concrete example of the digital fabrication for the on-demand pixel arrangement is shown in Fig. 8. Here, an OLED display is supposed. First, a display backplane with active matrix devices such as thin-film transistors is prepared. Next, pixel elements, for example, pixel electrodes, light emission materials, etc. for organic light emitting diode display, are fabricated in accordance with the on-demand pixel arrangement using ink-jet. Finally, signal processors and driver electronics are also customized.

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## Author Biographies

*Mutsumi Kimura received his BE (1989) and ME (1991) in Physical Engineering from Kyoto University and PhD in Electrical and Electric Engineering from Tokyo University of Agriculture and Technology (2001). He joined Matsushita Electric Industrial (1991), Seiko Epson (1995) and Ryukoku University (2003). His work has focused on the research and development of TFTs and FPDs. He is on the board of AM-LCD, IDW and TFMD and a member of SID, JSAP and EIC.*

*Akihiko Tsunoya received his BE in Electronics and Informatics from Ryukoku University (2005) and entered Graduate School of Ryukoku University (2005). His work has focused on picture evaluation of matrix displays.*