Color Image Information Processing

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Color science research, color image information processing research and development, as well as color printer product technology development, performed in relation to color image information processing, which is one of the core technologies of the color printing solutions at Oki Data, are described in three chapters of this paper. I should mention that this paper does not provide a detailed description of technical expositions, however, it is intended to offer an introduction outlining the technologies. The academic field which examines the relationship between light as well as human perception and places a particular emphasis on color perception is known as color science. Color science research is in the background supporting color image processing research and development, as well as color printer product technology development.

The color image information processing field in color engineering is for image input, output, storage, transfer, as well as incidental digital information processing and media information processing, based on key fields of color science, such as optics, visual perception, lighting and psychology. The color image processing field is explained as the main content of this paper. Summaries on a number of themes are provided with regards to color image information processing research and development. Also provided herein are color printer product technology developments, descriptions on the summaries of color processing firmware, color processing LSIs, driver embedded color processing systems and color processing applications, for which designs have already been developed for various modes and incorporated into our products.

The contents of the descriptions are provided from a wide perspective, since our mission of contributing to color printer products and the systematic provision of these products in printing solutions cover a wide range that not only includes color image information processing but also more broadly encompasses multimedia processing and information processing in general, including intelligent processing.

Color science research

Among the themes covered by color science research, this paper offers descriptions on the themes related to visual perception and brain science. These themes pick up on the modeling of a visual perceptive phenomena and ultimate foundation for a color reproduction technology to produce favorable results. The twenty-first century is referred to as an era of brain science, which is expected to impact a great deal all fields of information processing.

(1) Visual phenomena and color space

Color space for describing color is at the stage of color appearance model in which various environment conditions and visual phenomena are considered. In terms of historical development, it is in the third stage. The first stage was the XYZ color space, whereas the second stage was the L*a*b* uniform color space.

However, items exist that have not been clarified, even with regards to chromatic adaptation, which is most important and representative of visual phenomena. Chromatic adaptation is something we experience on a daily basis. This phenomenon occurs as the eye adapts, for example when the eye gazing at an object illuminated under a white light source switches to look at an identical object under a red light source. The eye soon adapts to the change and the object begins to appear as if it were under a white light source.

The author succeeded in mathematically proving that the model previously considered to be an error model for chromatic adaptation was actually an optimum model, as long as a certain set of conditions were met[1)]. This was something made evident for the very first time by the author, following a hundred year of historical developments for chromatic adaptation. There have been limitations to the approach thus far for building models based on psychophysical evaluations and it is considered critical for future progress to clarify visual phenomena through the acquisition of structural information based on a mathematical model and brain science, as well as by taking on the concept of developing a practical color visual model based on them. We are, therefore, proceeding with our research with such an approach.

(2) Pleasant color reproduction and minimization of bioenergy

At the foundation of our point of view is this concept that a color image, which is pleasant to look at, requires a smaller effort on the part of the human observing such an image, thereby minimizing the bioenergy consumption. This means that when the consumption of bioenergy is large for some sort of adaptation, the observed image is considered to be an unpleasant image. Edge enhancement can be mentioned as a simple and classical example. Edge enhancement is a mean of processing an image in advance to make borders easier to distinguish so that the burden for humans to use their visual perception to distinguish borders can be decreased. There are a variety of visual perceptive efforts and our objective is to minimize all sorts of energy for effort on the part of a living organism.

Super Color, marketed as photo enhancement, which has been developed and commercialized through the incorporation of this concept, is explained in a later chapter.

(3) Functional distributions between retina and brain

Experiments intended to estimate the functional distributions between the retina and brain are comparisons with the anticipated and actual results, using color samples prepared with conditions, for which the information we have thus far practically guarantees the major function of the retina. Results in Norway, for example, show that the retina was found to be taking charge of the function as anticipated, whereas in Spain, the obtained estimated results indicated that strong control by the brain relating to preference was at work.

Such studies are intended not only as a means for establishing color design methodologies derived from feedback based on psychophysical experiments with a limited number of experiments, rather they aim to realize a color design methodology based much more on the principles of human information processing.

A color design methodology based on psychophysical experiments and tests of hypothesis has already been established[2] but we aim to establish a color design methodology based on experiments and principles that invoke this principle based methodology.

Color information processing research and development

As mentioned previously, color engineering is implemented for image input, output, storage, transfer, as well as incidental digital information processing and media information processing, based on the key fields of color science, such as optics, visual perception, lighting and psychology. Descriptions are provided in this and following chapters. This is a category that dominates a major portion of our efforts, whereas research and development for elemental technologies are being conducted from the perspective of creating a system for realizing the required functions. Several of the themes are introduced.

(1) Emotional colors

Emotional color reproductions are separate from the category we have referred to thus far as accurate reproduction or pleasant color reproduction. This type makes a creative color reproduction belonging to the art category, which appeals to the emotions of humans. An example of a creative process output is shown in **Fig. 1**. **Fig. 1 (a)** shows the original color image, whereas **Figs. 1 (b)** and **1 (c)** are created emotional color images. An intelligent processing mechanism relating to emotions is built into the developed processing system, which creates emotional colors based on the results obtained from learning experiments in emotions.

It is possible to apply this technology to the presentation solution using color printers.

(2) Multi-spectral color

The use of images incorporating spectral information for each pixel of an image, in other words multi-spectral image attracts attention. This multi-spectral image is able to reproduce color information that cannot adequately be expressed by conventional RGB color images comprised of red, green and blue elements and is effective when accurate color reproduction is desired, for example in e-commerce. Furthermore, spectral information is suitable for building a color system independent of the environment or visual perception characteristics of the observer. The fact that spectral information contains a large amount of information becomes an obstruction when building a practical color system.

An effective method has been developed for estimating the spectral information from red, green and blue primary components and the method will be adopted for practical application in the future.

(a) Original image

(b) Emotional image 1

(c) Emotional image 2

Fig. 1 Color image example

Color printer product technology development

Elemental technologies for development are being applied to products from a wide perspective relating to information processing technologies in terms of four aspects, color processing firmware, color processing LSIs, printer drivers and color applications.

(1) Color processing firmware

The printer color management firmware is a proprietary development. Functions include the automatic density compensation process of printer engines, gamut mapping performed by mapping between devices with different color regions, as well as ICC work flow core functions that describe the flow of color data between different devices, realized through the integration of an ICC workflow LSI core described in the next segment, as well as other processing LSI cores (**Fig. 2**).

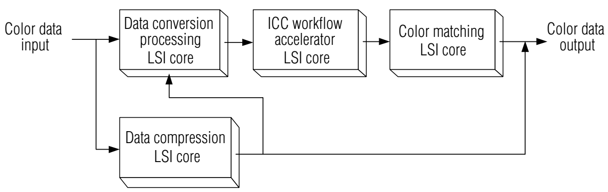

Fig. 2 Overall diagram of color processing LSI

(2) Color processing LSI: ICC workflow LSI

We developed and loaded into products an ICC workflow accelerator LSI, which accelerates an ICC workflow to high performances. The ICC workflow is employed in color management and stipulates the standard format for the exchange of color information and data flows between different color devices.

The ICC workflow example shown in **Fig. 3** is briefly explained. Each device has profiles that describe the color matching processing method for converting image data from the color space of a particular device to a common color space (PCS: Profile Connection Space) and from a common color space to a color space of another particular device. For example, when converting RGB values of a display monitor to the CMYK values of a printer, using the monitor profile, the RGB values displayed on the monitor color space are converted into coordinate values of a common color space which are converted into CMYK values for the printer color space using the printer profile.

In order to satisfy performance requirements for the color processing of high-speed color printers from Oki data, it is particularly important to optimize architectural designs from both the firmware and hardware processing aspects. The segment converted into an LSI was functionally and computationally designed from the perspectives of cost, speed, computational accuracy and versatility.

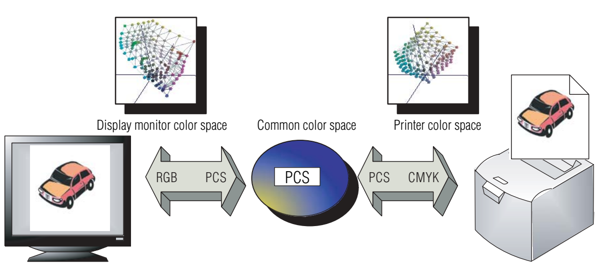

Fig. 3 ICC workflow

(3) Driver embedded processing system: Super Color

A processing system referred to as Super Color, which incorporates the principle of minimizing bioenergy described previously, is loaded into the product (Photo mode).

Color image examples are shown in **Fig. 4**. The original image is shown in **Fig. 4 (a)**, whereas **Fig. 4 (b)** shows the image in Super Color.

Fig. 4 (b) shows an image with a lesser burden on the human eye for individual depicted objects and an image comfortably perceived.

(a) Original image

(b) Super Color image

Fig. 4 Color image examples

(4) Application: Multimedia document processing

A document application was developed as an application theme for multimedia processing, which is one of the themes for our critical research and development. This application has been commercialized as "Inhouse Signage Application" (Ofisu-no Kanban-yasan) (**Fig. 5**).

Fig. 5 User interface of "Inhouse Signage Application" (Ofisu-no Kanban-yasan)

The Inhouse Signage Application (Ofisu-no Kanban-yasan) is briefly explained.

This application makes it possible to produce designs by freely arranging graphic, text and image objects on a document's space. Furthermore, the application incorporates a label printing function and long sheet printing function, accommodating the production of printed matter for a wide range of uses, including price cards and business cards, as well as flags and banners, satisfying the basic requirements for a layout application.

Other than the above, it is also possible to produce printed matter in super large sizes by pasting together long sheets (**Fig. 6**), an appealing function as well as a major characteristic of the Oki Data color printers, which are very good at handling the printing of long sheets.

Merge printing linked with a database, an essential aspect for improving the efficiency in sales promotion activities, can also be supported.

Fig. 6 Super large size printed matter is prepared by pasting together long sheets

As document processing is one of the most important fields in printing solutions, we intend to sequentially commercialize multimedia document processing applications with advanced information processing functions for specific purposes using this application as the platform.

Conclusion

An outline of our research and development relating to color image information processing, one of the core technologies of our color printing solutions, has been described in this paper.

Product developments are carried out by an organic organization, doing away with the boundaries that separated the fundamental, application and practical aspects. In the future we intend to continue commercializing the technologies we develop in a timely manner.

References

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