COLOR PICTURE PROCESSING BY COMPUTER

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Abstract

This paper introduces a computer cystem for color picyure processing and its principal features. First the hardware aspectB are explained, including the basic characteristics of I/O devices. The interactive feature of our system is singled out, and it is developed to a system concept called "Color Picture Analysis and Display System" The color analysis method and its software are presented and discussed, since the correct recognition of color information is important in color picture processing. This paper slso contains some methods and applications of effective use of color information in picture processing. They include (1) domain identification by color information (2) color effect method (3) color separation (4) conversational retouching of color (5) pseudo-color displaying and their applications.

1. Introduction

Picture processing by computer has been of considerable interest in computer science and robotics research. Most efforts in picture processing have been concerned with monochromatic pictures* But, as everyone realizes, actual scenes and pictures all contain color, and color information plays important roles in human perception and recognition of scenes and pictures. This suggests the usefulness of color information in picture processing by computer.

In Ito(1973) we have discussed some basic problems and a conceptual framework for color picture processing by computer. We stated there the need of an experimental computer system for color picture processing and emphasized the importance of "computer-oriented chromatics".

This paper contains an overall description of our computer system for color picture processing, the principal idea of color analysis, the use of color information to picture processing and some aspects of their applications,

2. A Computer System for Color Plxrfeorre Processing

A computer system for color picture processing should be equipped to facilitate computer acquisition of color pictures, computer analysis of color information, feature extraction by effective use of color information, structural analysis of color pictures and interactive processing complex color scenes and pictures.

In developing our system we initially encountered the lack of efficient real-time input devices of color pictures. Thus we started from constructing efficient real-time input devices which include a high-speed multi-head color film reader and a digital color TV scanner. In this section we Introduce our computer system for color picture processing with several color picture input/output devices.

2,1 A Computer System for Color Picture Processing

Our computer system for color picture processing consists of a computer complex of MELC0M7500 and PDP-11 and several I/O devices. A set of interactive color software are available on PDP-11, and MELC0M7500 enables us to use a picture compiler, picture preprocessing routines, list processing language LISP/M, SL deduction theorem prover.

Figure 1 shows the main body of our computer system for color picture processing , which works as a computer complex under a control of network handler*

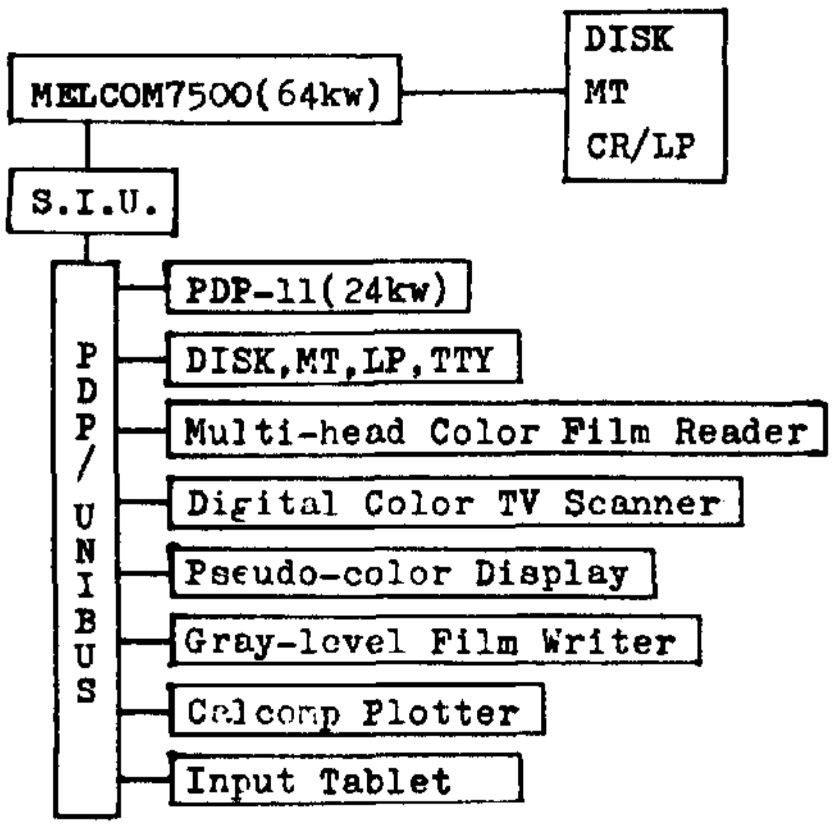


Figure 1 Computer System for Color Picture Processing

2.2 Picture I/O Devices and their features

As is shown in Figure 1 our system has several picture input/output devices in order to achieve an interactive picture processing capability. Among them the following devices are principal tools of our picture processing system:

(1) Multi-head color film reader#
(2) Digital color TV scanner#
(3) Pseudo-color picture display#
(4) Gray-scale film writer

where the devices with #-mark are made by us.

2.2.1 Multi-head color film reader

Various kinds of color film readers are possible in principle, but we have develop- a high speed multi-head color film reader devised by this author. Figure 2 shows its basic idea and mechanism.

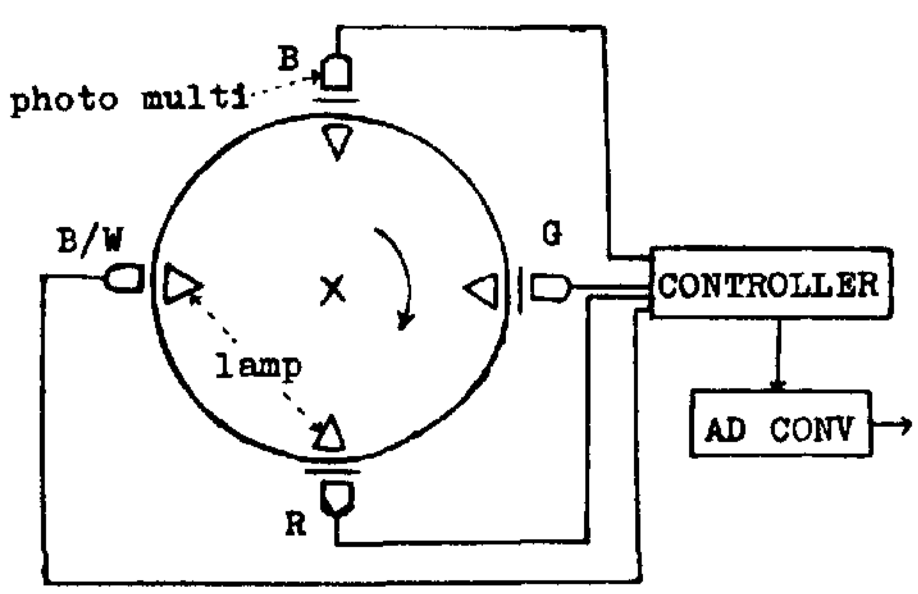


Figure 2 Multi-head color film reader(I)

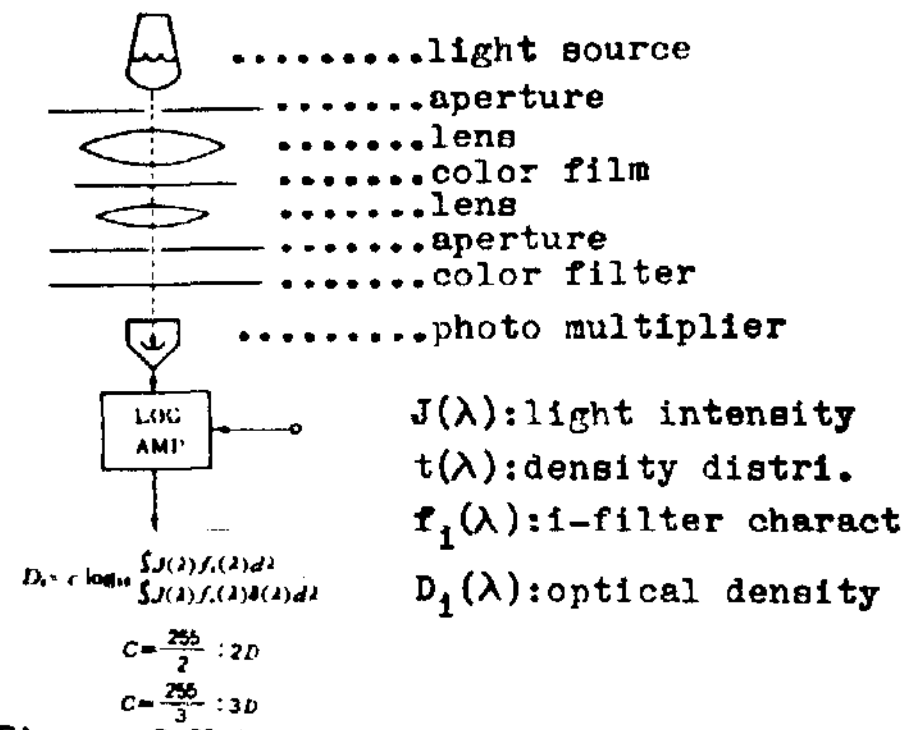


Figure 2 Multi-head color film reader(II)

no. of heads	4 (R,G,B,B/W)
max. film size	125mm x 175mm
aperture size	50μm x 50μm
scaling	0.0~3.0D
scaling mode	2D or 3D
bit density	8 bits/head
scanning mode	50,100,200 (μm)
data rate	200KB/sec
standard filters	Wratten 47B,58, 25 (B) (G) (R)

Table 1 The characteristics of film reader

Figure 3 shows an experimental Multi-head color film reader and pseudo-color display unit installed in the Central Research Laboratory,Mitsubishi Electric Corporation

Figure 3 Multi-head color film reader pseudo-color display

2.22 Digital color TV scanner

The multi-head color film reader can read filmed picture data, so that it is often inappropriate as an on-line picture input device. For such a situation v/e have developed a digital color TV scanner with the characteristics of Figure 4 and Table 2.

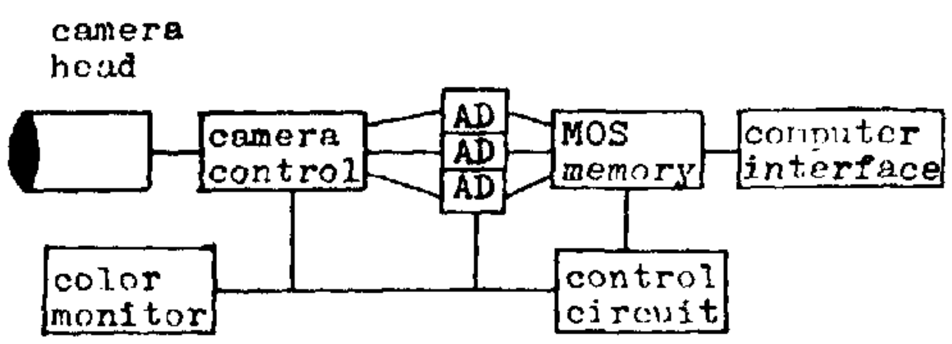


Figure 4 An Experimental Digital Color TV Scanner

scanning mode	scanning points:256x256/frame digitization level:4bits/pixel monochromatic picture/field
data rate	camera MOS memory:16.7ms/frame MOS mem. core mem.:500KB/sec core mem. MOS mem.:400KB/sec
camera head	3 tube type
MOS memory	capacity:96KB access time:500ns

Table 2 The characteristics of Digital Color TV Scanner

2.2.3 Pseudo-color Picture Display and Gray-scale Film Writer

A pseudo-color picture display and an input tablet are used in order to achieve an efficient interactive processing. The display characteristics is listed in Table 3.

no. of pixels	256 x 240
no. of colors	15colors/pixel
vector generation	8 direction
character mode	alphanumeric,Katakana
memory	

Table 3 The characteristics of Pseudo-Color Display

spot size	25,50,100,200 (μm)
density	0 - 2.5 D
resolution	64 gray levels
data rate	60 kHz
film size	8" x 10"

Table 4 The characteristics of film writer

Table 4 shows the charactcristics of the gray-scale film writer,

3. An Interactive Color Picture Analysis and Display System

Nov; we proceed to explain the applications of our computer system to interactive picture processing,color analysis and the use of color information to picture processing. In this section we introduce an interactive feature of our system,called "Color Picture Analysis and Display System"- The following devices are integrated to form this system:

(1) a mini-computer(PDP-11 or MEbCOM-70)
(2) Multi-head color film reader/Digital color TV scanner
(3) Pseudo-color picture display with an input tablet
(4) DISK and MT
(5) Standard I/O devices of the mini-computer.

This system is designed to achieve an efficient interactive processing of a considerably large amount of color pfcture data The functions of this system consists of (1) I/O control programs (2)pseudo-color display programs (3) color analysis programs (4) data transformation programs (5) conversational programs* The following are some of the svstem programs:

color analysis

TRIT	triangle representation of color
HSB	computeHue,Saturation,Brightness
ADM	Adams chromance specification

color picture feature extraction

COMPD	compute areas with specified colors
CLASS	classify by specified density ranges
HIST	compute density hist^ram
CLRSP	color separation by hue

color picture monitoring

CMONIT	pseudcy-color or monochromatic monitoring of raw data
PSEUD	pseodo-color display program
FREAD	read routine by Film Reader
TVREAD	input routine by TV scanner
PWHITE	write out routine by Film Writer

4. Methods of Color Analysis and Specification

Our computer system for color picture processing enables us to process color pictures in an interactive manner. Some of elementary functions are already -mentioned in the preceding section. In this section we discuss more details of color analysis and specification, and the next section explains some aspects of effective use of color information in picture processing.
Before going onto computer processing ot color pictures, we need to analyse and recognise color information obtained from color picture devices like the Multi-head color film reader and Digital color TV scanner,because the correct recognition of color is important in the effective use of color information to picture processing.
A number of color analysis and specification methods are known in the classical theory of color science. These methods are also useful in our situation, but we need some new considerations to adopt them, since they are hunan-orlented.We aim at computer-oriented chromatics based on our computer system and picture devices, but they are not—perhaps, should not be—different conceptually from the classical one.

4.1 Basic Concepts of Color Analysis and Specification by -Computer

The computer analysis and specification of color information may vary in each application. But the following methods will be applicable as the standard procedures in various applications:

color analysis

1) color comparison procedure
   This is the color identification method of comparing with the standard color chips. This method corresponds to the color appearance system.
2) chromaticity analysis procedure
   This Is the method of analysing color by chromaticity diagrams.

color specification

1) color quantities——hue,lightness,chroma
2) XYZ specification
3) Triangular representation
4) color band
5) Color difference chart

All of these methods are some modified versions or extensions of the classical methods in color science. Some features of these methods will be explained below. However the readers should notice that we are not concerned with strict and precise analysis of color,but we are interested in approximate and convenient methods which are useful in correct color recognition necessary for picture analysis and recognition. According to our experiences a single method is not sufficient for various applications, so that we listed a number of typical methods developed and used by us.
The filter characteristics and light source of Color Film Reader and Color TV Scanner are different from the standard ones in color science.but if we know the optical characteristics of the given filters and the light source, we can derive the standard stimulus value. This is also possible in an approximate sense, since those characteristics is known approximately in our situation. Taking account of the theoretical backgrounds from color science, our color analysis software is developed both on PDP-11 and MELCOM-7500.

4.2 Color Specification Methods

We explain our color specification methods implemented in color analysis software. They ere classified into the numerical specification and the diagram specification.

(1) numerical specification

In order to express the color Information as numerical quantities,we use the following quantities:

a) color quanties
   The hue,lightness and saturation are three standard color quantities.These quantites will be computed by the regular triangle for color specification. This is shown In Figure 5 below.
b) ZIZ specification
   In a rough approximation the optical density from picture devices may be used as a first approximation to XYZ values*

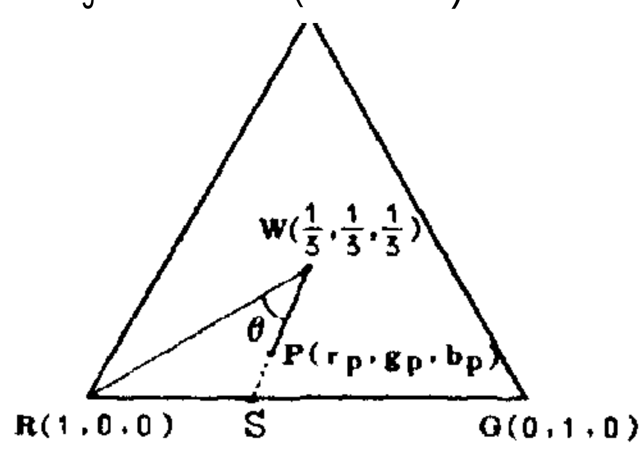
The precise values corresponding to CIS standard will be also computed, since v/e know the CIE-XYZ characteristics of the Wratten filters.

(ii)dia';ram specification

The following diagram specifications are proposed and implemented in our color analysis software. They include some non-standard ones.

a)standard triangle specification

There are the retailar triangle method and the right-angled triangle method as in Figure 5. R(0.0.1)



$$H = \theta$$

$$= \arccos \frac{(2r_p - g_p - b_p)}{\sqrt{6}\left[(r_p-\frac{1}{3})^2+(g_p-\frac{1}{3})^2+(b_p-\frac{1}{3})^2\right]^{\frac{1}{2}}}$$

$$C = \frac{\overline{WP}}{\overline{WS}}$$

$$= 1 - 3\min(r_p, g_p, b_p)$$

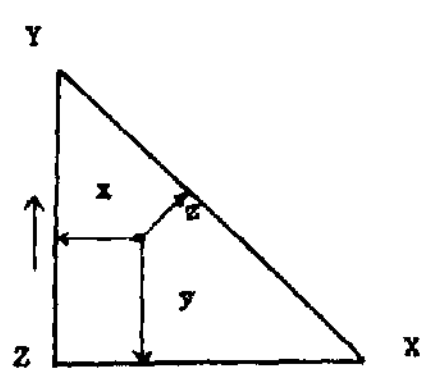


Figure 5 **Color triangle**

b)multi-triangle specification

In color picture processing we often like to represent the lightness in triangular diagrams. For this purpose we propose the multi-triangular specification as in Figure 6.

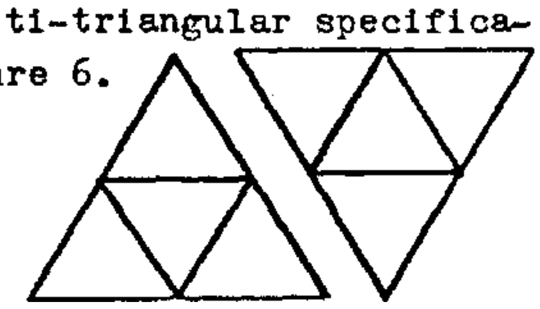


Figure 6
Color
Multi-triangle

c)color band

The hue circle can be expanded into the color band, and it is extended as Hue histogram of Figure 7.

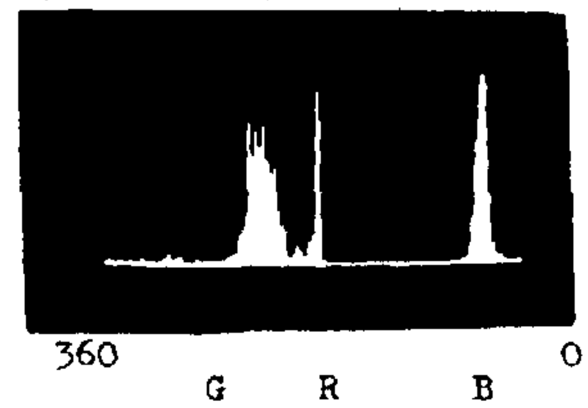


Figure 7 Color band

d)color differnce chart

The color difference and its distribution are good measures to know color structure and balance.Adams chromance space method seems to be very convenient for our purpose among various methods. Figure 8 shows an example of Adams chromance space method.

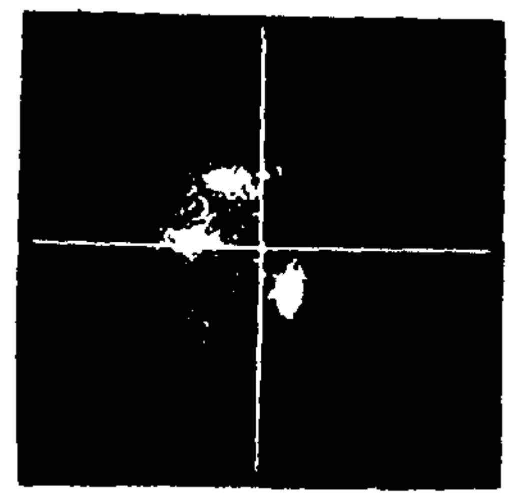


Figure 8
Adams chromance method

e)dynamic projection of color space

The diagram specification is intended to see the projection of color distribution in color space. Tie use of high performance graphic display will allow us to see the projection of color space dynamically.

4^3 Elementary operations on color space

(i) scalar operation

Example: Y=aR +bG + cB

(ii) color vector arithmetic

Every color will be represented as a vector in a color space, so thut we can construct a system of color arithmetic.

$x \oplus y$: vector addition of x and y
$x \ominus y$: vector subtraction of x and y
$x \otimes y$: vector multiplication of x and y
$x \oslash y$: vector division of x and y
where x and y are color vectors.

5. Use of Color nformation in Picture Processing

There are many possibilities for effective use of color information in picture processing. They range over from simple cases to complex and difficult cases- Most researchers would have Interest in rather difficult and complex problems such as recognition of color aerial photographs, recognition of color block worlds,identification of human faces,etc.Their developments are Interesting, but they will not meet direct applications in an industrial situation according to the present state of picture processing technology- Here we introduce several simple but useful ideas with direct applications.

5.1 Color Separation and its Applications

Using our color analysis software we can separate and identify colors,and this function is often needed In various applications of color picture processing. The color separation Itself finds several direct applications. Figure 9 shows an example in the automation of color textile printing.

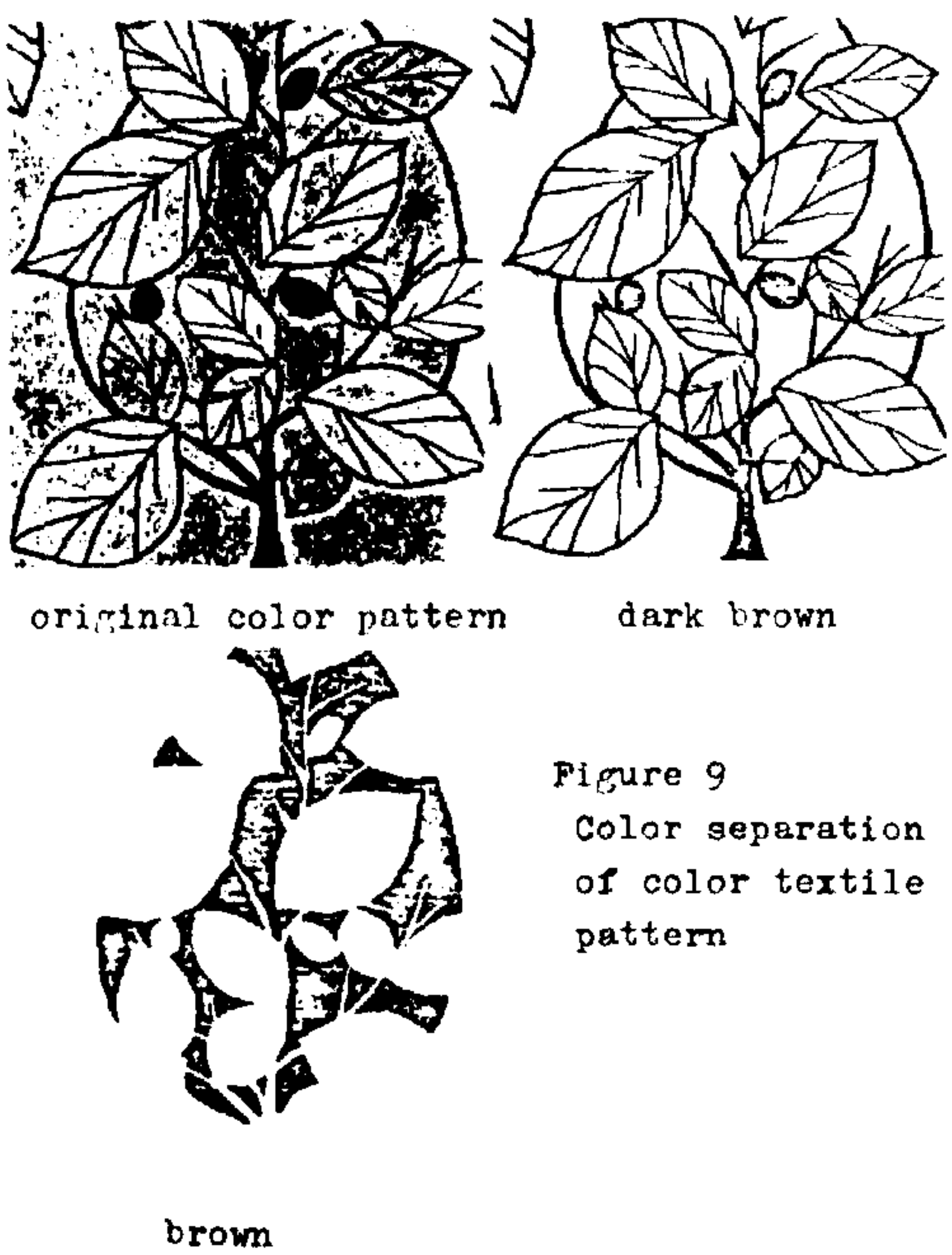


Figure 9 Color separation of color textile pattern

A different application is the computer analysis of colored maps of land utility. Also the detection of color Irregularity in color printing and color painting can be done as a simple application of color separation.

5.2 Color Effect Method and its Application

The color effect method is an effective method devised by this author. This method was originally proposed to detect some defects of mask patterns by an effective application of color Information to picture recognition. Figure 10 is an example to explain this method.

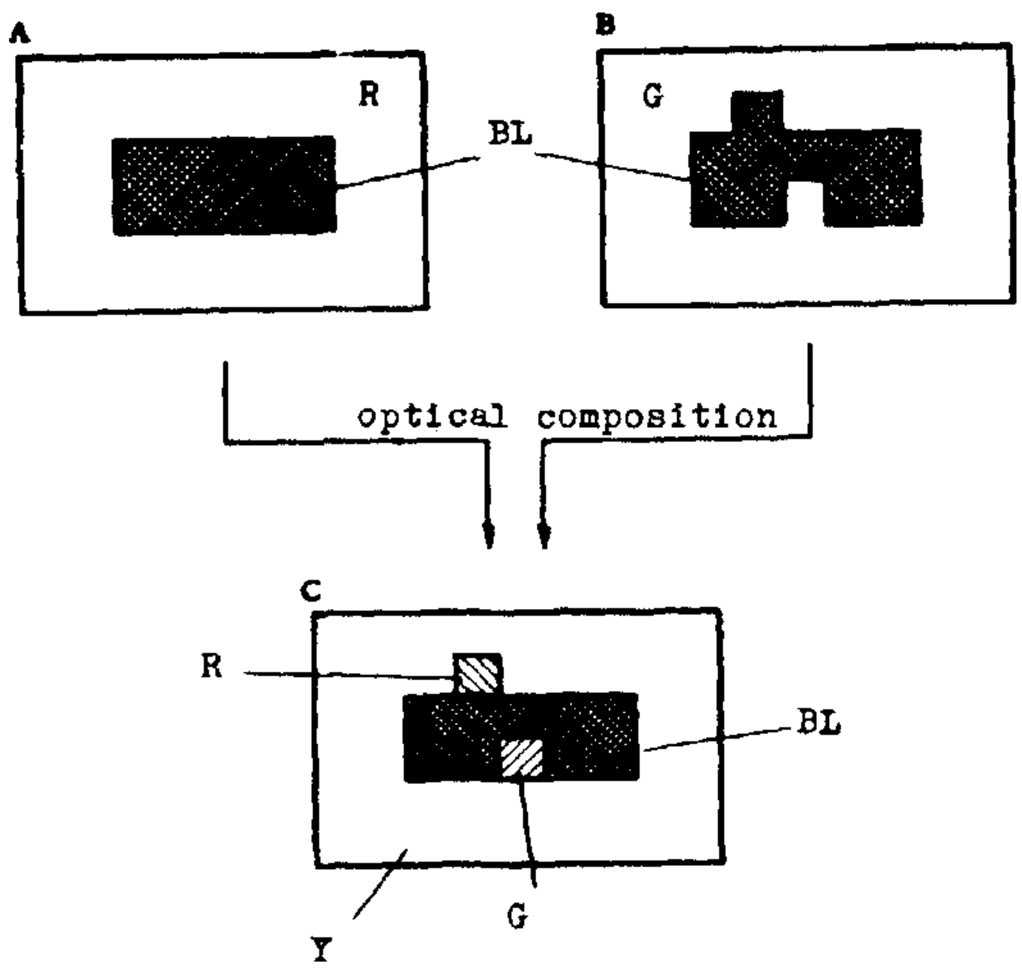


Figure 10 An example of color effect method

According to this example the detection of pattern defects can be performed by detecting sone specified color information (without handling any complex picture). This method has found several interesting applications in computer checking of various mask patterns, solving registration problems by simple techniques.

This color effect method can be extended to multi-color effect cases. If we use three colors, we can expect color majority decision, which is explained in Figure 11. Figure 12 explains the principle of color

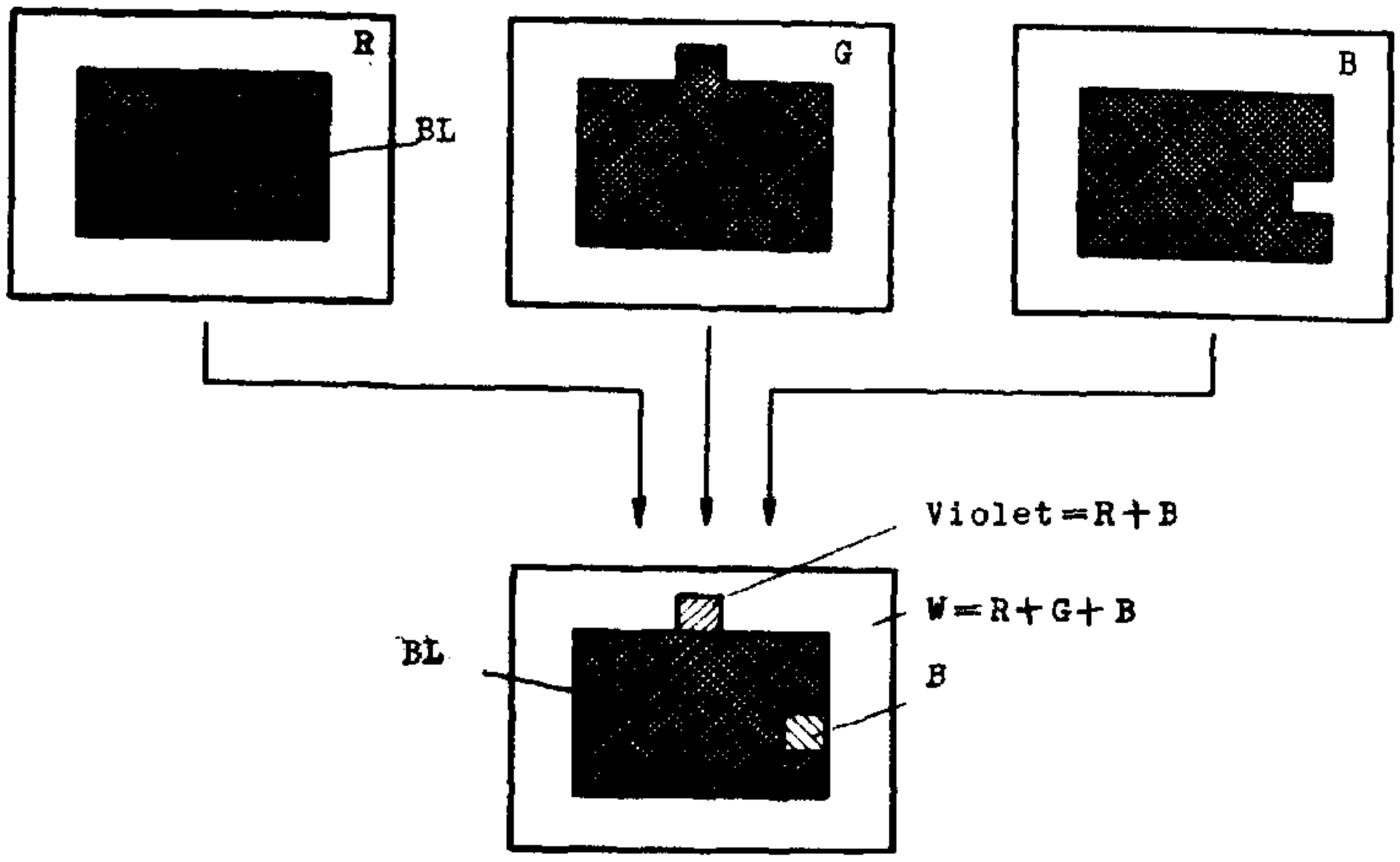


Figure 11 An example of multi-color effect

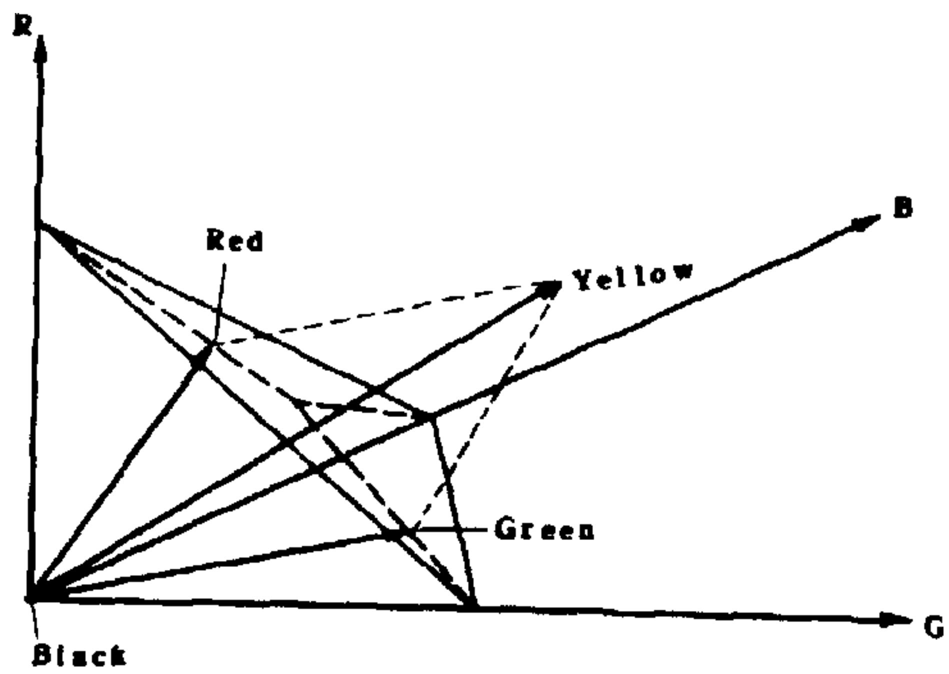


Figure 12 Vector representation of color effect method

effect method by color vector analysis in the color space.

5.3 Conversational Retouching of Color Pictures

The conversational retouching of color is useful in picture reproduction and digital film writing by computer, since it eliminates the wasteful process and feedback which require optical treatments. The following functions are necessary to implement the conversational retouching system.

(1) sharpness
(2) compression
(3) gradation
(4) masking
(5) color removal
(6) smoothing by interpolation or extrapolation
(7) computation of color density
(8) color separation and composition
(9) display of color picture
(10) picture editing

5.4 Pseudo-color Displaying and Picture Measures

The pseudo-color display of pictures is successfully used in analysing remote aensing data and in designing structured patterns.The assignment of pseudo-color to each pixel and its evaluation are important in this case. There are many case studies in remote sensing. But no general procedure is known to find optimal pseudo-color assignments. Also the complexity measures and some decree of picture beauty are necessary in color pattern design to evaluate picture quality.The degree of beauty B_b in color science can be effectively used from the standpoint of color harmony. This B_b can be defined as

$$B_b = W/Q$$

where W is the degree of order and Q is the degree of complexity.This quantity can be computed by Moon-Spencer formula in color science.This kind of measures will be interstinff from a theoretical standpoint. There are several possibilities to extend this idea, using information numbers and complexity measures in information theory and pattern recognition.The following are some of their examples:

(1) color entropy based on color histgram

(2) topological number in color pictures

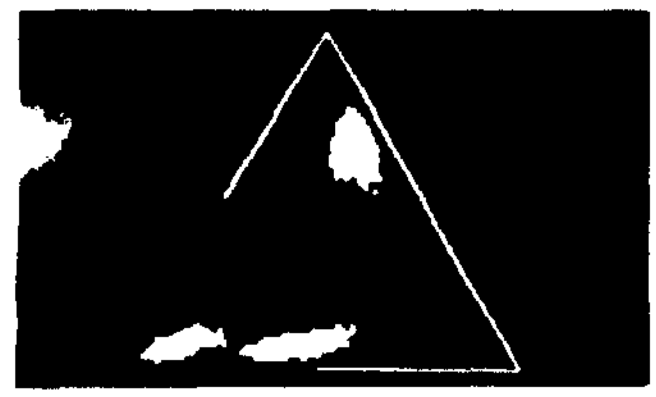
(3) heuristic picture complexity measure

(4) computational complexity Measures

5.5 Domain Identification by Color

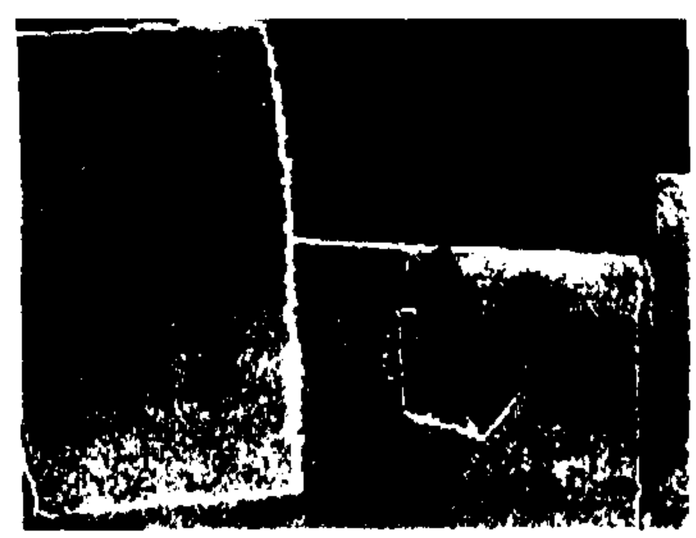
The domain identification is often important in scone ealysis. According to the suggestion of human perception the use of color information often helps to solve this problem if the domains are identified by color. The domain identification of color block v/orlds are often difficult in gray scale treatment when the shadow problem is comprised in a /riven situation.The chromaticity analysis and the minimum distance clustering are useful for this problem. In Figure 13 we show a simple domain identification, based on the chromaticity analysis and its effective application.

original color scene



color triangle

color band



simple domain identification

noise processing result

Figure 13 Example of Domain Identification

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Acknowledgement The author is grateful to the members of participating this project. They include Messrs. K. Akita,M.Fukushima, H.Nakajima,K.Sato,H.Tsuji and Y.Fukada.

This work was partly suppored PIPS