A microcomputer system for color video picture processing

by YOSHIKUNI OKAWA
Gifu University
Gifu, Japan

ABSTRACT

A color picture processing system is proposed. It consists of a microcomputer and a color video recorder. A picture is taken by a portable videotape recorder and a camera on cassette tapes in the field and brought back to the laboratory where the processing computer is installed.

The scenes are replayed on the videotape player on the monitor TV screen, from which signals are stolen by three A-D converters (one each for R, G, and B) and stored in the memory of the microcomputer.

The software package provides several commands which make it possible to process images on the CRT screen by man-machine interaction. A functional description of the commands is stated in some detail. One example of the application of this system is briefly described.
1. INTRODUCTION

A computing system to process color video pictures is described. The system consists of (1) a 16-bit microprocessor, (2) a color videocassette tape player, (3) a color monitor TV, and (4) a color graphic display.

We can record any scene onto videocassette tape by using a portable videotape recorder and a color TV camera. The scenes are replayed on the screen of a monitor TV. The signal voltages of red, green, and blue color components which drive the monitor TV are stolen and converted into three 8-bit digital signals and stored in the memory of the microcomputer. The scene will be processed digitally afterward by the software system provided by man-machine interaction.

As an example of a possible application of the system, the efficiency of road signs is studied. Various colors of tapes are placed on roads. Scenes are recorded on cassette tape in the field, carried back to the laboratory, and processed by the computer. The numerical measure of the recognizability of a sign against its background is defined and computed for all of the recorded scenes. The best color and form of a guiding line is determined for each road condition.

The cost of the proposed system is very low because microprocessors and color video picture recorders and players are produced massively by modern industry. A portable videotape recorder and a TV camera give mobility to the picture processing computer system. This computer will become a powerful tool in the field of digital color picture processing.

2. THE CONFIGURATION OF THE SYSTEM

The system configuration is shown in the block diagram of Figure 1. The central processing unit is a microprocessor (Z-8000) having 216 Kbyte of memory. A character display, a keyboard, a printer, and other usual computer peripherals are attached to the processor.

The picture input device is either a videotape player or a color TV camera. If the TV camera is used as a picture-taking instrument, scenes within the laboratory room in which the computer system is installed can be processed by the system. The numerical measure of the recognizability of a sign against its background is defined and computed for all of the recorded scenes. The best color and form of a guiding line is determined for each road condition.

The cost of the proposed system is very low because microprocessors and color video picture recorders and players are produced massively by modern industry. A portable videotape recorder and a TV camera give mobility to the picture processing computer system. This computer will become a powerful tool in the field of digital color picture processing.

3. THE COMMANDS OF THE CONTROL PROGRAM

3-1. Image Sampling

Picture processing, in general, proceeds in a conversational fashion. A regular command form is

\[ \text{prompt character from the control program} \]
\[ > \text{a command character [possible parameters]} (\text{CR}) \]
\[ \quad \text{a carriage return code} \]

Various commands provided in the control program are described in the following:

1. A command to set a sampling window in a picture plane:

\[ > W,SX,SY,NX,NY \ (\text{CR}) \]

The four command parameters SX, SY, NX, and NY assign a rectangular region in a picture plane, as shown in Figure 2. The parameters are key-input in a hexadecimal form and stored in the RAM area of the memory. This region will be sampled later.

2. A command to sample an image:

\[ > I \ (\text{CR}) \]

The DMA controller is initialized and the image sampling is started by this command. One vertical line in a window is sampled in one frame of television pictures. Since there are 60 frames in a second, the sampling time is calculated by

\[ t = \frac{NX}{60} \text{ (second)} \]

In general, the sampling time is directly dependent on the conversion time of the A-D converters used. If the speed of A-D conversion is increased, the sampling operation can be completed within 1/60 second.
3.2. R, G, and B Display Commands

The stored image must be called out from the memory and displayed on the screen of the color graphic display. The following commands are provided in the control program:

1. A command to erase the color graphic display screen.
   
   ```
   \text{> E(CR)}
   ```
   
   The screen of the graphic display is erased.

2. A command to display a cross-sectional figure of an image: As stated before, R, G, and B signals of an image are sampled in 8-bit digital form. That is, the representation at one picture element is 3 bytes in the computer. The color graphic display has only 8 colors (3 bits) at each picture position. There is a significant gap between sampled image and displaying capability. We must design commands to overcome this difficulty.

   First, we cut a three-dimensional distribution of an image in two pieces and make a cross-sectional distribution of the image. Three two-dimensional display lines are enough to display the image, which is easily shown on the CRT screen of the color graphic display. The command has the following form:

   ```
   \text{> H,h,v,F(CR)}
   ```

   where \(H\) is the command character, \((h,v)\) indicates the starting point in a picture plane, and \(F\) is a Freeman code to specify cutting direction. One example of the displayed results is shown in Figure 3. The three height lines consist of red, green, and blue color dots. But at a picture element where at least two out of three colors have the same intensity level, colors other than red, green, and blue are displayed, since the dots are overlapped.

3. A command to display a thresholded picture: If the sampled red, green, and blue brightness levels are thresholded at each picture element, the resulting image can be displayed on the screen of the color graphic display. The following command is provided for this purpose:

   ```
   \text{> F,RT,GT,BT(CR)}
   ```

   \(RT\), \(GT\), and \(BT\) are the threshold values in a hexadecimal form. Let us write sampled red, green, and blue brightness levels at a picture point \((i,j)\) as \(R_{ij}\), \(G_{ij}\), and \(B_{ij}\), respectively. Concerning the graphic display, if \(R_{ij} = 1\), then a red spot is displayed on the \((i,j)\) grid of CRT screen; and if \(R_{ij} = 0\), a red spot does not appear at that point. The terms \(g_{ij}\) and \(b_{ij}\) can be defined in the...
3. Display on the CIE plane

At this point we must consider the color transformation that will convert the measured color vector \((R_j, G_j, B_j)\) into CIEs \((X_{ij}, Y_{ij}, Z_{ij})\) at each picture element. The transformation equation can, in general, be written as

\[
\begin{bmatrix}
X_{ij} \\
Y_{ij} \\
Z_{ij}
\end{bmatrix} =
\begin{bmatrix}
a_{11} & a_{12} & a_{13} \\
a_{21} & a_{22} & a_{23} \\
a_{31} & a_{32} & a_{33}
\end{bmatrix}
\begin{bmatrix}
R_j \\
G_j \\
B_j
\end{bmatrix}
\]

where \(a_k (k=1,2,3)\) is an element of the conversion matrix and must be determined experimentally.

Munsell's standard color cards, listed in Table I, were placed before the TV camera one by one; and red, green, and blue values were sampled into the processor (R, G, and B column of Table I). The \(x\) and \(y\) values of the color cards are read from the Japanese Industrial Standard (JIS Z8721−1958), which are listed in the \(x\) and \(y\) columns of Table I. If we write

\[
\begin{align*}
x_q &= \frac{X_q}{X_q + Y_q + Z_q} \\
y_q &= \frac{Y_q}{X_q + Y_q + Z_q} \\
Y_q &= \frac{R_q + G_q + B_q}{3}
\end{align*}
\]

(brightness assumption)

then the conversion matrix is determined by the least-squares method. The result is written as

\[
\begin{bmatrix}
X_q \\
Y_q \\
Z_q
\end{bmatrix} =
\begin{bmatrix}
0.46 & -0.21 & 0.15 \\
-0.08 & 0.78 & -0.36 \\
-0.04 & -0.23 & 0.60
\end{bmatrix}
\begin{bmatrix}
R_q \\
G_q \\
B_q
\end{bmatrix}
\]

![Figure 4—Deviation of the least-squares fitted points from their true points](image)

![Figure 5—An example of color distributions on the CIE's plane.](image)
whose transformational matrix is seriously affected by lighting condition. Because of the least-squares fitting, \((X_i, Y_i, Z_i)\) do not lie exactly on \((X_i, Y_i, Z_i)\). Their corresponding position pairs are shown in Figure 4. Our control program can handle a picture in the CIE color coordinate system. A typical two of the provided commands are briefly described in the following:

1. A command to display a distribution on the color plane: Figure 5 shows the resulting display of this command. The sampled \(x_y\) and \(y_y\) in a picture are plotted in the CIE's color plane. The command form is

\[
> K(CR)
\]

The six standard color points (R, Y, G, B, P, W) are displayed at their location by their color.

2. A command to display the color frequencies:

Let us define a color frequency as

\[
f_{x_i} = \sum_{i=1}^{M} \sum_{j=1}^{N} \delta(x_i - k) \delta(y_i - 1)
\]

where \(\delta(\alpha) = 1\), if \(\alpha = 0\), and \(\delta(\alpha) = 0\), if \(\alpha \neq 0\). Its command form is

\[
> J(CR)
\]

The J command displays \(f_{x_i}\) on the CRT screen, as shown in Figure 6.

4. ONE EXAMPLE OF APPLICATIONS

We want, in general, to design a software package that can cover a wider area, but no software can be designed without a concrete objective, especially in its infancy. Our motive for designing this software package will be briefly explained in the following paragraphs.

We are studying automatic guidance of an electrically driven vehicle. A TV camera sees guidelines on the floor. The microprocessor estimates the driving path and controls its trajectory. Experience has shown us that a monochromatic TV camera is not enough for recognizing objects in a real world: color seems to provide us with vital information.

If we are to place guiding signs on the floor, there emerge several fundamental questions, such as what color is best for a sign, what form is best, and where to place the signs.

Color distribution of a sign and its background are displayed on the color graphic display (see Figure 5), using a command of the package. The background distribution is rather concentrated in the center region of the CIE plane. The signal has a long, thin distribution. We can define a measure \(S\) that indicates separability of a signal from its background, as

\[
S = (x_s - x_b)(\frac{1}{\sigma_x} + \frac{1}{\sigma_x'}) + (y_s - y_b)(\frac{1}{\sigma_y} + \frac{1}{\sigma_y'}) + (y_s - y_b)(\frac{1}{\sigma_y} + \frac{1}{\sigma_y'})
\]

where subscripts \(s\) and \(b\) indicate signal and background, respectively. \(\cdot\) is an average operation, and \(\sigma\) is a standard deviation. If two distributions are well separated, then \(S\) takes a large value. On the contrary, if the two are mixed, \(S\) becomes small.

Now a thin tape is placed on the ground, and \(S\) is calculated. Then another tape is measured in the same manner. The tape with a larger \(S\) may be said to be more suitable for that background. Continuing like this, we can determine the best guiding signal for the specified background.

5. CONCLUSION

A new color picture processing system is introduced. It makes full use of recently advanced videotape recording technology. It gives mobility to a computer vision system. A software package for color picture processing has been coded and tested. It aims at an interactive processing of color image recorded on cassette tapes.

Although the commands now available in the control program cover only basic areas, they can be easily extended in any desired direction. If we consider the rapidly decreasing cost of microprocessors and videotape recorders, the proposed system may be said capable of being constructed at a very low price.

It is already concluded by the researchers that picture processing by monochromatic images has met a severe limitation in its real applications, especially in object recognition. Human processes color images. If we drop the color factor in picture processing, then the computer can never equal human capability. It is unreasonable to want the same results from image processing by computers as by human vision without the essential information provided by color.

But there are some problems in color picture processing. At least three times as much information must be stored in the memory as for black and white. The complexity of the resulting processing program will increase rapidly. The control program package described herein will serve as a core for color image processing and thus contribute to expanding computer power to a wider range of applications.