CHAPTER IV

BLACK-AND-WHITE TO COLOR (BW2COLOR) SOFTWARE

Black-and-White to Color (BW2COLOR) is a program developed in this research for composing color images with a b/w image input device. There are several special features added to BW2COLOR, including a tool for assigning *pseudo colors* to a gray scale image by a heuristic approach of *gray level to color transformation* technique and a tool for adjusting *brightness* and *contrast* of a color image. A PCX image viewer with three modes of display: normal, *inverse* (or *negative*), and gray scale is also provided as an application of *image inversion*, and *color to gray level conversion* algorithms. BW2COLOR supports most VGA and super VGA (SVGA) adapters, such as Trident and Tseng Labs, and most display adapters with Video Electronics Standard Association (VESA) standard capability.

System Requirements

The following hardware and software are required to use BW2COLOR:

- Computer: An 80286 or higher with a hard disk. One with a math-coprocessor is recommended.
- Operating system: DOS version 3.1 or higher.
- Display adapter: VGA or SVGA. SVGA with 1 MB display RAM is recommended.
- Image input device: a flatbed scanner or video camera, with image input software supporting PCX image file format. A software providing automatic exposure feature is recommended.
- RGB filters: cellophane.
- Calibration card: white or white-and-gray(s).

Tools in BW2COLOR

BW2COLOR is composed of five tools: Configuration File Generator, PCX Mixer, Pseudo Colorer, PCX Viewer, and PCX Enhancer, each of which has its own separate menu. All the tools support both 16-level (4-bit) images with header palette and 256-level (8-bit) gray scale and 256-color images in PCX format, except the PCX Enhancer which supports only 256-level gray scale and 256-color images. Each tool will be described briefly here and in more details in the following sections.

- Configuration File Generator (Config)

The Config tool is used to create a Filter Characteristic File to be used by the PCX Mixer tool for data calibration in the Color Mixing process.

- PCX Mixer (Mixer)

The Mixer tool is used to generate a color image from three gray scale images containing RGB intensity data. There are two types of color look-up table (LUT) available for the output 256-color image, fixed LUT and unfixed LUT. The characteristic file generated by the Config tool is used by this tool for data calibration in the Color Mixing process.

- Pseudo Colorer (Colorer)

The Colorer tool is used to assign a fixed set of pseudo colors to a gray scale image. The *gray level to color transformation* technique applied is designed for maintaining continuity of colors, brightness of colors, and depth dimension of the output color images. The tool is good for applying to the images where colors have no relationship to any object in human sense, such as X-ray and paint images.

- PCX Viewer (Viewer)

The Viewer tool is used to view either gray scale or color images. There are five resolutions supported by BW2COLOR, including 320×200, 640×400, 640×480, 800×600, and 1024×768 pixels. Images can be viewed in 3 styles: normal, inverse (or negative), and gray scale styles, respectively.

- PCX Enhancer (Enhancer)

The Enhancer tool is used to adjust exposure of a 256-level gray scale or a 256-color image. Users can adjust brightness and/or contrast of an image within -100% to +100 % range. The adjusted images can then be saved to new files.

Output Color Image Generations

Generating an output color image from gray scale images can be achieved either by using color mixing or pseudo coloring method.

1. Color Image Generator by Color Mixing

Generating a color image by color mixing method requires two steps: first, generating a Filter Characteristic File with the Config tool, and then generating the output color image with the Mixer tool.

1.1 Configuration File Generator (Config)

The Config tool can be employed from the Config menu. This tool requires four input data which are four gray scale images of the calibration card: one without any filter, and three applied with each of the RGB filters. On capturing each image, the exposure must be the same as the exposure on capturing the source color picture applied without any filter and with each consistent filter, respectively.

Each of the input files required can be specified via the Grays, Red, Green, and Blue menu items. The output file name of the Filter Characteristic File can be specified via the Output menu item. On selection of an input/output file menu item, a File Specification Window with 'Open' caption will be popped up, allowing users to input the file specification with a default value (Fig. 4.1). If the file specification input contains a wildcard character, the File List Window with directory traversing capability will then be popped up, allowing users to select a file from the file list (Fig. 4.2).

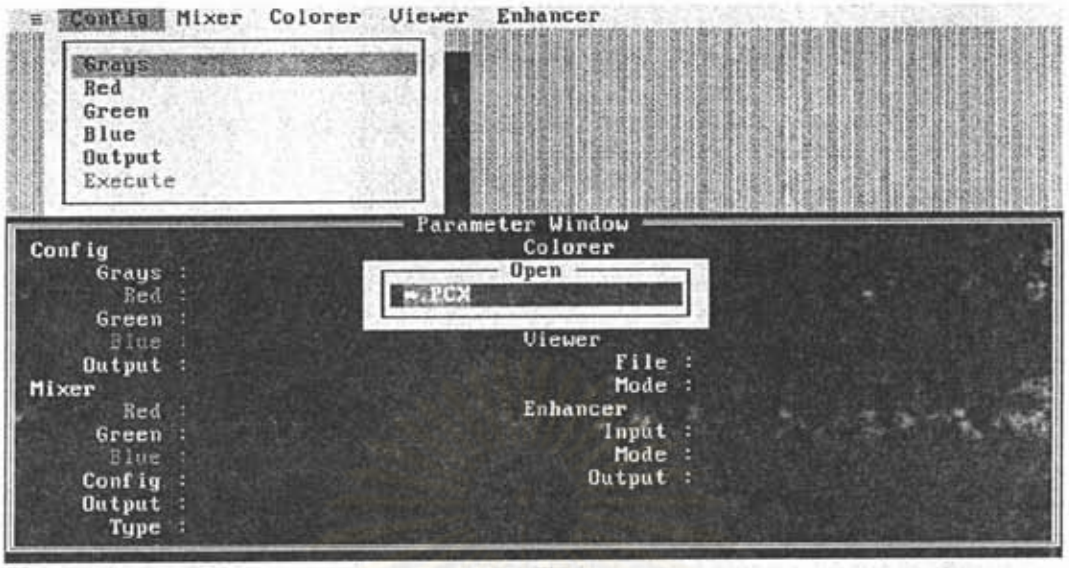

Fig. 4.1 File specification input with default value

Fig. 4.2 File selection via file list when the file specification contains wildcard character(s)

The name of the input or output file selected is displayed at its position on the Parameter Window as illustrated in Fig. 4.3. The file specification can also be an actual file name (with no wildcard character), usually when specifying a new output file, as illustrated in Fig. 4.4. In the case that no extension of file is specified, the default file type for a Filter Characteristic File of 'CFG' is appended to the file name.

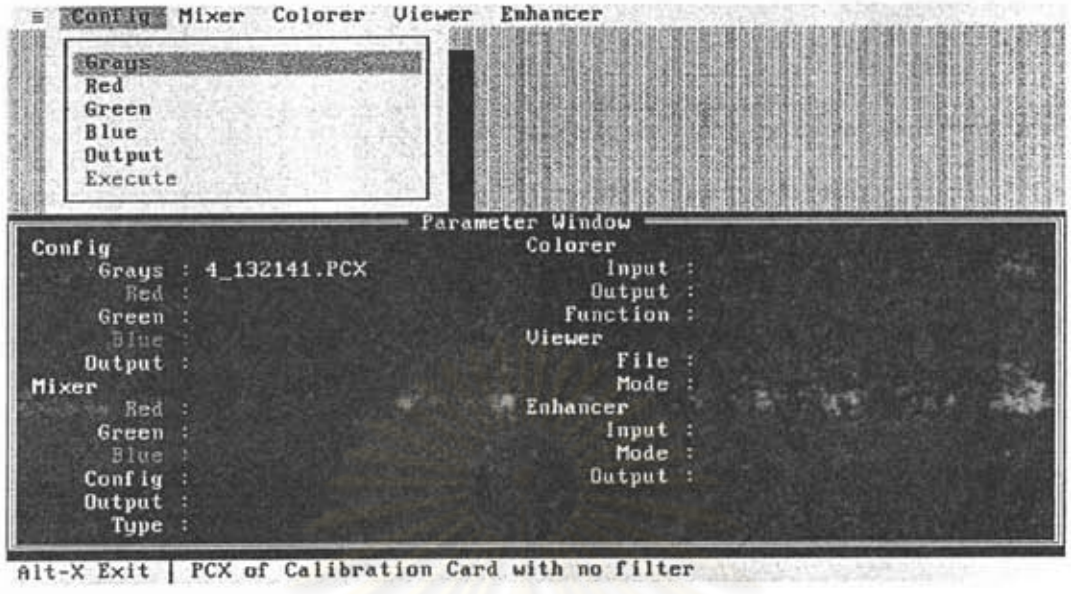

Fig. 4.3 The name of the file selected is shown on the Parameter Window

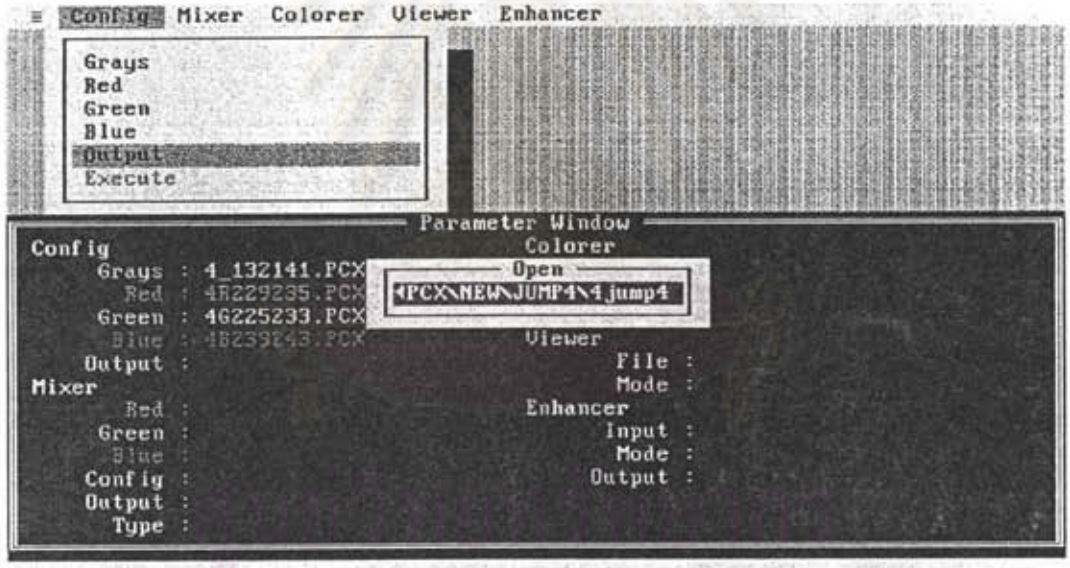

Fig. 4.4 A direct file specification, with no wildcard character

After all the required parameters are specified, the Execute menu item will be activated, as illustrated in Fig. 4.5.

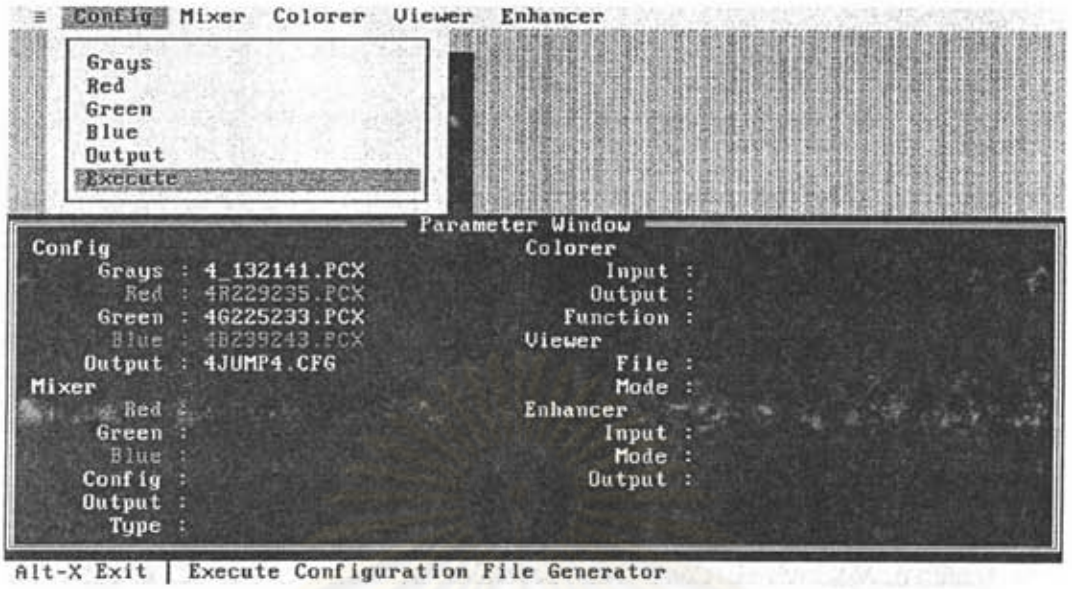

Fig. 4.5 The Execute menu item will be activated after all the parameters required have been specified

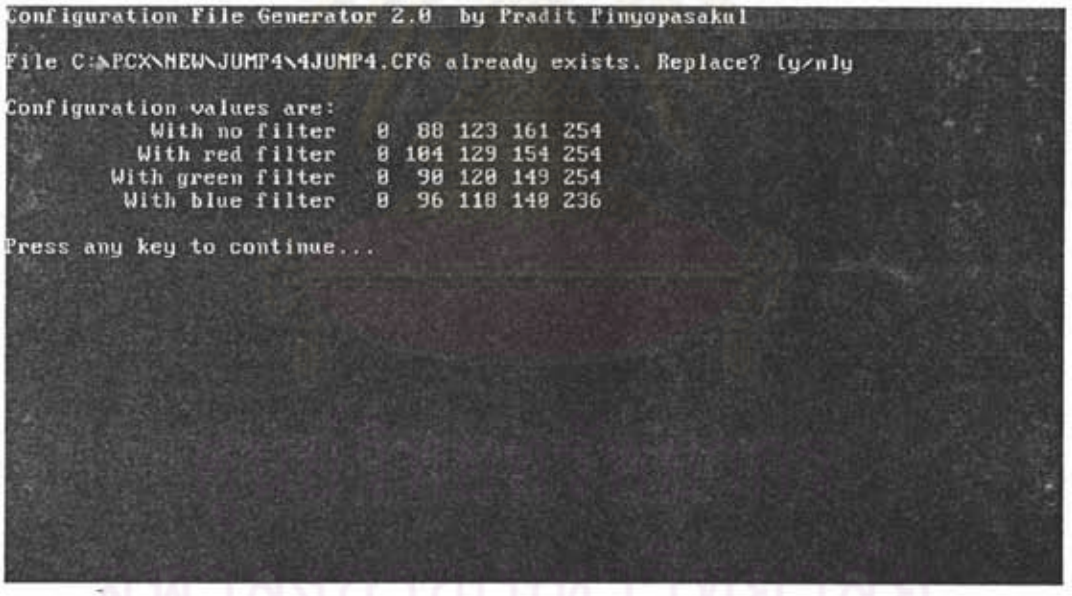

Fig. 4.6 The output screen after the Config tool has been executed and a Filter Characteristic File has been generated

Once the Execute menu item is activated, the Filter Characteristic File can be generated by executing the Execute menu item giving an output screen illustrated in Fig. 4.6. If the specified file already exists, users will be requested to

respond whether the file should be overwritten or the process should be terminated. This convention of checking existing output files is also performed throughout executions of the Execute menu items of all tools in this application.

The information written to the Filter Characteristic File is composed of four sets of the configuration values, each of which stores the gray levels of the white band and each of the gray bands respectively. The first set is for the image of the calibration card without any filter applied, and the three other sets are for the image of the calibration card applied with each of the RGB filters.

If any two adjacent bands on the calibration card are too similar,* the Config tool may be unable to distinguish those bands. An error message saying "*Problem in detecting configuration values. Removal of the darker band(s) of similar gray bands is needed.*" will be displayed. To correct this problem, every darker band of any 2 adjacent bands that are too similar must be removed from the calibration card, and all the input images of calibration card must be recaptured. If the problem is not severe,** the message will be "*Problem in detecting configuration values. Removal of the darker band(s) of similar gray bands is recommended. As this program is capable of compensating some errors, this problem may be ignored. However, if the output image of the Mixer tool using*

---

* The difference of adjacent bands should not be less than 20 gray levels on a 256-level gray scale for general images, as already described in Section 2.2 of Chapter 3, Making a Calibration Card. However, for the exposures of some images, higher degree of difference may be required.

** When the number of gray bands detected for the blue filter is greater than those for the other two filters, the excessive gray levels detected will not be written to the file. This process is included to help solving the effect caused by the limitation of the DeskScan II Version 1.51, the image capturing program which comes with the HP ScanJet IIc scanner, as described in Section 2.3 of Chapter III.

this configuration is of high color distortion. removal of the darker band(s) of similar gray bands is really needed.".

1.2 PCX Mixer (Mixer)

The Mixer tool can be employed from the Mixer menu as shown in Fig. 4.7.

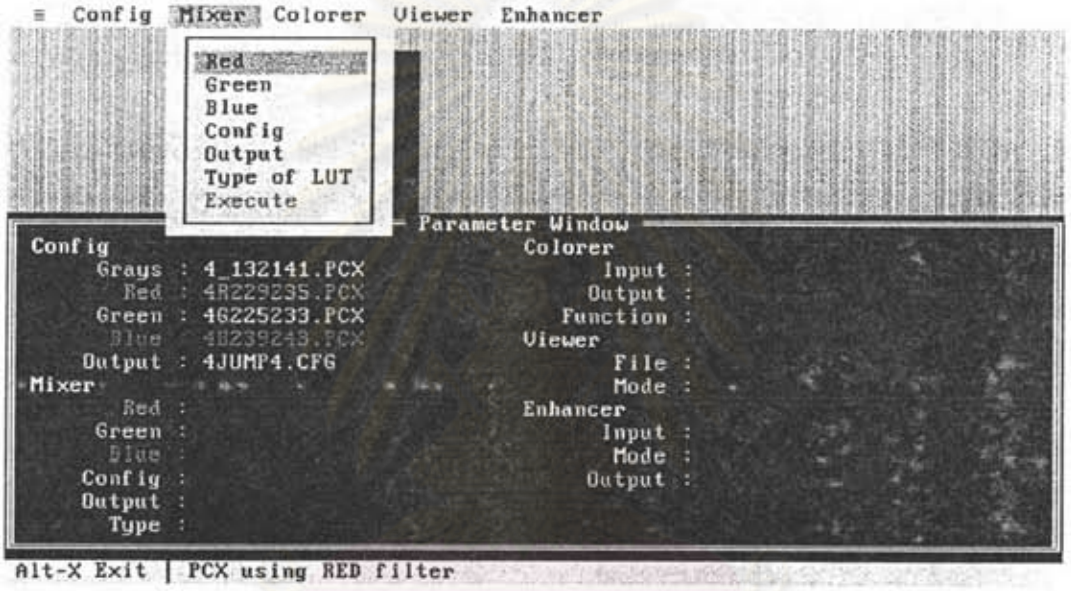

Fig. 4.7 The Mixer menu

The input data of this tool are three gray scale images of the original picture applied with each of the RGB filters and a Filter Characteristic File generated by the Config tool. On capturing each of the three images, the automatic exposure should be applied if available. All the three images must be of the same size and position so that each pixel on each image represents the same pixel on the original picture. The names of the required input image files can be specified via the Red, Green, and Blue menu items, the Filter Characteristic File via the Config menu item, and the name of the output 256-color image file via the Output menu item.

There are two types of the LUT to be applied to the output image, unfixed and fixed LUT's, which can be selected from the radio button menu with 'Type of LUT' caption as illustrated in Fig. 4.8.

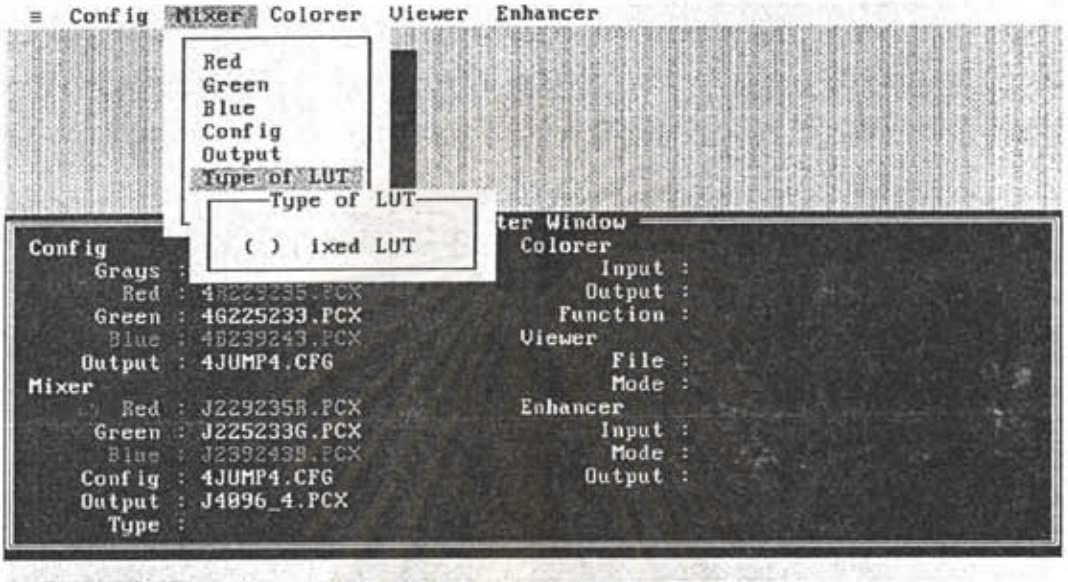

Fig. 4.8 Selecting the type of LUT to be applied to the output image

After all the required parameters are specified, the output color image can now be generated by executing the active Execute menu item. As mentioned before, only when the Execute menu item has been activated, the tool of that menu can then be executed. In the case that the output file already exists, the user will be requested to respond whether the file should be overwritten or the process should be canceled.

If the LUT is unfixed, the Mixer tool will first construct a temporary image of 4096 colors in memory. It then selects 256 colors that are most frequently used in the temporary image and stores them in the LUT of the output image. Finally, the output image file is then generated, as illustrated in Fig. 4.9.

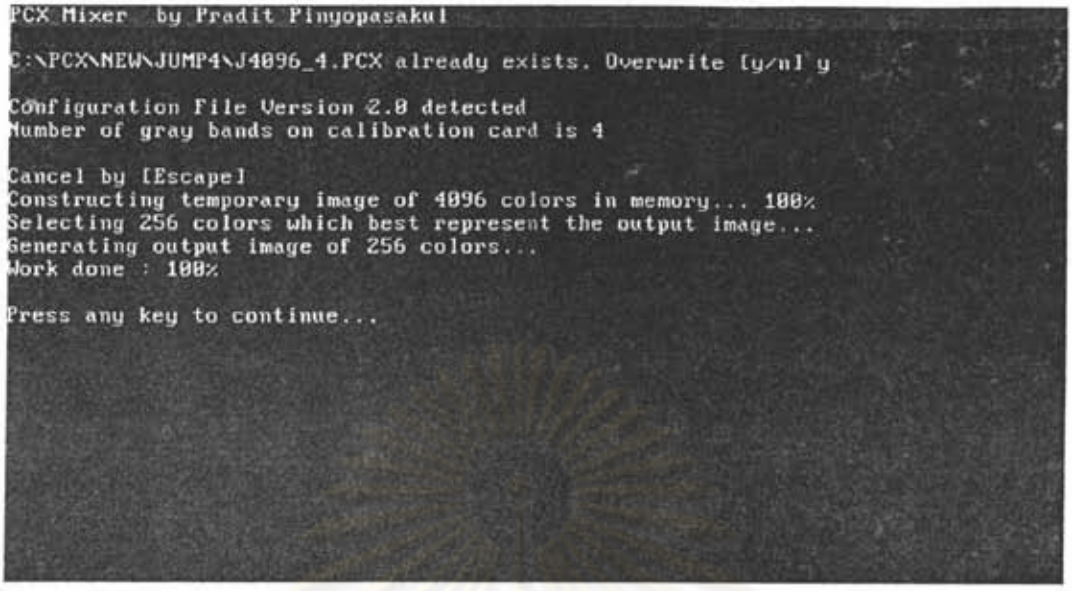

Fig. 4.9 The output screen after the Mixer process has been done

As the processes of constructing a temporary image and selecting the 256 colors suitable for the output image require a lot of floating point calculations. Moreover, the color assigned to each pixel on the output image with unfixed LUT must be obtained by searching the closest colors. Thus, a math-coprocessor is strongly recommended, otherwise, the processes will consume a very long time. If a math-coprocessor is not available, it is suggested that a fixed LUT should be selected to avoid the searching process.

2. Pseudo Colorer (Colorer)

The Colorer tool can be employed from the Colorer menu to assign pseudo colors to a 16-level or a 256-level gray scale image (Fig. 4.10).

The names of the input and the output image files can be specified by the Input and the Output menu items respectively. There are three available pseudo coloring functions that can be selected via the Function menu item (Fig. 4.11). These three functions were described earlier in Chapter 3. After these parameters have all been selected, the Execute menu item will be activated.

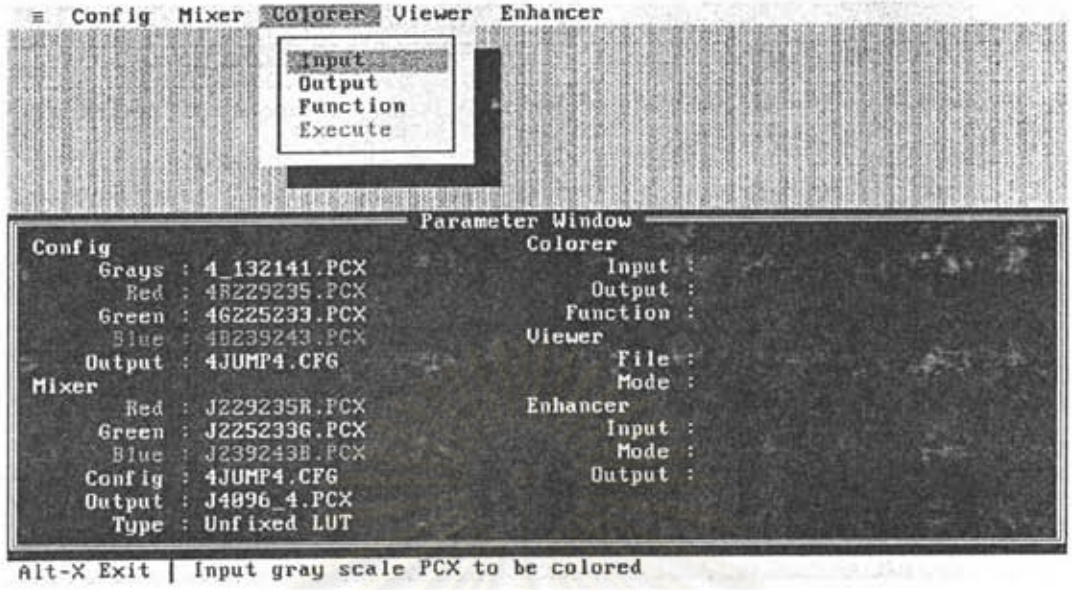

Fig. 4.10 The Colorer menu

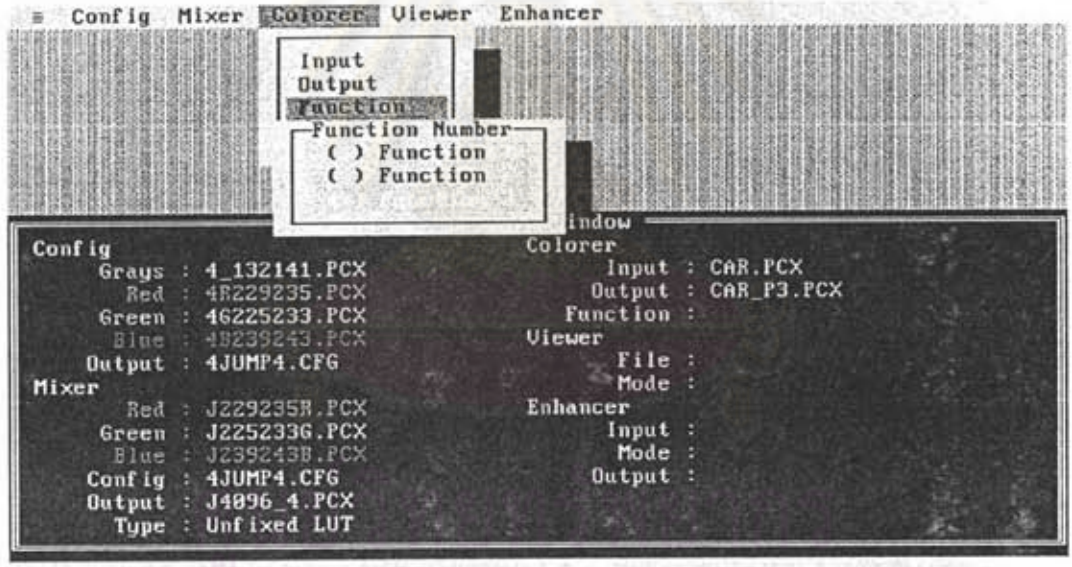

Fig. 4.11 Selecting the pseudo coloring function to be applied

After the output image is generated, it can then be viewed via the Viewer tool. As an example, the original image in Fig. 4.12 was colored, revealing the output image in Fig. 4.13.

Fig. 4.12* An image before pseudo colored

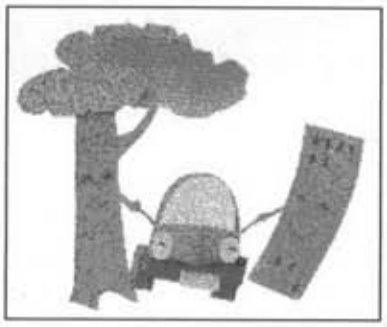

Fig. 4.13** An image after pseudo colored

3. PCX Viewer (Viewer)

Users can view a 256-color image generated by the Mixer tool or any other 16-level or 256-level gray scale or 256-color image by using the Viewer tool (Fig. 4.14).

Fig. 4.14 The Viewer menu

---

* and ** The original image was from the outer cover of Smart Drive, a handbook produced by Highway Police Constabulary and Bangchak Petroleum Co., Ltd., Thailand in 1994.

The image file to be viewed can be specified via the File menu item. The resolution of display screen can be selected from the radio-button Mode menu, as illustrated in Fig. 4.15. There are five resolutions supported by the Viewer tool. However, the maximum resolution depends on the size of display RAM on the VGA/SVGA adapter installed as shown in Table 4.1.

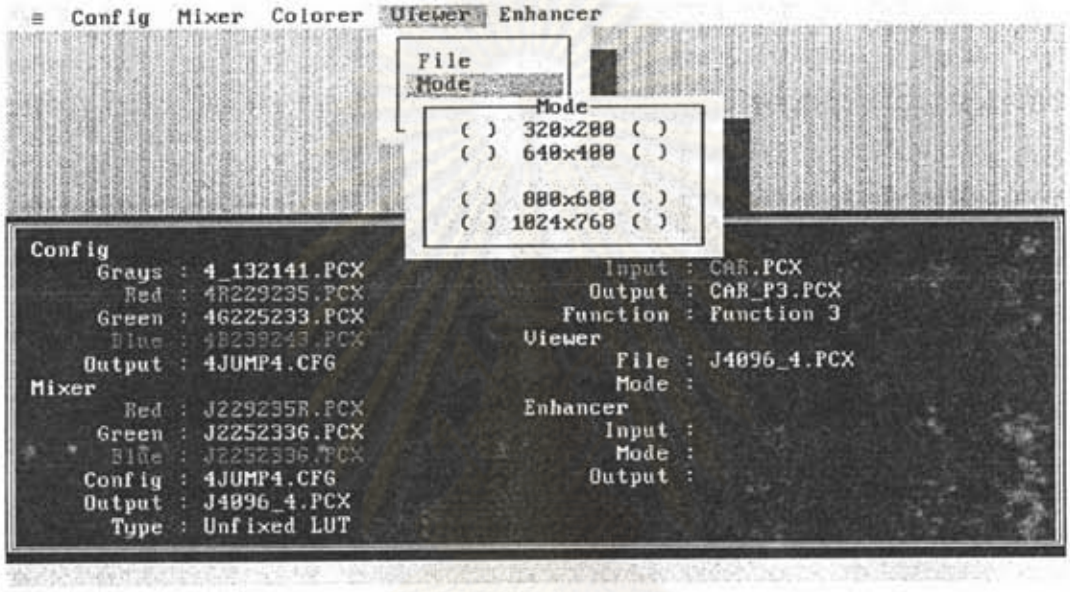

Fig. 4.15 Selecting the display resolution

Table 4.1 Size of extended display RAM on a VGA/SVGA adapter required for each resolution

Resolution (pixels)	Extended Display RAM required (KB)
300×200	0
640×400	256
640×480	512
800×600	512
1024×768	1024

After all the required parameters have been specified, the Execute menu item will be activated. On the execution of the Viewer tool, the image is first displayed in normal mode as illustrated in Fig. 4.16. The Viewer tool waits for any key on the keyboard to be pressed.

Fig. 4.16* An image displayed in normal mode

The image is then displayed in the inverse or negative mode, as illustrated in Fig. 4.17, and the Viewer tool waits for any key on the keyboard to be pressed. Finally, the image is displayed in gray scale (Fig. 4.18), and the Viewer tool waits for a key to be pressed again.

Fig. 4.17** An image displayed in negative mode

Fig. 4.18*** An image displayed in gray scale

---

*, ** and ***The original image was from a magazine.

In the case that the selected resolution is not supported by the display adapter in use, an error message saying "Mode not support on this card" will be displayed. Users must select one of the other lower resolutions supported by the display adapter in use. The maximum resolution that can be employed depends on the size of display RAM on the VGA/SVGA adapter installed. as already mentioned. Please refer to Table 4.1 for details.

4. PCX Enhancer (Enhancer)

The Enhancer tool can be employed from the Enhancer menu as illustrated in Fig. 4.19, to enhance a 256-color image generated by the Mixer tool or any other 256-level gray scale or 256-color image.

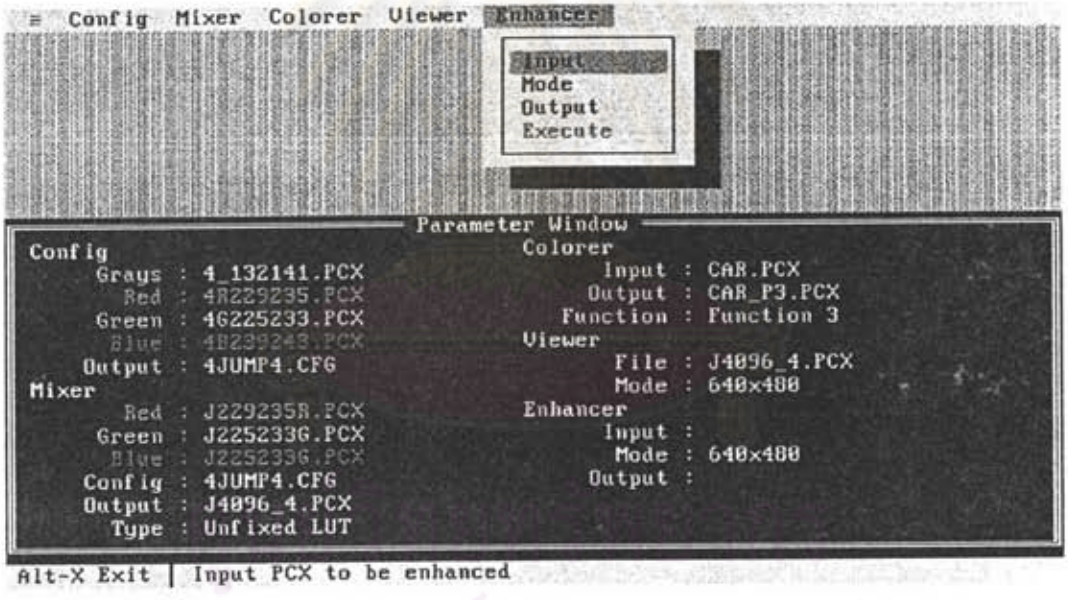

Fig. 4.19 The Enhancer menu

The name of the input image file can be specified via the Input menu item. The resolution of display can be selected from the radio-button Mode menu. There are five resolutions supported by the Enhancer tool. However, as already mentioned, the maximum resolution depends on the size of display RAM on the VGA/SVGA adapter installed as

shown in Table 4.1. Lastly, the name of the output image file can be specified via the Output menu item.

After all the required parameters have been specified, the Execute menu item will be activated. On the execution of the Enhancer tool, if the specified file already exists, users will be requested to response whether the file should be overwritten or the process should be terminated. If the output file is chosen to be overwritten or it is a new file, the original image is first displayed, with brightness change and contrast change of both 0%, as illustrated in Fig. 4.20.

There are eight function keys available on the execution of the Enhancer tool. For brightness adjustment, F1 and F2 keys are used to decrease and increase the brightness of the displayed image respectively, and F3 key is for canceling any brightness change. For contrast adjustment, F5 and F6 keys are used to decrease and increase the contrast of the displayed image, and F7 key is for canceling any contrast change. The F10 key is for saving the enhanced image, and the Escape key is for exiting from the Enhancer tool without saving the enhanced image.

For example, as the original image of Fig. 4.20 is too dark, its brightness was increased to +30% using F2 key to make it brighter, as illustrated in Fig. 4.21.

However, the increased brightness caused the background of the image to become gray instead of black. To get a black background, the contrast of the image was then increased to +100% with F5 key, as illustrated in Fig. 4.22.

As an example of canceling change made to an image, the brightness change was then canceled using F3 key, as illustrated in Fig. 4.23.

Finally, the enhanced image, with +27% brightness change and +100% contrast change, as illustrated in Fig. 4.24, was saved to a disk file using F10 key. The output file is always be of the same size as the input file since the changes are made to the LUT of the image only.

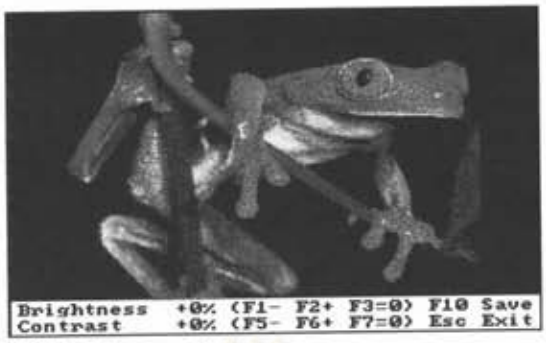

Fig. 4.20* The original image before enhancement

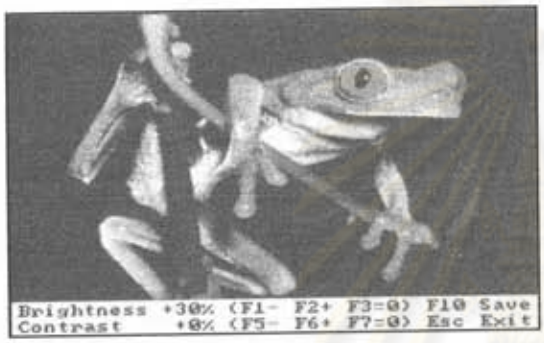

Fig. 4.21** The image with brightness changed to +30%

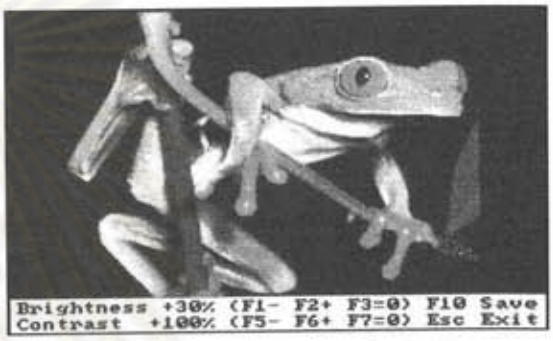

Fig. 4.22*** The image with +30% brightness change and +100% contrast change

Fig. 4.23+ The image with 0% brightness change and +100% contrast change

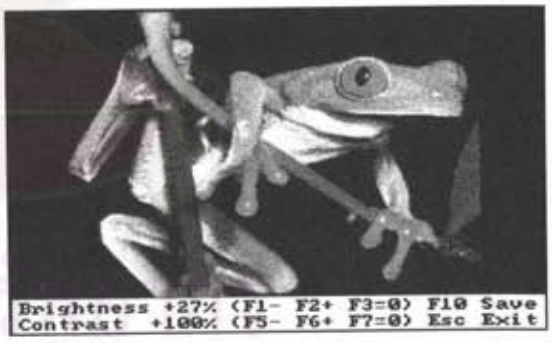

Fig. 4.24++ The image with +27% brightness change and +100 % contrast change

---

*,**,***,+, and ++ The original frog images were from the package of Graphic Workshop, a software produced by Alchemy Mindworks Inc.