AN IMAGE PROCESSING SYSTEM WHICH YOU CAN MAKE

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ABSTRACT

An image processing system based on an IBM PC/AT compatible
computer is being developed for teaching and research at The
National Chung Hsing University. The hardware consists of a
personal computer with a monochrome monitor, an EGA monitor, and
a color ink-jet printer. Pseudocolor images can be displayed on
an EGA monitor with maximum of 16 colors, while falsecolor images
and hard copies can be obtained on an ink-jet printer. Quite a
few programming efforts have been made to reformat data and
display it. Software to run the system is mainly utilizing
available PC-based statistical packages, say, SPSS, SAS, MINITAB,
BMDP, and IMSL. Image enhancement, classification, fast Fourier
transform, principal component analysis, factor analysis,
discriminant analysis, and texture analysis can be performed
smoothly.

0. INTRODUCTION

Applications of remote sensing techniques to solve a wide variety
of problems encounter in the management of natural resources
involve a lot of image processing techniques. A typical image
processing system based on a personal computer may not be very
expensive. However, ten or more sets of image processing system
are usually not affordable.

Marble (1984) indicated improved education and training for
working with geographic information systems is needed and more
students needed to be prepared. A variety of educational and
training opportunities are needed for refreshing and retraining

those in the field and for training potential users of the technology. It is also true in remote sensing.

An image processing system implemented in remote sensing would be highly desirable to have the ability to perform image enhancement, classification, principal component analysis, factor analysis, discriminant analysis, fast Fourier transform, and texture analysis. Color display and color hard copies are two basic functions of this type of systems. Its price will be so low that as many sets of systems as desired can be purchased. Those commercial statistical packages, either personal computer based or mainframe based, would be implemented to perform the major functions of an image processing system. Only minimum programming efforts are required. Special techniques to take care the image processor will not be necessary. This type of image processing system does exist and can be made easily.

The objective of this paper was to develop a very low cost personal-computer-based image processing system for teaching, training, and research.

1. HARDWARE SYSTEM

1.1 Computer System

The IBM PC/XT or AT would be a nice host computer. However, a compatible one is usually less expensive. 640 K bytes of random access memory (RAM) and a hard disk are desirable. A math co-processor is not required but would enhance system performance. The IBM enhanced graphic adapter (EGA) and monitor are required to display images in color. One additional monochrome monitor used to display Chinese characters in Chinese word processing is convenient but not necessary.

1.2 On-line Storage

A 20 megabyte hard disk would be sufficient for on-line storage. Optical diskettes as many as 800 megabytes are available on the market. In addition, a 9-track tape drive is useful to backup and archive data from a personal computer and bridges communication between personal computers and mainframes.

1.3 Input and Output Devices

One floppy disk drive is enough to input data into a computer. Two drives would be more convenient. Image data stored on a 9-track tape can be directly input into a personal computer if a 9-track tape drive is available.

An EGA monitor is handy for displaying raw and processed images in 16 colors with 640-by-350 resolution. A color ink-jet printer makes a color hard copy which is not only good for training area

selection but also a more informative final output. A desktop laser printer provides a high quality black and white output with 300 dots-per-inch resolution.

1.4 Interface with Mainframe

A personal computer serving as a terminal of a mainframe requires an interface card, say, RS-232-C. One set of MODEM is needed if communication by way of telephone lines. In this case, a personal computer can take advantages of all resources available on a mainframe, both software and hardware.

2. SOFTWARE SYSTEM

2.1 Operating System

Disk operating system version 3.20 or higher by IBM corporation and Microsoft, Inc. can be used.

2.2 Data Reformat

Digital imagery acquired by LANDSAT, SPOT, and airborne multispectral scanner (MSS) is stored in different format. The ORSER remote sensing analysis system converts imagery data into band-interleaved-by-line (BIL) format as the first step of image analysis (Turner et al, 1982). Commercial statistical packages, namely, BMDP (Dixon, 1983), SPSS (Norusis, 1986, 1987), MINITAB (Ryan et al, 1976), SAS (SAS Institute Inc., 1982a, 1982b), process data which is similar to band-interleaved-by-pixel (BIP) format. Image data converted into BIP format with one space between two data values is the single step of data reformat process so that they can be analyzed by commercial statistical packages, either on a personal computer or on mainframes.

2.3 Display and Hard Copy

An EGA monitor can display an image with maximum of 16 colors each time. Only pseudocolor images can be shown. In remote sensing, an image usually consists of several channels. Each time only one single channel can be displayed. The norm of multiple channels is calculated using statistical packages. Then, this norm can be displayed as an integrated information of these channels.

The gray value of a pixel is in the range of 0 to 255. However, only 16 colors can be displayed on an EGA monitor. It is necessary to resample these gray values into 0 to 15. The RECODE command in the SPSS package takes care this process easily. An image is resampled into 0 to 15 with almost flatten histogram. Then, it is displayed with histogram equalization such that more information contents will be shown. The two BASIC commands SCREEN 9 and PSET, are critical components of the display

program.

Color hard copies can be obtained on a color ink-jet printer.
A cheap printer such as Canon PJ-1080A only provides eight
different colors. Yellow, magenta, and cyan transparencies are
printed from three different channels with half-toning technique.
A falsecolor hard copy can be produced as an overlay of three
separate transparencies. A falsecolor hard copy, thus, looks
more like a true color image than a paper color hard copy.

A black and white hard copy provided by a desktop laser printer
with 300 dots-per-inch resolution is much better than that
printed by a dot matrix printer. Half-toning technique has been
applied to create a series of pattern defined by a 7-by-7 window.
These patterns are quite enough for printing an image with 256
gray values. Images as large as 6000-by-6000 pixels can be
produced. The histogram equalization is usually performed
beforehand in order to have better hard copies.

2.4 Statistical Package

Any statistical package can be used to take care image processing
tasks. These commercial statistical packages did not intend to
provide functions for image processing. Fortunately, a lot of
functions can be utilized to process an image. Although PC-based
statistical packages are more convenient but they usually don't
provide 100% of functions as their counterparts on mainframes.
No single package can take care all functions required for image
processing. This paper implemented BMDP and SPSS a lot.
Selection of statistical packages is simply a matter of personal
choice.

3. IMAGE PROCESSING

Using statistical packages to process images requires certain
amount of modification of a given technique applied. This paper
emphasizes these modified procedures rather than showing theory
of each image processing technique.

3.1 Basic Statistical Information

Statistical information of an image calculated by a statistical
package provides basic information for further analysis and
display. Mean, standard deviation, variance, covariance,
histogram, and scatter plots of any two channels are typical
statistical outputs too.

3.2 Unsupervised Image Classification

Clustering is a typical unsupervised image classification
algorithm. A raw image can be classified by clustering in order

to get an overview on an EGA monitor. The PKM program of BMDP
performs K-means clustering. The "/PRINT MEMBER." control
statement should be indicated in the program. Thus, cluster
membership will show on the output file. A word processor is
implemented to retain these cluster members only. To display
them on an EGA monitor the number of clusters can not exceed 16.

The QUICK CLUSTER procedure of the SPSS/PC+ (Norusis, 1986) which
performs agglomerative hierarchical clustering is very powerful
in dealing with a large data set. The following command
provides an 8-clusters output for the green channel.

> QUICK CLUSTER GREEN/CRITERIA=CLUSTER(8).

The CLUSTER procedure of SAS does clustering hierarchically,
while the FASTCLUS finds disjoint clusters of pixels using a
K-means method (SAS Institute, Inc. 1982a).

3.3 Supervised Image Classification

Supervised image classification required statistics obtained from
these training samples. A program written in BASIC is used to
extract rectangle training areas. Then their statistics can be
calculated. Mean and standard deviation are needed in the
parallelepiped classification algorithm (PPD). The PPD algorithm
requires all classified classes have their own lowest and highest
gray values. The lowest gray value of a given class is obtained
by subtracting two units of standard deviation from its mean,
while the highest value is calculated by adding two units of
standard deviation to its mean. The following RECODE procedure
of SPSS/PC+ does PPD classification on a given channel, say,
green.

> SET RESULTS="GREENPPD.CLS".
> ....
> RECODE GREEN (LO THRU 50=0) (51 THRU 100=1) (101 THRU
> 150=2) (151 THRU 200=3) (201 THRU HI=4).
> WRITE VAR=GREEN.

The output file "GREENPPD.CLS" is ready for displaying on a
monitor and making hard copies.

3.4 Image Enhancement

3.4.1 Histogram Equalization

Histogram equalization is needed if an image is displayed on a
monitor or hard copies to be made. If eight class intervals
(or eight colors) are going to be displayed, then each class (or
color) should consist of 12.5% of total pixels. Any type of
FREQUENCIES procedure provided by statistical packages clearly
indicates threshold values for these eight classes. The

RECODE procedure of SPSS is implemented to recode every pixel into one of eight classes. The recoded image then has flatten histogram.

3.4.2 Linear Contrast Enhancement

It is assumed that output gray values are in the range from 0 to 255. Linear contrast enhancement reassigns new gray value to every pixel using the following equation.

New Gray Value=(Gray value - Minimum)/(Maximum - Minimum)x255.

The following procedure takes care the same enhancement.

        COMPUTE NGL=(GL - MIN)/(MAX - MIN) * 255.

3.4.3 Ratio of Channels

Illumination differences such as sunlight and shadow can be removed by taking ratio of two channels. Special procedure should be taken to ensure the gray value in denominator is not zero.

        COMPUTE RATIO=GREEN/RED.
        COMPUTE RATIO1=(GREEN-RED)/(GREEN+RED).

The above two statements perform ratio of green and red channels and ratio of the difference of green and red channels to their sum.

3.4.4 Vegetation Index

Vegetation indices are useful in biomass estimation. Two useful indices derived from LANDSAT MSS data are given by

    TVI1=Square Root((BAND7-BAND5)/(BAND7+BAND5)+0.5),
    TVI2=Square Root((BAND6-BAND5)/(BAND6-BAND5)+0.5).

The corresponding SPSS commands can be written as

    COMPUTE TVI1=SQRT((BAND7-BAND5)/(BAND7+BAND5)+0.5).
    COMPUTE TVI2=SQRT((BAND6-BAND5)/(BAND6+BAND5)+0.5).

3.5 Principal Component Transformation

A principal component transformation consists of four steps:
(1) calculate variance-covariance matrix of a given image,
(2) calculate eigenvalues and eigenvectors of the variance-covariance matrix,
(3) multiply the image by the eigenvectors,
(4) check if the transformed image is uncorrelated.

3.5.1 Calculation of Variance-Covariance Matrix

Calculation of variances and covariances of a given image using statistical packages is very easy. If this image consists of four channels, the variance-covariance matrix has the dimension of 4 by 4.

3.5.2 Eigenvalue and Eigenvector

Eigenvalue and eigenvector problems require special packages such as IMSL (IMSL Inc., 1985), PC-MATLAB (The Mathworks Inc., 1985). A program written in FORTRAN can be implemented to calculate eigenvalues and eigenvectors using one subroutine in IMSL. The lower triangle of a variance-covariance matrix needs to be input only. Eigenvalues and eigenvectors can be obtained right away. This program can be implemented on both PC and mainframes.

3.5.3 Image Transformation

A principal-component-transform image is obtained through the following equation.

$$Y = XT,$$

where X is the original image, T is the eigenvectors, Y is the transformed image. An image consists of four channels, say, blue, green, red, and infrared, and T has following elements

$$
\begin{array}{cccc}
t11 & t12 & t13 & t14 \\
t21 & t22 & t23 & t24 \\
t31 & t32 & t33 & t34 \\
t41 & t42 & t43 & t44.
\end{array}
$$

The following procedures perform the required transformation and produce a transformed image.

```
COMPUTE PC1=BLUE*t11 + GREEN*t21 + RED*t31 + IR*t41.
COMPUTE PC2=BLUE*t12 + GREEN*t22 + RED*t32 + IR*t42.
COMPUTE PC3=BLUE*t13 + GREEN*t23 + RED*t33 + IR*t43.
COMPUTE PC4=BLUE*t14 + GREEN*t24 + RED*t34 + IR*t44.
WRITE VAR=PC1 PC2 PC3 PC4.
```

3.5.4 Correlation Check

It is necessary to check correlations of the transformed image. Correlations between any two principal component axes should be zero. The following command takes care this kind of check.

```
CORRELATION VAR=PC1 PC2 PC3 PC4.
```

3.6 Factor Analysis

The factor analysis is quite similar to the principal component analysis. When many channels are available, the factor analysis is useful in grouping them into some common factors. A data reduction process can be taken so that one common factor channel would be used instead of several channels. These common factors thus can be input into a discriminant analysis program for channel selection. The P4M program of BMDP, the FACTOR procedures of SAS and SPSS are suitable for factor analysis. Either whole image data set or its correlation matrix can be input into the FACTOR procedure in SPSS.

3.7 Discriminant Analysis

Discriminant analysis is very useful in solving problems of feature selection encountered in classifying an image with many channels. For a given number of classes to be classified, the optimal solution is to find the optimal number of channels and what kind of channels to be used (Wu, 1985).

The first step is simply to put all channels (or variables) together as shown in Sec. 2.2. The original channels, principal-component-transform channels, and textural channels all can be put into a discriminant-analysis program such as the DSCRIMINANT procedure of SPSS, the DISCRIM procedure of SAS, and the P7M program of BMDP. Usually training areas of known classes are analyzed by this program rather than the whole image data. The P7M program is very powerful.

3.8 Fast Fourier Transform and Texture Analysis

Both fast Fourier transform (FFT) and texture analysis are looking into an image in a spatial sense (Wu, 1986). A huge amount of computations are required if the FFT is performed on a personal computer. Our program written in FORTRAN took about 30 minutes to do FFT of a 64-by-64 image on the IBM PC/AT. The IMSL programs are quite powerful in doing fast Fourier transform. The power spectrum is used to display, for classification, for discriminant analysis, and for making hard copies. Gonzalez and Wintz (1987, pp.108) provided a FORTRAN subroutine for computing the fast Fourier transform.

The fast Fourier transform of an image is one kind of texture analysis. Thus, the power spectrum can be used for texture analysis. Another texture analysis such as statistical texture analysis (Wu, 1985) can be performed but a little of programming is needed.

4. CONCLUSIONS

An image processing system implemented to solve problems in remote sensing of natural resources has been developed, mainly for teaching, training, and research, at The National Chung Hsing University. This image processing system does exist every where and can be made easily. It can be configured as the way one likes. The users should pay attentions on how to modify those image processing procedures in order to perform image enhancement, classification, fast Fourier transform, principal component analysis, factor analysis, discriminant analysis and texture analysis. This system is still being expended to be more user friendly and more powerful.

5. ACKNOWLEDGMENTS

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