

AD-A101 072 SOUTHEASTERN MASSACHUSETTS UNIV NORTH DARTMOUTH DEPT --ETC F/B 9/2
AN IMAGE PROCESSING SOFTWARE PACKAGE.(U)
JUN 81 C YEN N00018-79-C-0000

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Technical Report
OSN - 45-T-41-111
Contract Number N00014-77-0-0004
June 1978

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6 AIR TRACON PROCEEDINGS

SOFTWARE PACKAGE

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10/ Johnson, Peter

Department of Electrical Engineering
Northeastern Massachusetts University
North Dartmouth, Massachusetts 01947

Principal Investigator: Dr. C. L. Chen

The report of the Statistics and Probability Group of the Office of Naval Research on this report is hereby acknowledged.

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AN IMAGE PROCESSING SOFTWARE PACKAGE

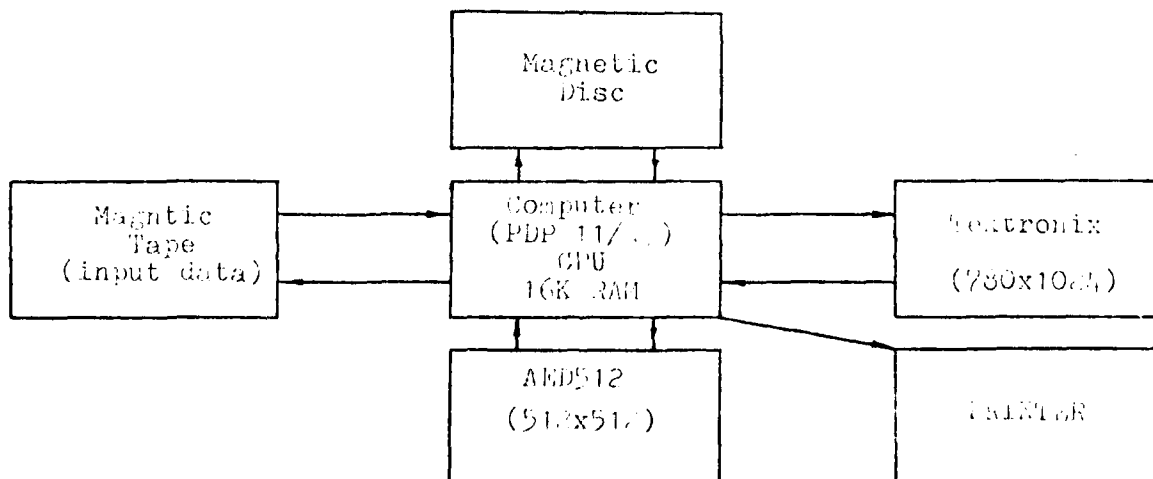
Chihsun, Yen

1. Introduction

Modern technology utilizes all types of pictures, or images, as sources of information for interpretation and analysis. These may be portions of the earth's surface viewed from an orbiting satellite or reconnaissance plane, the inner composition of a complex organic structure seen with the aid of X-rays or microscope. The proliferation of the pictorial data bases has created the need for a vision-based automation that can rapidly, accurately, and cost effectively extract the useful information contained in images. These requirements are being met through the new technology of image processing. The purpose of this report is to introduce the utilities that we have for using image processing and computer results by using some basic image processing functions. A software package is developed and described in detail in the report.

1.1 Utilities

The whole system used to produce the results described herein is shown in the Block Diagram.



A mini-computer (IBM 11/45) with a magnetic disc memory for the storage of pictures receives input data from the magnetic tape. Output data in the form of processed images are stored in the magnetic disc files and displayed on the Tektronix terminal with 2-level or on the ABB12 terminal with the color 16-level or on the printer with 16-level. Control of the image processing functions is made through the Tektronix or ABB12 keyboard. Data and reports are printed on the printer or displayed on the screens.

1.2 Data sources

The principal image data are provided by

- i Alabama data base (infrared images)
- ii USC data base
- iii Reconnaissance images
- iv Topographic images.

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1.3 How to used this package?

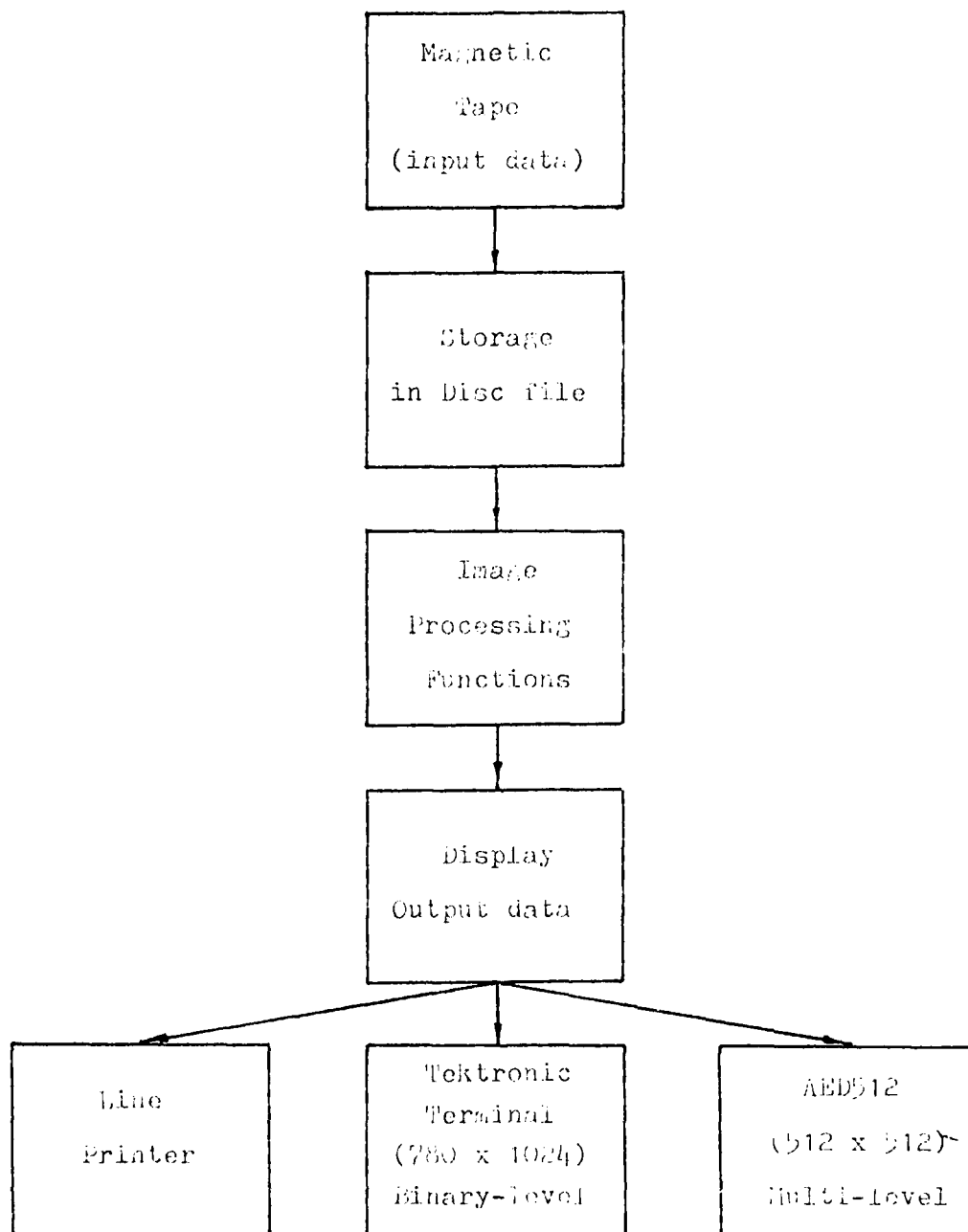
All the program listings are in the Appendix. Next page block diagram is shown how to used this package.

1.4 Some basic image processing functions

a. Histogram Equalization (1,2)

For many classes of images, in general, the ideal distribution of gray levels is a uniform distribution. A uniform distribution of gray levels makes equal use of each quantization level and tends to enhance low-contrast information. To use this transformation we may

- i compute the histogram of the image gray level values,



- ii add up the histogram values to obtain a distribution curve, and
- iii use this distribution curve for the gray level transformation $G = T(f)$

where G : transferred gray level value

T : transformation symbol

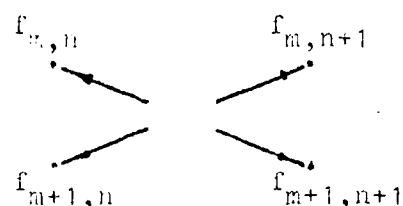
f : original gray level value

b. Robert Gradient Operator (3)

$$d_1 = f_{m,n} - f_{m+1,n+1}$$

$$d_2 = f_{m+1,n} - f_{m,n+1}$$

$$G(m,n) = (d_1^2 + d_2^2)^{\frac{1}{2}}$$



where $f_{m,n}$ is the gray level of point (m,n) ,

$G(m,n)$ is Robert gradient of point (m,n) .

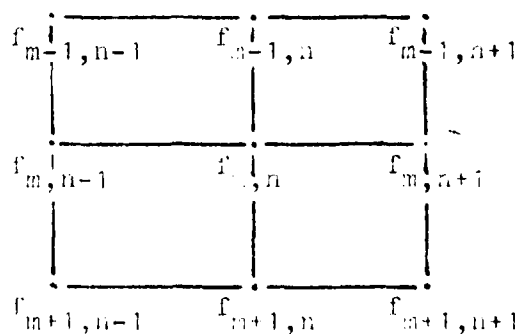
c. Sobel Operator (3)

$$d_X = (f_{m-1,n-1} + 2f_{m,n-1} + f_{m+1,n-1}) - (f_{m-1,n+1} + 2f_{m,n+1} + f_{m+1,n+1})$$

$$d_Y = (f_{m+1,n-1} + 2f_{m+1,n} + f_{m+1,n+1}) - (f_{m-1,n-1} + 2f_{m-1,n} + f_{m-1,n+1})$$

$$S(m,n) = (d_X^2 + d_Y^2)^{\frac{1}{2}}$$

where $S(m,n)$ is Sobel gradient of point (m,n) .



a. Modified Gradient (4)

A modification of the conventional gradient operations for the first derivative is called modified gradient. Consider a 16-point array

A	B	C	D
E	F	G	H
I	J	K	L
M	N	O	P

The modified gradient is defined as

$$\sqrt[4]{abcd}$$

where

$$a = |F - E| + |J - G|$$

$$b = |A - I| + |M - D|$$

$$c = |B - O| + |I - H|$$

$$d = |C - K| + |E - L|$$

e. Masks (5)

Two-dimensional discrete differentiation can be performed by convolving the original image with the compass gradient masks shown in Fig. A. The compass names indicate the slope direction of maximum response. The gradient image is obtained by taking the magnitude of the output of that mask.

<u>Direction of Gradient</u>	<u>Frewitt Masks</u>	<u>Kirsch Masks</u>	<u>Three-Level Simple Masks</u>	<u>Five-level Simple Masks</u>
North	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ -1 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 5 & 5 & 5 \\ -3 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \\ -1 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$
Northwest	$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & -1 \\ 1 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 5 & 5 & -3 \\ 5 & 0 & -3 \\ -3 & -3 & -3 \end{bmatrix}$	$\begin{bmatrix} 1 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -1 \end{bmatrix}$	$\begin{bmatrix} 2 & 1 & 0 \\ 1 & 0 & -1 \\ 0 & -1 & -2 \end{bmatrix}$
West	$\begin{bmatrix} 1 & 1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & -1 \end{bmatrix}$	$\begin{bmatrix} 5 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & -3 & -3 \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & -1 \\ 1 & 0 & -1 \\ 1 & 0 & -1 \end{bmatrix}$	$\begin{bmatrix} 1 & 0 & -1 \\ 2 & 0 & -2 \\ 1 & 0 & -1 \end{bmatrix}$
Southwest	$\begin{bmatrix} 1 & -1 & -1 \\ 1 & -2 & -1 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & -3 & -3 \\ 5 & 0 & -3 \\ 5 & 5 & -3 \end{bmatrix}$	$\begin{bmatrix} 0 & -1 & -1 \\ 1 & 0 & -1 \\ 1 & 1 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & -1 & -2 \\ 1 & 0 & -1 \\ 2 & 1 & 0 \end{bmatrix}$
South	$\begin{bmatrix} -1 & -1 & -1 \\ 1 & -2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & -3 & -3 \\ -3 & 0 & -3 \\ 5 & 5 & 5 \end{bmatrix}$	$\begin{bmatrix} -1 & -1 & -1 \\ 0 & 0 & 0 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ 1 & 2 & 1 \end{bmatrix}$
Southeast	$\begin{bmatrix} -1 & -1 & 1 \\ -1 & -2 & 1 \\ 1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & -3 & -3 \\ -3 & 0 & 5 \\ -3 & 5 & 5 \end{bmatrix}$	$\begin{bmatrix} -1 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -2 & -1 & 0 \\ -1 & 0 & 1 \\ 0 & 1 & 2 \end{bmatrix}$
East	$\begin{bmatrix} -1 & -1 & 1 \\ -1 & -2 & 1 \\ -1 & 1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & -3 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & 5 \end{bmatrix}$	$\begin{bmatrix} -1 & 0 & 1 \\ -1 & 0 & 1 \\ -1 & 0 & 1 \end{bmatrix}$	$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$
Northeast	$\begin{bmatrix} 1 & 1 & 1 \\ -1 & -2 & 1 \\ -1 & -1 & 1 \end{bmatrix}$	$\begin{bmatrix} -3 & 5 & 5 \\ -3 & 0 & 5 \\ -3 & -3 & -3 \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & 1 \\ -1 & 0 & 1 \\ -1 & -1 & 0 \end{bmatrix}$	$\begin{bmatrix} 0 & 1 & 2 \\ -1 & 0 & 1 \\ -2 & -1 & 0 \end{bmatrix}$

Fig. A

f. Unsharp masking (2)

$$G(m,n) = f(m,n) - F(m,n)$$

where the function $F(m,n)$ is a local average, for example,

$$F(m,n) = \frac{1}{8} \sum_{i=-1}^1 \sum_{j=-1}^1 f(m+i, n+j), \quad i+j \neq 0$$

g. First order Markov model (6)

A first-order Autoregressive image model can be written as

$$f(m,n) - \mu_c = \beta_c ((f(m-1,n) - \mu_c) + (f(m,n-1) - \mu_c)) + N(m,n)$$

$$m = 1, 2, \dots, M$$

$$n = 1, 2, \dots, N$$

where, $N(m,n)$ is an uncorrelated Gaussian white noise process,

and μ_c is the sample mean. Rearrange the above equation to get

$$f(m,n) = \alpha_c + \beta_c (f(m-1,n) + f(m,n-1)) + N(m,n)$$

where,

$$\alpha_c = (1 - 2\beta_c)\mu_c$$

Define

$$G(m,n) = f(m-1,n) + f(m,n-1)$$

Thus

$$f(m,n) = \alpha_c + \beta_c G(m,n) + N(m,n)$$

The least mean square estimator (also the maximum likelihood estimator because of Gaussian assumption (6)) is given by

$$b = \frac{\sum_m \sum_n G(m,n) f(m,n)}{\sum_m \sum_n (G(m,n))^2}$$

$$a = \bar{f} - bG$$

where

$$F = \frac{\sum_m \sum_n f(m,n)}{MN}$$

$$G = \frac{\sum_m \sum_n g(m,n)}{MN}$$

and

$b = \hat{\beta}_c$ = the estimator of β_c

$a = \hat{\alpha}_c$ = the estimator of α_c

h. The Kalman Filter (7)

The signal model of the Kalman filter is

$$X_{K+1} = F_K X_K + G_K W_K$$

$$Z_K = Y_K + V_K = F_K^T X_K + V_K$$

where, X_0 , $\{V_K\}$, and $\{W_K\}$ are jointly Gaussian and mutually independent; X_0 is Gaussian distributed with mean $\bar{X}_0$ and covariance P_0 respectively; $\{V_K\}$ is zero mean with covariance $R_K \delta_{KL}$; $\{W_K\}$ is zero mean with covariance $Q_K \delta_{KL}$.

The filter equations of the Kalman filter is given by

$$\hat{X}_{K+1/K} = (F_K - K_K H_K^T) \hat{X}_{K/K-1} + K_K Z_K$$

$$\hat{X}_{0/-1} = \hat{X}_0$$

$$K_K = F_K \Sigma_{K/K-1} H_K^T (H_K^T \Sigma_{K/K-1} H_K + R_K)^{-1}$$

$$\Sigma_{K/K-1} = F_K \left\{ \Sigma_{K/K-1} - \Sigma_{K/K-1} H_K^T (H_K^T \Sigma_{K/K-1} H_K + R_K)^{-1} H_K \right. \\ \left. \Sigma_{K/K-1} \right\} F_K^T + G_K Q_K G_K^T$$

$$\Sigma_{0/-1} = P_0$$

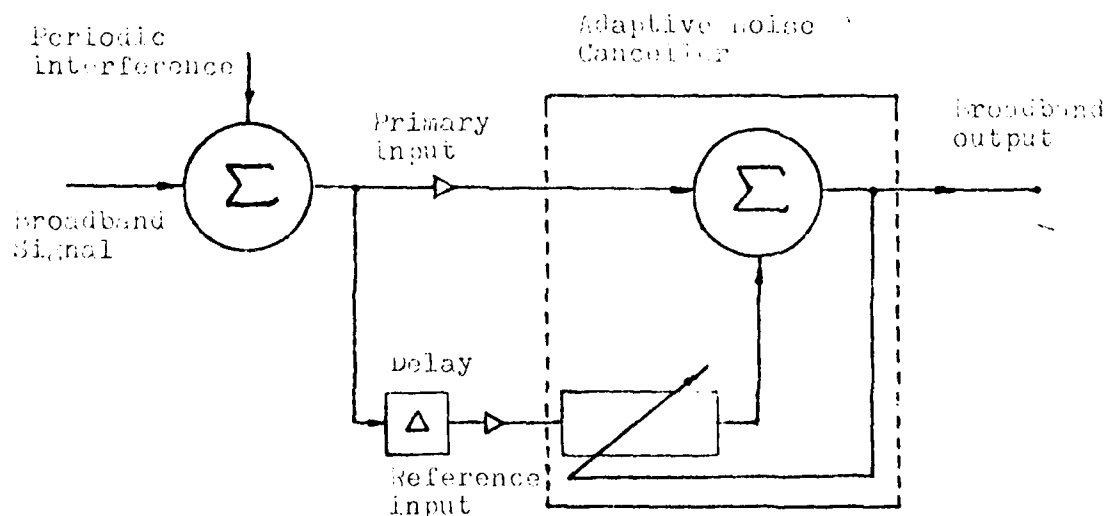
$$\hat{x}_{K/K} = \hat{x}_{K/K-1} + \Sigma_{K/K-1} h_K (h_K^T \Sigma_{K/K-1} h_K + R_K)^{-1} (y_K - h_K^T \hat{x}_{K/K-1})$$

$$\Sigma_{K/K} = \Sigma_{K/K-1} - \Sigma_{K/K-1} h_K (h_K^T \Sigma_{K/K-1} h_K + R_K)^{-1} h_K^T \Sigma_{K/K-1}$$

The Kalman filter above gives a set of recursive equations for estimating the state of a linear dynamic system. However, the Kalman filter requires a priori knowledge of all the system and noise parameters, which must be identified before using the filter. The following are useful suggestions for implementation: (Assume $K = 1$)

1. F_K , G_K , and H_K can be set as unity
 2. If the variance of additive noise is known or can be estimated, then, set the value of R_K to be the variance.
 3. Q_K is the system noise, and should be set to a value which is of the order of R ; otherwise the filtered results may be undesirable. Usually, $R_K > Q_K$.
1. Adaptive Noise Cancelling Filter (3)

Cancelling periodic interference without an external reference source model is



The input signal vector X_j is defined as

$$X_j = \begin{bmatrix} x_{0j} \\ x_{1j} \\ \vdots \\ x_{nj} \end{bmatrix}$$

The weight vector is

$$W = \begin{bmatrix} w_0 \\ w_1 \\ \vdots \\ w_n \end{bmatrix}$$

where w_0 is the bias weight

The output y_j is

$$y_j = X_j^T W = W^T X_j$$

The error e_j is defined as the difference between the desired response d_j and the actual response y_j .

$$e_j = d_j - X_j^T W = d_j - W^T X_j$$

Expanding the last equation obtains

$$e_j^2 = d_j^2 - 2d_j X_j^T W + W^T X_j X_j^T W$$

Taking the expected value of both sides yields

$$E[e_j^2] = E[d_j^2] - 2E[d_j X_j^T]W + W^T E[X_j X_j^T]W$$

defining the vector P as the cross correlation between the desired response and X vector then yields

$$P = E[d_j X_j^T]$$

The input correlation matrix R is defined as

$$R = E[X_j X_j^T]$$

The mean-square error can thus be expressed as

$$E[e_j^2] = E[d_j^2] = 2PW + 2WU$$

The gradient ∇ of the error function is obtained by

$$\nabla \hat{d} = -2P + 2WU$$

and the gradient estimate is

$$\hat{\nabla}_j = -2e_j \hat{X}_j$$

and

$$\hat{X}_{j+1} = \hat{X}_j + 2\mu e_j \hat{X}_j$$

where μ is the factor that controls stability and rate of convergence.

2. Experiments

Currently, we can display binary-level pictures on the Tektronix terminal and 16-level pictures on the AED512 terminal. In this report, all the pictures are displayed on the AED512 terminal except histogram figures. A reconnaissance image with a tank, a USC image with a cave, and a topographic image with a roadway are being used to demonstrate the capabilities of this package. Table 1 describes the number sequence of sub-pictures of Figures 1, 2 & 3.

1		1	2	1	2
		3	4	3	4
				5	6

Table 1

Figure 1a,c is original reconnaissance image with a tank.

Figure 1a.1 is equalized result. The histograms of Figure 1a are shown in the Figure 1b. Figure 1c is the results of using Prewitt masks, Kirsch masks, Three-level simple masks and Five-level simple masks, respectively. The results of using Robert gradient operator, Sobel operator and modified gradient operator are shown in the Figure 1d.2,3 & 4, respectively. Figure 1d.1 is original image. Figure 1e is the equalized results of Figure 1d except original image. Figure 1f.3-6 is the computer results of using 1st order ARMA model, Adaptive filter, Kalman filter with horizontal processing, and Kalman filter with vertical processing, respectively. Figure 1f.1 is original image. Figure 1f.2 is additive white Gaussian noise with variance 15 and zero mean. The histograms of Figure 1f are shown in the Figure 1g. The sequence of Figure 2 is same as Figure 1 except that the scene is the topographic image with a roadway and the variance of additive noise is 30. Almost the sequence of Figure 3 is also same as Figure 1 except that the scene is the USC image with a cave and the Figure 3c is the computer results of using unsharp masking technique.

3. Conclusion Remarks

Currently, we can only display 16-level pictures with any color, for example, Figure 8. In the next couple weeks, additional memory planes will be added to the AED512 terminal to display all 256 gray levels and the full color pictures. We also plan to add more advanced image processing functions in this package in the near future.

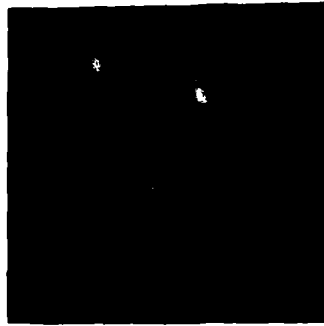


Fig. B

4. Acknowledgements

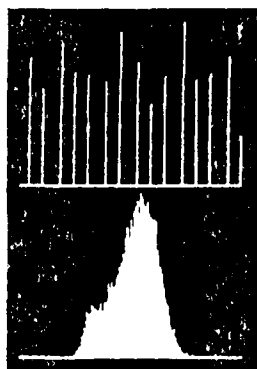
I would like to express my sincere thanks to Professor Peng-Fei Li for his suggestion in the adaptive noise cancelling filter.

Reference:

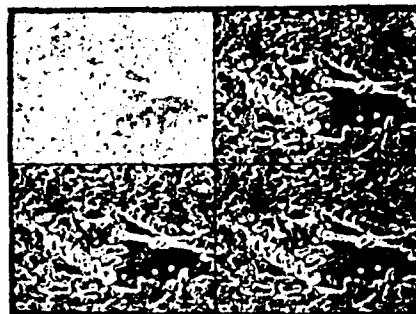
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Proceedings, Vol. 63, No. 12, December 1975.



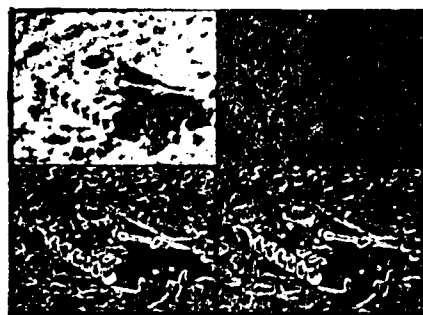
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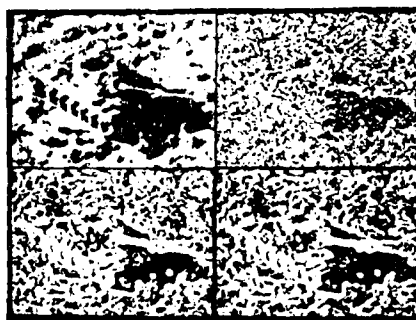
1b



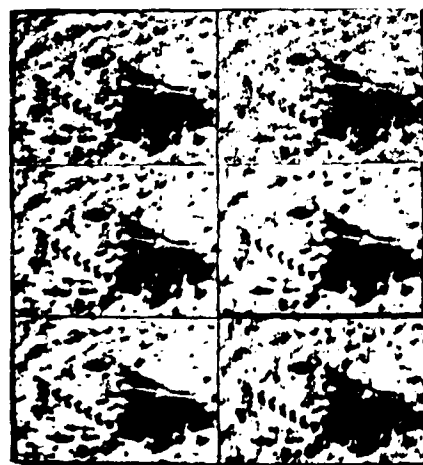
1c



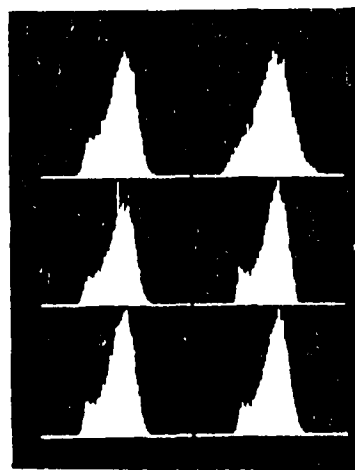
1d



1e



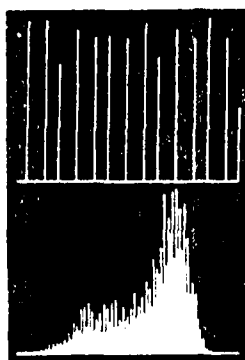
1f



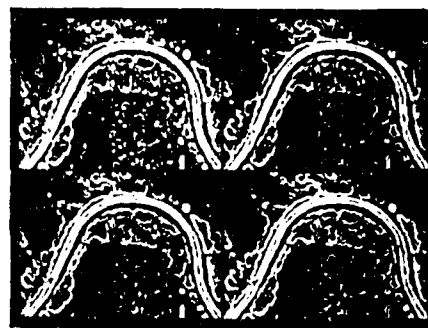
1g



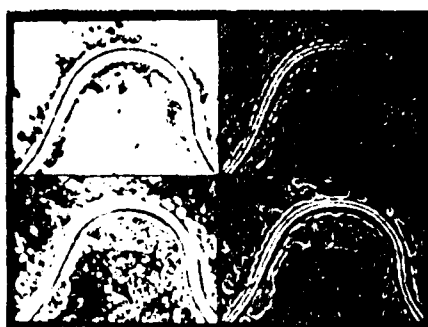
2a



2b



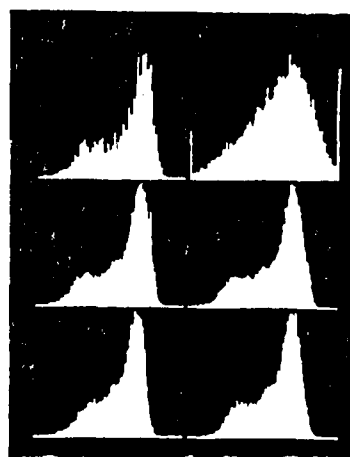
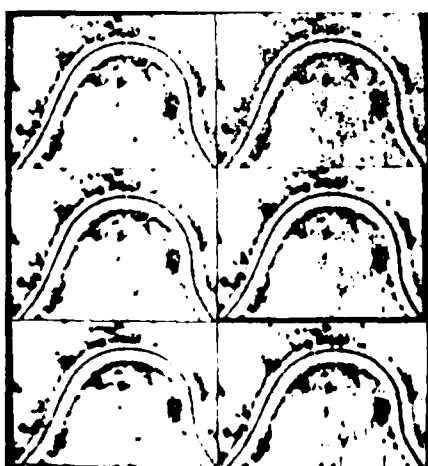
2c

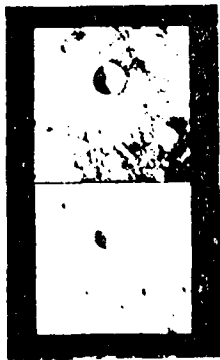


2d

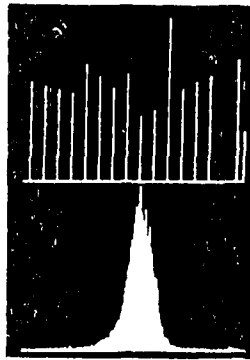


2e

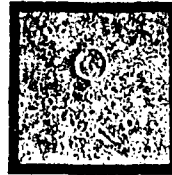




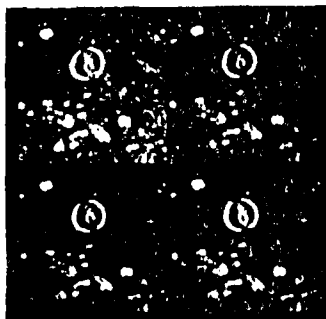
3a



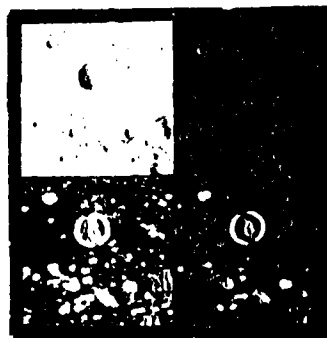
3b



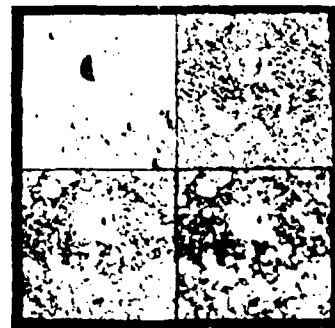
3c



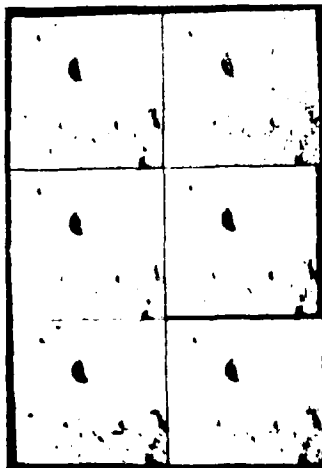
3d



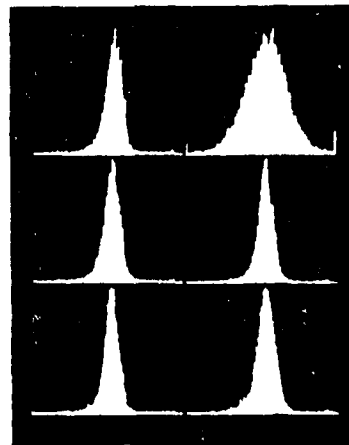
3e



3f



3g



3h

Appendix:

A.1 Introduction

The computer programs listed in this appendix were coded in FORTRAN on the IDP-11/45 Minicomputer system monitored under RT-11 operating system.

A.2 Programs

I STORAG.FOR

To storage the image from Magnetic tape to disc file.

II FMXFM1.FOR

To find out the maximum and minimum from a file.

III DISPLAY.FOR

To display the image on the AED512 terminal.

IV SETCOR.FOR

For set color table of AED512.

V HISTOG.FOR

To compute the histogram curve of a file and display on the Tektronix terminal.

VI ROBERT.FOR

The Robert gradient operator.

VII CUBEL.FOR

The Sobel operator.

VIII MODGRD.FOR

The modified gradient operator

IX EQ.FOR

The histogram equalization function.

- X PREWITT.FOR
 The Prewitt masks.
- XI LOCAL.FOR
 The unsharpening masks function.
- XII THSHO.FOR
 The simple thresholding function.
- XIII ANOS.FOR
 The adding Gaussian noise function.
- XIV ALPHA.FOR
 To compute coefficients for 1st order ARMA model.
- XV ARMA.FOR
 The 1st order ARMA model
- XVI KALMAN.FOR
 The Kalman Filter for horizontal processing.
- XVII VH.FOR
 The Kalman filter for vertical processing.
- XVIII ADPT.FOR
 The adaptive noise cancelling filter.

1.

```

C
C NAME: F1024.FOR
C PSGR: ROBERT C. YEH
C DATE: APR. 10, 1981
C
INTEGER F(1024)
WRITE(5,10)
10 FORMAT(5X,'1/P SOL,ROP,ROF,ROF'/)
READ(5,10) SOL,ROP,ROF,ROF
20 FORMAT(51A)
DEFINE LINE ROF(SOL,ROP,0,LINE)
WRITE(5,30)
30 FORMAT(5X,'1/P LINE1,LINEF,IPX1,IPXF,IORIGL'/)
READ(5,30) LINE1,LINEF,IPX1,IPXF,IORIGL
40 FORMAT(51B)
LINE=1
DO 40 I=1, IORIGL
CALL PRADUR(F, I, LINE)
IF(I.EQ.LINE1.OR.I.EQ.LINEF)GO TO 50
WRITE(ROF'LINE')(F(K),K=IPX1,IPXF)
50 CONTINUE
CALL FILL
CALL EXIT
END

```

II.

```

C
C NAME: FMAXMI.FOR
C PSGR: ROBERT C. YEH
C DATE: APRIL 10, 1981
C
INTEGER F(1024)
WRITE(5,5)
5 FORMAT(5X,'1/P SOL,ROP,ROF'/)
READ(5,10) SOL,ROP,ROF
10 FORMAT(51B)
DEFINE LINE ROF(SOL,ROP,0,LINE)
LINE=1
READ(ROF'LINE')(F(K),KK=1,ROP)
IMAX=F(1)
IMIN=F(1)
DO 40 I=1, SOL
LINE=1
READ(ROF'LINE')(F(K),K=1,ROP)
DO 30 J=1,ROP
IF(F(J).GT.IMAX)IMAX=F(J)
IF(F(J).LT.IMIN)IMIN=F(J)
30 CONTINUE
40 CONTINUE
WRITE(5,40) IMAX,IMIN
50 FORMAT(//5X,2110)
CALL EXIT
END

```

III.

```

C
C      NAME: L14001.FOR
C      AUTHOR: ROBERT C. YEN
C      DATE: APRIL 25, 1981
C
      INTEGER F(10,4)
      DIMENSION(5,10)
10    FORMAT(/X,'I/P ROL,ROP,ROF,IX,IY,LEN,FMIN/')
      READ(5,10)ROL,ROP,ROF,IX,IY,LEN,FMIN
20    FORMAT(10,4F12.5)
      DEFINE FILE ROP(ROL,ROP,LEN,FMIN)
      IIX=IX
      IIY=IY
      CALL GRABOP
      DO 40 I=1,ROL
      LII=-I
      READ(ROP,LII,5)(F(K),K=1,ROP)
      DO 30 J=1,ROP
      ICOLOR=100*((FLOAT(F(J))-FMIN)*11./LEN)
      CALL PLOT3(IIX,IIY,ICOLOR)
      IIX=IIX+1
30    CONTINUE
      IIX=IX
      IIY=IIY-1
40    CONTINUE
      CALL AROF
      CALL AROF
      CALL EXIT
      END

```

IV.

```

C
C      NAME: L14002.FOR
C      AUTHOR: ROBERT C. YEN
C      DATE: APRIL 25, 1981
C
      DIMENSION LRGB(10,5),RATIO(5)
      TYPE 10
10    FORMAT(/X,'ENTER 5 KEYB NO. FOR INTENSITY LEVELS OF RED,
1 GREEN, BLUE :'/)
      ACCEPT 10, (RATIO(K),K=1,5)
20    FORMAT(5F12.5)
      RMAX=RATIO(1)
      DO 30 I=2,5
      IF(RATIO(I).LT.RMAX)RMAX=RATIO(I)
30    CONTINUE
      DO 40 I=1,5
      RATIO(I)=RATIO(I)/RMAX
40    CONTINUE
50    FORMAT(/X,'ENTER N WHICH IS INDEX OF M=L*N, AND N IS
1 TO 10. OF INTENSITY LEVELS'/)
      ACCEPT 60,N

```

```

60      P=K*AT(15)
      IF(L.E..5)H=1
      IF(L.N..5)H=J**K
      P=P*./H*AT(N-1)
      ID=1./H
      DO 90 I=1,5
      DO 80 J=1,M
      DO 70 K=1,10
      K=(J-1)*10+K
70      INGR(K,1)=INT(RATIO(1)*ID*(J-1))
80      CONTINUE
90      CONTINUE
      TYPE 100
100     FORMAT(/17X,'RED'                GREEN'          BLUE'/)
      TYPE 110,((CIRGR(1,J),J=1,5),I=1,16)
110     FORMAT(5X,3I15)
      ACCEPT 120,JURK
120     FORM T(1)
      CALL GETHOD
      DO 130 J=1,16
      CALL COMTAB(J-1,INGR(J,1),INGR(J,2),INGR(J,3))
130     CONTINUE
      CALL ARIOD
      CALL BELL
      CALL EXIT
      END

```

V.

```

C
C      NAME: HISTOG.FOR
C      PRGM: ROBERT C. YEN
C      DATE: JULY12, 1981
C
      REAL HK(2048),HY(2048),HZ(256)
      INTEGER F(512)
      TYPE 10
10      FORMAT(/5X,'1/P RCL,ROP,LOF,ROG'/)
      ACCEPT 20,ROL,ROR,NOL,NOF,ROG
20      FORMAT(4I5)
      TYPE 110
110     FORMAT(/5X,'1/P 1X1,1XF,1Y1,1YF'/)
      ACCEPT 120,1X1,1XF,1Y1,1YF
120     FORMAT(4I10)
      DEFINE FILE ROF(ROL,ROR,C,LINE)
      DO 30 I=1,2048
      HY(I)=0.
      HK(I)=F*AT(1)
30      CONTINUE
      DO 35 I=1,ROG
35      HZ(I)=0.
      DO 40 J=1,NOL
      LINE=J
      READ(ROF,LINE)(F(K),K=1,ROP)

```

```

      CALL HISTOG(F,IN,ROP)
40    CONTINUE
      IG=CHS/IN
      DO 50 I=1,IG
      IS=(I-1)*IG+1
      RY(11)=IF(1)
50    CONTINUE
      CALL RSTROT(IX,RY,ZOAS,IX1,IXF,IY1,IYF)
      CALL EXIT
      AND
      CALL ROTIN HISTOG(F,IY,INL)
      RY(1)
      IY=INL-F(1)
      DO 10 I=1,INL
      J=F(1)
      RY(J)=RY(J)+1.
10    CONTINUE
      RETURN
      END

```

VI.

```

C
C      NAME: ROBERT.FOR
C      PRGR: ROBERT C. YER
C      DATE: MAY 10, 1981
C
      INTEGER F1(12),F2(12),G(12)
      TYPE 10
      PROGRAM('1/P-ROL,ROP,ROF1,ROF2')
      ACCEPT 20,*,ROL,ROP,ROF1,ROF2
20    PROGRAM(110)
      DEFLEN F1=ROF1(ROL,ROP,0,LL1)
      LOL1=ROL+1
      LOP2=ROP+1
      DEFLEN F2=ROF2(ROL,LOP2,0,LL1)
      DO 100 I=1,LOL2
      LL1=1
      READ(5,F1'LL1')(F1(K),K=1,LOP)
      LL1=I+1
      READ(5,F2'LL1')(F2(K),K=1,LOP)
      DO 50 J=1,LOP2
      X=FLOAT(F1(J)-F2(J+1))
      XS=X*X
      Y=FLOAT(F1(J+1)-F2(J))
      YL=Y*Y
      ZY=SQRT(XL+YL)
      IF(.NOT.(ZY.EQ.0.))ZY=256.
      IF(XY.LT.1.)ZY=1.
      G(J)=INT(ZY)
50    CONTINUE
      LL1=2+1
      WRITE(ROF1'LL1')(G(K),K=1,LOL2)
100   CONTINUE
      CALL EXIT
      END

```



```

151=15+1
152=15+2
CALL CHARGE(F1(15),F1(151),F1(152),F(15),F1(151),F2(152)
1,F3(15),F3(151),F3(152),5)
CALL HL(3,50,X(1))
CALL HL(3,51,X(2))
CALL HL(3,52,X(3))
CALL HL(3,53,X(4))
CALL HL(3,54,X(5))
CALL HL(3,55,X(6))
CALL HL(3,56,X(7))
CALL HL(3,57,X(8))
CALL HL(3,58,X(9))
G(15)=1
50 CONTINUE
LIMIT=15
WRITE(10F2'FILE')(G(K),K=1,NOP2)
CALL CHL
40 CALL CHL
CALL EXIT
END
SUBROUTINE CHARGE(H1,H2,H3,H4,H5,H6,I7,N8,I9,L)
INTEGER L(1)
L(1)=51
L(2)=52
L(3)=53
L(4)=54
L(5)=55
L(6)=56
L(7)=57
L(8)=58
L(9)=59
RETURN
END
SUBROUTINE HL(I,K,N)
INTEGER L(1),H(1)
L=0
DO 10 I=1,9
H=H+3(1)-L(1)
10 CONTINUE
RETURN
END
SUBROUTINE MAXVAL(X,M)
INTEGER X(1)
N=X(1)
DO 10 I=2,M
10 IF(X(I).GT.N)N=X(I)
CONTINUE
RETURN
END

```

XI.

```

C
C NAME: LOCAL.FOR
C PRGR: ROBERT C. YEN

```

```

C      DATE: JUNE 28, 1981
C
      INTEGER F1(512),F2(512),F3(512),G(512)
      TYPE 10
10     FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2'/)
      ACCEPT 20,NOL,NOP,NOF1,NOF2
20     FORMAT(4I10)
      DEFINE FILE NOF1(NOL,NOP,U,LINE1)
      NOL2=NOL-2
      NOP2=NOP-2
      DEFINE FILE NOF2(NOL2,NOP2,U,LINE2)
      DO 60 I6=1,NOL2
      LINE1=I6
      READ(NOF1'LINE1')(F1(K),K=1,NOP)
      READ(NOF1'LINE1')(F2(K),K=1,NOP)
      READ(NOF1'LINE1')(F3(K),K=1,NOP)
      DO 50 I5=1,NOP2
      I52=I5+2
      ISUM=0
      DO 30 I3=I5,I52
      ISUM=ISUM+F1(I3)
      DO 40 I4=I5,I52
      ISUM=ISUM+F3(I4)
      ISUM=ISUM+F2(I5)+F2(I52)
      SUM=FLOAT(ISUM)*.125
      ISUM=INT(SUM)
      III=F2(I5+1)-ISUM
      G(I5)=256-III
50     CONTINUE
      LINE2=I6
      WRITE(NOF2'LINE2')(G(K),K=1,NOP2)
      CALL BEHL
      CALL EXIT
      END

```

XII.

```

C
C      NAME: TRCHO.FOR
C      PRGR: ROBERT C. YEN
C      DATE: JUNE 28, 1981
C
      INTEGER F(512),G(512),TH
      TYPE 10
10     FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2,TH'/)
      ACCEPT 20,NOL,NOP,NOF1,NOF2,TH
20     FORMAT(5I10)
      DEFINE FILE NOF1(NOL,NOP,U,LINE1)
      DEFINE FILE NOF2(NOL,NOP,U,LINE2)
      DO 40 I4=1,NOL
      LINE1=I4
      READ(NOF1'LINE1')(F(K),K=1,NOP)
      DO 30 I3=1,NOP
      IF(F(I3).GT.TH)G(I3)=256
      IF(F(I3).LE.TH)G(I3)=1

```

```

30      CONTINUE
        LINE2=14
        WRITE(NOF2,'LINE2')(G(K),K=1,NOP)
        CALL BELL
40      CONTINUE
        CALL EXIT
        END

```

XIII.

```

C
C      NAME: ANOS.FOR
C      PRGR: ROBERT C. YEN
C      DATE: MAY 24, 1981
C
        INTEGER F(512)
        TYPE 10
10      FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2,VAR,I1,I2'/)
        ACCEPT 20,NOL,NOP,NOF1,NOF2,VAR,I1,I2
20      FORMAT(4I10,F12.5,2I10)
        DEFINE FILE NOF1(NOL,NOP,U,LINE1)
        DEFINE FILE NOF2(NOL,NOP,U,LINE2)
        DO 40 I=1,NOL
            LINE1=I
            READ(NOF1,'LINE1')(F(K),K=1,NOP)
            DO 30 J=1,NOP
                CALL GAUSS(S,VAR,I1,I2)
                IFN=F(J)+INT(S)
                IF(IFN.GT.256.OR.IFN.LT.1)IFN=F(J)
                F(J)=IFN
30          CONTINUE
            LINE2=I
            WRITE(NOF2,'LINE2')(F(K),K=1,NOP)
            CALL BELL
40          CONTINUE
            CALL EXIT
            END
        SUBROUTINE GAUSS(T,S,I1,I2)
            T=0.
            DO 10 I=1,40
                T=T+RAN(I1,I2)
10          CONTINUE
            T=T-24.
            T=T*.5
            T=T*S
            RETURN
        END

```

XIV.

```

C
C      NAME: ALPHA.FOR
C      PRGR: ROBERT C. YEN

```

```

C      DATE: MAY 1, 1981
C
      INTEGER F(512), PF(512)
      TYPE 10
10     FORMAT(/5X, 'I/P NOL,ROP,NOF'/)
      ACCEPT 20, NOL, ROP, NOF
20     FORMAT(3110)
      DEFINE FILE NOF(NOL,ROP,U,LINE)
      C1=0.
      C2=0.
      C3=0.
      C4=0.
      C5=0.
      C6=0.
      C7=0.
      D=FLOAT(NOL-1)*FLOAT(ROP-1)
      LINE=1
      READ(NOF'LINE')(PF(K),K=1,ROP)
      DO 50 J=2,NOL
      READ(NOF'LINE')(F(K),K=1,ROP)
      DO 30 I=2,ROP
      C1=FLOAT(F(I))+C1
      C2=FLOAT(F(I-1))+FLOAT(PF(1))+C2
      C3=FLOAT(F(I-1))*FLOAT(F(I))+C3
      C4=FLOAT(PF(1))*FLOAT(F(I))+C4
      C5=FLOAT(F(I-1))*FLOAT(F(I-1))+C5
      C6=FLOAT(F(I-1))*FLOAT(PF(1))+C6
      C7=FLOAT(PF(1))*FLOAT(PF(1))+C7
30     CONTINUE
      DO 40 K=1,ROP
40     PF(K)=F(K)
50     CONTINUE
      BETA=(C3+C4)/(C5+2.*C6+C7)
      XMEAN=C1/D
      ZMEAN=C2/D
      ALPHA=XMEAN-BETA*ZMEAN
      TYPE 60, ALPHA, BETA
60     FORMAT(/5X, 'ALPHA=', F15.5, 5X, 'BETA=', F15.5/)
      CALL BEH1
      CALL EXIT
      END

```

XV.

```

C
C      NAME: ARMA.FOR
C      PRGR: ROBERT C. YEN
C      DATE: MAY 1, 1981
C
      INTEGER F(512), PF(512)
      TYPE 10
10     FORMAT(/5X, 'I/P NOL,ROP,NOF1,NOF2,ALPHA,BETA'/)
      ACCEPT 20, NOL, ROP, NOF1, NOF2, ALPHA, BETA
20     FORMAT(415, 2F12.5)
      DEFINE FILE NOF1(NOL,ROP,U,LINE1)
      COL2=NOL-1

```

```

      DEFINE FILE NOF2(NOL2,NOP,U,LINE2)
      LINE1=1
      READ(NOF1'LINE1')(PF(K),K=1,NOP)
      DO 40 I=2,NOL
      LINE1=I
      READ(NOF1'LINE1')(F(K),K=1,NOP)
      CALL AUTO(ALPHA,BETA,F,PF,NOP)
      LINE1=1
      READ(NOF1'LINE1')(PF(K),K=1,NOP)
      DO 50 J=1,NOP
      IF(F(J).GT.256)F(J)=256
      IF(F(J).LT.1)F(J)=1
30      CONTINUE
      LINE2=I-1
      WRITE(NOF2'LINE2')(F(K),K=1,NOP)
40      CONTINUE
      CALL EXIT
      END
      SUBROUTINE AUTO(ALPHA,BETA,F,PF,NP)
      INTEGER F(1),PF(1)
      REAL PF(512)
      DO 10 I=2,NP
      RF(1)=ALPHA+BETA*(FLOAT(F(I-1))+FLOAT(PF(I)))
10      CONTINUE
      RF(1)=RF(2)
      DO 20 I=1,NP
      F(I)=INT(RF(I))
20      CONTINUE
      RETURN
      END

```

XVI.

```

C
C      NAME: KALMAN.FOR
C      PRGR: ROBERT C. YEN
C      DATE: MAY 1, 1981
C
      INTEGER F(512)
      TYPE 10
10      FORMAT(/5X,'1/I' NOL,NOP,NOF1,NOF2'/)
      ACCEPT 20,NOL,NOP,NOF1,NOF2
20      FORMAT(4I10)
      TYPE 30
30      FORMAT(/5X,'1/P' FKL,GKL,HKL,BKL,QKL,XKL,FKL'/)
      ACCEPT 40,FKL,GKL,HKL,BKL,QKL,XKL,FKL
40      F=FLOAT(NOF2.5)
      DEFINE FILE NOF1(NOL,NOP,U,LINE1)
      DEFINE FILE NOF2(NOL,NOP,U,LINE2)
      DO 50 I=1,NOL
      LINE1=I
      READ(NOF1'LINE1')(F(K),K=1,NOP)
      CALL KALMAN(F,NOP,FKL,GKL,HKL,BKL,QKL,XKL,FKL)
      LINE2=I
      WRITE(NOF2'LINE2')(F(K),K=1,NOL)
      CALL BELL

```

```

50      CONTINUE
      CALL EXIT
      END
      SUB ROUTINE KALM N(Y,NF,F,G,H,Q,XI,PI)
      INTEGER Y(1)
      Z=FLOAT(Y(1))
      GAIN=F*PI*H/(H*PI*H+R)
      XN=(F-GAIN*H)*XI+GAIN*Z
      PN=F*(PI-PI*H/(H*PI*H+R)*H*PI)*F+G*Q*G
      K=XI+PI*H/(H*PI*H+R)*(Z-H*XI)
      Y(1)=INT(X)
      XO=XN
      PO=PN
      DO 10 K=2,NF
      Z=FLOAT(Y(K))
      GAIN=F*PO*H/(H*PO*H+R)
      XN=(F-GAIN*H)*XO+GAIN*Z
      PN=(F-GAIN*H/(H*PO*H+R)*H*PO)*F+G*Q*G
      X=XO+PO*H/(H*PO*H+R)*(Z-H*XO)
      Y(K)=INT(X)
      XO=XN
      PO=PN
10      CONTINUE
      RETURN
      END

```

XVII.

```

C
C      NAME: VII.FOR
C      PRGR: JOLENT C. YEN
C      DATE: MAY 1, 1981
C
      INTEGER F(512),A(512)
      TYPE 10
10      FORMAT(/5X,'I/P NOL,NOP,NOF1,NOF2'/)
      ACCEPT 30,NOL,NOP,NOF1,NOF2
20      FORMAT(4I10)
      TYPE 30
30      FORMAT(/5X,'I/P FKL,GKL,HKL,XKL,RV,QV,PIV'/)
      ACCEPT 40,FKL,GKL,HKL,XKL,RV,QV,PIV
40      FORMAT(10F12.5)
      DEFINE FILE NOF1(NOL,NOP,*,LINE1)
      DEFINE FILE NOF2(NOF,NOL,*,LINE2)
      DO 70 J=1,NOP
      DO 50 I=1,NOL
      LINE1=I
      READ(NOF1'LINE1')(F(K),K=1,NOP)
      A(1)=F(J)
50      CONTINUE
      CALL KALM(N,NOP,FKL,GKL,HKL,RV,QV,XKL,PIV)
      LINE2=J
      WRITE(NOF2'LINE2')(A(K),K=1,NOL)
      CALL DELL
70      CONTINUE
      CALL EXIT
      END

```

XVIII.

```

C
C      DATE: 10PT.FOR
C      PRG:  ROBERT C. YEN
C      DATE: MAY 10, 1981
C
      INTEGER A1(256),A2(256),A3(256),A4(256),A5(256),A6(256)
      DOUBLE PRECISION C,D,I,D1,D2,A,B(256),G(50),W(50)
      DOUBLE PRECISION B1(256),B2(256),B3(256),B4(256),B5(256)
      TYPE 10
10      FORMAT(/5X,'I/P  NOL,NOP,NOP1,NOP2'/)
      ACCEPT 20,NOL,NOP,NOP1,NOP2
20      FORMAT(4I10)
      TYPE 30
30      FORMAT(/5X,'I/P  W1,WK,D1'/)
      ACCEPT 40,W1,WK,D1
40      FORMAT(3F12.5)
      DEFINE FILE NOP1(NOL,NOP,0,LINE1)
      M=5
      NOL2=NOL-M+1
      NOP2=NOP-M+1
      DEFINE FILE NOP2(NOL2,NOP2,0,LINE2)
      N1=(M+1)/2
      Z=0.00
      DO 130 K=2,32
      G(1)=.1
130      G(K)=WK
      DO 500 I=1,NOL2
      LINE1=I
      READ(NOP1'LINE1')(A1(IK),IK=1,NOP)
      READ(NOP1'LINE1')(A2(IK),IK=1,NOP)
      READ(NOP1'LINE1')(A3(IK),IK=1,NOP)
      READ(NOP1'LINE1')(A4(IK),IK=1,NOP)
      READ(NOP1'LINE1')(A5(IK),IK=1,NOP)
      DO 300 L=1,NOP
      B1(L)=A1(L)
      B2(L)=A2(L)
      B3(L)=A3(L)
      B4(L)=A4(L)
      B5(L)=A5(L)
300      CONTINUE
      DO 750 L=1,NOP2
      DO 800 K=1,M
      G(K)=B1(L+K-1)
      G(K+M)=B2(L+K-1)
      G(K+2*M)=B3(L+K-1)
      G(K+3*M)=B4(L+K-1)
      G(K+4*M)=B5(L+K-1)
800      CONTINUE
      M2=M*M
      DO 810 K=1,M2
810      C=C+G(K)
      C=C/M2
      DO 820 K=1,M2
820      G(K)=G(K)-C
      DO 840 K=1,M2
840      Z=Z+W(K)*G(K)

```

```
      B=G((M2+1)/2)-.5  
830    B(K)=B(K)+E*D1*B(K)  
      G((M2+1)/2)=0.00  
      E(1)=B+G-GN/2.00  
      G=0.00  
750    G=0.00  
      DO 240 L=1,NOF2  
      A6(L)=100000*(B(L))  
240    CONTINUE  
      LIND2=1  
      WRITE(60FC'LINE2')(A6(IK),IK=1,NOF2)  
      CALL FILL  
100    CONTINUE  
900    CALL EXIT  
      END
```

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