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Two Dimensional Recursive Digital Filters  
for Near Real Time Image Processing

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### Abstract

This program was specifically oriented toward the demonstration of the feasibility of using two dimensional recursive digital filters for subjective image processing applications that require rapid turn around. The concept of the use of a dedicated minicomputer for the processor for this application was also to be demonstrated. The minicomputer used was the HP1000 series E with a RTE II disc operating system and 32K words of memory. A Grinnel 256 X 512 X 8 bit display system was used to display the images.

Sample images were provided by NASA Goddard on a 800 BPI, 9 track tape. Four 512 X 512 images representing 4 spectral regions of the same scene were provided. These images were filtered with enhancement filters developed during this effort and returned to NASA Goddard for further analysis.

#### 1.0 INTRODUCTION

The goal of this program was to develop algorithms to be used in the laboratory on a near real time basis to enhance the capability of a trained observer to obtain geologically interesting information from Landsat satellite imagery. Each Landsat image is recorded with 4 separate spectral bands: 3 in the visible and 1 in the infrared. Thus each scene to be processed is composed of 4 images. Four such images of a scene of interest was provided by NASA Goddard as test images for the program. Each image was provided with 512 rows of 512 pixels per row and 8 bits per pixel.

The objectives of the program were to develop software to implement previously designed two dimensional recursive digital filters on the Department of Electrical Engineering's HP1000 computer system [3]. These filtering algorithms were to be used in an evaluation of the feasibility of their use to

aid the extraction of geologically interesting data from Landsat images. The sample images were to be processed and provided to NASA Goddard for analysis and evaluation.

It was not an objective of this program to approach near real time performance because there was no opportunity to optimize the system hardware for this purpose. A pipeline or array processor would have to be added to improve the computational capability of the system. However, the performance of the system could be used to assess feasibility of further research and development in this area.

## 2.0 BACKGROUND

Digital filters can be classified as being of two basic types: transform domain filters and time or spatial domain filters. The filtering process is performed in the frequency or transform domain with transform domain filters. The transforms of the signal to be filtered and the impulse response of the desired filter are multiplied to form the transform of the output signal. The inverse transform of the result provides the filtered output signal. Thus any filtering operation requires two transform operations and a multiplication operation. The Discrete Fourier (DFT) is commonly used for most transform domain filtering operations. The Fast Fourier Transform (FFT) algorithm provides a means of implementing the DFT in a computationally efficient manner. Time or spatial domain digital filters do not require a transform process. The filtering is done by taking a weighted average of input and past output values to compute the current output.

There are basically two types of image enhancement: subjective image enhancement and image correction. In subjective image enhancement, the object is to process the image in such a way as to make an improvement in its

appearance or ability to transfer information in some way. If this type of image enhancement is of interest, the user should have available a multitude of general purpose image processing functions. These would include (but not be limited to) low pass filters, high pass filters, low and high frequency enhancement filters, line enhancement filters and line suppression filters. Most of these filtering operations can effectively be accomplished by two dimensional spatial domain digital filters. There is no inherent need to obtain the DFT in the filtering process.

Spatial domain filtering using digital recursive filters offers savings in computation time and core requirements over the use of transform methods to achieve the same filtering process [1]. This is accomplished for many filtering operations with no sacrifice in the quality of the output. Therefore, it is advantageous to use recursive digital filters for those functions for which appropriate filtering algorithms can be developed.

Spatial domain filtering using digital nonrecursive filters offer advantages over both recursive digital filters and FFT digital filters when the number of filter coefficients are relatively small. However, the filters available that meet this requirement are limited. For this reason, nonrecursive digital filters can only be applied to special cases for use in near real time processing. In general, it requires a greater number of coefficients to realize a particular impulse response for nonrecursive digital filters than for recursive digital filters.

Image correction requires a much more complicated filtering process in general than does subjective image processing. The object is to make corrections for distortion, blurring, smearing, etc., that occurred while the image was being formed. This requires the approximation of a filtering function

which is the inverse of the modulation transfer function (MTF) of the imaging process. It is usually necessary to make modifications for the phase as well as the magnitude of the MTF. The resulting filtering requirements are often very complicated and the design of the required digital filter is not a trivial process.

The application of the two dimensional recursive digital filters to image processing and other two dimensional data has been hampered by two problems: stability and synthesis. The synthesis problem is the problem of expressing the two dimensional Z-Transform of the desired impulse response in closed form and thus determining the filter coefficients. The stability problem is important because the recursive filter requires feedback of past output values and therefore can become unstable. Research results obtained on both of these problems by the authors have demonstrated that two dimensional recursive digital filters are very practical for image processing applications [2,3].

### 3.0 MATHEMATICAL THEORY

The theoretical basis for the two dimensional ZW-Transform [4] involves the theory for sample data systems. Given discrete samples of a two dimensional function,  $f(x,y)$  with sampling increments  $X$  and  $Y$  respectively, the ZW-Transform for the function is defined by

$$F(z,w) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} f(mX,nY) z^{-m} w^{-n} \quad (3.1)$$

If the function is an image, then the problem can be set up so that  $m$  and  $n$  have no negative values and the range of  $m$  and  $n$  is finite. We further restrict the problem to the case where  $X$  and  $Y$  are constants. Then, if we use the notation  $f(m,n)$  to represent  $f(mX,nY)$ , we have

$$F(z,w) = \sum_{m=0}^M \sum_{n=0}^N f(m,n) z^{-m} w^{-n} \quad (3.2)$$

as the ZW-Transform for the image function,  $f(m,n)$ , which has  $(M + 1)$  columns and  $(N + 1)$  rows.

Consider the case where we have an input image with samples  $f(m,n)$  and we wish to filter this image to obtain an output image with corresponding samples,  $g(m,n)$ . The samples of the impulse response of the desired filter are given by  $h(m,n)$ . The range of  $m$  and  $n$  for the output is the same as for the input. Thus, the ZW-Transform of  $g(m,n)$  is given by

$$G(z,w) = \sum_{m=0}^M \sum_{n=0}^N g(m,n) z^{-m} w^{-n} \quad (3.3)$$

If we restrict the impulse response such that  $m$  and  $n$  cannot be negative (a causal system), we can write the ZW-Transform for the impulse response as

$$H(z,w) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} h(m,n) z^{-m} w^{-n} \quad (3.4)$$

In general, the ZW-Transform for the impulse response is an infinite series. In order to implement the spatial domain filter, we must find a closed form expression for  $H(z,w)$  such that



$$H(z,w) = \frac{\sum_{J=0}^L \sum_{K=0}^L a_{JK} z^{-J} w^{-K}}{\sum_{J=0}^L \sum_{K=0}^L b_{JK} z^{-J} w^{-K}} \quad (3.5)$$

Some of the coefficients,  $a_{JK}$  and  $b_{JK}$  may be zero. The convolution property of the ZW-Transform gives the relationship resulting from the convolution of  $f(m,n)$  and  $h(m,n)$  which is the filtering process

$$G(z,w) = H(z,w)F(z,w) \quad (3.6)$$

If we use the closed form of  $H(z,w)$  and restrict  $b_{00}$  to be equal to one and write the resulting equation for a single output value  $g(m,n)$ , we obtain the difference equation for the causal filter

$$g(m,n) = \sum_{J=0}^L \sum_{K=0}^L a_{JK} f(m-J, n-K) - \sum_{\substack{J=0 \\ K=0 \\ J+K>0}}^L \sum_{\substack{L \\ L}} b_{JK} g(m-J, n-K) \quad (3.7)$$

If  $L$  is relatively small (in practice,  $L$  is usually less than 10 for recursive digital filters), equation (3.7) represents a very efficient algorithm for filtering images. Equations (3.5) and (3.7) may also represent a nonrecursive filter if all  $b_{JK}$  except  $b_{00}$  are equal to zero.

#### 4.0 STABILITY ANALYSIS

Nonrecursive digital filters are inherently stable. Since there is no feedback of past output values, the impulse response has finite duration. Each output value is a finite sum which is always bounded if the input is bounded.

The stability problem for one dimensional digital recursive filters is straight forward. The roots of the denominator polynomial in the closed form of the one dimensional Z-Transform for the filter impulse response function must have magnitudes less than one. Stability analysis is therefore reduced to finding roots of nth degree polynomials with real, constant coefficients [5]. Stability analysis is not straight forward for the two dimensional problem because a two variable polynomial is not generally factorable into distinct roots. When the polynomial in the denominator of the two dimensional Z-Transform of the impulse response is factorable into distinct roots, the stability analysis procedure is the same as for the one dimensional problem.

The two dimensional stability problem is very complicated if the polynomial in the denominator is not factorable into distinct roots [6]. Efforts by other researchers have been directed toward examining regions of roots for two variable polynomials. The developed procedures are computationally feasible only for very simple filters. An alternate method of assessing stability for one dimensional digital recursive filters is to make a state space representation of the filter [7]. Then the filter is stable if the eigenvalues of the state transition matrix all have magnitudes less than one. Previous research has been directed toward developing the two dimensional equivalent of this procedure [2]. A pseudo-state variable representation is chosen because of difficulties in finding a true state space representation [8]. This difficulty is caused by the bivarience of the transfer function and by its causality. The

resulting matrix equation has two pseudo-state transition matrices.

Previous results have shown that the corresponding filter is unstable if any of the eigenvalues of either of these matrices have magnitudes greater than or equal to one or if any of the eigenvalues of the matrix sum have magnitudes greater than or equal to one. Reprints of papers presenting these results are included as in [2].

In practice, these constraints have been found to be very useful in that all tested filters that were known to be unstable were identified as such by the procedure. Conversely, all filters which were known to be stable met the criteria for stable filters and were not identified as unstable.

#### 5.0 SYNTHESIS

The synthesis of nonrecursive digital filters is not a major effort in the proposed research. Several simple nonrecursive digital filter designs may be found in the literature [9]. It would be appropriate to evaluate these designs with regard to application to near real time processing of Landsat satellite data. However, this was not a part of this program.

Often it is possible to express a desired two dimensional recursive digital filter as the product or sum of two one dimensional digital filters. That is the two dimensional Z-Transform of the digital recursive filter can be expressed as the product or sum of two one dimensional Z-Transforms. In either case, the two dimensional synthesis problem is reduced to the synthesis of two one dimensional filters. However, it is not possible to design sum separable or product separable digital recursive filters for all applications. For these applications, the design of the required two dimensional digital recursive filter is considerably more complicated.

Many imaging systems have a natural circular symmetry. In general, the optical transfer function of a circularly symmetric imaging system is circularly symmetric. Also, it is usually desirable to perform image processing where the processing is uniform with respect to direction. The natural consequence is that filters with circularly symmetric impulse response functions are generally very desirable for image processing. The relationship between circular symmetry of the impulse response and the frequency response dictates that the design requirement is for these filters to have a circularly symmetric frequency response [10].

Previous research efforts have led to a synthesis technique which yields two dimensional recursive lowpass, highpass, low frequency boost and high frequency boost recursive digital filters that are very close to being circularly symmetric when the cutoff frequencies are approximately one half the Nyquist frequency [3,11]. Some degradation is observed as the cutoff frequency approaches either the Nyquist frequency or zero.

In the design procedure, the squared magnitude characteristic of the desired circularly symmetric filter is chosen in the Laplace Transform domain. The bilinear transformation is then used to map the squared magnitude characteristic into the two dimensional Z-Transform domain. The pseudo-state space representation for the corresponding two dimensional Z-Transform is formed. The eigenvalues of the matrix sum of the two pseudo-state transition matrices are obtained. These eigenvalues occur in reciprocal pairs. The eigenvalues with magnitudes less than one are then used as roots of a denominator polynomial with distinct roots to form the two dimensional Z-Transform of the desired filter.

Note that this design procedure always ensures a stable filter. Stability analysis is simple because the denominator of the ZW - Transform is a product separable. Also note that no restrictions are placed on the numerator polynomial. That is, it is not necessary for the numerator polynomial to either be product separable, sum separable or minimum phase. Examples of stable two dimensional recursive filter designs are given in [12].

Another problem of interest in image processing is to filter with a one dimensional filter with the orientation of the filter specified and independent of the sampling direction. This type of filter would be useful for enhancing or suppressing linear features, for system noise suppression or for image correction (i.e., linear smear). However, any one dimensional digital recursive filter which is rotated becomes a two dimensional digital recursive filter with associated problems in stability and synthesis. Constraints with regard to stability of rotated digital filters have been developed [13,14]. However, the problems associated with the actual synthesis of rotated recursive digital filters have not been adequately addressed. This is a problem of interest to this research program. However, it was not pursued during this effort.

## 6.0 IMPLEMENTATION

### 6.1 Implementation Considerations

Recursive digital filters have many very desirable features that make them advantageous for real time or near real time image processing applications. In the practical application of recursive digital filters, only a small number of rows of the image to be processed are required to be stored in the computer at one time. Three rows of storage plus three rows of storage for each pair of complex poles in the transfer function to be realized are required. Thus a filter with two poles and two zeros would require the storage of the equivalent

of six rows of the input image. A filter with four poles and four zeros would require the storage of the equivalent of nine rows of the input image.

Most image filtering requirements may be met with a filter having no more than four zeros and four poles. Therefore, an algorithm which allows up to four zeros and four poles is practical. Such a filter would still require only slightly more than 9216 storage locations to filter a 1024 by 1024 image. Some additional storage would be required to store the code for the algorithm including its interface to data handling algorithms. Thus it is quite feasible to use recursive digital filters to filter images up to 1024 by 1024 using a 16 bit minicomputer with only 64k words of storage. If in addition a pipeline or array processor is used to implement the recursive digital filter itself, extremely fast processing can be accomplished. In fact, the processing time may be limited by the time required to transfer the data from and back to the storage medium during the actual filtering process.

Recursive digital filters typically require fewer data transfer operations to filter a given image than FFT filters. This is particularly true for very large images. The FFT filtering algorithm requires that the image be transformed by row and then by column. If the image is too large to fit in the computer at one time, the FFT algorithm becomes inconvenient to use for filtering images. One method commonly used to overcome this difficulty is to filter the image in blocks which are small enough to fit into the computer and then fit these filtered blocks back together to form the output image. Considerable overlap of these blocks is required to avoid artifacts due to periodic convolution. Average levels between blocks also have to be adjusted to avoid a checkerboard effect. Another method commonly used is to transform the image by rows, transpose the image and then transform the image by columns [15].

This procedure adds two transpose operations to each filtering operation. The result is that in the practical use of filtering large images, recursive digital filters are very significantly more efficient and require far less time to implement than FFT filters.

Recursive digital filters inherently have nonlinear phase characteristics. This is true because of feedback of past output values. However, linear phase can be obtained by filtering the image twice [3]. The image is filtered starting from the first row, first pixel and ending with the last row, last pixel. Then the image is filtered backward starting with the last row, last pixel and ending with the first row, first pixel. The result is a filter transfer characteristic which is the magnitude squared of the original characteristic. Thus, the filter with four poles and four zeros effectively has eight poles and eight zeros and linear phase when this procedure is used.

## 6.2 Transient Response

The use of past values of the output to compute the current output value results in the equivalent of long term storage of information about past inputs for recursive digital filters. Thus, such filters have an infinite impulse response (IIR). In addition, the beginning of each scan line in an image represents a transient which can cause very undesirable results if the implemented filter has a long term transient response. If this situation is not handled properly, then two dimensional recursive digital filters will give very poor results. This is particularly true for high frequency boost or highpass filters.

The approach used to minimize this problem is to place the filter in a stable state with an assumed input within the range of the image data. The best assumed input would be the expected value of the input image intensity.

However, this is usually not available. An approximation is obtained by averaging the intensity values of the middle row of the image. The final value theorem [5] is then used to determine the stable state for each of the output stages for the filter. The expected values approximation is then used as the initial condition input for each scan line and the stable state output is used as the initial condition output for each filter stage. Thus, if the initial input is the same as the assumed initial condition, then no transient response occurs.

In practice, the procedure outlined above is simple to implement and add very computations to the filtering process. However, additional improvement can be obtained by extending the image by using a reflection of future pixel values. Typically as few as 5 values produces very good results such that no transient response artifacts may be observed with most filter designs.

### 6.3 Implementation Algorithms

Equation 3.7 provides the fundamental algorithm for the two dimensional recursive digital filter. A straight forward approach is to implement the filter directly as provided. However, consideration must be given to roundoff error (the HP1000 computer uses 32 bit floating point arithmetic) and computational efficiency. In addition, the use of complex numbers should be avoided. Therefore, the fundamental stage for the filters was selected to be a second order stage with  $L$  equal to 2 in (3.7). Higher order filters may be implemented using multiple stages. This also allows combinations of filters such as a low pass filter for noise removal and a high frequency boost filter for edge enhancement.



In writing the actual algorithm, care was taken to use one dimensional arrays and to avoid transferring data between arrays when possible. Thus a computationally efficient algorithm was developed.

The fact that the HP1000 series E uses a software floating point arithmetic processor and only has a total of 32 K words (64 K bytes) of memory provided a severe hardware limitation. This system has just recently been upgraded to the series E RTE-IVB with an additional 64 K words of memory and a hardware floating point processor. Thus the performance of the image processing software should be very significantly improved with these hardware changes.

In addition to the implementation considerations described above, research was conducted with regard to devising special algorithms which can be used in parallel or pipeline architectures to approach real time image processing. Appendix A and B provide details on this effort. Appendix C and D gives documentation of the software developed.

## 7.0 APPLICATIONS

### 7.1 Dynamic Range Compression

Electro-optical sensors respond to reflected or emitted radiation. A typical electro-optical imaging system uses a single detector or an array of detectors in a scanning mode to form the image. If the signal of interest is the reflected radiation such as is the case for visible imaging systems, the detected signal is made up of two components: the illumination component and the reflection component. Infrared sensors typically detect radiation emitted by objects. It is typical that the available dynamic range of electro-optical imaging systems is several orders of magnitude. On the other hand, display systems are usually limited to at most two orders of magnitude and human observers can only detect approximately 50 different intensity levels [16].

Therefore, it is not possible to directly display all information obtained in many images.

The illumination component of optical images or the overall background radiation for infrared images generally has low spatial frequency content but may have a wide dynamic range [17]. This is the case where shadows exist in optical imagery or hot spots occur in infrared imagery. The reflected component or the emitted component of the signal is usually of priority interest and generally has higher spatial frequency content. This signal is formed by the different emissivity or reflectance of each item in the image.

The detected signal is therefore a product of the illumination or background radiation and the reflectance or emissivity at each point in the image. Homomorphic filtering using spatial domain digital filters provides an effective means of dynamic range compression by providing the capability to suppress the lower frequency component of the signal (illumination or background radiation component) and enhancing the higher frequency component of the signal (reflected or emitted component of the signal) [18]. This procedure is accomplished by taking the logarithm of the input signal, filtering with a high frequency boost filter and exponentiating the resulting output.

## 7.2 Subjective Image Processing

A simple design procedure can be used to allow an untrained operator to design digital filters for subjective image processing. For example, a low pass or high pass filter may be specified by the cutoff frequency and the number of poles desired [3]. A high frequency enhancement filter or a low frequency boost filter may be specified by a break frequency and the magnitude of the boost. Thus, the user does not have to learn filter theory or be concerned with signal to noise considerations, etc. to design the desired filter. This is a very

valid approach for subjective image processing because decisions about the type of filter desired are usually made based upon experience. Thus the user should be provided with several options which can be implemented with a minimum of effort and without special training. Recursive digital filters are well suited for this application.

### 7.3 Bandwidth Optimization

If an imaging system is used in an interactive mode, digital filters can be used to effectively change the bandwidth of the imaging system to meet a particular application. Thus under low signal to noise operating conditions, the operator can decrease the bandwidth of the system in an attempt to improve his ability to discern details of an object of interest. This can be accomplished with spatial digital filters simply by changing filter coefficients. No change in hardware is required.

### 7.4 Interpolation

Often it is desired to change the size of an image in image presentation or display operations. This usually requires a change in the number of rows or columns of the subject image. In changing the size of the image, the sampling theorem must be considered. Artifacts in output images after the use of a simple interpolation scheme are quite often due to aliasing.

An image is usually stored in discrete form. That is, only samples of the image are available in the form of pixel elements. Thus interpolation really involves reconstructing the image to a continuous form and then resampling at the new desired intervals. The ideal interpolation algorithm would involve a reconstruction filter based upon the sampling theorem [5] and a sampling algorithm to resample the image at the desired intervals. However, it is not computationally feasible to use this approach. Therefore, it is common practice

to use a simple algorithm such as nearest neighbor, bilinear or constrained polynomial interpolation for image processing requirements. These algorithms all result in aliasing when either the number of rows or columns is decreased. If the number of rows or columns is increased, these algorithms add undesired noise to the output image which is image dependent [16].

A means of improving the results of these interpolation schemes is to use prefiltering to avoid aliasing and/or post filtering to remove undesirable additive noise. The results using this procedure can be made to be very close to the ideal reconstruction filter interpolator with the proper combination of filtering and a simple interpolation algorithm. The use of recursive digital filters which have been shown to be considerable more efficient computationally than the FFT algorithm for image processing makes this procedure feasible. For example, the bilinear interpolation algorithm can effectively be combined with an antialiasing filter when needed to give results which are very significantly improved over the use of the bilinear interpolation algorithm alone. Computationally, such a scheme would compare very favorably to a constrained polynomial interpolation algorithm and would give superior results for many images.

#### 7.5 Image Registration, Classification and Evaluation

Image registration, classification and evaluation schemes generally do not take advantage of digital filtering. In general, relatively simple schemes are used with human interaction playing a very important role. This is partially true because of the inconvenience of using filtering with current techniques which employ the FFT algorithm and partially because the feasibility of using spatial filtering to improve image registration, classification and evaluation has not been demonstrated.

Two dimensional recursive digital filters have advantages which make them very attractive for use in exploring the feasibility of using spatial filtering to improve these procedures. The filters can be designed with only a small number of parameters specified by the user (usually no more than two parameters must be specified). The actual filtering process requires significantly fewer computations and data transfers than the FFT algorithm and image size is not constrained to power of 2. Thus, very fast turnaround can be achieved.

With very fast turnaround and with the availability of various types of filters, the exploration of the use of filtering for image registration, classification and evaluation becomes far more practical. If spatial filtering proves beneficial, then the implementation can be done with only a small sacrifice in time and without the use of a very large computer system. Thus two dimensional recursive digital filters may be very beneficial to image registration, classification and evaluation. In practice, the use of such filters may prove to be very beneficial in automating these vital procedures.

### 3.0 IMAGE PROCESSING FACILITIES

The Department of Electrical Engineering at A & T State University has a HP1000 Series E computer system and the University has a DEC10 computer system. Both of these computer systems were used with this program.

The HP1000 is a 16 bit minicomputer system with 32k words of core, a 14.6 megabyte disk drive and a 9 track tape drive. The core will be extended to 192k bytes and the CPU is being upgraded to series E with the RTE- IVB operating system. This upgrade will be completed by the end of February, 1981. The 9 track system can be used to transfer data from and to the DEC10 computer system. A Grinnell Model GMR-27 display image system is also available. This display can display an image with 256 rows and 512 pixels per row with 8 bit accuracy.

Plans also include additional graphics capability and a full color display system.

The DEC10 computer system is an interactive system with a 36 bit word length and double precision arithmetic capability. Thus, it can be used for stability analysis and filter synthesis and evaluation. The current DEC10 system consist of a KL-10 central processor , 512k words of memory, 2 self loading tape drives a communications controller for up to 96 asynchronous dial drives.

The Department of Electrical Engineering also has a HP2648 graphics terminal which is connected to the HP1000 computer. This graphics terminal is used for interactive stability analysis and filter synthesis.

#### 9.0 IMAGE PROCESSING RESULTS

The lack of a hard copy output capability presents considerable difficulty with regard to including actual Landsat images or the processed results in this report. A HP9872 plotter is connected to the HP1000 computer and may be used to plot frequency contour and perspective plots of the actual filter used in the image processing examples. However, a 35-mm camera was used to photograph the Grinnell display screen to obtain the examples that follows

Figure 1 is the frequency perspective plots of a 5 magitude High Boost Filter with 0.2 cutoff frequency. Figure 2 is the frequency contour plot of the same filter. Figure 3 is file number three (3) of the Landsat Imagery tape received from NASA. Figure 4 shows the results of processing images with the filter of Figure 1 and then mapping between minimum and maximum logarithmically.

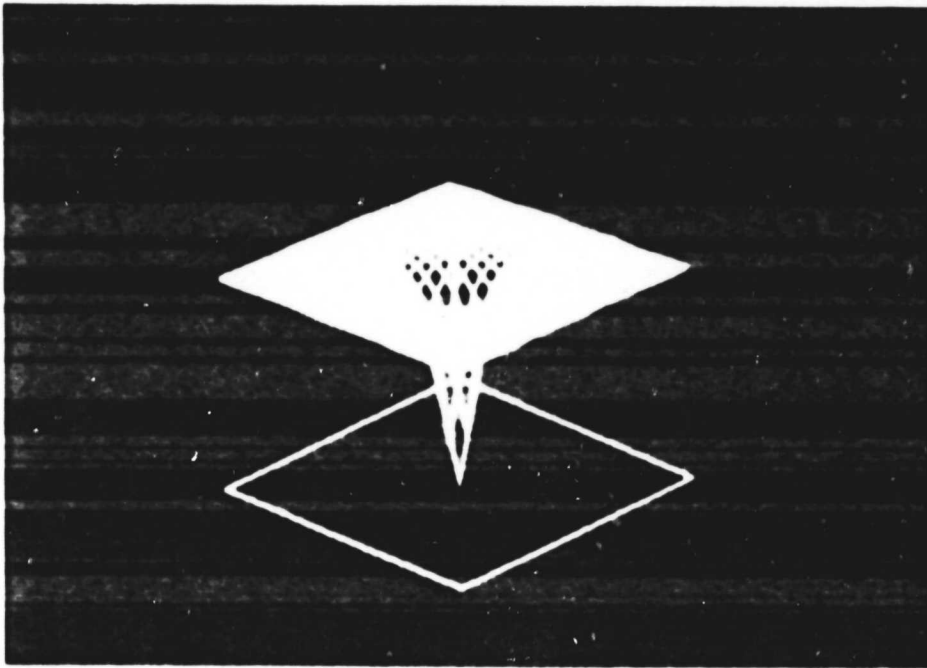


Figure 1. Perspective plot 5x-0.2 High Boost Filter

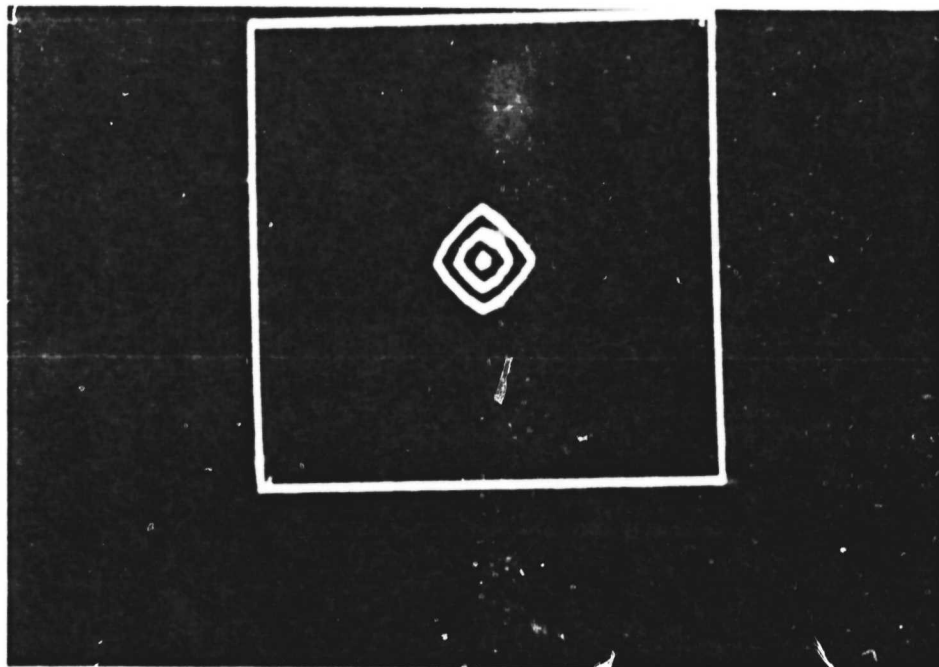


Figure 2. Contour plot 5x-0.2 High Boost Filter

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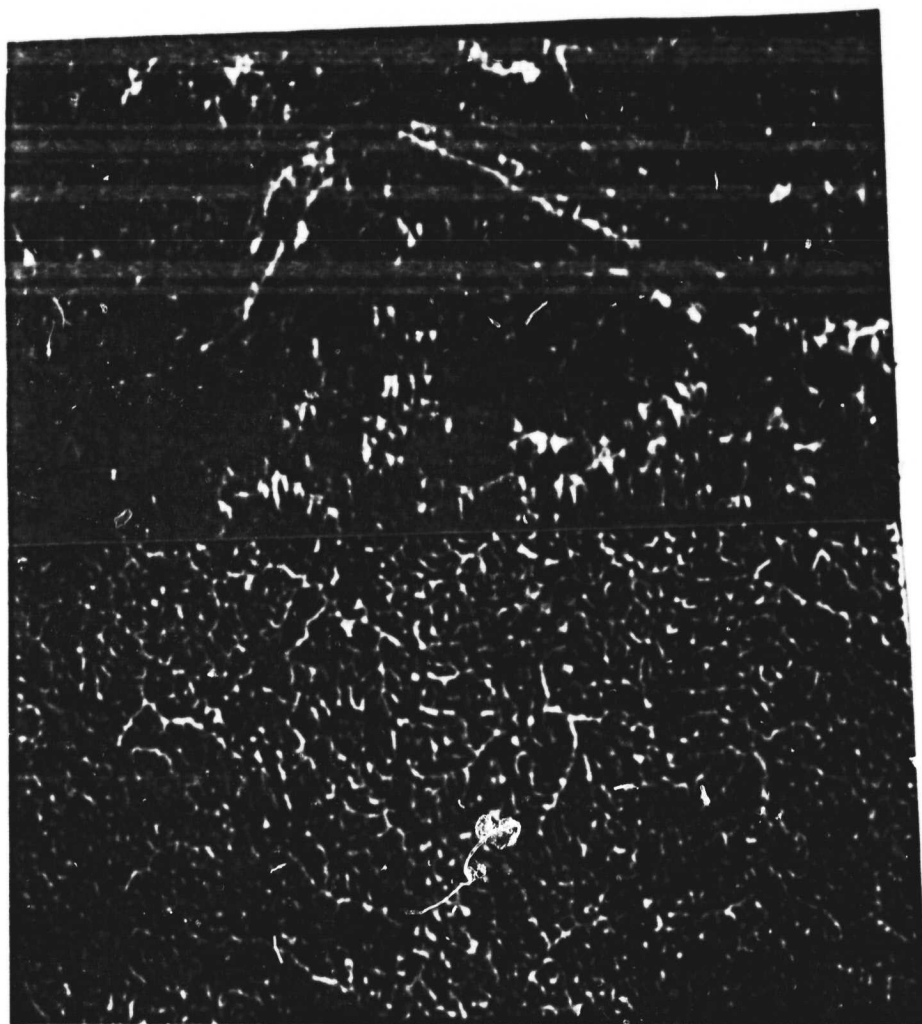


Figure 3. Original Landsat File-3 Image



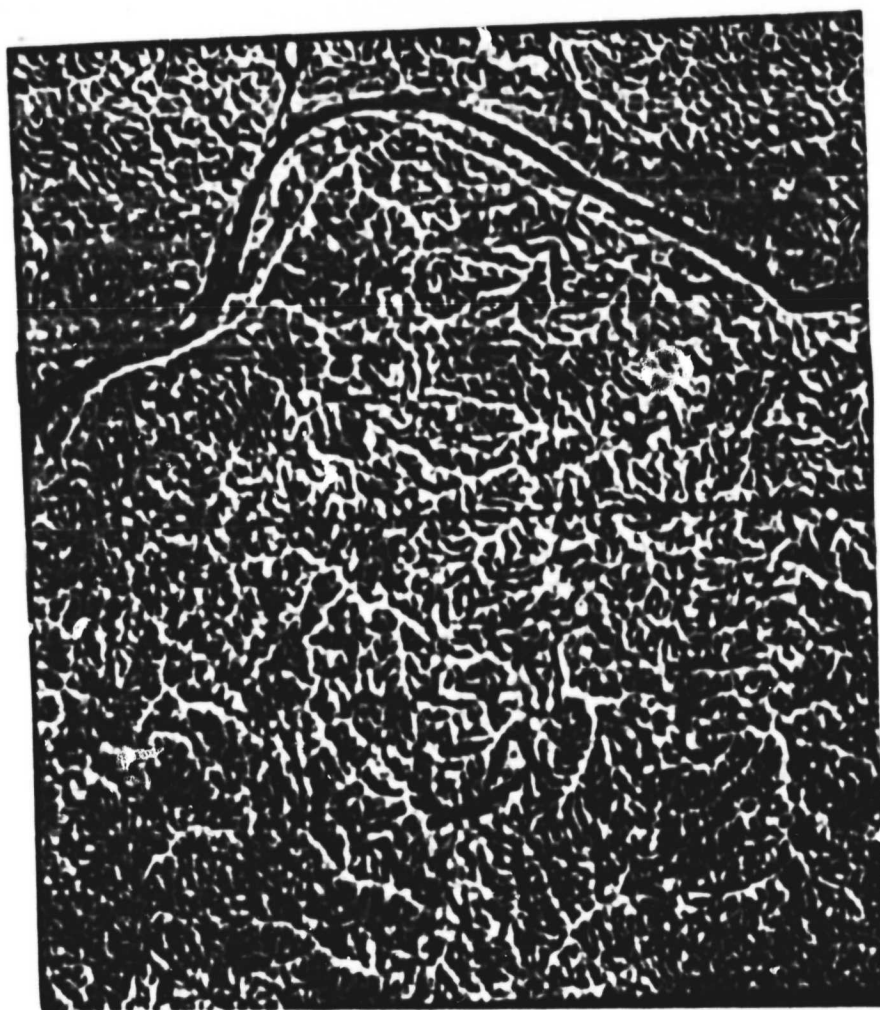


Figure 4. Enhanced Landsat file-3 Image

## 12.0 REFERENCES

1. Earnest L. Hall, "A Comparison of Computations for Spatial Filtering", Proceedings of the IEEE, Vol. 60, no. 7, 1972, pp 887-891.
2. Winser E. Alexander and Steven A. Pruess, "Stability Analysis of Two Dimensional Digital Recursive Filters", IEEE Transactions on Circuits and Systems, Vol. , No. 1, 1980, pp.
3. Winser E. Alexander and William J. Craft, Documentation for Spatial Domain Filtering Package, Department of Electrical Engineering, North Carolina A & T State University, January, 1979.
4. Lawrence R. Rabiner and Bernard Gold, Theory and Application of Digital Signal Processing, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1975, pp 442-455.
5. Samuel Stearns, Digital Signal Analysis, Hayden Publishing Co., Inc., Edison, N. J.
6. N. K. Bose, "Problems and Progress in Multidimensional System Theory", Proceedings of the IEEE, Vol. 65, No. 6, 1977, pp. 824-840.
7. Katsuhiko Ogata, State Space Analysis of Control Systems, Prentice-Hall, Inc., Englewood Cliffs, N. J., p. 487.
8. E. Fornasini and G. Marchesini, "State Space Realization Theore for Two Dimensional Filters", IEEE Transactions on Automatic Control, Vol. AC01t 1976, pp 484-492.
9. E. L. Hall, Digital Filtering of Images, Ph.D. Dissertation, University of Missouri, Columbia, Mo., 1971.
10. A. Papoulis, Systems and Transforms with Applications in Optics, McGraw-Hill Book Co. New York, N. Y., 1968, p. 140.
11. Winser E. Alexander, A Study of Two Dimensional Recursive Digital Filters, Final Report (Naval Air Systems Commd Contract No. NO-14-77-C-0199), School of Engineering, N. C. A T State University, Greensboro, N. C., November, 1978.
12. Winser E. Alexander and Earnest E. Sherrod, "Two Dimensional Recursive Digital Filters for Subjective Image Processing", 13th Asilomar Conference on Circuits, Systems and Computers, November, 1979.
13. J. M. Costa and A. N. Venetsonopoulos, "Design of Circularly Symmetric Two Dimensional Recursive Filters", IEEE Transactions on Acoustics, Speech and Signal Processing, Vol. ASSP-22, No. 6, 1974, pp 432-442.
14. Dennis Goodman, "A Design Technique for Circularly Symmetric Low Pass Filters", IEEE Transactions on Acoustics, Speech and Signal Processing, Vol. ASSP-26, No. 4, 1978, pp 290-304.

15. B. R. Hunt, "Data Structures and Computational Organization in Digital Image Enhancement", Proceedings of IEEE, Vol. 60, 1972, pp 884-887.
16. William K. Pratt, Digital Image Processing, John Wiley and Sons, Inc., Somerset, N. J., 1978.
17. Winser E. Alexander, "Electronic Target Enhancement in Infrared Reconnaissance", Proceedings of the 1968 Air Force Science and Engineering Symposium, October, 1968.
18. Thomas G. Stockham, Jr. "Image Processing in the Context of a Visual Model", Proceedings of the IEEE, Vo'. 60, 1972, pp 828-842.

## APPENDIX A

### INVESTIGATION OF ALTERNATIVE REALIZATION TECHNIQUES

Another aspect of the research conducted under this contract was that of investigating alternative realization techniques for not only the filter designs chosen, but also for a more general class of filters as well. This investigation although as yet incomplete has resulted in some interesting conceptual reformations of the filter realization problem [1], as well as the suggestion of possibly more computationally efficient algorithms for obtaining the filter solutions.

The typical approach taken in realizing recursive 2 D filters is one of processing the filtered output directly using the forward and backward difference equation formulations of the filter. This approach requires that one either already know the initial condition or boundary condition state of the filtered output (which generally is not the case), or that one uses various statistical estimates of what these boundary states might be in order to begin the resursion. In either case the direct use of the difference equations may not result in a minimum number of arithmetic operations being performed in obtaining a filtered solution [2,3,4].

The approach taken in this aspect of the conducted research was one of formulating the complete set of simultaneous linear algebraic equations to be solved in order to obtain a solution which satisfies the 2 D difference equation description of the filter. This serves to give one a complete description of the constraints which must be satisfied by the filtered solution with or without boundary conditions imposed on the problem.

The class of filters considered were those which possess a rational transfer function. Such a filter may be represented by its bivariate difference equation

written in tensor form as:

$$b_{ij} g_{p+i, q+j} = a_{ij} f_{p+i, q+j} \quad (1)$$

where  $1 \leq p \leq N$ ,  $1 \leq q \leq M$ ,  $-m \leq i \leq m$ ,  $-m \leq j \leq m$ ; and the double appearance of an indice on a given side of the equality implying the usual tensor notation for a summation over the specified range of that indice. The so called finite duration impulse response filter (FIR) is one which satisfies  $b_{00}=1$  with all other  $b_{ij}=0$ ; whereas the infinite duration impulse response filter (IIR) is one which allows nonzero  $g_{ij}$  for  $i, j \neq 0$ . A more formal tensor expression for (1) is given by:

$$B_{pq}^{kl} g_{kl} = A_{pq}^{kl} f_{kl} \quad (2)$$

where  $1 \leq k \leq N$ ,  $1 \leq l \leq M$ , and the non-zero components of the coefficient tensors given by  $A_{pq}^{kl} = a_{k-p, l-q}$  and  $B_{pq}^{kl} = b_{k-p, l-q}$ ; for  $-m \leq k-p \leq m$  and  $-m \leq l-q \leq m$ . The 2 D filtering operation requires that one determine all the elements  $g_{pq}$ , given all the coefficients  $a_{ij}$ ,  $b_{ij}$ , and the input array  $f_{pq}$ .

A solution to equation (2) will exist and be unique if there exists an inverse of the tensor  $B_{pq}^{kl}$ , say  $C_{uv}^{pq}$ ; with  $1 \leq u \leq N$ ,  $1 \leq v \leq M$ . For such a case, the filtered solution would then be given by:

$$g_{uv} = C_{uv}^{pq} A_{pq}^{kl} f_{kl} \quad (3)$$

Tensor equation (2) can also be interpreted as a matrix equation with  $A_{pq}^{kl}$ , and  $B_{pq}^{kl}$  taken as  $NM$  by  $NM$  dimensional coefficient matrices with row index "pq", column index "kl"; and  $g_{kl}$  and  $f_{kl}$  interpreted as column vectors. Viewing equation (2) as such a matrix equation reveals the enormity of the computer storage problem encountered in attempting a solution, for if both  $N$

and M were typically of the order to say 512 (for a 512 by 512 pixel array) then  $2^{36}$  memory locations would be required for the tensor of matrix  $B_{pq}^{kl}$  alone.

The matrix equation interpretation of equation (2) also reveals the following characteristics of the coefficient matrix  $B_{pq}^{kl}$  for these selected digital filters:

- (a) For the "Quarter Plane" digital filter,  $B_{pq}^{kl}$  is a triangular matrix. Hence, the solution for the filtered array  $g_{kl}$  requires no inversion of the coefficient matrix. By a simple back substitution process, starting at one corner of the array and proceeding by rows or columns, the filtered array may be computed provided that the iteration process is numerically stable.
- (b) For the "Symmetric" digital filter, with filter coefficients symmetric with respect to any diagonal passing through the central element  $b_{00}$  of the mask  $b_{ij}$ , the coefficient matrix  $B_{pq}^{kl}$  is symmetric.

Among the interesting results developed during the tenure of this research was the fact that for square arrays  $N=M$ , and filters with  $a_{00}, b_{00} \neq 0$ ; the filtering problem given by equation (2) is also expressible as a matrix equation involving only  $N$  by  $N$  dimensional sparse coefficient matrices given by:

$$LGR + \sum_{k=-m, k \neq 0}^m S_k G T_k = c PFQ + c \sum_{k=-m, k \neq 0}^m S_k F U_k \quad (4)$$

where  $c = a_{00}/b_{00}$ , the matrix  $G = (g_{pq})$  is the filtered array,  $F = (f_{pq})$  is the input array; and the nonzero components of the coefficient matrices  $L, R, P, Q, S_k, T_k$ , and  $U_k$  are given by:

(i) For  $p, q$  such that  $-m \leq q-p \leq m$ :

$$L_{pq} = b_{q-p,0}/b_{00}; \quad R_{pq} = b_{0,q-p}/b_{00}; \quad P_{pq} = a_{q-p,0}/a_{00}; \quad Q_{pq} = a_{0,q-p}/a_{00};$$

$$T_{kpq} = b_{k,p-q}/b_{00} - b_{k,0}b_{0,p-q}/b_{00}^2; \quad U_{kpq} = a_{k,p-q}/a_{00} - a_{k,0}a_{0,p-q}/a_{00}^2.$$

(ii) And finally, for  $p, q$  such that  $q-p=k$ :  $S_{kpq} = 1$ .

The reduction in the dimensions of the coefficient matrices shown in equation (4) is one of the practical reasons why one would prefer to solve that expression for the filtered output rather than equation (2). The coefficient matrices in (4) also have other appealing properties in that both  $L$  and  $R$  are symmetric matrices, all of the matrices have the "bandtype" structure in that they have but one distinct element per respective major or minor diagonal, and all of the matrices are relatively sparse (many zero elements).

Unfortunately expression (4) is not generally solvable by using linear methods due to the fact that one cannot combine those matrices which premultiply the unknown matrix  $G$  (i.e.,  $L$  and the  $S_k$ ), or those matrices which postmultiply  $G$  (i.e.,  $R$  and the  $T_k$ ). It should be noted, however, that for those cases in which equation (4) is not solvable for  $G$  using linear methods, this does not imply that there exists no unique solution. It is equation (2) that dominates in that it is always solvable if (4) is solvable, but (2) may still be solvable even if (4) is not linearly solvable. Hence, from the standpoint of linear analysis (2) possesses more potential in solving for  $g_{pq}$  than equation (4).

There is an important class of filters for which equation (4) is linearly solvable, and this class is the set of filters which are product separable. The coefficients involved in product separable filters have the properties:

$$a_{k,p-q}/a_{00} - a_{k,0}a_{0,p-q}/a_{00}^2 = 0$$

$$b_{k,p-q}/b_{00} - b_{k,0}b_{0,p-q}/b_{00}^2 = 0$$

Hence, the matrices  $T_k$ , and  $U_k$  are all identically zero and equation (4) reduces to:

$$LGR = c PFQ \quad (5)$$

and the solution for the filtered output  $G$  given by:

$$G = L^{-1}(cPFQ) R^{-1} \quad (6)$$

At first glance it would appear the the computation of the filtered output array  $G$  is still a formidable task due to the required inversions  $L^{-1}$ , and  $R^{-1}$ ; however both  $L$ , and  $R$  are Toeplitz matrices and can be inverted efficiently [5], hence we have our first instance of a possibly more efficient algorithm for obtaining filter solutions.

Adding additional restrictions, it has also been determined that if the filter is both product separable as well as symmetric then the coefficient matrices  $L$  and  $R$  can be further decomposed to give equation (5) the equivalent expression:

$$L_U L_L G R_U R_L = c PFQ \quad (7)$$

where  $L_L$  and  $R_L$  are lower triangular, and  $L_U$  and  $R_U$  are upper triangular matrices. Expression (5) is then solvable for  $G$  using a minimum number of arithmetic operations without requiring the inversion of  $L$  and  $R$ , provided that the intermediate results are numerically stable.

Finally, for the filter problem described by expression (4), iterative methods of solution such as:

$$G^{(n+1)} = L^{-1} \left( \sum_{k=-m, k \neq 0}^m S_k G^{(n)} T_k \right) R^{-1} + H \quad (8)$$

$$\text{where } H = L^{-1} \left( cPFQ + c \sum_{k=-m, k \neq 0}^m S_k F U_k \right) R^{-1}$$

as suggested as possible techniques to be applied to obtain filter solutions for those filters which do not satisfy the restrictions required for expressions (5), (6), and (7). The investigation of the convergence of such iterative solution techniques is the subject of current and future research.



## REFERENCES

- [1]. D. E. Olson, W. E. Alexander and E. E. Sherrod, "Simultaneous Linear Algebraic Equation Formulations of Two Dimensional Digital Filter Realizations," Eighteenth Annual Allerton Conference on Communications, Control, and Computing Proceedings, October 1980.
- [2]. R. M. Mersereau, and D. E. Dudgeon, "Two-Dimensional Digital Filtering," IEEE Proc. 63(4): 610-623 (1975).
- [3]. S. K. Mitra, A. D. Sagar, and N.A. Pendergrass, "Realizations of Two Dimensional Recursive Digital Filters," IEEE Trans. Circuits Syst. CAS-22(3): 177-184 (1975).
- [4]. E. L. Hall, "A Comparison of Computations for Spatial Filtering," IEEE Proc. 65(6), June, 1977.
- [5]. S. Zchar, "Toeplitz Matrix Inversion: The Algorithm of W. F. Trench," Journal of the Assoc. for Computing Machinery, Vol. 16, No. 4, October 1969: 592-601.

## Appendix B

### Implementation Consideration for Two Dimensional Recursive Digital Filters with Product Separable Denominators.

#### Introduction

Consideration is given to the implementation of two dimensional digital recursive filters that have transfer functions with product separable denominators. This structure is of particular importance to this program because the design technique used for the design of approximately circularly symmetric filters results in a transfer function with a product separable denominator. We seek to derive a computationally efficient structure that may also lend itself to implementation with the use of a pipeline or array processor.

#### Transfer Function

The bivariate Z-transform for the structure of interest is given by

$$H(Z,W) = \frac{\sum_{J=0}^2 \sum_{K=0}^2 a_{JK} Z^{-J} W^{-K}}{\sum_{J=0}^2 \sum_{K=0}^2 b_{JK} Z^{-J} W^{-K}} = \frac{N(Z,W)}{D(Z,W)} \quad (1)$$

We have assumed that  $L=2$  for a single second order filter stage. We also assume that the denominator polynomial,  $D(z,w)$  can also be represented as

$$D(Z,W) = \left[ \sum_{J=0}^2 c_J Z^{-J} \right] \left[ \sum_{K=0}^2 d_K W^{-K} \right] \quad (2)$$

We can implement  $H(z,w)$  in cascade form

$$H(Z,W) = H_1(Z,W)H_2(Z,W)H_3(Z,W) \quad (3)$$

where

$$H_1(Z,W) = \sum_{J=0}^2 \sum_{K=0}^2 a_{JK} Z^{-J} W^{-K} \quad (4)$$

$$H_2(Z,W) = 1 / \sum_{J=0}^2 c_J Z^{-J} \quad ; \quad c_0 = 1 \quad (5)$$

$$H_3(Z,W) = 1 / \sum_{K=0}^2 d_J W^{-K} \quad ; \quad d_0 = 1 \quad (6)$$

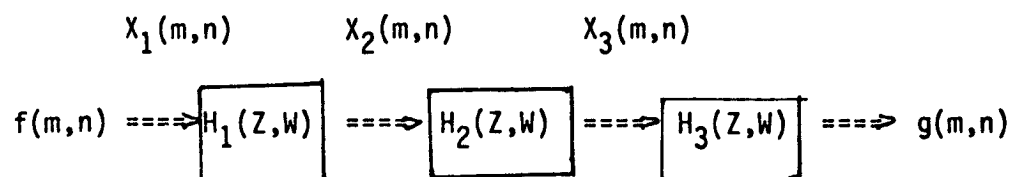
In direct form, the corresponding difference equations are given by

$$x_1(m,n) = \sum_{J=0}^2 \sum_{K=0}^2 a_{JK} f(m-J, n-K) \quad (7)$$

$$x_2(m,n) = x_1(m,n) - c_1 x_2(m-1,n) - c_2 x_2(m-2,n) \quad (8)$$

$$g(m,n) = x_2(m,n) - d_1 x_3(m,n-1) - d_2 x_3(m,n-2) \quad (9)$$

Note that this form only requires 13 multiplies and 13 adds as compared to 17 multiplies and 17 adds for the direct form associated with (1). The block diagram for this implementation is given below.



APPENDIX C

PROGRAM NAME: NASA

TYPE: Transfer

PROGRAMMER: W.E. ALEXANDER

Source:

Reloc:

FUNCTION: This transfer offs and RP's all necessary modules  
for Image Processing; mounts cartridge 23 and runs NASA 1.

FROM RTE: Run NASA

Modules Called:

SHOW  
BLDWF  
BLDIM  
WTAPE  
DSPLY  
CURSR  
FDIGN  
STABI  
DPLAM  
FILTR  
LFLTR  
HFLTR  
RESIZ  
IMAGE  
DINTP  
NOISE  
FIRO

Modules Run: NASA1

Subroutines Called:

PROGRAM NAME: NASA1

TYPE: Program

PROGRAMMER: W.E. ALEXANDER

SOURCE: &NASA1

Reloc: %NASA1

FUNCTION: This Program is the father program for the Image  
Processing from which the major modules are selected.

Modules Called:

DSPLY  
FDIGN  
FILTR  
RESIZ  
SHOW  
BLDIM  
NOISE

Modules Run:

Subroutines Called:

FILL

PROGRAM NAME: DSPLY

TYPE: Program

PROGRAMMER: DAVE JOHNSON

Source: &DSPLY

Reloc: %DSPLY

FUNCTION: This program Displays an Image on the Grinnell Image  
Display System GMR-27.

Modules Called:

SCROL  
CURSR

Modules Run:

Subroutines Called:

WLINE  
RLINE  
DRIVR  
RESET  
MOVEC

PROGRAM NAME: FDIGN

TYPE: Program

PROGRAMMER: E.E. SHERRUD

Source: &FDIGN, &FDIG1

Reloc: %FDIGN, %FDIG1

FUNCTION: This program designs, stability tests and displays a filter on either HP-2648G or on the Grinnell GMR-27.

Modules Called:

STABI  
DPLAM  
FIRO  
PLOTV

Data File Created:

COEFFS  
DATA1

Subroutines Called:

LPFLT  
BPFLT  
BSTFT  
TDLPF  
ROTAE  
FIR



PROGRAM NAME: STABI

TYPE: Program

PROGRAMMER: E.E. SHERROD

Source: &STABI

Reloc: %STABI

FUNCTION: This Program evaluates the Recursive Filter Stability Characteristics.

Modules Called:

Subroutines Called:

STABT  
PRTN

PROGRAM NAME: DPLAM

TYPE: Program

Source: &DPLAM, &DPLA1

Reloc: %DPLAM, %DPLA1

PROGRAMMER: E.E. SHERROD

FUNCTION: This program displays the Filter Characteristics.

Modules Called:

COEFFS  
DPLA1

Subroutines Called:

ZWC  
CONTR  
SET3D  
PLT3D  
SET2D  
PLT2D

PROGRAM NAME: FIRO

TYPE: PROGRAM

PROGRAMMER: E.E. SHERROD

Reloc: %FIRO

Source: &FIRO

FUNCTION: This program designs Non-Recursive FIR Filters.

Modules Called:

Subroutines Called:

BESJ  
BESIO

PROGRAM NAME: PLOTV

TYPE: Program

PROGRAMMER: E.E. SHERROD

Source: &EES3

Reloc: %PLOTV

FUNCTION: This program displays Filter Characteristics on the  
Grinnell Display GMR-27.

Modules Called:

DATA1

Subroutines Called:

DVECT

PROGRAM NAME: FILTR

TYPE: Program

PROGRAMMER: E.E. SHERROD

Source: &FILTR

Reloc: %FILTR

FUNCTION: This program schedules Linear or Homorphic  
filtering of Images.

Modules Called:

LFLTR  
HFLTR  
SHOW  
BLDWF

Subroutines Called:

PROGRAM NAME: BLDWF

TYPE: Program

PROGRAMMER: DAVE JOHNSON

Source: &BLDWF

Reloc: %BLDWF

FUNCTION: This program creates and maintains an Image  
work file named WF0000 with pixel values stored  
as 15-bit real numbers.

Modules Called:

DIREC  
WF0000

Subroutines Called:

ICMPW

PROGRAM NAME: LFLTR

TYPE: Program

PROGRAMMER: E.E. SHERRON

Source: &LFLTR

Reloc: %FILTR

FUNCTION: This program does Linear Filtering using Spatial Domain Recursive Digital Filters.

Modules Called:

COEFFS

Subroutines Called:

READL  
RITLN  
FILTR  
WFINT  
CLSWF

PROGRAM NAME: HFLTR

TYPE: Program

PROGRAMMER: E.E. SHERROD

Source: &HFLTR

Reloc: %HFLTR

FUNCTION: This program performs Homomorphic Filtering using  
Spatial Domain Recursive Digital Filters.

Modules Called:

COEFFS

Subroutines Called:

WFINT  
READL  
RITLN  
HFILT  
CLSWF



PROGRAM NAME: RESIZ

TYPE: Program

PROGRAMMER: W.E. ALEXANDER and RICHARD MOORE

Source: &RESIZ

R ELOC: %RESIZ

FUNCTION: This program allows the user to scale an Image and change an Image from 8-bits to 15-bits and vice versa. The resizing of an Image is being developed.

Modules Called:

LFLTR  
DINTP  
TRMGN  
LBR SZ  
BLDNF

Subroutines Called:

TRMGN  
BLANX  
SPCHR  
CKFLD  
WFINT  
READL  
XYFLT  
CLSWF  
READL  
RITEL

PROGRAM NAME: SHOW

TYPE: Program

PROGRAMMER: DAVE JOHNSON

Source: &SHOW

Reloc: %SHOW

FUNCTION: This program displays an image from the work  
file onto the Grinnell System GMR-27.

Modules Called:

WF0000

Subroutines Called:

READL  
WLINE  
CLSWF

PROGRAM NAME: BLDIM

TYPE: Program

PROGRAMMER: DAVE JOHNSON

Source: &BLDIM

Reloc: %BLDIN

Loadfile: LBLDIN

FUNCTION: This program constructs an 8 or 15-bit image from magnetic tape, disc, GMR-27 display or work file.

Modules Called:

WF0000  
DIREC

Subroutines Called:

MVW  
ROT8  
DCODE  
DRIVR

PROGRAM NAME: NOISE

TYPE: Program

PROGRAMMER: E.E SHERROD

Source: &NOISE

Reloc: %NOISE

FUNCTION: This program add Gaussian Noise to an Image with user defined Mean and Standard Deviation from a Gaussian Noise disc file.

Modules Called:

BLDWF

Subroutines Called:

READL  
RITEL  
CLSWF

APPENDIX D

# LOAD FILES

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## PROGRAM FILES

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LDIREC T=00004 IS ON CRO0025 USING 00002 BLKS R=0002

0001 :PU,IMDIRC:IM:23:4:100  
0002 :CR,IMDIRC:IM:23:4:100

LWTAPE T=00004 IS ON CRO0022 USING 00002 BLKS R=0010

0001 :LG,3  
0002 :SV,0  
0003 :OF,WTAPE  
0004 :PU,WTAPE  
0005 :MR,%WTAPE  
0006 :MR,%ROTS  
0007 :MR,%ICMPW  
0008 :MR,%TRMGN  
0009 :RU,LOADR,99,OG,,,2  
0010 :SP,10G::3  
0011 :TR

LDPLAM T=00004 IS ON CRO0022 USING 00002 BLKS R=0010

0001 :SV,0  
0002 :OF,DPLAM  
0003 :PU,DPLAM  
0004 :LG,3  
0005 :MR,%DPLAM  
0006 :MR,%DPLA1  
0007 :RU,LOADR,99,OG  
0008 :SP,10G::3  
0009 :OF,10G  
0010 :RP,10G::3  
0011 ::

LPLOTV T=00004 IS ON CRO0022 USING 00002 BLKS R=0011

0001 :SV,0  
0002 :OF,PLOTV  
0003 :PU,PLOTV  
0004 :LG,3  
0005 :MR,%EES3  
0006 :MR,%DRIVR  
0007 :RU,LOADR,99,OG  
0008 :SP,10G::3  
0009 :OF,10G  
0010 :RP,10G::3  
0011 ::



LFDIGN T=00004 IS ON CR00022 USING 00002 BLKS R=0011

0001 :SV,0  
 0002 :OF,FDIGN  
 0003 :PU,FDIGN  
 0004 :LG,3  
 0005 :MR,%FDIGN  
 0006 :MR,%FDIG1  
 0007 :RU,LOADR,99,1G  
 0008 :PU,LOG::3  
 0009 :SP,LOG::3  
 0010 :OF,LOG  
 0011 ::  
 0012

LBLDIM T=00004 IS ON CR00022 USING 00002 BLKS R=0009

0001 :LG,2  
 0002 :OF,BLDIM  
 0003 :PU,BLDIM  
 0004 :MR,%BLDIM  
 0005 :MR,MVW.  
 0006 :MR,%ROTS  
 0007 :MR,%RLINE  
 0008 :MR,DCODE.  
 0009 :MR,%DRIVR  
 0010 :RU,LOADR,99,0G,,,2  
 0011 :SP,LOG::3  
 0012 :OF,LOG::3  
 0013 :RP,LOG::3  
 0014 ::

LLFTR T=00004 IS ON CR00022 USING 00002 BLKS R=0011

0001 :SV,0  
 0002 :OF,LFLTR  
 0003 :PU,LFLTR::3  
 0004 :LG,3  
 0005 :MR,%LFLTR  
 0006 :MR,%WFINT  
 0007 :MR,DCODE.  
 0008 :MR,%WLINE  
 0009 :MR,%DRIVR  
 0010 :RU,LOADR,99,1G  
 0011 :SP,LOG::3  
 0012 :OF,LOG  
 0013 :RP,LOG::3  
 0014 ::

LHFTR T=00004 IS ON CRO0022 USING 00002 BLKS R=0014

0001 :SV,0  
0002 :OF,HFLTR  
0003 :PU,HFLTR::3  
0004 :LG,3  
0005 :MR,%HFLTR  
0006 :MR,%WFINT  
0007 :RU,LOADR,99,1G  
0008 :SP,10G::3  
0009 :OF,10G  
0010 :RP,10G::3  
0011 ::

LSHOW T=00004 IS ON CRG0022 USING 00002 BLKS R=0011

0001 :LG,1  
0002 :MR,%SHOW  
0003 :MR,%WFINT  
0004 :MR,%DRIVR  
0005 :MR,%WLINE  
0006 :OF,SHOW  
0007 :RU,LOADR,99,1G  
0008 :PU,10G::3  
0009 :SP,10G::3  
0010 :OF,10G  
0011 ::

LFIRO T=00004 IS ON CRO0022 USING 00002 BLKS R=0010

0001 :LG,1  
0002 :MR,%FIRO  
0003 :MR,%WINDO  
0004 :MR,%BESIO  
0005 :OF,FIRO  
0006 :RU,LOADR,99,0G  
0007 :PU,10G::3  
0008 :SP,10G::3  
0009 :OF,10G  
0010 :RP,10G::3  
0011 ::

LIMAGE T=00004 IS ON CRO0022 USING 00002 BLKS R=0009

0001 :LG,1  
0002 :OF,IMAGE  
0003 :MR,%IMAGE  
0004 :MR,%SPACE  
0005 :MR,%ICMPW  
0006 :MR,%ROTS  
0007 :RU,LOADR,99,1G  
0008 :PU,LOG::3  
0009 :SP,LOG::3  
0010 :OF,LOG

LRESIZ T=00004 IS ON CRO0022 USING 00002 BLKS R=0004

0001 :LG,3  
0002 :SV,0  
0003 :OF,RESIZ  
0004 :PU,RESIZ  
0005 :MR,%RESIZ  
0006 :MR,%DRIVR  
0007 :MR,%WLINE  
0008 :MR,%TRMGN  
0009 :MR,%LBRSZ  
0010 :MR,%WFINT  
0011 :RU,LOADR,99,OG,,,2  
0012 :SP,LOG::3  
0013 :TR

LDINTP T=00004 IS ON CRO0022 USING 00002 BLKS R=0011

0001 :LG,3  
0002 :SV,0  
0003 :OF,DINTP  
0004 :PU,DINTP  
0005 :MR,%DINTP  
0006 :MR,%DRIVR  
0007 :MR,%WLINE  
0008 :MR,%TRMGN  
0009 :MR,%LBRSZ  
0010 :MR,%WFINT  
0011 :RU,LOADR,99,OG,,,2  
0012 :SP,LOG::3  
0013 :TR

LBLDWF T=00004 IS ON CR00022 USING 00002 BLKS R=0009

0001 :LG,0  
0002 :LG,2  
0003 :OF,BLDWF  
0004 :PU,BLDWF  
0005 :MR,%BLDWF  
0006 :MR,%ICMPW  
0007 :RU,LOADR,99,0G,,,2  
0008 :SP,10G::3  
0009 :OF,10G::3  
0010 :RP,10G::3  
0011 ::

LDSPLY T=00004 IS ON CR00022 USING 00002 BLKS R=0011

0001 :LG,1  
0002 :MR,%DSPLY  
0003 :MR,%SCROL  
0004 :MR,%WLINE  
0005 :MR,%DRIVR  
0006 :MR,%RESET  
0007 :OF,DSPLY  
0008 :RU,LOADR,99,0G  
0009 :PU,10G::3  
0010 :SP,10G::3  
0011 :OF,10G

LCURSR T=00004 IS ON CR00022 USING 00002 BLKS R=0012

0001 :LG,1  
0002 :MR,%CURSR  
0003 :MR,%WLINE  
0004 :MR,%RLINE  
0005 :MR,%DRIVR  
0006 :MR,%MOVEC  
0007 :OF,CURSR  
0008 :RU,LOADR,99,1G  
0009 :PU,10G::3  
0010 :SP,10G::3  
0011 :OF,10G  
0012 ::

LNOISE T=00004 IS ON CRO0022 USING 00002 BLKS R=0011

0001 :LG,1  
0002 :MR,%NOISE  
0003 :MR,%BLDWF  
0004 :MR,%WFINT  
0005 :MR,%ICMPW  
0006 :OF,NOISE  
0007 :RU,LOADR,99,1G  
0008 :PU,10G::3  
0009 :SP,10G::3  
0010 :OF,10G  
0011 ::

NASA T=00004 IS ON CR00022 USING 00002 BLKS R=0008

- 0001 : SV,4
- 0002 : OF, SHOW
- 0003 : RP, SHOW
- 0004 : OF, BLDWF
- 0005 : RP, BLDWF
- 0006 : OF, BLDIM
- 0007 : RP, BLDIM
- 0008 : OF, WTAPE
- 0009 : RP, WTAPE
- 0010 : OF, DSPLY
- 0011 : RP, DSPLY
- 0012 : OF, CURSR
- 0013 : RP, CURSR
- 0014 : OF, FDIGN
- 0015 : RP, FDIGN
- 0016 : OF, STABI
- 0017 : RP, STABI
- 0018 : OF, DPLAM
- 0019 : RP, DPLAM
- 0020 : OF, FILTR
- 0021 : RP, FILTR
- 0022 : OF, LFLTR
- 0023 : RP, LFLTR
- 0024 : OF, PLOTV
- 0025 : RP, PLOTV
- 0026 : OF, HFLTR
- 0027 : RP, HFLTR
- 0028 : OF, RESIZ
- 0029 : RP, RESIZ
- 0030 : OF, IMAGE
- 0031 : RP, IMAGE
- 0032 : OF, DINTP
- 0033 : RP, DINTP
- 0034 : OF, NOISE
- 0035 : RP, NOISE
- 0036 : MC, 23
- 0037 : SV, 0
- 0038 : RU, NASA 1
- 0039 : OF, SHOW
- 0040 : OF, BLDWF
- 0041 : OF, DSPLY
- 0042 : OF, CURSR
- 0043 : OF, FDIGN
- 0044 : OF, STABI
- 0045 : OF, DPLAM
- 0046 : OF, FILTR
- 0047 : OF, LFLTR
- 0048 : OF, PLOTV
- 0049 : OF, HFLTR
- 0050 : OF, RESIZ
- 0051 : OF, IMAGE
- 0052 : OF, BLDIM
- 0053 : OF, DINTP
- 0054 : OF, WTA PWTAPE
- 0055

SNASAI T=00004 IS ON CRO0022 USING 00008 BLKS R=0054

```

0001 FTN4,L
0002 PROGRAM NASAI
0003 C THIS PROGRAM IS THE FATHER PROGRAM FOR THE IMAGE FILTERING
0004 C PROGRAMS
0005 C
0006 DIMENSION IPRAM(5),NAME(3),NSON(3,8),IMESS(30)
0007 DATA NSON/2HDS,2HPL,2HY ,2HFD,2HIG,2HN ,2HFI,2HLT,
0008 *2HR ,2HRE,2HSI,2HZ ,2HSH,2HOW,2H ,2HIM,2HAG,2HE ,
0009 *2HNO,2HIS,2HE /
0010 C
0011 C SON PROGRAM NAMES (FILES SAME PRESEDED WITH "&")
0012 C DSPLY - DISPLAY PROGRAM
0013 C FDIGN - FILTER DESIGN MODULE
0014 C FILTR - FILTER IMPLEMENTION MODULE
0015 C RESIZ - IMAGE MODIFICATION MODULE
0016 C SHOW - DISPLAYS WORK FILE
0017 C IMAGE - IMAGE DATA MANAGEMENT MODULE
0018 C NOISE - ADDITIVE GAUSSIAN NOISE
0019 C
0020 CALL RMPAR(IPRAM)
0021 LU=IPRAM(1)
0022 IF(LU.LE.0) LU=1
0023 C
0024 C NPRG IS THE NUMBER OF SONS
0025 C
0026 NPRG=6
0027 ICNT=9
0028 C
0029 C DISPLAY MENU
0030 C
0031 5 WRITE(LU,30)
0032 30 FORMAT(" SELECT PROCESSING OPTION"/," 1. IMAGE DISPLAY"/,"
0033 *FILTER DESIGN"/," 3. FILTER IMAGE"/," 4. MODIFY IMAGE"/,
0034 * SHOW WORK FILE"/," 6. IMAGE DATA MANAGEMENT"/," 7. NOIS
0035 *ON"/," 8. TERMINATE PROGRAM")
0036 READ(LU,*) IOPT
0037 IF(IOPT.EQ.0.OR.IOPT.EQ.1) IOPT = 1
0038 IF(IOPT.LT.1.OR.IOPT.GT.8) GO TO 16
0039 IF(IOPT.EQ.8) GO TO 500
0040 C
0041 IPRAM(2)=IOPT
0042 DO 10 I=1,3
0043 10 NAME(I)=NSON(I,IOPT)
0044 WRITE(LU,15) NAME
0045 15 FORMAT(" MODULE TO BE SCHEDULED IS ",3A2)
0046 GO TO 20
0047 16 WRITE(LU,17)
0048 17 FORMAT(" INVALID RESPONSE")
0049 GO TO 5
0050 C

```

```
0051 C
0052   20 ICNW=LU+200B
0053     CALL EXEC(13,ICNW,IPRAM(3),IPRAM(4),IPRAM(5))
0054     CALL EXEC(23,NAME,IPRAM(1),IPRAM(2),IPRAM(3),IPRAM(4),IPRAM(
0055     WRITE(LU,40) (IPRAM(I),I=1,5)
0056   40 FORMAT("PARAMETERS RETURNED FROM MODULE"/,5(1H,4E11.3,2X))
0057     GO TO 5
0058   500 CONTINUE
0059 C
0060 C     OF ALL SON PROGRAMS
0061 C
0062     DO 510 I=1,NPRG
0063     CALL FILL(IMESS,2H ,30)
0064     CALL CODE
0065     WRITE(IMESS,520) (NSON(J,I),J=1,3)
0066   520 FORMAT("OF," ,3A2)
0067     IRTN=MESSS(IMESS,ICNT,LU)
0068     IF(IRTN.LT.0) CALL EXEC(2,LU,IMESS,IRTN)
0069   510 CONTINUE
0070 C
0071     STOP
0072     END
0073 C
0074 C
0075     SUBROUTINE FILL (IARAY,IA,N)
0076 C
0077 C     THIS SUBROUTINE FILLS ARRAY IARAY WHICH HAS N WORDS WITH THE
0078 C     OF IA.
0079 C
0080     DIMENSION IARAY(N)
0081     DO 10 I=1,N
0082   10 IARAY(I)=IA
0083     RETURN
0084
0085 $     END
```



```

0001 FTN4
0002 PROGRAM DSPLY
0003 C
0004 C THIS PROGRAM DISPLAYS AN IMAGE ON THE GMR-27. IMAGE FILE MUST
0005 C BE IN FORMAT DESCRIBED BY IMAGE DISPLAY SUBSYSTEM.
0006 C
0007 INTEGER SLU11,STRTL,STRTP,SCROL
0008 C
0009 DIMENSION NAME(6),IDCB(144),IBLK(513),ISET(10),LU(5),JNAME(3
0010 INTEGER TEXT1(38),TEXT2(38),TEXT3(38)
0011 C
0012 EQUIVALENCE (IBLK(7),IBLK7),(IBLK(8),IBLK8),(IBLK(12),IBLK12)
0013 1 (IBLK(13),JNAME),(TEXT1,IBLK(129)),(IBLK(169),TEXT2),
0014 2 (IBLK(209),TEXT3)
0015 EQUIVALENCE (ISET(5),ISET5),(ISET(6),ISET6),(ISET(7),ISET7),
0016 1 (ISET(8),ISET8),(ISET(9),ISET9)
0017 C
0018 DATA ISET/100377B,10377B,24001B,30000B,5*-1,260C2B/
0019 DATA SLU11/34011B/
0020 DATA LLA0,LEA0,LECO,LLB1,LLBX,LEB1,LEBX/64000B,44000B,54000B
0021 1 70001B,71777B,50001B,51777B/
0022 C
0023 C
0024 C GET INPUT PARAMETERS
0025 C
0026 CALL RMPAR(LU)
0027 IF (LU .LE. 0) LU = 1
0028 C
0029 C OPEN IMAGE DIRECTORY FILE
0030 C
0031 100 CALL OPEN(IDCB,IERR,6HIMDIRC)
0032 IF (IERR .LT. 0) GO TO 991
0033 C
0034 C GET IMAGE FILE NAME
0035 C
0036 CALL RESET(LU)
0037 WRITE(LU,20)
0038 C
0039 WRITE(LU,21)
0040 WRITE(LU,22)
0041 WRITE(LU,23)
0042 WRITE(LU,24)
0043 WRITE(LU,26)
0044 WRITE(LU,26)
0045 WRITE(LU,26)
0046 20 FORMAT(20X,"I M A G E D I S P L A Y S Y S T E M"//)
0047 21 FORMAT("IMAGE NAME: dB d@"/)
0048 22 FORMAT("# LINES: dB d@",20X,
0049 1"# PIXELS/LINE: dB d@"/)
0050 23 FORMAT("MIN PIXEL: dB d@",18X,
0051 1"MAX PIXEL: dB d@"/)
0052 24 FORMAT("TEXT:",/)
0053 26 FORMAT("dB",38" ", "d@")
0054 25 FORMAT(" ")
0055 27 FORMAT(" ")
0056 105 WRITE(LU,25)
0057 READ(LU,2) NAME
0058 2 FORMAT(6A2)
0059 IF (NAME .EQ. 2H/E) GO TO 9000

```

```
0060 C
0061 C FIND IMAGE FILE
0062 C
0063 CALL RWNDF(IDC B)
0064 110 CALL READF(IDC B, IERR, IBLK, 256, LEN)
0065 IF (IERR .LT. 0) GO TO 991
0066 IF (LEN .EQ. -1) GO TO 800
0067 C
0068 DO 120 I=1,6
0069 IF (IBLK(I) .NE. NAME(I)) GO TO 110
0070 120 CONTINUE
0071 C
0072 C IMAGE FOUND--CHECK IF ON DISC
0073 C
0074 IF (IBK12 .EQ. 1) GO TO 130
0075 C
0076 C IMAGE NOT ON DISC
0077 C
0078 WRITE(LU, 12)
0079 12 FORMAT("
0080 GO TO 105
0081 C
0082 C IMAGE IS ON DISC
0083 C
0084 130 CALL CLOSE(IDC B)
0085 RMIN = IBLK(9)
0086 RMAX = IBLK(10)
0087 WRITE(LU, 29)(IBLK(I), I=7, 10)
0088 28 FORMAT("
0089 CALL EXEC(2, LU, TEXT1, 37)
0090 CALL EXEC(2, LU, TEXT2, 37)
0091 CALL EXEC(2, LU, TEXT3, 37)
0092 WRITE(LU, 27)
0093 CALL OPEN(IDC B, IERR, JNAME)
0094 IF (IERR .LT. 0) GO TO 991
0095 C
0096 C EXTRACT DISPLAY INFORMATION
0097 C
0098 NUML = IBLK7
0099 NUMP = IBLK8
0100 STRTL = (256-MINO(256, NUML))/2
0101 STRTP = (512-MINO(512, NUMP))/2
0102 C
0103 500 ISET5 = IOR(LLAO, IAND(STRTL, 1777B))
0104 ISET6 = IOR(LEAO, IAND(STRTP, 1777B))
0105 ISET7 = LLB1
0106 ISET8 = LEB1
0107 ISET9 = IOR(LECO, IAND(STRTP, 1777B))
0108 C
0109 CALL DRIVR(2, ISET, 10)
0110 C
```

```

0111      IERR = 0
0112      DO 600 I=1,MINO(NUML,256)
0113      IF (IERR .LT. 0) GO TO 991
0114      CALL READF(IDC B,IERR,IBLK,512,NUM)
0115      IF (NUM .LT. 0) GO TO 600
0116      C
0117      DO 595 J=1,NUM
0118      IBLK(J) = (255./(RMAX-RMIN))*(FLOAT(IBLK(J))-RMIN)
0119      IF (IBLK(J) .LT. 0) IBLK(J) = 0
0120      IF (IBLK(J) .GT. 377B) IBLK(J) = 377B
0121      595 CONTINUE
0122      C
0123      IBLK(NUM+1) = SLU11
0124      CALL DRIVR(40002B,IBLK,NUM+1)
0125      600 CONTINUE
0126      IFRST = 0
0127      ILAST = 255
0128      C
0129      C
0130      C OUTPUT SOFT KEY FUNCTIONS
0131
0132      WRITE(LU,29)
0133      29  FORMAT(/"FUNCTION KEYS:"/)
0134      WRITE(LU,30)
0135      WRITE(LU,30)
0136      30  FORMAT(4("dB          d@  ")/)
0137      605 WRITE(LU,31)
0138      31  FORMAT("
0139      WRITE(LU,32)
0140      32  FORMAT(" << SCROLL  SCROLL >>           CURSOR  ",
0141      124X," NEW IMAGE      EXIT  ")
0142      610 CALL EXEC(1,LU,INPT,1)
0143      INPT = INPT-7023
0144      IF (INPT .LT. 1 .OR. INPT .GT. 8) GO TO 610
0145      C
0146      C BRANCH TO APPROPRIATE SECTION
0147      C
0148      C
0149      GO TO (1000,2000,3000,4000,5000,6000,100,9000),INPT
0150      C
0151      C
0152      C
0153      C SCROLL IMAGE BACK
0154      C
0155      1000 IERR = SCROL(IDC B,-9,NUML,IFRST,ILAST,RMAX,RMIN)
0156      IF (IERR .LT. 0) GO TO 991
0157      GO TO 610

```

```
0158 C
0159 C  SCROLL FORWARD
0160 C
0161 2000  IERR = SCROL(IDC B,17,NUML,IFRST,ILAST,RMAX,RMIN)
0162         IF (IERR .LT. 0) GO TO 991
0163         GO TO 610
0164 3000  CONTINUE
0165 C
0166 C  POSITION CURSOR
0167 C
0168 4000  CALL EXEC(23,6HCURSR ,LU)
0169         GO TO 605
0170 5000  CONTINUE
0171 6000  CONTINUE
0172         GO TO 610
0173 C
0174 C  TERMINATE
0175 C
0176 9000  CALL CLOSE(IDC B)
0177         CALL RESET(LU)
0178         WRITE(LU,33)
0179 33    FORMAT("END PROGRAM")
0180         CALL EXEC(6)
0181 C
0182 C  FILE NOT FOUND
0183 C
0184 800    WRITE(LU,3)
0185 3     FORMAT("
0186         GO TO 105
0187 C
0188 991   CALL RESET(LU)
0189         WRITE(LU,9) IERR
0190 9     FORMAT("FILE ERROR",I6)
0191         CALL CLOSE(IDC B)
0192         END
0193 $
```

SCUR3R T=00004 IS ON CRO0022 USING 00005 BLKS R=0037

```

0001 FTN4
0002     PROGRAM CURSR
0003 C
0004     DIMENSION LU(5),IBUF(2352),IZERO(2)
0005 C
0006     INTEGER EA,LA
0007 C
0008     DATA IZERO/44000B,64000B/
0009 C
0010 C
0011     CALL RMPAR(LU)
0012 C
0013 C
0014 C SAVE IMAGE LINES
0015 C
0016 C
0017     DO 50 I=0,20
0018     CALL RLINE(I,0,111,IBUF(112*I+1))
0019 50 CONTINUE
0020     WRITE(LU,1)
0021 1   FORMAT("
0022     WRITE(LU,2)
0023 2   FORMAT("      LEFT          UP          RIGHT          ",
0024     "12X,"      DOWN      ",12X,"      RETURN      ")
0025     CALL MOVEC(0,255)
0026     EA = 0
0027     LA = 255
0028 100  CALL EXEC(1,LU,INPT,1)
0029     INPT = INPT-7023
0030     IF (INPT .LT. 1 .OR. INPT .GT. 8) GO TO 100
0031 C
0032 C
0033 C BRANCH TO APPROPRIATE SECTION
0034 C
0035 C
0036     GO TO (400,200,500,100,100,300,100,600), INPT
0037 C
0038 C MOVE CURSOR UP
0039 C
0040 200  LA = MOD(LA+11,256)
0041     CALL MOVEC(EA,LA)
0042     GO TO 100
0043 C
0044 C MOVE CURSOR DOWN
0045 C
0046 300  LA = MOD(LA+249,256)
0047     CALL MOVEC(EA,LA)
0048     GO TO 100
0049 C
0050 C MOVE CURSOR LEFT
0051 C
0052 400  EA = MOD(EA+499,512)
0053     CALL MOVEC(EA,LA)
0054     GO TO 100
0055 C

```

```

0056 C MOVE CURSOR RIGHT
0057 C
0058 500 EA = MOD(EA+17,512)
0059 CALL MOVEC(EA,LA)
0060 GO TO 100
0061 C
0062 C RETURN TO PREVIOUS SCREEN
0063 C
0064 600 DO 610 I=0,20
0065 CALL WLINE(I,0,111,IBUF(112*I+1))
0066 610 CONTINUE
0067 C
0068 CALL DRIVR(2,IZERO,2)
0069 C
0070 END
0071 $

```

&ICMPW T=00004 IS ON CRO0022 USING 00002 BLKS R=0011

```

0001 FTN4
0002 FUNCTION ICMPW(IBUF1,IBUF2,ILEN)
0003 DIMENSION IBUF1(1),IBUF2(1)
0004 DO 100 I=1,ILEN
0005 IF (IBUF1(I) NE. IBUF2(I)) GO TO 200
0006 100 CONTINUE
0007 ICMPW = 0
0008 RETURN
0009 200 ICMPW = I
0010 END
0011 $

```

&RESET T=00004 IS ON CRO0022 USING 00002 BLKS R=0017

```

0001 FTN4
0002 SUBROUTINE RESET(LU)
0003 C
0004 C
0005 WRITE(LU,1)
0006 1 FORMAT("
0007 C
0008 C WAIT 200 MSEC
0009 C
0010 CALL EXEC(12,0,1,0,-20)
0011 C
0012 C CLEAR DISPLAY
0013 C
0014 WRITE(LU,2)
0015 2 FORMAT("")
0016 END
0017 $

```

&RLINE T=00004 IS ON CROOJ22 USING 00005 BLKS R=0039

```
0001 FTN4,L
0002     SUBROUTINE RLINE(LINE,IPIX,JPIX,IDATA)
0003 C
0004 C     THIS SUBROUTINE READS A LINE FROM GMR-27.
0005 C
0006 C     WHERE
0007 C         LINE = LINE # TO READ
0008 C         IPIX = STARTING PIXEL
0009 C         JPIX = ENDING PIXEL
0010 C
0011 C         IDATA = BUFFER IN WHICH DATA IS RETURNED (1 PIXEL/WORD)
0012 C
0013 C
0014 C     DIMENSION IDATA(512),INIT(5)
0015 C
0016 C     EQUIVALENCE (LLA,INIT(2)),(LEA,INIT(3)),(LEB,INIT(4))
0017 C
0018 C     DATA INIT/100377B,64000B,44000B,50000B,26002B/
0019 C
0020 C     COMPUTE DIRECTION
0021 C
0022 C     IDIRC = 1
0023 C     IF (IPIX .GT. JPIX) IDIRC = -1
0024 C
0025 C     SET UP FOR READ BACK
0026 C
0027 C     LLA = 64000B + IAND(LINE,377B)
0028 C     LEA = 44000B + IAND(IPIX,777B)
0029 C     LEB = 50000B + IDIRC + 512
0030 C     CALL DRIVR(2,INIT,5)
0031 C
0032 C     READ BACK LINE
0033 C
0034 C     NUM = IDIRC*(JPIX-IPIX)+1
0035 C     CALL DRIVR(1,IDATA,NUM)
0036 C
0037 C     RETURN
0038 C     END
0039 $
```

MOVEC T=00004 IS ON CRO022 USING 00004 BLKS R=0031

```

0001 FTN4,L
0002     SUBROUTINE MOVEC(IX,IY)
0003 C
0004 C THIS SUBROUTINE MOVES THE CURSOR ON THE GMR-27. ITS POSITION I
0005 C INDICATED IN THE LOWER LEFT HAND CORNER OF THE SCREEN.
0006 C
0007 C     IX = X-COORDINATE
0008 C     IY = Y-COORDINATE
0009 C
0010 C
0011 C     INTEGER WACO
0012 C
0013 C     DIMENSION ICR(7),IPOO(5),IPXY(3)
0014 C
0015 C     EQUIVALENCE (ICR,ICR1),(ICR(2),ICR2),(ICR(3),ICR3),(ICR(5),I
0016 C 1 (ICR(6),ICR6),(ICR(7),ICR7),(IPXY,IPXY1),(IPXY(2),IPXY2)
0017 C
0018 C     DATA IPOO/44000B,64000B,24015B,50010B,20002B/
0019 C     DATA ICR/0,0,0,22054B,0,0,0/
0020 C     DATA IPXY/0,0,24001B/
0021 C     DATA WACO,LEAO,LLAO/22000B,44000B,64000B/
0022 C
0023 C
0024 C
0025 C WRITE POSITION ON SCREEN
0026 C
0027 C     CALL DRIVR(2,IPOO,5)
0028 C
0029 C     ID1 = IY/100
0030 C     ICR1 = WACO + ID1 +60B
0031 C     ID2 = (IY-ID1*100)/10
0032 C     ICR2 = WACO + ID2 +60B
0033 C     ID3 = (IY-ID1*100-ID2*10)
0034 C     ICR3 = WACO + ID3 + 60B
0035 C     ID1 = IX/100
0036 C     ICR5 = WACO +ID1 + 60B
0037 C     ID2 = (IX-ID1*100)/10
0038 C     ICR6 = WACO + ID2 + 60B
0039 C     ID3 = IX-ID1*100-ID2*10
0040 C     ICR7 = WACO + ID3 + 60B
0041 C
0042 C     CALL DRIVR(2,ICR,7)
0043 C
0044 C POSITION CURSOR
0045 C
0046 C     IPXY1 = IOR(LEAO,IAND(IX,777B))
0047 C     IPXY2 = IOR(LLAO,IAND(IY,377B))
0048 C     CALL DRIVR(2,IPXY,3)
0049 C     RETURN
0050 C     END
0051 $

```



&IMAGE T=00004 IS ON CRO0022 USING 00015 BLKS R=0161

```

0001 FTN4,Q,C,T
0002     PROGRAM IMAGE
0003 C
0004 C
0005 C THIS PROGRAM IS THE IMAGE FILE MANAGER FOR THE IMAGE DISPLAY
0006 C SUBSYSTEM.
0007 C
0008 C
0009     DIMENSION LU(5),IDCB1(272),IDCB2(528),IDCB3(144),JNAME(3),
0010     1 IFNAM(3),NAME(6),IDATA(512),KNAME(6)
0011 C
0012     INTEGER ENTRY(256),ISIZE(2),TEXT1(19)
0013 C
0014     EQUIVALENCE (ENTRY(7),NLINE),(ENTRY(8),NPIXL),(ENTRY(12),LOC
0015     1 (ENTRY(13),JNAME),(ENTRY(16),IFNAM),(ENTRY(19),IFNUM)
0016     2,(ENTRY,KNAME)
0017     2,(TEXT1,ENTRY(129))
0018     EQUIVALENCE (ISIZE(2),ISIZ2)
0019 C
0020 C
0021 C GET INPUT PARAMETERS
0022 C
0023     CALL RMPAR(LU)
0024     IF (LU .LE. 0) LU = 1
0025 C
0026 C OUTPUT HEADING
0027 C
0028 900 WRITE(LU,1)
0029 1   FORMAT(// "      I M A G E   F I L E   M A N A G E R"//)
0030 C
0031 C GET COMMAND INPUT
0032 C
0033 1000 WRITE(LU,2)
0034 2   FORMAT("> ")
0035     READ(LU,3) ICMD
0036 3   FORMAT(A2)
0037 C
0038 C EXECUTE COMMAND
0039 C
0040     IF (ICMD .NE. 2H??) GO TO 1010
0041 C
0042 C COMMAND IS HELP
0043 C
0044     WRITE(LU,4)
0045 4   FORMAT("/" COMMANDS ARE:"/,
0046     1" BU-BUILD IMAGE FILE"/,
0047     2" DI-DISPLAY IMAGE ON GMR-27"/,
0048     3" SA-SAVE IMAGE TO TAPE"/,
0049     4" RE-RESTORE IMAGE TO DISC"/,
0050     4" DL-DIRECTORY LIST"/,
0051     4" PU-PURGE IMAGE"/,
0052     4" WT-WRITE NASA TAPE"/,
0053     5" ??-HELP"/,
0054     6" EX-EXIT"//)
0055     GO TO 1000

```

```
0056 C
0057 1010 IF (ICMD .NE. 2HBU) GO TO 1030
0058 C
0059 C BUILD IMAGE COMMAND
0060 C
0061 CALL EXEC(23+100000B,6HBLDIM ,LU)
0062 GO TO 1020
0063 5 GO TO 900
0064 C
0065 C PROGRAM NOT RP'ED
0066 C
0067 1020 WRITE(LU,6)
0068 6 FORMAT(" BLDIM NOT RP'ED!")
0069 GO TO 1000
0070 C
0071 1030 IF (ICMD .NE. 2HDI) GO TO 1045
0072 C
0073 C DISPLAY IMAGE COMMAND
0074 C
0075 CALL EXEC(23+100000B,6HDSPLY ,LU)
0076 GO TO 1040
0077 7 GO TO 900
0078 C
0079 C DSPLY NO RP'ED
0080 C
0081 1040 WRITE(IU,8)
0082 8 FORMAT(" DSPLY NOT RP'ED!")
0083 GO TO 1000
0084 C
0085 1045 IF (ICMD .NE. 2HWT) GO TO 1050
0086 C
0087 C WRITE NASA TAPE
0088 C
0089 CALL EXEC(23,6HWTAPE ,LU)
0090 GO TO 1000
0091 C
0092 C
0093 1050 IF (ICMD .NE. 2HSA .AND. ICMD .NE. 2HRE .AND.
0094 1 ICMD .NE. 2HPU) GO TO 1200
0095 C
0096 C SAVE/RESTORE IMAGE TO/FROM TAPE AND PURGE IMAGE
0097 C
0098 C OPEN DIRECTORY FILE
0099 C
0100 CALL OPEN(IDCBI,IERR,6HIMDIRC,2,2HIM,23,272)
0101 IF (IERR .LT. 0) GO TO 9999
0102 C
0103 C GET IMAGE NAME
0104 C
0105 WRITE(LU,9)
0106 9 FORMAT(" ENTER IMAGE NAME (12 CHARACTERS)?_")
0107 READ(LU,10) NAME
0108 10 FORMAT(6A2)
0109 C
0110 C FIND IMAGE
```

```

0111 C
0112 1060 CALL READF(IDCBI,IERR,ENTRY,256,LEN)
0113     IF (LEN .NE. -1) GO TO 1070
0114 C
0115 C EOF REACHED
0116 C
0117     WRITE(LU,11)
0118 11     FORMAT(" IMAGE NOT FOUND!")
0119     CALL CLOSE(IDCBI)
0120     GO TO 1000
0121 C
0122 1070 IF (IERR .LT. 0) GO TO 9999
0123 C
0124 C COMPARE NAME OF IMAGE
0125 C
0126     IF (ICMPW(ENTRY,NAME,6) .NE. C) GO TO 1060
0127 C
0128 C IMAGE FOUND
0129 C
0130     IF (ICMD .EQ. 2HRE) GO TO 1120
0131     IF (ICMD .EQ. 2HPU) GO TO 1300
0132 C
0133 C TASK IS TO SAVE IMAGE
0134 C
0135     IF (LOC .EQ. 1) GO TO 1090
0136 C
0137 C IMAGE ALREADY ON TAPE
0138 C
0139     WRITE(LU,12)
0140 12     FORMAT(" IMAGE NOT ON DISC!")
0141     GO TO 1000
0142 C
0143 C IMAGE ON DISC
0144 C
0145 1090 CALL OPEN(IDCBI,IERR,JNAME,0,0,0,528)
0146     IF (IERR .LT. 0) GO TO 9999
0147 C
0148 C GET TYPE 0 FILE
0149 C
0150 C     WRITE(LU,13)
0151 C13    FORMAT(" TYPE MT LU 000# ?_")
0152 C     READ(LU,14) IFNAM
0153 C14    FORMAT(3A2)
0154     IFNAM=2HLU
0155     IFNAM(2) =2H00
0156     IFNAM(3) =2H08
0157     WRITE(LU,131)
0158 131   FORMAT(" SELECT OPTION"/" 1. 8-BIT PACKED"/" 2. UNPACKED
0159     READ(LU,*) IPACK
0160     CALL OPEN(IDCBI,IERR,IFNAM)
0161     IF (IERR .LT. 0) GO TO 9999
0162     CALL RWPDF(IDCBI,IERR)
0163     IF (IERR .LT. 0) GO TO 9999
0164     WRITE(LU,15)
0165 15    FORMAT(" FILE #?_")
0166     READ(LU,*) IFNUM
0167     CALL SPACE(IDCBI,IERR,IFNUM-1)
0168     IF (IERR .LT. 0) GO TO 9999

```

```
0169 C
0170 C WRITE HEADER ON TAPE
0171 C
0172 CALL WRITF(IDC3,IERR,ENTRY,11)
0173 IF (IERR .LT. 0) GO TO 9999
0174 C
0175 C NOW TRANSFER DATA
0176 C
0177 DO 1100 I = 1,NLINE
0178 CALL READF(IDC2,IERR,ILATA,512)
0179 IF (IERR .LT. 0) GO TO 9999
0180 C
0181 IF(IPACK .NE. 1) GO TO 1101
0182 C
0183 C PACK DATA
0184 C
0185 DO 1102 J =1,NPIXL,2
0186 K = 0.5*(J+1)
0187 IVAR=IDATA(J+1)
0188 CALL ROT8(IVAR,KVAR)
0189 1102 IDATA(K)=IOR(IDATA(J),KVAR)
0190 1101 CALL WRITF(IDC3,IERR,IDATA,NPIXL)
0191 IF (IERR .LT. 0) GO TO 9999
0192 1100 CONTINUE
0193 C
0194 C WRITE EOF
0195 C
0196 CALL WRITF(IDC3,IERR,0,-1)
0197 IF (IERR .LT. 0) GO TO 9999
0198 C
0199 C PURGE DISC FILE
0200 C
0201 CALL PURGE(IDC2,IERR,JNAME,2HIM)
0202 IF (IERR .LT. 0) GO TO 9999
0203 C
0204 C UPDATE ENTRY
0205 C
0206 LOC = 2
0207 C
0208 CALL POSNT(IDC1,IERR,-1)
0209 IF (IERR .LT. 0) GO TO 9999
0210 CALL WRITF(IDC1,IERR,ENTRY,256)
0211 IF (IERR .LT. 0) GO TO 9999
0212 C
0213 CALL CLOSE(IDC1)
0214 CALL RWNDF(IDC3)
0215 CALL CLOSE(IDC3)
0216 GO TO 1000
0217 C
0218 C RESTORE IMAGE FROM TAPE
0219 C
0220 1120 IF (LOC .EQ. 2) GO TO 1130
0221 C
0222 C IMAGE ON DISC
0223 C
0224 WRITE(LU,16)
0225 16 FORMAT(" IMAGE ALREADY ON DISC!")
0226 CALL CLOSE(IDC1)
0227 GO TO 1000
```

```

0228 C
0229 C CREATE DISC FILE
0230 C
0231 1130 ISIZE = (FLOAT(NLINE)*FLOAT(NPIXL)+127.)/128.
0232 ISIZ2 = NPIXL
0233 C
0234 CALL CREAT(IDC B2,IERR,JNAME,ISIZE,2,2HIM,23,528)
0235 IF (IERR .GE. 0) GO TO 1135
0236 C
0237 C CAN'T CREATE DISC FILE
0238 C
0239 WRITE(LU,19)
0240 19 FORMAT(" CAN'T CREATE DISC FILE!!")
0241 CALL CLOSE(IDC B1)
0242 GO TO 1000
0243 C
0244 C OPEN TYPE O FILE
0245 C
0246 1135 CALL OPEN(IDC B3,IERR,IFNAM)
0247 C
0248 C GET LU OF TYPE O FILE
0249 C
0250 CALL LOCF(IDC B3,IERR,IREF,IRB,IOFF,JSEC,MTLU)
0251 IF (IERR .LT. 0) GO TO 9999
0252 C
0253 C TELL USER TO MOUNT TAPE
0254 C
0255 WRITE(LU,17) MTLU
0256 17 FORMAT(" MOUNT TAPE ON LU ",I2" ENTER RETURN WHEN READY")
0257 CALL EXEC(1,LU,IREF,1)
0258 C
0259 C REWIND TAPE
0260 C
0261 CALL RW NDF(IDC B3,IERR)
0262 IF (IERR .LT. 0) GO TO 9999
0263 C
0264 C SPACE FORWARD TO FILE
0265 C
0266 CALL SPACE(IDC B3,IERR,IFNUM-1)
0267 C
0268 C READ HEADER
0269 C
0270 CALL READF(IDC B3,IERR,IDATA,11)
0271 IF (IERR .LT. 0) GO TO 9999
0272 IF(ICMPW(IDATA,ENTRY,11) .NE. 0) GO TO 1160
0273 C
0274 C HEADPR COMPARES
0275 C
0276 C TRANSFER DATA
0277 C
0278 DO 1140 I=1,NLINE
0279 CALL READF(IDC B3,IERR,IDATA,NPIXL)
0280 IF (IERR .LT. 0) GO TO 9999
0281 CALL WRITF(IDC B2,IERR,IDATA,NPIXL)
0282 IF (IERR .LT. 0) GO TO 9999
0283 1140 CONTINUE
0284 C

```

```

0285      CALL RWNDF(IDC3)
0286      CALL CLOSE(IDC3)
0287      CALL CLOSE(IDC2)
0288 C
0289 C  UPDATE DIRECTORY ENTRY
0290 C
0291      LOC = 1
0292 C
0293      CALL POSNT(IDC1,IERR,-1)
0294      IF (IERR .LT. 0) GO TO 9999
0295      CALL WRITF(IDC1,IERR,ENTRY,256)
0296      IF (IERR .LT. 0) GO TO 9999
0297      CALL CLOSE(IDC1,IERR)
0298      IF (IERR .LT. 0) GO TO 9999
0299 C
0300      GO TO 1000
0301 C
0302 C  LABEL DOES NO MATCH
0303 C
0304 1160 WRITE(LU,18)
0305 18   FORMAT(" WRONG FILE!!")
0306      CALL RWNDF(IDC3)
0307      CALL CLOSE(IDC3)
0308      CALL CLOSE(IDC1)
0309      GO TO 1000
0310 C
0311 C
0312 1200 IF (ICMD .NE. 2HDL) GO TO 1230
0313 C
0314 C  DIRECTORY LIST
0315 C
0316 C  OPEN DIRECTORY FILE
0317 C
0318      CALL OPEN(IDC1,IERR,6HIMDIRC)
0319      IF (IERR .LT. 0) GO TO 9999
0320 C
0321 C  OUTPUT HEADING
0322 C
0323      WRITE(LU,30)
0324 30   FORMAT(//"IMAGE NAME      #LINES  #PIXELS  LOC      TEXT"/)
0325 C
0326 C  OUTPUT INFO
0327 C
0328 1210 CALL READF(IDC1,IERR,ENTRY,256,LEN)
0329      IF (LEN .NE. -1) GO TO 1220
0330 C
0331 C  EOF REACHED
0332 C
0333      CALL CLOSE(IDC1)
0334      GO TO 1000
0335 C
0336 1220 IF (IERR .LT. 0) GO TO 9999
0337 C
0338      IF (ENTRY .EQ. -1) GO TO 1210
0339      ICHR = 2HD
0340      IF (LOC .NE. 1) ICHR = 2HT
0341      WRITE(LU,31)KNAME,NLINE,NPIXL,ICHR,TEXT1
0342 31   FORMAT(6A2,2X,I4,4X,I4,3X,A5,2X,19A2)
0343      GO TO 1210

```

```
0344 C
0345 1230 IF (ICMD .EQ. 2HEX) GO TO 1240
0346 C
0347 C ILLEGAL COMMAND
0348 C
0349 WRITE(LU,22)
0350 22 FORMAT("ILLEGAL COMMAND!")
0351 GO TO 1000
0352 C
0353 1240 WRITE(LU,23)
0354 23 FORMAT("END PROGRAM")
0355 CALL EXEC(6)
0356 C
0357 C PURGE FILE
0358 C
0359 1300 CALL POSNT(IDCBI,IERR,-1)
0360 IF (IERR .LT. 0) GO TO 9999
0361 ENTRY = -1
0362 CALL WRITF(IDCBI,IERR,ENTRY,256)
0363 IF (IERR .LT. 0) GO TO 9999
0364 C
0365 C PURGE DATA FILE
0366 C
0367 CALL PURGE(IDCBI,IERR,JNAME,2HIM)
0368 CALL CLOSE(IDCBI)
0369 GO TO 1000
0370 C
0371 C
0372 C ERROR
0373 C
0374 C
0375 9999 WRITE(LU,20) IERR
0376 20 FORMAT(" FILE ERROR ",I6)
0377 CALL CLOSE(IDCBI)
0378 GO TO 1000
0379 END
0380 $
```

```
0001 FTN4
0002     SUBROUTINE SPACE(IDC B,IERR,NUM)
0003 C
0004 C     THIS SUBROUTINE IS USED TO SPACE FORWARD OR BACKWARD THE
0005 C     NUMBER OF FILES SPECIFIED.
0006 C
0007     DIMENSION IDC B(144)
0008 C
0009     DATA IFRWD,IBACK/1300B,1400B/
0010 C
0011 C
0012 C
0013     IERR = 0
0014     IF (NUM .EQ. 0) RETURN
0015 C
0016     IDIR = IFRWD
0017     IF (NUM .GT. 0) GO TO 100
0018     IDIR = IBACK
0019     NUM = -NUM
0020 C
0021 C
0022 100 DO 110 I=1,NUM
0023     CALL FCONT(IDC B,IERR,IDIR)
0024     IF (IERR .LT. 0) RETURN
0025 110 CONTINUE
0026 C
0027     RETURN
0028     END
0029 $
```



&RESIZ T=00004 IS ON CRO022 USING 00060 BLKS R=0541

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0001 FTN4,Q,T,C
0002 PROGRAM RESIZ
0003 C WRITTEN BY W. E. ALEXANDER
0004 C
0005 C PROGRAM FORMS A PART OF THE SPATIAL DOMAIN FILTERING PACKAGE
0006 C
0007 C PROGRAM ALLOWS THE USER TO INTERPOLATE AND SCALE AN IMAGE AN
0008 C CHANGE ITS DATA TYPE. THUS A FLOATING POINT IMAGE CAN BE MAD
0009 C INTO AN EIGHT BIT IMAGE.
0010 C
0011 C
0012 C
0013 DIMENSION F(512),G(512),IOP(512),IPRAM(5),NSON(3,2)
0014 DIMENSION A(3,2,2),B(3,2,2),NAME(3),INM(3)
0015 DIMENSION JMES(40),DIRC(515),IKTM(5)
0016 INTEGER WFINT,READL,RITEL
0017 EQUIVALENCE(G(1),IOP(1))
0018 EQUIVALENCE(F(1),G(1))
0019 EQUIVALENCE (DIRC(4),F(1)),(DIRC(1),INM(1)),(INM(1),NROW)
0020 EQUIVALENCE (INM(2),ICOLS),(DIRC(2),AMAX),(DIRC(3),AMIN)
0021 C
0022 DATA NSON/2HLF,2HLT,2HR ,2HDI,2HNT,2HP /
0023 CALL RMPAR(IPRAM)
0024 LU=IPRAM(1)
0025 IF(LU.EQ.0) LU=1
0026 C
0027 C INITIALIZE PARAMETERS
0028 C
0029 C ITYPE = 8
0030 C
0031 CALL CODE
0032 WRITE (JMES,6)
0033 6 FORMAT (" RESIZE")
0034 CALL TRMGN (JMES,LU,0)
0035 CALL BLANK (JMES)
0036 NTYPE=32
0037 IRTCD=0
0038 IMXX=512
0039 IMXP1=IMXX+1
0040 IFE=0
0041 ILE=511
0042 IFR=0
0043 ILR=511
0044 C
0045 5 CALL CODE
0046 WRITE (JMES,995)
0047 995 FORMAT (" RESIZE IMAGE ")
0048 CALL TRMGN (JMES,LU,0)
0049 CALL BLANK (JMES)
0050 C
0051 C SPECIFY DATA LENGTH FOR OUTPUT
0052 C

```

```

0053      10 CALL CODE
0054      WRITE(JMES,11)
0055      11 FORMAT(" SPECIFY OUTPUT DATA TYPE")
0056      CALL TRMGN(JMES,LU,0)
0057      CALL BLANK(JMES)
0058      CALL CODE
0059      WRITE(JMES,12)
0060      12 FORMAT(" 1. 8 BIT IMAGE")
0061      CALL TRMGN(JMES,LU,0)
0062      CALL BLANK(JMES)
0063      CALL CODE
0064      WRITE(JMES,13)
0065      13 FORMAT(" 2. 15 BIT IMAGE")
0066      CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0067      C
0068      IRTM=ICD
0069      C
0070      CALL BLANK(JMES)
0071      15 CALL SPCHR (IRTM,IRT)
0072      GO TO (500,10,5,20,17,17),IRT
0073      17 CALL CKFLD(2,ICD,IRS)
0074      GO TO (25,25,30,30,20),IRS
0075      20 IW=1
0076      GO TO 950
0077      25 ITYPE =8
0078      IMAX=255
0079      GO TO 32
0080      30 ITYPE =15
0081      IMAX=32767
0082      C
0083      C SPECIFY WORK FILE
0084      C
0085      C
0086      32 CALL BLANK(JMES)
0087      CALL CODE
0088      WRITE(JMES,450)
0089      450 FORMAT(" SELECT OPTION")
0090      CALL TRMGN(JMES,LU,0)
0091      CALL BLANK(JMES)
0092      CALL CODE
0093      WRITE(JMES,455)
0094      455 FORMAT(" 1. SPECIFY NEW IMAGE")
0095      CALL TRMGN(JMES,LU,0)
0096      CALL BLANK(JMES)
0097      CALL CODE
0098      WRITE(JMES,460)
0099      460 FORMAT(" 2. USE CURRENT WORK FILE")
0100      CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0101      CALL BLANK(JMES)
0102      465 CALL CKFLD(2,ICD,IRS)
0103      GO TO (475,475,480,485),IRS
0104      485 IW=12
0105      C
0106      C OPEN WORK FILE
0107      C

```

```

0109 475 IGET=WFINT (NROW,ICOLS,AMAX,AMIN,LU)
0110 IF(IGET.LT.0) GO TO 999
0111 480 IGET=READL(-1,0,511,DIRC)
0112 IF(IGET.LT.0) GO TO 999
0113 40 CALL CODE
0114 WRITE(JMES,45) AMAX,AMIN
0115 45 FORMAT(" AMAX= ",E12.5,5X," AMIN= ",E12.5,5X,"FOR IMAGE")
0116 CALL TRMGN(JMES,LU,0)
0117 CALL BLANK(JMES)
0118 C
0119 C SPECIFY IMAGE SCALING OPTION
0120 C
0121 50 CALL CODE
0122 WRITE(JMES,51)
0123 51 FORMAT(" SPECIFY IMAGE SCALING OPTION")
0124 CALL TRMGN(JMES,LU,0)
0125 CALL BLANK(JMES)
0126 CALL CODE
0127 WRITE(JMES,52)
0128 52 FORMAT(" 1. AUTOMATIC SCALING")
0129 CALL TRMGN(JMES,LU,0)
0130 CALL BLANK(JMES)
0131 CALL CODE
0132 WRITE(JMES,53)
0133 53 FORMAT(" 2. SYSTEM DEFAULT OPTION")
0134 CALL TRMGN(JMES,LU,0)
0135 CALL BLANK(JMES)
0136 CALL CODE
0137 WRITE(JMES,54)
0138 54 FORMAT(" 3. USER SPECIFIED SCALE FACTOR")
0139 CALL TRMGN(JMES,LU,0)
0140 CALL BLANK(JMES)
0141 CALL CODE
0142 WRITE(JMES,56)
0143 56 FORMAT(" 4. USER SPECIFIED MAX AND MIN")
0144 CALL TRMGN(JMES,LU,0)
0145 CALL BLANK(JMES)
0146 CALL CODE
0147 WRITE(JMES,57)
0148 57 FORMAT(" 5. LOG COMPRESSION")
0149 CALL TRMGN(JMES,LU,0)
0150 CALL BLANK(JMES)
0151 CALL CODE
0152 WRITE(JMES,58)
0153 58 FORMAT(" 6. EXPONENTIATION OPTION")
0154 CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0155 CALL BLANK(JMES)
0156 55 CALL CKFLD(6,ICD,IRS)
0157 GO TO (65,65,75,80,105,160,165,60),IRS
0158 60 IW=2
0159 GO TO 950
0160 C
0161 C AUTOMATIC SCALING SELECTED
0162 C
0163 65 SCL=AMAX-AMIN
0164 IF (ABS(SCL).LE.1.0E-5) GO TO 70
0165 SCL=FLOAT(IMAX)/SCL
0166 IOPT=1
0167 GO TO 190
0168 C
0169 C SYSTEM DEFAULT SCALING OPTION SELECTED
0170 C
0171 75 SCL=1.0
0172 IOPT=2
0173 GO TO 120

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OF POOR QUALITY

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0234      CALL CODE
0235      WRITE(JMES,151)
0236 151  FORMAT(" SCALE TOO SMALL")
0237      CALL TRMGN(JMES,LU,0)
0238      CALL BLANK(JMES)
0239      CALL CODE
0240      WRITE(JMES,152)
0241 152  FORMAT(" ENTER CR TO GO TO SYSTEM LEVEL MENU")
0242      CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0243      CALL BLANK(JMES)
0244          IRTCD=1HX
0245          GO TO 1000
0246 155  SCL=(1.0/SCL)*FLOAT(IMAX)
0247          GO TO 190
0248  C
0249  C      LOG COMPRESSION OPTION SELECTED
0250  C
0251 160  CALL CODE
0252      WRITE(JMES,161)
0253 161  FORMAT(" LOG COMPRESSION OPTION SELECTED")
0254      CALL TRMGN(JMES,LU,0)
0255      CALL BLANK(JMES)
0256          IOPT=5
0257          SCL=FLOAT(IMAX)/ALOG(AMAX-AMIN+1.0)
0258          GO TO 190
0259  C
0260  C      EXPONENTIATION OPTION SELECTED
0261  C
0262 165  CALL CODE
0263      WRITE(JMES,166)
0264 166  FORMAT(" ENTER DESIRED EXPONENT")
0265      CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0266      CALL BLANK(JMES)
0267 170  CALL SPCHR (IRTM,IRT)
0268          POWER=RTM
0269          IF (IRT .EQ. 5) GO TO 180
0270 175  IW=6
0271          GO TO 950
0272 180  POWER=ABS(POWER)
0273      CALL CODE
0274      WRITE(JMES,185) POWER
0275 185  FORMAT(" EXPONENT= ",1F10.4)
0276      CALL TRMGN(JMES,LU,0)
0277      CALL BLANK(JMES)
0278          SCL=FLOAT(IMAX)/((AMAX-AMIN)**POWER)
0279          IOPT=6
0280  C
0281  C      OBTAIN PARAMETERS FOR RESIZING IMAGE
0282  C
0283 190  INUM=64
0284          INCNT=0
0285          IMCNT=0
0286          NTST=INUM
0287 195  CALL CODE
0288      WRITE(JMES,196)
0289 196  FORMAT(" INDEPENDENT DIRECTIONAL SCALING")
0290      CALL TRMGN(JMES,LU,0)
0291      CALL BLANK(JMES)

```

```

0174 C
0175 C   USER ENTERS SCALE FACTOR
0176 C
0177   80   CALL CODE
0178       WRITE(JMES,81)
0179   81   FORMAT(" ENTER DESIRED SCALE FACTOR")
0180       CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0181       CALL BLANK(JMES)
0182   85   CALL SPCHR (IRTM,IRT)
0183       GO TO (1000,1000,1000,1000,855),IRT
0184  855   GAIN=ABS(RTM)
0185       IF (IRT .EQ. 5) GO TO 95
0186   90   IW=3
0187       GO TO 950
0188   95   CALL CODE
0189       WRITE(JMES,100) GAIN
0190  100   FORMAT (" SCALE FACTOR = ",F10.4)
0191       CALL TRMGN(JMES,LU,0)
0192       CALL BLANK(JMES)
0193       IOPT=3
0194       SCL=GAIN
0195       GO TO 190
0196 C
0197 C   USER SPECIFIED MAXIMUM AND MINIMUM
0198 C
0199  105   IOPT=4
0200       CALL CODE
0201       WRITE(JMES,106)
0202  106   FORMAT(" ENTER MAXIMUM FOR IMAGE")
0203       CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0204       CALL BLANK(JMES)
0205  110   CALL SPCHR (IRTM,IRT)
0206       GO TO (1000,1000,1000,1000,910),IRT
0207  910   AMXIN=RTM
0208       IF(RTM.NE.OB) GO TO 120
0209  115   IW=4
0210       GO TO 950
0211  120   CALL CODE
0212       WRITE(JMES,121) AMXIN
0213  121   FORMAT(" MAXIMUM FOR IMAGE = ",1PE15.8)
0214       CALL TRMGN(JMES,LU,0)
0215       CALL BLANK(JMES)
0216  130   CALL CODE
0217       WRITE(JMES,131)
0218  131   FORMAT(" ENTER MINIMUM FOR IMAGE")
0219       CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0220       CALL BLANK(JMES)
0221  135   CALL SPCHR (IRTM,IRT)
0222       GO TO (1000,1000,1000,1000,935),IRT
0223  935   AMNIN=RTM
0224       IF (IRT .EQ. 5) GO TO 145
0225  140   IW=5
0226       GO TO 950
0227  145   CALL CODE
0228       WRITE(JMES,150) AMNIN
0229  150   FORMAT ("-- MINIMUM FOR IMAGE =",F10.4)
0230       CALL TRMGN(JMES,LU,0)
0231       CALL BLANK(JMES)
0232       SCL=AMXIN-AMNIN
0233       IF(SCL.GE.1.OE-5) GO TO 155

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```

0292 931 CALL CODE
0293 WRITE(JMES,197)
0294 197 FORMAT(" ENTER ROW SCALE FACTOR")
0295 CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0296 CALL BLANK(JMES)
0297 200 CALL SPCHR (IRTM,IRT)
0298 YS=RTM
0299 IF (IRT .EQ. 5) GO TO 210
0300 205 IW=7
0301 GO TO 950
0302 210 CALL CODE
0303 WRITE(JMES,211)
0304 211 FORMAT(" ENTER COLUMN SCALE FACTOR ")
0305 CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0306 CALL BLANK(JMES)
0307 215 CALL SPCHR (IRTM,IRT)
0308 XS=RTM
0309 IF (IRT .EQ. 5) GO TO 225
0310 220 IW=8
0311 GO TO 950
0312 C
0313 C CHECK TO SEE IF INTERPOLATION IS REQUIRED. IF NOT BRANCH.
0314 C
0315 C
0316 C COMPUTE NEW SIZE OF IMAGE
0317 C
0318 225 NNEW=YS*NROW+.5
0319 NCOLS=XS*ICOLS+.5
0320 C
0321 IF(XS.EQ.1.0.AND.YS.EQ.1.0) GO TO 260
0322 IF(NCOLS.LE.512) GO TO 230
0323 CALL CODE
0324 WRITE(JMES,690) NCOLS,XS
0325 690 FORMAT(" CALCULATED COLUMN SIZE = ",1I5,"(SF =",1F5.2)")
0326 CALL TRMGN(JMES,LU,0)
0327 CALL BLANK(JMES)
0328 CALL CODE
0329 WRITE (JMES,969)
0330 969 FORMAT (" 512 IS MAXIMUM ALLOWABLE OUTPUT")
0331 CALL TRMGN (JMES,LU,0)
0332 CALL BLANK(JMES)
0333 CALL CODE
0334 WRITE(JMES,226)
0335 226 FORMAT(" REENTER COLUMN SCALE FACTOR")
0336 CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0337 CALL BLANK(JMES)
0338 GO TO 215
0339 230 CALL CODE
0340 WRITE(JMES,695) NNEW,YS,NCOLS,XS
0341 695 FORMAT("-- OUTPUT IMAGE-",14X,"ROWS = ",1I5,"(SF=",1F5.2,")
0342 *14X,"COLUMNS = ",1I5," (SF = ",1F5.2,")")
0343 231 CALL TRMGN(JMES,LU,0)
0344 CALL BLANK(JMES)
0345 CALL CODE
0346 WRITE(JMES,1232)
0347 1232 FORMAT(" 1. VALUES OKAY")
0348 CALL TRMGN(JMES,LU,0)
0349 CALL BLANK(JMES)

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0350      CALL CODE
0351      WRITE(JMES,1233)
0352  1233  FORMAT(" 2. REENTER SCALE FACTOR")
0353      CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0354      CALL BLANK(JMES)
0355  232   CALL SPCHR (IRTM,IRT)
0356      CALL CKFLD(2,ICD,IRS)
0357      GO TO (234,234,931),IRS
0358  233   IW=9
0359      GO TO 950
0360  C
0361  C      COMPUTE INCREMENTS FOR INTERPOLATION
0362  C
0363  234   MM=NNEW
0364      IFLT=0
0365      DY=FLOAT(NROW)/FLOAT(NNEW)
0366      DX=FLOAT(ICOLS)/FLOAT(NCOLS)
0367      IF(DY.LE.1.0) GO TO 235
0368  700   CALL CODE
0369      WRITE(JMES,1750)
0370  1750  FORMAT(" IMAGE SHOULD BE FILTERED BEFORE INTERPOLATION")
0371      CALL TRMGN(JMES,LU,0)
0372      CALL BLANK(JMES)
0373      CALL CODE
0374      WRITE (JMES,9750)
0375  9750  FORMAT (" TO PREVENT ALIASING")
0376      CALL TRMGN(JMES,LU,0)
0377      CALL BLANK(JMES)
0378      CALL CODE
0379      WRITE(JMES,760)
0380  760   FORMAT(" 1. CONTINUE ")
0381      CALL TRMGN(JMES,LU,0)
0382      CALL BLANK(JMES)
0383      WRITE(JMES,761)
0384  761   FORMAT(" 2. PREFILTER IMAGE")
0385      CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0386  704   CALL SPCHR (IRTM,IRT)
0387      GO TO (1000,1000,1000,1000,904),IRT
0388  904   CALL CKFLD(2,ICD,IRS)
0389      GO TO (702,702,710),IRS
0390  710   IW=10
0391      GO TO 950
0392  C
0393  C      SCHELULE FILTER TO PREVENT ALIASING
0394  C
0395  702   FCX=0.8*FLOAT(NCOLS)/FLOAT(ICOLS)
0396      FCY=0.8*FLOAT(NNEW)/FLOAT(NROW)
0397      NX=2
0398      NY=2
0399      ITME=0
0400      CALL XYFLT(U,V,FCX,FCY,NX,NY,N,A,B)
0401  C
0402      DO 705 II=1,3
0403  705   NAME(II)=NSON(II,1)
0404      CALL EXEC (9,NAME,LU,0,NCOLS-1)
0405  C
0406  C      INITIALIZE FOR RESIZING

```

```

0407 C
0408 135 CALL CODE
0409 WRITE(JMES,810)
0410 810 FORMAT(" RESIZING OF IMAGE IN PROGRESS")
0411 CALL TRMGN(JMES,LU,0)
0412 CALL BLANK(JMES)
0413 C
0414 C SCHEDULE DINTP FOR RESIZING IMAGE
0415 C
0416 INCW=LU+200B
0417 DO 250 II=1,3
0418 250 NAME(II)=NSON(II,2)
0419 C
0420 C CLOSE WORK FILE
0421 C
0422 CALL CLSWF(NROW,ICOLS,AMAX,AMIN)
0423 CALL EXEC(13,ICNW,IPTAM(3),IPTAM(4),IPTAM(5))
0424 CALL EXEC(23,NAME,IPTAM(1),NNEW,NCOLS,IPTAM(4),IPTAM(5))
0425 C
0426 C OPEN WORK FILE
0427 C
0428 C
0429 C
0430 C CALL OPEN(IDCIB,IPTAM,6HWF0000,2,0,0,528)
0431 C IF(IPTAM.LT.0) GO TO 999
0432 C
0433 C REMAP INTENSITY VALUES FOR IMAGE
0434 C
0435 C OBTAIN NEW SIZE PARAMETERS
0436 C
0437 C
0438 IPTAM=READL(-1,0,511,DIRC)
0439 IF(IPTAM.LT.0) GO TO 999
0440 C
0441 260 IMCNT=0
0442 IZCNT=0
0443 DO 405 NN=1,NROW
0444 C
0445 C READ IN NEW ROW
0446 C
0447 NNMI=NN-1
0448 IPTAM=READL(NNMI,IFE,ICOLS-1,F)
0449 IF(IPTAM.LT.0) GO TO 999
0450 IF (IOPT .GT. 6) GO TO 310
0451 GO TO (306,310,320,330,340,350),IOPT
0452 306 DO 305 I=1,ICOLS
0453 305 G(I)=(F(I)-AMIN)*SCL+0.5
0454 GO TO 360
0455 310 DO 315 I=1,ICOLS
0456 315 G(I)=F(I)+0.5
0457 GO TO 360
0458 320 DO 325 I=1,ICOLS
0459 325 G(I)=(F(I)*SCL+0.5)
0460 GO TO 360
0461 330 DO 335 I=1,ICOLS
0462 335 G(I)=(F(I)-AMIN)*SCL+0.5
0463 GO TO 360
0464 340 DO 345 I=1,ICOLS
0465 F(I)=AMAX1(F(I),AMIN)
0466 345 G(I)=SCL*(ALOG(F(I)-AMIN+1.0))+0.5
0467 GO TO 360
0468 350 DO 355 I=1,ICOLS
0469 355 G(I)=SCL*(F(I)-AMIN)**POWER+0.5

```



```

0470 C
0471 C     WRITE OUTPUT TO WORK FILE
0472 C
0473   360 IGET=RITEL(NNM1,0,ICOLS-1,G)
0474     IF(IGET.LT.0) GO TO 999
0475 C
0476 C     IF OUTPUT IS 8 BIT, WRITE TO DISPLAY
0477 C
0478     IF(ITYPE.EQ.15) GO TO 365
0479 C
0480     DO 370 I=1,ICOLS
0481     IF(G(I).GT.(FLOAT(IMAX)+0.5))IMCNT=IMCNT+1
0482     IF(G(I).LT.0.0) IZCNT=IZCNT+1
0483     IOP(I)=MINO(IFIX(G(I)),IMAX)
0484   370 IOP(I)=MAXO(IOP(I),0)
0485   365 IF(NN.LT.NTST) GO TO 400
0486     NTST=NTST+INUM
0487     CALL CODE
0488     WRITE(JMES,375) NN,NNEW
0489   375 FORMAT("- RESIZE ROWS DONE/ TO DO ",1I4,"/",1I4,/)
0490     CALL TRMGN(JMES,LU,0)
0491     CALL BLANK(JMES)
0492 C
0493   400 IF(ITYPE.NE.8) GO TO 405
0494     IGET=WLINE(NNM1,00,ICOLS-1,IOP)
0495     IF(IGET.LT.0) GO TO 999
0496   405 CONTINUE
0497 C
0498 C     CLOSE WORK FILE
0499 C
0500     AMAX=FLOAT(IMAX)
0501     AMIN=0.0
0502     CALL CLSWF(NROW,ICOLS,AMAX,AMIN)
0503     IRTCD=0
0504     ITOT=NROW*ICOLS
0505     ATOT=100.0/FLOAT(ITOT)
0506     PZERO=ATOT*FLOAT(IZCNT)
0507     PMAX=ATOT*FLOAT(IMCNT)
0508     IF(PZERO.EQ.0.0 .AND. PMAX.EQ.0.0) GO TO 1000
0509     CALL CODE
0510     WRITE(JMES,410) PZERO,PMAX
0511     CALL TRMGN(JMES,LU,0)
0512     CALL BLANK(JMES)
0513   410 FORMAT("- PERCENT CLIPPED AT ZERO =",F6.2,
0514     1" - PERCENT CLIPPED AT MAX =",F6.2)
0515   420 CALL TRMGN(JMES,LU,0)
0516     CALL BLANK(JMES)
0517     CALL CODE
0518     WRITE(JMES,421)
0519   421 FORMAT(" 1. CONTINUE[ 2. RESCALE IMAGE")
0520     CALL TRMGN(JMES,LU,1,RTM,ICD,IRTM)
0521     CALL BLANK(JMES)
0522   425 CALL SPCHR (IRTM,IRT)
0523     GO TO (1000,1000,1000,1000,925),IRT
0524   925 CALL CKFLD(2,ICD,IRS)
0525     GO TO (1000,1000,440,430),IRS
0526   430 IW=11
0527     GO TO 950

```

```

0528 440 CALL READL(-1,0,511,DIRC)
0529      GO TO 5
0530 70  CALL CODE
0531      WRITE(JMES,921)
0532 921  FORMAT (' SCALING SIZE ERROR')
0533      CALL TRMGN(JMES,LU,0)
0534      CALL BLANK(JMES)
0535 500  CONTINUE
0536      GO TO 999
0537 950  CALL CODE
0538      WRITE (JMES,21)
0539 21   FORMAT (" /INVALID SELECTION/")
0540      CALL TRMGN (JMES,LU,1,RTM,ICD,IRTM)
0541      CALL BLANK (JMES)
0542      GO TO (15,55,85,110,135,170,200,215,232,704,425),IW
0543 999  IF(IGET.EQ.-8) CALL CLSWF(NROW,ICOLS,AMAX,AMIN)
0544 1000 CALL EXEC(6)
0545      END
0546 $
0547 $

```

&ROT8 T=00004 IS ON CR00J22 USING 00002 BLKS R=0014

```

0001 ASMB,R,L,C
0002      NAM ROT8,6
0003      ENT ROT8
0004      EXT .ENTR
0005 *
0006 WORD  BSS 1
0007 OUT   BSS 1
0008 *
0009 ROT8  NOP
0010      JSB .ENTR
0011      DEF WORD
0012      LDA WORD,I
0013      ALF,ALF
0014      STA OUT,I
0015      JMP ROT8,I
0016      END

```

&TRMGN T=00004 IS ON CRO0022 USING 00056 BLKS R=0439

```

0001 FTN4,L
0002     SUBROUTINE TRMGN(JMES,LU,IP,RTM,ICD,IRTM)
0003 C
0004 C THIS SUBROUTINE IS USED TO WRITE OUT AND POSSIBLY READ BACK
0005 C FROM THE TERMINAL INFORMATION NECESSARY FOR PROGRAM CONTROL.
0006 C JMES IS TRHE MESSAGE TO BE OUTPUT TO THE LU. IP (IF =0) MEANS
0007 C WRIE ONLY, (IF =1) MEANS TO WAIT FOR A RESPONSE FROM THE OPERAT
0008 C RTM IC THE RETURN FOR REAL NUMBERS, ICD IS A RETURN FOR INTEGER
0009 C IRTM IS THE RETURN FOR ASCII CHARACTERS. ALL THREE TYPES OF RES
0010 C ARE GENERATED EACH TIME THIS SUBROUTINE IS CALLED. THE MAXIMUN
0011 C OUTPUT MESSAGE IS 80 CHARACTERS LONG. THE MAXIMUN INPUT MESSAGE
0012 C 10 CHARACTERS LONG.
0013 C
0014     DIMENSION JMES(40),IRTM(5)
0015     ICNWD=400B+LU
0016 C     WRITE THE MESSAGE TO THE LU
0017     CALL EXEC (2,ICNWD,JMES,40)
0018     IF (IP .EQ. 0) RETURN
0019 C     READ THE MESSAGE BACK FROM THE LU
0020     CALL EXEC (1,ICNWD,IRTM,5)
0021     CALL CODE
0022     READ (IRTM,*)ICD
0023     CALL CODE
0024     READ (IRTM,*)RTM
0025     RETURN
0026     END
0027     SUBROUTINE XYFLT(U,V,FCX,FCY,NX,NY,N,A,B)
0028 C
0029 C     WRITTEN BY W.E.ALEXANDER
0030 C     SUBROUTINE FORM A PART OF THE SPATIAL
0031 C     DOMAIN FILTERING PACKAGE.
0032 C     LOW PASS RECURSIVE FILTER DESIGN ROTINE
0033 C     WITH FCX NOT EQUAL TO FCY.
0034 C     FCX=RCX*S/PI WHERE RCX IS THE CUTOFF
0035 C     FREQUENCY IN THE X DIRECTION AND S IS THE SAMPLING
0036 C     INTERVAL (X DIRECTION)
0037 C     FCY = RCY*S/PI WHERE RCX IS THE CUTOFF
0038 C     THE Y DIRECTION AND S IS THE SAMPLING INTERVAL
0039 C     (Y DIRECTION)
0040 C     (0.010.LE.FCX.LE.0.950)
0041 C     (0.010.LE.FCY.LE.0.950)
0042 C
0043     COMPLEX P
0044     DIMENSION U(3,3,2),V(3,3,2),A(3,2,2),B(3,2,2)
0045 C
0046     PI=3.141592654
0047     D = 1.0E-10
0048     N = 3
0049     IF(NX.LE.2.AND.NY.LE.2)N=2
0050     EPS = 1.0
0051     DO 6 I=1,18
0052     IF (I.GT. 12) GO TO 7
0053     A(I)=0
0054     B(I)=0
0055 7     U(I)=0
0056 6     V(I)=0
0057 C

```

```

0058      A(1,2,1) = 1.0
0059      A(1,2,2) = 1.0
0060      B(1,2,1) = 1.0
0061      B(1,2,2) = 1.0
0062  C
0063      NXP = NX-1
0064      TX = SIN(PI*FCX*0.5)/COS(PI*FCX*0.5)
0065      TX = TX**2
0066      IF(TX.LE.D)TX=D
0067      CNX = TX**NXP/EPS
0068      DX = C.25
0069      IF(NX.EQ.3)DX=0.125
0070      DX = CNX**DX
0071  C
0072      NYP = NY-1
0073      TY = SIN(PI*FCY*0.5)/COS(PI*FCY*0.5)
0074      TY=TY**2
0075      IF(TY.LE.D)TY=D
0076      CNY = TY**NYP/EPS
0077      DY = 0.25
0078      IF(NY.EQ.3)DY=0.125
0079      DY = CNY**DY
0080  C
0081  C
0082      NNN=N-1
0083      DO 10 J=1,NNN
0084      DO 10 K = 1,2
0085      IF(K.EQ.2) GO TO 20
0086      CN = CNX
0087      DD = DX
0088      IF (NX.EQ.3) GO TO 22
0089      THT = 135.0*PI/180.0
0090      GO TO 23
0091  22      IF(J.EQ.1)THT=112.5*PI/180.0
0092          IF(J.EQ.2)THT=157.5*PI/180.0
0093          GO TO 23
0094  20      CN=CNY
0095          DD = DY
0096          IF (NY.EQ.3) GO TO 21
0097          THT=135.0*PI/180.0
0098          GO TO 23
0099  21      IF(J.EQ.1)THT=112.5*PI/180.0
0100          IF(J.EQ.2)THT=157.5*PI/180.0
0101  23      ALP=COS(THT)
0102          BET = SIN(THT)
0103          S1 = 1.0+ALP*DD
0104          S2 = 1.0-ALP*DD
0105          S3 = BET*DD
0106          S4=-S3
0107          P=CMPLX(S1,S3)/CMPLX(S2,S4)
0108          S1 = -2*REAL(P)
0109          S2 = (CABS(P))**2
0110  C

```

```

0111      AA = 0.25 * ( 1.0 + S1 +S2 )
0112      A(1,J,K) = AA
0113      A(2,J,K) = 2.0*AA
0114      A(3,J,K) = AA
0115      B(1,J,K) = 1.0
0116      B(2,J,K) = S1
0117  10   B(3,J,K)=S2
0118      C
0119      C      OBTAIN TWO DIMENSION FILTER
0120      C
0121      IF(NX.EQ.3)GO TO 30
0122      A(1,2,1) = 1.0
0123      B(1,2,1) = 1.0
0124  30   IF(NY.EQ.3)GO TO 31
0125      A(1,2,2) = 1.0
0126      B(1,2,2) = 1.0
0127      C
0128  31   DO 40 I = 1,3
0129      DO 40 J = 1,3
0130      DO 40 K = 1,2
0131      U(I,J,K) = A(I,K,1)*A(J,K,2)
0132  40   V(I,J,K) = B(I,K,1)*B(J,K,2)
0133      RETURN
0134      END
0135  C *****SUBROUTINE INTRP*****
0136  C/L60
0137  C *****SUBROUTINE INTRP*****
0138  C *
0139  C * THIS SUBROUTINE IS FOR INTERPOLATING POINTS IN AN ARRAY *
0140  C *
0141  C *****SUBROUTINE VARIABLES*****
0142  C * AINT:STORAGE ARRAY FOR DATA POINTS *
0143  C * Y:THE DISTANCE BETWEEN LINES OF DATA POINTS *
0144  C * DX:INTERVAL VALUE BETWEEN INTERPOLATING POINTS *
0145  C * NCOLS:NUMBER OF POINTS REQUIRED PER ROW IN OUTPUT *
0146  C * ICOLS:NUMBER OF POINTS TO PER ROW IN INPUT *
0147  C * FOP:THE OUTPUT ARRAY *
0148  C *****
0149  C
0150  C
0151      SUBROUTINE INTRP(AINT,Y,DX,NCOLS,ICOLS,FOP)
0152      DIMENSION AINT(1), FOP(1),JMES(40)
0153      CALL CODE
0154      WRITE (JMES,150)
0155  150   FORMAT(' NOW IN INTRP')
0156      CALL TRMGN(JMES,LU,0)
0157  C
0158      IMAX=512
0159      IMXP=IMAX+1
0160      ICM1=ICOLS-1
0161      I=1
0162      M=I
0163  15   X=(I-1)*DX-(M-1)
0164      IF(X.LT.1.0) GO TO 25
0165      M=M+1
0166      IF(M.GT.ICM1) GO TO 50
0167      GO TO 15
0168  25   E=(AINT(M+1)-AINT(M))*X+AINT(M)
0169      F=(AINT(M+IMXP)-AINT(M+IMAX))*X+AINT(M+IMAX)
0170      FOP(I)=(F-E)*Y+E

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```

0171      I=I+1
0172      IF(I.LE.NCOLS) GO TO 15
0173      IF(X.LT.1.0.AND.I.GT.NCOLS) GO TO 51
0174 C
0175 C          COMPLETE INTERPOLATION
0176 C
0177 50      FOP(NCOLS)=(AINT(ICOLS+IMAX)-AINT(ICOLS))*Y+AINT(ICOLS)
0178 51      CALL CODE
0179          WRITE(JMES,160)
0180 160      FORMAT(' NOW LEAVING INTRP')
0181          CALL TRMGN(JMES,LU,0)
0182          RETURN
0183          END

```

&LBR SZ T=00004 IS ON CRO0022 USING 00010 BLKS R=0100

```

0001 FTN4,L
0002      SUBROUTINE SPCHR (LRTCD,IRT)
0003 C
0004 C          THIS ROUTINE CHECKS FOR SPECIAL CHARACTERS IN THE INPUT DATA
0005 C
0006          IRT=5
0007          IF (LRTCD.EQ. 0B) IRT=0
0008          IF ((LRTCD.EQ.1HX) .OR. (LRTCD .EQ. 2HX ))IRT=1
0009          IF ((LRTCD.EQ.1HB) .OR. (LRTCD .EQ. 2HB ))IRT=2
0010          IF ((LRTCD.EQ.1HD) .OR. (LRTCD .EQ. 2HD ))IRT=3
0011          IF ((LRTCD.EQ.1HR) .OR. (LRTCD .EQ. 2HR ))IRT=4
0012          RETURN
0013          END
0014      SUBROUTINE CKFLD(LA,ICD,IRS)
0015 C
0016 C          SUBROUTINE TO CHECK FOR CARRIAGE RETURN OR NUMERIC VALUE
0017 C
0018          IRS=ICD+1
0019          IF (ICD .EQ. 0B) IRS=1
0020          RETURN
0021          END
0022      SUBROUTINE INFRM (LA,LU)
0023          DIMENSION LA(3)
0024          ICNWD=400B +LU
0025          CALL EXEC (2,ICNWD,LA,3)
0026          RETURN
0027          END
0028 C
0029 C
0030      SUBROUTINE XFLTR(AINT,ICOLS,F,A,B,FCX,ITME)
0031          DIMENSION B(3,2)
0032          DIMENSION F(1),A(3,2),WF(3),WG(3)
0033 C          IF (ITME.EQ.0) CALL BOOST(0.0,1.0,FCX,2,A,B)
0034          ITME=ITME+1
0035          A1=A(1,1)
0036          A2=A(2,1)
0037          A3=A(3,1)
0038          B2=B(2,1)
0039          B3=B(3,1)
0040 C

```

```

0041 C   INITIALIZE
0042 C
0043     IMAX=512
0044     INT=ICOLS/2-1
0045     IMXP1=IMAX+1
0046     ASTT=AINT(INT)+AINT(INT+1)+AINT(INT+2)
0047     ASTT=ASTT/3
0048     DO 10 I=1,3
0049     WF(I)=ASTT
0050 10   WG(I)=ASTT
0051 C
0052 C   START FORWARD FILTER
0053 C
0054     MM=IMXP1
0055     WF(1)=AINT(IMXP1)
0056 20   WG(1)=A1*WF(1)+A2*WF(3)+A3*WF(3)-B2*WG(2)-B3*WG(3)
0057 C
0058 C   UPDATE
0059 C
0060     AINT(MM)=WG(1)
0061     WG(3)=WG(2)
0062     WG(2)=WG(1)
0063     WF(3)=WF(2)
0064     WF(2)=WF(1)
0065     MM=MM+1
0066     IF (MM.GT. ICOLS) GO TO 30
0067     WF(1)=AINT(MM)
0068     GO TO 20
0069 C
0070 C   START REVERSE FILTER
0071 C
0072 30   ASTT=AINT(INT)
0073     DO 40 I=1,3
0074     WF(I)=ASTT
0075 40   WG(I)=ASTT
0076 C
0077     MM=IMAX+ICOLS
0078     WF(1)=AINT(MM)
0079 41   WG(1)=A1*WF(1)+A2*WF(2)+A3*WF(3)-B2*WG(2)-B3*WG(3)
0080 C
0081 C   UPDATE
0082 C
0083     AINT(MM)=WG(1)
0084     WG(3)=WG(2)
0085     WG(2)=WG(1)
0086     WF(3)=WF(2)
0087     WF(2)=WF(1)
0088     MM=MM-1
0089     IF (MM.LE. IMAX) GO TO 50
0090     WF(1)=AINT(MM)
0091     GO TO 41
0092 50   RETURN
0093     END
0094     SUBROUTINE BLANK (JMES)
0095     DIMENSION JMES(40)
0096     DO 10 I=1,40
0097 10   JMES(I)=2H
0098     RETURN
0099     END
0100     ENDS

```

&WFINT T=00004 IS ON CRO0022 USING 00006 BLKS R=0044

```

0001 FTN4
0002     INTEGER FUNCTION WFINT(NLINE,NPIXL,PMAX,PMIN,LU)
0003 C
0004 C
0005 C THIS SUBROUTINE IS USED IN CONJUNCTION WITH IMAGE PROCESSING
0006 C IT CREATES AND MAINTAINS AN IMAGE WORK FILE WITH PIXEL VALUES
0007 C STORED AS REAL NUMBERS TO PRESERVE PRECISION.
0008 C
0009 C THIS ONE INITIALIZES THE PROCESS BY CREATING THE WORK FILE
0010 C AND RETURNING CERTAIN PERTINENT INFO TO CALLER. IT SHOULD
0011 C ONLY BE CALLED ONCE BY EACH CALLER. THE OTHER TWO ARE
0012 C READL, WHICH READS A PARTICULAR LINE AND RITEL WHICH WRITES
0013 C A PARTICULAR LINE.
0014 C
0015 C     LU     = INTERACTIVE TERMINAL LU
0016 C
0017 C     NLINE = # LINES IN IMAGE
0018 C     NPIXL = # PIXELS/LINE
0019 C     PMAX  = MAXIMUM PIXEL INTENSITY IN IMAGE (REAL)
0020 C     PMIN  = MINIMUM PIXEL INTENSITY IN IMAGE (REAL)
0021 C
0022 C
0023     DIMENSION IDCBI(144),IRTN(5),IB(6)
0024 C
0025     EQUIVALENCE (IB2,IB(2)),(IB(3),RMAX),(IB(5),RMIN)
0026 C
0027 C
0028 C
0029 C SCHEDULE BUILD WORK FILE PROGRAM
0030 C
0031     CALL EXEC(23,6HBLDWF ,LU)
0032 C
0033 C GET RETURNED PARAMETERS
0034 C
0035     CALL RMPAR(IRTN)
0036     WFINT = IRTN
0037     IF (IRTN .LT.0 ) RETURN
0038 C
0039 C GET MAX MIN DATA
0040 C
0041     CALL OPEN(IDCBI,IERR,6HWF0000)
0042     IF (IERR .LT. 0) GO TO 100
0043 C
0044     CALL READF(IDCBI,IERR,IB,6)
0045     IF (IERR .LT. 0) GO TO 100
0046     NLINE = IB
0047     NPIXL = IB2
0048     PMAX  = RMAX
0049     PMIN  = RMIN
0050     CALL CLOSE(IDCBI)
0051     WFINT = 0
0052     RETURN
0053 C
0054 100  WFINT = IERR
0055     CALL CLOSE(IDCBI)
0056     END
0057 C

```



```
0057 C
0058 C
0059 C READ LINE FROM WORK FILE SUBROUTINE
0060 C
0061 C
0062 C INTEGER FUNCTION READL(LINE, IPIXL, JPIXL, RBUF)
0063 C
0064 C COMMON /CBLK/IDCB(528), TBUF(512), IFLAG
0065 C
0066 C DIMENSION RBUF(512)
0067 C
0068 C
0069 C CHECK IF FILE OPEN
0070 C
0071 C IF (IFLAG .EQ. 1) GO TO 100
0072 C
0073 C MUST OPEN FILE
0074 C
0075 C CALL OPEN(IDCB, IERR, 6HWF0000, 2, 0, 0, 528)
0076 C IF (IERR .LT. 0) GO TO 999
0077 C IFLAG = 1
0078 C
0079 C FILE OPENED--READ APPROPRIATE LINE
0080 C
0081 100 CALL READF(IDCB, IERR, TBUF, 1024, LEN, LINE+2)
0082 C IF (IERR .LT. 0) GO TO 999
0083 C
0084 C POSITION DATA IN BUFFER
0085 C
0086 C ISTEP = 1
0087 C IF (IPIXL .GT. JPIXL) ISTEP = -1
0088 C
0089 C J = 1
0090 C DO 110 I=IPIXL+1, JPIXL+1, ISTEP
0091 C RBUF(J) = TBUF(I)
0092 110 J = J+1
0093 C READL = 0
0094 C RETURN
0095 C
0096 C ERROR
0097 C
0098 999 READL = IERR
0099 C END
0100 C
0101 C
0102 C WRITE WORK FILE SUBROUTINE
0103 C
0104 C
0105 C INTEGER FUNCTION RITEL(LINE, IPIXL, JPIXL, RBUF)
0106 C
0107 C COMMON /CBLK/IDCB(528), TBUF(512), IFLAG
0108 C
0109 C DIMENSION RBUF(512)
0110 C
0111 C CHECK IF FILE OPENED
0112 C
0113 C IF (IFLAG .EQ. 1) GO TO 100
0114 C
```

```

0110 C MUST OPEN FILE
0116 C
0117 CALL OPEN(IDC B,IERR,6HWF0000,2,0,0,528)
0118 IF (IERR .LT. 0) GO TO 999
0119 IFLAG = 1
0120 C
0121 C FILE OPENED--WRITE APPROPRIATE LINE
0122 C
0123 100 CALL READF(IDC B,IERR,TBUF,1024,LEN,LINE+2)
0124 IF (IERR .LT. 0) GO TO 999
0125 C
0126 ISTEP = 1
0127 IF (IPIXL .GT. JPIXL) ISTEP = -1
0128 J = 1
0129 DO 110 I=IPIXL+1,JPIXL+1,ISTEP
0130 TBUF(I) = RBUF(J)
0131 110 J = J+1
0132 C
0133 CALL WRITF(IDC B,IERR,TBUF,0,LINE+2)
0134 IF (IERR .LT. 0) GO TO 999
0135 C
0136 RITEL = 0
0137 RETURN
0138 C
0139 C ERROR RETURN
0140 C
0141 999 RITEL = IERR
0142 END
0143 C
0144 C
0145 C BLOCK DATA SUBROGRAM
0146 C
0147 C
0148 BLOCK DATA
0149 C
0150 COMMON /CBLK/IDCB(528),TBUF(512),IFLAG
0151 C
0152 DATA IFLAG/0/
0153 C
0154 END
0155 C
0156 C
0157 C CLOSE WORK FILE SUBROUTINE
0158 C
0159 C
0160 SUBROUTINE CLSWF(NLINE,NPIXL,PMAX,PMIN)
0161 C
0162 COMMON /CRLK/ IDCL(528)
0163 C
0164 DIMENSION IB(6)
0165 C
0166 EQUIVALENCE (IB2,IB(2)),(IB(3),RMAX),(IB(5),RMIN)
0167 C
0168 C
0169 C THIS ROUTINE IS USED TO CLOSE THE WORK FILE
0170 C
0171 C WRITE DATA ON WORK FILE
0172 C
0173 IB = NLINE
0174 IB2 = NPIXL
0175 RMAX = PMAX
0176 RMIN = PMIN
0177 C
0178 CALL WRITF(IDC B,IERR,IB,6,1)
0179 CALL CLOSE(IDC B)

```

ORIGINAL PAGE IS  
OF POOR QUALITY

C-2

&DINTF T=00004 IS ON CR00022 USING 00009 ELKS R=0087

```

0001 FTN4,Q,T,C
0002 PROGRAM DINTP
0003 C
0004 C THIS PROGRAM IS USED CHANGE THE PHYSICAL SIZE OF AN IMAGE
0005 C
0006 C WRITTEN BY WINSER E. ALEXANDER
0007 C
0008 DIMENSION AINT(1024),F(512),IPRAM(5),DIRC(515),INM(2)
0009 EQUIVALENCE (F(1),DIRC(4)),(DIRC(1),INM(1))
0010 EQUIVALENCE (INM(1),NROW),(INM(2),ICOLS),(DIRC(2),AMAX)
0011 EQUIVALENCE (DIRC(3),AMIN)
0012 C
0013 C INPUT PARAMETERS (CALL RMPAR)
0014 C IPRAM(1)= LOGICAL UNIT FOR INTERACTIVE DEVICE
0015 C IPRAM(2) = NUMBER OF DESIRED ROWS IN OUTPUT IMAGE
0016 C IPRAM(3) = NUMBER OF DESIRED COLUMNS IN OUTPUT IMAGE
0017 C
0018 C IMAGE TO BE USED IS ASSUMED TO BE IN IMAGE WORK FILE (WFO000)
0019 C
0020 CALL RMPAR(IPRAM)
0021 LU=IPRAM(1)
0022 IF(LU.LE.0) LU=1
0023 NNEW=IPRAM(2)
0024 NCOLS=IPRAM(3)
0025 NCM1=NCOLS-1
0026 IMX=512
0027 IMXP1=IMX+1
0028 C
0029 C OBTAIN PARAMETERS FROM CURRENT IMAGE
0030 C
0031 IGET=READL(-1,0,511,DIRC)
0032 ICM1=ICOLS-1
0033 IF(IGET.LT.0) GO TO 999
0034 C
0035 C INTERPOLATE IMAGE
0036 C
0037 DY=FLOAT(NRCW)/FLOAT(NNEW)
0038 DX=FLOAT(ICOLS)/FLOAT(NCOLS)
0039 IFLT=0
0040 IF(DY.GT.1.0) STOP 111
0041 IF(DX.LT.0.0) IFLT=1
0042 IFR=0
0043 IFE=0
0044 C

```

```

0045 C      INITIALIZE ARRAYS
0046 C
0047      IGET=READL(0,IFE,ICOLS-1,AINT(MXP1))
0048      IF(IGET.LT.0) GO TO 999
0049      IGET=READL(1,IFE,ICM1,AINT(1))
0050      IF(IGET.LT.0) GO TO 999
0051 C
0052      MCNT=2
0053      MORG=NROW
0054      DO 100 KK=NNEW,1,-1
0055 C
0056 C      COMPUTE Y
0057 C
0058      20 Y=(NNEW-KK)*DY-(NROW-MORG)
0059      IF(Y.LT.1.0) GO TO 50
0060 C
0061 C      BRING IN NEW ROW
0062 C
0063      CALL MOVE(AINT,ICOLS,IMXP1)
0064 C
0065      MCNT=MCNT+1
0066      IGET=0
0067      IF(MCNT.GT.NROW) IGET=-150
0068      IF(IGET.LT.0) GO TO 999
0069      IGET=READL(MCNT,IFE,ICM1,AINT)
0070      IF(IGET.LT.0) GO TO 999
0071      MORG=MORG-1
0072 C
0073 C      RECOMPUTE Y
0074 C
0075      GO TO 20
0076 C
0077 C      INTERPOLATE FOR NEW ROW
0078 C
0079      50 CALL INTRP(AINT,Y,DX,NCOLS,ICOLS,F)
0080 C
0081 C      OUTPUT CURRENT ROW
0082 C
0083      100 CALL RITEL(KK-1,0,NCM1,F)
0084 C
0085 C      NOTE THAT WORK FILE IS NOT CLOSED BY THIS PROGRAM
0086 C
0087 C      INSERT PARAMETERS IN WORK FILE
0088 C
0089      NROW=NNEW
0090      ICOLS=NCOLS
0091      CALL RITEL(-1,0,ICM1,DIRC)
0092      999 CONTINUE
0093 C
0094 C      ERROR PROCESSING
0095 C
0096      WRITE(LU,1000) IGET
0097      1000 FORMAT(" ERROR CODE = ",I15)
0098      CALL EXEC(6)
0099      END
0100 C

```

```

0101 C
0102     SUBROUTINE MOVE(AINT,ICOLS,IMXP1)
0103 C
0104 C     THIS SUBROUTINE MOVES ICOLS ELEMENTS IN ARRAY AINT FROM
0105 C     A START POINT OF 1 TO A START POINT OF IMXP1
0106 C
0107     DIMENSION AINT(1)
0108 C
0109     DO 10 I=1,ICOLS
0110 10 AINT(IMXP1+I) = AINT(I)
0111     RETURN
0112     END
0113     ENDS

```

&WTAPE T=00004 IS ON CRO022 USING 00012 BLKS R=0127

```

0001 FTN4,Q,C,T
0002     PROGRAM WTAPE
0003 C
0004 C     THIS PROGRAM FORMS A PART OF THE IMAGE PROCESSING SYSTEM
0005 C
0006 C     IT IS USED TO STORE AN IMAGE ON TAPE AND THEN PURGE FROM DIS
0007 C
0008 C     THE IMAGE INVENTOPRY FILE IS UPDATED TO SHOW THAT THE IMAGE
0009 C     TAPE
0010 C
0011 C     WRITTEN BY WINSER E. ALEXANDER
0012 C
0013     DIMENSION IDCB1(272),IDCB2(528),IMAGE(6),IPRAM(5),JNAME(3)
0014     DIMENSION IDATA(512),ISIZE(2),IRTN(5),IBUF(15)
0015 C
0016     EQUIVALENCE (IBUF(12),ILOC),(IBUF(13),JNAME),(IBUF(7),NLINE)
0017     EQUIVALENCE (IBUF(8),NPIXL),(IBUF(9),IPMIN),(IBUF(10),IPMAX)
0018 C
0019 C     GET INPUT PARAMETERS
0020 C
0021     CALL RMPAR(IPRAM)
0022     LU = IPRAM(1)
0023     IF(LU.LE.0) LU=1
0024 C
0025     LU2 = 8
0026 C
0027 C POSITION TAPE
0028 C
0029     WRITE(LU,45)
0030     READ(LU,46) IOPT
0031     IF (IOPT .NE. 2HGO) GO TO 1000
0032     WRITE(LU,51)
0033     READ(LU,*) IFNUM
0034 C
0035 C SPACE TO FILE POSITION
0036 C
0037     CALL EXEC(3,400B+LU2)
0038     IF (IFNUM .LE. 0) GO TO 1000
0039     IF (IFNUM .EQ. 1) GO TO 5
0040 C

```

```

0041      DO 55 I=1,IFNUM-1
0042      CALL EXEC(3,13008+LU2)
0043 55    CONTINUE
0044 C
0045 C      GET IMAGE NAME FROM USER
0046 C
0047 C
0048 5      WRITE(LU,10)
0049      10 FORMAT(" ENTER IMAGE NAME (12 CHARACTERS /E TO EXIT)?_")
0050      READ(LU,20) IMAGE
0051      20 FORMAT(6A2)
0052      IF (IMAGE .EQ. 2H/E) GO TO 1001
0053 C
0054 C      OPEN DIRECTORY FILE
0055 C
0056      30 CALL OPEN(IDCBI,IERR,6HIMCIRC,1,2HIM,23,272)
0057      IF(IERR.LT.0) GO TO 999
0058 C
0059 C      FIND IMAGE FILE
0060 C
0061      40 CALL READF(IDCBI,IERR,IBUF,15,LEN)
0062      IF(LEN.NE.-1) GO TO 35
0063      WRITE(LU,36)
0064 36    FORMAT("IMAGE NOT FOUND")
0065      GO TO 5
0066 35    IF(IERR.LT.0) GO TO 999
0067 C
0068      IF(ICMPW(IMAGE,IBUF,6).NE.0) GO TO 40
0069 C
0070 C      IMAGE FOUND
0071 C
0072 C      CLOSE DIRECTORY FILE AND OPEN IMAGE FILE
0073 C
0074      CALL CLOSE(IDCBI)
0075 C
0076      CALL OPEN(IDCBI,IERR,JNAME,1,2HIM,23,528)
0077      IF(IERR.LT.0) GO TO 999
0078 C
0079 C      CHECK FOR TAPE ON TRANSPORT
0080 C
0081 45    FORMAT(" PUT TAPE ON TRANSPORT & PUT TAPE UNIT ON LINE."
0082      */" ENTER -GO- WHEN READY"/)
0083      46 FORMAT(1A2)
0084 C
0085 C
0086      WRITE(LU,48) IPMAX,IPMIN
0087      48 FORMAT(" MAXIMUM VALUE = ",1I8,". MINIMUM = ",1I8)
0088 C
0089 C      IF(IPMAX.LE.255) IMAGE WILL BE PACKED FOR OUTPUT (8 BIT IMAG
0090 C
0091      ITYPE = 15
0092      IF(IPMAX.LE.255.AND.IPMIN.GE.0) ITYPE = 8
0093 C
0094 C
0095 51    FORMAT("FILE #?_")
0096 C
0097 C

```

```
0098 C
0099 C OUTPUT DATA TO TAPE
0100 C
0101 60 DO 80 I =1,512
0102 CALL FILL(IDATA,0,512)
0103 IERR =0
0104 IF (I .LE. NLINE) CALL READF(IDC2,IERR,IDATA,512)
0105 IF (IERR .LT. 0) GO TO 999
0106 C
0107 NOUT = 512
0108 IF (ITYPE .EQ. 15) GO TO 70
0109 C
0110 C PACK DATA
0111 C
0112 DO 65 J=1,512,2
0113 CALL ROT8(IDATA(J),ITEMP)
0114 65 IDATA(J) = IOR(ITEMP,IDATA(J+1))
0115 NOUT = 256
0116 C
0117 C WRITE DATA
0118 C
0119 70 CALL EXEC(2,LU2,IDATA,NOUT)
0120 80 CONTINUE
0121 C
0122 CALL EXEC(3,100B+LU2)
0123 CALL CLOSE(IDC2)
0124 GO TO 5
0125 C
0126 C FILE ERROR
0127 C
0128 999 WRITE(LU,996) IERR
0129 996 FORMAT(" FILE ERROR = ",1I4)
0130 CALL CLOSE(IDC1)
0131 CALL CLOSE(IDC2)
0132 1001 CALL EXEC(3,400B+LU2)
0133 C
0134 1000 CONTINUE
0135 END
0136 C
0137 C
0138 SUBROUTINE FILL(IARRAY,ICCHAR,NUM)
0139 C
0140 C THIS SUBROUTINE IS USED TO FILL THE ARRAY "IARRAY" WITH
0141 C THE CHARACTER "ICCHAR"
0142 C DIMENSION IARRAY(NUM)
0143 C
0144 DO 10 I=1,NUM
0145 10 IARRAY(I)=ICCHAR
0146 RETURN
0147 END
0148 ENDS
```

```

0001 FTN4,L
0002 PROGRAM PLOTV
0003 DIMENSION LU(5)
0004 INTEGER IDCB(144 ),BUFF( 4 ), NAME(3)
0005 DATA NAME/2HDA,2HTA,2H1 /
0006 C
0007 C GET LU
0008 C
0009 CALL RMPAR(LU)
0010 C
0011 CALL INITA(0)
0012 CALL OPEN(IDCB,IERR,NAME)
0013 IF (IERR .GE. 0) GO TO 20
0014 WRITE(LU,10) IERR
0015 10 FORMAT ("OPEN ERROR",F5.0)
0016 STOP
0017 C20 CONTINUE
0018 20 CALL READF(IDCB,IERR,BUFF,4,IERR)
0019 IF (IERR .GE. 0) GOTO 40
0020 WRITE(LU,30) IERR
0021 30 FORMAT("READ ERROR",F5.0)
0022 GO TO 55
0023 40 CONTINUE
0024 CALL DVECT(BUFF,BUFF(2),BUFF(3),BUFF(4),LU)
0025 50 GO TO 20
0026 55 STOP
0027 END
0028 SUBROUTINE DVECT(IX1,IY1,IX2,IY2,LU)
0029 DIMENSION IBUFF(5)
0030 C
0031 C DRAWS A VECTOR BETWEEN X1,Y1 AND X2,Y2
0032 C
0033 SCAL =255./1024.
0034 IBUFF1 =(SCAL*IX1+0.5)+128
0035 IBUFF2 =(SCAL*IY1+0.5)
0036 IBUFF3 =(SCAL*IX2+0.5)+128
0037 IBUFF4 =(SCAL*IY2+0.5)
0038 IBUFF1 = IAND(IBUFF1,777B)
0039 IBUFF2 = IAND(IBUFF2,377B)
0040 IBUFF3 = IAND(IBUFF3,777B)
0041 IBUFF4 = IAND(IBUFF4,377B)
0042 IBUFF(1) = IBUFF1 + 44000B
0043 IBUFF(2) = IBUFF2 + 64000B
0044 IBUFF(3) =-- IBUFF1 + IBUFF3 + 50000B + 512
0045 IBUFF(4) =-- IBUFF2 + IBUFF4 + 72000B + 256
0046 C
0047 CALL DRIVR(2,IBUFF,4)
0048 C
0049 RETURN
0050 END
0051 SUBROUTINE INITA(IBACK)
0052 DIMENSION INIT(6)
0053 DATA INIT/30000B,100377B,10377B,24021B,26000B/
0054 C
0055 C IBACK = 1 FOR REVERSE BACKGROUND
0056 C INITIALIZE
0057 C
0058 IF(IBACK .EQ. 1) INIT(4)=24221B
0059 CALL DRIVR(2,INIT,5)
0060 RETURN
0061 END
0062 $

```



&DPLAM T=00004 IS ON CRO0022 USING 00022 BLKS R=0210

```

0001 FTN4,L
0002     PROGRAM DPLAM
0003 C
0004 C THIS PROGRAM DISPLAYS THE FILTER CHARACTERISTICS
0005 C
0006 C
0007     COMMON/CNT/XM(30,30)
0008     COMMON/WORK/WO(130)
0009     COMMON/QDCAZ/IQ(40)
0010     INTEGER BUFF
0011     COMMON/ /IDCB(144),BUFF(10)
0012     DIMENSION IBUF(80),ILU(5),A(25),B(25),AA(5,5),BB(5,5)
0013     DIMENSION XXX(31),YYY(31),XYP(31,2),LXY(15,3),AR(60)
0014     DIMENSION XERR(31),CZ( 9),IREG(2),U(3,3,2),V(3,3,2)
0015     COMPLEX HA,HB,Z(25)
0016     EQUIVALENCE (AA(1,1),XM(1,1)),(BB(1,1),XYP(1,1))
0017     EQUIVALENCE (IREG(1),REG)
0018     EQUIVALENCE (IBUF(1),U(1,1,1)),(IBUF(41),V(1,1,1))
0019 C
0020     CALL RMPAR(ILU)
0021     LU=ILU(1)
0022     MN=ILU(2)
0023     AMAX = 0.0
0024     AMIN =1000.0
0025     MDIM = 30
0026     NDIM = 30
0027 C
0028 C
0029 C GET FILTER COEFF'S
0030     CALL EXEC(14,1,IBUF,80)
0031 C
0032     IF(MN.EQ.3) GO TO 100
0033     MNL=9
0034     DO 10 J=1,3
0035     DO 10 K=1,3
0036     II=J+(K-1)*3
0037     A(II)=U(J,K,1)
0038     10  B(II)=V(J,K,1)
0039     GO TO 101
0040     100 DO 103 I=1,5
0041     DO 103 J=1,5
0042     AA(I,J)=0.0
0043     103 BB(I,J)=0.0
0044     DO 102 I=1,3
0045     DO 102 J=1,3
0046     DO 102 K=1,3
0047     DO 102 L=1,3
0048     IK=I+K-1
0049     JL=J+L-1
0050     AA(IK,JL)=AA(IK,JL)+U(I,J,1)*U(K,L,2)
0051     102 BB(IK,JL)=BB(IK,JL)+V(I,J,1)*V(K,L,2)
0052     DO 11 J=1,5
0053     DO 11 K=1,5
0054     II=J+(K-1)*5
0055     A(II)=AA(J,K)
0056     11  B(II)=BB(J,K)
0057     MNL=25

```

```

0058 101 WRITE(LU,1011)
0059 1011 FORMAT(21H COEFFICIENT MATRICES,/ )
0060 WRITE(LU,105) (A(I),I=1,25)
0061 WRITE(LU,105)(B(I),I=1,25)
0062 105 FORMAT(5(1H ,5E10.2//))
0063 C
0064 C COMPUTE THE CENTER OF OUTPUT ARRAY
0065 C
0066 WRITE(LU,12)
0067 12 FORMAT(" ENTER MX FOR HORIZONTAL FREQUENCIES"/)
0068 READ(LU,13)MX
0069 13 FORMAT(1I2)
0070 WRITE(LU,14)
0071 14 FORMAT(" ENTER MY FOR VERTICAL FREQUENCIES"/)
0072 READ(LU,13) MY
0073 203 MXC=MX/2
0074 MXT=2*MXC
0075 NX=0
0076 IF(MXT.NE.MX) NX=1
0077 MYC=MY/2
0078 MYT=2*MYC
0079 NY=0
0080 IF(MYT.NE.MY) NY=1
0081 MXN=MXC+1
0082 MYN=MYC+1
0083 WRITE(LU,301)
0084 300 FORMAT(" COMPUTE SQUARED MAGNITUDE "/)
0085 301 FORMAT(" INITIALIZE ARRAY"/)
0086 C
0087 C COMPUTE SQUARED MAGNITUDE CHARACTERISTIC
0088 C
0089 MX=MXT+NX
0090 MY=MYT+NY
0091 FCX=2.0/FLOAT(MX)
0092 FCY=2.0/FLOAT(MY)
0093 IF(MX.LE.101.AND.MY.LE.61) GO TO 204
0094 IF(MX.LE.101) GO TO 202
0095 MX=101
0096 WRITE(LU,200)
0097 200 FORMAT(" SIZE OF ARRAY WAS REDUCED TO 31 FOR HORIZONTAL "
0098 202 IF(MY.LE.61) GO TO 203
0099 MY=61
0100 WRITE(LU,201)
0101 GO TO 203
0102 201 FORMAT(" SIZE OF ARRAY WAS REDUCED TO 31 FOR VERTICAL "/)
0103 204 WRITE(LU,300)
0104 DO 20 I=1,MX+1
0105 DO 20 J=1,MY+1
0106 XF=FCX*(I-MXC-1)
0107 XXX(I)=XF
0108 YF=FCY*(J-MYC-1)
0109 YYY(J)=YF
0110 CALL ZWC(Z,XF,YF,MN)
0111 HA=CPLX(0.0,0.0)
0112 HB=HA
0113 DO 21 K=1,MNL
0114 HA=HA+A(K)*Z(K)
0115 HB=HB+B(K)*Z(K)

```

```

0116 21      CONTINUE
0117      XA=CABS(HA)
0118      XB=CABS(HB)
0119      IF(XB.LE.1.OE-20) XB=1.OE-20
0120      XA=XA/XB
0121      XM(I,J)=XA**2
0122      IF(XM(I,J).LT.AMIN) AMIN=XM(I,J)
0123      IF(XM(I,J).GT.AMAX) AMAX=XM(I,J)
0124      20 CONTINUE
0125      WRITE(LU,302)AMAX,AMIN
0126      302 FORMAT(" AMAX = ",1E10.2,3X,"AMIN = ",1E10.2/)
0127      C
0128      C SQUARED MAGNITUDE NORMALIZED
0129      C
0130      C
0131      C      OBTAIN W=1 PLOT FROM ARRAY
0132      C
0133      DO 22 I=1,MXN
0134      XYP(I,2)=XM(I+MXC,MYN)
0135      XERR(I)=XYP(I,2)
0136      22 XYP(I,1)=FCX*(I-1)
0137      WRITE(LU,306)(XYP(I,1),XYP(I,2),I=1,MXN)
0138      306 FORMAT(///1H ,6(1E10.2,3X)/)
0139      XL=0.0
0140      XU=1.0
0141      MC=2
0142      C
0143      C      CALCULATE Z=W PLOT
0144      C
0145      X=(MXN)**2+(MYN)**2
0146      FCX=0.7071*FCX
0147      NUM=SQRT(X)+1
0148      DO 30 I=1,MXN
0149      XF=FCX*(I-1)
0150      CALL ZWC(Z,XF,XF,MN)
0151      HA=CMPLX(0.0,0.0)
0152      HB=HA
0153      DO 31 K=1,MNL
0154      HA=HA+A(K)*Z(K)
0155      31 HB=HB+B(K)*Z(K)
0156      XA=CABS(HA)
0157      XB=CABS(HB)
0158      IF(XB.LE.1.OE-20)XB=1.OE-20
0159      XA=XA/XB
0160      XYP(I,2)=XA**2
0161      30 XYP(I,1)=XF*1.414
0162      WRITE(LU,306)(XYP(I,1),XYP(I,2),I=1,MXN)
0163      C

```

```

0164 C COMPUTE ERROR FUNCTION
0165 C
0166 ERR=0.0
0167 DO 350 J=1,MDIM
0168 350 ERR=ERR+((XERR(J)-XYP(J,2))/AMAX)**2
0169 WRITE(LU,360) ERR
0170 360 FORMAT(" RELATIVE ERROR = ",1E15.7/)
0171 C COMPUTE CONTOURS
0172 C
0173 C
0174 C PLOT IMAGE OF TRANSFER FUNCTION
0175 C
0176 CALL CONTR(XXX,YYY,AMAX,AMIN,MX+1,MY+1,LU)
0177 C
0178 4443 STOP
0179 END
0180 SUBROUTINE ZWC(Z,XF,YF,MN)
0181 C
0182 C THIS SUBROUTINE COMPUTES COMPLEX
0183 C VALUES FOR Z**I*W**J FOR
0184 C ZW TRANSFORM AND PLACES RESULTS
0185 C IN ONE DIMENSIONAL ARRAY Z
0186 C XF=HORIZONTAL RELATIVE FREQUENCY
0187 C YF=VERTICAL RELATIVE FREQUENCY
0188 C
0189 COMPLEX Z(25),R,S
0190 IF(ABS(XF).EQ.1.0 ) XF = 0.99
0191 IF(ABS(YF).EQ.1.0) YF = 0.99
0192 PI=3.1415926
0193 RX=COS(PI*XF)
0194 RY=SIN(PI*XF)
0195 SX=COS(PI*YF)
0196 SY=SIN(PI*YF)
0197 R=CPLX(RX,RY)
0198 S=CPLX(SX,SY)
0199 IF(MN.GE.3) GO TO 20
0200 DO 10 J=1,3
0201 DO 10 K=1,3
0202 I=J+(K-1)*3
0203 10 Z(I)=S**(J-1)*R**(K-1)
0204 GO TO 22
0205 20 DO 21 J=1,5
0206 DO 21 K=1,5
0207 I=J+(K-1)*5
0208 21 Z(I)=S**(J-1)*R**(K-1)
0209 22 RETURN
0210 END
0211 BLOCK DATA WORK
0212 COMMON/WORK/WO(130)
0213 COMMON/CNT/XM(900)
0214 COMMON/QCAZ/IQ(40)
0215 END
0216 $

```

&DPLA1 T=00004 IS ON CRO0022 USING 00052 BLKS R=0437

```

0001 FTN→,L
0002     SUBROUTINE CONTR(XXX,YYY,AMAX,AMIN,MX,MY,LU)
0003     COMMON/CNT/XM(30,30)
0004     DIMENSION XXX(MX),YYY(MY),CZ(9),ISIZE(2)
0005     INTEGER BUFF,NAME9(3)
0006     COMMON / /IDCB(144),BUFF(4)
0007     DATA NAME9/2HDA,2HTA,2H1 /
0008     WRITE(LU,100)
0009 100   FORMAT(" SELECT TYPE OF FILTER PLOT "/
0010 1" 1. CONTOUR"/" 2. PERSPECTIVE"/)
0011     READ(LU,*) IFLAG
0012 C
0013 C     GENERATE CZ
0014 C
0015     CZ(1)=-1.
0016     DO 3 K=2,9
0017     CZ(K)=CZ(K-1)+.25
0018 3 CONTINUE
0019 C
0020 C CREATE A PLOT DATA FILE
0021 C
0022     ITYPE=3
0023     ISIZE(1)=96
0024     CALL PURGE(IDCB,IERR,NAME9)
0025     IF(IERR .LT. 0) WRITE(LU,101) IERR
0026     CALL CREAT(IDCB,IERR,NAME9,ISIZE,ITYPE)
0027     IF(IERR .GE. 0) GO TO 201
0028     WRITE(LU,101) IERR
0029 101   FORMAT("CREATE ERROR",F5.0)
0030     STOP
0031 C
0032 C     DO 3-D PLOTS
0033 C
0034 201   IF (IFLAG.EQ.1) GO TO 10
0035     IF (IFLAG.EQ.2) GO TO 20
0036 20    CONTINUE
0037     CALL SET3D(1.,-1.,1.,-1.,AMAX,AMIN,2,0,.5,.5)
0038     CALL PLT3D(XXX,YYY,XM,30,MX,MY,LU)
0039     IF(IFLAG.EQ.2) GOTO 30
0040 C
0041 C     DO ISOGRAMS
0042 C
0043 10    CONTINUE
0044     DO 11 I=1,MX
0045     DO 11 J=1,MY
0046     XM(I,J)=XM(I,J)/AMAX
0047 11    CONTINUE
0048     CALL SET2D(1.,-1.,1.,-1.,3,0,1.)
0049     CALL PLT2D(XXX,YYY,XM,30,MX,MY,CZ,9,LU)
0050 30    CONTINUE
0051     CALL CLOSE(IDCB)
0052     RETURN
0053     END

```

```

0054     SUBROUTINE SET2D(ALPMAX,ALPMIN,BETMAX,BETMIN,IORGN,IALPCL,AL
0055     COMMON/ QCAZ/ IXXYB(4,4),XZ,AX,BX,YZ,AY,BY
0056     DATA XCNTR, YCNTR, EL/512.,512.,1000./
0057     XZ=XCNTR
0058     YZ=YCNTR
0059     IF(ALTOBL-1.)6,7,8
0060     6 CONTINUE
0061     ELALP=ALTOBL*EL
0062     ELBET=EL
0063     GO TO 9
0064     7 CONTINUE
0065     ELALP=EL
0066     ELBET=EL
0067     GO TO 9
0068     8 CONTINUE
0069     ELALP=EL
0070     ELBET=EL/ALTOBL
0071     9 CONTINUE
0072     IF (IORGN.EQ.1) GO TO 1
0073     IF (IORGN.EQ.2) GO TO 2
0074     IF (IORGN.EQ.3) GO TO 3
0075     GO TO 4
0076     1 CONTINUE
0077     IF (IALPCL.EQ.1) GO TO 10
0078     BX=0.
0079     AY=0.
0080     AX=-ELALP/(ALPMAX-ALPMIN)
0081     BY=-ELBET/(BETMAX-BETMIN)
0082     XZ=XZ+.5*ELALP
0083     YZ=YZ+.5*ELBET
0084     GO TO 5
0085     10 CONTINUE
0086     AX=0.
0087     BY=0.
0088     BX=-ELBET/(BETMAX-BETMIN)
0089     AY=-ELALP/(ALPMAX-ALPMIN)
0090     XZ=XZ+.5*ELBET
0091     YZ=YZ+.5*ELALP
0092     GO TO 5
0093     2 CONTINUE
0094     IF(IALPCL.EQ.1) GO TO 20
0095     AX=0.
0096     BY=0.
0097     AY=ELALP/(ALPMAX-ALPMIN)
0098     BX=-ELBET/(BETMAX-BETMIN)
0099     XZ=XZ+.5*ELBET
0100     YZ=YZ-.5*ELALP
0101     GO TO 5
0102     20 CONTINUE
0103     AY=0.
0104     BX=0.
0105     AX=-ELALP/(ALPMAX-ALPMIN)
0106     BY=ELBET/(BETMAX-BETMIN)
0107     XZ=XZ+.5*ELALP
0108     YZ=YZ-.5*ELBET
0109     GO TO 5
0110     3 CONTINUE

```

```

0111     IF (IALPCL.EQ.1) GO TO 30
0112     AY=0.
0113     BX=0.
0114     AX=ELALP/(ALPMAX-ALPMIN)
0115     BY=ELBET/(BETMAX-BETMIN)
0116     XZ=XZ-.5*ELALP
0117     YZ=YZ-.5*ELBET
0118     GO TO 5
0119 30 CONTINUE
0120     AX=0.
0121     BY=0.
0122     AY=ELALP/(ALPMAX-ALPMIN)
0123     BX=ELBET/(BETMAX-BETMIN)
0124     XZ=XZ-.5*ELBET
0125     YZ=YZ-.5*ELALP
0126     GO TO 5
0127 4 CONTINUE
0128     IF(IALPCL.EQ.1) GO TO 40
0129     AX=0.
0130     BY=0.
0131     AY=-ELALP/(ALPMAX-ALPMIN)
0132     BX=ELBET/(BETMAX-BETMIN)
0133     XZ=XZ-.5*ELBET
0134     YZ=YZ+.5*ELALP
0135     GO TO 5
0136 40 CONTINUE
0137     AY=0.
0138     BX=0.
0139     AX=ELALP/(ALPMAX-ALPMIN)
0140     BY=-ELBET/(BETMAX-BETMIN)
0141     XZ=XZ-.5*ELALP
0142     YZ=YZ+.5*ELBET
0143 5 CONTINUE
0144     XZ=XZ-AX*ALPMIN-BX*BETMIN
0145     YZ=YZ-AY*ALPMIN-BY*BETMIN
0146     IXXYB(1,1)=IFIX(XZ+AX*ALPMIN+BX*BETMIN)
0147     IXXYB(2,1)=IFIX(YZ+AY*ALPMIN+BY*BETMIN)
0148     IXXYB(1,2)=IFIX(XZ+AX*ALPMIN+BX*BETMAX)
0149     IXXYB(2,2)=IFIX(YZ+AY*ALPMIN+BY*BETMAX)
0150     IXXYB(1,3)=IFIX(XZ+AX*ALPMAX+BX*BETMAX)
0151     IXXYB(2,3)=IFIX(YZ+AY*ALPMAX+BY*BETMAX)
0152     IXXYB(1,4)=IFIX(XZ+AX*ALPMAX+BX*BETMIN)
0153     IXXYB(2,4)=IFIX(YZ+AY*ALPMAX+BY*BETMIN)
0154     IXXYB(3,1)=IXXYB(1,2)
0155     IXXYB(4,1)=IXXYB(2,2)
0156     IXXYB(3,2)=IXXYB(1,3)
0157     IXXYB(4,2)=IXXYB(2,3)
0158     IXXYB(3,3)=IXXYB(1,4)
0159     IXXYB(4,3)=IXXYB(2,4)
0160     IXXYB(3,4)=IXXYB(1,1)
0161     IXXYB(4,4)=IXXYB(2,1)
0162     RETURN
0163     END

```

```

0164 C *****
0165 C
0166 C
0167 SUBROUTINE PLT2D(ALPHA,BETA,GAMMA,IDMN,IALPHA,JBETA,C,NUMC
0168 1 ,IFILE,LU)
0169 COMMON/QCAZ /IXYXB(4,4),XZ,AX,BX,YZ,AY,BY
0170 DIMENSION ALPHA(1),BETA(1),GAMMA(IDMN,1),C(1)
0171 INTEGER BUFF(4),NAME9(3)
0172 COMMON IDCB(144)
0173 COMMON/WORK/IXIY(2,62),JXJY(2,62)
0174 DATA NAME9/2HDA,2HTA,2H1 /
0175 CALL OPEN(IDCB,IERR,NAME9)
0176 NOGRID=0
0177 IF(NUMC.LE.0) GO TO 1
0178 IF (IALPHA)2,1,3
0179 2 CONTINUE
0180 NOGRID=1
0181 3 CONTINUE
0182 IMAX=IABS(IALPHA)
0183 IMAXP2=IMAX+2
0184 IF (JBETA)4,1,5
0185 4 CONTINUE
0186 NOGRID=1
0187 5 CONTINUE
0188 JMAX=IABS(JBETA)
0189 IF (NOGRID.EQ.1) GO TO 6
0190 DO 7 K=1,4
0191 CALL FLBUF(IXYXB(1,K),IXYXB(2,K),
0192 1 IXYXB(3,K),IXYXB(4,K),BUFF)
0193 CALL WRITE(IDCB,IERR,BUFF,4)
0194 7 CONTINUE
0195 6 CONTINUE
0196 DO 8 N=1,NUMC
0197 DO 9 I=1,IMAXP2
0198 IXIY(1,I)=0
0199 JXJY(1,I)=0
0200 9 CONTINUE
0201 DO 10 J=1,JMAX
0202 IF(J.EQ.1) GO TO 11
0203 DO 12 I=1,IMAX
0204 IF(GAMMA(I,J).EQ.GAMMA(I,J-1)) GO TO 13
0205 IF (GAMMA(I,J).GE.C(N).AND.C(N).GE.GAMMA(I,J-1)) GO TO 14
0206 IF(GAMMA(I,J).LE.C(N).AND.C(N).LE.GAMMA(I,J-1)) GO TO 14
0207 13 CONTINUE
0208 JXJY(1,I+1)=0
0209 GO TO 12
0210 14 CONTINUE
0211 BETINT=BETA(J-1)+(BETA(J)-BETA(J-1))*(C(N)-GAMMA(I,J-1))/(GA
0212 1J)-GAMMA(I,J-1))
0213 ALPINT=ALPHA(I)
0214 IXR=IFIX(XZ+AX*ALPINT+BX*BETINT)

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0215     IYR=IFIX(YZ+AY*ALPINT+BY*BETINT)
0216     IF(JXJY(1,I).EQ.0) GO TO 15
0217     CALL FLBUF(IXR,IYR,JXJY(1,I),JXJY(2,I),BUFF)
0218     CALL WRITF(IDC3,IERR,BUFF,4)
0219 15 CONTINUE
0220     IF(IXIY(1,I+1).EQ.0) GO TO 16
0221     CALL FLBUF(IXR,IYR,IXIY(1,I+1),IXIY(2,I+1),BUFF)
0222     CALL WRITF(IDC3,IERR,BUFF,4)
0223 16 CONTINUE
0224     IF(IXIY(1,I+2).EQ.0) GO TO 17
0225     CALL FLBUF(IXR,IYR,IXIY(1,I+2),IXIY(2,I+2),BUFF)
0226     CALL WRITF(IDC3,IERR,BUFF,4)
0227 17 CONTINUE
0228     JXJY(1,I+1)=IXR
0229     JXJY(2,I+1)=IYR
0230 12 CONTINUE
0231 111 CONTINUE
0232     DO 18 I=2,IMAX
0233     IF(GAMMA(I,J).EQ.GAMMA(I-1,J)) GO TO 19
0234     IF (GAMMA(I,J).GE.C(N).AND.C(N).GE.GAMMA(I-1,J)) GO TO 20
0235     IF (GAMMA(I,J).LE.C(N) .AND. C(N).LE.GAMMA(I-1,J)) GO TO 20
0236 19 CONTINUE
0237     IXIY(1,I+1)=0
0238     GO TO 18
0239 20 CONTINUE
0240     ALPINT=ALPHA(I-1)+(ALPHA(I)-ALPHA(I-1))*(C(N)-GAMMA(I-1,J))/
0241     1(I,J)-GAMMA(I-1,J))
0242     BETINT=BETA(J)
0243     IXR=IFIX(XZ+AX*ALPINT+BX*BETINT)
0244     IYR=IFIX(YZ+AY*ALPINT+BY*BETINT)
0245     IF(JXJY(1,I).EQ.0) GO TO 21
0246     CALL FLBUF(IXR,IYR,JXJY(1,I),JXJY(2,I),BUFF)
0247     CALL WRITF(IDC3,IERR,BUFF,4)
0248 21 CONTINUE
0249     IF (IXIY(1,I+1).EQ.0) GO TO 22
0250     CALL FLBUF(IXR,IYR,IXIY(1,I+1),IXIY(2,I+1),BUFF)
0251     CALL WRITF(IDC3,IERR,BUFF,4)
0252 22 CONTINUE
0253     IF(JXJY(1,I+1).EQ.0) GO TO 23
0254     CALL FLBUF(IXR,IYR,JXJY(1,I+1),JXJY(2,I+1),BUFF)
0255     CALL WRITF(IDC3,IERR,BUFF,4)
0256 23 CONTINUE
0257     IXIY(1,I+1)=IXR
0258     IXIY(2,I+1)=IYR
0259 18 CONTINUE
0260 10 CONTINUE
0261 8 CONTINUE
0262 1 CONTINUE
0263     RETURN
0264     END

```

```

0265 C *****
0266 C
0267 C
0268 C
0269 SUBROUTINE SET3D(ALPMAX,ALPMIN,BETMAX,BETMIN,GAMMAX,GAMMIN,
0270 IORGN,IALPCL,GAMFAC,ALPFAC)
0271 COMMON/QDCAZ /IXYXB(4,5),XZ,AX,BX,YZ,AY,BY,CY
0272 DATA ELX,ELY,EXLEFT,YBOTOM/1012.,856.,12.,156./
0273 AX=ALPFAC*ELX/(ALPMAX-ALPMIN)
0274 AY=ALPFAC*(1.-GAMFAC)*ELX/(ALPMAX-ALPMIN)
0275 BX=(1.-ALPFAC)*ELX/(BETMAX-BETMIN)
0276 BY=(1.-ALPFAC)*(1.-GAMFAC)*ELY/(BETMAX-BETMIN)
0277 CY=GAMFAC*ELY/(GAMMAX-GAMMIN)
0278 YZ=-CY*GAMMIN+YBOTOM
0279 XZ=EXLEFT
0280 IF(IORGN.EQ.1)GO TO 1
0281 IF(IORGN.EQ.2)GO TO 2
0282 IF(IORGN.EQ.3)GO TO 3
0283 GO TO 4
0284 1 CONTINUE
0285 XZ=XZ+ELX
0286 AX=-AX
0287 BX=-BX
0288 IF(IALPCL.EQ.1)GO TO 10
0289 YZ=YZ+BY*(BETMAX-BETMIN)
0290 BY=-BY
0291 ALPVRT=ALPMAX
0292 BETVRT=BETMIN
0293 GO TO 5
0294 10 CONTINUE
0295 YZ=YZ+AY*(ALPMAX-ALPMIN)
0296 AY=-AY
0297 ALPVRT=ALPMIN
0298 BETVRT=BETMAX
0299 GO TO 5
0300 2 CONTINUE
0301 ALPVRT=ALPMAX
0302 BETVRT=BETMAX
0303 IF(IALPCL.EQ.1)GO TO 20
0304 XZ=XZ+BX*(BETMAX-BETMIN)
0305 BX=-BX
0306 GO TO 5
0307 20 CONTINUE
0308 XZ=XZ+AX*(ALPMAX-ALPMIN)
0309 AX=-AX
0310 GO TO 5
0311 3 CONTINUE

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0312      IF(IALPCL.EQ.1)GO TO 30
0313      YZ=YZ+AY*(ALPMAX-ALPMIN)
0314      AY=-AY
0315      ALPVRT=ALPMIN
0316      BETVRT=BETMAX
0317      GO TO 5
0318 30 CONTINUE
0319      YZ=YZ+BY*(BETMAX-BETMIN)
0320      BY=-BY
0321      ALPVRT=ALPMAX
0322      BETVRT=BETMIN
0323      GO TO 5
0324 4 CONTINUE
0325      YZ=YZ+ELY*(1.-GAMFAC)
0326      ALPVRT=ALPMIN
0327      BETVRT=BETMIN
0328      AY=-AY
0329      BY=-BY
0330      IF(IALPCL.EQ.1)GO TO 40
0331      XZ=XZ+AX*(ALPMAX-ALPMIN)
0332      AX=-AX
0333      GO TO 5
0334 40 CONTINUE
0335      XZ=XZ+BX*(BETMAX-BETMIN)
0336      BX=-BX
0337 5 CONTINUE
0338      XZ=XZ-BX*BETMIN-AX*ALPMIN
0339      YZ=YZ-BY*BETMIN-AY*ALPMIN
0340      IXYXYB(1,1)=XZ+AX*ALPMIN+BX*BETMIN
0341      IXYXYB(2,1)=YZ+AY*ALPMIN+BY*BETMIN+CY*GAMMIN
0342      IXYXYB(3,1)=XZ+AX*ALPMAX+BX*BETMIN
0343      IXYXYB(4,1)=YZ+AY*ALPMAX+BY*BETMIN+CY*GAMMIN
0344      IXYXYB(1,2)=IXYXYB(3,1)
0345      IXYXYB(2,2)=IXYXYB(4,1)
0346      IXYXYB(3,2)=XZ+AX*ALPMAX+BX*BETMAX
0347      IXYXYB(4,2)=YZ+AY*ALPMAX+BY*BETMAX+CY*GAMMIN
0348      IXYXYB(1,3)=IXYXYB(3,2)
0349      IXYXYB(2,3)=IXYXYB(4,2)
0350      IXYXYB(3,3)=XZ+AX*ALPMIN+BX*BETMAX
0351      IXYXYB(4,3)=YZ+AY*ALPMIN+BY*BETMAX+CY*GAMMIN
0352      IXYXYB(1,4)=IXYXYB(3,3)
0353      IXYXYB(2,4)=IXYXYB(4,3)
0354      IXYXYB(3,4)=IXYXYB(1,1)
0355      IXYXYB(4,4)=IXYXYB(2,1)
0356      IXYXYB(1,5)=XZ+AX*ALPVRT+BX*BETVRT
0357      IXYXYB(2,5)=YZ+AY*ALPVRT+BY*BETVRT+CY*GAMMIN
0358      IXYXYB(3,5)=IXYXYB(1,5)
0359      IXYXYB(4,5)=YZ+AY*ALPVRT+BY*BETVRT+CY*GAMMAX
0360 45  FORMAT (5(7X,17))
0361      RETURN
0362      END

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```

0363 C *****
0364 C
0365 C
0366 C
0367 SUBROUTINE PLT3D(ALPHA,BETA,GAMMA,IDMN,IALPHA,JBETA,IFILE,L
0368 DIMENSION ALPHA(1),BETA(1),GAMMA(IDMN,1)
0369 COMMON/WORK/LASTXY(2,200)
0370 COMMON/QDCAL /IXYXYB(4,5),XZ,AX,BX,YZ,AY,BY,CY
0371 INTEGER BUFF(4)
0372 COMMON IDCB(144)
0373 NOGRID=0
0374 IF(IALPHA)1,2,3
0375 1 CONTINUE
0376 NOGRID=1
0377 3 CONTINUE
0378 IMAX=IABS(IALPHA)
0379 IF(JBETA)4,2,5
0380 4 CONTINUE
0381 NOGRID=1
0382 5 CONTINUE
0383 JMAX=IABS(JBETA)
0384 IF(NOGRID.EQ.1)GO TO 6
0385 67 FORMAT (5(7X,I7))
0386 68 FORMAT (10X,"GOOD",I5)
0387 DO 7 K=1,5
0388 CALL FLBUF( IXYXYB(1,K),IXYXYB(2,K),
0389 1 IXYXYB(3,K),IXYXYB(4,K),BUFF)
0390 CALL WRITF(IDCB,IERR,BUFF,4)
0391 7 CONTINUE
0392 6 CONTINUE
0393 DO 8 J=1,JMAX
0394 DO 8 I=1,IMAX
0395 IXR=IFIX(XZ+AX*ALPHA(I)+BX*BETA(J))
0396 IYR=IFIX(YZ+AY*ALPHA(I)+BY*BETA(J)+CY*GAMMA(I,J))
0397 IF(I.EQ.1)GO TO 9
0398 CALL FLBUF(IXR,IYR, LASTXY(1,I-1),LASTXY(2,I-1),BUFF)
0399 CALL WRITF(IDCB,IERR,BUFF,4)
0400 9 CONTINUE
0401 IF(J.EQ.1)GO TO 10
0402 CALL FLBUF(IXR,IYR, LASTXY(1,I),LASTXY(2,I),BUFF)
0403 CALL WRITF(IDCB,IERR,BUFF,4)
0404 10 CONTINUE
0405 LASTXY(1,I)=IXR
0406 LASTXY(2,I)=IYR
0407 8 CONTINUE
0408 2 CONTINUE
0409 RETURN
0410 END
0411 SUBROUTINE FLBUF(IX1,IY1,IX2,IY2 ,BUFF)
0412 INTEGER BUFF(4)
0413 BUFF(1) = IX1
0414 BUFF(2) = IY1
0415 BUFF(3) = IX2
0416 BUFF(4) = IY2
0417 RETURN
0418 END
0419 $

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&FDIGN T=00004 IS ON CRO022 USING 00056 BLKS R=0498

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0001 FTN4,L
0002     PROGRAM FDIGN
0003 C
0004 C THIS PROGRAM SCHEDULE FILTER DESIGN,STABILITY,AND DISPLAY
0005 C
0006     COMMON/WORK/WO(75)
0007     DIMENSION NAME1(3),NAME2(3),NAME3(3),IRTN(5)
0008     DIMENSION IDCB(144),NAME4(3),NAME5(3)
0009     DIMENSION U(3,3,2),V(3,3,2),ILU(5),IBUF(80),IBUF2(80)
0010     EQUIVALENCE (ILU(1),LU),(IBUF,IBUF2)
0011     EQUIVALENCE (IBUF(1),U(1,1,1)),(IBUF(41),V(1,1,1))
0012     DATA NAME1/2HST,2HAB,2HI /
0013     DATA NAME2/2HDP,2HLA,2HM /
0014     DATA NAME3/2HCO,2HEF,2HFS/
0015     DATA NAME4/2HFI,2HRO,2H /
0016     DATA NAME5/2HPL,2HOT,2HV /
0017     DATA V/18*0./
0018     DATA U/18*0./
0019     DATA IBUF/80*0/
0020 C
0021 C GET LU
0022     CALL RMPAR(ILU)
0023 C
0024 C GET FILTER PARAMETERS
0025 C
0026     MN=1
0027 4     WRITE(LU,400)
0028     400 FORMAT(" SELECT FILTER DESIGN"/" 1. LOWPASS"/" 2. BANDPA
0029     1 3. HIGHPASS"/ " 4. BOOST FILTER"/" 5. TDLPF (LOWPASS)"
0030     2" 6. ROTATING FILTER "/" 7. NON-RECURSIVE FILTERS ")
0031     READ(LU,401) IFIL
0032     IF(IFIL.EQ.4) GO TO 500
0033     IF(IFIL.EQ.3)GO TO 410
0034     IF(IFIL.EQ.6) GO TO 408
0035     IF(IFIL .EQ. 7) GO TO 1102
0036     WRITE(LU,402)
0037     402 FORMAT(" ENTER RELATIVE CUTOFF FREQUENCY FOR LOWPASS"/)
0038     READ(LU,403)F2
0039     403 FORMAT(F2.2)
0040     IF(IFIL.NE.2) GO TO 407
0041     WRITE(LU,404)
0042     404 FORMAT(" ENTER RELATIVE CUTOFF FREQUENCY FOR HIGHPASS"/)
0043     READ(LU,403) F1
0044     407 WRITE(LU,405)
0045     405 FORMAT(" ENTER NUMBER OF FILTER STAGES"/)
0046     READ(LU,401) MN
0047     IBUF(40) =MN
0048     401 FORMAT(1I1)
0049     GO TO 411
0050     500 WRITE(LU,510)
0051     510 FORMAT(" SELECT OPTION"/," 1. LOW BOOST FILTER"/," 2. HI
0052     *ST FILTER"/)
0053     READ(LU,515) IOPT
0054     515 FORMAT(1I1)
0055     IF(IOPT.GE.0.AND.IOPT.LE.2) GO TO 530

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0056      WRITE(LU,520)
0057      520 FORMAT(" INVALID RESPONSE"/)
0058      GO TO 500
0059  C
0060      530 WRITE(LU,535)
0061      535 FORMAT(" ENTER BOOST MAGNITUDE"/)
0062      READ(LU,*) BF
0063      WRITE(LU,540)
0064      540 FORMAT(" ENTER RELATIVE BREAK FREQUENCY"/)
0065      READ(LU,403) F1
0066      IF(IOPT.EQ.0.OR.IOPT.EQ.1) WRITE(LU,545) BF,F1
0067      545 FORMAT(" BOOST MAGNITUDE = ",1E15.5," FREQUENCY = ",1F10.5,"
0068      *OWBOOST FILTER."/," IS THIS CORRECT?"/)
0069      IF(IOPT.EQ.2) WRITE(LU,550) BF,F1
0070      550 FORMAT(" BOOST MAGNITUDE = ",1E15.5," BREAK FREQUENCY = ",1F
0071      * FOR HIGH BOOST FILTER."/," IS THIS CORRECT"/)
0072      READ(LU,551) IRES
0073      551 FORMAT(1A1)
0074      IF(IRES.EQ.1HY.OR.IRES.EQ.1Hy) GO TO 552
0075      GO TO 530
0076      552 BF=SQRT(ABS(BF))
0077      IF(IOPT.EQ.2) GO TO 560
0078      ALP=1.0
0079      BET=BF-1.0
0080      GO TO 412
0081      560 ALP=BF
0082      BET=1.0-BF
0083      GO TO 412
0084      410 WRITE(LU,404)
0085      READ(LU,403) F1
0086      412 WRITE(LU,405)
0087      READ(LU,401) MN
0088      411 MN=MN+1
0089      408 IF(IFIL.EQ.1) CALL LPFLT(U,V,F2,MN,LU)
0090      IF(IFIL.EQ.2) CALL BPFLT(U,V,F1,F2,MN,LU)
0091      IF(IFIL.EQ.3) CALL BSTFT(U,V,F1,MN,1.0,-1.0,LU)
0092      IF(IFIL.EQ.4) CALL BSTFT(U,V,F1,MN,ALP,BET,LU)
0093      IF(IFIL.EQ.5) CALL TDLPF(U,V,MN,F2,2,LU)
0094  IL.E      CALL BPFLT(U,V,F1,F2,MN,LU)
0091      IF(IFIL.EQ.3) CALL BSTFT(U,V,F1,MN,1.0,-1.0,LU)
0092      IF(IFIL.EQ.4) CALL BSTFT(U,V,F1,MN,ALP,BET,LU)
0093      IF(IFIL.EQ.5) CALL TDLPF(U,V,MN,F2,2,LU)
0094  IL.E      IF(IFIL.EQ.6) CALL ROTAE(U,V,MN,LU)
0095  C      IF(IFIL.EQ.7) CALL FIR(U,MN,WR,LU)
0096      CONTINUE
0097      ILU(2) = MN
0098      IF(IFIL.EQ.2) ILU(2) =MN + 1
0099      IF(IFIL.EQ.6) ILU(2)=MN-1
0100  C
0101  C SCHEDULE STABILITY TEST-STABT
0102  C
0103      CALL EXEC(23,NAME1,LU,ILU(2),0,0,0,IBUF,80)
0104  C
0105  C
0106  C SCHEDULE DISPLAY PROGRAM-DPLAY
0107      IF(IFIL.EQ.3) ILU(2) =MN + 1
0108      IF(IFIL.EQ.4) ILU(2) =MN+1
0109      CALL EXEC(23,NAME2,LU,ILU(2),0,0,0,IBUF2,80)
0110  C

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0111      IF(IFIL .EQ. 3) IBUF(40) =MN
0112      IF(IFIL .EQ. 4) IBUF(40) =MN
0113      IF(IFIL .EQ. 6) IBUF(40)=MN-1
0114      C
0115      CALL PURGE(IDC B,IERR,NAME3,2HES)
0116      IF(IERR .LT. 0) WRITE(LU,1101) IERR
0117      CALL CREAT(IDC B,IERR,NAME3,2,3,2HES)
0118      IF(IERR .LT. 0) WRITE(LU,1101) IERR
0119      1101  FORMAT("CREATE ERROR",F5.0)
0120      CALL WRITF(IDC B,IERR,IBUF,80)
0121      IF(IERR .LT. 0) WRITE(LU,1101) IERR
0122      CALL CLOSE(IDC B,IERR)
0123      WRITE(LU,1105)
0124      1105  FORMAT(" ENTER DISPLAY DEVICE "//" 1. TV"/" 2. HP2648A")
0125      READ(LU,*) IDEV
0126      C
0127      IF(IDEV .EQ. 2) GO TO 1106
0128      CALL EXEC(23,NAME5,LU,0,0,0,0)
0129      GO TO 1107
0130      1106  CONTINUE
0131      CALL HP48A(LU)
0132      1107  CONTINUE
0133      CALL EXEC(6)
0134      C
0135      C SCHEDULE NON-RECURSIVE FILTERS
0136      1102  CONTINUE
0137      CALL EXEC(23,NAME4,LU,0,0,0,0)
0138      STOP
0139      END
0140      SUBROUTINE BPFLT(U,V,F1,F2,N,LU)
0141      C
0142      C      WRITTEN BY W. E. ALEXANDER
0143      C
0144      C      F1----BREAK FREQUENCY FOR LOW FREQUENCY CUTOFF
0145      C      F2----BREAK FREQUENCY FOR HIGH FREQUENCY CUTOFF
0146      C
0147      C      SUBROUTINE DESIGNS BANDPASS FILTER FROM LPFLT AND HPFLT
0148      C
0149      DIMENSION U(3,3,2),V(3,3,2),AA(3,3,2),BB(3,3,2)
0150      IF(F1.LT.0.001.OR.F1.GT.0.999) RETURN
0151      IF(F2.LT.0.001.OR.F2.GT.0.999) RETURN
0152      C
0153      FC=AMAX1(F1,F2)
0154      CALL LPFLT(AA,BB,FC,N,LU)
0155      C
0156      DO 20 I=1,3
0157      DO 20 J=1,3
0158      U(I,J,1)=AA(I,J,1)
0159      20 V(I,J,1)=BB(I,J,1)
0160      C
0161      FC=AMIN1(F1,F2)
0162      CALL BSTFT(AA,BB,FC,N,1.0,-1.0,LU)

```

```

0163 C
0164 DO 21 I=1,3
0165 DO 21 J=1,3
0166 U(I,J,2)=AA(I,J,1)
0167 21 V(I,J,2)=BB(I,J,1)
0168 C
0169
0170 RETURN
0171 END
0172 SUBROUTINE BSTFT(U,V,FC,N,ALP,BET,LU)
0173 C FREQUENCY BOOST DESIGN ROUTINE
0174 C FC=RC*S/PI WHERE RC IS THE CUTOFF FREQUENCY IN RADIAN AND
0175 C S IS THE SAMPLING INTERVAL. THUS FC=0.5 GIVES A CUTO
0176 C FREQUENCY AT ONE FOURTH SAMPLING FREQUENCY.
0177 C
0178 C FOR HIGH PASS FILTER, LET ALP=1.0 AND BET=-1.0
0179 C FOR HIGH FREQUENCY BOOST FILTER, ALP=BF AND BET=-1.0*(BF-1.0
0180 C WHERE BF=SQRT(DESIRED FILTER GAIN AT ONE HALF SAMPLING
0181 C FOR LOW FREQUENCY BOOST FILTER, ALP=1.0 AND BET=(BF-1.0)
0182 C
0183 C
0184 DIMENSION U(3,3,2),V(3,3,2)
0185 C
0186 DO 21 K=1,2
0187 DO 21 I=1,3
0188 DO 21 J=1,3
0189 U(I,J,K)=0.0
0190 21 V(I,J,K)=0.0
0191 WRITE(LU,14) FC
0192 14 FORMAT(1H0," FC = ",1E22.5," FOR BOOST FILTER"/)
0193 PI=3.141592654
0194 D=1.0E-10
0195 PWR=0.25
0196 IF (N.EQ.3) PWR=0.125
0197 EPS=2.0**PWR-1.0
0198 IF(N.EQ.2.AND.BET.LT.0.0) EPS=1.50702
0199 IF(N.EQ.3.AND.BET.LT.0.0) EPS=2.4711
0200 XP=PI*FC*0.5
0201 T=(SIN(XP)/COS(XP))**2.0
0202 IF(T.GT.D) GO TO 10
0203 AAA=EPS/D
0204 GO TO 11
0205 10 AAA=EPS/T
0206 11 SALP=SQRT(AAA)
0207 DEM=1.0-2.0*AAA
0208 IF(DEM.LT.D) GO TO 12
0209 13 P1=(+2.0*AAA-2.0*SQRT(2.0)*SALP+1.0)/DEM
0210 GO TO 20
0211 12 F=-1.0*DEM
0212 IF(F.GT.D) GO TO 13
0213 P1=0.0
0214 C
0215 20 A=((1.0+P1)**2)/4.0
0216 AS=A**2
0217 POS=P1**2
0218 R=4.0*(POS-AS)+((1.0+POS)**2-4.0*AS)-4.0*(P1*(1.0+POS)-2.0*A
0219 IF(ABS(R).LT.D) R=SIGN(D,R)
0220 S=((1.0-P1)**4)/R
0221 C

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0222      U(1,1,1)=S*(ALP*POS+BET*AS)
0223      U(1,2,1)=S*(ALP*P1*(1.0+POS)+2.0*BET*AS)
0224      U(2,1,1)=U(1,2,1)
0225      U(2,2,1)=S*(ALP*(1.0+POS)**2+4.0*BET*AS)
0226      U(1,3,1)=S*(ALP*POS+BET*AS)
0227      U(3,1,1)=U(1,3,1)
0228      U(2,3,1)=S*(ALP*P1*(1.0+POS)+2.0*BET*AS)
0229      U(3,2,1)=U(2,3,1)
0230      U(3,3,1)=S*(ALP*POS+BET*AS)
0231 C
0232      V(1,1,1)=1.0
0233      V(1,2,1)=2.0*P1
0234      V(2,1,1)=V(1,2,1)
0235      V(2,2,1)=4.0*POS
0236      V(1,3,1)=POS
0237      V(3,1,1)=V(1,3,1)
0238      V(2,3,1)=2.0*P1*POS
0239      V(3,2,1)=V(2,3,1)
0240      V(3,3,1)=POS**2
0241 C
0242      IF(N.EQ.2) GO TO 27
0243      DO 26 I=1,3
0244      DO 26 J=1,3
0245      U(I,J,2)=U(I,J,1)
0246 26 V(I,J,2)=V(I,J,1)
0247 27 N = N-1
0248      RETURN
0249      END
0250      SUBROUTINE LPFLT(U,V,FC,N,LU)
0251 C      LOW PASS RECURSIVE FILTER DESIGN ROUTINE
0252 C      FC#RC*S/PI WHERE RC IS THE CUTOFF FREQUENCY IN RADIAN AND
0253 C      S IS THE SAMPLING INTERVAL.  THUS FC#0.5 GIVES A CUTO
0254 C      FREQUENCY AT ONE FOURTH SAMPLING FREQUENCY.
0255 C
0256      DIMENSION U(3,3,2),V(3,3,2)
0257      COMMON/WORK/A(5,5),B(5,5)
0258 C
0259      DO 21 K=1,2
0260      DO 21 I=1,3
0261      DO 21 J=1,3
0262      U(I,J,K)=0.0
0263 21 V(I,J,K)=0.0
0264      IF(FC.GE.0.99) FC=0.99
0265      WRITE(LU,14)FC
0266 14 FORMAT(1H0," FC = ",1E10.4," FOR LOWPASS FILTER ",/)
0267      PI=3.141592654
0268      D=1.0E-10
0269      PWR=0.25
0270      IF (N.EQ.3) PWR=0.125
0271      EPS=2.0**PWR-1.0
0272      XP=PI*FC*0.5
0273      T=(SIN(XP)/COS(XP))**2.0
0274      IF(T.GT.D) GO TO 10
0275      ALP=EPS/D
0276      GO TO 11
0277 10 ALP=EPS/T
0278 11 SALP=SQRT(ALP)
0279      DEM=1.0-2.0*ALP
0280      IF(DEM.LT.D) GO TO 12
0281 13 P1=(+2.0*ALP-2.0*SQRT(2.0)*SALP+1.0)/DEM

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0282      P2=P1
0283      IF(FC.GT.0.3)GO TO 10
0284      P2=(SQRT(T)-EPS)/(SQRT(T)+EPS)
0285      GO TO 20
0286  12  F=-1.0*DEM
0287      IF(F.GT.D) GO TO 13
0288      P1=0.0
0289      P2=0.0
0290  20  V(1,1,1)=1.0
0291      V(1,2,1)=P1+P2
0292      V(2,1,1)=V(1,2,1)
0293      V(1,3,1)=P1*P2
0294      V(3,1,1)=V(1,3,1)
0295      V(2,2,1)=V(1,2,1)**2
0296      V(2,3,1)=P1*P2**2+P2*P1**2
0297      V(3,2,1)=V(2,3,1)
0298      V(3,3,1)=V(1,3,1)**2
0299  C
0300      SUM=0.0
0301      DO 25 I=1,3
0302      DO 25 J=1,3
0303  25  SUM=SUM+V(I,J,1)
0304  C
0305      U(1,1,1)=SUM/16.0
0306      U(1,3,1)=U(1,1,1)
0307      U(3,1,1)=U(1,1,1)
0308      U(3,3,1)=U(1,1,1)
0309      U(1,2,1)=SUM/8.0
0310      U(2,1,1)=U(1,2,1)
0311      U(2,3,1)=U(1,2,1)
0312      U(3,2,1)=U(1,2,1)
0313      U(2,2,1)=SUM/4.0
0314      IF(N.EQ.2) GO TO 1
0315      DO 26 I=1,3
0316      DO 26 J=1,3
0317      U(I,J,2)=U(I,J,1)
0318  26  V(I,J,2)=V(I,J,1)
0319      GO TO 2
0320  1  U(1,1,2)=1.0
0321      V(1,1,2)=1.0
0322  2  DO 30 I=1,5
0323      DO 30 J=1,5
0324      A(I,J)=0.0
0325  30  B(I,J)=0.0
0326      DO 31 I=1,5
0327      DO 31 J=1,5
0328      DO 31 K=1,3
0329      DO 31 L=1,3
0330      IK=I-K+1
0331      JL=J-L+1
0332      IF(IK.LE.0.OR.IK.GT.3)GO TO 31
0333      IF(JL.LE.0.OR.JL.GT.3)GO TO 31
0334      A(I,J)=A(I,J)+U(IK,JL,1)*U(K,L,2)
0335      B(I,J)=B(I,J)+V(IK,JL,1)*V(K,L,2)
0336  31  CONTINUE
0337      RETURN
0338      END

```

```

0339     SUBROUTINE TDLPF(A,B,MN,RC,NDIM,LU)
0340     C     INPUTS
0341     C         N - NUMBER OF FILTER STAGES
0342     C         RC - RELATIVE CUTOFF FREQUENCY FOR FILTER
0343     C         NDIM - ARRAY DIMENSION IN CALLING PROGRAM
0344     C     OUTPUTS
0345     C         A - COEFFICIENT ARRAY (NUMERATOR)
0346     C         B - COEFFICIENT ARRAY (DENOMINATOR)
0347     C
0348     DIMENSION A(3,3,NDIM),B(3,3,NDIM)
0349     COMPLEX P(10),PK,Q,Z1,Z2
0350     C
0351     C     INITIALIZE
0352     C
0353     N=MN-1
0354     PI=3.141592654
0355     D=1.0E-10
0356     IF(N.GT.NDIM) GO TO 300
0357     IF(0.01.GT.RC.OR.0.99.LT.RC) GO TO 400
0358     AA=0.5*PI*RC
0359     AA=SIN(AA)/COS(AA)
0360     PWR=1.0/FLOAT(N)
0361     C     EPS=SQRT(2.0)-1.0
0362     EPS=1.0
0363     EPS=EPS**PWR
0364     C=AA**2/EPS
0365     C
0366     C     FIND ROOTS
0367     C
0368     L=1
0369     NN=2.0*N
0370     CONST=FLOAT(NN+1)/FLOAT(NN)
0371     DO 10 K=1,NN
0372     THETA=PI*(1.0+2.0*(K-1))*CONST
0373     PK=C*CMPLX(COS(THETA),SIN(THETA))
0374     C     WRITE(LU,14) PK
0375     14 FORMAT(" PK = ",1E15.5," + J",1E15.5/)
0376     Q=2.0-PK
0377     IF(CABS(Q).LE.D) Q=D
0378     IF(CABS(PK).LE.D) PK=SIGN(D,REAL(PK))
0379     Z1=(2.0+PK+2.0*CSQRT(2.0*PK))/Q
0380     C     WRITE(LU,12) Z1
0381     12 FORMAT(" Z1 = ",1E15.5," + J",1E15.5/)
0382     IF(CABS(Z1).GE.1.0) GO TO 15
0383     P(L)=Z1
0384     C     WRITE(LU,11) L,P(L)
0385     11 FORMAT(" P(",1I2,") = ",1E15.5," + J",1E15.5/)
0386     L=L+1
0387     15 Z2=(2.0+PK-2.0*CSQRT(2.0*PK))/Q
0388     C     WRITE(LU,13) Z2
0389     13 FORMAT(" Z2 = ",1E15.5," + J",1E15.5/)
0390     IF(CABS(Z2).GE.1.0) GO TO 20
0391     F(L)=Z2
0392     C     WRITE(LU,11) L,P(L)
0393     L=L+1
0394     20 IF((L-1).EQ.NN) GO TO 25
0395     10 CONTINUE

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0396 C
0397 C   PAIR COMPLEX PAIRS OF ROOTS
0398 C
0399   25 L=1
0400     DO 30 K=1,NN
0401     S1=AIMAG(P(K))
0402     IF(S1.LT.0.0) GO TO 30
0403     P(L)=P(K)
0404     L=L+1
0405   30 CONTINUE
0406 C
0407 C   OBTAIN FILTER COEFFICIENTS
0408 C
0409   IF((L-1).LT.N) GO TO 500
0410   DO 40 K=1,N
0411   C1=-2.0*REAL(P(K))
0412   C2=CABS(P(K))**2
0413   AM=(1.0+C1+C2)**2/16.0
0414 C
0415   A(1,1,K)=AM
0416   A(1,2,K)=2.0*AM
0417   A(2,1,K)=2.0*AM
0418   A(1,3,K)=AM
0419   A(3,1,K)=AM
0420   A(2,2,K)=4.0*AM
0421   A(2,3,K)=2.0*AM
0422   A(3,2,K)=2.0*AM
0423   A(3,3,K)=AM
0424 C
0425   B(1,1,K)=1.0
0426   B(2,1,K)=C1
0427   B(1,2,K)=C1
0428   B(1,3,K)=C2
0429   B(3,1,K)=C2
0430   B(2,2,K)=C1**2
0431   B(2,3,K)=C1*C2
0432   B(3,2,K)=C1*C2
0433   40 B(3,3,K)=C2**2
0434 C
0435   GO TO 600
0436   300 WRITE(LU,310)
0437   310 FORMAT(" NUMBER OF STAGES TOO LARGE FOR DIMENSION"/)
0438   GO TO 600
0439   400 WRITE(LU,410)
0440   410 FORMAT(" FREQUENCY SPECIFICATION OUT OF RANGE"/)
0441   GO TO 600
0442   500 WRITE(LU,510)
0443   510 FORMAT(" NUMBER OF ROOTS LESS THAN EXPECTED"/)
0444   600 RETURN
0445   END

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```

0446      BLOCK DATA WORK
0447      COMMON/WORK/WO(75)
0448      END
0449      SUBROUTINE HP48A( JJ)
0450      DIMENSION IB(14), IA(4)
0451      INTEGER IDCB(144 ), BUFF( 4 ), NAME(3)
0452      DATA NAME/2HDA,2HTA,2H1 /
0453      C
0454      CALL OPEN(IDCB, IERR, NAME)
0455      IF (IERR .GE. 0) GO TO 30
0456      WRITE(LU,10) IERR
0457      10  FORMAT ("OPEN ERROR",F5.0)
0458      STOP
0459      30  CALL GRAFC(1,LU)
0460      20  CALL READF(IDCB, IERR, BUFF, 4, ILOG)
0461      IF(ILOG .EQ. -1) GO TO 55
0462      IF (IERR .GE. 0) GOTO 40
0463      WRITE(LU,31) IERR
0464      31  FORMAT("READ ERROR",F5.0)
0465      GO TO 55
0466      40  CONTINUE
0467      CALL DVECT(BUFF, BUFF(2), BUFF(3), BUFF(4), LU)
0468      50  GO TO 20
0469      55  CALL EXEC(13, LU, ISTAT)
0470      ISTAT=IAND(ISTAT,140000B)
0471      IF(ISTAT.NE.0) GO TO 55
0472      CALL GRAFC(0,LU)
0473      CALL CLOSE(IDCB)
0474      RETURN
0475      END
0476      SUBROUTINE GRAFC(IFLAG,LU)
0477      INTEGER IESC
0478      IESC= 33B
0479      C
0480      C GRAPHICS OFF=0; GRAPHICS ON NOT=0
0481      C
0482      IF(IFLAG.EQ.0) GO TO 100
0483      C
0484      C GRAPHIC ON
0485      C
0486      WRITE(LU,10) IESC
0487      10  FORMAT(1R2,"*dC")
0488      WRITE(LU,12) IESC
0489      12  FORMAT(1R2,"*dF")
0490      WRITE(LU,14) IESC
0491      14  FORMAT(1R2,"*dA")
0492      C

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```

0493          GO TO 200
0494 C
0495 C GRAPHICS OFF
0496 C
0497 100      WRITE(LU,30) IESC
0498 30       FORMAT(1R2,"*Id")
0499          WRITE(LU,40) IESC
0500 40       FORMAT(1R2,"*dE")
0501 200      RETURN
0502          END
0503          SUBROUTINE DVECT(IX1,IY1,IX2,IY2,LU)
0504 C
0505 C SUBROUTINE DRAWS A LINE BETWEEN THE TWO POINTS (IX1,IY1)
0506 C AND (IX2,IY2). THE POINT (IX0,IY0) DEFINES THE
0507 C THE ORIGIN.
0508 C
0509          IX0=0
0510          IY0=0
0511          XSCAL =356.0/1024.0
0512          YSCAL =XSCAL
0513          X1 = IX1*XSCAL + 0.5
0514          X2 = IX2*XSCAL + 0.5
0515          Y1 = IY1*YSCAL + 0.5
0516          Y2 = IY2*YSCAL + 0.5
0517          JX1 = X1 + IX0
0518          JX2 = X2 + IX0
0519          JY1 = Y1 + IY0
0520          JY2 = Y2 + IY0
0521          WRITE(LU,10) JX1,JY1,JX2,JY2
0522 10       FORMAT("pa",1I3,1H,,1I3,1H,,1I3,1H,,1I3,"Z")
0523          RETURN
0524          END
0525          ENDS
0526 $

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&BLDIM T=00C04 IS ON CRO022 USING 00034 BLKS R=0330

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0001 FTN4
0002     PROGRAM BLDIM
0003 C
0004 C THIS PROGRAM BUILDS AN IMAGE FILE FOR THE NCA&T IMAGE DISPLAY
0005 C SYSTEM. IMAGE FILES MAY BE GENERATED FROM THE GMR-27 DISPLAY,
0006 C TAPES OR DISC (TYPE 2 FILES).
0007 C
0008 C PROGRAMMER: DLJ
0009 C
0010     DIMENSION LU(5),IDCB1(272),IDCB2(528),NAME(6),ISIZE(2),IDATA
0011     DIMENSION JNAME(3),IBUF(6)
0012 C
0013     INTEGER ENTRY(256),TEXT1(40),TEXT2(40),TEXT3(40),RDREC
0014 C
0015     EQUIVALENCE (ENTRY,NAME),(ENTRY(7),NLINE),(ENTRY(8),NPIXL),
0016     1 (ENTRY(9),IPMIN),(ENTRY(10),IPMAX),(ENTRY(11),ISRC),
0017     2 (ENTRY(13),JNAME),(ENTRY(129),TEXT1),(ENTRY(169),TEXT2),
0018     3 (ENTRY(209),TEXT3),(ENTRY(12),ILOC)
0019     EQUIVALENCE (JNAME(2),JNAM2),(JNAME(3),JNAM3),(ISIZE(2),ISIZ
0020 C
0021 C CONSTANTS
0022 C     MPIXL = MAXIMUM PIXELS/LINE (WHEN CHANGING BE SURE TO MODIF
0023 C     ARRAY SIZES)
0024 C
0025     DATA MPIXL/512/
0026 C
0027 C GET INPUT PARAMETERS
0028 C
0029     CALL RMPAR(LU)
0030     IF (LU .LE. 0) LU = 1
0031 C
0032 C OUTPUT HEADING
0033 C
0034     WRITE(LU,1)
0035 1     FORMAT(//"          B U I L D   I M A G E   S U B S Y S T E M"
0036 C
0037 C OPEN DIRECTORY FILE
0038 C
0039     CALL OPEN(IDCB1,IERR,6HIMDIRC,0,2HIM,23,272)
0040     IF (IERR .LT. 0) GO TO 9999
0041 C
0042 C GET IMAGE NAME
0043 C
0044 1000 WRITE(LU,2)
0045 2     FORMAT("ENTER 12 CHARACTER IMAGE NAME?(/E TO EXIT)_")
0046     READ(LU,"` NAME
0047 3     FORMAT(6A2)
0048     IF (NAME .EQ. 2H/E) GO TO 1060
0049 C
0050 C CHECK FOR DUPLICATE NAME
0051 C

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```

0052      IREC = 0
0053      KREC = 0
0054      CALL RWNDF(IDCBI,IERR)
0055      IF (IERR .LT. 0) GO TO 9999
0056 1010  IREC = IREC + 1
0057      CALL READF(IDCBI,IERR,IBUF,6,LEN)
0058      IF (IERR .LT. 0) GO TO 9999
0059      IF (LEN .EQ. -1) GO TO 1030
0060 C
0061 C  COMPARE NAME
0062 C
0063      IF (IBUF .EQ. -1) KREC = IREC
0064 C
0065      DO 1020 I=1,6
0066      IF (NAME(I) .NE. IBUF(I)) GO TO 1010
0067 1020  CONTINUE
0068 C
0069 C  DUPLICATE NAME FOUND
0070 C
0071      WRITE(LU,4)
0072 4      FORMAT("ERROR-DUPLICATE NAME")
0073      CALL RWNDF(IDCBI,IERR)
0074      IF (IERR .LT. 0) GO TO 9999
0075      GO TO 1000
0076 C
0077 C  EOF REACHED AND NO DUPLICATE FOUND
0078 C
0079 C  GET IMAGE PARAMETERS
0080 C
0081 1030  WRITE(LU,5)
0082 5      FORMAT("# LINES IN IMAGE?_")
0083      READ(LU,*) NLINE
0084      WRITE(LU,6)
0085 6      FORMAT(" # PIXELS/LINE?_")
0086      READ(LU,*) NPIXL
0087      IF (NPIXL .GT. MPIXL) NPIXL = MPIXL
0088 C
0089 C  GET 3-LINES OF DESCRIPTIVE TEXT
0090 C
0091      WRITE(LU,7)
0092 7      FORMAT(" ENTER UP TO 3 LINES OF DESCRIPTIVE TEXT"/)
0093      TEXT1 = 2H
0094      CALL MVW(TEXT1,TEXT1(2),119)
0095      CALL EXEC(1,400B+LU,TEXT1,40)
0096      CALL EXEC(1,400B+LU,TEXT2,40)
0097      CALL EXEC(1,400B+LU,TEXT3,40)
0098 C
0099 C  GET SOURCE OF IMAGE
0100 C
0101 1040  WRITE(LU,8)
0102 8      FORMAT("IMAGE SOURCE?(1=DISC FILE;2=TAPE;3=DISPLAY;4=WORK FI
0103      READ(LU,*) ISRC
0104      IF (ISRC .LT. 0) GO TO 1060
0105      IF (ISRC .LT. 1 .OR. ISRC .GT. 4) GO TO 1040
0106 C

```



```
0107 C CREATE DATA FILE
0108 C
0109     ISIZE = (FLOAT(NPIXL)*FLOAT(NLINE) + 127.)/ 128.
0110     ISIZ2 = NPIXL
0111     IF (KREC .EQ. 0) KREC = IREC
0112     JNAME = 2HIM
0113     CALL DCODE(KREC,JNAM2,JNAM3)
0114     CALL PURGE(IDC2,IERR,JNAME,2HIM,23)
0115     CALL CREAT(IDC2,IERR,JNAME,ISIZE,2,2HIM,23,528)
0116     IF (IERR .LT. 0) GO TO 9999
0117 C
0118 C INITIALIZE INPUT ROUTINE
0119 C
0120     IERR = RDREC(-LU,ISRC,NLINE,NPIXL)
0121     IF (IERR .LT. 0) GO TO 9999
0122 C
0123 C GET EACH LINE AND WRITE TO FILE
0124 C
0125     IPMAX = 0
0126     IPMIN = 377B
0127     DO 1050 I=1,NLINE
0128     IERR = RDREC(1,IDATA,IPMAX,IPMIN)
0129     IF (IERR .LT. 0) GO TO 9999
0130     CALL WRITF(IDC2,IERR,IDATA,NPIXL)
0131     IF (IERR .LT. 0) GO TO 9999
0132 C     WRITE(LU,1051) IPMAX,IPMIN
0133 1051  FORMAT(2I12)
0134 1050  CONTINUE
0135 C
0136     CALL CLOSE(IDC2)
0137 C
0138 C WRITE DIRECTORY ENTRY
0139 C
0140     IF (KREC .EQ. IREC) GO TO 1055
0141     CALL OPEN(IDC1,IERR,6HIMDIRC,2,2HIM,23,272)
0142     IF (IERR .LT. 0) GO TO 9999.
0143     CALL POSNT(IDC1,IERR,KREC)
0144     IF (IERR .LT. 0) GO TO 9999
0145 1055  ILOC = 1
0146     CALL WRITF(IDC1,IERR,ENTRY,256)
0147     IF (IERR .LT. 0) GO TO 9999
0148     GO TO 1000
0149 C
0150 C TERMINATE
0151 C
0152 1060  CALL CLOSE(IDC1)
0153     CALL EXEC(6)
0154 C
0155 C ERROR
0156 C
0157 9999  WRITE(LU,9)IERR
0158 9     FORMAT(" FILE ERROR-",I6)
0159     CALL CLOSE(IDC1)
0160     END
```

```

0161          INTEGER FUNCTION RDREC(ICODE,IBUF,IP1,IP2)
0162 C
0163 C THIS SUBROUTINE IS USED TO INPUT IMAGE FROM DISC,TAPE OR DISPLA
0164 C
0165          DIMENSION IBUF(1),IDATA(1024),NAME(3),RDATA(512),IDCB(1040)
0166 C
0167          LOGICAL PACKED
0168 C
0169          EQUIVALENCE (IDATA,RDATA)
0170 C
0171 C
0172          IF (ICODE .GT. 0) GO TO 120
0173 C
0174 C INITIALIZATION
0175 C
0176          NLINE = IP1
0177          NPIXL = IP2
0178          LU = -ICODE
0179 C
0180          IF (LU .GT. 0) GO TO 90
0181 C
0182 C SPACE FOR CALL WITH NO INTERACTION
0183 C
0184 C
0185 C INTERACTIVE CALL
0186 C
0187 90          IF (IBUF .NE. 1) GO TO 100
0188 C
0189 C GET DISC FILE NAME
0190 C
0191          WRITE(LU,1)
0192 1          FORMAT("ENTER DISC FILE NAME?_")
0193          READ(LU,2) NAME
0194 2          FORMAT(3A2)
0195 C
0196 C OPEN FILE
0197 C
0198          CALL OPEN(IDCB,IERR,NAME,0,0,0,1040)
0199          IF (IERR .LT. 0) GO TO 999
0200          WRITE(LU,3)
0201 3          FORMAT(" DATA FORMAT (1=UNPACKED; 2=PACKED; 3=REAL)?_")
0202          READ(LU,*)IFMT
0203          PACKED = .TRUE.
0204          IF (IFMT .NE. 2) PACKED = .FALSE.
0205          NUM = NPIXL
0206          IF (PACKED) NUM = (NPIXL+1)/2
0207          IF (IFMT .EQ. 3) NUM = 2*NPIXL
0208          IBCOD = 1
0209          RETURN
0210 C
0211 100         IF (IBUF .NE. 2) GO TO 110
0212 C
0213 C TAPE INPUT
0214 C
0215          WRITE(LU,4)
0216 4          FORMAT("TAPE LU?_")
0217          READ(LU,*) MTLU
0218 C

```

```

0219 C REWIND TAPE
0220 C
0221 CALL EXEC(3,MTLU+400B)
0222 WRITE(LU,9)
0223 9 FORMAT(" FILE #? ")
0224 READ(LU,*) IFILE
0225 IF (IFILE .LE. 0) CALL EXEC(6)
0226 IF (IFILE .EQ. 1) GO TO 107
0227 DO 105 I=1,IFILE-1
0228 CALL EXEC(3,MTLU+1300B)
0229 105 CONTINUE
0230 C
0231 107 WRITE(LU,3)
0232 READ(LU,*) IFMT
0233 PACKED = .TRUE.
0234 IF (IFMT .NE. 2) PACKED = .FALSE.
0235 NUM = NPIXL
0236 IF (PACKED) NUM = (NPIXL+1)/2
0237 IF (IFMT .EQ. 3) NUM = 2*NPIXL
0238 IBCOD = 2
0239 RETURN
0240 C
0241 110 IF (IBUF .NE. 3) GO TO 115
0242 C
0243 C DISPLAY INPUT
0244 C
0245 WRITE(LU,5)
0246 5 FORMAT("ENTER START LINE,END LINE,START PIXEL,END PIXEL? ")
0247 READ(LU,*) ISTRTL,IENDL,ISTRTP,IENDP
0248 ISTEP = 1
0249 IF (ISTRTL .GT. IENDL) ISTEP = -1
0250 PACKED = .FALSE.
0251 NUM = NPIXL
0252 IBCOD = 3
0253 RETURN
0254 C
0255 C INPUT IS WORK FILE
0256 C
0257 115 CALL OPEN(IDC B,IERR,6HWF0000,0,0,0,1040)
0258 IF (IERR .LT. 0) GO TO 999
0259 PACKED = .FALSE.
0260 NUM = 2*NPIXL
0261 IBCOD = 1
0262 C
0263 C POSITION FILE
0264 C
0265 CALL READF(IDC B,IERR,IDATA,0)
0266 IF (IERR .LT. 0) GO TO 999
0267 C
0268 RETURN
0269 C
0270 C
0271 C DATA INPUT SECTION
0272 C
0273 C BRANCH TO APPROPRIATE SUB SECTION
0274 C

```

```

0275 C
0276 120 GO TO (130,140,150),IBCOD
0277 C
0278 C FILE INPUT
0279 C
0280 130 CALL READF(IDCIB,IERR,RDATA,NUM)
0281     IF (IERR .LT. 0) GO TO 999
0282     IFMT=3
0283     GO TO 160
0284 C
0285 C TAPE INPUT
0286 C
0287 140 CALL EXEC(1,MTLU,IDATA,NUM)
0288     GO TO 160
0289 C
0290 C DISPLAY INPUT
0291 C
0292 150     IBUF = 0
0293     CALL MVW(IBUF,IBUF(2),NPIXL-1)
0294     IF ((ISTEP .GT. 0) .AND.(ISTRTL .GT. IENDL)) RETURN
0295     IF (ISTEP .LT. 0 .AND. ISTRTL .LT. IENDL) RETURN
0296     CALL RLINE(ISTRTL,ISTRTP,IENDP,IDATA)
0297     ISTRTL = ISTRTL + ISTEP
0298 C
0299 C MOVE DATA TO OUTPUT ARRAY AND UNPACK IF NECESSARY
0300 C
0301 160 IF (.NOT. PACKED) GO TO 180
0302 C
0303 C DATA IN PACKED FORMAT
0304 C
0305     DO 170 I=1,NUM
0306     ITEM = IDATA(I)
0307     CALL ROT8(ITEM,JTEMP)
0308     JTEMP = LAND(JTEMP,377B)
0309     IF (JTEMP .GT. IP1) IP1 = JTEMP
0310     IF (JTEMP .LT. IP2) IP2 = JTEMP
0311     ITEM = LAND(ITEM,377B)
0312     IF (ITEM .GT. IP1) IP1 = ITEM
0313     IF (ITEM .LT. IP2) IP2 = ITEM
0314     IBUF(2*I-1) = JTEMP
0315 170 IBUF(2*I) = ITEM
0316     RETURN
0317 C
0318 C DATA IS UNPACKED
0319 C
0320 180 DO 190 I=1,NPIXL
0321     ITEM = IDATA(I)
0322     IF (IFMT .EQ. 3) ITEM = RDATA(I)
0323     IF (ITEM .GT. IP1) IP1 = ITEM
0324     IF (ITEM .LT. IP2) IP2 = ITEM
0325 190 IBUF(I) = ITEM
0326     RETURN
0327 C
0328 999 RDREC = IERR
0329     END
0330 $
0331 $

```

&LFLTR T=00003 IS ON CRO0022 USING 00024 BLKS R=0000

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0001 FTN4,L
0002     PROGRAM LFLTR
0003 C
0004 C     WRITTEN BY E. E. SHERROD
0005 C
0006 C     PROGRAM DOES LINEAR FILTERING USING SPATIAL DOMAIN
0007 C           RECURSIVE DIGITAL FILTERS
0008 C
0009 C
0010 C
0011 C
0012 C
0013     DIMENSION A(3,3,2),B(3,3,2),ILU(5),SUM(3,2)
0014     DIMENSION F1(524),F2(524),F3(524)
0015     DIMENSION G1(1),G2(1),G3(1),IX1(3)
0016     DIMENSION X1(524),X2(524),X3(524)
0017     DIMENSION IDCB(144),NAME(3),IRTN(5)
0018     COMMON /IBLK/IBUF(80)
0019     INTEGER READL,RITEL,WFINT
0020     EQUIVALENCE(IBUF(1),A(1,1,1)),(IBUF(41),B(1,1,1))
0021     EQUIVALENCE(IRTN(2),RMAX),(IRTN(4),RMIN)
0022     DATA NAME/2HCO,2HEF,2HFS/
0023 C
0024 C NROW X 512 IMAGE
0025 C
0026     CALL RMPAR(ILU)
0027 C
0028     LU=ILU(1)
0029     IPIXL=ILU(2)
0030     JPIXL=ILU(3)
0031 C
0032 C GET FILTER COEFF'S
0033     CALL OPEN(IDCB,IERR,NAME)
0034     IF(IERR .LT. 0) GO TO 9999
0035     CALL READF(IDCB,IERR,IBUF,80,IERR)
0036     IF(IERR .LT. 0) GO TO 9999
0037     NSTAG = IBUF(40)
0038     N = NSTAG + 1
0039     CALL CLOSE(IDCB,IERR)
0040 C
0041 C GET CONTROL BLOCK INFORMATION
0042 C
0043     IERR=WFINT(NROW,ICOLS,RMAX,RMIN,LU)
0044     IF(IERR .LT. 0)GOTO 9999
0045     IPIXL = 2
0046     ICOLS=ICOLS-2
0047     JPIXL =ICOLS - 1
0048 C

```

```

0049 C
0050 C      INITIALIZE FILTER TO MID LINE-COL AVG
0051 C
0052      NMID=NROW/2
0053      CNST=0.0
0054      IERR=READL(NMID,0,511,F1)
0055      IF(IERR .LT. 0) GO TO 9999
0056 701    DO 110 I=1,ICOLS
0057 110    CNST=CNST+F1(I)
0058 602    CNST=CNST/FLOAT(ICOLS)
0059 C
0060      DO 13 I=1,524
0061      F3(I)=CNST
0062      F2(I)=CNST
0063 13     F1(I)=CNST
0064 C
0065 C      CALCULATE FINAL VALUE FOR EACH STAGE
0066 C
0067      DO 10 NSTG=2,N
0068      SUM(NSTG,1)=0.0
0069      SUM(NSTG,2)=0.0
0070      DO 11 I=1,3
0071      DO 11 J=1,3
0072      SUM(NSTG,1)=SUM(NSTG,1)+A(I,J,NSTG-1)
0073 11     SUM(NSTG,2)=SUM(NSTG,2)+B(I,J,NSTG-1)
0074      DEL=ABS(SUM(NSTG,2))
0075      IF(DEL.LT.1.0E-20)CALL EXEC(2,LU,16HFILTER UNSTABLE ,8)
0076 10     SUM(NSTG,1)=SUM(NSTG,1)/SUM(NSTG,2)
0077 C
0078 C      CALCULATE INITIAL CONDITIONS FOR EACH STAGE
0079 C
0080      SUM(1,2)=CNST
0081      DO 12 NSTG=2,N
0082 12     SUM(NSTG,2)=SUM(NSTG,1)*SUM(NSTG-1,2)
0083 C
0084 C      INITIALIZE FILTER
0085 C
0086      DO 14 I=1,524
0087      X3(I)=SUM(2,2)
0088      X2(I)=SUM(2,2)
0089      X1(I)=SUM(2,2)
0090      IF (NSTAG .EQ. 1) GO TO 14
0091      G3(I) = SUM(3,2)
0092      G2(I)=SUM(3,2)
0093      G1(I)=SUM(3,2)
0094 14     CONTINUE
0095      RMX=-1.0E38
0096      RMI= 1.0E38
0097 C
0098 C      FILTER REVERSE
0099 C
0100      IERR=READL(8,IPIXL,JPIXL,F3)
0101      IF(IERR .LT. 0) GO TO 9999
0102      IERR=READL(7,IPIXL,JPIXL,F2)
0103      IF(IERR .LT. 0) GO TO 9999
0104      IERR=READL(6,IPIXL,JPIXL,F1)
0105      IF(IERR .LT. 0) GO TO 9999

```

```

0106 C
0107     LNCK = 1
0108     DO 300 NRO=-6,NROW - 1,3
0109     CALL FILTR(2,F1,F2,F3,X1,X2,X3,G1,NSTAG,ICOLS)
0110     IF(LNCK .LT. 7) GO TO 301
0111     LINE = IABS(NRO)
0112     CALL RITLN(LINE, IPIXL, JPIXL, X1, G1, NSTAG, 2, LU, RMX, RMI)
0113 301     LNCK =LNCK +1
0114     LINE=IABS(NRO+1)
0115     IF(LINE .GT. NROW-1) GO TO 300
0116     IERR=READL(LINE, IPIXL, JPIXL, F3)
0117     IF(IERR .LT. 0) GO TO 9999
0118     CALL FILTR(2,F3,F1,F2,X3,X1,X2,G1,NSTAG,ICOLS)
0119     IF(LNCK .LT. 7) GO TO 302
0120     CALL RITLN(LINE, IPIXL, JPIXL, X3, G1, NSTAG, 2, LU, RMX, RMI)
0121 302     LNCK =LNCK +1
0122     LINE=IABS(NRO+2)
0123     IF(LINE .GT. NROW-1) GO TO 300
0124     IERR=READL(LINE, IPIXL, JPIXL, F2)
0125     IF(IERR .LT. 0) GO TO 9999
0126     CALL FILTR(2,F2,F3,F1,X2,X3,X1,G1,NSTAG,ICOLS)
0127     IF(LNCK .LT. 7) GO TO 303
0128     IF(LINE .GT. NROW-1) GO TO 300
0129     CALL RITLN(LINE, IPIXL, JPIXL, X2, G1, NSTAG, 2, LU, RMX, RMI)
0130 303     LNCK =LNCK +1
0131     LINE=IABS(NRO+3)
0132     IF(LINE .GT. NROW-1) GO TO 300
0133     IERR=READL(LINE, IPIXL, JPIXL, F1)
0134     IF(IERR .LT. 0) GO TO 9999
0135 300     CONTINUE
0136 C
0137 C REINITIALIZE FILTER
0138 C
0139     CONST=(RMX-RMI)/2.
0140     DO 15 II=1,524
0141     F1(II) = CONST
0142     F2(II) = CONST
0143     F3(II) = CONST
0144 15     CONTINUE
0145 C
0146 C     FILTER FORWARD
0147 C
0148     RMX=-0.1E38
0149     RMI= 0.1E38
0150     LINE =NROW-9
0151     IERR=READL(LINE, IPIXL, JPIXL, F3(12))
0152     IF(IERR .LT. 0) GO TO 9999
0153     LINE=LINE+1
0154     IERR=READL(LINE, IPIXL, JPIXL, F2(12))
0155     IF(IERR .LT. 0) GO TO 9999
0156     LINE=LINE+1
0157     IERR=READL(LINE, IPIXL, JPIXL, F1(12))
0158     IF(IERR .LT. 0) GO TO 9999

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0159 C
0160 LNCK =-6
0161 DO 400 NRO= -6,NROW - 1,3
0162 CALL FILTR(1,F1,F2,F3,X1,X2,X3,G1,NSTAG,ICOLS)
0163 IF(LNCK .LT. 0) GO TO 401
0164 CALL RITLN(LINE,IPIXL,JPIXL,X1,G1,NSTAG,1,LU,RMX,RMI)
0165 401 LNCK=LNCK+1
0166 LINE=(NROW-1)-IABS(NRO+1)
0167 IERR=READL(LINE,IPIXL,JPIXL,F3(12))
0168 IF(IERR .LT. 0) GO TO 9999
0169 CALL FILTR(1,F3,F1,F2,X3,X1,X2,G1,NSTAG,ICOLS)
0170 IF(LNCK .LT. 0) GO TO 402
0171 CALL RITLN(LINE,IPIXL,JPIXL,X3,G1,NSTAG,1,LU,RMX,RMI)
0172 402 LNCK =LNCK +1
0173 LINE=(NROW-1)-IABS(NRO+2)
0174 IF(LINE .LT. 0) GO TO 400
0175 IERR=READL(LINE,IPIXL,JPIXL,F2(12))
0176 IF(IERR .LT. 0) GO TO 9999
0177 CALL FILTR(1,F2,F3,F1,X2,X3,X1,G1,NSTAG,ICOLS)
0178 IF(LNCK .LT. 0) GO TO 403
0179 CALL RITLN(LINE,IPIXL,JPIXL,X2,G1,NSTAG,1,LU,RMX,RMI)
0180 403 LNCK =LNCK +1
0181 LINE=(NROW-1)-IABS(NRO+3)
0182 IF(LINE .LT.0) GO TO 400
0183 IERR=READL(LINE,IPIXL,JPIXL,F1(12))
0184 IF(IERR .LT. 0) GO TO 9999
0185 400 CONTINUE
0186 C
0187 51 CONTINUE
0188 RMAX=RMX
0189 RMIN=RMI
0190 CALL CLSWF(NROW,ICOLS,RMAX,RMIN)
0191 CALL PRTN(IRTN)
0192 CALL EXEC(6)
0193 9999 CALL EXEC(2,LU,16HREAD FILE ERROR ,8)
0194 END
0195 SUBROUTINE FILTR(IFLAG,F1,F2,F3,X1,X2,X3,G1,NSTAG,ICOLS)
0196 DIMENSION F1(1),F2(1),F3(1),X1(1),X2(1),X3(1),A(1),B(1)
0197 COMMON /IBLK/IBUF(80)
0198 DIMENSION G1(1),G2(1),G3(1)
0199 C
0200 EQUIVALENCE (IBUF,A),(IBUF(41),B)
0201 C IFLAG =1 FOR FORWARD FILTERING, = 2 FOR REVERSE
0202 C
0203 C REVERSE FILTERING
0204 C
0205 IF(IFLAG .EQ. 1) GO TO 200
0206 DO 20 I=1,11
0207 L =ICOLS+12 - I
0208 J = ICOLS-12 + I
0209 F1(L) = F1(J)
0210 F2(L) = F2(J)
0211 20 F3(L) = F3(J)
0212 C

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```

0213      DO 10 M = ICOLS+9,1,-1
0214      J = M + 1
0215      K = M + 2
0216      X1(M) = A(1) * F1(M)
0217      1      + A(2) * F1(J)-B(2)*X1(J)
0218      1      + A(3) * F1(K)-B(3)*X1(K)
0219      1      + A(4) * F2(M)-B(4)*X2(M)
0220      1      + A(5) * F2(J)-B(5) *X2(J)
0221      1      + A(6) * F2(K)-B(6) *X2(K)
0222      1      + A(7) * F3(M)-B(7)*X3(M)
0223      1      + A(8) * F3(J)-B(8) *X3(J)
0224      1      + A(9) * F3(K) - B(9)*X3(K)
0225      IF(NSTAG .EQ. 1) GO TO 10
C          G1(M) = A(10) * X1(M)
0227      1      + A(11) * X1(J)-B(11)*G1(J)
0228      1      + A(12) * X1(K)-B(12)*G1(K)
0229      1      + A(13) * X2(M)-B(13)*G2(M)
0230      1      + A(14) * X2(J)-B(14) *G2(J)
0231      1      + A(15) * X2(K)-B(15) *G2(K)
0232      1      + A(16) * X3(M)-B(16)*G3(M)
0233      1      + A(17) * X3(J)-B(17) *G3(J)
0234      1      + A(18) * X3(K) - B(18)*G3(K)
0235      10      CONTINUE
0236      GO TO 400
0237      200      CONTINUE
0238      C
0239      C FORWARD FILTERING
0240      C
0241      DO 30 I=1,11
0242      L =12 - I
0243      J = 12 + I
0244      F1(L) = F1(J)
0245      F2(L) = F2(J)
0246      30      F3(L) = F3(J)
0247      C
0248      DO 40 M = 3,ICOLS + 11
0249      J = M - 1
0250      K = M - 2
0251      X1(M) = A(1) * F1(M)
0252      1      + A(2) * F1(J)-B(2)*X1(J)
0253      1      + A(3) * F1(K)-B(3)*X1(K)
0254      1      + A(4) * F2(M)-B(4)*X2(M)
0255      1      + A(5) * F2(J)-B(5) *X2(J)
0256      1      + A(6) * F2(K)-B(6) *X2(K)
0257      1      + A(7) * F3(M)-B(7)*X3(M)
0258      1      + A(8) * F3(J)-B(8) *X3(J)
0259      1      + A(9) * F3(K) - B(9)*X3(K)
0260      IF(NSTAG .EQ. 1) GO TO 40
0261      G1(M) = A(10) * X1(M)
0262      1      + A(11) * X1(J)-B(11)*G1(J)
0263      1      + A(12) * X1(K)-B(12)*G1(K)
0264      1      + A(13) * X2(M)-B(13)*G2(M)
0265      1      + A(14) * X2(J)-B(14) *G2(J)
0266      1      + A(15) * X2(K)-B(15) *G2(K)
0267      1      + A(16) * X3(M)-B(16)*G3(M)
0268      1      + A(17) * X3(J)-B(17) *G3(J)
0269      1      + A(18) * X3(K) - B(18)*G3(K)
0270      40      CONTINUE
0271      400      CONTINUE
0272      RETURN
0273      END

```

```

0274 C
0275 C   COMMON BLOCK SUBPROGRAM
0276 C
0277     BLOCK DATA IBLK
0278     COMMON /IBLK/IBUF(80)
0279     DATA IBUF/80*0/
0280     END
0281     SUBROUTINE RITLN(LINE, IPIXL, JPIXL, X1, G1, NSTAG, IFLAG, LU, RMX, R
0282     DIMENSION X1(1), G1(1), IX1(524)
0283     INTEGER RITEL
0284     IFL=1
0285     IF(IFLAG .EQ. 1) IFL = 12
0286     IF(NSTAG .EQ. 2) GO TO 100
0287     IERR= RITEL(LINE, IPIXL, JPIXL, X1(IFL))
0288 12  IF(IERR .LT. 0) GO TO 9999
0289     DO 120 I=IFL, JPIXL-IPIXL +IFL
0290     IF(X1(I) .GT. RMX) RMX=X1(I)
0291     IF(X1(I) .LT. RMI) RMI=X1(I)
0292     ITEMP= X1(I) + 0.5
0293     IF(ITEMP .LT. 0) ITEMP=0
0294     IF(ITEMP .GT. 377B) ITEMP=377B
0295 120 IX1(I) = ITEMP
0296     GO TO 200
0297 100  CONTINUE
0298     IERR= RITEL(LINE, IPIXL, JPIXL, G1(IFL))
0299     IF(IERR .LT. 0) GO TO 9999
0300     DO 121 I=1, 524
0301     ITEMP=G1(I) + 0.5
0302     IF(ITEMP .LT. 0) ITEMP=0
0303 121  IX1(I) =IAND(ITEMP, 777B)
0304 200  ISTRT=(511-JPIXL)/2
0305     ISTOP=ISTRT+JPIXL
0306     CALL WLINE(LINE, ISTRT, ISTOP, IX1(IFL))
0307     RETURN
0308 9999 CALL EXEC(2, LU, 16HWRITE FILE ERROR, 8)
0309     END
0310     ENDS$

```

SHFLTR T=00004 IS ON CRO0022 USING 00036 BLKS R=0289

```

0001 FTN4,L
0002          PROGRAM HFLTR
0003 C
0004 C          WRITTEN BY E. E. SHERROD
0005 C
0006 C          PROGRAM DOES HOMOMORPHIC FILTERING USING SPATIAL DOMAIN
0007 C                    RECURSIVE DIGITAL FILTERS
0008 C
0009          COMMON /IBLK/IBUF(80)
0010          DIMENSION IF1(2),IF2(523),R1(523)
0011          DIMENSION A(3,3,2),B(3,3,2),ILU(5),SUM(3,2)
0012          DIMENSION F1(523),F2(523),F3(523)
0013          DIMENSION G1(1),G2(1),G3(1),IX1(3)
0014          DIMENSION X1(523),X2(523),X3(523)
0015          DIMENSION IDCB(144),NAME(3),IRTN(5)
0016          INTEGER READL,RITEL,WFINT
0017          EQUIVALENCE(IBUF(1),A(1,1,1)),(IBUF(41),B(1,1,1))
0018          EQUIVALENCE(IRTN(2),RMAX),(IRTN(4),RMIN)
0019          EQUIVALENCE(F1,R1),(F2,IF2),(R1,IF1),(IF1,ILINE),(IF1(2),ICO
0020          L(R1(2),RMAXX),(R1(3),RMINN)
0021          DATA NAME/2HCO,2HEF,2HFS/
0022 C
0023          CALL RMPAR(ILU)
0024          LU=ILU(1)
0025          IF(LU .EQ. 0) LU=1
0026          IPIXL = ILU(2)
0027          IF(IPIXL .EQ. 0) IPIXL =0
0028          JPIXL = ILU(3)
0029          IF(JPIXL .EQ. 0) JPIXL = 511
0030 C
0031 C GFT FILTER COEFF'S
0032          CALL OPEN(IDC B,IERR,NAME)
0033          IF(IERR .LT. 0) GO TO 9999
0034          CALL READF(IDC B,IERR,IBUF,80,IERR)
0035          IF(IERR .LT. 0) GO TO 9999
0036          NSTAG = IBUF(40)
0037          N = NSTAG + 1
0038          CALL CLOSE(IDC B,IERR)
0039 C
0040 C GET CONTROL BLOCK INFORMATION
0041          IERR=WFINT(NROW,ICOLS,RMAX,RMIN,LU)
0042          IF(IERR .LT. 0)GOTO 9999
0043          IPIXL=2
0044          ICOLS=ICOLS-2
0045          JPIXL = ICOLS -1
0046 C
0047 C          INITIALIZE FILTER TO MID LINE-COL AVG
0048          NMID=NROW/2
0049          CNST=0.0
0050          IERR=READL(NMID,IPIXL,JPIXL,F1)
0051          IF(IERR .LT. 0) GO TO 9999
0052          CALL BIAS(F1,RMIN,ICOLS)
0053 701          DO 110 I=1,ICOLS
0054 110          CNST=CNST+AMAX0(F1(I),1)
0055 602          CNST=(CNST/FLOAT(ICOLS))
0056          CNST = ALOG(CNST)

```

```

0057 C
0058 DO 9 I=1,523
0059 F1(I) = CNST
0060 F2(I) = CNST
0061 F3(I) = CNST
0062 9 CONTINUE
0063 C
0064 C CALCULATE FINAL VALUE FOR EACH STAGE
0065 DO 10 NSTG=2,N
0066 SUM(NSTG,1)=0.0
0067 SUM(NSTG,2)=0.0
0068 DO 11 I=1,3
0069 DO 11 J=1,3
0070 SUM(NSTG,1)=SUM(NSTG,1)+A(I,J,NSTG-1)
0071 11 SUM(NSTG,2)=SUM(NSTG,2)+B(I,J,NSTG-1)
0072 DEL=ABS(SUM(NSTG,2))
0073 IF(DEL.LT.1.0E-70)CALL EXEC(2,LU,16HFILTER UNSTABLE ,8)
0074 10 SUM(NSTG,1)=SUM(NSTG,1)/SUM(NSTG,2)
0075 C
0076 C CALCULATE INITIAL CONDITIONS FOR EACH STAGE
0077 SUM(1,2)=CNST
0078 DO 12 NSTG=2,N
0079 12 SUM(NSTG,2)=SUM(NSTG,1)*SUM(NSTG-1,2)
0080 C
0081 C INITIALIZE FILTER
0082 DO 14 I=1,523
0083 X3(I)=(SUM(2,2))
0084 X2(I)=(SUM(2,2))
0085 X1(I)=(SUM(2,2))
0086 IF (NSTAG .EQ. 1) GO TO 14
0087 G3(I) =( SUM(3,2))
0088 G2(I)=(SUM(3,2))
0089 G1(I)=(SUM(3,2))
0090 14 CONTINUE
0091 RMX=-1.0E38
0092 RMI= 1.0E38
0093 C
0094 C FILTER REVERSE
0095 CALL EXEC(2,LU,16HREVERSE FILTERIN,8)
0096 SCL = 1.0
0097 IERR=READL(8,IPIXL,JPIXL,F3)
0098 IF(IERR .LT. 0) GO TO 9999
0099 CALL BIAS(F3,RMIN,ICOLS)
0100 IERR=READL(7,IPIXL,JPIXL,F2)
0101 IF(IERR .LT. 0) GO TO 9999
0102 CALL BIAS(F2,RMIN,ICOLS)
0103 IERR=READL(6,IPIXL,JPIXL,F1)
0104 IF(IERR .LT. 0) GO TO 9999
0105 C

```

```

0106         LNCK = 1
0107         DO 300 NRO=-6,NROW - 1,3
0108         CALL BIAS(F1,RMIN,ICOLS)
0109         CALL HFILT(2,F1,F2,F3,X1,X2,X3,G1,NSTAG,ICOLS)
0110         IF(LNCK .LT. 7) GO TO 301
0111         LINE = IABS(NRO)
0112         CALL RITLN(LINE,IPIXL,JPIXL,X1,G1,NSTAG,2,LU,RMX,RMI,SCL)
0113 301      LNCK =LNCK +1
0114         LINE=IABS(NRO+1)
0115         IF(LINE .GT. NROW-1) GO TO 300
0116         IERR=READL(LINE,IPIXL,JPIXL,F3)
0117         IF(IERR .LT. 0) GO TO 9999
0118         CALL BIAS(F3,RMIN,ICOLS)
0119         CALL HFILT(2,F3,F1,F2,X3,X1,X2,G1,NSTAG,ICOLS)
0120         IF(LNCK .LT. 7) GO TO 302
0121         CALL RITLN(LINE,IPIXL,JPIXL,X3,G1,NSTAG,2,LU,RMX,RMI,SCL)
0122 302      LNCK =LNCK +1
0123         LINE=IABS(NRO+2)
0124         IF(LINE .GT. NROW-1) GO TO 300
0125         IERR=READL(LINE,IPIXL,JPIXL,F2)
0126         IF(IERR .LT. 0) GO TO 9999
0127         CALL BIAS(F2,RMIN,ICOLS)
0128         CALL HFILT(2,F2,F3,F1,X2,X3,X1,G1,NSTAG,ICOLS)
0129         IF(LNCK .LT. 7) GO TO 303
0130         IF(LINE .GT. NROW-1) GO TO 300
0131         CALL RITLN(LINE,IPIXL,JPIXL,X2,G1,NSTAG,2,LU,RMX,RMI,SCL)
0132 303      LNCK =LNCK +1
0133         LINE=IABS(NRO+3)
0134         IF(LINE .GT. NROW-1) GO TO 300
0135         IERR=READL(LINE,IPIXL,JPIXL,F1)
0136         IF(IERR .LT. 0) GO TO 9999
0137 300      CONTINUE
0138 C
0139 C REINITIALIZE FILTER
0140         CONST = (RMX-RMI)/2.
0141         DO 15 J=1,523
0142         F1(J) = CONST
0143         F2(J) = CONST
0144         F3(J) = CONST
0145 15      CONTINUE
0146 C
0147 C     FILTER FORWARD
0148 C
0149         CALL EXEC(2,LU,16HFORWARD FILTERIN,8)
0150 C
0151 C SCALE FOR LN(32766)
0152         SCL = 10.397147 /(RMX)
0153         RMI=0.1E38
0154         RMX=-0.1E38
0155         JPIXL=JPIXL-1
0156         LINE =NROW-9
0157         IERR=READL(LINE,IPIXL,JPIXL,F3(12))
0158         IF(IERR .LT. 0) GO TO 9999
0159         LINE=LINE+1
0160         IERR=READL(LINE,IPIXL,JPIXL,F2(12))
0161         IF(IERR .LT. 0) GO TO 9999
0162         LINE=LINE+1
0163         IERR=READL(LINE,IPIXL,JPIXL,F1(12))
0164         IF(IERR .LT. 0) GO TO 9999

```

```

0165 C
0166 LNCK =-6
0167 DO 400 NRO= -6,NROW - 1,3
0168 CALL HFILT(1,F1,F2,F3,X1,X2,X3,G1,NSTAG,ICOLS)
0169 IF(LNCK .LT. 0) GO TO 401
0170 CALL RITLN(LINE,IPIXL,JPIXL,X1,G1,NSTAG,1,LU,RMX,RMI,SCL)
0171 401 LNCK=LNCK+1
0172 LINE=(NROW-1)-IABS(NRO+1)
0173 IERR=READL(LINE,IPIXL,JPIXL,F3(12))
0174 IF(IERR .LT. 0) GO TO 9999
0175 CALL HFILT(1,F3,F1,F2,X3,X1,X2,G1,NSTAG,ICOLS)
0176 IF(LNCK .LT. 0) GO TO 402
0177 CALL RITLN(LINE,IPIXL,JPIXL,X3,G1,NSTAG,1,LU,RMX,RMI,SCL)
0178 402 LNCK =LNCK +1
0179 LINE=(NROW-1)-IABS(NRO+2)
0180 IF(LINE .LT. 0) GO TO 400
0181 IERR=READL(LINE,IPIXL,JPIXL,F2(12))
0182 IF(IERR .LT. 0) GO TO 9999
0183 CALL HFILT(1,F2,F3,F1,X2,X3,X1,G1,NSTAG,ICOLS)
0184 IF(LNCK .LT. 0) GO TO 403
0185 CALL RITLN(LINE,IPIXL,JPIXL,X2,G1,NSTAG,1,LU,RMX,RMI,SCL)
0186 403 LNCK =LNCK +1
0187 LINE=(NROW-1)-IABS(NRO+3)
0188 IF(LINE .LT.0) GO TO 400
0189 IERR=READL(LINE,IPIXL,JPIXL,F1(12))
0190 IF(IERR .LT. 0) GO TO 9999
0191 400 CONTINUE
0192 C
0193 51 CONTINUE
0194 CALL EXEC(2,LU,10HCOMPLETED ,5)
0195 C
0196 CALL CLSWF(NROW,ICOLS,RMX,RMI)
0197 C
0198 RMAX = RMX
0199 RMIN = RMI
0200 CALL PRN(IRTN)
0201 CALL EXEC(6)
0202 9999 CALL EXEC(2,LU,16HREAD FILE ERROR ,8)
0203 END
0204 SUBROUTINE HFILT(IFLAG,F1,F2,F3,X1,X2,X3,G1,NSTAG,ICOLS)
0205 DIMENSION F1(1),F2(1),F3(1),X1(1),X2(1),X3(1),A(1),B(1)
0206 COMMON /IBLK/IBUF(80)
0207 DIMENSION G1(1),G2(1),G3(1)
0208 C
0209 EQUIVALENCE (IBUF,A),(IBUF(41),B)
0210 C IFLAG =1 FOR FORWARD FILTERING, = 2 FOR REVERSE
0211 C
0212 C REVERSE FILTERING
0213 C
0214 IF(IFLAG .EQ. 1) GO TO 200
0215 DO 20 I=1,11
0216 L =ICOLS+12 - I
0217 J = ICOLS-12 + I
0218 F1(L) = F1(J)
0219 F2(L) = F2(J)
0220 20 F3(L) = F3(J)
0221 C

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```

0222      DO 10 M = ICOLS+9,1,-1
0223          J = M + 1
0224          K = M + 2
0225          X1(M) = A(1) * ALOG(F1(M))
0226      1      + A(2) * ALOG(F1(J))-B(2)*X1(J)
0227      1      + A(3) * ALOG(F1(K))-B(3)*X1(K)
0228      1      + A(4) * ALOG(F2(M))-B(4)*X2(M)
0229      1      + A(5) * ALOG(F2(J))-B(5) *X2(J)
0230      1      + A(6) * ALOG(F2(K))-B(6) *X2(K)
0231      1      + A(7) * ALOG(F3(M))-B(7)*X3(M)
0232      1      + A(8) * ALOG(F3(J))-B(8) *X3(J)
0233      1      + A(9) * ALOG(F3(K))- B(9)*X3(K)
0234      IF(NSTAG .EQ. 1) GO TO 10
0235          G1(M) = A(10) * X1(M)
0236      1      + A(11) * X1(J)-B(11)*G1(J)
0237      1      + A(12) * X1(K)-B(12)*G1(K)
0238      1      + A(13) * X2(M)-B(13)*G2(M)
0239      1      + A(14) * X2(J)-B(14) *G2(J)
0240      1      + A(15) * X2(K)-B(15) *G2(K)
0241      1      + A(16) * X3(M)-B(16)*G3(M)
0242      1      + A(17) * X3(J)-B(17) *G3(J)
0243      1      + A(18) * X3(K) - B(18)*G3(K)
0244      10      CONTINUE
0245          GO TO 400
0246      200      CONTINUE
0247      C
0248      C FORWARD FILTERING
0249      C
0250          DO 30 I=1,11
0251          L =12 - I
0252          J = 12 + I
0253          F1(L) = F1(J)
0254          F2(L) = F2(J)
0255      30      F3(L) = F3(J)
0256      C
0257          DO 40 M = 3,ICOLS+11
0258          J = M - 1
0259          K = M - 2
0260          X1(M) = A(1) * F1(M)
0261      1      + A(2) * F1(J)-B(2)*X1(J)
0262      1      + A(3) * F1(K)-B(3)*X1(K)
0263      1      + A(4) * F2(M)-B(4)*X2(M)
0264      1      + A(5) * F2(J)-B(5) *X2(J)
0265      1      + A(6) * F2(K)-B(6) *X2(K)
0266      1      + A(7) * F3(M)-B(7)*X3(M)
0267      1      + A(8) * F3(J)-B(8) *X3(J)
0268      1      + A(9) * F3(K) - B(9)*X3(K)
0269      IF(NSTAG .EQ. 1) GO TO 40
0270          G1(M) = A(10) * X1(M)
0271      1      + A(11) * X1(J)-B(11)*G1(J)
0272      1      + A(12) * X1(K)-B(12)*G1(K)
0273      1      + A(13) * X2(M)-B(13)*G2(M)
0274      1      + A(14) * X2(J)-B(14) *G2(J)
0275      1      + A(15) * X2(K)-B(15) *G2(K)
0276      1      + A(16) * X3(M)-B(16)*G3(M)
0277      1      + A(17) * X3(J)-B(17) *G3(J)
0278      1      + A(18) * X3(K) - B(18)*G3(K)
0279      40      CONTINUE
0280      400      CONTINUE
0281      RETURN
0282      END

```

```

0283 C
0284 C   COMMON BLOCK SUBPROGRAM
0285 C
0286     BLOCK DATA IBLK
0287     COMMON/IBLK/IBUF(80)
0288     END
0289     SUBROUTINE RITLN(LINE, IPIXL, JPIXL, X1, G1, NSTAG, IFLAG, LU, RMX, R
0290     1SCL)
0291     DIMENSION X1(1), G1(1), XX1(523)
0292     INTEGER RITEL
0293 C
0294 C IFLAG =1 FOR FORWARD  =2 FOR REVERSE
0295 C REV
0296     IF(NSTAG .EQ. 2) GO TO 12
0297     IF(IFLAG .EQ. 1) GO TO 11
0298     DO 10 M=1, JPIXL-IPIXL+1
0299     IF(X1(M) .GT. RMX) RMX=X1(M)
0300     IF(X1(M) .LT. RMI) RMI=X1(M)
0301 10  CONTINUE
0302     IERR=RITEL(LINE, IPIXL, JPIXL, X1)
0303     IF(IERR .LT. 0) GO TO 9999
0304     GO TO 12
0305 C
0306 11  CONTINUE
0307 C FORWARD
0308     DO 20 M=12, JPIXL-IPIXL+12
0309     X=SCL*(X1(M))
0310     IF(X .GT. 10.397147) X = 10.397177
0311     XX1(M) = EXP(X)
0312     IF(XX1(M) .GT. RMX) RMX=XX1(M)
0313     IF(XX1(M) .LT. RMI) RMI=XX1(M)
0314 20  CONTINUE
0315     IERR= RITEL(LINE, IPIXL, JPIXL, XX1(12))
0316     IF(IERR .LT. 0) GO TO 9999
0317 12  CONTINUE
0318     RETURN
0319 9999 CALL EXEC(2, LU, 16HWRITE FILE ERROR, 8)
0320     END
0321     SUBROUTINE BIAS(F1, RMIN, ICOLS)
0322     DIMENSION F1(1)
0323     DO 10 I=1, ICOLS + 11
0324     F1(I) = F1(I) - RMIN + 1.0
0325     IF(F1(I) .LT. 1.) F1(I) = 1.0
0326 10  CONTINUE
0327     RETURN
0328     END
0329 $

```



&SHOW T=00004 IS ON CRO022 USING 00005 BLKS R=0037

```

0001 FTN4
0002     PROGRAM SHOW
0003 C
0004     DIMENSION RDATA(512),IDATA(512),LU(5)
0005 C
0006     INTEGER READL
0007     EQUIVALENCE (RDATA,LU(2)),(LU(2),ILINE),(LU(3),IPIXL),
0008     1 (RDATA(2),RMAX),(RDATA(3),RMIN)
0009 C
0010 C GET INPUT PARAMETERS
0011 C
0012     CALL RMPAR(LU)
0013 C
0014 C GET SCALE
0015 C
0016     WRITE(LU,1)
0017 1     FORMAT("INPUT RANGE? _")
0018     READ(LU,*)RL,RH
0019 C
0020 C READ WORK FILE HEADER
0021 C
0022     IERR = READL(-1,0,511,RDATA)
0023     IF (IERR .LT. 0) GO TO 999
0024     NLINE = ILINE
0025     NPIXL = IPIXL
0026     PMAX = RMAX
0027     PMIN = RMIN
0028     DO 100 I=0,NLINE-1
0029     IF (READL(I,0,NPIXL-1,RDATA) .LT. 0) GO TO 999
0030     DO 90 J =1,NPIXL
0031     IDATA(J) = RL +((RH-RL)/(PMAX-PMIN))*(RDATA(J)-PMIN)
0032     IF (IDATA(J) .GT. 255) IDATA(J) = 255
0033     IF (IDATA(J) .LT. 0) IDATA(J) = 0
0034 90    CONTINUE
0035 C
0036     CALL WLINE(I,0,511,IDATA)
0037 100   CONTINUE
0038     CALL CLSWF(NLINE,NPIXL,PMAX,PMIN)
0039     CALL EXEC(6)
0040 999   WRITE(LU,2) IERR
0041 2     FORMAT("FILE ERROR",I7)
0042     END
0043 $

```

&FIRO T=00004 IS ON CRO0022 USING 00003 BLKS R=0023

```

0001 FTN4,L
0002 PROGRAM FIRO
0003 DIMENSION ILU(5),IBUF(80),A(3,3,2),H(5,5),NAME(3),IDCB(144)
0004 DIMENSION NAME1(3),NAME2(3)
0005 EQUIVALENCE (IBUF(1),A(1,1,1))
0006 DATA H/25*0./
0007 DATA IBUF/80*0/
0008 DATA NAME/2HCO,2HEF,2HFS/
0009 DATA NAME1/2HDP,2HLA,2HM /
0010 DATA NAME2/2HPL,2HST,2HV /
0011 C
0012 C GET LU
0013 CALL RMPAR(ILU)
0014 LU=ILU
0015 WRITE(LU,10)
0016 10 FORMAT(" ENTER NUMBER OF STAGES _")
0017 READ(LU,*) NSTG
0018 IBUF(40)=NSTG
0019 C
0020 WRITE(LU,11)
0021 11 FORMAT(" ENTER ALPHA VALUE _")
0022 READ(LU,*) ALPHA
0023 C
0024 H(1,1)=1.0
0025 DO 100 I=1,3
0026 DO 100 J=1,3
0027 CALL WINDO(ALPHA,I,J,WIN)
0028 A(I,J,NSTG)=WIN*H(I,J)
0029 100 CONTINUE
0030 CALL PURGE(IDCB,IERR,NAME,2HES)
0031 IF(IERR .LT. 0) WRITE(LU,999) IERR
0032 CALL CREAT(IDCB,IERR,NAME,2,3,2HES)
0033 IF(IERR .LT. 0) WRITE(LU,999) IERR
0034 CALL WRITF(IDCB,IERR,IBUF,80)
0035 CALL CLOSE(IDCB,IERR)
0036 C
0037 C SCHEDULE DISPLAY
0038 CALL EXEC(23,NAME1,LU,NSTG,0,0,0,IBUF,80)
0039 C
0040 WRITE(LU,40)
0041 40 FORMAT("//" ENTER DISPLAY DEVICE "/" 1. TV"/" 2. HP2648A")
0042 READ(LU,*) IDEV
0043 IF(IDEV .EQ. 2) GO TO 41
0044 CALL EXEC(23,NAME2)
0045 GO TO 42
0046 41 CONTINUE
0047 CALL HP48A(LU)
0048 42 CONTINUE
0049 999 FORMAT(" FILE ERROR ")
0050 STOP
0051 END

```

```

0052      SUBROUTINE HP48A(LU)
0053      DIMENSION IB(14),IA(4)
0054      INTEGER IDCB(144 ),BUFF( 4 ), NAME(3)
0055      DATA NAME/2HDA,2HTA,2H1 /
0056  C
0057      CALL OPEN(IDCB,IERR,NAME)
0058      IF (IERR .GE. 0) GO TO 30
0059      WRITE(LU,10) IERR
0060 10     FORMAT ("OPEN ERROR",F5.0)
0061      STOP
0062 30     CALL GRAFC(1,LU)
0063 20     CALL READI (IDCB,IERR,BUFF,4,ILOG)
0064      IF(ILOG .EQ. -1) GO TO 55
0065      IF (IERR .GE. 0) GOTO 40
0066      WRITE(LU,31) IERR
0067 31     FORMAT("READ ERROR",F5.0)
0068      GO TO 55
0069 40     CONTINUE
0070      CALL DVECT(BUFF,BUFF(2),BUFF(3),BUFF(4),LU)
0071 50     GO TO 20
0072 55     CALL EXEC(13,LU,ISTAT)
0073      ISTAT=IAND(ISTAT,140000B)
0074      IF(ISTAT.NE.0) GO TO 55
0075      CALL GRAFC(0,LU)
0076      CALL CLOSE(IDCB)
0077      RETURN
0078      END
0079      SUBROUTINE GRAFC(IFLAG,LU)
0080      INTEGER IESC
0081      IESC= 33B
0082  C
0083  C GRAPHICS OFF=0; GRAPHICS ON NOT=0
0084  C
0085      IF(IFLAG.EQ.0) GO TO 100
0086  C
0087  C GRAPHIC ON
0088  C
0089      WRITE(LU,10) IESC
0090 10     FORMAT(1R2,"*dC")
0091      WRITE(LU,12) IESC
0092 12     FORMAT(1R2,"*dF")
0093      WRITE(LU,14) IESC
0094 14     FORMAT(1R2,"*dA")
0095  C
0096      GO TO 200
0097  C
0098  C GRAPHICS OFF
0099  C
0100 100    WRITE(LU,30) IESC
0101 30     FORMAT(1R2,"*dd")
0102      WRITE(LU,40) IESC
0103 40     FORMAT(1R2,"*dE")
0104 200    RETURN
0105      END

```

```
0106      SUBROUTINE DVECT(IX1,IY1,IX2,IY2,LU)
0107 C
0108 C      SUBROUTINE DRAWS A LINE BETWEEN THE TWO POINTS (IX1,IY1)
0109 C          AND (IX2,IY2).  THE POINT (IX0,IY0) DEFINES THE
0110 C          THE ORIGIN.
0111 C
0112          IX0=0
0113          IY0=0
0114          XSCAL =356.0/1024.0
0115          YSCAL =XSCAL
0116          X1 = IX1*XSCAL + 0.5
0117          X2 = IX2*XSCAL + 0.5
0118          Y1 = IY1*YSCAL + 0.5
0119          Y2 = IY2*YSCAL + 0.5
0120          JX1 = X1 + IX0
0121          JX2 = X2 + IX0
0122          JY1 = Y1 + IY0
0123          JY2 = Y2 + IY0
0124          WRITE(LU,10) JX1,JY1,JX2,JY2
0125 10      FORMAT("pa",1I3,1H,,1I3,1H,,1I3,1H,,1I3,"Z")
0126          RETURN
0127          END
0128          ENDS$
0129 $
0130 $
```

&WINDO T=00004 IS ON CRO0022 USING 00003 BLKS R=0012

```

0001 FTN4
0002     SUBROUTINE WINDO(ALPHA,N,M,WIN)
0003     XN=SQRT(M**2 + N**2)
0004     BETA=ALPHA*SQRT(1.-XN)
0005     CALL BESIO(ALPHA,BIAA)
0006     CALL BESIO(BETA,BIBB)
0007     BETA1=ALPHA*SQRT(2)
0008     CALL BESIO(BETA1,BIB)
0009     ZMIN=BIB/BIAA
0010     WIN=(BIBB/BIAA-ZMIN)/(1.0-ZMIN)
0011     RETURN
0012     END
0013 $

```

&BESIO T=00004 IS ON CRO0022 USING 00002 BLKS R=0015

```

0001 FTN4
0002     SUBROUTINE BESIO(X,RIO)
0003     RIO=ABS(X)
0004     IF(RIO-3.75) 1,1,2
0005 1     Z=X*X*7.111111E-2
0006     RIO=((((4.5813E-3*Z+3.60768E-2)*Z+2.659732E-1)*Z+1.206749E0
0007     1089942E0)*Z+3.515623E0)*Z+1.
0008     RETURN
0009 2     Z=3.75/RIO
0010     RIO=EXP(RIO)/SQRT(RIO)*(((((((3.92377E-3*Z-1.647633E-2)*Z+2
0011     17E-2)*Z-2.057706E-2)*Z+9.16281E-3)*Z-1.57565E-3)*Z+2.25319E-
0012     2+1.328592E-2)*Z+3.989423E-1)
0013     RETURN
0014     END
0015     ENDS$

```

&BESJ T=00004 IS ON CRO0022 USING 00014 BLKS R=0129

```

0001 C
0002 C .....
0003 C
0004 C     SUBROUTINE BESJ
0005 C
0006 C     PURPOSE
0007 C         COMPUTE THE J BESSEL FUNCTION FOR A GIVEN ARGUMENT AND
0008 C
0009 C     USAGE
0010 C         CALL BESJ(X,N,BJ,D,IER)
0011 C
0012 C     DESCRIPTION OF PARAMETERS
0013 C         X -THE ARGUMENT OF THE J BESSEL FUNCTION DESIRED
0014 C         N -THE ORDER OF THE J BESSEL FUNCTION DESIRED
0015 C         BJ -THE RESULTANT J BESSEL FUNCTION
0016 C         D -REQUIRED ACCURACY
0017 C         IER-RESULTANT ERROR CODE WHERE,
0018 C             IER=0 NO ERROR
0019 C             IER=1 N IS NEGATIVE
0020 C             IER=2 X IS NEGATIVE OR ZERO
0021 C             IER=3 REQUIRED ACCURACY NOT OBTAINED
0022 C             IER=4 RANGE OF N COMPARED TO X NOT CORRECT (SEE R
0023 C
0024 C     REMARKS
0025 C         N MUST BE GREATER THAN OR EQUAL TO ZERO, BUT IT MUST B
0026 C         LESS THAN
0027 C             20+10*X-X** 2/3   FOR X LESS THAN OR EQUAL TO 15
0028 C             90+X/2           FOR X GREATER THAN 15
0029 C
0030 C     SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
0031 C         NONE
0032 C
0033 C     METHOD
0034 C         RECURRENCE RELATION TECHNIQUE DESCRIBED BY H. GOLDSTEI
0035 C         R.M. THALER, 'RECURRENCE TECHNIQUES FOR THE CALCULATION
0036 C         BESSEL FUNCTIONS', M.T.A.C., V.13, PP.102-108 AND I.A. ST
0037 C         AND M. ABRAMOWITZ, 'GENERATION OF BESSEL FUNCTIONS ON H
0038 C         SPEED COMPUTERS', M.T.A.C., V.11, 1957, PP.255-257
0039 C
0040 C .....
0041 C
0042 C     SUBROUTINE BESJ(X,N,BJ,D,IER)
0043 C
0044 C         BJ=.0
0045 C         IF(N)10,20,20
0046 10     IER=1
0047 C         RETURN
0048 20     IF(X)30,30,31
0049 30     IER=2
0050 C         RETURN
0051 31     IF(X-15.)32,32,34
0052 32     NTEST=20.+10.*X-(X**(2/3))
0053 C         GO TO 36
0054 34     NTEST=90.+X/2.
0055 36     IF(N-NTEST)40,38,38
0056 38     IER=4
0057 C         RETURN

```

```
0058 40 IER=0
0059     N1=N+1
0060     BPREV=0.
0061 C
0062 C COMPUTE STARTING VALUE OF M
0063 C
0064     IF(X-5.)50,60,60
0065 50 MA=X+6.
0066     GO TO 70
0067 60 MA=1.4*X+60./X
0068 70 MB=N+IFIX(X)/4+2
0069     MZERO=MAX0(MA,MB)
0070 C
0071 C SET UPPER LIMIT OF M
0072 C
0073     MMAX=NTEST
0074 100 DO 190 M=MZERO,MMAX,3
0075 C
0076 C SET F(M),F(M-1)
0077 C
0078     FM1=1.0E-28
0079     FM=.0
0080     ALPHA=.0
0081     IF(M-(M/2)*2)120,110,120
0082 110 JT=-1.
0083     GO TO 130
0084 120 JT=1.
0085 130 M2=M-2
0086     DO 160 K=1,M2
0087     MK=M-K
0088     BMK=2.*FLOAT(MK)*FM1/X-FM
0089     FM=FM1
0090     FM1=BMK
0091     IF(MK-N-1.)150,140,150
0092 140 BJ=BMK
0093 150 JT=-JT
0094     S=1+JT
0095 160 ALPHA=ALPHA+BMK*S
0096     BMK=2.*FM1/X-FM
0097     IF(N)180,170,180
0098 170 BJ=BMK
0099 180 ALPHA=ALPHA+BMK
0100     BJ=BJ/ALPHA
0101     IF(ABS(BJ-BPREV)-ABS(D*BJ))200,200,190
0102 190 BPREV=BJ
0103     IER=3
0104 200 RETURN
0105     END
0106 $
```

&BLDWF T=00004 IS ON CRO022 USING 00022 BLKS R=4113

```

0001 FTN4
0002     PROGRAM BLDWF
0003 C
0004 C
0005 C THIS PROGRAM IS USED IN CONJUNCTION WITH IMAGE PROCESSING
0006 C IT CREATES AND MAINTAINS AN IMAGE WORK FILE WITH PIXEL VALUES
0007 C STORED AS REAL NUMBERS TO PRESERVE PRECISION.
0008 C
0009 C
0010 C
0011 C
0012     DIMENSION IDCB1(272),IDCB2(1040),IDCB3(528),IMAGE(6),LU(5)
0013     DIMENSION IRTN(5),JNAME(3),IBUF(15),RDATA(512),IDATA(512),
0014     1 ISIZE(2)
0015 C
0016     EQUIVALENCE (ILINE,IRTN(4)),(IPIXL,IRTN(5)),(ILINE,RDATA),
0017     1(RDATA(2),RMAX),(RDATA(3),RMIN),(IBUF(12),ILOC),(IBUF(13),JN
0018     EQUIVALENCE (IBUF(7),NILINE),(IBUF(8),NPIXL),(IBUF(9),IPMIN),
0019     1 (IBUF(10),IPMAX),(ISIZE(2),JSIZE2)
0020 C
0021 C
0022 C
0023 C
0024 C GET INPUT PARAMETERS
0025 C
0026     CALL RMPAR(LU)
0027     IF (LU .LE. 0) LU = 1
0028 C
0029 C REUSE WORK FILE
0030 C
0031     WRITE(LU,7)
0032 7     FORMAT(//,"DO YOU WANT TO REUSE THE CURRENT WORK FILE? Y OR
0033     READ(LU,2) IANS
0034     IF(IANS .EQ. 1HY )GO TO 200
0035 C GET IMAGE NAME FROM USER
0036 C
0037     WRITE(LU,1)
0038 1     FORMAT("ENTER IMAGE NAME (12 CHARACTER)?_")
0039     READ(LU,2) IMAGE
0040 2     FORMAT(6A2)
0041 C
0042 C CHECK IF WORK FILE WANTED
0043 C
0044     IF (ICMPW(IMAGE,12H           ,6) .EQ. 0) GO TO 140
0045 C
0046 C OPEN DIRECTORY FILE
0047 C
0048 90    CALL OPEN(IDCB1,IERR,6HIMDIRC,1,2HIM,23,272)
0049     IF (IERR .LT. 0) GO TO 9999
0050 C

```



```

0051 C FIND IMAGE
0052 C
0053 100 CALL READF(IDCBI,IERR,IBUF,15,LEN)
0054 IF (IERR .LT. 0) GO TO 9999
0055 IF (LEN .EQ. -1) GO TO 9990
0056 C
0057 IF (ICMPW(IMAGE,IBUF,6) .NE. 0) GO TO 100
0058 C
0059 C IMAGE FOUND
0060 C
0061 C
0062 IF (ILOC .NE. 1) GO TO 9980
0063 C
0064 C IMAGE IS ON DISC
0065 C
0066 C CREATE WORK FILE
0067 C
0068 CALL OPEN(IDCBI,IERR,6HWF0000)
0069 IF (IERR .EQ. -6) GO TO 110
0070 IF (IERR .LT. 0) GO TO 9999
0071 C
0072 C ASK IF USER WANTS TO SAVE WORK FILE
0073 C
0074 WRITE(LU,6)
0075 6 FORMAT(" DO YOU WANT TO SAVE IMAGE IN CURRENT WORK FILE? ")
0076 READ(LU,2) IANS
0077 IF (IANS .EQ. 2HNO) GO TO 110
0078 C
0079 C SCHEDULE BUILD IMAGE PROGRAM
0080 C
0081 CALL CLOSE(IDCBI)
0082 CALL EXEC(23,6HBLDIM ,LU)
0083 C
0084 110 CALL PURGE(IDCBI,IERR,6HWF0000)
0085 IF (NPIXL .LT. 3) NPIXL = 3
0086 ISIZE = (2.0*FLOAT(NLINE+1)*FLOAT(NPIXL)+127.)/128.
0087 ISIZ2 = 2*NPIXL
0088 CALL CREAT(IDCBI,IERR,6HWF0000,ISIZE,2,0,0,1040)
0089 IF (IERR .LT. 0) GO TO 9999
0090 C
0091 C OPEN IMAGE DATA FILE
0092 C
0093 CALL OPEN(IDCBI,IERR,JNAME,1,2HIM,23,528)
0094 IF (IERR .LT. 0) GO TO 9999
0095 C
0096 C COPY DATA AND CONVERT TO REAL
0097 C
0098 C POSITION TO RECORD # 2
0099 C
0100 CALL WRITF(IDCBI,IERR,RDATA,1)
0101 C
0102 DO 120 I=1,NLINE
0103 CALL READF(IDCBI,IERR,IDATA,512,LEN)
0104 IF (IERR .LT. 0) GO TO 9999
0105 C
0106 DO 115 J=1,NPIXL
0107 115 RDATA(J) = IDATA(J)
0108 C
0109 CALL WRITF(IDCBI,IERR,RDATA)

```

```
0110      IF (IERR .LT. 0) GO TO 9999
0111 120  CONTINUE
0112 C
0113      RPMAX = IPMAX
0114      RPMIN = IPMIN
0115 C
0116 C CLOSE ALL IMAGE FILES
0117 C
0118 130  CALL CLOSE(IDCBI)
0119      CALL CLOSE(IDCBI)
0120 C
0121 C WRITE INFO IN WORK FILE RECORD 1
0122 C
0123      ILINE = NLINE
0124      IPIXL = NPIXL
0125      RMAX = RPMAX
0126      RMIN = RPMIN
0127      CALL WRITE(IDCBI,IERR,RDATA,6,1)
0128      IF (IERR .LT. 0) GO TO 9999
0129 C
0130      CALL CLOSE(IDCBI)
0131 C
0132 140  IRTN = 0
0133 200  CALL PRN(IRTN)
0134      CALL EXEC(6)
0135 C
0136 C ERRORS
0137 C
0138 C
0139 C IMAGE NOT ON DISC
0140 C
0141 9980 WRITE(LU,4)
0142 4    FORMAT(" IMAGE NOT ON DISC!")
0143      IRTN = -100
0144      GO TO 200
0145 C
0146 C IMAGE NOT FOUND
0147 C
0148 9990 WRITE(LU,3)
0149 3    FORMAT(" IMAGE NOT FOUND!")
0150      IRTN = -101
0151      GO TO 200
0152 C
0153 C FILE ERROR
0154 C
0155 9999 WRITE(LU,5) IERR
0156 5    FORMAT("FILE ERROR =",I6)
0157 201  IF(IERR.EQ.-8) CALL CLOSE(IDCBI,IERR)
0158      IRTN = -103
0159      GO TO 200
0160      END
0161 $
```

```

0001 FTN4
0002     INTEGER FUNCTION SSCROL(IDCBB, IDIRC, NLINE, IFRST, ILAST, RMAX, RMI
0003 C
0004 C THIS SUBROUTINE IS USED TO SCROLL AN IMAGE ON THE GMR-27
0005 C
0006 C     IDCBB = OPENED DATA CONTROL BLOCK FOR THE IMAGE
0007 C     IDIRC = DIRECTION TO SCROLL (-N= BACK N LINES N= FORWARD N LI
0008 C     NLINE = # LINES IN IMAGE
0009 C     IFRST = LOWEST IMAGE LINE DISPLAYED
0010 C     ILAST = HIGHEST IMAGE LINE DISPLAYED
0011 C
0012 C
0013     DIMENSION IDCBB(144), IDATA(512)
0014 C
0015     INTEGER SSCROL
0016 C
0017     DATA IUP, IDOWN/34060B, 34040B/
0018 C
0019 C CHECK IF NO WORK NECESSARY
0020 C
0021     IF (IDIRC .EQ. 0) RETURN
0022 C
0023     IF (IDIRC .GT. 0) GO TO 200
0024 C
0025 C SCROLL IMAGE UP
0026 C
0027     DO 100 I=-1, IDIRC, -1
0028     IF (IFRST .LE. 0) RETURN
0029     CALL READF(IDCBB, SSCROL, IDATA, 512, LEN, IFRST)
0030 C
0031     DO 110 J=1, LEN
0032     IDATA(J) = (255. / (RMAX-RMIN)) * (IDATA(J) - RMIN)
0033     IF (IDATA(J) .LT. 0) IDATA(J) = 0
0034     IF (IDATA(J) .GT. 255) IDATA(J) = 255
0035 110 CONTINUE
0036 C
0037     IF (SSCROL .LT. 0) RETURN
0038     CALL DRIVR(2, IUP, 1)
0039     CALL WLINE(0, 0, LEN-1, IDATA)
0040     IFRST = IFRST-1
0041 100 ILAST = ILAST-1
0042     RETURN
0043 C
0044 C SCROLL IMAGE DOWN
0045 C
0046 200 DO 210 I=1, IDIRC
0047     IF (ILAST .GE. NLINE-1) RETURN
0048     CALL READF(IDCBB, SSCROL, IDATA, 512, LEN, ILAST+1)
0049 C
0050     DO 220 J=1, LEN
0051     IDATA(J) = (255. / (RMAX-RMIN)) * (IDATA(J) - RMIN)
0052     IF (IDATA(J) .LT. 0) IDATA(J) = 0
0053     IF (IDATA(J) .GT. 255) IDATA(J) = 255
0054 220 CONTINUE
0055 C
0056     IF (SSCROL .LT. 0) RETURN
0057     CALL DRIVR(2, IDOWN, 1)
0058     CALL WLINE(255, 0, LEN-1, IDATA)
0059     ILAST = ILAST+1
0060 210 IFRST = IFRST+1
0061 C
0062     RETURN
0063     END

```

SWLINE T=00004 IS ON CRO0022 USING 00005 BLKS R=0036

```
0001  FTN4,L
0002      SUBROUTINE WLINE(LINE,IPIX,JPIX,IDATA)
0003  C
0004  C  THIS SUBROUTINE WRITES A DESIGNATED LINE TO THE GMR-27
0005  C
0006  C      LINE = LINE NUMBER
0007  C      IPIX = STARTING PIXEL
0008  C      JPIX = ENDING PIXEL
0009  C      IDATA = BUFFER CONTAINING IMAGE DATA FOR LINE
0010  C
0011  C
0012      DIMENSION IDATA(512),INIT(6)
0013  C
0014      EQUIVALENCE (LLA,INIT(2)),(LEA,INIT(3)),(LEB,INIT(4))
0015  C
0016      DATA INIT/100377B,64000B,44000B,50000B,24041B,26002B/
0017  C
0018  C  COMPUTE DIRECTION
0019  C
0020      IDIRC = 1
0021      IF (IPIX .GT. JPIX) IDIRC = -1
0022  C
0023  C  SET UP TO WRITE LINE
0024  C
0025      LLA = 64000B + IAND(LINE,377B)
0026      LEA = 44000B + IAND(IPIX,777B)
0027      LEB = 50000B + IDIRC + 512
0028      CALL DRIVR(2,INIT,6)
0029  C
0030  C  WRITE LINE
0031  C
0032      NUM = IDIRC*(JPIX-IPIX)+1
0033      CALL DRIVR(2,IDATA,NUM)
0034  C
0035      RETURN
0036      END
0037  $
```

&DRIVR T=00004 IS ON CRO0022 USING 00012 BLKS R=0241

```

0001 ASMB,R,L,C
0002     NAM DRIVR,6
0003     ENT DRIVR
0004     EXT .ENTR,$LIBR,$LIBX
0005 *
0006 *
0007 OPCOD BSS 1
0008 BUFR BSS 1
0009 LEN BSS 1
0010 *
0011 DRIVR NOP           ENTRY
0012     JSB .ENTR       GET
0013     DEF OPCOD       PARAMETERS.
0014     LDA LEN,I       GET # WORDS
0015     CMA,INA         NEGATE
0016     STA CNT         & SAVE.
0017     SSA,RSS        IF NOT NEGATIVE
0018     JMP EXIT       EXIT
0019 *
0020     JSB $LIBR       TURN OFF
0021     NOP             INTERRUPTS.
0022     LDA OPCOD,I    CHECK REQUEST
0023     SLA,ELA        IF READ
0024     JMP D.2       GO PROCESS
0025 *
0026 * WRITE REQUEST
0027 *
0028     SSA,RSS        IF DMA NOT REQUIRED
0029     JMP D.1       GO DO PROGRAMMED I O
0030 *
0031 * DMA OUTPUT
0032 *
0033     LDA CW1        GET CONTROL WORD 1
0034     OTA DMA2       USE CHANNEL 2
0035     CLC 3B        PREPARE TO SEND ADDRESS
0036     LDA BUFR
0037     OTA 3B
0038     STC 3B        PREPARE TO SEND COUNT
0039     LDA CNT
0040     OTA 3B
0041     LDA BUFR,I
0042     OTA SC
0043     STC SC,C      START DEVICE
0044     STC DMA2,C    START DMA
0045     SFS DMA2
0046     JMP *-1
0047     CLF DMA2
0048     JMP EXIT+1
0049 *
0050 *

```

```

0051 D.1 LDA BUFR,I GET DATA WORD
0052     OTA SC      OUTPUT IT.
0053     STC SC,C   TURN ON DEVICE
0054     SFS SC     WAIT 'TIL
0055     JMP *-1    DONE
0056     ISZ BUFR   BUMP BUFFER ADDRESS
0057     ISZ CNT    LAST WORD?
0058     JMP D.1    NO GO BACK.
0059     JMP EXIT   GO EXIT
0060 *
0061 * READ ENTRY
0062 *
0063 D.2 SSA        SKIP IF SPECIAL
0064     JMP D.3    MODE
0065     LDA SPDB   SET UP
0066     OTA SC
0067     STC SC,C   FOR
0068     SFS SC
0069     JMP *-1    READ.
0070 D.3 LDA RDPD   GET READ DATA CODE
0071     OTA SC
0072     STC SC,C   START DEVICE
0073     SFS SC     WAIT 'TIL
0074     JMP *-1
0075 D.4 LDA RDPD
0076     OTA SC
0077     STC SC,C
0078     SFS SC
0079     JMP *-1
0080     LLA SC     DONE. GET WORD.
0081     STA BUFR,I STUFF IN BUFFER
0082     ISZ BUFR   BUMP BUFFER
0083     ISZ CNT    DONE?
0084     JMP D.4    NO GO BACK.
0085 *
0086 EXIT CLC SC     TURN OFF DEVICE
0087     JSB $LIBX  RESTORE RTE AND
0088     DEF DRVR   RETURN
0089 *
0090 *
0091 *
0092 A EQU 0
0093 *
0094 SC EQU 22B
0095 RDPD OCT 160000
0096 SPDB OCT 120400
0097 CNT BSS 1
0098 CW1 OCT 120022 * HAVE TO CHANGE WITH SELECT CODE
0099 DMA2 EQU 7
0100     END

```

&FDIGI T=00004 IS ON CRO0022 USING 00018 BLKS R=0132

```

0001 FTN4,L
0002     SUBROUTINE ROTAE(U,V,MN,LU)
0003     COMPLEX P(10),Q(10),QQ,PP
0004     DIMENSION U(3,3,2),V(3,3,2)
0005     COMMON/WORK/AMAG(10),A(3,3),B(3,3)
0006     WRITE(LU,100)
0007 100   FORMAT(" SELECT FILTER  "/", " 1. BUTTERWORTH  "/",
0008     1   " 2. CHEBYSHEV  "/", " 3. LINEAR PHASE  "/)
0009     READ(LU,*) ITYPE
0010     WRITE(LU,110)
0011 110   FORMAT(" ENTER THE NUMBER OF FILTER STAGES  "/)
0012     READ(LU,*) NSTG
0013     WRITE(LU,120)
0014 120   FORMAT(" ENTER RELATIVE CUTOFF FREQUENCY FOR LOWPASS  "/)
0015     READ(LU,*) WR
0016     WRITE(LU,140)
0017 140   FORMAT(" ARE ALL ZEROS LOCATED AT INFINITY  "/",
0018     1   " 1 = YES  "/", " 2 = NO  "/)
0019     READ(LU,*) IFLAG
0020     WRITE(LU,151)
0021 151   FORMAT(" ENTER RIPPLE FACTOR  "/)
0022     READ(LU,*) ELP
0023     C
0024     C     IF(ITYPE.EQ.1) CALL BUTTER
0025     C     IF(ITYPE.EQ.2) CALL CHEB1(NSTG,WR,P,AMAG,ELP)
0026     C     IF(ITYPE.EQ.3) CALL LINEAR PHASE
0027     C
0028     DO 10 J=1,NSTG
0029     30   WRITE(LU,130) J
0030 130   FORMAT(" ENTER ROTATION ANGLE IN NEG. DEGREES FOR STAGE #
0031     1,I2/)
0032     READ(LU,*) THETA
0033     C
0034     PMAG = AMAG(J)
0035     Q(J) = CMPLX(-1.,0.)
0036     QQ = Q(J)
0037     PP = P(J)
0038     CALL SROTT(A,B,PMAG,PP,QQ,IFLAG,THETA)
0039     DO 1111 I=1,3
0040     DO 1111 K=1,3
0041     U(I,K,J) = A(I,K)
0042 1111   V(I,K,J) = B(I,K)
0043     WRITE(LU,40) P(J),AMAG(J)
0044     40   FORMAT(1X,1(" P=",1E15.5," +J",1E15.5,/)," PMAG= ",E15.5
0045     10   CONTINUE
0046     MN = NSTG + 1
0047     WRITE(1,1112) U
0048     WRITE(1,1112) V
0049 1112   FORMAT(3E15.4)
0050     RETURN
0051     END

```

```
0052      SUBROUTINE CHEB1(N,WR,P,AMAG,ELP)
0053      DIMENSION AMAG(N)
0054      COMPLEX P(N),PN
0055      PI=3.1415927
0056      E=1.0/ELP
0057      SINHIV=ALOG(E+SQRT(E**2+1.0))
0058      ALP=(-1.0*SINHIV)/FLOAT(N)
0059      IF(WR.EQ.1.0) GO TO 30
0060      X=0.5*WR*PI
0061      IF(COS(X).EQ.0.0) GOTO 30
0062      XTAN=SIN(X)/COS(X)
0063      KK=1
0064      NTWO=4*N
0065      XX=1.0/FLOAT(NTWO)
0066      DO 20 I=1,NTWO
0067      GAMMA=(2*I-1)*PI*XX
0068      C1=(EXP( ALP)-EXP(-ALP))/2.
0069      C2=SIN(GAMMA)
0070      C3=(EXP( ALP)+EXP(-ALP))/2.
0071      C4=COS(GAMMA)
0072      XR=C1*C2
0073      XI=C3*C4
0074      PN=XTAN*CMPLX(XR,XI)
0075      IF(REAL(PN).GT.0.0) GO TO 20
0076      IF(AIMAG(PN).LT.0.0) GO TO 20
0077      P(KK)=PN
0078      AMAG(KK)=CABS(PN)**2
0079 20     KK=KK+1
0080      GO TO 34
0081 30     WRITE(LU,33)
0082 33     FORMAT("      CUTOFF FREQ. CAN NOT = 1.0 "/)
0083 34     RETURN
0084      END
```



```

0085     SUBROUTINE  SROTT(A,B,PMAG,PP,QQ,IFLAG,THETA)
0086     DIMENSION A(3,3),B(3,3)
0087     COMPLEX PP,QQ
0088     ADJ=0.999
0089     X=THETA*0.0174533
0090     C1=COS(X)**2
0091     C2=-2.0*COS(X)*SIN(X)
0092     C3=SIN(X)**2
0093     C7=-2.0*REAL(PP)*COS(X)
0094     C8=2.0*REAL(PP)*SIN(X)
0095     C9=CABS(PP)**2
0096     B(1,1)=C1+C2+C3+C7+C8+C9
0097     B(1,2)=2.0*(C1-C3+C7+C9)*ADJ
0098     B(1,3)=(C1-C2+C3+C7-C8+C9)*ADJ**2
0099     B(2,1)=2.0*(C3-C1+C8+C9)*ADJ
0100     B(2,2)=4.0*(C9-C1-C3)*ADJ**2
0101     B(2,3)=2.0*(C3-C1-C8+C9)*ADJ**3
0102     B(3,1)=(C1-C2+C3-C7+C8+C9)*ADJ**2
0103     B(3,2)=2.0*(C1-C3-C7+C9)*ADJ**3
0104     B(3,3)=(C1+C2+C3-C7-C8+C9)*ADJ**4
0105     IF(IFLAG.EQ.1) GO TO 10
0106     C4=-2.0*REAL(QQ)*COS(X)
0107     C5=2.0*REAL(QQ)*SIN(X)
0108     C6=CABS(QQ)**2
0109     A(1,1)=C1+C2+C3+C4+C5+C6
0110     A(1,2)=2.0*(C1-C3+C4+C6)
0111     A(1,3)=C1-C2+C3+C4-C5+C6
0112     A(2,1)=2.0*(C3-C1+C5+C6)
0113     A(2,2)=4.0*(C6-C1-C3)
0114     A(2,3)=2.0*(C3-C1-C5+C6)
0115     A(3,1)=C1-C2+C3-C4+C5+C6
0116     A(3,2)=2.0*(C1-C3-C4+C5+C6)
0117     A(3,3)=C1+C2+C3-C4-C5+C6
0118     GO TO 20
0119 10    A(1,1)=1.0
0120     A(1,2)=2.0
0121     A(1,3)=1.0
0122     A(2,1)=2.0
0123     A(2,2)=4.0
0124     A(2,3)=2.0
0125     A(3,1)=1.0
0126     A(3,2)=2.0
0127     A(3,3)=1.0
0128 20    CONTINUE
0129     SCAL = 1./B(1,1)
0130     DO 30 I=1,3
0131     DO 30 K=1,3
0132         B(I,K)=( B(I,K)*SCAL)
0133         A(I,K)=(A(I,K)*SCAL*PMAG)
0134 30    CONTINUE
0135     RETURN
0136     END
0137 $
0138 $

```

&STABI T=00004 IS ON CRO0022 USING 00070 BLKS R=0668

```

0001 FTN4,L
0002     PROGRAM STABI
0003 C
0004 C THIS PROGRAM EVALUATES THE FILTER STABILITY CHARACTERISTICS
0005 C
0006 C
0007     COMMON/WORK/WO(130)
0008 C     INTEGER BUFF
0009     DIMENSION IBUF(80),ILU(5),IRTN(5)
0010     DIMENSION V(3,3,2),U(3,3,2)
0011     EQUIVALENCE (IBUF(1),U(1,1,1)),(IBUF(41),V(1,1,1))
0012 C
0013     CALL RMPAR(ILU)
0014     LU=ILU(1)
0015     MN=ILU(2) + 1
0016 C
0017 C
0018 C GET FILTER COEFF'S
0019     CALL EXEC(14,1,IBUF,80)
0020 C
0021 C
0022     CALL STABT(V,MN,IRTC,LU)
0023     IRTN = IRTC
0024 C
0025     CALL PRIN(IRTN)
0026     END
0027     SUBROUTINE STABT(V,MN,IRTC,LU)
0028 C     SUBROUTINE CHECKS STABILITY OF SYSTEM EQUATION-
0029 C      $Y(M,N)=A*Y(M-1,N)+B*Y(M,N-1)$ 
0030 C
0031 C     C---COEFFICIENT MATRIX OF DENOMINATOR OF ZW-TRANSFORM OF SYS
0032 C     IMPULSE FUNCTION
0033 C
0034     LOGICAL ISTAB
0035     DIMENSION V(3,3,2)
0036     DIMENSION C(5,5),A(25,25),B(25,25),S(25,25),EVR(25),EVI(25)
0037     COMMON/WORK/IERR(25)
0038     MDIM=25
0039     N=2*(MN-1)+1
0040     M=N**2
0041     IF(MN.EQ.3) GO TO 5
0042 C
0043 C     PUT COEFFICIENTS IN STABILITY ARRAY
0044 C
0045     DO 6 I=1,3
0046     DO 6 J=1,3
0047     6 C(I,J)=V(I,J,1)
0048     GO TO 13
0049     5 DO 10 I=1,5
0050     DO 10 J=1,5
0051     DO 10 K=1,3
0052     DO 10 L=1,3
0053     IK=I-K+1
0054     JL=J-L+1
0055     IF((IK .LE. 0) .OR. (IK .GT. 3)) GO TO 10
0056     IF((JL .LE. 0) .OR. (JL .GT. 3)) GO TO 10
0057     C(I,J)=C(I,J)+V(IK,JL,1)*V(K,L,2)
0058     10 CONTINUE

```

```

0059 C
0060 13 CONTINUE
0061 C WRITE(LU,11)
0062 11 FORMAT(20H0 COEFFICIENT MATRIX,/)
0063 C DO 21 I=1,N
0064 C 21 WRITE(LU,12) (C(I,J),J=1,N),N
0065 12 FORMAT(1H ,5F15.6)
0066 C
0067 C FORM A AND B MATRICES
0068 C
0069 DO 22 I=1,M
0070 DO 22 J=1,M
0071 A(I,J)=0.0
0072 B(I,J)=0.0
0073 22 S(I,J)=0.0
0074 NNOW=N-1
0075 DO 23 J=1,N
0076 DO 23 I=1,NNOW
0077 K=I+(J-1)*N
0078 IF(J.EQ.1) GO TO 24
0079 24 A(1,K)=-C(I+1,J)
0080 IF(J.GT.1) A(1,K)=-0.5*C(I+1,J)
0081 IF(J.GT.1) A(K+1,K)=0.5
0082 IF(J.EQ.1) A(K+1,K)=1.0
0083 23 CONTINUE
0084 DO 25 J=1,NNOW
0085 DO 25 I=1,N
0086 K=I+(J-1)*N
0087 KN=K+N
0088 IF(I.EQ.1) GO TO 26
0089 26 B(1,K)=-C(I,J+1)
0090 IF(I.GT.1) B(1,K)=-0.5*C(I,J+1)
0091 IF(I.GT.1) B(KN,K)=0.5
0092 IF(I.EQ.1) B(KN,K)=1.0
0093 25 CONTINUE
0094 C
0095 C
0096 C FIND EIGENVALUES OF A AND B
0097 C
0098 DO 27 I=1,M
0099 DO 27 J=1,M
0100 27 S(I,J)=A(I,J)
0101 CALL RNAN(MDIM,M,S,EVR,EVI,IERR)
0102 WRITE(LU,71)
0103 71 FORMAT(/,10X,19HEIGEN VALUES OF (A))
0104 C
0105 TEST=1.0
0106 IONE=0
0107 C
0108 CALL PNTEV(EVR,EVI,M,MDIM,TEST,IONE,ISTAB,IERR,LU)
0109 IF(ISTAB) GOTO 405
0110 400 FORMAT(" FILTER IS UNSTABLE!"/)
0111 401 FORMAT(" FILTER IS STABLE"/)
0112 C
0113 DO 94 I=1,M
0114 DO 94 J=1,M
0115 94 S(I,J)=0.0
0116 DO 28 I=1,M
0117 DO 28 J=1,M
0118 28 S(I,J)=B(I,J)

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0119      CALL RNAN(MDIM,M,S,EVR,EVI,IERR)
0120      WRITE(LU,72)
0121      72 FORMAT(/,10X,19HEIGEN VALUES OF (B))
0122      CALL PNTEV(EVR,EVI,M,MDIM,TEST,IONE,ISTAB,IERR,LU)
0123      IF(ISTAB) GOTO 405
0124      C
0125      C      FIND EIGENVALUES OF A+B
0126      C
0127      DO 29 I=1,M
0128      DO 29 J=1,M
0129      29 S(I,J)=A(I,J)+B(I,J)
0130
0131      CALL RNAN(MDIM,M,S,EVR,EVI,IERR)
0132      WRITE(LU,73)
0133      73 FORMAT(/,10X,21HEIGEN VALUES OF (A+B))
0134      CALL PNTEV(EVR,EVI,M,MDIM,TEST,IONE,ISTAB,IERR,LU)
0135      405 IF(ISTAB) WRITE(LU,400)
0136      IF(ISTAB) GO TO 404
0137      WRITE(LU,401)
0138      404 IRTCD = 0
0139      GO TO 500
0140      C
0141      C      FIND EIGENVALUES OF A*S
0142      C
0143      DO 30 I=1,M
0144      DO 30 J=1,M
0145      30 S(I,J)=0.0
0146      DO 31 I=1,N
0147      DO 31 J=1,N
0148      K=J+(I-1)*N
0149      L=I+(J-1)*N
0150      31 S(K,L)=1.0
0151      CALL MLTMX(A,S,M,MDIM)
0152      CALL RNAN(MDIM,M,S,EVR,EVI,IERR)
0153      WRITE(LU,74)
0154      74 FORMAT(/,10X,21HEIGEN VALUES OF (A*S))
0155      C
0156      IONE=1
0157      TEST=0.5
0158      C
0159      ICNT=0
0160      CALL PNTEV(EVR,EVI,M,MDIM,TEST,IONE,ISTAB,IERR,LU)
0161      IF(ISTAB) ICNT=1
0162      DO 230 I=1,M
0163      DO 230 J=1,M
0164      230 S(I,J)=0.0
0165      DO 231 I=1,N
0166      DO 231 J=1,N
0167      K=J+(I-1)*N
0168      L=I+(J-1)*N
0169      231 S(K,L)=1.0
0170      CALL MLTMX(B,S,M,MDIM)
0171      CALL RNAN(MDIM,M,S,EVR,EVI,IERR)
0172      WRITE(LU,75)
0173      75 FORMAT(/,10X,21HEIGEN VALUES OF (B*S))
0174      CALL PNTEV(EVR,EVI,M,MDIM,TEST,IONE,ISTAB,IERR,LU)
0175      IF(ISTAB) ICNT=ICNT+1
0176      IF(ICNT.EQ.2) WRITE(LU,401)

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C177 C
0178 C   FIND EIGENVALUES OF ABS(A)+ABS(B)
0179 C
0180     DO 33 I=1,M
0181     DO 33 J=1,M
0182   33 S(I,J)=ABS(A(I,J))+ABS(B(I,J))
0183     CALL RNAN(MDIM,M,S,EVR,EVI,IERR)
0184     WRITE(LU,76)
0185   76 FORMAT(/,10X,29HEIGEN VALUES OF ABS(A)+ABS(B))
0186 C
0187     TEST=1.0
0188 C
0189     CALL PNTEV(EVR,EVI,M,MDIM,TEST,IONE,ISTAB,IERR,LU)
0190     IF(ISTAB) WRITE(LU,401)
0191 C
0192 C   FIND EIGENVALUES OF A*B
0193 C
0194     CALL MLTMX(A,B,M,MDIM)
0195     CALL RNAN(MDIM,M,S,EVR,EVI,IERR)
0196     WRITE(LU,77)
0197   77 FORMAT(/,10X,21HEIGEN VALUES OF (A*B))
0198     CALL PNTEV(EVR,EVI,M,MDIM,TEST,IONE,ISTAB,IERR,LU)
0199     IF(ISTAB) WRITE(LU,401)
0200     GO TO 501
0201   500     IF(ISTAB) IRTCD = 1000
0202   501     RETURN
0203     END
0204     SUBROUTINE PNTEV(EVR,EVI,M,MDIM,TEST,IONE,ISTAB,IERR,LU)
0205     LOGICAL ISTAB
0206     DIMENSION EVR(MDIM),EVI(MDIM),IERR(MDIM)
0207 C
0208     ISTAB=.FALSE.
0209     D=1.0E-20
0210     RMX=0.0
0211     DO 20 I=1,M
0212     R=EVR(I)**2+EVI(I)**2
0213     R=SQRT(R)
0214     RMX=AMAX1(RMX,R)
0215     IF(R.LT.D) GO TO 20
0216     IF(IERR(I).LT.0) WRITE(LU,93) I,IERR(I)
0217   20 CONTINUE
0218     WRITE(LU,30) RMX
0219 C
0220     IF(IONE.EQ.0.AND.RMX.GE.TEST) ISTAB=.TRUE.
0221     IF(IONE.EQ.1.AND.RMX.LE.TEST) ISTAB=.TRUE.
0222   10 FORMAT(1H ,E14.7,4X,2H+J,E14.7)
0223   11 FORMAT(13H ABS(LMDA) = ,E14.7)
0224   30 FORMAT(19H SPECTRAL RADIUS = ,E14.7/)
0225   93 FORMAT(/,10X,"IERR(",I2,") = ",I2/)
0226     RETURN
0227     END
0228     SUBROUTINE RNAN(N,M,S,EVR,EVI,IERR)
0229 C   SUBROUTINE WAS WRITTEN TO CALL HSBG AND ATEIG IBM SCIENTIFIC
0230 C   SUBROUTINES TO CALCULATE THE EIGENVALUES OF A REAL MATR
0231 C   M----ORDER OF THE MATRIX S
0232 C   N----SIZE OF FIRST DIMENSION ASSIGNED TO THE ARRAY S IN THE
0233 C   CALLING PROGRAM

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0234 C
0235 DIMENSION S(25,25),EVR(25),EVI(25)
0236 COMMON/WORK/IANA(25)
0237 CALL HSBG(M,S,N)
0238 CALL ATEIG(M,S,EVR,EVI,IANA,N)
0239 RETURN
0240 END
0241 C SUBROUTINE ATEIG
0242 C PURPOSE
0243 C COMPUTE THE EIGENVALUES OF A REAL ALMOST TRIANGULAR MA
0244 C
0245 C USAGE
0246 C CALL ATEIG(M,A,RR,RI,IANA,IA)
0247 C
0248 C DESCRIPTION OF THE PARAMETERS
0249 C M ORDER OF THE MATRIX
0250 C A THE INPUT MATRIX, M BY M
0251 C RR VECTOR CONTAINING THE REAL PARTS OF THE EIGENVA
0252 C ON RETURN
0253 C RI VECTOR CONTAINING THE IMAGINARY PARTS OF THE EI
0254 C VALUES ON RETURN
0255 C IANA VECTOR WHOSE DIMENSION MUST BE GREATER THAN OR
0256 C TO M, CONTAINING ON RETURN INDICATIONS ABOUT TH
0257 C THE EIGENVALUES APPEARED (SEE MATH. DESCRIPTION
0258 C IA SIZE OF THE FIRST DIMENSION ASSIGNED TO THE ARR
0259 C IN THE CALLING PROGRAM WHEN THE MATRIX IS IN DO
0260 C SUBSCRIPTED DATA STORAGE MODE.
0261 C IA=M WHEN THE MATRIX IS IN SSP VECTOR STORAGE M
0262 C
0263 C REMARKS
0264 C THE ORIGINAL MATRIX IS DESTROYED
0265 C THE DIMENSION OF RR AND RI MUST BE GREATER OR EQUAL TO
0266 C
0267 C SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
0268 C NONE
0269 C
0270 C METHOD
0271 C QR DOUBLE ITERATION
0272 C
0273 C REFERENCES
0274 C J.G.F. FRANCIS - THE QR TRANSFORMATION---THE COMPUTER
0275 C JOURNAL, VOL. 4, NO. 3, OCTOBER 1961, VOL 4, NO. 4, J
0276 C 1962. J. H. WILKINSON - THE ALGEBRAIC EIGENVALUE PROB
0277 C CLARENDON PRESS, OXFORD, 1965.
0278 C
0279 C .....
0280 C
0281 C SUBROUTINE ATEIG(M,A,RR,RI,IANA,IA)
0282 C DIMENSION A(1),RR(1),RI(1),PRR(2),PRI(2),IANA(1)
0283 C INTEGER P,P1,Q
0284 C
0285 C E7=1.0E-8
0286 C E6=1.0E-6
0287 C E10=1.0E-10
0288 C DELTA=0.5
0289 C MAXIT=30

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```

0290 C
0291 C      INITIALIZATION
0292 C
0293      N=M
0294      20 N1=N-1
0295      IN=N1*IA
0296      NN=IN+N
0297      IF(N1) 30,1300,30
0298      30 NP=N+1
0299 C
0300 C      ITERATION COUNTER
0301 C
0302      IT=0
0303 C
0304 C      ROOTS OF THE 2ND ORDER MAIN SUBMATRIX AT THE PREVIOUS
0305 C      ITERATION
0306 C
0307      DO 40 I=1,2
0308      PRR(I)=0.0
0309      40 PRI(I)=0.0
0310 C
0311 C      LAST TWO SUBDIAGONAL ELEMENTS AT THE PREVIOUS ITERATION
0312 C
0313      PAN=0.0
0314      PAN1=0.0
0315 C
0316 C      ORIGIN SHIFT
0317 C
0318      R=0.0
0319      S=0.0
0320 C
0321 C      ROOTS OF THE LOWER MAIN 2 BY 2 SUBMATRIX
0322 C
0323      N2=N1-1
0324      NN1=IN-IA
0325      NN1=IN1+N
0326      N1N=IN+N1
0327      N1N1=IN1+N1
0328      60 T=A(N1N1)-A(NN)
0329      U=T*T
0330      V=4.0*A(N1N)*A(NN1)
0331      IF(ABS(V)-U*E7) 100,100,65
0332      65 T=U+V
0333      IF(ABS(T)-AMAX1(U,ABS(V))*E6) 67,67,68
0334      67 T=0.0
0335      68 U=(A(N1N1)+A(NN))/2.0
0336      V=SQRT(ABS(T))/2.0
0337      IF(T)140,70,70
0338      70 IF(U) 80,75,75
0339      75 RR(N1)=U+V
0340      RR(N)=U-V
0341      GO TO 130
0342      80 RR(N1)=U-V
0343      RR(N)=U+V
0344      GO TO 130
0345      100 IF(T)120,110,110
0346      110 RR(N1)=A(N1N1)
0347      RR(N)=A(NN)
0348      GO TO 130

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0349 120 RR(N1)=A(NN)
0350 RR(N)=A(N1N1)
0351 130 RI(N)=0.0
0352 RI(N1)=0.0
0353 GO TO 160
0354 140 RR(N1) = U
0355 RR(N)=U
0356 RI(N1)=V
0357 RI(N)=-V
0358 160 IF(N2)1280,1280,180
0359 C
0360 C TESTS OF CONVERGENCE
0361 C
0362 180 N1N2=N1N1-LA
0363 RMOD=RR(N1)*RR(N1)+RI(N1)*RI(N1)
0364 EPS=E10*SQRT(RMOD)
0365 IF(ABS(A(N1N2))-EPS)1280,1280,240
0366 240 IF(ABS(A(NN1))-E10*ABS(A(NN))) 1300,1300,250
0367 250 IF(ABS(PAN1-A(N1N2))-ABS(A(N1N2))*E6) 1240,1240,260
0368 260 IF(ABS(PAN-A(NN1))-ABS(A(NN1))*E6)1240,1240,300
0369 300 IF(IT-MAXIT) 320,1240,1240
0370 C
0371 C COMPUTE THE SHIFT
0372 C
0373 320 J=1
0374 DO 360 I = 1,2
0375 K=NP-I
0376 IF(ABS(RR(K)-PRR(I))+ABS(RI(K)-PRI(I))-DELTA*(ABS(RR(K))
0377 1 ABS(RI(K)))) 340,360,360
0378 340 J=J+I
0379 360 CONTINUE
0380 GO TO (440,460,460,480),J
0381 440 R=0.0
0382 S=0.0
0383 GO TO 500
0384 460 J=N+2-J
0385 R=RR(J)*RR(J)
0386 S=RR(J)+RR(J)
0387 GO TO 500
0388 480 R=RR(N)*RR(N1)-RI(N)*RI(N1)
0389 S=RR(N)+RR(N1)
0390 C
0391 C SAVE THE LAST TWO SUBDIAGONAL TERMS AND THE ROOTS OF THE
0392 C SUBMATRIX BEFORE ITERATION
0393 C
0394 500 PAN=A(NN1)
0395 PAN1=A(N1N2)
0396 DO 520 I=1,2
0397 K=NP-I
0398 PRR(I)=RR(K)
0399 520 PRI(I)=RI(K)
0400 C
0401 C SEARCH FOR A PARTITION OF THE MATRIX, DEFINED BY P AND Q
0402 C
0403 P=N2
0404 IF (N-3)600,600,525
0405 525 IPI=N1N2
0406 DO 580 J=2,N2
0407 IPI=IPI-LA-1
0408 IF(ABS(A(IPI))-EPS) 600,600,530
0409 530 IPIP=IPI+LA

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0410      IPIP2=IPIP+IA
0411      D=A(IPIP)*(A(IPIP)-S)+A(IPIP2)*A(IPIP+1)+R
0412      IF(D)540,560,540
0413      540 IF(ABS(A(IPI)*A(IPIP+1))*(ABS(A(IPIP)+A(IPIP2+1)-S)+ABS(A(IP
0414      1 )) -ABS(D)*EPS) 620,620,560
0415      560 P=N1-J
0416      580 CONTINUE
0417      600 Q=P
0418      GO TO 680
0419      620 P1=P-1
0420      Q=P1
0421      IF (P1-1) 680,680,650
0422      650 DO 660 I=2, P1
0423      IPI=IPI-IA-1
0424      IF(ABS(A(IPI))-EPS)680,680,660
0425      660 Q=Q-1
0426      C
0427      C      QR DOUBLE ITERATION
0428      C
0429      680 II=(P-1)*IA+P
0430      DO 1220 I=P,N1
0431      III=II-IA
0432      IIP=II+IA
0433      IF(I-P)720,700,720
0434      700 IPI=II+1
0435      IPIP=IIP+1
0436      C
0437      C      INITIALIZATION OF THE TRANSFORMATION
0438      C
0439      G1=A(II)*(A(II)-S)+A(IIP)*A(IPI)+R
0440      G2=A(IPI)*(A(IPIP)+A(II)-S)
0441      G3=A(IPI)*A(IPIP+1)
0442      A(IPI+1)=0.0
0443      GO TO 780
0444      720 G1=A(III)
0445      G2=A(III+1)
0446      IF(I-N2)740,740,760
0447      740 G3=A(III+2)
0448      GO TO 780
0449      760 G3=0.0
0450      780 CAP=SQRT(G1*G1+G2*G2+G3*G3)
0451      IF(CAP)800,860,800
0452      800 IF(G1)820,840,840
0453      820 CAP=-CAP
0454      840 T=G1+CAP
0455      PSI1=G2/T
0456      PSI2=G3/T
0457      ALPHA=2.0/(1.0+PSI1*PSI1+PSI2*PSI2)
0458      GO TO 880
0459      860 ALPHA=2.0
0460      PSI1=0.0
0461      PSI2=0.0
0462      880 IF(I-Q)900,960,900
0463      900 IF(I-P)920,940,920
0464      920 A(III)=-CAP
0465      GO TO 960
0466      940 A(III)=-A(III)
0467      C
0468      C      ROW OPERATION
0469      C

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0470      960 IJ=II
0471      DO 1040 J=I,N
0472      T=PSI1*A(IJ+1)
0473      IF(I-N1)980,1000,1000
0474      980 IP2J=IJ+2
0475      T=T+PSI2*A(IP2J)
0476      1000 ETA=ALPHA*(T+A(IJ))
0477      A(IJ)=A(IJ)-ETA
0478      A(IJ+1)=A(IJ+1)-PSI1*ETA
0479      IF(I-N1)1020,1040,1040
0480      1020 A(IP2J)=A(IP2J)-PSI2*ETA
0481      1040 IJ=IJ+IA
0482      C
0483      C          COLUMN OPERATION
0484      C
0485      IF(I-N1)1080,1060,1060
0486      1060 K=N
0487      GO TO 1100
0488      1080 K=I+2
0489      1100 IP=IIP-I
0490      DO 1180 J=Q,K
0491      JIP=IP+J
0492      JI=JIP-IA
0493      T=PSI1*A(JIP)
0494      IF(I-N1)1120,1140,1140
0495      1120 JIP2=JIP+IA
0496      T=T+PSI2*A(JIP2)
0497      1140 ETA=ALPHA*(T+A(JI))
0498      A(JI)=A(JI)-ETA
0499      A(JIP)=A(JIP)-ETA*PSI1
0500      IF(I-N1)1160,1180,1180
0501      1160 A(JIP2)=A(JIP2)-ETA*PSI2
0502      1180 CONTINUE
0503      IF(I-N2)1200,1220,1220
0504      1200 JI=II+3
0505      JIP=JI+IA
0506      JIP2=JIP+IA
0507      ETA=ALPHA*PSI2*A(JIP2)
0508      A(JI)=-ETA
0509      A(JIP)=-ETA*PSI1
0510      A(JIP2)=A(JIP2)-ETA*PSI2
0511      1220 II=IIP+1
0512      IT=IT+1
0513      GO TO 60
0514      C
0515      C          END OF ITERATION
0516      C
0517      1240 IF(ABS(A(NN1))-ABS(A(N1N2))) 1300,1280,1280
0518      C
0519      C          TWO EIGENVALUES HAVE BEEN FOUND
0520      C
0521      1280 IANA(N)=0
0522      IANA(N1)=2
0523      N=N2
0524      IF(N2)1400,1400,20
0525      C
0526      C          ONE EIGENVALUE HAS BEEN FOUND
0527      C

```

```

0528 1300 RR(N)=A(NN)
0529      RI(N)=0.0
0530      IANA(N)=1
0531      IF(N1)1400,1400,1320
0532 1320 N=N1
0533      GO TO 20
0534 1400 RETURN
0535      END
0536 C      SUBROUTINE HSBG
0537 C
0538 C      PURPOSE
0539 C          TO REDUCE A REAL MATRIX INTO UPPER ALMOST TRIANGULAR F
0540 C
0541 C      USAGE
0542 C          CALL HSBG(N,A,IA)
0543 C
0544 C      DESCRIPTION OF THE PARAMETERS
0545 C          N      ORDER OF THE MATRIX
0546 C          A      THE INPUT MATRIX, N BY N
0547 C          IA     SIZE OF THE FIRST DIMENSION ASSIGNED TO THE ARR
0548 C          A IN THE CALLING PROGRAM WHEN THE MATRIX IS IN
0549 C          DOUBLE SUBSCRIBED DATA STORAGE MODE. IA=N WHE
0550 C          THE MATRIX IS IN SSP VECTOR STORAGE MODE.
0551 C
0552 C      REMARKS
0553 C          THE HESSENBERG FORM REPLACES THE ORIGINAL MATRIX IN TH
0554 C          ARRAY A.
0555 C
0556 C      SUBROUTINES AND FUNCTION SUBPROGRAMS REQUIRED
0557 C          NONE
0558 C
0559 C      METHOD
0560 C          SIMILARITY TRANSFORMATIONS USING ELEMENTARY ELIMINATIO
0561 C          MATRICES, WITH PARTIAL PIVOTING.
0562 C
0563 C      REFERENCES
0564 C          J.H. WILKINSON - THE ALGEBRAIC EIGENVALUE PROBLEM -
0565 C          CLARENDON PRESS, OXFORD, 1965.
0566 C
0567 C          .....
0568 C
0569 C      SUBROUTINE HSBG(N,A,IA)
0570 C          DIMENSION A(1)
0571 C          DOUBLE PRECISION S
0572 C          L=N
0573 C          NIA=L*IA
0574 C          LIA=NIA-IA
0575 C
0576 C          L IS THE ROW INDEX OF THE ELIMINATION
0577 C
0578 C          20 IF(L-3) 360,40,40
0579 C          40 LIA=LIA-IA
0580 C          L1=L-1
0581 C          L2=L1-1
0582 C
0583 C          SEARCH FOR THE PIVOTAL ELEMENT IN THE LTH ROW
0584 C

```

```

0585      ISUB=LIA+L
0586      IPIV=ISUB-IA
0587      PIV=ABS(A(IPIV))
0588      IF(L-3) 90,90,50
0589      50 M=IPIV-IA
0590      DO 80 I=L,M,IA
0591      T=ABS(A(I))
0592      IF(T-PIV) 80,80,60
0593      60 IPIV=I
0594      PIV=T
0595      80 CONTINUE
0596      90 IF(PIV) 100,320,100
0597      100 IF(PIV-ABS(A(ISUB))) 180,180,120
0598      C
0599      C      INTERCHANGE THE COLUMNS
0600      C
0601      120 M=IPIV-L
0602      DO 140 I=1,L
0603      J=M+I
0604      T=A(J)
0605      K=LIA+I
0606      A(J)=A(K)
0607      140 A(K)=T
0608      C
0609      C      INTERCHANGE THE ROWS
0610      C
0611      M=L2-M/IA
0612      DO 160 I=L1,NIA,IA
0613      T=A(I)
0614      J=I-M
0615      A(I)=A(J)
0616      160 A(J)=T
0617      C
0618      C      TERMS OF THE ELEMENTARY TRANSFORMATION
0619      C
0620      180 DO 200 I=L,LIA,IA
0621      200 A(I)=A(I)/A(ISUB)
0622      C
0623      C      RIGHT TRANSFORMATION
0624      C
0625      J=-IA
0626      DO 240 I=1,L2
0627      J=J+IA
0628      LJ=L+J
0629      DO 220 K=1,L1
0630      KJ=K+J
0631      KL=K+LIA
0632      220 A(KJ)=A(KJ)-A(LJ)*A(KL)
0633      240 CONTINUE
0634      C
0635      C      LEFT TRANSFORMATION
0636      C

```

```

0637      K=-IA
0638      DO 300 I=1,M
0639      K=K+IA
0640      LK=K+L1
0641      S=A(LK)
0642      LJ=L-IA
0643      DO 280 J=1,L2
0644      JK=K+J
0645      LJ=LJ+IA
0646      280 S=S+A(LJ)*A(JK)*1.0D0
0647      300 A(LK)=S
0648      C
0649      C          SET THE LOWER PART OF THE MATRIX TO ZERO
0650      C
0651      DO 310 I=L,LIA,IA
0652      310 A(I)=0.0
0653      320 L=L1
0654      GO TO 20
0655      360 RETURN
0656      END
0657      SUBROUTINE MLTMX(A,S,M,MDIM)
0658      C
0659      C          SUBROUTINE OBTAINS THE MATRIX MULTIPLICATION OF A AND S AND
0660      C          THE RESULTS IN S.
0661      C
0662      DIMENSION S(MDIM,MDIM),A(MDIM,MDIM)
0663      COMMON/WORK/T(25,25)
0664      DO 10 I=1,M
0665      DO 10 J=1,M
0666      C=0.0
0667      DO 20 K=1,M
0668      20 C=C+A(I,K)*S(K,J)
0669      10 T(I,J)=C
0670      DO 50 I=1,M
0671      DO 50 J=1,M
0672      50 S(I,J)=T(I,J)
0673      RETURN
0674      END
0675      BLOCK DATA WORK
0676      COMMON /WORK/ WO(625)
0677      END
0678      $

```

&FILTR T=00004 IS ON CRO0022 USING 00004 BLKS R=0022

```

0001 FTN4,L
0002     PROGRAM FILTR
0003 C WRITTEN BY E. E. SHERROD
0004 C
0005 C THIS PROGRAM SELECTS THE FILTERING TYPE
0006 C
0007     DIMENSION ILU(5),NAME1(3),NAME2(3),IRTN(5),NAME3(3)
0008     EQUIVALENCE(IRTN(2),RMAX),(IRTN(4),RMIN)
0009     DATA NAME1/2HLF,2HLT,2HR /
0010     DATA NAME2/2HHF,2HLT,2HR /
0011     DATA NAME3/2HSH,2HOW,2H  /
0012 C
0013 C GET LU
0014 C
0015     CALL RMPAR(ILU)
0016     IPIXL =0
0017     JPIXL =511
0018     LU=ILU(1)
0019     WRITE(LU,10)
0020 10  FORMAT(" SELECT FILTERING TYPE "/" 1. LINEAR "/" 2. HOMOMORP
0021     READ(LU,*) IFITR
0022     IF(IFITR .EQ. 1) CALL EXEC(23,NAME1,LU,IPIXL,JPIXL,0,0)
0023     CALL RMPAR(IRTN)
0024     IF(IFITR .EQ. 1) GO TO 30)
0025     IF(IFITR .EQ. 2) CALL EXEC(23,NAME2,LU,IPIXL,JPIXL,0,0)
0026     CALL RMPAR(IRTN)
0027 30  WRITE(LU,40) RMAX,RMIN
0028 40  FORMAT(" MAX PIXEL = ",F12.2,10X," MIN PIXEL = ",1F12.2)
0029     IX=RMAX-RMIN +0.5
0030     WRITE(LU,50) IX
0031 50  FORMAT(" NUMBER OF GRAY LEVELS = ",I5)
0032     IF(IFITR .EQ. 2)CALL EXEC(23,NAME3,LU,0,511,0,0)
0033     STOP
0034     END
0035     END$

```

SNOISE T=00004 IS ON CRO0022 USING 00010 BLKS R=0097

```

0001 FTN4,L
0002     PROGRAM NOISE
0003 C
0004     DIMENSION RDATA(512),GNOISE(512),LU(5),IU(5),IBUF(40)
0005 C
0006     INTEGER READL
0007     EQUIVALENCE (RDATA,LU(2)),(LU(2),ILINE),(LU(3),IPIXL),
0008     1 (RDATA(2),RMAX),(RDATA(3),RMIN)
0009     DATA RDATA/512*0.0/
0010 C
0011 C GET INPUT PARAMETERS
0012 C
0013     CALL RMPAR(LU)
0014 C
0015 C SCHEDULE BUILD WORK FILE PROGRAM
0016     CALL EXEC(23,6HBLDWF ,IU)
0017 C
0018 C READ WORK FILE HEADER
0019 C
0020     IERR = READL(-1,0,511,RDATA)
0021     IF (IERR .LT. 0) GO TO 999
0022     NLINE=ILINE
0023     NPIXL=IPIXL
0024     PMAX=RMAX
0025     PMIN=RMIN
0026 C
0027 C GET NOISE INFO
0028     WRITE(LU,13)
0029 13     FORMAT(" ENTER NOISE MEAN VALUE _")
0030     READ(LU,*) AM
0031     WRITE(LU,14)
0032 14     FORMAT(" ENTER STANDARD DEVIATION VALUE _")
0033     READ(LU,*) S
0034     IF(S .LE. 0) GO TO 1000
0035 C
0036     DO 100 I=0,NLINE-1
0037     IF (READL(I,0,NPIXL-1,RDATA) .LT. 0) GO TO 999
0038 C
0039 C GET NOISE
0040 C
0041     DO 101 JA=0,51
0042     CALL EXEC(1,8,IBUF,40)
0043     JJ=10*JA
0044     CALL CODE (80)
0045     READ( IBUF,12) (GNOISE(K+JJ),K=1,10 )
0046 12     FORMAT(10F8.5)
0047 101    CONTINUE

```

```
0048 C
0049     DO 90 J =1,NPIXL
0050     RDATA(J)= RDATA(J) +GNOISE(J)*S+AM
0051 600   FORMAT( F20.3)
0052 90    CONTINUE
0053 C
0054 C WRITE SIGNAL + NOISE TO WORK FILE
0055 C
0056     IF(RITEL(I,0,NPIXL-1,RDATA) .LT. 0) GO TO 999
0057     IF(MOD(I,64) .EQ. 0) WRITE(LU,4)
0058 4     FORMAT(" **** ADDING NOISE ****")
0059 100   CONTINUE
0060 C
0061 1000  CALL CLSWF(NLINE,NPIXL,PMAX,PMIN)
0062     CALL CLOSE(IDCBI)
0063     CALL EXEC(6)
0064 999   WRITE(LU,2) IERR
0065 2     FORMAT("FILE ERROR",I7)
0066     END
0067 $
0068 $
```



APPENDIX E

# Stability Analysis of Two-Dimensional Digital Recursive Filters

WINNER E. ALEXANDER, MEMBER, IEEE, AND STEVEN A. PRUESS

**Abstract**—A new approach to the stability problem for the two-dimensional digital recursive filter is presented. The bivariate difference equation representation of the two-dimensional recursive digital filter is converted to a multiple-input-multiple-output (MIMO) system similar to the state-space representation of the one-dimensional digital recursive filter. In this paper, a pseudo-state representation is used and three coefficient matrices are obtained. A general theorem for stability of two-dimensional digital recursive filters is derived and a very useful theorem is presented which expresses sufficient requirements for instability in terms of the spectral radii of these matrices.

## I. INTRODUCTION

A two-dimensional digital recursive filter can be characterized by the bivariate difference equation

$$g(m, n) = \sum_{J=0}^L \sum_{K=0}^L a_{JK} f(m-J, n-K) - \sum_{\substack{J=0 \\ J+K>0}}^L \sum_{K=0}^L b_{JK} g(m-J, n-K) \quad (1)$$

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where the coefficients  $a_{JK}$  and  $b_{JK}$  are constants [1] and some of these constants may be zero. In general, this form does not require that the corresponding numerator and denominator polynomials for the two-dimensional  $Z$  transform of the transfer function both be of degree  $L$ . Zeros may be added to form the structure as given in (1). There are two major problems to consider in the design of recursive filters for two-dimensional signal processing: synthesis and stability. The synthesis problem consists of determining the filter coefficients so that the required frequency response is realized. If the resulting filter is to be useful, it must be bounded-input-bounded-output (BIBO) stable. In this paper the stability problem is considered and a new approach to stability analysis for the two-dimensional digital recursive filter is presented.

For the one-dimensional case, there are essentially two methods of determining necessary and sufficient conditions for stability of digital filters: examining regions of analyticity for the characteristic polynomial and by direct evaluation of the characteristics of the impulse response [2]–[4]. In particular, if the system corresponding to the digital filter is represented by a state-space equation, then one can determine stability from the coefficient matrices in the state-space equation [4]. For the two-dimensional case, generalizations of the first method involves examining regions of analyticity for bivariate polynomials [5].

This paper attempts to generalize the second method for the two-dimensional case, i.e., to establish stability by computing the spectral radii of coefficient matrices with real coefficients. The spectral radius of a matrix is the magnitude of the largest magnitude eigenvalue of that matrix.

## II. PSEUDO-STATE-SPACE REPRESENTATION

A pseudo-state-space representation of (1) is used in the development of the stability analysis theorems in this paper. This representation is very similar to a state-space representation of the two-dimensional digital recursive filter as defined by Fornasini and Marchesini [6]. The two can be made to be equivalent by letting one of the coefficient matrices in the Fornasini and Marchesini model be the null matrix. The pseudo-state-space representation of the two-dimensional recursive filter is given by

$$\left. \begin{aligned} G_{m,n} &= \bar{B}_1 G_{m,n-1} + \bar{B}_2 G_{m-1,n} + \bar{A} F_{m,n} \\ g(m,n) &= DG_{m,n} \end{aligned} \right\} \quad (2)$$

$G_{m,n}$  is a column vector such that its elements are the outputs,  $g(m-J, n-K)$  where  $0 < J < L$  and  $0 < K < L$ . Note that  $G_{m,n}$  contains all of the outputs that are represented in (1) including  $g(m,n)$ . Similarly,  $F_{m,n}$  is a column vector such that its elements are the inputs,  $f(m-J, n-K)$  where  $0 < J < L$  and  $0 < K < L$ .

We can then define matrices  $\bar{B}_1$ ,  $\bar{B}_2$ , and  $\bar{A}$  [7] such that (1) and (2) are equivalent. The matrices  $\bar{B}_1$ ,  $\bar{B}_2$ , and  $\bar{A}$  are all of order  $(L+1)^2$  by  $(L+1)^2$ . The vector  $D$  is a row vector with  $L+1$  elements.

The ordering of the outputs in  $G_{m,n}$  and of the inputs in  $F_{m,n}$  is not unique. However, the ordering does affect the relative position of the elements of the corresponding coefficient matrices. Also note that  $G_{m-1,n}$  and  $G_{m,n-1}$  have elements in common. Where this occurs, the corresponding elements of  $\bar{B}_1$  and  $\bar{B}_2$  can be divided such that the magnitude of each is no larger than that of the corresponding  $b_{JK}$  or one as appropriate. It is convenient to consistently divide equally and choose a particular ordering scheme for  $G_{m,n}$ .

### Example

Consider the two-dimensional digital recursive filter with bivariate difference equation given by

$$\begin{aligned} g(m,n) &= a_{00}f(m,n) + a_{10}f(m-1,n) + a_{01}f(m,n-1) \\ &\quad + a_{11}f(m-1,n-1) - b_{10}g(m-1,n) \\ &\quad - b_{01}g(m,n-1) - b_{11}g(m-1,n-1). \end{aligned} \quad (3)$$

For this example, with  $G_{m,n}$  and  $F_{m,n}$  given in transpose form, we have

$$G_{m,n} = [g(m,n) \quad g(m-1,n) \quad g(m,n-1) \quad g(m-1,n-1)]^T \quad (4)$$

$$F_{m,n} = [f(m,n) \quad f(m-1,n) \quad f(m,n-1) \quad f(m-1,n-1)]^T \quad (5)$$

$$\bar{B}_1 = \begin{bmatrix} -b_{10} & 0 & -\frac{1}{2}b_{11} & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & \frac{1}{2} & 0 \end{bmatrix}$$

$$\bar{B}_2 = \begin{bmatrix} -b_{01} & -\frac{1}{2}b_{11} & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & \frac{1}{2} & 0 & 0 \end{bmatrix} \quad (6)$$

$$\bar{A} = \begin{bmatrix} a_{00} & a_{10} & a_{01} & a_{11} \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (7)$$

## III. STABILITY ANALYSIS

The stability analysis herein will be confined to the linear shift invariant (LSI) two-dimensional discrete system. Such a system is BIBO stable if and only if the discrete impulse response of the system,  $h(m,n)$ , is absolutely summable, i.e.,  $\sum_{m,n=-\infty}^{\infty} |h(m,n)| < \infty$  [1].

Let us define the particular vector  $H_{JK}$  as that input vector which represents a single unit sample at the  $(J,K)$  position of the two-dimensional data array with all other inputs samples zero. Let us further define the initial condition vectors,  $G_{J-1,K}$  and  $G_{J,K-1}$ , as null vectors. Then for  $m=J$  and  $n=K$ , (2) reduces to

$$\begin{aligned} G_{J,K} &= \bar{A} H_{J,K} \\ h(J,K) &= DG_{J,K}. \end{aligned} \quad (8)$$

Define the term  $C(\bar{B}_1^J, \bar{B}_2^K)$  as the sum of all product terms involving all permutations of  $\bar{B}_1$  as a factor  $J$  times and  $\bar{B}_2$  as a factor  $K$  times. It is helpful to note that if  $\bar{B}_1$  and  $\bar{B}_2$  commute, then

$$C(\bar{B}_1^J, \bar{B}_2^K) = \binom{J+K}{K} \bar{B}_1^J \bar{B}_2^K = (J+K)! \bar{B}_1^J \bar{B}_2^K / (J!K!).$$

In general, the matrices do not commute. Therefore, we give as an example  $C(\bar{B}_1^2, \bar{B}_2^1) = \bar{B}_1 \bar{B}_2 + \bar{B}_1 \bar{B}_2 \bar{B}_1 + \bar{B}_2 \bar{B}_1^2$ .

### Lemma 1

The contribution to the output vector,  $G_{m,n}$ , for a single input vector,  $H_{J,K}$ , which corresponds to a unit impulse at the  $(J,K)$  position where  $J < m$  and  $K < n$ , is given by  $G_{m,n} = C(\bar{B}_1^{m-J}, \bar{B}_2^{n-K}) \bar{A} H_{J,K}$  for the LSI system represented by (2).

The proof of Lemma 1 is given in the Appendix. Lemma 1 provides a convenient means of finding the output of the two-dimensional digital recursive filter for all values of  $m$  and  $n$  when the filter is excited by a single input at any point in the array. Since the filter is linear and shift invariant, we can use the principle of superposition to find the output for any particular sequence of inputs. Thus the unit impulse response of the filter is given

by

$$G_{m,n} = C(\bar{B}_1^m, \bar{B}_2^n) \bar{A} H_{0,0} \quad (9)$$

$$h(m,n) = DG_{m,n} = DC(\bar{B}_1^m, \bar{B}_2^n) \bar{A} H_{0,0} \quad (10)$$

### Lemma 2

Given the discrete LSI system represented by (2) for which the corresponding transfer function has mutually prime numerator and denominator polynomials. If the contribution to the output vector  $G_{m,n}$  by a bounded sequence of input vectors  $F_{J,K}$  where  $0 < J < m$  and  $0 < K < n$  can be expressed by  $G_{m,n} = \bar{Q}^m \bar{A} F_{J,K}$  or  $G_{m,n} = \bar{Q}^n \bar{A} F_{J,K}$ , then the system is unstable if  $\rho(\bar{Q})$ , the spectral radius of  $\bar{Q}$ , is greater than one. The proof of Lemma 2 is given in the Appendix.

### Theorem 1

The discrete LSI system represented by (2) is stable if and only if for at least one matrix norm

$$S = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} \|DC(\bar{B}_1^m, \bar{B}_2^n) \bar{A} H_{0,0}\| < \infty. \quad (11)$$

Theorem 1 follows directly from (10) and the requirement that the discrete impulse response be absolutely summable. Since  $h(m,n)$  is a scalar, its matrix norm is equivalent to its absolute value and the proof of Theorem 1 is obvious.

### Theorem 2

The discrete LSI system represented by (2) and for which the numerator and denominator polynomials of the corresponding transfer function are mutually prime is unstable if any one of the spectral radii  $\rho(\bar{B}_1)$ ,  $\rho(\bar{B}_2)$ , or  $\rho(\bar{B}_1 + \bar{B}_2)$  is greater than or equal to one. The proof of Theorem 2 is given in the Appendix.

In the practical application of two-dimensional digital recursive filters, any filter with  $\rho(\bar{B}_1)$ ,  $\rho(\bar{B}_2)$ , or  $\rho(\bar{B}_1 + \bar{B}_2)$  equal to one can be considered to be unstable and should be avoided [8]. Goodman [5] has shown by clever examples that two-dimensional filters with nonessential singularities of the second kind on the unit bidisc may be stable. Such a filter may have  $\rho(\bar{B}_1)$ ,  $\rho(\bar{B}_2)$ , or  $\rho(\bar{B}_1 + \bar{B}_2)$  equal to one. However, roundoff errors and coefficient truncation would prevent satisfactory performance by such a filter for most applications.

## IV. CONCLUSIONS

In this paper, a new approach to stability analysis of two-dimensional digital recursive filters has been presented. Theorems have been presented which can be used in the practical application of this approach. The authors feel that it is important to note that no known unstable filter has been found in this research effort which did not have either  $\rho(\bar{B}_1)$ ,  $\rho(\bar{B}_2)$ , or  $\rho(\bar{B}_1 + \bar{B}_2)$  greater than or equal to one. One is led to conjecture that for a large class of filters, any filter in the class is stable if the subject spectral radii are all less than one. However, the proof of this is not trivial.

Several other theorems relating to sufficient conditions for stability have been found [7]. However, it has been shown that these constraints are too restrictive for general use. That is, useful stable filters can be found which do not satisfy the corresponding sufficient conditions for stability.

Computer algorithms are readily available to find the spectral radius of a matrix with real coefficients. Thus Theorem 2 presents a convenient and easily implemented technique to assess the stability of two-dimensional digital recursive filters.

## APPENDIX

In this Appendix, the proofs for Lemmas 1 and 2 and Theorem 2 are given. When a specific norm is not given, any convenient norm is appropriate.

### A1. Proof of Lemma 1

We proceed with a proof by induction. If we use (2) and (8) to obtain  $G_{J+1,K}$ ,  $G_{J,K+1}$ , and  $G_{J+1,K+1}$  for input vector  $H_{J,K}$  and if all initial condition vectors are null vectors, we obtain

$$\left. \begin{aligned} G_{J+1,K} &= \bar{B}_1 G_{J,K} = \bar{B}_1 \bar{A} H_{J,K} \\ G_{J,K+1} &= \bar{B}_2 G_{J,K} = \bar{B}_2 \bar{A} H_{J,K} \\ G_{J+1,K+1} &= \bar{B}_1 G_{J,K+1} + \bar{B}_2 G_{J+1,K} = (\bar{B}_1 \bar{B}_2 + \bar{B}_2 \bar{B}_1) \bar{A} H_{J,K} \end{aligned} \right\} \quad (A1)$$

If we use Lemma 1, we obtain

$$\left. \begin{aligned} G_{J+1,K} &= C(\bar{B}_1^1, \bar{B}_2^0) \bar{A} H_{J,K} = \bar{B}_1 \bar{A} H_{J,K} \\ G_{J,K+1} &= C(\bar{B}_1^0, \bar{B}_2^1) \bar{A} H_{J,K} = \bar{B}_2 \bar{A} H_{J,K} \\ G_{J+1,K+1} &= C(\bar{B}_1^1, \bar{B}_2^1) \bar{A} H_{J,K} = (\bar{B}_1 \bar{B}_2 + \bar{B}_2 \bar{B}_1) \bar{A} H_{J,K} \end{aligned} \right\} \quad (A2)$$

Thus for any arbitrary  $m$  and  $n$  such that  $m > J$  and  $n > K$ , we can use (2) to write

$$G_{m+1,n} = \bar{B}_1 G_{m,n} + \bar{B}_2 G_{m+1,n-1} \quad (A3)$$

Then using (9) to find expressions for  $G_{m,n}$  and  $G_{m+1,n-1}$ , we have

$$G_{m+1,n} = \left[ \bar{B}_1 C(\bar{B}_1^{m-J}, \bar{B}_2^{n-K}) + \bar{B}_2 C(\bar{B}_1^{m-J+1}, \bar{B}_2^{n-K-1}) \right] \bar{A} H_{J,K} \quad (A4)$$

Consider the term,  $C(\bar{B}_1^J, \bar{B}_2^K)$ . All of the products in the term either have  $\bar{B}_1$  as the first factor or  $\bar{B}_2$  as the first factor. If  $\bar{B}_1$  is the first factor, we must postmultiply by the sum of all possible products such that the power of  $\bar{B}_1$  is decreased by one. If  $\bar{B}_2$  occurs as the first factor, we must post-multiply by the sum all possible products such that the power of  $\bar{B}_2$  is decreased by one. We conclude that

$$C(\bar{B}_1^J, \bar{B}_2^K) = \bar{B}_1 C(\bar{B}_1^{J-1}, \bar{B}_2^K) + \bar{B}_2 C(\bar{B}_1^J, \bar{B}_2^{K-1}) \quad (A5)$$

for all  $J$  and  $K$ , such that both  $J$  and  $K$  are greater than or

equal to one. It follows directly that

$$G_{m+1,n} = C(\bar{B}_1^{m+1-j}, \bar{B}_2^{n-k}) \bar{A} H_{j,k} \quad (A6)$$

Similarly from (2) we can write

$$G_{m,n+1} = \bar{B}_1 G_{m-1,n+1} + \bar{B}_2 G_{m,n} \quad (A7)$$

Using (9) to find expressions for  $G_{m-1,n+1}$  and  $G_{m,n}$ , we have

$$G_{m,n+1} = [\bar{B}_1 C(\bar{B}_1^{m-1-j}, \bar{B}_2^{n+1-k}) + \bar{B}_2 C(\bar{B}_1^{m-j}, \bar{B}_2^{n-k})] \bar{A} H_{j,k} \quad (A8)$$

It follows that

$$G_{m,n+1} = C(\bar{B}_1^{m-j}, \bar{B}_2^{n+1-k}) \bar{A} H_{j,k} \quad (A9)$$

Finally, from (2) we obtain

$$G_{m+1,n+1} = \bar{B}_1 G_{m,n+1} + \bar{B}_2 G_{m+1,n} \quad (A10)$$

Using Lemma 1 to express  $G_{m,n+1}$  and  $G_{m+1,n}$ , we obtain

$$G_{m+1,n+1} = [\bar{B}_1 C(\bar{B}_1^{m-j}, \bar{B}_2^{n+1-k}) + \bar{B}_2 C(\bar{B}_1^{m+1-j}, \bar{B}_2^{n-k})] \bar{A} H_{j,k} \quad (A11)$$

It follows from (A5) and (A11) that

$$G_{m+1,n+1} = C(\bar{B}_1^{m+1-j}, \bar{B}_2^{n+1-k}) \bar{A} H_{j,k} \quad (A12)$$

and Lemma 1 holds.

### A2. Proof of Lemma 2

In the proof of Lemma 2, we shall show that if the response to a particular sequence of input vectors can be represented as given in Lemma 2, then the system is unstable if  $\rho(\bar{Q}) > 1$  [9].

Define the eigenvalue corresponding to the spectral radius of  $\bar{Q}$  as  $\lambda_Q$  and the corresponding eigenvector as  $P_Q$ . Then if the system transfer function has mutually prime numerator and denominator polynomials we can select a sequence of input vectors such that

$$\bar{A} F_{j,n} = \epsilon P_Q + R_{j,n} \quad \text{for all } j \text{ and } n. \quad (A13)$$

where  $\epsilon$  is an arbitrary nonzero finite constant and  $R_{j,n}$  is not in the direction of  $P_Q$ . We then have

$$G_{m,n} = \bar{Q}^m \bar{A} F_{j,n} = \epsilon \bar{Q}^m P_Q + \bar{Q}^m R_{j,n} \quad (A14)$$

Then since  $\lambda_Q$  is the eigenvalue corresponding to the spectral radius, the norm of  $G_{m,n}$  is dominated by the term  $\epsilon \bar{Q}^m P_Q$  in the limit as  $m$  approaches infinity. Thus

$$S = \lim_{m \rightarrow \infty} \|G_{m,n}\| = \lim_{m \rightarrow \infty} \|\epsilon \bar{Q}^m P_Q\| = \lim_{m \rightarrow \infty} \|\epsilon \lambda_Q^m P_Q\|. \quad (A15)$$

Note that  $S$  is infinite if  $\lambda_Q$  is greater than one and Lemma 2 holds.

### A3. Proof of Theorem 2

For this proof, we show that we can find a particular sequence of inputs that give unbounded output if any one of the spectral radii specified in Theorem 2 is greater than one.

From Lemma 1 the output from a single arbitrary bounded input at the  $(J, K)$  position can be given by

$$G_{M,N} = f(J, K) C(\bar{B}_1^{M-j}, \bar{B}_2^{N-k}) \bar{A} H_{j,k} \quad (A16)$$

where  $f(J, K)$  is the scalar input at the  $(J, K)$  position. If we let  $K = N$  and  $J = 0$  in (A16), we have

$$G_{M,N} = f(0, N) C(\bar{B}_1^M, \bar{B}_2^0) \bar{A} H_{0,N} = f(0, N) \bar{B}_1^M \bar{A} H_{0,N} \quad (A17)$$

If we apply Lemma 2, we see that the system is unstable if  $\rho(\bar{B}_1) > 1$ . If we let  $J = M$  and  $K = 0$  in (A16), we have

$$G_{M,N} = f(M, 0) C(\bar{B}_1^0, \bar{B}_2^N) \bar{A} H_{M,0} = f(M, 0) \bar{B}_2^N \bar{A} H_{M,0} \quad (A18)$$

If we apply Lemma 2, we see that the system is unstable if  $\rho(\bar{B}_2) > 1$ .

If we use a particular sequence of inputs  $f(J, M-J)$  for  $0 < J < M$  where all  $f(J, M-J)$  are bounded and equal. Using the principle of superposition and (A16) we have

$$G_{M,M} = \sum_{J=0}^M f(J, M-J) C(\bar{B}_1^{M-j}, \bar{B}_2^j) \bar{A} H_{j, M-j} \quad (A19)$$

Since all inputs are equal, we can write

$$G_{M,M} = f(0, M) \left[ \sum_{J=0}^M C(\bar{B}_1^{M-j}, \bar{B}_2^j) \right] \bar{A} H_{0,M} \quad (A20)$$

$$G_{M,M} = f(0, M) (\bar{B}_1 + \bar{B}_2)^M \bar{A} H_{0,M} \quad (A21)$$

since

$$(\bar{B}_1 + \bar{B}_2)^M = \sum_{J=0}^M C(\bar{B}_1^{M-j}, \bar{B}_2^j) \quad (A22)$$

whether or not  $\bar{B}_1$  and  $\bar{B}_2$  commute. If we apply Lemma 2, we see that the system is unstable if  $\rho(\bar{B}_1 + \bar{B}_2) > 1$  and Theorem 2 holds.

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### REFERENCES

- [1] Lawrence R. Rabiner and Bernard Gold, *Theory and Application of Digital Signal Processing*. Englewood Cliffs, NJ: Prentice-Hall, 1975, pp. 442-455.
- [2] Samuel Stearns, *Digital Signal Analysis*. Hayden Publishing Company, 1975, p. 134.
- [3] E. I. Jury, "Theory and application of inners," *Proc. IEEE*, vol. 63, pp. 1044-1068, 1975.
- [4] Katsuhiko Ogata, *State Space Analysis of Control Systems*. Englewood Cliffs, NJ: Prentice-Hall, 1967, p. 487.
- [5] Dennis Goodman, "Some stability properties of two-dimensional linear shift-invariant digital filters," *IEEE Trans. Circuits Syst.*, vol. CAS-24, pp. 201-208, 1977.
- [6] E. Fornasini and G. Marchesini, "State space realization theory for two-dimensional filters," *IEEE Trans. Automat. Contr.*, vol. AC-21, pp. 484-492, Aug. 1976.
- [7] Winser E. Alexander, "Stability and synthesis of two-dimensional digital recursive filters," Ph.D. dissertation, Univ. of New Mexico, Albuquerque, NM, 1974 (University Microfilms, Ann Arbor, MI).

- [8] N. K. Bose, "Problems and progress in multidimensional system theory", *Proc IEEE*, vol. 65, pp. 724-840, 1977.
- [9] Alston S. Householder, *The Theory of Matrices in Numerical Analysis*. New York, NY: Blaisdell, 1964, ch. 2.

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# STABILITY ANALYSIS OF TWO DIMENSIONAL DIGITAL RECURSIVE FILTERS

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## The Matrix Recursive Form

### ABSTRACT

This paper presents a new procedure for stability analysis of two dimensional recursive digital filters. A matrix recursive equation which is similar to the state space representation of the one dimensional digital recursive filter is formulated. This matrix recursive equation is used to assess stability of the two dimensional digital recursive filter in terms of the spectral radii of the coefficient matrices.

Examples of the use of this technique to assess stability of two dimensional digital recursive filters are given. It is demonstrated that this technique reduces the stability analysis problem to examining the spectral radii of matrices with constant coefficients.

### INTRODUCTION

A causal two dimensional digital recursive filter may be represented by the bivariate difference equation

$$g(m,n) = \sum_{J=0}^L \sum_{K=0}^L a_{JK} f(m-J, n-K) - \sum_{\substack{J=0 \\ J+K>0}}^L \sum_{K=0}^L b_{JK} g(m-J, n-K) \quad (1)$$

where some of the coefficients  $a_{JK}$  and  $b_{JK}$  may be zero. Such a filter uses feedback of past output values to calculate the current output. Therefore, it may be bounded input-bounded output (BIBO) unstable. That is, the output may not be bounded for a given bounded input. This paper considers this stability problem and present a simple technique to assess stability of two dimensional recursive digital filters.

The bivariate difference equation represented by (1) can be described by the matrix recursive equation

$$G_{m,n} = B_1 G_{m-1,n} + B_2 G_{m,n-1} + A F_{m,n} \quad (2)$$

where  $G_{m,n}$  is a column vector made up of all outputs in (1),  $F_{m,n}$  is a column vector made up of all inputs in (1) and the matrices  $B_1$ ,  $B_2$  and  $A$  are appropriate matrices to make (1) and (2) equivalent. The matrices  $B_1$ ,  $B_2$  and  $A$  are all of order  $(L+1)^2$  by  $(L+1)^2$ . The current output is then given by  $g(m,n) = D G_{m,n}$  where  $D$  is a row vector with  $(L+1)$  elements.

The ordering of the outputs in  $G_{m,n}$  and of the inputs in  $F_{m,n}$  is not unique. However, the ordering does affect the relative position of the elements of the corresponding  $B_1$  and  $B_2$  matrices. Also note that there are identical elements in  $B_1$  and  $B_2$ . Where this occurs, the corresponding elements of  $B_1$  and  $B_2$  can be divided such that the magnitude of each is no longer than that of the corresponding  $b_{JK}$  or one as appropriate. It is convenient to consistently divide equally and choose a particular ordering scheme.

### Example 1

Consider the recursive digital filter with bivariate difference equation given by

$$g(m,n) = f(m,n) - b_{10}g(m-1,n) - b_{01}g(m,n-1) - b_{11}g(m-1,n-1) \quad (3)$$

For this example, we have

$$G_{m,n} = \begin{bmatrix} g(m,n) \\ g(m-1,n) \\ g(m,n-1) \\ g(m-1,n-1) \end{bmatrix}; F_{m,n} = \begin{bmatrix} f(m,n) \\ f(m-1,n) \\ f(m,n-1) \\ f(m-1,n-1) \end{bmatrix}$$

$$\underline{B}_1 = \begin{bmatrix} -b_{10} & 0 & b_{11} & 0 \\ 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & b_1 & 0 \end{bmatrix}; \underline{B}_2 = \begin{bmatrix} -b_{01} & -b_{11} & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 1 & 0 & 0 & 0 \\ 0 & b_1 & 0 & 0 \end{bmatrix} \quad (5)$$

and

$$\underline{A} = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \quad (6)$$

### Stability Analysis

For the one dimensional case, there are essentially two methods of determining necessary and sufficient conditions for stability; examining regions of analyticity for the characteristic polynomial and by direct evaluation of the characteristics of the impulse response [1,2,3]. In particular, if the filter is represented as a state space equation, then one can determine stability from the coefficient matrices in the state space equation [1]. The usual approach for stability analysis of two dimensional digital recursive filters involves examining regions of analyticity for bivariate polynomials [4] which is computationally feasible only for very simple filters. This paper represents an attempt to generalize the second method for the two dimensional case, i.e. to establish stability by computing the spectral radii of coefficient matrices with real coefficients.

The following theorems relating to stability analysis of two dimensional digital recursive filters have been developed [5]. Space will not allow proof of the theorems in this paper. The reader is referred to reference [5] for further details.

#### Theorem 1

The linear space invariant (LSI) two dimensional digital recursive filter represented by (2) and for which the numerator and denominator polynomials of the corresponding transfer function are mutually prime is unstable if any one of the spectral radii  $\rho(\underline{B}_1)$ ,  $\rho(\underline{B}_2)$ ,  $\rho(\underline{B}_1 + \underline{B}_2)$  is greater than or equal to one. The spectral radius of a given matrix is the magnitude of the largest magnitude eigenvalue of that matrix).

#### Theorem 2

The LSI two dimensional digital recursive filter represented by (2) is stable if the spectral radius of the matrix made up of the sum of the magnitude of the coefficients of  $\underline{B}_1$  and  $\underline{B}_2$  is less than one ( $\rho[\text{abs}(\underline{B}_1) + \text{abs}(\underline{B}_2)] < 1$ ).

#### Theorem 3

There is a particular permutation matrix  $\underline{S}$  [5] such that if  $\rho(\underline{B}_1)$ ,  $\rho(\underline{B}_2)$ ,  $\rho(\underline{B}_1 + \underline{B}_2)$  are all less than one, then the LSI digital recursive filter is stable if both  $\rho(\underline{B}_1 \underline{S})$  and  $\rho(\underline{B}_2 \underline{S})$  are less than one-half.

#### Conjecture

If the coefficients of (1) are symmetric such that  $b_{JK} = b_{KJ}$  for all J and K, then the LSI recursive digital filter described by (2) and for which the numerator and denominator polynomials of the corresponding transfer function are mutually prime is stable if and only if  $\rho(\underline{B}_1)$ ,  $\rho(\underline{B}_2)$ , and  $\rho(\underline{B}_1 + \underline{B}_2)$  are all less than one.

#### Example 2

From Theorem 1, we obtain the results that the filter represented by (3) is unstable if  $|b_{01}| \geq 1$ ,  $|b_{10}| \geq 1$ , or if

$$\max \left[ \left| \frac{-(b_{10} + b_{01}) \pm \frac{1}{2} \sqrt{(b_{10} + b_{01})^2 - 4b_{11}}}{2} \right| \right] \geq 1 \quad (7)$$

#### Example 3

Consider the example (also used by Shanks [6]) where the bivariate difference equation is given by

$$g(m,n) = f(m,n) + 0.95 g(m-1,n) + 0.95 g(m,n-1) - 0.5 g(m-1,n-1) \quad (8)$$

If we apply Theorem 1, we obtain  $\rho(\underline{B}_1) = 0.95$ ,  $\rho(\underline{B}_2) = 0.95$  and  $\rho(\underline{B}_1 + \underline{B}_2) = 1.584$ . Thus it follows that this filter is unstable.

#### Example 4

Consider the example used by Read and Treitel [7] with bivariate difference equation given by

$$g(m,n) = f(m,n) + 0.75 g(m-1,n) - 1.5 g(m,n-1) - 0.9 g(m-2,n) - 1.2 g(m,n-2) - 1.3 g(m-2,n-1) - 0.9 g(m-1,n-2) - 0.5 g(m-2,n-2) \quad (9)$$

If we apply Theorem 1, we obtain  $\rho(\underline{B}_1) = 1.095$ ,  $\rho(\underline{B}_2) = 0.949$  and  $\rho(\underline{B}_1 + \underline{B}_2) = 1.284$ . We conclude as did Read and Treitel that this filter is unstable.

#### Example 5

Consider the example by Huang [8] with difference equation given by

$$g(m,n) = f(m,n) - 0.5 g(m-1,n) - 0.5 g(m,n-1) - 0.25 g(m-1,n-1) - 0.25 g(m-2,n) - 0.25 g(m,n-2) \quad (10)$$



If we apply Theorem 3, we obtain  $\rho(\underline{B}_1) = 0.5$ ,  $\rho(\underline{B}_2) = 0.5$ ,  $\rho(\underline{B}_1 + \underline{B}_2) = 0.866$ ;  $\rho(\underline{B}_1 \underline{S}) = \rho(\underline{B}_2 \underline{S}) = 0.35355$ . Therefore, we conclude that this filter is stable. This filter was verified to be stable by Maria and Fahmy [8].

#### Example 6

Consider the example used by Huang [8] with difference equation given by

$$g(m,n) = f(m,n) - b_{10} g(m-1,n) - b_{01} g(m,n-1) \quad (11)$$

If we apply Theorem 2, it is interesting to note that we get the same sufficient condition for stability as obtained by Huang:

$$|b_{10}| + |b_{01}| < 1 \quad (12)$$

In considering more complex example, it is convenient to present the coefficients  $b_{JK}$  in matrix form. Let the matrix  $\underline{V}$  be made up of the elements  $V_{JK}$  for row  $J$  and column  $K$  where

$V_{JK} = b_{J-1, K-1}$ . For example, the  $\underline{V}$  matrix corresponding to example (1) is given by

$$\underline{V} = \begin{bmatrix} 1.0 & b_{01} \\ b_{10} & b_{11} \end{bmatrix} \quad (13)$$

Note that  $\underline{V}$  is of order  $(L+1)$  by  $(L+1)$ .

#### Example 7

Consider the example used by Read and Treitel where  $\underline{V}$  is given by

$$\underline{V} = \begin{bmatrix} 1.0 & 1.5 & -1.9 & -0.8 & 1.1 \\ 1.4 & 2.1 & -2.6 & -1.1 & 1.5 \\ -1.8 & -2.4 & 3.3 & 1.3 & -1.6 \\ -0.7 & -0.9 & 1.1 & 0.5 & -0.8 \\ -0.9 & 1.3 & -1.6 & -0.6 & 1.0 \end{bmatrix} \quad (14)$$

For this example,  $\rho(\underline{B}_1) = 2.169$ ;  $\rho(\underline{B}_2) = 2.104$  and  $\rho(\underline{B}_1 + \underline{B}_2) = 2.599$ . Thus Read and Treitel's conclusion that this filter is unstable is verified.

#### CONCLUSION

A new procedure for assessing stability of two dimensional recursive digital filters has been presented. The formulation of the  $\underline{B}_1$  and  $\underline{B}_2$  matrices is very simple and straight forward and the matrices are sparse (mostly zeros). Computer algorithms are readily available to obtain the spectral radius of a matrix with real coefficients. Thus stability analysis is greatly simplified with respect to methods which have previously been presented.

It is also important to note that in this research effort all known unstable filters have been detected as being unstable when Theorem 1 was applied. We surmise that for a very large class of filters, any filter within the class not detect-

ed as being unstable after applying Theorem 1 is stable. Research continues to prove or disprove this conjecture.

#### REFERENCES

- [1] Samuel Stearns, Digital Signal Analysis, Hayden Publishing Company, 1975, p. 134.
- [2] E. I. Jury, "Theory and Applications of Inners", Proc. IEEE, Vol. 63, No. 7, 1975, pp 1044-1068.
- [3] Katsuhiko Ogata, State Space Analysis of Control Systems, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1967, p. 487.
- [4] Dennis Goodman, "Some Stability Properties of Two Dimensional Linear-Shift Invariant Digital Filters", IEEE Transactions on Circuits and Systems, Vol CAS24, No. 4, 1977, pp 201-208.
- [5] Winsor E. Alexander, Stability and Synthesis of Two-Dimensional Digital Recursive Filters, Ph.D. Dissertation, University of New Mexico, Albuquerque, N. M., 1974 (Available from University Microfilms, Ann Arbor, Mich.).
- [6] J. L. Shanks, Sven Treitel and J. H. Justice, "Stability and Synthesis of Two Dimensional Recursive Filters", IEEE Transactions on Audio and Electroacoustics, Vol. Au-20, No. 2, 1972 pp 115-128.
- [7] Randel R. Read and Sven Treitel, "The Stabilization of Two Dimensional Recursive Filters Via the Discrete Hilbert Transform", IEEE Transactions on Geoscience Electronics, Vol. GE-11, No. 3, 1973, pp 153-160.
- [8] G. A. Maria and M. M. Fahmy, "On the Stability of Two Dimensional Digital Filters", IEEE Transactions on Audio and Electroacoustics, Vol. Au-21, 1973, pp 470-472.
- [9] Thomas S. Huang, "Stability of Two Dimensional Recursive Filters", IEEE Transactions on Audio and Electroacoustics, Vol. Au-20, No. 2, 1972, pp 158-163.

Two Dimensional Digital Filters for Subjective Image Processing

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Abstract

This paper presents a design technique for designing approximately circularly symmetric lowpass, highpass, bandpass, high frequency boost and low frequency boost digital filters for subjective image processing applications. An approach is used which parallels the use of the Butterworth, Chebyshev or other type of polynomial approximations to obtain one dimensional lowpass digital recursive filters. The other filter designs are then derived from the lowpass filter design. The designed filters are very close to being circularly symmetric for a wide range of critical frequencies. In the design procedure, the squared magnitude characteristic of the desired circularly symmetric filter is chosen in the Laplace Transform domain. The bilinear transformation is then used to map the squared magnitude characteristic into the two dimensional ZW-Transform domain. A pseudo-state space representation for the corresponding two dimensional ZW-Transform is obtained. The eigenvalues with magnitudes less than one are then used as roots of a denominator polynomial with distinct roots to form the ZW-Transform of the stable two dimensional digital filter.

1.0 INTRODUCTION

There are basically two types of image processing: subjective image processing and image correction. Subjective image processing involves the modification of an image in some way to improve the ability of the observer to obtain information or to improve the appearance of the image. Image correction involves the removal of noise or other errors in the image caused by the system producing the image. This paper primarily addresses the design of digital filters for use in subjective image processing.

The user interested in subjective image processing typically desires a variety of filters that can be applied based upon experience or a preliminary evaluation of the subject image. He then wants to observe the results of this filtering operation and make adjustments in the filter parameters before filtering again. Therefore, a computationally efficient algorithm is desirable and fast turn around is vital.

The two dimensional recursive digital filter is a good choice to meet these requirements [1]. The size of the image is not constrained to powers of integers and the number of computations per pixel does not increase as the size of the image is increased. In addition, the image is processed by row which is the normal mode for storage of images on tape or disk.

The common techniques of edge enhancement, contrast enhancement, dynamic range compression, etc. may be accomplished with recursive digital filters. These applications involve lowpass,

highpass, bandpass, high boost and low boost digital filters. This paper presents a design technique which can be used to design approximately circularly symmetric recursive digital filters.

2.0 MATHEMATICAL THEORY

The theoretical basis for the two dimensional ZW-Transform [2] involves the theory for sample data systems. Given discrete samples of a two dimensional function,  $f(x,y)$  with sampling increments  $X$  and  $Y$  respectively, the ZW-Transform for the function is defined by

$$F(z,w) = \sum_{m=-\infty}^{\infty} \sum_{n=-\infty}^{\infty} f(mX,nY)z^{-m}w^{-n} \quad (2.1)$$

If the function is an image, then (2.1) reduces to the case where  $m$  and  $n$  have no negative values and the range of  $m$  and  $n$  is finite. We further restrict the problem to the case where  $X$  and  $Y$  are constants. Then, if we use the notation  $f(m,n)$  to represent  $f(mX,nY)$ , we have

$$F(z,w) = \sum_{m=0}^M \sum_{n=0}^N f(m,n)z^{-m}w^{-n} \quad (2.2)$$

as the ZW-Transform for the image function,  $f(m,n)$ , which has  $(M+1)$  columns and  $(N+1)$  rows.

Consider the case where we have an input image with samples  $f(m,n)$  and we wish to filter this image to obtain an output image with corresponding samples,  $g(m,n)$ . The samples of the impulse response of the desired filter are given by  $h(m,n)$ . The range of  $m$  and  $n$  for the output is the same as for the input. Thus, the ZW-Transform of  $g(m,n)$  is given by

$$G(z,w) = \sum_{m=0}^M \sum_{n=0}^N g(m,n)z^{-m}w^{-n} \quad (2.3)$$

If we restrict the impulse response such that  $m$  and  $n$  cannot be negative (a causal system), we can write the ZW-Transform for the impulse response as

$$H(z,w) = \sum_{m=0}^{\infty} \sum_{n=0}^{\infty} h(m,n)z^{-m}w^{-n} \quad (2.4)$$

In general, the ZW-Transform for the impulse response is an infinite series. In order to implement the spatial domain filter, we must find a closed form expression for  $H(z,w)$  such that

$$H(z,w) = \frac{\sum_{j=0}^L \sum_{k=0}^L a(j,k)z^{-j}w^{-k}}{\sum_{j=0}^L \sum_{k=0}^L b(j,k)z^{-j}w^{-k}} \quad (2.5)$$

The convolution property of the ZW-Transform gives the relationship resulting from the convolution of  $t(m,n)$  and  $h(m,n)$  which is the filtering process

$$G(z,w) = H(z,w)F(z,w) \quad (2.6)$$

If we use the closed form of  $H(z,w)$  and restrict  $b(0,0)$  to be equal to one and write the resulting equation for a single output value  $g(m,n)$ , we obtain the difference equation

$$g(m,n) = \sum_{j=0}^L \sum_{k=0}^L a(j,k)f(m-j,n-k) - \sum_{\substack{j=0 \\ j+k>0}}^L \sum_{k=0}^L b(j,k)g(m-j,n-k) \quad (2.7)$$

If  $L$  is relatively small (in practice,  $L$  is usually less than 10 for recursive digital filters), equation (2.7) represents a very efficient algorithm for filtering images. Equations (2.5) and (2.7) may also represent a nonrecursive filter if all  $b(j,k)$  except  $b(0,0)$  are equal to zero.

### 3.0 STABILITY ANALYSIS

Nonrecursive digital filters are inherently stable. Since there is no feedback of past output values, the impulse response has finite duration. Each output value is a finite sum which is always bounded if the input is bounded.

The stability problem for one dimensional digital recursive filters is straight forward. The roots of the denominator polynomial in the closed form of the one dimensional Z-Transform for the filter impulse response function must have magnitudes less than one. Stability analysis is therefore reduced to finding roots of  $n$ th degree polynomials with real, constant coefficients [3]. Stability analysis is not straight forward for the two dimensional problem because a two variable polynomial is not generally factorable into distinct roots. When the polynomial in the denominator of the two dimensional Z-Transform of the impulse response is factorable into distinct roots, the stability analysis procedure is the same as for the one dimensional problem.

The two dimensional stability problem is very complicated if the polynomial in the denominator is not factorable into distinct roots [4]. Efforts by other researchers have been directed toward examining regions of roots for two variable polynomials. An alternate method of assessing stability for one dimensional digital recursive filters is to make a state space representation of the filter [5]. Then the filter is stable if the eigenvalues of the state transition matrix all have magnitudes less than one. Previous research has been directed toward developing the two dimensional equivalent of this procedure [6,7]. A pseudo-state variable representation is chosen because of difficulties in finding a true state space representation [8]. This difficulty is caused by the bivarience of the transfer function and by its causality. The resulting matrix equation has two pseudo-state transition matrices.

Alexander [6] has shown that the recursive algorithm of (2.7) can be represented by the matrix recursive equation:

$$G_{m,n} = \bar{B}G_{m,n-1} + \bar{C}G_{m-1,n} + \bar{A}F_{m,n} \quad (3.1)$$

Where  $G_{m,n}$  is a vector such that the elements of  $G_{m,n}$  are the outputs  $g(m-j,n-k)$  in (2.7) where  $0 \leq j \leq L$  and  $0 \leq k \leq L$ .  $F_{m,n}$  is a vector such that the elements of  $F_{m,n}$  are the inputs  $f(m-j,n-k)$  in (2.7) where  $0 \leq j \leq L$  and  $0 \leq k \leq L$ .  $\bar{B}$ ,  $\bar{C}$  and  $\bar{A}$  are appropriate coefficient matrices such that (2.7) and (3.1) are equivalent.

If the filter is unstable, then either  $\bar{B}$ ,  $\bar{C}$  or  $(\bar{B} + \bar{C})$  has at least one eigenvalue with a magnitude greater than or equal to one. Thus, stability analysis involves setting up the matrices  $\bar{B}$  and  $\bar{C}$  and finding the spectral radius of each matrix individually and of their sum.

### 4.0 SYNTHESIS

Often it is possible to express a desired two dimensional recursive digital filter as the product or sum of two one dimensional digital filters. That is, the ZW-Transform of the two dimensional filter may be expressed as the product

$$H(z,w) = H1(z)H2(w) \quad (4.1)$$

or as the sum

$$H(z,w) = H1(z) + H2(w) \quad (4.2)$$

In either case, the two dimensional synthesis problem is reduced to the synthesis of two one dimensional filters [9,10]. However, it is not possible to design sum separable or product separable digital recursive filters for all applications. For these applications where sum separable or product separable designs are not possible, the design of the required two dimensional digital recursive filter is considerably more complicated.

Many imaging systems have a natural circular symmetry. In general, the optical transfer function (OTF) of a circularly symmetric imaging system is circularly symmetric. Also, it is usually desirable to perform image processing where the processing is uniform with respect to direction. The natural

consequence is that filters with circularly symmetric impulse response functions are generally very desirable for image processing. A filter with a circularly symmetric impulse response is assured by restricting the Discrete Fourier Transform (DFT) for the filter to be circularly symmetric [11].

One popular method of designing digital recursive filters is to start with the Laplace Transform of the desired filtering function, make a suitable transformation to the Z-Transform domain and thus obtain the coefficients for the digital recursive filter. One such technique involves designing digital recursive filters from the squared magnitude characteristics of the desired filter which is really the squared magnitude of the Fourier Transform. This procedure is difficult to extend to two dimensions because of the difficulties encountered in factoring bivariate polynomials.

To illustrate this difficulty, consider the circularly symmetric Butterworth low pass filter squared magnitude characteristic.

$$H(r,s) = \frac{1}{1 + (-1)^n (r^2 + s^2)^n / R^{2n}} \quad (4.3)$$

where  $r$  and  $s$  are the Laplace Transform variables for the  $x$  and  $y$  direction respectively and  $R$  is the desired radial cutoff frequency.

The bilinear transformation [9] can be used to obtain the corresponding recursive digital filter. First, we prewarp  $H(r,s)$  to obtain

$$H_1(r,s) = \frac{1}{1 + a^{2n} (r^2 + s^2)^n} \quad (4.4)$$

where

$$a^2 = (-1)^n \tan^2(RT/2) \quad (4.5)$$

(The assumption is made in this example that the sampling increment is the same in each direction and is equal to  $T$ .) Applying the bilinear transformation, we have an approximation for the ZW-Transform for the squared magnitude characteristic of the desired filter.

$$H(z,w) = \frac{1}{1 + a^{2n} \left[ \left( \frac{z-1}{z+1} \right)^2 + \left( \frac{w-1}{w+1} \right)^2 \right]^n} \quad (4.6)$$

If the polynomial in the denominator of (4.6) were factorable into distinct roots of  $z$  and  $w$ , then those roots would occur in reciprocal pairs. The design procedure would then be completed by forming  $H(z,w)$  from those roots for which the magnitude of  $z$  is less than one and those for which the magnitude of  $w$  is less than one. The numerator polynomial of  $H(z,w)$  is allowed to have roots with a magnitude of one.

$H(z,w)$  which is formed with the smaller in magnitude of each of the reciprocal pairs of roots in the numerator and denominator is said to have minimum phase. The minimum phase version of any filter is stable for any input sequence unless the denominator of its ZW-Transform has roots where either the magnitude of  $z$  or  $w$  is equal to one. In that case, it is conditionally stable.

However, the polynomial in the denominator of (4.6) is not factorable into distinct roots. Therefore, forming of the minimum phase version of  $H(z,w)$  is not straightforward and the design procedure is not successful.

A minimum phase approximation to  $H(z,w)$  can be obtained with the following procedure:

1. Construct the coefficient matrices  $\bar{B}$  and  $\bar{C}$  of (3.1) which corresponds to (4.6).
2. Calculate the eigenvalues of the matrix sum  $(\bar{B} + \bar{C})$ . They occur in reciprocal pairs.
3. Form the minimum phase approximation of the filter by using the smaller magnitude eigenvalue of each of the reciprocal pairs as a root of  $z$  and of  $w$  for the denominator polynomial and by using the minimum phase version of the numerator polynomial.

The resulting filter ZW-Transform is given by

$$H(z,w) = \frac{(1+p)^2 (z+1)(w+1)}{4 (z+p)(w+p)} \quad (4.7)$$

where

$$p = \frac{(2a - (2\sqrt{2})a + 1)}{1 - 2a} \quad (4.8)$$

## 5.0 FILTER DESIGN

### 5.1 Low Pass filter

Equation (4.7) gives the ZW-Transform for the low pass filter approximation which was derived from the circularly symmetric low pass filter squared magnitude characteristic of (4.3). For this particular design, the roots of  $H(z,w)$  are real. In general, the roots may be real or they may occur in complex conjugate pairs. If the resulting filter is applied in a straightforward manner, the algorithm must handle complex numbers. This can be avoided by using a basic filter structure which uses only binomial functions resulting from the multiplication of two roots. When complex roots are involved, the pair of complex conjugate roots would form a basic filter stage. The penalty paid for this basic filter structure is that filters with odd numbers of zeros or poles can only be implemented by adding at least one null root. The addition of this null root results in unnecessary calculations in the algorithm which implements the filter. Thus, all filters designed will have the basic structure:

$$H(z,w) = \prod \frac{A_1 [z^2 + q(1)z + q(2)] [w^2 + q(1)w + q(2)]}{1 [z^2 + p(1)z + p(2)] [w^2 + p(1)w + p(2)]} \quad (5.1)$$

The basic low pass filter using this form is then given by

$$LP(z,w) = \frac{(1+p)^4 (z^2 + 2z + 1)(w^2 + 2w + 1)}{16 (z^2 + 2pz + p^2)(w^2 + 2pw + p^2)} \quad (5.2)$$

## 5.2 The Frequency Boost Filter

A frequency boost filter can be designed from the magnitude response characteristics of the low pass filter. Consider the filter which has a ZW-Transform given by:

$$H(z,w) = c + d|LP(z,w)|^2 \quad (5.3)$$

Note that (5.3) has roots of  $z$  and of  $w$  with magnitude greater than one since the roots occur in reciprocal pairs. This problem is overcome by using the minimum phase version of (5.3). Thus the ZW-Transform of the desired filter is given by:

$$H(z,w) = \frac{N(z,w)}{D(z,w)} \quad (5.4)$$

where  $N(z,w)$  and  $D(z,w)$  have minimum phase.

A high frequency boost filter can be designed by changing the values of  $c$  and  $d$  in (5.3). For the high pass filter,  $c$  has a value of one and  $d$  has a value of minus one. If a low frequency boost filter is desired with a magnitude gain of  $BF$  at DC and a gain of one at the Nyquist frequency, this can be achieved by setting:

$$\begin{aligned} c &= 1.0 \\ d &= BF - 1.0 \end{aligned} \quad (5.5)$$

If a high frequency boost filter is desired with a magnitude gain of  $BF$  at the Nyquist frequency and a gain of one at DC, this can be achieved by setting:

$$\begin{aligned} c &= BF \\ d &= 1.0 - BF \end{aligned} \quad (5.6)$$

The shape of the resulting filter is also affected by the value of the root  $p$  which is derived from the design of the low pass filter. From (4.7) and (4.8), observe that  $p$  is a function of the desired radial cutoff frequency  $R$ , for the low pass filter. Note that three parameters,  $c$ ,  $d$  and  $R$ , are required to design the filter specified by (5.3). However, if a high frequency boost or a low frequency boost filter is desired, then only two parameters,  $R$  and  $BF$  are required because  $c$  and  $d$  can be derived from  $BF$ .

## 6.0 FILTER DESIGN EXAMPLES

Figure 1 gives the perspective plot of a lowpass filter designed with the described technique with a cut off frequency which is 0.3 times the Nyquist frequency. Figure 2 gives the contour plot for this filter design. Figure 3 gives the perspective plot for a high frequency boost filter with a break frequency of 0.5 times the Nyquist frequency and a boost magnitude of 25.6. Figure 4 gives the contour plot for this filter design. Note that these examples are essentially circularly symmetric. Some degradation is observed as the break frequency approaches the Nyquist frequency. This is caused by the mapping characteristics of the bilinear transformation. Some degradation also occurs as the break frequency approaches DC. However, this can be corrected by using rotated filter combinations [12].

## 7.0 CONCLUSION

A design technique has been presented which can be used to design approximately circularly symmetric digital recursive filters for subjective image processing applications. These filters include lowpass, highpass, low and high frequency boost and bandpass filters. The filters are inherently stable because the denominator polynomial of the ZW-Transform is minimum phase.

## REFERENCES

1. Ernest L. Hall, "A Comparison of Computations for Spatial Filtering", Proceedings of the IEEE, Vol. 60, no. 7, 1972, pp 887-891.
2. Lawrence R. Rabiner and Bernard Gold, Theory and Application of Digital Signal Processing, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1975, pp 442-455.
3. Samuel Stearns, Digital Signal Analysis, Hayden Publishing Co., Inc., Edison, N. J. p 134.
4. N. K. Bose, "Problems and Progress in Multidimensional System Theory", Proceedings of IEEE, Vol. 65, No. 6, 1977, pp 1000-1001.
5. Katsuniko Ogata, State Space Analysis of Control Systems, Prentice-Hall, Inc., Englewood Cliffs, N. J., p. 487.
6. Winsor E. Alexander and Steven A. Pruess, "Stability Analysis of Two Dimensional Digital Recursive Filters", accepted for publication in IEEE Transactions on Circuits and Systems.
7. Winsor E. Alexander, "Stability Analysis of Two Dimensional Digital Recursive Filters", 12th Asilomar Conference on Circuits, Systems, and Computers, November, 1978.
8. E. Fornasini and G. Marchesini, "State Space Realization Theory for Two Dimensional Filters", IEEE Transactions on Automatic Control, Vol. AC-21 1976, pp 484-492.
9. Bernard Gold and Charles Rader, Digital Processing of Signals, McGraw Hill, Inc., New York, N. Y., 1969.
10. Andreas Antoniou, Digital Filters; Analysis and Design, McGraw Hill, Inc., New York, N. Y., 1979.
11. Athanasios Papoulis, Systems and Transforms with Applications in Optics, McGraw Hill, Inc., New York, N. Y., 1968.
12. Dennis Goodman, "A Design Technique for Circularly Symmetric Low Pass Filters", IEEE Transactions on Acoustics, Speech and Signal Processing, Vol. ASSP-26, No. 4, 1978, pp 290-304.

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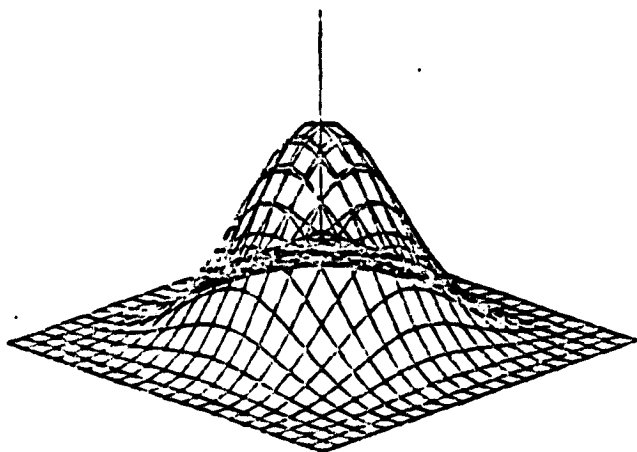


FIGURE 1. LOW PASS FILTER  
STAGE = 1 RC = 0.3

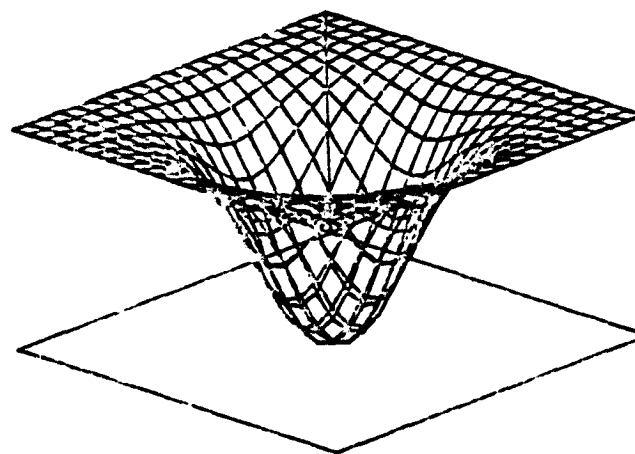


FIGURE 3. HIGH BOOST FILTER  
BOOST FACTOR = 25.6 RC = 0.5

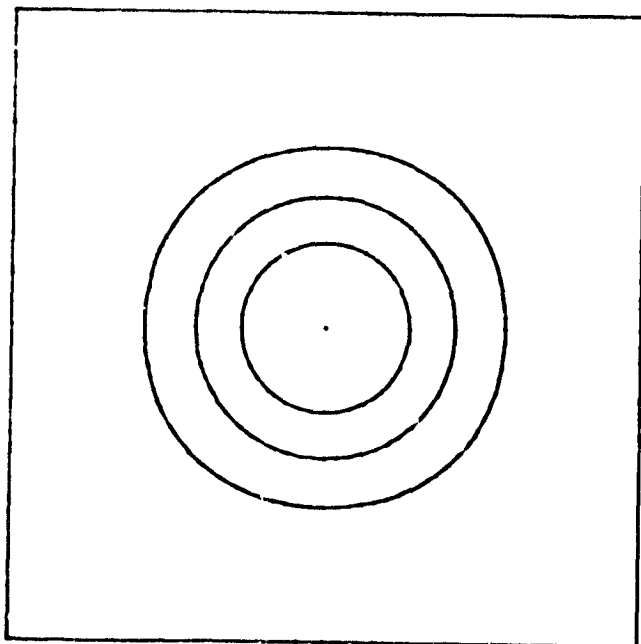


FIGURE 2. LOW PASS FILTER  
STAGE = 1 RC = 0.3

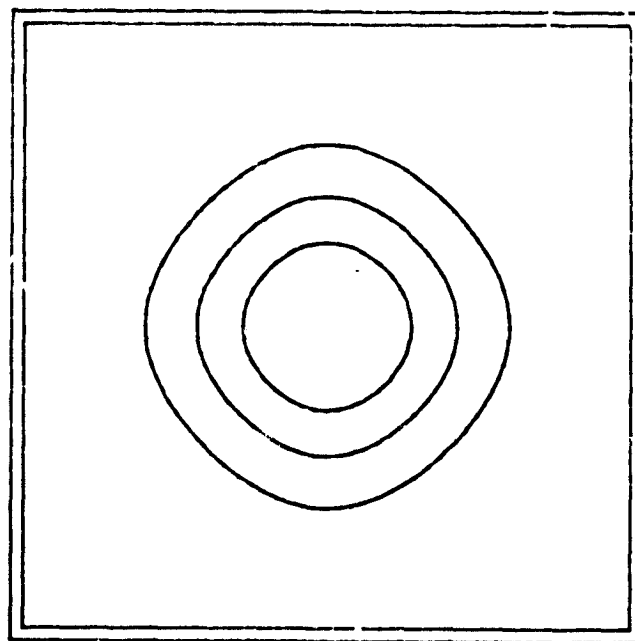


FIGURE 4. HIGH BOOST FILTER  
BOOST FACTOR = 25.6 RC = 0.5

# SIMULTANEOUS LINEAR ALGEBRAIC EQUATION FORMULATIONS OF 2D FILTERS

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## ABSTRACT

It is shown that 2D digital filter realizations are equivalent to the solution of tensor equations, and they are also equivalent to the solution of matrix equations. Both recursive and non-recursive filters are included in these formulations.

## SUMMARY

A 2D digital filter, which possesses a rational transfer function, may be represented by its bivariate difference equation written in tensor form as:

$$b_{ij} g_{p+i, q+j} = a_{ij} f_{p+i, q+j} \quad (1)$$

where  $1 \leq p \leq N$ ,  $1 \leq q \leq M$ ,  $-m \leq i \leq m$ ,  $-m \leq j \leq m$ ; and the double appearance of an indice on a given side of the equality implying the usual summation over the appropriate range of that indice. A more formal expression of (1) is:

$$B_{pq}^{kl} g_{kl} = A_{pq}^{kl} f_{kl} \quad (2)$$

where  $1 \leq k \leq N$ ,  $1 \leq l \leq M$ , and the non-zero components of the coefficient tensors given by  $A_{pq}^{kl} = a_{k-p, l-q}$ ; and  $B_{pq}^{kl} = b_{k-p, l-q}$ ; for  $-m \leq k-p \leq m$ ,  $-m \leq l-q \leq m$ .

The 2D filtering operation requires that one determine all the  $g_{pq}$ , given all  $a_{ij}$ ,  $b_{ij}$ , and  $f_{pq}$ . A solution will exist and be unique if there exists an inverse of the tensor  $B_{pq}^{kl}$ , say  $C_{uv}^{pq}$ ; with  $1 \leq u \leq N$ ,  $1 \leq v \leq M$ . For such a case, the filtered solution would then be given by:

$$g_{uv} = C_{uv}^{pq} A_{pq}^{kl} f_{kl} \quad (3)$$

Tensor equation (2) can also be interpreted as a matrix equation with the  $A_{pq}^{kl}$ ,  $B_{pq}^{kl}$  taken as  $NM \times NM$  dimensional coefficient matrices with row index "pq", column index "kl"; and  $g_{kl}$ ,  $f_{kl}$  taken as column matrices.

For the case when  $N=M$ , and  $a_{00}$ ,  $b_{00} \neq 0$ ; then equation (2) is also expressible as a matrix equation involving only  $N \times N$  matrices given by:

$$LGR + \sum_{k=-m, k \neq 0}^m S_k G T_k = c PFQ + c \sum_{k=-m, k \neq 0}^m S_k F U_k \quad (4)$$

where  $c = a_{00}/b_{00}$ , the matrices  $G = [g_{pq}]$ ,  $F = [f_{pq}]$ ; and the non-zero components of the coefficient matrices  $L$ ,  $R$ ,  $P$ ,  $Q$ ,  $S_k$ ,  $T_k$  and  $U_k$  given by:

$$L_{pq} = b_{q-p, 0}/b_{00}; \quad R_{pq} = b_{0, q-p}/b_{00}; \quad P_{pq} = a_{q-p, 0}/a_{00}; \quad Q_{pq} = a_{0, q-p}/a_{00}.$$

$$T_{kpq} = b_{k, p-q}/b_{00} - b_{k, 0} b_{0, p-q}/b_{00}^2; \quad U_{kpq} = a_{k, p-q}/a_{00} - a_{k, 0} a_{0, p-q}/a_{00}^2.$$

$$(ii) \text{ And finally, for } p, q \text{ such that } q-p=k: S_{kpq} = 1.$$

Non-recursive filters generally require solutions of the form given by (3). For recursive filters (4) simplifies allowing solution by compact schemes.