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SMALL INTERACTIVE IMAGE PROCESSING SYSTEM (SMIPS) USERS MANUAL

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SYSTEM (SMIPS)
USERS MANUAL

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A SMALL INTERACTIVE IMAGE PROCESSING SYSTEM

1. INTRODUCTION

The analysis of digital pictures requires the examination of complex data from many different viewpoints. In a batch processing mode it is necessary to specify the entire analysis to be performed prior to submitting the computer run. This is inconvenient and may stretch the period of performing a careful analysis over a long time. Often the experimenter is not familiar with the computer system and the special analysis programs available, which further complicates a successful analysis.

An interactive system differs from a conventional one in its interface with the user. By taking full advantage of the man-machine combination the efficiency of a picture analysis can be increased considerably. By means of a display device which allows interactive control of the computer, the user specifies his input and the system displays the results on the screen. Thus, the short time between specification of a problem and the return of intermediate results provides a more intelligent choice and sequencing of the analysis steps that are applied to the pictures.

Such an interactive system must provide a simple and convenient communication between man and computer. The experimenter should be able to use the computer like a desk calculator as a tool in his analysis. Without being a skilled programmer and without having to know particularities of the computer system available, he should be able to conduct the analysis from the graphic display unit. By means of keyboard and light pen as input devices, the experimenter can transfer pictures stored on magnetic tape into the system, display them on the screen, change parameters like sampling rate and quantization levels dynamically, combine two pictures to a new one (ratio, difference), specify operations to be performed on the picture (transforms, filtering) and display the results, compute statistical parameters and histograms and direct eventually the final results of the analysis to printer, plotter or film device. This cycle can be repeated as often as necessary. The convenience with which it is possible to proceed around this deductive-inductive loop allows concentration on the analysis over a short period of time without the mechanical steps being normally a problem (punching cards, submitting decks, waiting for printout).

All the features described are available in the Small Interactive Image Processing System (SMIPS). This system has been designed to provide the user with interactive capabilities which allow the immediate display of intermediate results and the flexible specification of the analysis steps. SMIPS is intended as an experimental system allowing quick familiarization with the characteristics of

the image data rather than a production system. It can, however, also be used for production work and its full compatibility with the VICAR system allows access to the numerous image processing programs in the VICAR library. Because of its modular design, new interactive capabilities can easily be included and SMIPS could be used as an experimental tool to gain further experience for the design of larger and more sophisticated interactive image processing systems.

The convenient access to pictorial data combined with the ability to display these data, to modify the display parameters, to reference a library of image processing programs, to add new procedures as it becomes necessary and to compare the results of alternative processing methods in an interactive way provides a concept for the on-line analysis of pictorial data and for developing new interactive processing methods.

The SMIP system uses an IBM-2250 model 1 graphics terminal connected to an IBM 360/75 or 360/91 computer, one 9-track tape unit, one 7-track tape unit and space on five scratch disk units. The current implementation of the system operates under the operating system OS/MVT-Release 20 and needs a region size of 200 K.

This document describes SMIPS from a users viewpoint. A detailed description of the system is given in [1], a summary of image processing concepts can be found in [2].

2. GENERAL DESCRIPTION

2.1 PURPOSE

The Small Interactive Image Processing System (SMIP) is designed to facilitate the acquisition, digital processing and recording of image data as well as pattern recognition in an interactive mode. Objectives of the system are ease of communication with the computer by personnel who are not expert programmers, fast response to requests for information on pictures, complete error recovery as well as simplification of future programming efforts for extension of the system.

The SMIP system is intended for operation under OS/MVT on an IBM 360/75 or 91 computer equipped with the IBM-2250 Model 1 display unit. This terminal is used as an interface between user and main computer. It has an alphanumeric keyboard, a programmed function keyboard and a light pen which are used for specification of input to the system. Output from the system is displayed on the screen as messages and pictures.

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To allow the use of already existing image processing programs and to avoid considerable reprogramming effort, the SMIP system was made fully compatible with the VICAR system designed at the Jet Propulsion Laboratory. A SMIP user can execute any image processing program contained in the VICAR-Library on the SESD-75. To accomplish this, SMIP uses the I/O routines of VICAR as well as a routine which processes the calling sequence for any image processing program contained in a library.

The SMIP system provides a very simple language for the communication between user and computer. This language allows one to specify:

- The transfer of pictures from magnetic tape into the system.

- The display of any part of a picture with a grey level representation which can be changed dynamically.

- Operations on pictures (transforms, convolution, rotation, forming ratios and differences, etc.).

- The calculation of statistical information.

- The output of results as printout on lineprinter, on Calcomp-plotter or on black and white or color photograph.

Errors made by the user are detected, an explanatory message is displayed on the screen and the system waits for input of the corrected statement. This error recovery feature makes the use of an interactive system very convenient for there is little delay due to a mistake.

The system provides the necessary routines to process all user requests and to bring the results of operation into a displayable format; it interfaces with the OS/MVT operating system and adapts it to the needs of interactive digital image processing.

Digital pictures are usually stored as files on magnetic tapes. Since in most cases a number of pictures reside on the same tape, convenient and efficient handling of multifile tapes is an important feature of an interactive image processing system. In the SMIPS system all job control language is transparent to the user. Reading a picture from tape involves only the specification of the tape identifier and a file number indicating the position of the picture on the tape in the READ command. The same applies for writing a processed picture to a tape.

2.2   FUNCTIONAL CHARACTERISTICS

Operation of the SMIP system is similar to the use of a desk calculator. It is
a repeated sequence of single requests followed by responses. The user requests
a computation by typing a command, pressing a function key or using the light-
pen. The system responds with the display of a message or picture on the screen
of the graphic terminal or by indicating the completion of the request with an
audible alarm signal.

The structure of the command language is very simple. Only a few commands
are required for any particular application. Thus a user can quickly learn to
master the system in a limited mode. For example, a user may be only inter-
ested in the computation of histograms or Fourier transforms. This user would
see the system only as a histogram or Fourier transform calculating machine.

The system has two operational modes, the dialogue mode and the input mode.
In the dialogue mode, in which a basic set of image processing functions is avail-
able, each request is immediately executed.

Commands valid in this mode are:

RESERVE   Reserve direct access storage for a picture.

READ   Transfer a picture from magnetic tape to direct access storage.

WRITE   Transfer a picture from direct access storage to magnetic tape.

SET   Set certain parameters for the display of a picture.

DISPLAY   Display a picture (grey levels simulated by different characters),
             its histogram or its label information.

THRESHOLD   Create a threshold picture from a given input picture.

SAVE   Transfer a picture from core to disk.

TASKS   Display the waiting image processing tasks.

EXECUTE   Execute a previously entered image processing program from
             the task queue.

EXIT   Terminate processing.

DISCONNECT   Disconnect the graphic terminal but process all tasks from the
             queue and then terminate.

All the routines necessary to perform these functions are contained in one pro-
gram module. Image processing with these functions is, however, very re-
stricted. Therefore, the system can be extended by an unlimited number of image

processing programs which have to be stored in the SMIPS library. In order to use such a program, the user specifies the name of the program, the required input and output pictures as well as optional parameters. Because of the limited size of main memory available for SMIPS, the execution involves deletion of the interactive module from core, loading and execution of the specific image processing program and its deletion and reloading of the interactive module. This is accomplished automatically. The specification of the various image processing programs is done in the input mode.

In the input mode each Image Processing function specified in a command is inserted into a queue of tasks for later processing. All the image processing programs in the SMIP and VICAR system library can be used in this mode. Checking the syntactic correctness of the command as well as the availability of the specified program is done in this mode. Only correct requests for available programs are inserted into the task queue. These operations are performed by a routine in the dialogue processor. The command END returns control to the dialogue mode.

The user can now proceed with the dialogue or he can reenter the input mode in order to add additional tasks to the queue. At any time he can issue the EXECUTE command which starts execution of the tasks waiting in the queue. During execution a user cannot enter further commands. He has to wait until processing of the tasks is completed and the system indicates with the audible alarm and a cursor displayed in the lower left corner of the screen that it is ready to accept input from the user.

2.3 STANDARD PICTURE FORMAT

A standard format is used for pictures on both disk and magnetic tape. The format is the same as used in the VICAR system because all VICAR processing programs are designed to operate with this standard picture format.

Tape Format

Picture elements (pixels) are normally represented as eight-bit data bytes. With the Data Converter Feature of the IBM tape-controller, both seven and nine track tapes may be logically equivalent. The standard tape format in use at the SESD computer center is FORMAT 2 (see Table 1), IBM-compatible nine-track tape written with ODD parity at 1600 b.p.i. Each reel of tape may contain up to 99 files, determined only by the size of the files. Each file contains a set of label records describing a picture and one picture frame followed by an End-of-file mark.

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The tapes have no IBM-label (LABEL parameter NL when created). The label set describing the picture consists of one or up to five 360-byte physical records. The 360-byte label records are subdivided into five 72-byte logical label records. The first 72-byte logical label record in the label set is reserved for system use and must contain certain specified data. All subsequent logical label records may contain variable I-D information (text) as required, (see Fig. 1).

Label Record

1	73	145	217	289	360
System Label	Label 2	Label 3	Label 4	Label 5

System Label

1				72
Reserved	NL	NS	Unused	C or L

NL   number of lines - picture
NS   number of samples per picture line

User Label

Label data	b or H	C or L

C   another label follows
L   last label in this set
H   history label

Figure 1.

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Byte 72 of each logical record is used as a continuation character and contains a 'C' to indicate the presence of additional logical records or an 'L' if the last such record. Likewise, a 'C' in byte 360 indicates an additional 360-byte label record. In addition byte 71 of each logical record normally will be blank. Otherwise, variable I-D data may be recorded in bytes 1 through 70. The number of lines in a picture (NL) is recorded in EBCDIC in word 9 of the first label block, the line length (NS for number of samples) is recorded in word 10. All other label characters are also in EBCDIC.

The data of a picture line can be recorded on the tapes as blocked or unblocked records. Upon transfer of a picture from tape to disk (READ command) the unblocked lines are automatically packed into the blocked disk format described in the next section. Blocked records are unblocked using the length NS of one record from the label and converted to the blocked disk format.

Disk Format

The format of the standard data set is logically identical to the standard tape format described above. To contain the label records, the minimum size of a block (line length) is 360 bytes. The maximum blocksize for a 2314 Disk Drive is 7294 bytes. With the track overflow feature enabled the maximum blocksize can be 32768 bytes (track overflow is on in SMIPS). The default blocksize used is 7200 bytes. The system packs automatically a number of lines (determined by 7200/NS, NS from RESERVE command) into one block.

3.   COMMANDS FOR THE DIALOGUE MODE

3.1   RESERVE

Used to reserve a picture name and allocate space for a picture on disk. To improve efficiency the user has to specify the disk name on which the space requested is to be allocated.

Format:

RESERVE, name, NL = k, NS = 1, diskname

name   is the picture name to be reserved. It is a string of characters beginning with a letter. Up to 8 characters are significant, strings with a length greater than 8 will be truncated, names with less than 8 characters will be left justified and padded with blanks.

NL = k   k (integer) is the number of lines in the picture for which space is to be reserved. NL is only limited by the amount of available disk space.

NS = 1   1 (integer) is the number of points per picture line. Minimum NS is 360 because of the label length. If the user specifies a smaller value the system will automatically correct it to NS = 360. NS should not be less than the actual line length. The maximum is NS = 32768, it is, however, further limited by the amount of available disk space.

diskname   specifies the disk pack on which NS X NL bytes are to be reserved for the picture. One of the following five disknames available on the SESD 360/75 has to be used:

K3SCR2   K3SCR5
K3SCR3   K3SCR6
K3SCR4

Example:

RESERVE, ERTS.MS5,NL=585,NS=810,K3SCR3

The name ERTS.MS5 will be assigned to the space of 585 X 810 bytes reserved on the disk K3SCR3.

Space for three pictures can be reserved on one diskpack, the maximum size of each is 145000, 290000 and 580000 bytes respectively (1 pixel = 1 byte). The system computes the size necessary to hold the picture using the parameters NL and NS and allocates space with the best-fit method. The input and output pictures specified in an Image Processing program should be reserved on different disks. This will increase the efficiency of I/O-operations.

A table of the reserved picture names showing also the disk name and line length can be displayed on the screen by pressing key 9, labeled with NAME.

Note: Disk space for ERTS-1 images in the format described in the Memorandum from March 29, 1973 has to be reserved with NS = 810, NL = 585.

3.2 READ

The READ command is used to transfer a picture from magnetic tape into the system, i.e. to copy it from tape to disk.

Format:

READ,tapeno,FILE=i,TO,name [,FORMAT=k]

tapeno	is the volume serial number of the magnetic tape on which the picture is stored. It should be a string of characters beginning with a letter and the first six characters are significant.
FILE=i	i (integer) is the position of the picture to be transferred into the system on the magnetic tape.
name	is the name which is to be associated with the picture in the system. It should be a string of characters beginning with a letter. The first eight characters are significant. name has to be reserved previously with the RESERVE command.
FORMAT=k	is optional and describes the format of the tape (density, labels, 7 or 9 track).

The following tape formats are available:

Table 1

k	track	density [bpi]	DEN	label
1	9	800	2	std. 360 bytes
2	9	1600	3	std
3	9	800	2	no label
4	9	1600	3	no label
5	7	800	2	no label
6	7	556	1	no label
7	7	800	2	std
8	7	556	1	std

The default value is k=2, specifying a picture with standard label (describing the size of the picture) on a 9 track tape written with density 1600 bpi (DEN=3). As delimiter between the fields of the command either a comma or a blank can be used.

The system checks the validity of the command and indicates errors with the following possible messages:

'NO FILE NUMBER SPECIFIED'	if the keyword FILE is missing in the command.
'-TO-IS MISSING IN COMMAND'	if the keyword TO was not specified.
'name NOT RESERVED'	if the name specified in the name field of the READ command was not previously reserved and hence no disk space was allocated.

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'FORMAT INCORRECTLY SPECIFIED' if the keyword FORMAT was used and
misspelled.

'INVALID FORMAT IN READ'   if the FORMAT number is less than 1 or
greater than 8.

'FILE NUMBER <1'   if the integer number specified with the key-
word FILE was zero or negative.

'SAME FILE CANNOT BE READ' if the same file number was specified in 2
subsequent READ-commands.

In any of these cases the errormessage is displayed on the screen and the system
waits for further action from the user.

Example:

READ L999 FILE=6 TO ERTS.MS5

The system copies file 6 (the 6th picture on the tape) from tape L999 to the re-
served disk area associated with the name ERTS.MS5.

If the command is correctly specified the system checks if the requested tape
is already mounted. If not it prints the request to mount the tape on the opera-
tors console and starts the read operation. Upon completion, the message
PICTURE ERTS.MS5 AS FILE 6 FROM TAPE L999 SUCCESSFULLY READ
is displayed on the screen (for the preceeding example).

3.3   WRITE

The WRITE command is used to transfer a picture from the system to a magnetic
tape. Its main application is to save a processed picture on magnetic tape. A
READ command followed by a WRITE command with the same picture name but
a different tapename will copy the picture to the other tape.

Format:

WRITE, name, TO, tapeno, FILE=i [, FORMAT=k]

name   is the name of a picture defined with the RESERVE command. It
            is a string of characters beginning with a letter.

tapeno   is the volume serial number of the magnetic tape on which the pic-
            ture specified by 'name' is to be written. Tapeno should be a string
            of characters beginning with a letter, the first six characters are
            significant.

FILE=i   the integer $1 \leqslant i \leqslant 99$ specifies the filenumber of the picture to be
              written on the tape, i.e. the position of the picture on the tape.

FORMAT=k   is optional and describes the format of the tape to which the picture
              is to be written. The formats available are listed in Table 1. The
              default value is k=2, describing a 9-track tape, density 1600 bpi and
              standard 360 bytes label.

3.4   DISPLAY

The DISPLAY command is used to display a character representation, the histogram or the label information of a picture on the screen of the IBM-2250 display device.

The format of the DISPLAY command is:

$$\left\{ \begin{matrix} \text{DISPLAY} \\ \text{D} \end{matrix} \right\} \text{, name, mode [, params]}$$

name   is the name of a picture defined with the RESERVE command. It is a
         string of characters beginning with a letter, the first eight characters
         are significant.

         Note: The picture to be displayed must exist in the system, i.e. the
               picture was previously either transferred from tape with the
               READ command or it is the result of some picture processing
               operation which was specified in the input mode. The RESERVE
               command only allocates disk space to hold a picture and associ-
               ates a unique name to it. It does, however, not create the pic-
               ture itself.

mode   there are three display modes presently implemented: the display of
         the picture with a certain character representing a greyvalue, the dis-
         play of the histogram of the picture and the display of the information
         in the label associated with the picture. These modes are specified
         by the keywords PICTURE, HISTOGRAM and LABEL respectively.

params   are optional parameters corresponding to a mode.

3.4.1   Picture Display

The picture display is selected by the keyword PICTURE. The size of the screen
of the display device permits the display of 68 characters in a line and 45 lines.
Thus only a portion of a picture can normally be displayed on the screen. Speci-
fication of the parameters for starting line, starting sample and sampling rate
permits, however, to display any portion of a picture. Up to 32 greylevels can
be displayed by different characters.

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The following optional parameters can be specified in any order after the keyword PICTURE:

SL=i   the display is to begin at picture line i (i integer, default: SL=1).

SS=j   the first column to be displayed is picture column j (j integer, default: SS=1).

SAMP=k   the sampling rate for lines and columns is set to k (k integer, default: SAMP=4).

COLSAMP=m   the sampling rate for columns is set to m (default: COLSAMP=4).

LINSAMP=n   the sampling rate for lines is set to n (default: LINSAMP=4).

GREYVAL=$char_1 > n_1, char_2 > n_2, \ldots$ This parameter allows to quantize the picture in up to 32 quantization levels (greylevels). Up to 31 relations $char_i > n_i$ can be specified. Greyvalues from $\emptyset$ to n_1 will appear as blank on the screen, the character $char_1$ will be assigned to greyvalues $> n_1$ and including n_2, $char_2$ will represent greyvalues $> n_2$ and including n_3 etc. The number of quantization levels used for the display is equal to the number or relations specified with the parameter GREYVAL plus one. Default: The range of picture values from $\emptyset$ to 127 is divided into 32 quantization levels each containing 4 greyvalues. Greyvalues from 128 to 255 are displayed as W. (Table 2)

THRESHOLD,n1,n2 the greyvalues $p_i (n_1 \leqslant p_i \leqslant n_2)$ are displayed as the character '0' on the screen. All other greyvalues appear as blank.

RESET   starting line, starting column, sampling rate and character set are reset to their default values.

The system remains in the display picture state and awaits further action by the user. The user can interact with the system by means of the function keys enabled for this state and with the light pen. The enabled keys are lightened. A copy of the display on the screen can be printed on the lineprinter by pressing function key 3 labeled with PRINT.

Numerical Display of Picture Values

It is possible to display the numerical values of a small picture area on the screen. Pointing the light pen firmly onto a character on the screen will display a 10 by 10 array of picture values numerically. The picture element pointed at is the upper left element in the array displayed.

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Table 2

Greyvalue	Character	Greyvalue	Character
0-3	(blank)	64-67	G
4-7	1	68-71	H
8-11	2	72-75	I
12-15	3	76-79	J
16-19	4	80-83	K
20-23	5	84-87	L
24-27	6	88-91	M
28-31	7	92-95	N
32-35	8	96-99	O
36-39	9	100-103	P
40-43	A	104-107	Q
44-47	B	108-111	R
48-51	C	112-115	S
52-55	D	116-119	T
56-59	E	120-123	U
60-63	F	124-255	W

In this state it is possible to modify the values of picture points. The picture element to be modified has to be selected with the light pen. The selection is acknowledged when the cursor appears in front of the number. Now the system is ready to accept the correction which is accomplished by typing the new number on the α-numeric key board. The digit typed in will be inserted at the location of the cursor, the cursor can be moved to the desired position with the space and backspace keys respectively.

The correction of a value has to be terminated by simultaneously pressing the keys labeled with ALT CODING and END. The procedure can be repeated as often as wanted.

NOTE: The pixel modification procedure described above is presently only implemented for pictures whose size does not exceed 200 lines or 200 columns. These pictures are entirely maintained in core.

A modified picture is flagged and upon issuing the next DISPLAY command with a different picture name the message, 'A PICTURE IS ALREADY IN CORE AND WAS MODIFIED - WANT TO SAVE IT?' will be displayed on the screen. The user can now save the modified picture by using the SAVE command or he repeats the DISPLAY command in which case the modified picture will be overlaid by the picture referenced in the command.

The system remains in this state until the user points with the light pen to the asterisk displayed in the following message on the screen:

' HIT * TO CONTINUE '

Upon pointing to the asterisk the system returns into the display picture mode.

Return to the dialogue mode in which further commands can be issued is accomplished by pressing key 8, labeled with CONTINUE.

Examples:

1. DISPLAY ERTS.MS7 PICTURE

   The picture ERTS.MS7 is displayed on the screen using the default character set from Table 2 (32 greylevels). The display starts at line 1 and column 1 and every 4th line and column is displayed (default: SAMP=4).

2. D ERTS.MS7 PICTURE SL=100 SS=50 SAMP=1

   An area of the picture ERTS.MS7 starting at line 100 and column 50 is displayed with the default character set. Every picture point is displayed. The command can be abbreviated with a D.

3. D ERTS.MS7 PICTURE QUANT=.$>$10,*$>$20,%$>$30,$\$>$40

   The same area of picture ERTS.MS7 as in example 2, is displayed with 5 different greylevels. Picture values$\leqslant$10 will appear as blank, values $>$10 and $\leqslant$20 will be represented by a dot, values $>$20 and $\leqslant$30 by an asterisk etc.

   NOTE: The changed parameter values will not be automatically set back to their default values until after an EXECUTE command. Therefore, the same area of the picture with the same sampling rate is displayed in example 3 as in example 2.

3.4.2 Histogram Display

The histogram display is selected by the keyword HISTOGRAM. The histogram of the picture specified is computed and displayed on the screen as well as mean and standard deviation. Use of the parameters for starting line, starting column, number of lines and number of columns permits to display the histogram of any area of the picture.

The following optional parameters can be specified in any order after the keyword HISTOGRAM:

SL=i   the first picture line to be included in the calculation of the histogram is line i (default: SL=1).

SS=j   the first picture column to be included in the calculation of the histogram is column j (default: SS=1).

NL=m the histogram is computed for m lines starting with line SL. (default: NL=total number of lines in the picture).

NS=n the histogram is computed for n columns starting with column SS. (default: NS=total number of columns in the picture).

If the parameters are omitted, the histogram of the full picture will be computed and displayed on the screen.

The system remains in the display histogram state and waits for further action from the user. The user can interact with the system by means of the function keys enabled for this state. These keys are lightened.

The histogram displayed is normalized with the available width of the screen, thus the maximum frequency will be represented by 53 characters (asterisks). If the histogram is too large in the direction of the greyvalues to be displayed completely on the screen it can be shifted by means of function keys. Pressing key 12, labeled with UP, will shift the histogram upwards by 4 greyvalues, pressing key 24, labeled DOWN, will shift the histogram downwards by 4 greylevels.

Pressing key 17, labeled SHRINK, will each time apply a threshold of 1/53 of the maximum frequency for the display, i.e. only values of the histogram above this threshold will be displayed on the screen after having pressed this key. Consequently the histogram can be shrunk to its dominant values by repeatedly pressing key 17.

A copy of the display on the screen can be printed on the lineprinter by pressing key 20, labeled with PRINT.

Return to the dialogue mode in which further commands can be issued is accomplished by pressing key 18, labeled with CONTINUE.

    Examples:

1. DISPLAY ERTS.MS7 HISTOGRAM

    The histogram of the full picture ERTS.MS7 is computed and displayed.

2. D ERTS.MS7 HISTOGRAM SL=100 SS=50 NL=64 NS=64

> The histogram of a 64 by 64 area starting at line 100 and column 50 of picture ERTS.MS7 is computed and displayed.

The calculation of the histogram includes normally all greyvalues in the range from $\emptyset$ to 255. It is, however, possible to exclude greyvalues above an upper bound and below a lower bound from the histogram. This can be accomplished by changing the parameters GREYMAX and GREYMIN with the SET command.

In order to redisplay the histogram of the same picture area with respect to the changed values of GREYMAX and GREYMIN the keyword SAME should be used instead of the picture name. This will save the time for the computation of the frequencies of the greyvalues, for only mean and standard deviation have to be recomputed if the same area of the picture is used.

> Example:

DISPLAY SAME HISTOGRAM

3.4.3 Label Information Display

The information contained in the first two 360 bytes labels of the picture can be displayed by use of the keyword LABEL. This will also show the size of the picture. There are no parameters for this option.

> Example:

DISPLAY ERTS.MS5 LABEL

The label information and size of the picture named ERTS.MS5 is displayed on the screen.

3.5 SET

The SET command is used to change the default values of various parameters in the system.

> Format:

SET [, NGREY=n, GREYVAL=char$_1$ > n$_1$, char$_2$ > n$_2$, GREYMIN=i, GREYMAX=j,
> BIAS=m, SL=i, SS=j, SAMP=k]

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Any of these parameter keywords can be used in any order.

NGREY=n the number of greylevels used for the next picture display is set to n, i.e. the first n relations are taken from the default character set given in Table 2. The number of greylevels is also changed by the GREYVAL parameter in the DISPLAY, name, PICTURE command and by the GREYVAL parameter in the SET command.

GREYVAL=$char_1 > n_1$, $char_2 > n_2$,... up to 31 relations $char_i > n_i$ can be specified to set the different greylevels. Greyvalues from $\emptyset$ to n_1, will appear as blank on the screen, the character $char_1$ will be assigned to greyvalues $> n_1$ and including n_2, $char_2$ will represent greyvalues $> n_2$ and including n_3 etc.

GREYMIN=i the smallest greyvalue which is included in the computation of the histogram in the DISPLAY name HISTOGRAM command is set to i (default: GREYMIN=$\emptyset$).

GREYMAX=j the largest greyvalue which is included in the computation of the histogram in the DISPLAY name HISTOGRAM command is set to j (default: GREYMAX=255).

BIAS=m if the digital values of each picture point are reduced by m to make them <256 on the input tape, then BIAS=m has to be specified to correct for this subtraction (default: BIAS=$\emptyset$).

SL=i the first line to be displayed is line i (default: SL=1).

SS=j the first column to be displayed is column j (default: SS=1).

SAMP=k the sampling rate for lines and columns is set to k (default: SAMP=4).

3.6 SAVE

The SAVE command is used to transfer a picture which is in core (a picture with number of lines ≤200 and number of columns ≤200) to disk. The disk area to receive the picture must have been previously allocated with the RESERVE command.

Format:

SAVE, name

name is the name of a picture defined with the RESERVE command. It is a string of characters beginning with a letter, the first eight characters are significant. The saved picture can then be referenced by this name.

3.7 THRESHOLD

The THRESHOLD command is used to create a thresholded picture from a given input picture or a part of it. The new picture is generated by using the current values of the parameters SL, SS, LINESAMP, COLSAMP, and GREYVAL. These parameters may have their default values or the values assigned by the DISPLAY or SET commands.

Format:

THRESHOLD, iname, oname, [, NS=m, NL=n]

iname is the name of the original picture

oname is the reserved name of the picture to be generated

NS=m specifies the number of columns in the output picture (default: the number of columns is determined by the size of the input picture, the starting columns SS and the sampling rate COLSAMP).

NL=n specifies the number of lines in the output picture (default: the number of lines is determined by the size of the input picture, the starting line SL and the sampling rate LINESAMP).

3.8 TASKS

The TASKS command displays the image processing tasks specified in the input mode which are waiting in the task queue for execution. Execution can be started at any time with the EXECUTE command.

3.9 EXECUTE

The EXECUTE command starts the execution of all the image processing tasks which have been previously specified in the input mode and are held in the task queue.

3.10 FREE

The FREE command is used to release a reserved picture name. The command is also useful for changing the line length of a picture in which case the FREE command will be followed by a RESERVE command with the same picture name but a different line length parameter NS.

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3.11 EXIT

The EXIT command terminates processing and disconnects the display terminal from the main computer.

3.12 DISCONNECT

The DISCONNECT command disconnects the display terminal from the main computer but starts execution of the image processing tasks which are still in the task queue. Upon completion of the last task processing is terminated.

4. INPUT MODE

The input mode is entered by pressing key 10 which is labeled with INPUT. Each image processing task specified in this mode involves later execution of a program which must exist in the systems library (JOBLIB). If a task name which is not in the library is specified, a message will be displayed and the user will check the existence or a possible misspelling of the name with the list in section 6 of this manual. Errors in specification of the input and output pictures, the size of the output picture and the parameter and label information for the program involved will be detected and indicated by an appropriate message on the screen. After each such message the system waits for further input from the user.

4.1 FORMAT OF TASK SPECIFICATION

The format for specification of image processing tasks is very similar to the format of the EXEC command in the VICAR system to assure compatibility with this system. In fact any image processing function contained in the library of the VICAR system on the SESD-75 computer can be executed.

The task specification statement defines a task, its input and output pictures and the parameters required as well as label information. The statement contains up to six fields. Fields are separated by commas. A field consists of one to ten subfields. Subfields are also separated by commas. If a field includes more than one subfield the field must be enclosed in parentheses.

Parentheses may be used if the field consists of only a single sub-field. Fields and sub-fields may be surrounded by blanks. Except where explicitly specified, sub-fields are limited to eight characters.

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Certain statements permit a field or fields to be defaulted (not coded). If there are additional fields, the defaulted field must be indicated by coding a comma.

Brackets [ ] indicate that the field or sub-field is optional. Default parameters are indicated in the text.

Braces { } indicate that a choice must be made from the optional parameters indicated.

Format:

$$
\text{tname,} \quad
\begin{bmatrix} \begin{Bmatrix} \text{b} \\ \text{(name1, name2, --)} \end{Bmatrix} \end{bmatrix}
\begin{bmatrix} \begin{Bmatrix} \text{,} \quad \text{b} \\ \text{(name1, name2, --)} \end{Bmatrix} \end{bmatrix}
$$

$$
\begin{bmatrix} \begin{Bmatrix} \text{(sl, ss, nl, ns)} \\ \text{,} \\ \text{(SL=sl, SS=ss, NL=nl, NS=ns)} \end{Bmatrix} \end{bmatrix}
$$

[, (param1, param2, --)] [, (label1, label2, --)]

Field	Contents
1	tname is the name of the program to be queued for execution. If the first character in the program name is the character 'V', automatic label processing is suppressed. The system will not write a system or user label on any of the output data sets. In this case, the program itself must write any required system or user labels.
2	Input picture field name1, name2, --are names of pictures (data sets) to be used as parallel input for the task. Up to 10 input pictures can be specified for one task. The picture names should be defined previously with the RESERVE command. If no input picture is needed the field must nevertheless be indicated by a comma. A blank b indicates that the task has no input pictures.
3	Output picture field name1, name2, ---are names of the output pictures for the task. Up to four names which have to be reserved previously can be specified. A blank indicates that the task has no output pictures.

4   Output size field

(sl, ss, nl, ns) describe the size of the output pictures. If required, all four parameters must be coded as shown. (SL=sl, SS=ss, NL=nl, NS=ns) Any or all of the size parameters may also be specified in keyword format as shown. When keywords are used, any or all four parameters may be coded and the order is of no significance.

5   Parameter field

The parameter field places no restriction on the number of parameter subfields except that no subfield may contain more than 68 characters. If there is more than one subfield, the field must be enclosed in parentheses and the subfields must be separated by a comma.

6   Label field

This field allows for label specification or changing of labels. The label field may contain up to five subfields. If the first subfield is the word RELABEL, then the output picture will be relabeled with the labels in the following subfields. Otherwise, each subfield specifies a label to be added to the output picture. Each label must be less than 69 characters. When a label contains special characters (blank, comma, etc.) it must be enclosed in apostrophes. A double apostrophe is used to represent a single apostrophe within a label.

When a label field contains more than one subfield, the entire field must be enclosed in parentheses and the subfields are separated by commas.

5.   OPERATIONAL PROCEDURE

Picture data have to be on magnetic tape in the standard format described in section 2.3 for processing with the SMIP System. The user should make sure that the tapes he wants to use are in the appropriate slots and that all output tapes have the ring in.

Pictures transferred to or created in the system will be stored on the scratch disks listed in section 3.1. Since these disks are scratched every morning at the beginning of the dayshift it is only possible to hold pictures in the system for one day. Therefore, it is necessary to allocate the disk space used to accommodate the picture data every morning prior to using the system. The allocation is done as a separate job which can be submitted from a CRBE terminal on the IBM 360/75 computer in the following way:

```
Submit XXX
= s0jgm.allocate
  endinput
```

The JCL for this job is listed in Appendix A. Upon successful completion of this job SMIPS can be used.

The SMIP System runs as a job on the SESD 360/75 computer. To submit this job on a CRBE terminal use:

    submit XX$, time
    = s0jgm.image
    endinput

The JCL necessary to use SMIP is contained in the CRBE file s0jgm.image and is listed in Appendix B.

The $ sign in the job identifier means that the system can run in LCS. CPU execution time in LCS is 5 to 8 times greater than in high speed core. Because of the impact of an interactive program on total system performance it is, however, preferable to run SMIPS in the less valuable LCS. An exception can be made (submit without $ sign) if the user plans to execute image processing programs which are very CPU-bound like convolution filtering (FILTER, FASTFIL2, --) and generation of color pictures (FOTO).

The time parameter allows for specification of CPU and I/O time. It should be a string of 6 characters, the first 3 being the CPU time in minutes, the second 3 the I/O time which the SMIP-System will be allowed to use. Specification of half minute estimates is possible if the first character in each group is an H.

        Example:

Submit 11$,H02H01

In this example, the system will be allowed to use 2-1/2 minutes CPU time and 1-1/2 minutes I/O time.

The maximum time request allowed during the prime shift is 5 minutes (sum of CPU and I/O time). After the prime shift higher time estimates can be specified. The default values in IMAGE are: CPU time = 2-1/2 minutes, I/O time = 2-1/2 minutes.

The submitted job (the SMIP-System) is put on the hold queue of the operating system until the user requests its release from the operator. The user has to go to the computer room in the basement of Building 1 to the IBM 2250 Display Unit and put the Enable Switch in the enabled position (Fig. 2). The alphameric keyboard is shown in Fig. 3, the programmed function keyboard with the corresponding overlay in Fig. 4.
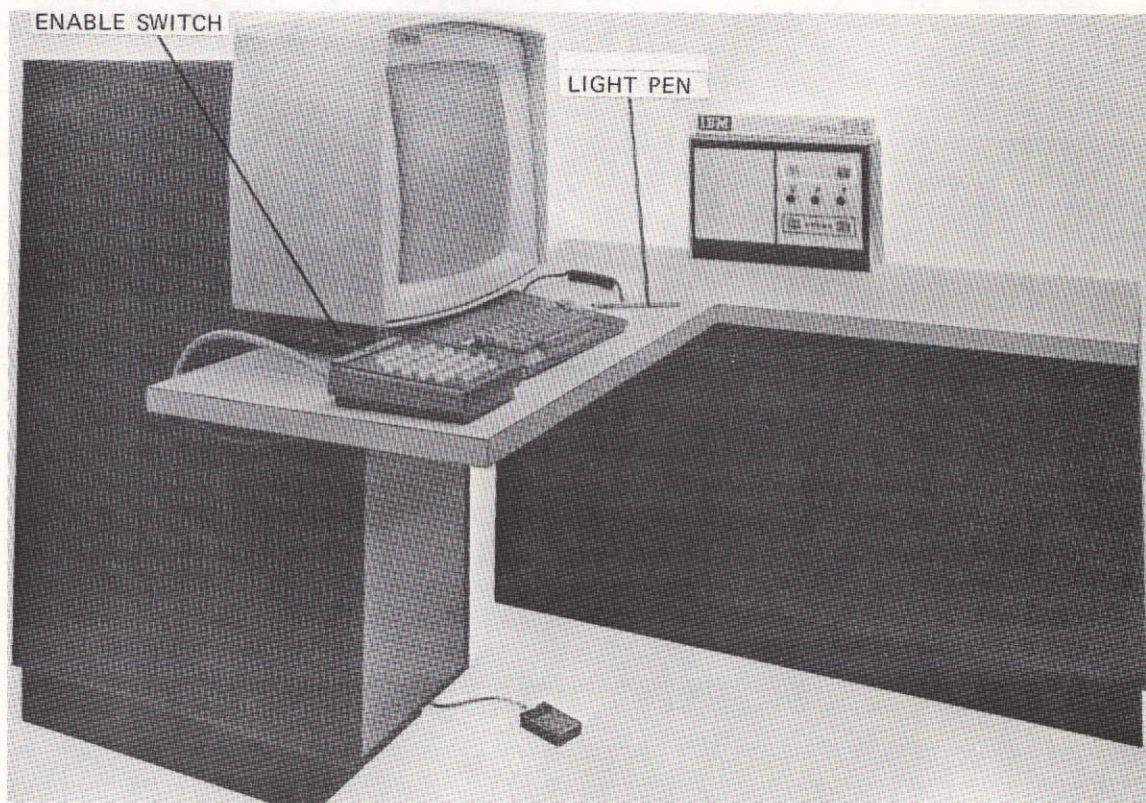
ENABLE SWITCH

LIGHT PEN

Figure 2.

This page is reproduced at the back of the report by a different reproduction method to provide better detail.
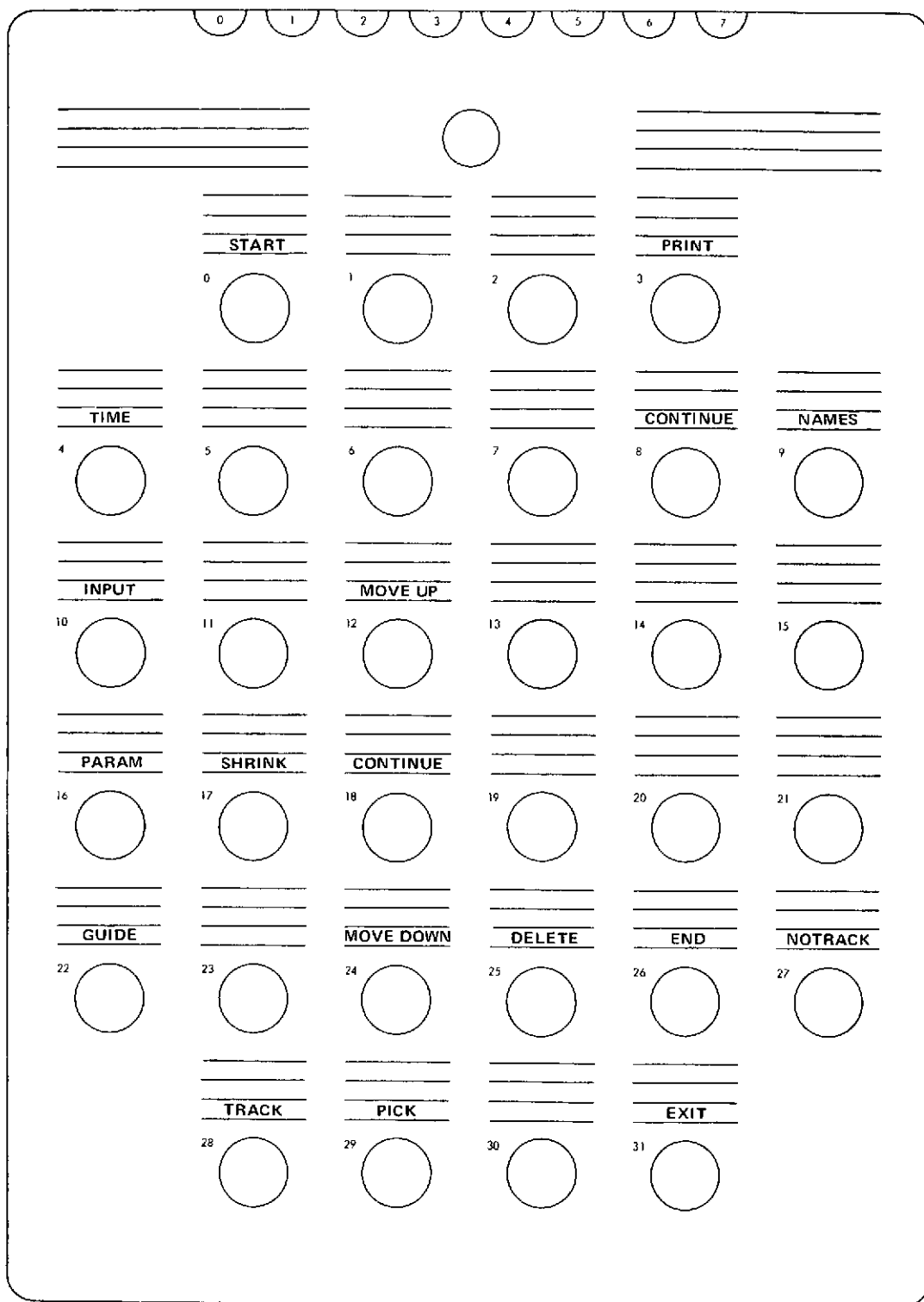

Figure 3. Alpameric Keyboard

0 1 2 3 4 5 6 7

START

PRINT

0   1   2   3

TIME   CONTINUE   NAMES

4   5   6   7   8   9

INPUT   MOVE UP

10   11   12   13   14   15

PARAM   SHRINK   CONTINUE

16   17   18   19   20   21

GUIDE   MOVE DOWN   DELETE   END   NOTRACK

22   23   24   25   26   27

TRACK   PICK   EXIT

28   29   30   31

Figure 4. Programmed Function Keyboard Overlay for SMIPS

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The user will then ask the computer operator to release the submitted job from the hold queue. The operator should also check if a G-INITIATOR is active. If not, the operator has to start a G-INITIATOR from his console with the command.

S INIT.G,,,G

The SMIPS user will then go back to the IBM 2250 display unit and wait until the first display appears on the screen. The first display is a brief description of operation and commands of the system (Fig. 5). To continue operation press key 0 labeled with START. The next display which will appear on the screen is shown in Figure 6.

Figure 5.

Figure 6.

NOT REPRODUCIBLE

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This display is a table of all picture names used in the system, the name of the disk volumes available and the size of the areas on each to accommodate picture data as well as reserved line length for a picture. Up to 15 pictures can reside in the system at the same time in the present implementation.

If no picture exists in the system (as at the first session on a day) the column for picture names will be empty and the message '**NO PICTURE IN SYSTEM - READ FROM TAPE' indicates that the user has to create picture names and to allocate space for pictures with the RESERVE command. Then he can transfer picture data from magnetic tape into the system using the READ command. If pictures exist in the system from a preceeding session their name will be displayed in the table and the user can immediately use them.

At any time key 9, labeled with NAMES, can be pressed which will display the current state of the system. There are two attributes associated with a picture name. The appearance of only the name in a line of the display means that the name has been reserved and space is allocated for a picture. There are, however, no picture data associated with the picture name. The attribute ON DISK indicates that picture data exist on the disk and can be referenced by the picture name. This attribute is set after successful completion of a READ command or after creation of a picture as output of an image processing program. The attribute IN CORE indicates that a copy of the picture exists also in core. This is only possible for pictures smaller than 200 lines by 200 columns.

The user should periodically check the remaining time for the session in order to avoid the abrupt termination of the run due to time-out. In this case all data in the system would be lost. Pressing key 4 labeled TIME will display the remaining CPU and I/O time.

Depressing key 16 labeled PARAM will display the current values of various system parameters (Fig. 7). Some of them can be changed with the SET command. NGREY is the number of greylevels used, SCOL the starting column, SLINE the starting line, COLSAMP and LINSAMP are the sampling rates for columns and lines, GREYMAX and GREYMIN represent the largest and the smallest greyvalue included in the computation of the histogram. LARGE=0 indicates that the last picture displayed was not larger than 200 lines by 200 columns. LARGE$\neq$0 means the picture was larger than 200 lines by 200 columns. MODFLAG=0 indicates that the last picture displayed has not been modified. TRACE is only used for debugging purposes.

Pressing key 22 labeled GUIDE will redisplay the brief users guide, normal operation can then be resumed by pressing key 0.
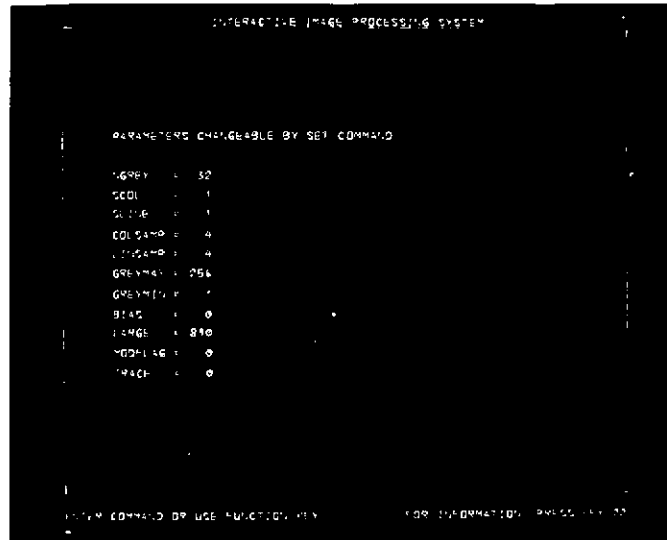
Figure 7.

Specification of Image Processing Tasks

Image Processing Tasks are specified in the input mode. Pressing the INPUT key transfers the system into the input mode and the message: 'INPUT MODE ENTERED: TYPE IN PICTURE PROCESSING FUNCTIONS' displayed in the lower left corner of the screen indicates that the system is ready to accept task specifications (see section 4). The termination of a task specification statement is achieved by the simultaneous depression of the ALTN CODING and END keys. It is then necessary to wait for the audible alarm and the reappearance of the cursor in the lower left corner before the next statement can be entered. The statements are displayed as shown in Figure 8.

If a taskname specified is not contained in the SMIPS-library the message: 'taskname NOT IN LIBRARY' will be displayed and the user can correct his input. The END command terminates the input mode and returns the system to the dialogue mode which is indicated by the message: 'INPUT MODE LEFT, CONTINUE DIALOGUE'. The user can now continue with the dialogue and at any time he can check which tasks are waiting for execution in the task queue by issuing the command TASKS. The EXECUTE command will start execution of the waiting tasks. Execution is indicated by the message: 'TASK(S) SPECIFIED BEING PROCESSED - WAIT FOR AUDIBLE ALARM'. The user has to wait until execution of all tasks is completed. Successful completion of each task will be indicated by an appropriate message. Upon completion of the last task the audible alarm and appearance of a cursor in the lower left corner of the screen notify the user that he may continue with the interaction. An error

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Figure 8.

condition encountered during execution of a task terminates the execution, an appropriate error message is displayed and the user has to correct the specification. All tasks following the one with the error are lost and must be specified again.

Table 3 lists the function keys which are used for utility purposes.

Table 3

KEY	LABEL	MEANING
0	START	Start on restart operation
4	TIME	Display remaining time
9	NAMES	Display state of system
10	INPUT	Enter input mode
16	PARAM	Display system parameters
22	GUIDE	Display users guide
28	TRACK	Enter light pen tracking mode
31	EXIT	Terminate processing (equivalent to EXIT command)

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6. IMAGE PROCESSING PROGRAMS

This chapter describes the image processing programs contained in the SMIPS library. The programs have been written during implementation of the system or they are modifications of VICAR programs. Furthermore all programs contained in the library of the VICAR system can be used. These programs, however, have no automatic error recovery and will abnormally terminate and crash SMIPS in case of an error (e.g. wrong input parameters). The VICAR programs are described in the Jet Propulsion Laboratory Publication "IPL Program Modifications," Ref. 324-IPG/1364, January 1, 1971.

CONCAT

Purpose:

To combine up to ten pictures into a single picture.

General Description:

CONCAT allows up to ten input pictures of the same size to be combined into a single picture. The size parameters NL and NS are used to calculate the arrangement of the input pictures in the output picture. This program was adopted from the VICAR library.

Usage:

CONCAT, (X1, X2, ---, Xn), OUT, (NL = k, NS = m)

X1, X2, Xn are one to ten input pictures to be combined into one output picture. They must be in order of usage.

OUT is the name of the output picture. CONCAT will fill in 128 when required to complete a rectangle.

NL = k k(integer) represents the number of lines of the combination.

NS = m m(integer) represents the number of points in a line of the combination.

Example:

CONCAT, (X1, X3, X5, X2, X4, X6), OUT, (NS = 600, NL = 400)

Six pictures 200 by 200 are to be combined in a 400 lines by 600 points/line picture as shown in the figure below.

X1	X3	X5
X2	X4	X6

DIFFPIC

Purpose:

To compute the difference or sum of two pictures.

General Description:

The program computes the difference or sum of two pictures which may be linearly displaced from each other, and scales the resultant picture according to user specifications. This program has been adapted from the VICAR library.

Usage:

DIFFPIC, (IN1, IN2), OUT, (SL, SS, NL, NS), PARAMS

IN1 and IN2 are the names of the input pictures

OUT is the name assigned to the difference or sum picture.

SL, SS, NL, NS describe the size of the output picture. When the input pictures are displaced, SL should refer to the picture whose line coordinate is the minimum of SL1 and SL2 and SS should refer to the picture whose sample coordinate is the minimum of SS1 and SS2.

Displacement of the input pictures always causes a reduction in the size of the output picture. If the reduced size is smaller than the size given by NL and NS, DIFFPIC will produce the smaller size picture and will change the system label accordingly.

PARAMS There are three groups of parameters, any of which may be defaulted. If any groups are specified, the groups must appear in the sequence shown below, i.e., group 1 must precede group 2 or 3, etc.

Group 1:

SL1, SS1, SL2, SS2 where SL1 and SS1 are the fixed point line and sample coordinates in picture 1 (first input data set) of a point corresponding to the point at SL2, SS2 in picture 2 (second input data set). These parameters allow a relative translation between pictures 1 and 2 before differencing. (Default = 1,1,1,1)

Group 2:

NMIN, NMAX where these fixed point parameters define a linear transformation applied to the differences or sums before storage in the output picture. For two input pictures, each with an intensity range of 0 to 255, the pixel differences can range from -255 to 255 and the pixel sums from 0 to 510. This linear transformation allows these large resulting ranges to be packed into the output range 0 to 255 as desired. If S is a difference or a sum

$$OUTPUT = 255* (S-NMIN)/(NMAX-NMIN)$$
$$S = NMIN \text{ becomes } OUTPUT = 0$$
$$S = NMAX \text{ becomes } OUTPUT = 255$$

(Default: NMIN = -128, NMAX = 127)

Group 3:

DIFF or ADD where these keywords cause picture 2 (second input data set) to be subtracted or added respectively to picture 1. (first input data set). (Default = DIFF)

These parameter groups must appear in the basic order:

Group 1, Group 2, Group 3

Any or all of the groups may be omitted.

FILTER

Purpose:

To perform two-dimensional convolution filtering.

General Description:

The program computes for each output sample a weighted average of a rectangular set of input pixel followed by a linear transformation. FILTER may be used to perform high pass (correction for blurring) or low pass (removal of glare) filtering. Other desired changes, such as enchancement or elimination of frequencies around a given value can also be performed. Before FILTER can be used, a proper set of weights must be generated for the desired filtering action. These weights can be generated with the Filter Weight Generator Program WTGEN.

Usage:

FILTER, IN, OUT, (SL, SS, NL, NS), PARAMS

IN is the name of the picture which is to be filtered.

OUT is the name which will be given to the filtered output picture.

SL, SS, NL, NS describe the section of the input picture to be filtered.

PARAMS are optional parameters. They are position independent with the restriction that if NLW and/or NSW are used, they must appear in the parameter list prior to the keyword WEIGHTS. The keywords and their associated values are:

NLW = M specifies the number of lines of weights. M must be an odd integer (Default: NLW = 7).

NSW = N specifies the number of points in each line of the filter. N must be an odd integer (Default: NSW = 7).

WEIGHTS = W_1, W_2, . . . , W_k This keyword is followed by k=(M+1). (N+1)/4 integers representing the upper left quadrant of a four-way symmetric filter matrix. W_i must be less than 32768 in absolute value. (Default is a 7 x 7 symmetric high emphasis filter with the

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transfer function shown below. The default filter weights are: 28, 5, -42, -67, 5, -98, -235, -300, -42, -235, -466, -571, -67, -300, -571, 10000).
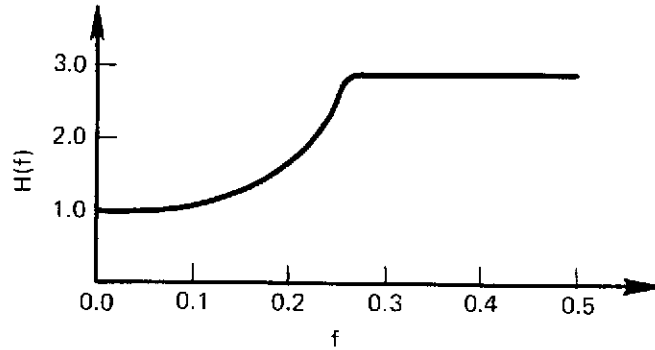
SCALE = A, B this keyword specifies the application of the linear transformation (2) to each output picture point G(k, 1). (Default: A=0, B=1).

DIVIDE = D D is used in the transformation (2). It will be generated by the filter weight generation program WTGEN. (Default: the sum of the weight table entries is used, if this is zero, then D is set to 1).

Mathematical Formulation:

FILTER performs the convolution of a picture with a rectangular set of weights, appropriate to the filtering task. FILTER calculates each output point $G(k,\ell)$ from the input picture F in the following way:

$$G(k,\ell) = \sum_{i=1}^{M} \sum_{j=1}^{N} F(k - \frac{M+1}{2} + i, \ell - \frac{N+1}{2} + j) \cdot W(i,j) \qquad (1)$$

$$k = SL, SL + 1, ----, SL + NL$$

$$\ell = SS, SS + 1, ----, SS + NS$$

W is the M by N filter weight matrix. The final output picture is scaled as follows:

$$GF(k,\ell) = A + B \frac{G(k,\ell)}{D} \qquad (2)$$

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where A, B and D are the constants determined by the parameters SCALE and DIVIDE respectively.

Examples:

FILTER, IN, OUT
The picture IN will be filtered with the default high-pass filter.

FILTER, IN, OUT, (50, 100, 256, 256), (NLW=7, NSW=7, WEIGHTS=-159, 179, 445, 413, 179, 265, -921, -1265, 445, -921, 263, 3964, 413, -1265, 3964, 10000, DIVIDE = 21547)

A 256 by 256 area of the picture IN, starting at line 50 and column 100, will be filtered with a 7 by 7 low pass filter. The filter weights can be generated with the program WTGEN. The spectral response of the symmetric filter is shown below.
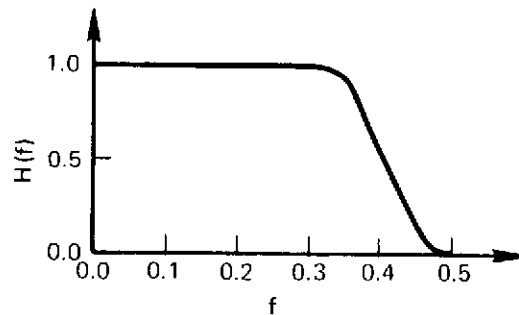
FOTO - Color or black and white photo generation

Purpose:

To produce a tape in the format suitable for the E. I. S. (Electronics Imaging Systems) machine for generation of black and white or color polaroid or negative film for print.

General Description:

The program reads input picture and parameters and selects depending on the specified size of the output picture one of the 4 picture formats for the E. I. S. machine (i. e. 1024x300, 2048x600, 4096x1200, 8192x2400). It generates the characters for the annotation lines, sets the aspect ratio and computes the color codes for the range of intensity values using a table derived from the input parameters.

Shrinking or magnifying the input picture is optional, as well as writing such a modified picture to an output data set. The color codes correspond to contrast tape #9 for color pictures, for black and white polaroids contrast tape #13 should be used at the E. I. S. machine. Zero values will be displayed as black, values from MAXVALUE to 255 as white.

Usage:

    FOTO, IN, OUT, (SL, SS, NL, NS), (PARAMS)

    IN   Name of the input picture.

    OUT Name of the output picture in which the shrunk or magnified picture
    is to be written. If the SIZE parameter is omitted and OUT is specified,
    IN is simply copied to OUT. OUT should only be specified if a modification
    of the input picture is wanted.

    SL, SS, NL, NS describe the section of the input picture to be processed.

    PARAMS are the parameters specified by keywords in any order:

        TAPE = volser, where volser is the volume serial number of a 7-track
        tape on which the picture is to be written. This tape is then processed
        off-line on the E. I. S. machine.

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TYPE = ERTS - to correct the respect ratio of ERTS-MSS pictures by 3:2. The aspect ratio of an ERTS-MSS frame is 13:18. (Default = 1:1).

MAXVALUE = N, where N (integer) is the maximum value in the table used to calculate color codes and grey or color scale. (Default = 255)

DELTA = N, where N (integer) is the decrement used to build the table for the color or grey scale starting with MAXVALUE (Default = 14)

NCOLOR = N, where N$\leqslant$18 (integer) is the number of grey or color levels used for the table (Default = 18)

SIZE: NL = M, NS = N, where M and N are integer used for magnifying or shrinking the picture if M$\neq$NL and N$\neq$NS (NL, NS from size field). Magnification is accomplished by linear interpolation, shrinking by deletion of lines and columns (Default: no magnification or shrinking is done).

COLORS: COL = K, L, COL = M,N, ----
Where COL is a color code word from the following list and K, L and M,N are pairs of integers limiting the range of picture values to which the color COL is to be assigned. The color names can be specified in any order. Up to 18 colors can be specified.

Color Names: BLACK, PURPLE, MAROON, PINK, RED, ORANGE, BEIGE, BROWN, YELLOW, DYELLOW (dark yellow), CREAM, PGREEN (pale green), OGREEN (olive green), MGREEN (medium green), DGREEN (dark green), LBLUE (light blue) MBLUE (medium blue), DBLUE (dark blue), GRAY, WHITE.

If COLORS is used NCOLOR is determined by the number of color names specified and MAXVALUE and DELTA are ignored.

TEXT1 = ' line 1 '
TEXT2 = ' line 2 '
Line 1 and line 2 are strings of characters enclosed by quotes used for picture annotation. TEXT1 or TEXT2 or both can be omitted.

Examples:

FOTO, IN,*, (1,1, 500,700), (TAPE = Z9999, MAXVALUE = 127, DELTA = 6, TEXT1 = ' one line of annotation')

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A photo of size 500x700 with a grey or color scale of 18 levels with a decrement of 6 starting at value 127 is generated on tape Z9999.

    FOTO, IN,*,*,(TAPE = Z9999, TYPE = ERTS,

    COLORS: YELLOW = 0,30, RED = 31,60, GREEN = 61,90,

    BLUE = 91,127, Black = 128,255, TEXT1 = 'ASPECT RATIO CORRECTION

    FOR ERTS-MSS PICTURE ', TEXT2 = 'FIVE COLORS USED')

A photo with 2 annotation lines (text from parameters TEXT1 and TEXT2 is generated on tape Z9999. A color scale with 5 colors assigned to the digital numbers as specified in the parameter COLORS is used.

FOURIER2

Purpose:

To compute the direct and inverse two-dimensional fast Fourier-transformations of real image-like data.

General Description:

The input data must have vertical and horizontal dimensions of two. For a direct transform, the input may be in byte, halfword, fullword or complex format and the output will be complex. For an inverse transform, the input must be complex while the output can be in byte, halfword, fullword or complex format. For the inverse transform with byte or halfword output, the transform is computed in complex form and the real part is extracted for output. In byte format, a number less than 0 is set to 0 and a number greater than 255 is set to 255. In halfword format, a number less than -32768 is set to -32768 and a number greater than 32767 is set to 32767. For a complex inverse transform, the computed transform is written in full COMPLEX format. For a direct transform, the SIZE field in the task specification statement is used to determine the area of an input picture to be processed. The maximum size of an input picture in the current implementation is 256 by 256 picture elements. For an inverse transform, the size of the transform is determined from the label, the input being assumed to be a properly formatted complex transform which is to be inverted. If for a direct transform the requested size exceeds the available input data, the input will be padded on the right and bottom with zeros.

Frequency Space Organization and Phase Conventions:

The direct two-dimensional transform of a picture is an array of COMPLEX*8 numbers, each one giving the real and imaginary spectral components of the picture at a corresponding two-dimensional spatial frequency. The correspondence between spatial frequency components and line and sample coordinates in the Fourier-transform array is defined as follows. The discrete transform pair used in the program is

$$G_{k\ell} = \frac{1}{N} \sum_{m=0}^{M-1} \sum_{n=0}^{N-1} F_{mn} e^{-2\pi i[km/M + \ln/N]}$$

$$F_{mn} = \frac{1}{M} \sum_{k=0}^{M-1} \sum_{\ell=0}^{N-1} G_{kl} e^{2\pi i[km/M + \ln/N]}$$

where F_{mn} is the input picture matrix (m is the column coordinate and n is the line coordinate), G_{kl} is the two-dimensional transform matrix (k is the column and l is the line coordinate), M is the horizontal transform size and N is the vertical transform size. Both M and N are powers of two and the coordinates (k,l) and (m,n) are defined so that (0,0) is the upper left corner of each matrix. Clearly G_{kl} and F_{mn} are periodic with horizontal period M and vertical period N. The real plane on which the input picture is defined can be thought of as covered with a periodic lattice, each cell of which is the input picture.
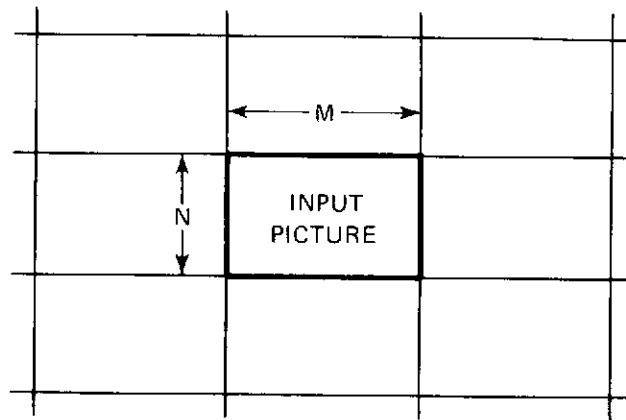
The transform plane can similarly be considered as a periodic lattice of transform functions.
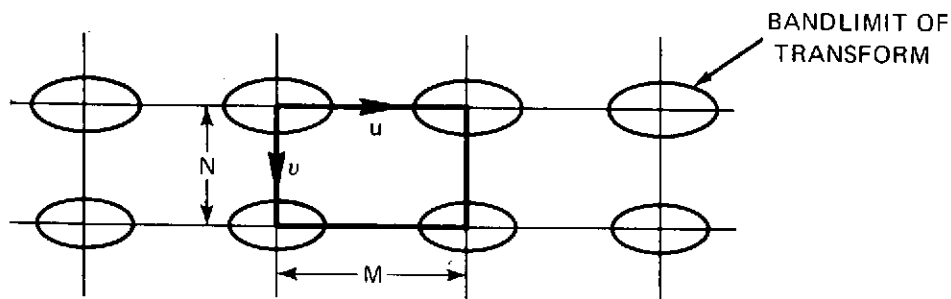
The transform matrix computed is outlined as a solid rectangle M by N on this lattice. The dc component appears, thus, in the upper left corner of the matrix. The other corners of the transform matrix include the various quadrants of the frequency space.

The phase origin of the transform is defined to be the upper left hand corner (m=0, n=0) of the input picture. This means that if the upper left corner is a point of central symmetry in the real space lattice, then the resulting transform

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will be pure real. If the upper left corner is a point of central anti-symmetry, the complex transform will be pure imaginary.

Usage:

FOURIER2, IN, OUT, (SL, SS, NL, NS), PARAMS

IN   1. for a direct transform, IN is the name of a byte, halfword, fullword or complex picture to be transformed.

    2. for an inverse transform, IN is a complex Fourier-transform matrix as described above.

OUT   is the name to be assigned to the transformed image. If the transform has a horizontal size $M=2^m$ and a vertical size $N=2^n$, then

    1. for a direct transform, OUT must have been previously allocated by the RESERVE command with NS=8xM and NL=N+3.

    2. for an inverse transform, OUT must be reserved previously with NL=N+3 and NS=M for output in byte format, NS=2xM for halfword, NS=4xM for fullword and NS=8xM for complex output.

SL, SS, NL, NS

    1. describe for the direct transform the section of the input picture to be transformed. These parameters refer to bytes for all input formats.

    2. not specified for an inverse transform.

PARAMS   are optional parameters specified by position independent keywords:

POWX=M   specifies the horizontal size 2^M of a direct transform by a power of two. The size is currently limited such that $3 \leqslant M \leqslant 8$. This parameter is ignored for inverse transforms. (Default: POWX=8).

POWY=N   specifies the vertical size 2^N of a direct transform by a power of two. The size is limited such that $3 \leqslant N \leqslant 8$. This parameter is ignored for inverse transforms. (Default: POWY=8).

POW=M   specifies the horizontal and vertical size of a direct transform
for a square picture by a power of two. The horizontal size
is 2^M and the vertical size is 2^M. The size is limited such
that $3 \leqslant M \leqslant 8$.

INVERSE   specifies an inverse transform. The input is assumed to be
a properly organized COMPLEX*8 transform.

IFMT=BYTE   the input format of a pixel is a byte,

=HALF   a halfword,

=FIX   an integer fullword,

=FLOAT   a real fullword or

=COMP   a complex value

(Default: IFMT=BYTE for a direct transform, IFMT=COMP for an
inverse transform. IFMT other than COMP for an inverse transform
will result in an error.)

OFMT=BYTE   (or HALF, FIX, FLOAT COMP) specifies the output for-
mat of a pixel. (Default: OFMT=COMP for a direct
transform, OFMT=BYTE for an inverse transform.
OFMT other than COMP for a direct transform will re-
sult in an error.)

Restrictions:

The pictures IN and OUT should not be reserved on the disk volume K3SCR6
since the data set used to store intermediate results resides on this volume.

The maximum transform size in the current implementation is 256 x 256. This
program is a modified version of a program contained in the VICAR library.

Examples:

1. FOURIER2, IN, OUT, (1,1,256,256)
   The two-dimensional Fourier-transform of a 256 x 256 section of the
   picture IN in BYTE format will be computed and placed in picture OUT.

2. FOURIER2, IN, OUT, (100,50,128,128), (POW = 7, IFMT = FIX)
    The transform will be performed on a 128 x 128 section of a picture in
    fullword integer format. The section starts at line 100 and column 50.

3. FOURIER2, IN, OUT, (INVERSE, OFMT = HALF)
    The inverse two-dimensional FOURIER-transform of IN (assumed to be
    in complex format) is computed and put in halfword format into picture
    OUT.

FOURPIC

Purpose:

FOURPIC processes complex Fourier-transformations or other complex pictures
to extract information from the complex data for display purposes.

General Description:

According to the twofold function of FOURPIC two modes are provided. The
transform mode processes complex-Fourier-transform data and the only input
accepted in this mode is in complex format. The output produced is packed in
byte format. Available functions of the complex input which can be displayed in-
clude amplitude, intensity, phase, real part and imaginary part. All functions
except phase can be linearly scaled or logarithmically scaled prior to output. In
the transform mode, FOURPIC assumes that the input Fourier-transformation
has complex conjugate symmetry, i.e., it resulted from transforming real image
data. The format of the input data is assumed to be equivalent to the output pro-
duced by a direct transformation with the fast Fourier-transform program
FOURIER2.

In the second mode determined by the parameter INVERS, the program accepts
input data in byte, halfword, fullword and complex format.

The Fourier-transform computed by FOURIER2 has its origin in the upper left
corner of the complex array. For display purposes it is convenient to shift the
origin to the center of the transform domain. In the TRANSFORM mode the ori-
gin is relocated to the center, in the INVERSE mode no relocation is performed.

The picture size to be processed in the TRANSFORM mode is derived from the
picture label, the SIZE field is ignored. In the INVERSE mode, the output pic-
ture dimensions are derived from the SIZE field.

In the INVERSE mode the entire picture is processed uniformly. In the TRANS-
FORM mode the assumed conjugate symmetry of the input picture is used and
only the left half of the transform matrix is processed. In this mode two dis-
play types can be specified independently for the left and right half of the image
respectively. If the two halves of the transform display are of the same type,
the output display exhibits the assumed conjugate symmetry. The origin is lo-
cated at $(M/2 + 2, N/2 + 1)$, where M and N are the horizontal and vertical trans-
form dimensions. If the two halves are of different type, the display is organ-
ized symmetrically about the vertical axis. The origin for the right half is at
$(M/2 + 2, N/2 + 1)$ and for the left half at $(M/2 + 1, N/2 + 1)$. Positive

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horizontal spatial frequency increases to the right for the right hand display and to the left for the left hand display. Negative horizontal spatial frequency components are not displayed in this case. The scaling applied to both halves is the same except if one half is phase and the other amplitude or another non-phase display.

The available display functions are computed as follows:
Let $C = R + i \cdot I$ be a complex value with its real and imaginary components, d_{LIN} be the linear output value and d_{LOG} be the logarithmic output value, then:

1) Amplitude

$$x = \sqrt{R^2 + I^2} \qquad\qquad d_{LIN} = y$$

$$y = \begin{cases} x & \text{for } x \geqslant 1.0 \\ 1.0 & x < 1.0 \end{cases} \qquad\qquad d_{LOG} = \log_{10}(y)$$

2) Intensity

$$x = R^2 + I^2 \qquad\qquad d_{LIN} = y$$

$$y = \begin{cases} x & \text{for } x \geqslant 1.0 \\ 1.0 & x < 1.0 \end{cases} \qquad\qquad d_{LOG} = \log_{10}(y)$$

3) Real part

$$x = R \qquad\qquad d_{LIN} = y$$

$$y = \begin{cases} x & \text{for } |x| \geqslant 1.0 \\ \text{sgn}(x) & |x| < 1.0 \end{cases} \qquad\qquad d_{LOG} = \text{sgn}(y) \log_{10}(|y|)$$

4) Imaginary part

$$x = I \qquad\qquad d_{LIN} = y$$

$$y = \begin{cases} x & \text{for } |x| \geqslant 1.0 \\ \text{sgn}(x) & |x| < 1.0 \end{cases} \qquad\qquad d_{LOG} = \text{sgn}(y) \log_{10}(|y|)$$

5) Phase

$$x = \arctan I/R \qquad -\pi < x \leqslant \pi$$

$$y = \begin{cases} x & R \neq 0 \text{ or } I \neq 0 \\ 0.0 & R = I = 0 \end{cases}$$

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d_{LIN} = y if parameter SIGN specified
d_{LIN} = |y| if SIGN not specified
d_{LOG} =   invalid display

In order to scale and pack the results into byte format, a logarithmic histogram is accumulated for the entire input. Then based on the input parameters determining the percentage of the display data to be saturated white (255) or black (0), the histogram is used to determine a linear transformation for scaling the output. The scaling parameters are printed out (VMIN is transformed to 0 and VMAX to 255). This program is a modified version of a VICAR program.

Usage:

> FOURPIC, IN, OUT, (SL, SS, NL, NS), PARAMS

> IN   is the name of the input picture to be displayed. In the TRANSFORM mode, IN should be a complex matrix (output of FOURIER2). In the INVERSE mode IN can be any picture.

> OUT   is the output picture name. In the TRANSFORM mode OUT will have its origin in the center of the display. In the INVERSE mode the origin is in the upper left corner of the display.

> SL, SS, NL, NS   are ignored in the TRANSFORM mode and determine the size of the output picture in the INVERSE mode.

> PARAMS   are optional, position independant parameters specified by the keywords (only the first 4 characters are checked):

>> 1.   Mode setting:
>> INVERSE specifies the INVERSE mode. The default is TRANSFORM mode.

>> 2.   Display type:
>> AMPLITUDE display amplitude information
>> INTENSITY display intensity
>> REAL display real part
>> IMAGINARY display imaginary part
>> PHASE display phase information without sign

> In the TRANSFORM mode (default mode) up to two display types may be specified in the order left side type followed by right side type. (Default: AMPLITUDE, AMPLITUDE). In the INVERSE mode only one display type may be specified. (Default: AMPLITUDE).

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3. Modifier keywords:
   LINEAR specifies linear scaling. (Default=LINEAR)
   LOG specifies logarithmic scaling for non=phase information.
   SIGN specifies that the sign of the angle $\varphi\,(-\pi < \varphi \leq \pi)$ is to be pre-
         served in scaling. (Default: suppress sign in phase displays).

4. Input format for INVERSE mode:
   INFM=BYTE the input data are in byte,
       =HALF halfword,
       =FLOAT real fullword,
       =FIX integer fullword,
       =COMP complex format
   (Default: INFM=COMP).

5. Numerical control keywords:
   NMIN=F specifies the floating point fraction in percent of non-
           phase information of the display which will be set to 0.
           (Default: F=0.1).
   NMAX=F specifies the floating point fraction (per cent) of non-
           phase information which will be set to 255. (Default:
           F=0.1).

Restrictions:

The pictures IN and OUT should not be reserved on the disk volume K3SCR6 since
the data set used to store intermediate results resides on this volume.

The maximum transform size in the current implementation is 256 x 256.

Examples:

1. FOURPIC, IN, OUT
   The picture IN is assumed to be a complex FOURIER-transform pro-
   duced by FOURIER2. The origin will be shifted to the center of the dis-
   play, the amplitude extracted, linearily scaled and put into picture OUT.

2. FOURPIC, IN, OUT,,(AMPLITUDE, PHASE, LOG)
   The logarithmically scaled amplitude of the picture IN will be put into
   the left half, the phase information of IN into the right half of OUT.

3. FOURPIC, IN, OUT,,(INVERSE, LOG)
   The logarithmically scaled amplitude of IN will be put into OUT. IN is
   assumed to be in complex format. In the INVERSE mode the origin is
   the upper left corner. Hence, if IN is a complex Fourier-transform, it
   will be displayed with the origin in the upper left corner.

LAPLACE

Purpose:

To perform edge enhancement in a picture.

General Description:

The program performs sharpening of edges by using a Laplacian operator. The operation is performed by convolving the picture with the mask

$$
W_L = \begin{pmatrix} -1 & -1 & -1 \\ -1 & 8 & -1 \\ -1 & -1 & -1 \end{pmatrix}
$$

The convolution of this mask with the picture is zero in regions where the picture is constant or linear, but not at edges across which this approximation of the second derivative is nonzero.

Usage:

LAPLACE, IN, OUT, (SL, SS, NL, NS)

IN is the name of the input picture.

OUT is the name of the output picture.

SL, SS, NL, NS describe the segment of the input picture to be processed.

MAP - Map printing on line printer

Purpose:

To display a picture or a portion of a picture on the line printer, using double-printing to achieve different grey levels.

General Description:

The high order six bits of each pixel are used to determine the characters to be printed allowing for up to 64 different grey-levels. Two default character sets provided by MAP can be used. The first set which is automatically taken if nothing else is specified consists of the following two character-lines which are double-printed giving 8 different greylevels:

'   ========+++++++++$$$$$$$$$--------========$$$$$$$$'

'   OOOOOOOOOOOOOOOOOOOOOOOOOOOO'

The default set prints zero as white, but a complement option is provided. Up to 125 pixels are printed in a line on each page. The other default character set which was taken from the PAX-II Image Processing System provides 32 different greylevels and is invoked by the parameter keyword PAXCH.

The user may specify his own character set. If single printing is desired 64 characters should be specified with the parameter L1CHARS, for double printing 128 characters are needed (use also L2CHARS). This is a modification of a JPL-VICAR program.

Usage:

MAP, IN, *, (SL, SS, NL, NS), PARAMS

IN is the name of the picture for which the map is to be printed. There is no output picture, hence its name is defaulted with an asterisk.

SL, SS, NL, NS describe the section of the input picture to be processed.

PARAMS are parameters separated by commas which can be specified in any order:

LSPACE = n, sets the line spacing to n (integer). Every n^{th} line is printed (Default = 1).

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SSPACE = n, sets the column spacing to n (integer). Every n^{th} column is printed (default = 1). Since the printer character density is 10 characters per inch and 6 lines per inch, the parameters LSPACE = 5, SSPACE = 3 will provide a 1:1 aspect ratio. When better resolution is required, the parameters LSPACE = 2, SSPACE = 1 provide a 12:10 aspect ratio.

NONUM   line and column number headings are not printed.

COMP   The complemented default character set is used.

PAXCH   The PAX-II character set is used giving 32 grey levels.

L1CHARS = ' 64 characters ' . The 64 characters specified between quotes are used for overprinting.

POWER - Power spectrum program

Purpose:

To compute and plot the one-dimensional power spectrum of a picture frame.

General Description:

The program computes, using the fast Fourier transform, the power spectrum
of a specified portion of each line of a picture and produces a single result and
power spectrum by averaging these as a function of frequency. The square root
of the average power spectrum is then displayed on the line-printer. If a tape
is specified in the parameter list then the power spectrum is written on this
tape suitable for plotting on the 780 stand-alone Calcomp plotter.

This is a modification of a program contained in JPL's VICAR library.

Usage:

Two types of usage are possible:

1. One or more input picture names causing each plotter file to be identi-
   fied with sequential block addresses.

   POWER, (IN1, IN2, IN3),, (SL, SS, NL, NS), (P)

The section of the picture to be processed is specified in the usual way by SL,
SS, NL, NS. The parameters P can be specified in any order using the following
keywords:

   a. BITS = N, where N is 6 or 8 to define the bit resolution of the data
      (Default = 8).

   b. EXPONENT = N, where N is a fixed point number specifying the ex-
      ponent of 2 for the desired transform size ($3 < N \leqslant 10$, default = 10).

   c. TAPE = volser, where volser is the volume-serial no. of a 7-track
      tape on which the CALCOMP plot is to be written (Default: no CAL-
      COMP plot is produced).

   d. SCALE = N, where N is a fixed point number specifying the output plot
      amplitude scale (both line printer and calcomp plot) in peak-peak
      digital numbers per inch (Default = 2). Full scale on the line printer
      is 10 inches and 9 inches on the Calcomp plotter.

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e. FMAX = freq., where freq. is a floating point number, the highest frequency in the spectrum (Nyguist frequency). It is equal to one half the reciprocal of the pixel-to-pixel spacing measured in whatever units are used (seconds, mm., etc.). If FMAX is not used, the default value is 0.5, corresponding to a pixel spacing of unity. This default value is considered to be of more general use than one associated with a particular hardware system. Example FMAX = 0.0775.

f. YLEN = y, where y is a floating point number, the length of the y-axis in the Calcomp plot. $0.0 < y \leqslant 30.0$ (Default = 7.0 for 12" paper).

g. TITLEX, nchar, 'x-axis title' - Example: TITLEX, 29, 'Spatial frequency (Cycles/mm)' - This set of parameters may be used to change the x-axis label in the Calcomp graph. 'nchar' is the number of characters in the title, expressed as an integer, and must be less than or equal to 52. 'X-axis title' is a character string parameter (quotes required) which will be placed on the x-axis of the graph. If TITLEX is not specified, the default is 'Frequency (CPS)', where CPS conveniently can be interpreted as 'cycles per second' or 'cycles per sample'. If FMAX is not in one of these units, it is suggested that TITLEX be used to provide a more accurate axis label.

h. TITLE, nchar, 'title' - example: TITLE, 37, 'Horizontal Noise Spectrum, Upper Left' - This set of parameters may be used to add labeling information to both the calcomp graph and the line printer graph. 'nchar' is the number of characters in the title, expressed as an integer, and must be less than or equal to 52. 'title' is a character string parameter (quotes required) which will be placed at the top of the graphs. If TITLE is not used, none is provided automatically.

These keywords can be specified in any order. If POWER is called more than once with the same tape volserno the generated calcomp plots will be added on the tape.

2. Specifying no input picture causes a block address of 999 to be written on the plotter tape. This can be used as upper block count for the calcomp plotter operator. POWER,,,,(TAPE = Volserno)

Example:

POWER, (ERT.MSS5, ERT.MSS6),, (50,100,10,512), (TAPE = Z9999, EXPONENT = 9, FMAX = 0.00877, TITLEX, 22, 'SPATIAL FREQU. (CYC/ M')

POWER,,,,(TAPE = Z9999)

The averaged power spectrum of a section 10 lines by 512 points starting at the point (50,100) is computed for the pictures ERT.MSS5 and ERT.MSS6. Both spectra are written as a Calcomp plot for 12" paper on tape Z9999 with the specified annotation. After that a block address of 999 is written as an end mark for the Calcomp plotter.

ROTATE

Purpose:

To rotate a picture or segments of a picture either 90° clockwise or counter-clockwise.

General Description:

The ROTATE program provides a 90-degree rotation of a picture up to 1024 x 1024 elements. The program has been adopted from the VICAR library.

Usage:

ROTATE, IN, OUT, (SL, SS, NL, NS), PARAMS

IN is the name of the picture to be rotated.

OUT is the name of the rotated picture.

SL, SS, NL, NS specify the segment to be rotated (Default: the full input picture will be rotated).

PARAMS

COUNTER is the required parameter to obtain counterclockwise rotation.

CLOCK may be used to specify clockwise rotation (Default: clockwise rotation is assumed, also if an incorrect parameter is provided).

Restrictions:

ROTATE uses an intermediate data set on K3SCR6. Therefore, IN and OUT should not be reserved on the volume K3SCR6 for reasons of I/O efficiency.

SPREAD

Purpose:

To produce a non-linear contrast stretch of a picture such that the histogram of the resulting picture is on the average uniformly distributed.

General Description:

The equalized histogram is built by accumulating its cells with occupants of the original histogram to satisfy the calculated equalized value. A large number of the original cells will have been occupied to a level higher than the calculated equalized value. Since it is undesirable to arbitrarily distribute these occupants among a group of nearby intensity values in the equalized histogram, the entire original cell is located in the equalized histogram within a span containing empty cells. This span is calculated so that its average occupancy is the desired value. Thus, the equalized histogram will contain many cells with greater than the desired value but due to the empty cells between the average will be the desired value.

Usage:

SPREAD, IN, OUT, (SL, SS, NL, NS)

IN is the name of the input picture.

OUT is the name of the output picture with equalized histogram.

SL, SS, NL, NS describe the part of the input picture to be processed. (Default: the entire input picture will be processed).

STRETCH

Purpose:

To change the scaling of a picture or to contour a picture.

General Description:

The program can be used to alter the intensity range of a picture point-by-point in various ways. The possible options are described by keyword parameters. This program has been adopted from the VICAR library.

Usage:

STRETCH, IN, OUT, (SL, SS, NL, NS), PARAMS

IN is the name of the input picture.

OUT is the name of the scaled or contoured output picture.

SL, SS, NL, NS describe the section of the input picture to be processed.

PARAMS are the keyword parameters used to select the following options:

1. FLIP which causes the transfer function
$$OUTPUT = F (INPUT)$$
defined by a subsequent keyword to be transposed to the form
$$OUTPUT = F (255 - INPUT)$$

2. COMPLEMENT which causes the transfer function
$$OUTPUT = F (INPUT)$$
If FLIP or COMPLEMENT are specified they must appear before any of the following transfer defining keywords (underlined).

1. LINEAR, NMIN, NMAX where a linear transfer function is computed for which
$$OUTPUT = 255 \frac{(INPUT - NMIN)}{(NMAX - NMIN)}$$
and
$$OUTPUT = 255 \text{ if } INPUT = NMAX$$
$$= 0 \text{ if } INPUT = NMIN$$
NMIN and NMAX are fixed point numbers.

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2. CONTOUR, INTERVAL where the number INTERVAL is the fixed point contour interval as a digital number such that input digital numbers (DN) which are multiples of INTERVAL are set to 0 or 255 depending on the sign of INTERVAL.

INTERVAL > 0 produces 255 DN contours
        < 0 produces 0 DN contours

3. CLIP, NBIT where NBIT most significant or least significant bits are truncated depending on the sign of the fixed point number NBIT. The transfer function is:

$$OUTPUT = (2^{NBIT} * INPUT) \; Mod \; 256$$

4. TABLE, X_1, Y_1, X_2, Y_2, ..., X_N, Y_N where the transfer funtion is defined by the user supplied table x_i, y_i. The x_i correspond to input DN values (fixed point) and y_i correspond to the output DN values (floating point). The x_i must be in ascending order and intermediate values are determined by linear interpolation.

5. CUBEROOT causes the input data to be cube rooted such that

INPUT = 0 becomes OUTPUT = 0
INPUT = 255 becomes OUTPUT = 255

The actual transfer function is

$$OUTPUT = 255* \; \left(\frac{INPUT}{255}\right)^{1/3}$$

6. POWER, P, NMIN, NMAX where an explicit power law transfer

$$OUTPUT = A* \; (INPUT--NMIN)^{P}$$

INPUT = NMIN becomes OUTPUT = 255
A is determined so that INPUT - NMAX becomes
OUTPUT = 255
P = Floating point power (may be negative)
NMIN and NMAX are fixed point numbers.

7. ADAPT, NMIN, NMAX where an adaptive power law transfer function is generated:

$$OUTPUT = (INPUT/NMIN)^{P}$$

In this case

INPUT = NMIN becomes OUTPUT = 1
P is determined so that INPUT = NMAX
becomes OUTPUT = 255
NMIN and NMAX are fixed point numbers.

If STRETCH is executed without any parameters, a simple complementation results:

$$OUTPUT = 255-INPUT$$

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THREED

Purpose:

To produce a 3-dimensional plot on the Calcomp plotter.

General Description:

THREED generates a 3-dimentional perspective of a 2-dimensional data array and transforms it into X and Y values for a Calcomp plotter. The array may be viewed from any angle.

Usage:

THREED, IN,,(SL, SS, NL, NS), PARAMS

IN is the name of the picture for which a 3-dimensional perspective plot is to be produced.

SL, SS, NL, NS describe the segment of IN to be processed.

PARAMS are the following position independant keyword parameters:

TAPE = XXXX specifies the 7-track magnetic tape onto which the plot is to be written.

MODE = 1 all points are plotted with straight line connection.

= 2 all points are plotted in a perspective histogram.

= 3 only visible points are plotted with straight line connection.

= 4 only visible points are plotted in a perspective histogram.
(Default: MODE = 3).

Mode 3 and 4 are particularly useful when the array has complicated hills and valleys. No information need be lost by deleting invisible points since the array can be viewed from any angle.

XDELTA = 1 1(integer) specifies the line increment for points of the picture array to be included in the plot.
(Default: XDELTA = 1)

YDELTA = j j(integer) specifies the column increment for points to be included in the plot. (Default: YDELTA = 1).

MAXVALUE = m m(integer) specifies the maximum value in the picture array. (Default: MAXVALUE = 255).

PHI = f f(floating point) specifies the rotation of the x-y plane of the plot in the display surface. (Default: PHI = 45.0).

THETA = g g(floating point) is the angle between the z-axis of the plot and the display surface. (Default: THETA = 45.0 degrees).

Omitting the input picture name causes a block address of 999 to be written on the plotter tape.

Example:

   THREED, FOURIER,, (1,1,64,64), (TAPE = XXXXX, PHI = 30.0)

   THREED,,,, (TAPE = XXXXX)

A three-dimensional plot of the picture FOURIER is written onto tape XXXXX followed by a block address of 999.

Restrictions:

The maximum array size in the current implementation is 64 x 64. Thus, for parameters NL and NS greater than 64 by 64, XDELTA and YDELTA should be specified to yield an array to be plotted not greater than 64 x 64.

VGEN

Purpose:

To generate a picture, given an initial value, a horizontal increment and a vertical increment.

Usage:

VGEN,, OUT, (SL, SS, NL, NS), (IV, HI, VI)

OUT is the name of the generated picture.

SL and SS have to be set to 1, respectively.

NL and NS specify the size of the generated picture.

IV is the initial value for point 1 in line 1.

HI is the horizontal increment.

VI is the vertical increment for generating picture points.

REFERENCES

(1) Moik, J. G.: Small Interactive Image Processing System (SMIPS) – System Description. GSFC X-Document X-650-73-286.

(2) Moik, J. G.: Introduction to Computer Image Processing. GSFC X-document X-650-73-287.

```
//SOJGM000 JOB (S200126040,P,L00222,H00H00),JOB,MSGLEVEL=1
//STEP2 EXEC PGM=IEFBR14
//SYSPRINT DD SYSOUT=A
//VSYS00   DD UNIT=2314,VOL=SER=K3SCR3,DISP=(NEW,KEEP),
//            DSN=S0.SOJGM,SPACE=(TRK,2)
//VSYS01   DD      UNIT=(2314),VOL=SER=K3SCR2,DISP=(NEW,KEEP),
//            DSN=S1.SOJGM,SPACE=(CYL,(1))
//VSYS02   DD      UNIT=(2314),VOL=SER=K3SCR2,DISP=(NEW,KEEP),
//            DSN=S2.SOJGM,SPACE=(CYL,(2))
//VSYS03   DD      UNIT=(2314),VOL=SER=K3SCR2,DISP=(NEW,KEEP),
//            DSN=S3.SOJGM,SPACE=(CYL,(5))
//VSYS04   DD      UNIT=(2314),VOL=SER=K3SCR3,DISP=(NEW,KEEP),
//            DSN=S4.SOJGM,SPACE=(CYL,(1))
//VSYS05   DD      UNIT=(2314),VOL=SER=K3SCR3,DISP=(NEW,KEEP),
//            DSN=S5.SOJGM,SPACE=(CYL,(2))
//VSYS06   DD      UNIT=(2314),VOL=SER=K3SCR3,DISP=(NEW,KEEP),
//            DSN=S6.SOJGM,SPACE=(CYL,(4))
//VSYS07   DD      UNIT=(2314),VOL=SER=K3SCR4,DISP=(NEW,KEEP),
//            DSN=S7.SOJGM,SPACE=(CYL,(1))
//VSYS08   DD      UNIT=(2314),VOL=SER=K3SCR4,DISP=(NEW,KEEP),
//            DSN=S8.SOJGM,SPACE=(CYL,(2))
//VSYS09   DD      UNIT=(2314),VOL=SER=K3SCR4,DISP=(NEW,KEEP),
//            DSN=S9.SOJGM,SPACE=(CYL,(4))
//VSYS10   DD      UNIT=(2314),VOL=SER=K3SCR5,DISP=(NEW,KEEP),
//            DSN=S10.SOJGM,SPACE=(CYL,(1))
//VSYS11   DD      UNIT=(2314),VOL=SER=K3SCR5,DISP=(NEW,KEEP),
//            DSN=S11.SOJGM,SPACE=(CYL,(2))
//VSYS12   DD      UNIT=(2314),VOL=SER=K3SCR5,DISP=(NEW,KEEP),
//            DSN=S12.SOJGM,SPACE=(CYL,(8))
//VSYS13   DD      UNIT=(2314),VOL=SER=K3SCR6,DISP=(NEW,KEEP),
//            DSN=S13.SOJGM,SPACE=(CYL,(1))
//VSYS14   DD      UNIT=(2314),VOL=SER=K3SCR6,DISP=(NEW,KEEP),
//            DSN=S14.SOJGM,SPACE=(CYL,(2))
//VSYS15   DD      UNIT=(2314),VOL=SER=K3SCR6,DISP=(NEW,KEEP),
//            DSN=S15.SOJGM,SPACE=(CYL,(4))
//VSYS18   DD UNIT=2314,VOL=SER=K3SCR3,DISP=(NEW,KEEP),
//            DSN=S18.SOJGM,SPACE=(TRK,2)
%
```

APPENDIX B

```
//SOJGM000 JOB (S000226040,P,L00222,H03H01),JDB,MSGLEVEL=1,
//        CLASS=G,TYPRUN=HOLD
//*IMAGE-PROCESSING
//JOBLIB DD DSN=K3.SOJGM.S0002.PAXII,DISP=SHR
//         DD DSN=K3.SOJGM.S1011.VICINT,DISP=SHR
//         DD DSN=K3.T1BII.T1005.LTESTLIB,DISP=SHR
//         DD DSN=K3.T1DAK.T1005.LVICARAP,DISP=SHR
//IMAGE   EXEC  PGM=VICINT,REGION=200K
//SYSOUT DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=6991)
//SYSPUNCH DD SYSOUT=B,DCB=(RECFM=FB,LRECL=80,BLKSIZE=3200)
//SYSUDUMP DD SYSOUT=A,DCB=(RECFM=VBA,LRECL=137,BLKSIZE=7265)
//FT06F001 DD SYSOUT=A,DCB=*.SYSUDUMP
//SNAP     DD SYSOUT=A,DCB=*.SYSUDUMP
//GRAVIC   DD UNIT=0E0
//SYSBFDMP DD SYSOUT=A,DCB=*.SYSUDUMP
//VSYS00   DD UNIT=2314,VOL=SER=K3SCR3,DISP=(OLD,KEEP),
//            DSN=S0.SOJGM
//VSYS01   DD    UNIT=(2314),VOL=SER=K3SCR2,DISP=(OLD,KEEP),
//            DSN=S1.SOJGM
//VSYS02   DD    UNIT=(2314),VOL=SER=K3SCR2,DISP=(OLD,KEEP),
//            DSN=S2.SOJGM
//VSYS03   DD    UNIT=(2314),VOL=SER=K3SCR2,DISP=(OLD,KEEP),
//            DSN=S3.SOJGM
//VSYS04   DD    UNIT=(2314),VOL=SER=K3SCR3,DISP=(OLD,KEEP),
//            DSN=S4.SOJGM
//VSYS05   DD    UNIT=(2314),VOL=SER=K3SCR3,DISP=(OLD,KEEP),
//            DSN=S5.SOJGM
//VSYS06   DD    UNIT=(2314),VOL=SER=K3SCR3,DISP=(OLD,KEEP),
//            DSN=S6.SOJGM
//VSYS07   DD    UNIT=(2314),VOL=SER=K3SCR4,DISP=(OLD,KEEP),
//            DSN=S7.SOJGM
//VSYS08   DD    UNIT=(2314),VOL=SER=K3SCR4,DISP=(OLD,KEEP),
//            DSN=S8.SOJGM
//VSYS09   DD    UNIT=(2314),VOL=SER=K3SCR4,DISP=(OLD,KEEP),
//            DSN=S9.SOJGM
//VSYS10   DD    UNIT=(2314),VOL=SER=K3SCR5,DISP=(OLD,KEEP),
//            DSN=S10.SOJGM
//VSYS11   DD    UNIT=(2314),VOL=SER=K3SCR5,DISP=(OLD,KEEP),
//            DSN=S11.SOJGM
//VSYS12   DD    UNIT=(2314),VOL=SER=K3SCR5,DISP=(OLD,KEEP),
//            DSN=S12.SOJGM
//VSYS13   DD    UNIT=(2314),VOL=SER=K3SCR6,DISP=(OLD,KEEP),
//            DSN=S13.SOJGM
//VSYS14   DD    UNIT=(2314),VOL=SER=K3SCR6,DISP=(OLD,KEEP),
//            DSN=S14.SOJGM
//VSYS15   DD    UNIT=(2314),VOL=SER=K3SCR6,DISP=(OLD,KEEP),
//            DSN=S15.SOJGM
//VSYS18   DD UNIT=2314,VOL=SER=K3SCR3,DISP=(OLD,KEEP),
//            DSN=S18.SOJGM
//VSYS19   DD UNIT=2314,VOL=SER=K3SCR6,SPACE=(CYL,(5))
//VSYS16   DD UNIT=(2400-9,,DEFER),VOL=SER=TRACK9,DISP=(OLD,KEEP),
//            DSN=NINTRACK,LABEL=(1,NL),DCB=(BLKSIZE=8192,DEN=3)
//VSYS17   DD UNIT=(2400-7,,DEFER),VOL=SER=TRACK7,DISP=(OLD,KEEP),
//            DSN=SEVTRACK,LABEL=(1,NL),DCB=(DEN=2,BLKSIZE=8192)
```