BUFFER MEMORY MONITOR SYSTEM FOR INTERACTIVE IMAGE PROCESSING

NCI/IP Technical Report #21

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Abstract

BMON2 is a PDP8e image processing system running on the Image Processing Units' Real Time Picture Processor. It uses the PDP8e, Quantimet, Axiomat microscope with stage, focus and zoom stepping motor control, control desk, GraphPen tablet, and buffer memory parts of the RTPP. Control of the system is by either the teletype or control desk. Teletype commands are entered via the OS8 command decoder (implying that BMON2 may be run under OS8 BATCH). Over 70 operations are available with most operations being performed in microns for user convenience. Teletype commands may be dynamically assigned to the 12 command keys on the control desk which may be saved and restored from disk files.

T A B L E O F C O N T E N T S

A GraphPen tablet is used to enter (x,y) constant gray value line drawings into BMs and to deliniate BM mask regions.

Although most operation parameters are specified in microns, some of the operations which include posting BMs on the QMT screen are in pixels. The pixel coordinate system is the RTPP Logical Coordinate System [4] or LCS. The LCS has (0,0) as the upper left hand corner and (1023,1023) as the lower right hand corner. The QMT screen size is effectively (0:860,0:680).

The pixel/micron conversion factor is derived using the Axiomat zoom position to interpolate a 3rd order polynomial fitting magnification to zoom position and objective lens micron/pixel calibration. Thus if the zoom is changed after an image is acquired, the pixel/micron conversion factor will be wrong. The zoom is calibrated by turning off the stepping motor power (via a switch on the control desk), manually turning the zoom to 0.8X (minimum zoom), and then pressing the decrease zoom control until all slack is taken up at which time the stepping motor power may be turned on and the zoom will be recalibrated.

This document lists the BMON2 commands; teletype input format; operating conditions; use of chained operators; and teletype input command switches.

BMON2 is derived from an earlier buffer memory monitor program called BMON1 by P. Lemkin and G. Grosfeld.

SECTION 1

Introduction

BMON2 is a PDP8e image processing system running on the Image Processing Units' Real Time Picture Processor ([1], [2], [3], [4]). It uses the PDP8e, Quantimet, Axiomat microscope with stage, focus and 4:1 zoom (0.8X:3.2X) stepping motor controls, control desk, GraphPen tablet, and buffer memory parts of the RTPP. Control of the system is by either the teletype or control desk. Teletype commands are entered via the OS8 command decoder (implying that BMON2 may be run under OS8 BATCH [8]). Over 70 operations are available with most operations being performed in microns for user convenience. Teletype commands may be dynamically assigned to the 12 command keys on the control desk which may be saved and restored from disk files.

The eight buffer memories (BM) each store two 8-bit 256x256 pixel images and may be accessed at video frame rates for image acquisition and display, or randomly accessed on the order of less than 1 microsecond/pixel. The BMs may be posted on the Quantimet (QMT) display, unposted, loaded with QMT camera video images and moved around the QMT screen. Data in the memories may be random accessed by the PDP8e and processed with the resultant transformed images stored in the memories. The I/O operations between the memories and the PDP8e's RK05 disk files uses the DDTG system [4] to perform the actual operations.

Rapid feature extraction of isolated objects may be performed using the QMT "function computer" hardware with a special data acquisition interface on the PDP8e to acquire density, area, perimeter and projections at TV frame rates. QMT video images are the result of either QMT camera video or of BM synthesized video inserted into the image in place of the QMT camera video.

The RTPP digitizes QMT camera video using a 8-bit 125 nanosecond A/D conversion. The digitized video is then multiplexed with digital video from the BMs. Camera video may be stored in the BMs at this point in 1 TV frame. Alternatively, BM digital video may be output from the multiplexer instead of the digitized camera video. This digital output is then converted back to an analogue video signal using a high speed D/A converter. In the above scheme, it is also possible to display the output of either the QMT camera or a single 8-bit BM at any single pixel in the image. It is possible however, as an option, to use the other half of the BM being displayed at a particular pixel as a mask by generating an effective QMT live frame from this mask BM using the sign bit of the data to denote a mask pixel. Only video under this mask is used for QMT measurements.

13. CMDS - List the legal BMON2 commands with ^S, ^Q, and ^O active.

14. INIT - Power clear the PDP8e and initialize BMON2 parameters as follows:
Set the magnification of the Axiomat [3] according to /1 for 10X, /2 for 25X, /3 for 50X oil, /4 for 100X oil where 100X is the default;
Unpost all images;
Set F&S to 256x256 image at (384;384);
Freeze F&S size keys;
Zero assigned command key list;
Set all BMS to STDBM configuration.

15. <BMj> _ COLOR, (Opt. density) (Opt. /C for black) - color entire image specified density. If no arg is given, it will zero the memory, If /C and no arg then it colors it black.

16. <BMj> _ COPY, <BMi> - copy entire image (/U is inoperative).

17. <BMj> _ COMPLEMENT, <BMi> - for entire image, compute: g=255-g (/U is inoperative).

18. (opt. <BMj>) _ HIST, <BMi>, (Opt. parameter value d)
(Opt./X or /Y for col or row grayscale projections)
(/R grayscale run length/line)
(Opt. /L to print histogram)
- The histogram is computed for the specified BMi with parameter d and the maximum and minimum range of gray values and their associated sums are printed. If BMj is not specified then the histogram is not displayed. If it is displayed, then a scale is also displayed at the bottom of the histogram with short scale lines every 10 points and larger ones every 50. For /R, d is used to specify the magnitude difference between the start of any run gray value Gi and successive points in the run Gj such that [Gj | Gj in Run Gi and |Gj-Gi|<d]. For the grayscale projections, (including /X and /Y) d (default 1) is the spatial sampling distance.

19. <BMj> _ CONTRAST, <BMi> - Contrast stretch <BMi>, according to the last histogram computed, as folows: If hi and lo are the maximum and minimum values of data in the range of the histogram, g the gray value at a pixel, then stretch the image according to the linear interpolation:
$$g' = ((hi-lo)/255)*(g-lo).$$

20. <BMj> _ <BMi1>, SLICE, (Opt. <BMi2>), dmin, dmax (opt. /C)
- Threshold slice an input image data into an output image using the following algorithm:
BMj(x,y) _If (dmin leq Bmi1(x,y) leq dmax)
Then
If BMi2 specified

SECTION 2

Teletype Commands

The BMON2 commands are listed below with the specific syntax for each command. Descriptions of operators implemented via CHAINed files have a "*" after the command number. In general, <BMj> is a "sink" BM and <BMi> is a "source" BM. The "_" is a leftarrow symbol and denotes assignment of <BMi> related data to <BMj>. All pixel computations are clipped to the range [0:255].

1. GET, <BMi> (opt. /B, /M; /A for all) - Get a Video scan from the QMT camera at the current position of the specified <BMi> into <BMi>.

2. POST, <BMi> (opt. /B, /M; /A for all) - Post the specified <BMi> on the QMT display at its current location.

3. UNPOST, <BMi> (opt. /B, /M; /A for all) - unpost (remove) the specified BMi from the Quantimet display. It does nothing it the image was not previously posted.

4. POSXY, <BMi>, X,Y - Set <BMi> position to x,y.

5. POSFS, <BMi> - Set <BMi> position from the Quantimet Frame and Scale module (F&S).

6. SETFS X,Y,(Opt. HSIZE,VSIZE) - Set F&S to specified position and size (if the size arguments are zero, then do not change the size).

7. ALL384 - Set all BM positions to (384,384).

8. STDBM - Set all buffer memories to the standard position which is up to 3 BMs/row with 3 rows as:

```
0 | 1 | 4
2 | 3 | 5
6 | 7 | -
```

STDBM is also performed in the INIT command.

9. <filespec> _ QMT - Acquire QMT Function Computer data using DDTG (See [4]).

10. <filespec> _ WRITE, <BMi> - Write <BMi> into a file using DDTG (See [4]).

11. <BMj> _ READ, <filespec> - Read <BMi> from a file using DDTG (See [4]).

12. CMDKEYS - List the user assigned command keys. ^S, ^Q, ^O are active.

28. <Opt. BMj> _ GRAPHPEN, (Opt. gray value), (Opt. brush size) (Opt. /C) - read the GraphPen (x,y) coordinates relative to the F&S and put them into (DISP1,DISP2) displays. When the pen tip is pressed, if a BM is specified then also write a black (255) pixel at that location. The F&S will be used to position the specified BM. If POST,BMj/B/M was specified for BMj then treat the <BMj> as a QMT live frame mask data <BMj>, thus permitting editing of mask type data.

The class keys menu is:

CLASSKEY[0] complements the ink density.

CLASSKEY[1] causes the "ink" to be "brushed" on using a nxn neighborhood at the pen point. The value n=(2*FBW5)+1.

CLASSKEY[2] causes the Roberts gradient to be displayed in the right QMT display,

$$Gr=MAX(|(I0+I1+I2)-(I4+I5+I6)|, |(I2+I3+I4)-(I6+I7+I0)|).$$

CLASSKEY[3] causes the Laplacian to be displayed, computed as:

$$Lp=|8*I8-(I0+I1+I2+I3+I4+I5+I6+I7)|.$$

CLASSKEY[4] requests a new brush size from the keypad.

CLASSKEY[5] requests a new gray value from the keypad.

CLASSKEY[6] clears <BMj> by zeroing it.

CLASSKEY[11] or typing ^0 return control to the BMON2 monitor.

When the pen is not writing, it will display the grayscale value of the pixel pointed to by the cursor in the right QMT display. It is possible to draw into the opposite 1/2 of a BM that is being displayed by drawing into the 1/2 being displayed as a mask. This permits editing the data in the memory by writing zeros and writing lines (black). Such a mask may be used with QMT data acquisition. The POST must be setup as follows:

```
*POST,BMi/B/M
*BMiH_GRAPHPEN
```

The mask generated is the logical AND of the F&S and the BMiH data (>127).

29.* <BMj> _ SEGBND, <BMi>,lower boundary size, upper boundary size (Opt /H /T /U /C) - isolated pixels and pixels outside of the specified segment perimeter size (default 0:2047) are labeled in the output image as background value (zero). The components are labeled as pixels having component values of 2 through 255 (253 components). The input image should have background pixels set to zero. The /H switch fills in holes inside segments. The /T switch traces the boundaries as black (255) and filled holes as gray (128) in the other 1/2 of <BMj> eg. (BMjH if BMj, BMj if BMjH). The /C reverses the sense of the sizing criteria. The /U only segments those parts of <BMi> inside of the frame and scale. The histogram aray is used as a scratch area and is destroyed. This algorithm is derived from one given in [7].

```
                    Then BMi2(x,y)
                    Else BMi1(x,y)
          Else 0;
```

The SLICE operator may be used to extract pixels from <BMi2> based on data in <BMi1>.

The following neighborhood definition is used in many of the following operations:

```
I3 I2 I1
I4 I8 I0
I5 I6 I7.
```

21. <BMj> _ LAPLACIAN, <BMi> (Opt. /C) - compute the 8 neighbor Laplacian by:
$g=|8*I8 - (I0+I1+I1+I3+I4+I5+I6+I7)|$.

22. <BMj> _ AVG8, <BMi> (Opt. /C) - compute the eight neighbor average by:
$g=(I0+I1+I2+I3+I4+I5+I6+I7+I8)/9$

23. <BMj> _ GRAD4, <BMi>, (Opt numerator, denominator scaling) (Opt /D to store direction values Dx<==>1, Dy<==>3, D45 or D225<==>2, D135 or D325<==>4)
- Compute the 4 major axis gradient. The four differences are computed using a filter emphasising the central points discussed in [5].

$$Di = \begin{matrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1. \end{matrix} \quad \text{(for i=0, 45, 90, 135 degrees)}$$

24. <BMj> _ GRAD8, <BMi>, (Opt. numerator, denominator scaling) (Opt /D to store direction values D0=1, D45=2, D90=3, D135=4, D180=5, D225=6, D270=7, D325=8) (Opt /C)
- Compute the 8-neighbor gradient used by Kirsch.

$$Fi=\sum_{j=0}^{7} (5*(I(j)+I(j+1)+I(j+2))-(3*(I(j+3)+...+I(j+7))$$

Then,
$g=Max(F0,F1,...,F7)$.

25. <BMj> _ GRAYBAR, (Opt. graybar width - default=256) (Opt. /C)
- display horizontal graybar where the bars are 16 pixels wide with the first bar =255 are related by $g(y=0)=255$, $g(y+16)=g(y)/sqrt(2)$; If the /1 switch is specified, then a linear scaling is used: $g=255-y$.

26. <BMj> _ TEXT, x,y, (Opt. gray value) (Opt. /C) - add text to <BMj> starting at (x,y). The default text density is white.

27. <BMj> _ GRID, (Opt. gray value),(Opt. size in microns) (Opt. /C) - write a (default black) grid with squares corresponding to 10x10 microns (default). If /N is specified, then make the squares 10x10 pixels.

factor) (Opt /C) - Requests a 3x3 neighborhood via the command decoder as:
(1)* N3, N2, N1
(2)* N4, N8, N0
(3)* N5, N6, N7.

46. <BMj> _ FILLPINHOLES, <BMi>, density difference (Opt. /C) - Fill pinholes in the image as follows:
g = If |I8-AVG8| > density difference
Then I8_AVG8 Else I8;

47. <BMj> _ CIRCLE, <BMi>, xcenter, ycenter, radius (Opt./C) - Extract a circular region from <BMi>.

48. <BMj> _ RECTANGLE, <BMi> (Opt /C) - Extract a retangular region from <BMi>. additional args are requested with another command decoder call:
*xcenter, ycenter, xside, yside

49. <BMj> _ WHITENOISE, std dev. density, mean dens. (Opt. /C) - Generate Gaussian noise in <BMj>.

50. <BMj> _ SHIFT, <BMi>, delta x, delta y (Opt. /C) - Shift pixels in <BMi> by (delta x, delta y). Pixels shifted outside of (0:255,0:255) are ignored.

51. AREA, <BMi>, (Opt. min density, max density) - Computes the total area of the image pixels within the density range. The measurement is in microns unless /N is specified in which case it is in number of pixels.

52. DENSITY, <BMi>, (Opt. min density, max density) - Computes the total normalized density (sum of gray values divided by area) where area is in microns (or pixels if /N).

53. PERIMETER, <BMi>, (Opt. min density, max density) - Computes the total perimeter of the image for pixels within the density range. The perimeter is computed in microns unless /N is specified in which case it is in pixels. Diagonal edges are counted as square root 2 pixels.

54. <BMj>_EDGE,<BMi>, gradient-threshold, Laplacian-threshold - compute GRAD4 and the LAPLACIAN for each (x,y) and test whether |grad| > gradient threshold AND |Laplacian| > Laplacian threshold. If the boolean is true then store BMi(x,y) else 0; The EDGE operator is discussed in [5].

55. EXIT - Return to OS8 after saving the state of BMON2 (i.e. COMMON) in the SYS: files (SVDDTG.DA, SVBMON.DA).

56.* <BMj> _ FILLBOUNDARY, (Opt. boundary density) /C - fill in the hole inside of a boundary with the value specified by the optional argument. If no argument is specified, then black is assumed.

30. PARAMETERS - print the state of BMON2
The state consists of:
(F&S positions and sizes and area
(BM posting active and mode status - omit if /P)
(Active BM x,y positions - omit if /P)
(Values of 8 stepping motors:
[stage-x, stage-y, focus, zoom, threshold-1,
threshold-2, wavelength, neutral-density])
(Values of the 8 control desk knob pots)

31. <filespec> _ SAVCMD - save the 12 command key commands in the specified OS8 output file.

32. RSTCMD <filespec> - Restore the 12 command key commands from the OS8 input file (previously created with the SAVCMD operation).

33. <BMj> _ SCALE, <BMi>, n, d, b (Opt. /C) - scale by ((n*<BMi>/d) +b) Mod 2047. Negative b may be expressed as 2's complement numbers, (i.e. -1=4095, -2=4094, etc.).

34. HELP - print the BMON2.HL file on the TTY: (LPT: if OPENFILEd) (ctrl/S, /Q and /O active)

35. <BMi1> SUMDIFF <BMi2>- Sum of the absolute value of the pixel differences/(image area).

If the <BMi2> argument for binary operators 36 (ADD) to 44 (DIFF) is a scalar value rather than a BM specification, then the scalar value is used rather than pixel data from in the BM.

36. <BMj> _ <BMi1>, ADD, <BMi2> (Opt. /C)

37. <BMj> _ <BMi1>, SUB, <BMi2> (Opt. /C)

38. <BMj> _ <BMi1>, MUL, <BMi2> (Opt. /C)

39. <BMj> _ <BMi1>, DIV, <BMi2> (Opt. /C)

40. <BMj> _ <BMi1>, AND, <BMi2> (Opt. /C) - bit AND.

41. <BMj> _ <BMi1>, OR, <BMi2> (Opt. /C) - bit inclusive OR.

42. <BMj> _ <BMi1>, MAX, <BMi2> (Opt. /C)

43. <BMj> _ <BMi1>, MIN, <BMi2> (Opt. /C)

44. <BMj> _ <BMi1>, DIFF, <BMi2>, threshold value (Opt. /C)
- Set <BMj> to the difference between the two input images if the difference is > the threshold value.

45. <BMj> _ FILTER, <BMi>, (Opt. numerator, denominator scale

being generated.

61. CLOSEFILE - close the file previously opened with the OPENFILE command.

62. NOBATCH - Turn off OS8 Batch in case it is on.

63. <BMj> _ SHOWHISTOGRAM - show the histogram already in histogram IH[1:512] in EAE double precision format. /L lists the histogram on the teletype.

64.* RLTXTURE, <BMi> - Compute the five texture measures discussed in [6].
NOTATION

Ng=# distinct gray levels (16 levels=g(x,y)/16)
Nr=# distinct runs (8):
(0, 1, 2:3, 4:7, 8:15, 16:31, 32:63, 64:127, 128:255)
Pk(i,j)=run length histogram matrix for angle k where i=gray level, j=run length.
Let: S(m:N) denote

$$\sum_{m=1}^{N}$$

alpha(k)=S(i:Ng)S(j:Nr)Pk(i,j)
Pt=# points in picture.
Five measures of Pk(i,j) are computed as follows:
==========
RF1k (short run emphasis)
=S(i:Ng)S(j:Nr)(Pk(i,j)/(j*j))/alpha(k);
RF2k (long run emphasis)
=S(i:Ng)S(j:Nr)(Pk(i,j)*(j*j))/alpha(k);
RF3k (gray level distributions of runs)
=S(i:Ng)([S(j:Nr)(Pk(i,j)]**2)/alpha(k);
(RF3 is low when runs are equally distributed throughout the gray levels. High run length values contribute most to this function.)
RF4k (run length distribution)
=S(j:Nr)([S(i:Ng)(Pk(i,j)]**2)/alpha(k);
RF5k (Run %=(total # runs/total # runs if all runs were of length 1)
= alpha(k)/Pt.

65.* COMASS,<BMi> - compute the center of mass of the single (assumed) object in <BMi> using the maximums of the horizontal and vertical line density projections.After the center of mass is computed,
the frame and scale window is positioned at the center of mass of <BMi>.

66.* <BMj>_SEG2PS,<BMi>,(Opt. lower, upper area sizing) - compute the connected components image of <BMi> using a 2 pass segmentation algorithm discussed in [7].

67.* <File spec>_DUMPXY,<BMi> (Opt. /R for relative [0:255]) - find all x,y coordinates of pixels > 0 and dump them

57. QDATA (OPT. /F),(Opt. lower,upper sizes) - run the Quantimet (QMT) on the current detected video (which need not be that of a BM). The QMT is explained in more detail in [3]. print the full field data, lens and zoom magnification, Detector module thresholds B (max) and C (min) values. The /F switch causes the data to be taken from the two function computers. If the sizing is specified, it will accept data which matches function computer #1 such that (lower size < data < upper size) and the upper size limit is optional.

If /W is used, then wait after every entry foreither class[0] to "accept" the data for the object and print it, or class[1] to reject the data for this object. Class[11] may be pressed to terminate the search.

If switch /K (possibly instead of or in addition to /W) then it waits after every cursor movement for you to enter the cell class number via the key pad by doing a (clear, enter #, send). If 0 is sent, then reject the cell.

If switches /1 through /7 are used, then the function computers are programed as follows with the result of FC1/FC2 being printed. The assumption is that FC2 is set to "area".

Teletype switches

Switch	FC1	FC2
/1	DENSITY	AREA
/2	AREA	AREA
/3	PERIMETER	AREA
/4	VERT.PROJ	AREA
/5	HOR. PROJ	AREA
/6	HOR. FERET	AREA
/7	VERT.FERET	AREA

If /N is used then convert the output to pixels otherwise convert the output to microns.

If /Q is used, then compute FC1*FC1/area rather than FC1/area.

58. DDTGFN,<$EX filename> - Chain to DDTG after saving Common requesting the specified .DA $EXECUTE file be executed. DDTG functions are discussed in [4].

59. SETIOT,<QMT output IOT name>=nnnn - load nnnn (octal) into the specified PDP8e IOT. The following IOTs are implemented: DET34, DETB, DETC, GETMSK, HPL, HSL, LDXP, LDYP, LFBW2 LGALX, LGALY, LQDT1, LQDT2, LQDT3, MSKADR, MSTAG, QPROG1, QPROG2, QPROG3, QPROG4, QPROG5, QPROG6, QPROG7, QPROG8, QSTAT, SIZEA, SIZEC, SIZEM, SIZES, STEP, STQMT, VPL, VSL, EXADR, EXOUT. The PDP8e IOTs mentioned here are discussed in [3,4].

60. <Opt. output file on DSK>_OPENFILE - open the specified output file on logical device DSK:. If no file is specified, then the LPT: is opened. Since the output is buffered, it may not immediately appear on the LPT: on

	std dev. ==>left 4 digits of a neighborhood of size (1+2*FBW5).
5	Display minimum gray value==>left 4 digits, maximum gray value==>right 3 digits of a neighborhood of size (1+2*FBW5).

The CLASS keys are used as a menu for selecting editing functions.

CLASS KEY	function
0	Erase <BMi'> image locally using the GraphPen.
1	Write (when not in vector generator mode) with a brush of size (1+2N) where N<==FBW5.
2	Acquire QMT data from <BMj>. Dump the data on the LPT: file QDATA.DA. Note that the usual QDATA switches (/K, /F, /W, and lower:upper sizing) may be used.
3	<BMj>_EXTRACT data from <BMi> using boundary raster fill of <BMi'>. If key 0 is also pressed, then fill with 0's.
4	Zero <BMj>.
5	
6	Zero <BMi'>, reset Run Length Map (RLM), and turn off vector generator.
7	Turn on vector generator, reset RLM.
8	Turn off vector generator and close the boundary.
9	Fill mask inside boundary <BMi'> using RLM. (Use after (5)).
10	Extract <BMi> pixels using RLM (generated by (5)) and store them in <BMj>. If key 0 is also pressed, then fill with 0's.
11	Exit to BMON2.

73.* WINDMP,<BMi>/U,(Opt. numerator, denominator scale factor) - Dump the <BMi> pixel values in the specified F&S window (to a maximum of 18 pixels). The pixel data is scaled by: numerator/denominator before being printed. If the OPENFILE is active, then the data is also dumped on the LPT: file WINDMP.DA.

74.* <BMj>_ZOOM,<BMi>, (magnification (m=N/D) specified as N,D) - Zoom <BMi> the specified magnifaction m by repeating pixels if m > 1.0, or sampling pixels if m < 1.0. The resulting output image is centered in <BMj>. If the output image is magnified so that it is larger than 256x256, then only the upper left hand corner of the magnified image is displayed such that it fits into a 256x256 pixel window.

75.* JGSTXTURE,<BMi>,(distance d in pixels) (/L to dump Pk(i,j): k=0, 45, 90, 135 degrees) - Compute the Joint Gray Scale (JGS) probability density distributions, Pk(i,j), where k is an angle 0, 45, 90 or 135 degrees.

into the specified file. If /R is specified then only dump x,y pairs as decimal numbers in the range [0:255]. If /R is not specified, then dump the (focus, zoom, lens, microns/pixel) followed by the absolute x,y pairs. This is computed as:

Xabs=Xrel+Xstage
Yabs=Yrel+Ystage.

68.* <File spec> _ BOUNDARY, <BMi>,(Opt. low and high perimeter sizing) - segment <BMi> into the scratch BM and write out all boundaries into the DDTG formated file specified.

69.* SMOOTH - smooth the histogram in memory using disaster analysis.

70. LOADTHRESHOLDS, threshold B, Threshold C - load the QMT Detector module thresholds B (maximum) and C (minimum) over the density range of 0:255 (white to black). Note the QMT Detector module switches should be set to "slice" mode with the select switch on "3".

71. <BMj> _ ZERO (/C for black) - zero BMj by coloring it white. The entire image is zeroed, thus /U is inoperative.

72.* <BMj>_EXTRACT,<BMi> - Position BMi under the F&S which is expanded to 256x256 pixels. The EXTRACT command set the QMT display to the equivalent of "POST/B/M,<BMi>"; "POST,<BMj>". It then enables the graphpen editor for writing into <BMi'>. The editor has the capability of extracting data from <BMi> under a boundary drawn in <BMi'> and storing the data into <BMj>. GraphPen data is entered into <BMi'> only when the pen tip is pressed. Otherwise, the pen may be used to direct the QMT display cursor over <BMi>.

Two region extraction methods are available: a raster (single line) inside/outside boundary detector; and a more sophisticated method. The latter, in tracing the boundary , generates a run length map (RLM) which is translated to a list of runlengths indexed by row value for rapid inside/outside predicate evaluation. This method is similar to that of Merrill [9], except that he sorts his run lengths and searches them differently.

When the pen is not pressed, a function of the gray scale data in <BMi> (pointed to by the pen cursor) is posted in the right QMT display. The function is selected by the number in the FBW6 switches.

FBW6	Function of <BMi>(x,y)==>right QMT display
0	Display the gray value of <BMi>(x,y).
1	Display GRAD4.
2	Display LAPLACIAN.
3	Display AVG8.
4	Display mean gray value==>right 3 digits

SECTION 3

Teletype Command Decoder Input

Buffer memories are specified as "BMnh" where n is the buffer memory number and h denotes an optional byte selector (h=null for low byte, h="H" for high byte). The notation <BMi'> denotes the other half of <BMi>. Notice <args> includes physical devices such as: the 8 knob pots, the control desk switches FBW1:8, and the keypad (low order numbers 0:999). Commands are entered, one per line as follows:

```
<cmd line>::=<cmd> <switches>
<cmd>::=<op>, <args>
<cmd>::=<op>, <BM>, <args>
        ::=<BM> _ <op>,<args>
        ::=<op>, <BM>, <BM>, <args>
        ::=<BM>, <op>, <BM>, <args>
        ::=<BM> _ <op>, <BM>, <BM>, <args>
        ::=<BM> _ <BM>, <op>, <BM>, <args>
<args>::= decimal numbers up to 4095
        ::= <knob>
        ::= <control desk switch>
        ::= <keypad>
<knob>::=P<digit>   (Knobs 0:7 with values [0:511])
<control desk switch>::=FBW<digit>   (control desk switchs 0:8
                        with values [0:4095])
<keypad>::= KPD  (keypad values [0:999])
<op>::= legal command.
<BM>::= BM<digit><byte>
<digit>::= 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7
<byte>::= H | L | null
<switches>::= /<letter> | /<digit> | /S=<2 digit octal #>
```

Before the Pk(i,j) are computed, the image is contrast stretched using the histogram of the image to normalize the gray values. Index i is the central pixel gray value/32, j is the k'th direction gray value/32. After the Pk(i,j) are computed, then the mean(i), mean(j), stddev(i), stddev(j) and covar(ij) are computed. The JGS is discussed in [7]. If the OPENFILE command was active, then the statistics are also dumped on the LPT: file JGSTXT.DA.

76.* MTAi:_MAG10,<filespec>,BMON2 - Dump the specified file(s) according to the file specification (with wild card characters *, ? legal) onto MTAi: (where i is unit 0 or 1) and return to BMON2 when finished. If the /D switch is specified, then post delete the files after they are transfered to magtape. Files may also be transfered the other way using:

<DSK:filespec>_MAG10,<MTAi:filespec>,BMON2.

MAG10 is documented in [10].

77.* <BMj>_MEDIAN,<BMi> - compute the median gray value of each 3x3 neighborhood by finding the maximum and minimum gray values and taking the average of the two.

78.* <BMj>_MTV,<BMi> - compute the minimum of the horizontal and vertical differences as follows:

$$Hd = |I13-I12|+|I12-I11| + |I14-I18|+|I18-I10| + |I15-I16|+|I16-I17|,$$

$$Vd = |I13-I14|+|I14-I15| + |I12-I18|+|I18-I16| + |I11-I10|+|I10-I17|,$$

$$g = Min(Hd,Vd).$$

This function was developed by [11].

current line number being processed is displayed in DISP2 (octal) when image raster operations are being performed.

4.4 Computing Window

Normally, all image operations are performed on the entire image with resulting pixels gray values < 0 being clipped to 0 and pixel values > 255 being clipped to 255. If the /U switch is specified, the image operation is restricted to the region specified by the Quantimet Frame and Scale rectangular window. The restrictions on using the F&S as a computing window are:

(1) The F&S must be positioned entirely inside of the 1st input buffer memory (<BMi1>) specified in the command.
(2) If the above condition is not true, then the default window is the entire buffer memory 256x256.

4.5 Spooling output

The OPENFILE command causes all output which is performed on the teletype to be repeated on the output spooling device. The CLOSEFILE command must be used to close the file. If no output file is mentioned with the OPENFILE, then the OS8 lineprinter (LPT:) device is assumed. If one chains to a program with the spooler active, then the spooler is closed and upon restarting BMON2, the OPENFILE command is simulated with the LPT: device specified. The spooler switch IOUTSPOOL (in DDTG common area BMCMN.FT) remains active during the CHAIN and thus can be accesed by chained programs.

4.6 Teletype Control Characters

Various special teletype characters are activated during different times in BMON2 during command decoder input, processing, and waiting for a command.

1. Command decoder input:
   carriage return - execute the command.
   rubout - erase last character typed.
   ^U - erase input line
   line feed - type cleaned up line.
   ^C - return immediately to OS8 (do not use, use EXIT)
2. During processing:
   ^S - stop processing until ^Q is typed
   ^Q - continue processing (after having previously typed ^S)
   ^O - terminate processing
3. Waiting for command:
   ^C - save DDTG command and return to OS8 (same as EXIT above)

SECTION 4

Operating conditions

The initial and normal BMON2 operating conditions are discussed.

4.1 Initial Conditions

Nothing is initialized upon entering BMON2, except the stepping motor positions (x,y,focus,zoom,thresholds etc) which are set to those last used with DDTG or BMON2. The INIT, SET--, POS--, STDBM, ALL384, commands may be used to perform initializations. Note that the QMT must be turned on before the PDP8e computer. The GraphpPen reset button must also be pressed whenever the PDP8e is first turned on.

4.2 Normal Operating Conditions

During normal operation, BMON2 is waiting for either teletype command input or control desk input while it counts up the 200 Hz clock in the MQ register. The control desk keys which are active include the joystick for controlling the Zeiss x,y stage; the focus, zoom, thresholds B and C; as well as the command keys assigned via the teletype using the /S=n (assign associated command to command key n) construction.

The frame and scale (horizonal position, vertical position) is displayed in the BCD control desk lights (DISP1,DISP2) if FBW7 > 7. If FBW7 is in the range of 0:7, it displays the value of the knob potentiometer specified in FBW7 in DISP2 and the channel number in DISP1 (both BCD displays) with data in the range of [0:511].

Several control desk keys such as the 8 pots, FBW1:8 and the keypad (KPD) may be used as numerical arguments which are evaluated each time the command is evaluated. The latter rings the teletype bell when expecting input. The values of the pots may be used with commands by specifying a pot as "P<digit>". Currently, explicit numbers and control desk arguments may NOT be used in conjunction with one another as the BMON2 parser gets confused.

4.3 Elapsed time

For each teletype directed operation, BMON2 reports the elapsed time for the operation when it is completed. The

SECTION 6

BMON2 Teletype Command Switches

Various switches may be included in the teletype commands. The switches are entered by preceeding the letter name switch with a "/". The semantics of the switches is mentioned in the individual command descriptions as well as repeated here alphabetically.

/A switch is used with GET, POST, and UNPOST to specify all buffer memories.

/B switch is used with GET, POST, UNPOST to swap binary and gray scale halves of the specified memory. Normally, if BM0 is specified, then BM0L is the gray scale image and BM0H is the binary mask if the /M switch is specified. If /B is specified, then this correspondence is reversed.

/C switch is used to complement output resulting from raster operations using the function:

gray value = 255-gray value.

/D switch saves the direction of the gradient coded as an integer 1,2,3, etc. for the GRAD4 and GRAD8 commands instead of the magnitude of the gradient. See the specific commands for the coding assignment.

/F switch is used with the QDATA command to acquire data from the QMT function computers rather than from the MS3 computer. As the data is printed out, the QMT cursor is moved to the ACP coqrdinates (with ^S,^Q,^O active) where the /W and /K switches are actived if specified.

/H is used with the SEGBND operator to fill holes in objects after finding the boundaries of those objects.

/K is used with QDATA to classify or reject (if class=0) objects scanned in function computer mode by entering class numbers in the range of 0:999 from the keypad.

/L switch is used with the HIST operator to print the histogram on the teletype (or file if OPENFILEd).

/M switch turns on the QMT mask generated by taking the logical AND of (BM mask) and (QMT variable frame) /V is the inverse of /M.

/N is used with QDATA to cause QMT data to be presented in terms of pixels rather than being converted to microns (which takes the lens and zoom into account).

/O omits printing the command key specification when the key is pressed.

SECTION 5

Chained Operators

Various operator segments such as SEGBND, EXTRACT, ZOOM, etc. are chained OS8 ".SV" files. The state of BMON2 (including the parsed command line) is saved in system (SYS:) files (SVDDTG.DA, SVBMON.DA) before the CHAIN is performed. The operator segment, on being started may restore the state of BMON2 from these files and use the parsed argument specifications. After it performs the operation, it may save the new state of BMON2. It then chains back to BMON2. The chain operation is parsed by BMON2 as follows:

[1] The operator is checked against a list of internal BMON2 operators. If it is a internal operator, it is executed within BMON2.

[2] An unknown operator (potential CHAIN operator) X is looked up on the SYS: as "SYS:X.SV". If it is found, then the state of BMON2 is saved, and SYS:X.SV is chained to. If it is not found, then it searches the rest of the disks in the following order: DSKB, DSKC, DSKD, DSKE, DSKF, DSKG, and DSKH. If it is found on any of these disks then it is copied to SYS:JUNK.SV and that file is chained to. Otherwise an error message is printed.

SECTION 7

References

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/P is used with all commands to specify that the PARAMETERS with /P be printed after the command operation is finished. If specified with with the PARAMETERS command, it prints the parameters without the status of the buffer memories.

/Q switch is used with the QDATA command to compute FC1*FC1/AREA rather than FC1/AREA.

/R used with HIST causes the histogram to be a runlength histogram of the gray values in each line of the image.

/S is used to save the current command line and associate it with a control desk command key 0 through 11. The command key is specified by an octal number nn by "=nn" where nn is 0:13 (0:11 dec.).

/T switch used with the SEGMENT operator traces the boundary while the image is being segmented in the opposite 1/2 of the output <BMj> memory. Use POST,<BMj>/M to see it.

/U switch is used with image operations requiring an input image BMi1 which is posted. The frame and scale when positioned over the image may be used to delimit a computing window for the operation.

/V switch turns off the QMT mask generated by the BM anded with the F&S so that the so that the QMT frame is the (normal) variable frame. /M is the inverse of /V. The INIT command will also set the mode to variable frame.

/W is used with QDATA to accept, reject or terminate processing of function computer data by pressing CLASSKEY[0] to accept an object, CLASSKEY[1] to reject an object, or CLASSKEY[11] to terminate processing. The cursor stops at the current object in question. Note: /W and /K may be used together, in which case /W has its effect first.

/X used with HIST causes a row profile to be generated.

/Y used with HIST causes a column profile to be generated.

The /1 switch is used with the GRAYBAR command to select a linear (versus the sqrt(2) related) test pattern. /1 is also used to select perimeter with QDATA. /1 is used with INIT to select the 10X lens.

/2 is used with INIT to select the 25X objective lens.

/3 is used with INIT to select the 50X objective lens.

/4 is used with INIT to select the 100X objective lens.

Switches /1 through /7 are used with QDATA to select the function computer program (see QDATA operator).

EXTRACT.BI - Batch file to compile and build EXTRACT.SV.
EXTRACT.FT - EXTRACT main.
GPEDIT.FT - Major polling loop for EXTRACT.
BFOLLOW.FT - Point by point boundary following procedure.
BRUN.FT - Run Length Map procedure.
DSPNGH.FT - Neighborhood gray value function display procedure.
BQDATA.FT - QMT data acquisition procedure.

RLTXTURE function

RLTXTURE.BI - Batch file to compile and build RLTXTURE.SV.
RLTXTURE.FT - RLTXTURE main.
RLTX1.FT - Compute run-length distributions procedure.
RLTX2.FT - Print run-length distributions procedure.

JGSTXTURE function

JGSTXTURE.BI - Batch file to compile and build JGSTXTURE.SV.
JGSTXTURE.FT - JGSTXTURE main.
JGST1.FT - Compute joint-gray-scale distributions procedure.
JGST2.FT - Print joint-gray-scale distributions procedure.

WINDMP function

WINDMP.BI - Batch file to compile and build WINDMP.SV.
WINDMP.FT - WINDMP main.

ZOOM function

ZOOM.BI - Batch file to compile and build ZOOM.SV.
ZOOM.FT - ZOOM main.

COMASS function

COMASS.BI - Batch file to compile and build COMASS.SV.
COMASS.FT - COMASS main.

MEDIAN function

MEDIAN.BI - Batch file to compile and build MEDIAN.SV.
MEDIAN.FT - MEDIAN main.

MTV function

MTV.BI - Batch file to compile and build MTV.SV.
MTV.FT - MTV main.

FILLBD function

FILLBD.BI - Batch file to compile and build FILLBD.SV.
FILLBD.FT - FILLBD main.

BOUNDARY function

APPENDIX A

List of files required for BMON2

Documentation files

BMSRC.BI - Batch job to print BMON2 files.
BMON2P.PUB - PUB (PDP10) input file to produce BMON2.HL file.
BMON2.PUB - PUB (PDP10) input file to generate complete indexed listing.
BMON2.HL - help file.
BMON2.BI - Batch file to compile and build the BMON2.SV file.
BMLOAD.BI - Batch file to load and build the BMON2.SV file.

COMMON file

BMCMN.FT - Common area for all BMON2 files using COMMON.

BMON2 proper files

BMON2.FT - BMON2 main.
BMAX1.FT - Auxillary procedures for BMON2.FT
BMAX2.FT - Auxillary procedures for BMON2.FT
BMAX3.FT - Auxillary procedures for BMON2.FT
BMAX4.FT - Auxillary procedures for BMON2.FT
BMAX5.FT - Auxillary procedures for BMON2.FT
BMAX6.FT - Auxillary procedures for BMON2.FT
BMAX7.FT - Auxillary procedures for BMON2.FT
BMAX9.FT - Auxillary procedures for BMON2.FT
BMAP1.FT,BMAP2.FT - Zoom interpolation procedure for microns/pixel calibration.
BMIO.FT - Buffer memory I/O through COMMON.
BCDSPEC.FT - OS8 Command Decoder interface procedure.
GETDEVICE.FT - Procedure to return the Ascii device name from its number.
FINDOPR.FT - Procedure to lookup builtin function names and PDP8e IOTs.
BSCOMMON.FT - Save and restore the state of BMON2 COMMON via files.
TIMER.FT - One second timer and 200Hz clock procedures.
MATCH.FT - Pattern matcher used in command recognition.
QUESTION.FT - Guesser used in MATCH for guessing commands.

SEGBND function

SEGBND.BI - Batch file to compile and build SEGBND.SV.
SEGBND.FT - SEGBND main.
SEGB1.FT - Auxillary file.
BWINDOW.FT - Minimum window and Min(entrance,exit,y) procedure.
BMAX8.FT - Boundary follow, fill and pack.

EXTRACT function

APPENDIX B

Adding new functions via CHAIN .SV files

It is possible to append new functions to the BMON2 system via the CHAIN feature of OS8. This feature permits programs (such as BMON2 or the functions themselves) to run other programs by requesting the OS8 monitor to run another program. These programs are core image (.SV) files created by compiling, loading and saving a program. The critical factor in interfacing these new function programs to BMON2 is in saving and restoring as well as using the state information generated in BMON2 and the function programs. The state of BMON2 is contained in two files SYS:SVDDTG.DA (which also contains the state of DDTG) and SYS:SVBMON.DA. A single prgcedure BSCOMMON can be used to either save or restore the state from these files and thus enables easy communication between BMON2 and the set of function programs.

Most functions are created by taking the skeleton procedure BMBODY.FT and changing the occurance of BMBODY in every instance to the new procedure name. It has a prologue to restore the state and an epilogue to save it and chain back to BMON2. It uses GPPCMN so that any procedures using common will have it available. Actual BM I/O may be performed either using BMIO.FT which is a set of procedure calls passing arguments through common or BMOMNI.FT which is a single procedure passing arguments via the subroutine argument list. The latter oof course is much slower but is also easier for the novice to use.

BMOMNI also facilitates writing function programs because it has a nearly complete set of interface functions for: BM I/O, posting, and display; GraphPen; Quantimet control and data acquisition; Control Desk keys, pots and lights. It also has a clipping vector generator for use in drawing and/or generating vectors in the [0:255] pixel square domain.

BOUNDARY.BI - Batch file to build BOUNDARY.SV.
BOUNDARY.FT - BOUNDARY main.
BND1.FT - Auxillary file.
BDUMP.FT - Boundary stack and dump procedure.

Hardware interface procedures

BMQMNI.FT - BM I/O, QMT, Control Desk, GrafPen control.
STAGE.FT - Stepping motor (x,y,focus,zoom,thB,thC,wv,nd) control.

Skeleton function program mains

BMBODY.FT - Skeleton of pixel or neighborhood raster function.
BMFAST.FT - Skeleton of fast raster function.

Auxillary procedures

IOB.FT - OS8 general access file interface.
DPCVRT.FT - Double precision integer to/from floating point conversion.
OCT.FT - Octal to/from double precision integer conversion.
IBCD.FT - BCD to/from decimal conversion.
MAX.FT - Return the Max of two integers.
MIN.FT - Return the Min of two integers.