A NEW IMAGE PROCESSING SOFTWARE SYSTEM FOR STRUCTURAL ANALYSIS AND CONTRAST ENHANCEMENT

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We report on the development of a new image processing software system SPIDER (System for Processing of Image Data in Electron Microscopy and Related Fields). The need for a user-oriented software system for electron image processing has been previously recognized /1-4/. These systems have in common that they allow users with a minimum amount of computer experience to define complex operations on images.

The present system runs under the PDP 11/45 RSX-11D (Digital Equipment Corp.) executive in a multi-user, multi-task environment. Image enhancement of large images (e.g., box convolution and point mapping operations) as well as structural electron microscopy (Fourier operations, 3-d reconstruction) had to be accommodated. Characteristic for the electron microscope application is the need to process series of images closely related to each other (defocus, tilting, and averaging series).

In SPIDER, the images are read and transferred by magnetic tape from the microdensitometer to PDP 11 disk files. Statistics, titles and other data relevant to the image are kept in a label contained in the file. Part of the label is a classification flag which divides image files into four categories: real, Fourier, polar and auxiliary data. This flag is used to prevent the application of inconsistent operations.

SPIDER consists of a main task DRIVER and a set of co-tasks (see fig. 1). The user starts a session by executing DRIVER, and specifying the data library he wishes to access. The normal mode of operation is interactive. Upon encountering an operation command (e.g., RT for rotation) DRIVER will activate the appropriate co-task and suspend itself. Once activated, the co-task performs the operation, soliciting any information required (input files, output file etc.) from the user. The co-task then reactivates DRIVER and terminates unless the next operation is within its own menu. The main advantages of this organization are minimization of compile and link time for program changes, and minimization of core use.

DRIVER as well as the co-tasks continually update a LOG file of all input records entered by the user. In addition, any listing that is too lengthy to be listed on the terminal is written to the RESULTS file which may be later spooled to the line printer.

The SPIDER system may also utilize a batch mode in which all input to the system is read from a sequential command file (BATCH file). This may be created by editing the LOG file of a previous session. In the batch mode, all input to the system as well as all listings generated are written to the RESULTS file.

Procedures are command sequences containing parameters that have to be specified at run time. Any frequently used sequence of operations can thus be invoked by a single command in the interactive or batch mode of operation.

To facilitate the processing of many images with little repetition, the user may use FORTRAN-like DO loops in his batch or procedure files. Here the same command sequence is applied to a set of sequentially named files (e.g., PIC001, PIC002, etc.). Fig. 2 shows a BATCH file list containing a DO loop.

Syntax checking is performed upon entering of each parameter value so that the user will be notified of typographical errors or errors of data type (e.g., a floating point number where an integer is expected).

Two sets of co-tasks are available for big and small picture sizes. A special command that switches between big and small picture mode makes an economic use of core possible. Also available are system registers for storing or transferring data such as rotation angles from one operation to the other. In addition, a special feature of SPIDER allows basic arithmetic operations on input numbers as well as register contents to be carried out in the same manner as a pocket calculator.

Special software has been developed for efficient use of a Princeton Electronics halftone image storage and display terminal. By positioning a cursor, portions of a displayed image may be selected and stored in separate files. For film writing, the processed images are written onto magnetic tape together with visible label information and a gray scale.

While the organization part of the system is completed in the present form, a considerable effort has yet to go into the extension of the application (60 at present), mainly in the direction of 3-d reconstruction.

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REFERENCES

[1] An extensive system for 3-d reconstruction has been developed by R. A. Crowther, L. A. Amos and co-workers at the MRC in Cambridge.
[2] W. O. Saxton, Comp. Graph. Im. Proc. 3, 266 (1974).
[3] M. Horner, in 'Developments in Electron Microscopy and Analysis', ed. J. A. Venables (Academic Press, London 1975) p. 209.
[4] R. Smith, "Structural Data Processing Program", Biozentrum of the University Basel, private communication.

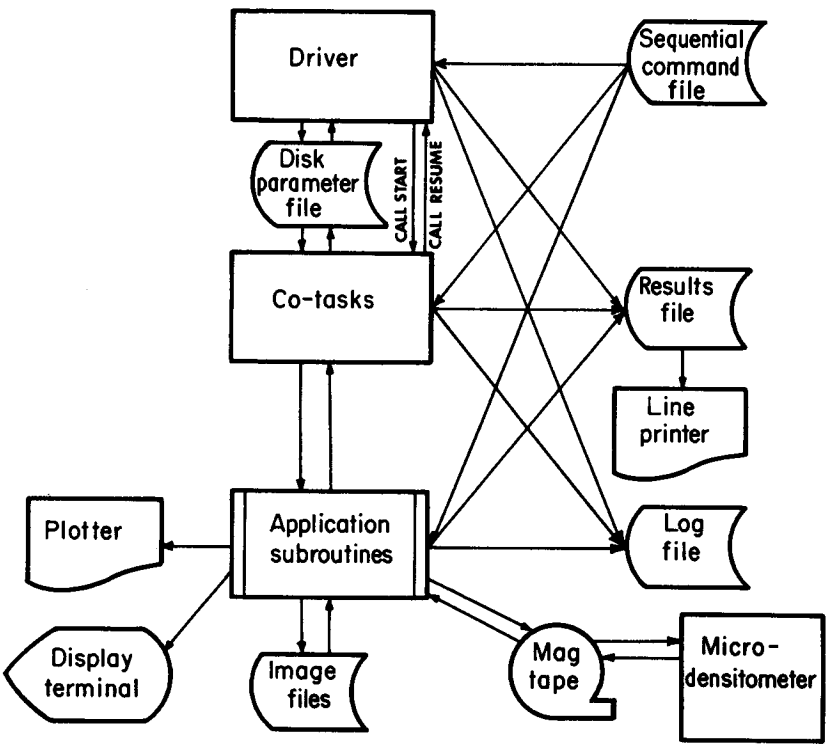

Fig. 1 (top) schematic diagram showing the organization of the SPIDER system.

Fig. 2 (right) example of a procedure command sequence AL1 and a batch sequence B01 which calls AL1. The procedure aligns two images defined by the ?...? delimiters. The images are first padded (PD) into larger arrays, then autocorrelated (AC), and the angle between the autocorrelation functions is determined (OR). The second image is rotated (RT) by the angle found, then padded (PD) and crosscorrelated (CC) with the padded reference. The operation (PK) locates the correlation peak and passes the coordinates (X1, X2) to (SH) which shifts the rotated image into exact alignment with the reference. Temporary files are deleted at the end (DE). To use the procedure, one specifies the name AL1 and gives the expected file names for reference image (GSH001), image to be aligned (GSH002) and output image (NEW001).

```
; AL1 ### PROCEDURE FOR
;          ALIGNMENT
PD
?REFERENCE IMAGE?
REF001
128,128
Y
33,33
CP
REF001
ACF001
AC
ACF001
PD
?IMAGE TO BE ALIGNED?
TMP002
128,128
Y
33,33
AC
TMP002
OR X0
ACF001
TMP002
5
N
DE
TMP002
RT
?IMAGE TO BE ALIGNED?
COP001
-X0
PD
COP001
PAD001
128,128
Y
33,33
CC
PAD001
REF001
PK X1,X2
PAD001
3
SH
COP001
?OUTPUT IMAGE?
-X1,-X2
DE
COP001
DE
PAD001
RE
```

```
; B01 ### BATCH FILE
          TO TEST AL1
AL1
GSH001
GSH002
GSH002
NEW002
EN
N
```