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Z80 MICROPROCESSOR BASED SUBROUTINE SYSTEM FOR EVALUATING NUCLEAR TRACK DETECTORS

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A hardware and operational system independent subroutine package was developed in machine code for the Z80 microprocessor to perform the necessary track parameter /diameter, area etc./ measurements on a solid state nuclear track detector and to store the results in a RAM for further statistical evaluation. It is assumed that the digitized image, taken by a TV camera through a microscope, is stored in a RAM addressable by the same Z80 processor being the CPU of any type of microcomputer.

Introduction

The contour of a nuclear track in a plastic revealed by chemical etching has a circular or elliptical shape which can be characterized by four quantities, viz. the minor and major diameters, perimeter and area. However, when electrochemical etching is applied only the perimeter and the area can be related to the particle's parameters in most of the cases because of the multi-armed or star like track shape. The measurements and statistical evaluation of all those data for hundreds of tracks within reasonable time can only be done in an automated way.

For the automated measurements an appropriate hardware and software system is needed. The minimum hardware system should contain the TV camera mounted on a microscope and connected to a microcomputer /having the Z80 type CPU/ via an "interface" which digitizes the image and enables the CPU to load the data into the RAM. The only requirement for the microcomputer is to have 28 Kbytes of free RAM to store temporarily the program, the measured data and the digitized image during the operation. A massive data and program storage /tape or disc/ as well as the communication possibilities between the operator and the computer /TV monitor and keyboard/ must be ensured.

The hardware must be supported by an adequate operational system /CP/M, DOS etc./ to enable the user to work with the whole system /including the image analyzing subroutines/ in an interrupted way. Small personal computers /run by the Z80 CPU!/ having their special operational system /as the Sinclair ZX Spectrum, for example/ can be used as well, if the above mentioned hardware requirements are fulfilled.

Image characteristics

Image storage

The analog video signal coming from the TV camera is sampled by the "interface" N times during one image line in a way that if the illumination is exceeding a given grey level /adjustable by the operator by a helipot/ then a subsequent bit of a serial to parallel latch /on the interface board/ is set to 1 otherwise left to be Ø. When eight bits /pixels/ have been set they are fed into a 4118 type memory chip of the interface as one byte. It goes on this way until 16 lines investigated and then the N/8 ⁎16 bytes are read from that temporary memory into the computer's RAM started from a pre-defined address by the Z80 CPU via a Z80 PIO chip /belonging to the interface/ in the order of data collection. The whole process is repeated until 256 lines, all together N⁎256 pixels or N/8 ⁎256 bytes are stored in the RAM in a linear order.

The number of pixels in one line /N/ depends on the screen editor ability of the computer therefore it is one of the input data of the subroutine system and the "interface" must be built up accordingly.

Pixel addressing

It follows from the image storage system that the location of a given image point /pixel/ in the RAM can be characterized in two ways:

- defining the absolute address /HL/ of the byte in the RAM and the number of bits /C/ inside that byte /the left most bit is considered to be the most significant or 7th bit/, or
- only by one number /HL_i/ using the following formula: $HL_i=(HL-HL_f+1)*8-C$, where HL_f is the absolute address of the first image byte. Also the HL_f is one of the input data of the subroutine system, because the image storage entirely depends on the RAM organisation of the host computer.

The latter mode is the most suitable method to store an image object for reconstruction and further evaluation on a tape or disc. In the subroutine system both methods are used.

Pixel's attributes

The subroutine system must recognise image objects, distinguish and handle them individually. Therefore each pixel is characterized by its, so called, surrounding byte /SB/ as it can be seen in Fig. 1. The pixel in question is blackened, those pixels which were set to 1 /during the digitizing process/ are marked by a number which is the bit number inside the SB /the most significant bit is the upmost left one/. So that pixel which can be found by the co-ordinates: HL=8ØC2 and C=ØØØ2 or HL_i=Ø616 will have a SB equal to ØØE9. /Values are given in hexadecimal./

Object recognition

If an object of the image is selected for investigation by finding its left upper most pixel /FP/ /see Fig. 1/ then, at first, the SB of FP is calculated in order to follow the object's contour in clock-wise direction. Using a special selecting rule /based on the SB test and not detailed here/ that pixel will be chosen as the next contour point which has, at least, two common sides with the object or having only one common side but if it is separated it would remain an object of single pixelled. In Fig. 1 the objects marked by A, B and C will be separated from the object under investigation but that pixel marked by D will belong to the main object.

The object itself is characterized /or can be recognized/ by all the HL_i type co-ordinates and the SBs of its contour pixels therefore these are the important data to be stored for further use.

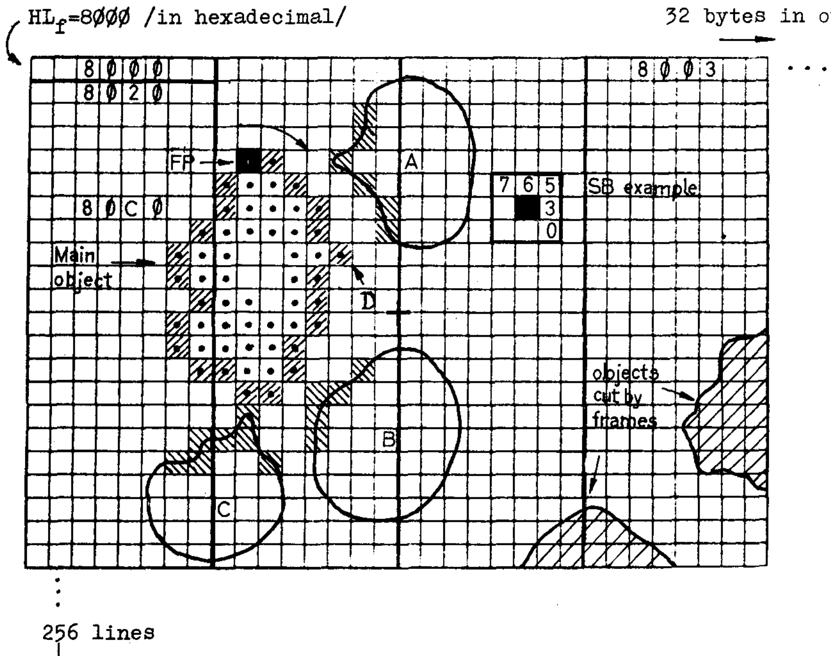

Fig.1. Illustrations to the functions of the subroutines /details in the text/

Subroutines

Three types of subroutines /written in machine code/ can be found in the system and listed below. All of them can be CALL-ed and combined in many ways by the operator directly or using a frame program written in any high level language which fits to the operational system.

Screen handling routines

- To visualize that part of the RAM where the digitized /or the reconstructed/ image is stored.
- To subtract or superimpose two images stored in two different arrays of the RAM.
- To clear the whole screen.
- To set the screen to be an alpha-numerical or a high resolution display.

Interface routines

- To program the Z80 PIO for data transfer between the 4118 memory chip and the Z80 CPU.
- To read the data from the 4118 to the RAM via the PIO.
- To set the proper initial values of the variables and arrays used by the object handling routines.

Object handling routines

- To remove the objects from the image field which were truncated by the frame of the field.
- To remove the objects from the image field if the number of pixels /forming the object/ is too small or large /the limits are preselectable by the operator/.
- To find an object and separate it from the others by following its contour, to store temporarily the contour attributes /see the previous section/.
- To fill up the empty inner part of an object /see squares not dotted inside the main object in Fig. 1/.
- To calculate the perimeter, area and diameter of an object, to store these data in arrays in the RAM and in hexadecimal format.

Notes

The data collected by the subroutine system and stored in RAM temporarily can be SAVED by the operator.

These data /area, perimeter etc./ are stored in the RAM in pixel units but easily convertible to any conventional units by simple calibrational procedures. The format of the data storage is hexadecimal so a conversion to a floating-point format is needed if further calculations /as statistical evaluation etc./ are required.

For these the necessary subroutines can be written separately in a high level language or in machine code and then added to the highly versatile and expandable program system which in its original form occupies only 4 Kbytes of the RAM.

Conclusion

The subroutine system developed was adapted to a NASCOM /Lucas Logic Ltd, UK/ type computer in Birmingham and to a ZX Spectrum /Sinclair/ in Budapest and successfully used for measuring nuclear track detectors. The typical running time for both machines is about 1 second per track if the image resolution is selected to be 256 by 256 pixels and the number of tracks on one image field is less than about 20. In one step maximum 512 tracks can be investigated not to overload more area than 28 Kbytes of the RAM.