COMPUTER AIDED DIGITIZED MICROSCOPE (CADIM) FOR NUCLEAR EMULSION ANALYSIS

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ABSTRACT

The CADIM apparatus is a combination of: a) a microscope equipped with a motorized stage and a drawing attachment; b) high precision digitizers of X, Y and Z coordinates; c) television camera, monitors and tape recorder; d) a microcomputer and its peripherals. In addition to fast scanning and measurements in nuclear emulsion, it enables to perform a direct visual comparison between the topology of an event seen in emulsion and its reconstructed topology from the data taken by associated electronic detectors. The use of television techniques allows image display and storing. This apparatus will be used in the first place for the CERN hybrid experiment WA71 searching for beauty particles.

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1. INTRODUCTION

The prediction and discovery of several new short-lived particles containing heavy quarks (charm, beauty and maybe others) has brought back nuclear emulsion in the forefront of visual detectors used in high energy physics. The so far unrivalled spatial resolving power of nuclear emulsion makes it particularly suited for measuring decay paths which have been found or are expected to be shorter than a millimeter. However, in view of the low production cross-sections of these new particles and of the complexity of their decay modes, the traditional scanning and measuring techniques in nuclear emulsion are prohibitively tedious and slow. Therefore new techniques have been developed. On the one hand, emulsions are exposed to high energy particle beams as part of so-called hybrid systems ¹⁾ including other detectors (magnetic spectrometers, Cerenkov counters, photon detectors, silicon electronic devices, etc.). On the other hand, automated microscopes ²⁾ are used in order to localize, identify and measure in emulsion those events selected as interesting ones by the other elements of the hybrid system. The present paper describes an automated microscope developed at CERN primarily to contribute to the CERN WA71 hybrid experiment searching for beauty particles ³⁾.

2. GENERAL DESCRIPTION

The CADIM apparatus (Figs. 1 et 2) is composed of four interconnected basic parts which are:

- a) a microscope equipped with a motorized stage and a drawing attachment;
- b) a coordinate digitizer in X-Y and one in Z;
- c) television camera, monitors and tape recorder;
- d) a microcomputer and its peripherals (terminal, floppy disk driver and printer).

The drawing attachment allows the superimposition of the microscope, digitizer and television images.

A general software provides for calibration of the basic parts, enabling the apparatus to perform traditional operations in nuclear emulsions like: systematic scanning around a given position, three-dimensional observation of an event, track following, coordinate measurements of any point in the field of view, etc.

A special software enables the apparatus to perform specific operations or data handling related to a given experiment as, for example:

- visual check of the matching between the topology of an event seen in the emulsion and the topology of the same event as reconstructed from spectrometer data, both displayed on the TV monitor or optically superimposed through the drawing attachment (WA71 experiment);
- angular distribution or scattering of isolated single tracks crossing emulsions exposed perpendicular to a beam (background analysis in a neutrino beam).

Apart from the versatility and speed of the apparatus, its two main advantages are:

- the visual aid provided by the computer display of either predictions or measurements;
- the "micro-kinematographic" observation of the emulsion thanks to the automatic control of the microscope focus.

3. THE HARDWARE

The control hardware consists of two crates: one containing the power supplies and power drivers, and a second containing the control modules, i.e. the interface between the optical devices and the microcomputer. This hardware interface allows essentially the driving of the stage motors and the measurement of data from the emulsion.

The driving system of the stage consists of three stepping motors, control modules (1 per axis) and manual controls. A microprocessor interface for computer control of the motors ("automatic driving") consists of a universal bus adapter card placed inside the microprocessor and connected to a module in the crate by a flat cable; an interpolation module in 2 (or 3) axes allows to follow given track patterns existing in emulsion (by software control only).

In more detail, the manual motor control is composed of: a) acceleration and deceleration ramps, allowing higher speeds to cover longer paths; b) a tracker ball device to drive the X, Y displacements; c) a joystick for the scanning in Z at a presetable speed; d) a push button panel allowing

fine control of the Z movement for special scanning conditions like choice of different Z values as scanning limits, reset at a given Z, local storage of a given Z position, move to this position, etc.; e) a digital display is available for control of X, Y, Z current position; f) reset, go to or go back to a given X, Y, Z position are also implemented.

The measurement system allows either the measurement of "relative" coordinates (the x, y, z position of a point in the local frame of the microscope field), or "absolute" coordinates (the X, Y, Z position of a point in the general frame of the stage); adequate calibration allows the correlation to the frame of the hybrid experimental set up. The measurement apparatus consists of: a) a digitizing table (HiPad) for x, y and an optical encoder (Heidenhain) for z relative coordinates; b) the stepping motors (Märzhäuser) for recording the absolute coordinates.

The nominal resolution and accuracy of the x, y digitizer are 0.13 mm and 0.38 mm respectively. Typical corresponding resolution and accuracy in emulsion are 1.3 μm and 3.8 μm when using a x 100 objective on the microscope. The resolution and accuracy of the z encoder are 1 μm . The resolution of the stepping motors is 1/4000. Therefore, ideally, one can reach a resolution in X, Y of 0.25 μm when using transmission screws with 1 mm pitch, and a resolution in Z of 0.025 μm when the motor acts directly on the micrometric screw of the microscope.

A hardware interface converts the outputs from the x, y digitizing tablet and the z encoder into a suitable binary format for the processor (Fig. 3 shows the electronic block diagram); data sent to the memory of the processor have the following format:

A video control module consisting of a digital delay allows to match in time the CAVIAR output with the camera image, and to generate high resolution TV images. Also, it allows to select either the prediction display (link microprocessor-TV) or the emulsion image (link camera of microscope-TV). The screen resolution (using x 100 objective) is 1 pixel $\approx$ 1 μ m.

4. COMPUTER CONTROL

CADIM makes use of: a) the local microcomputer, by which visual display and motors are controlled and measurements are made; and b) of a host computer, for processing the information coming from other detectors coupled to the emulsion and for storage of emulsion data. As shown in the general block diagram (Fig. 2) the local microcomputer is composed of: a) the microprocessor central unit and the video display unit, both included in a Super Caviar (CAMac Video Autonomous Read-out⁴) equipped with 256 kbytes Ram (16 bit words); b) a two floppy disk driver for local storage (data and interactive programs); c) a local (Silent 700) paper printer and plotter; d) an INDEX link to a host computer (actually IBM or CDC 7600), where more complicated software procedures are available; e) a teletype unit allowing dialogue either with the local or the host computer. Scanning, matching and measurement procedures in emulsion are implemented interactively through the terminal keyboard and screen. Numerical data are also displayed on the terminal screen for each event.

The local microprocessor unit is used essentially for the scanning (motor driving) and matching (on-line visual display) procedures. To improve the efficiency of emulsion data processing, however, the use of more efficient processors is required, especially if more than one scanning unit are used. This also applies if more sophisticated matching procedures are required.

5. THE SOFTWARE

The computer programs follow the general strategy of helping the operator rather than substituting him. "Helping" means speeding up and gaining in precision. So far, no attempt has been made at automating

completely any critical operation (like identification of secondary vertices topology), the operator being still the best pattern recognizer. The software is strongly dependent on the particular application of CADIM to a given experiment, except for a few basic procedures like calibrations which are in common. The software package we will describe here is the basic software i.e. the set of experiment independent programs. It consists of:

a) A data transfer program, between host and local computer. Data processed on the host computer (IBM) are saved on the host memory as DST in compact format and, using INDEX links, transferred to a local floppy disk unit.

b) A stage calibration program which allows automatic positioning on any given point of the X, Y plane. Using fiducial marks printed on the emulsion, it is possible to establish correlations between the frame of reference of the microscope stage and the frame of reference of the other detectors to which the emulsion was coupled. The block diagram is shown in Fig. 4.

c) An optical calibration program which allows direct visual comparison between the emulsion information and the stored information provided by the other detectors. This comparison is implemented by a set of programs for optical alignment of the microscope stage, the monitor screen and the digitizing tablet and for normalization of their respective scale factors.

d) In each measurement program, a subroutine is activated to perform on-line corrections for shrinkage and distortion of the emulsion. The latter is achieved by measuring a probe track of known direction (e.g. beam track) and applying the vectorial method for distortion correction of Cosyns & Vanderhaeghe ⁵⁾.

e) A data transfer program which allows transfer of measured data from local to host computer, where a more refined analysis and quantitative comparison to the spectrometer information is possible.

6. FUTURE DEVELOPMENTS

Some refinement in the display will be introduced by making use of a new four channel pointer on the x, y digitizer and the colours available on the Super Caviar computer. Coupling two microscopes, optically and mechanically, would facilitate and therefore speed-up track following through consecutive emulsions of a stack.

More essential improvements are then considered, calling on digital image processing. Preliminary tests indicate the possibility of eliminating some of the background (.e.g. isolated grains and irrelevant tracks) by "integrating" and "comparing" images at different depths in the emulsion. Three-dimensional signal processing and track detection algorithms are being developed and are beginning to give promising results ⁶⁾.

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Fig. 1: CADIM II

Fig. 2: CADIM general block diagram

Fig. 3: X, Y motors control module

Device:

Program:

Fig. 4: X, Y stage calibration