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MICROPROCESSOR SYSTEM FOR TRACKING ISODENSITY LINES IN FILM DOSIMETRY

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The recent fall in price of microprocessors offers interesting possibilities for new approaches in plotting isodensity curves for radiation dosimetry. A relative inexpensive equipment is now described which uses an INTEL 8080 microprocessor. The apparatus tracks the isodensity line directly by deriving the step length and the step direction from preceding density measurements.

The tracking procedure is based on the following points.

(1) The length and the direction of each new step are based on the combination of up to the last 10 previous steps. After each step the local density is measured and a new step length and direction is computed.

(2) Isodensity tracking is initiated with a preset starting position, taking the local value as isodensity value. Also the direction for the first few steps must be entered if default values are unsuitable.

(3) The step length is adapted to the local density gradient. Density gradients in the central region of the beam are considered as the normal ones. At small depths high dose variations exist at the beam edges; this will produce high density gradients on a film. Inside the beam at greater depths and in regions outside the direct beam, the corresponding density gradient is low. For steps not coinciding with the mean direction the procedure checks whether the local gradient belongs to the high, normal or low gradient category.

(4) The ragged appearance of isodensity lines caused by small film irregularities, dust particles etc., is reduced by defining an upper limit between the local signal and the preset isodensity value; only outside this limit the spot will start to diverge from the mean direction.

(5) The tracking procedure copes with the appearance of film stains (caused by dust particles, for instance) of a diameter greater than the step length. If the spot enters a stain, it tends to move in a circle inside the stain because it has lost its orientation to the isodensity line. The direction of the last steps are retained to discern this circling.

Equipment

The equipment consists of a densitometer, a moving film table coupled with a drawing board, a fixed pen and a microprocessor (Fig. 1).

Any densitometer can be used which fulfils the following requirements. The light spot on the film should have a diameter of less than 1 mm. The resolution of the densitometer should be about 0.1 per cent of the full scale with density 1.0, i.e. the lowest density which should give full scale response with maximum amplification. The densitometer signal is fed by means of an AD converter (11 bits) into the microprocessor.

Two stepping motors move the film drawing board assembly in two orthogonal directions. Combining both motors, a step can only be in one of the 8 principal directions (A, Fig. 2). When the equipment

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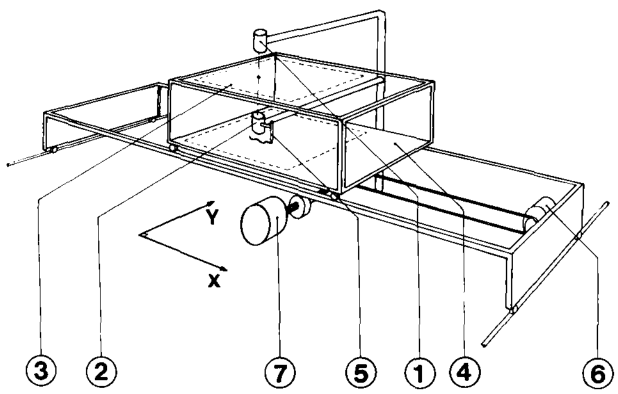


Fig. 1

Fig. 1. Isodensity tracking device. (1) Photomultiplier. (2) Lamphousing. (3) Film table top. (4) Drawing board. (5) Drawing pen. (6) Stepping motor. (7) Stepping motor with high precision threaded axis.

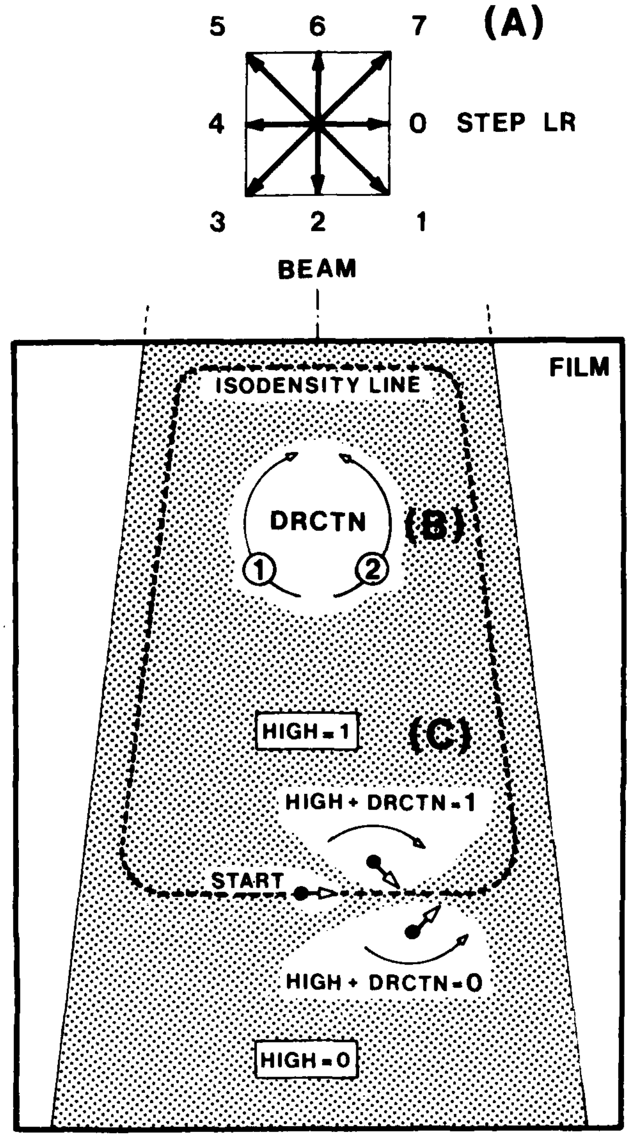


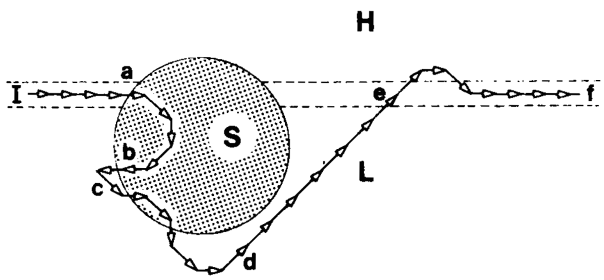
Fig. 2

Fig. 2. Isodensity tracking procedure. (A) The eight directions for a step, performed by moving the drawing board in two orthogonal directions. (B) Movement of the measuring light spot is either clockwise ① or anticlockwise ②, indicated by DRCTN = 1 and DRCTN = 0, respectively. (C) The inner area of the isodensity line to be tracked is indicated by HIGH = 1, the outer area by HIGH = 0. The position to start the isodensity tracking (START) is entered manually. The default start direction is LR = 0. The directions of next steps are governed by HIGH + DRCTN.

is switched on, high precision potentiometers indicate to the processor the table assembly position. All further positioning is made by counting the impulses given to the stepping motors. The drawing board moves under a rigidly fixed drawing pen; the lift mechanism of the pen is controlled by the microprocessor software. A similar mechanical coupling for drawing isodose curves is given by HASKARD (1975).

The microprocessor of the isodensity tracking equipment consists of an INTEL 8080 processor, 6 k bytes Read Only Memory for the software instructions including the tracking procedure and 1 k bytes Random Access Memory for data handling and program stack.

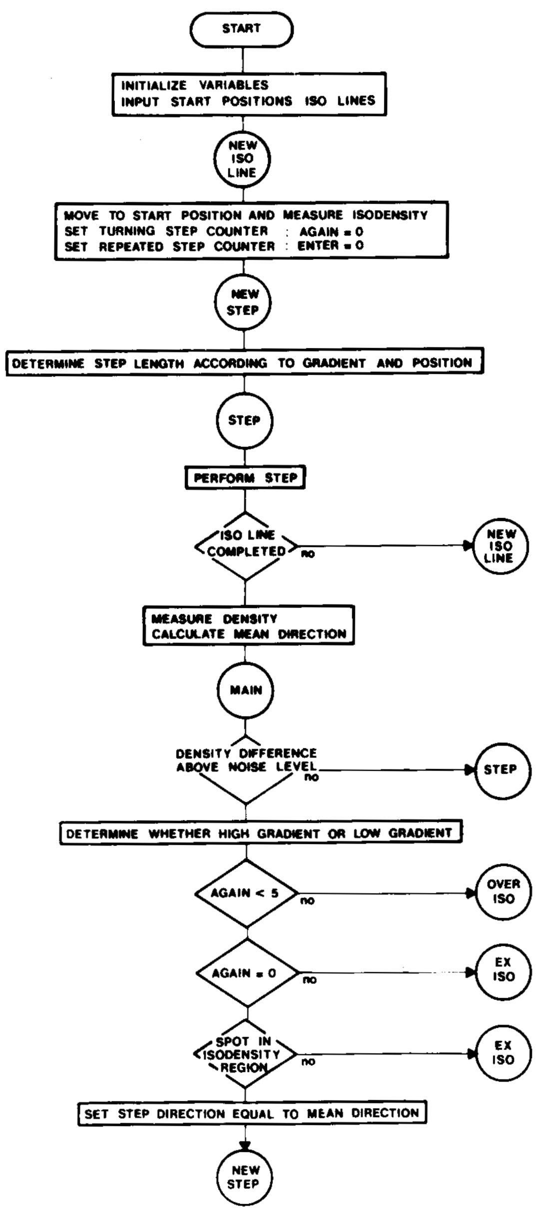
A numerical keyboard is available on the front panel to manipulate the film table-drawing board assembly or to enter a series of (x, y) coordinates on the film. In the manual mode the position of the film table assembly and the corresponding relative density are displayed by 4 digits LED displays. The manual mode is used to measure the highest density of the film and to adjust the densitometer gain accordingly. Next the (x, y) coordinates of points on the film are entered from which isodensity tracking has to start. These positions are usually derived from percentage depth dose data obtained by other dosimetric methods. This approach was chosen to avoid the problem of converting relative density to relative dose.



a

b

Fig. 3. a) Movement of measuring spot with respect to a stain. I: Region along isodensity line inside which steps are taken in the mean direction. H: Region with densities higher than in region I. L: Region with densitities lower than in region I. S: Region with equal density. a: Spot enters high density stain, 4 times turning until spot moves in reverse direction (AGAIN = 5). b: Step in reverse direction is repeated and the number of these steps stored in ENTER. c: Spot leaves stain. In this example the isodensity value is crossed also and the step direction is equated to the mean direction. However, the spot moves away from the isodensity line and the turning process restarts. d: After a few turns the spot moves towards the isodensity line and steps are repeated. e: Spot in isodensity region. Next step in mean direction moves spot out of the isodensity region. f: Spot in isodensity region. Mean step direction has taken the correct value. b) Actual tracking around a circular stain.



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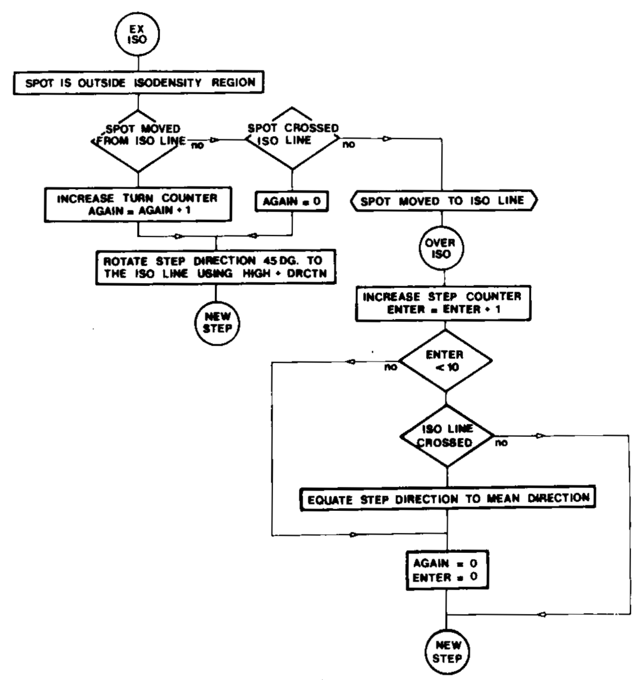

b

Fig. 4. Flowchart of the tracking procedure.

Tracking procedure

The procedure starts with moving the measuring light spot (called spot hereafter) to a position entered manually; the corresponding density is taken as the isodensity value. The pen is lowered and the first few steps are done in either the default direction (LR=0; A, Fig. 2) or in a direction entered manually.

The procedure uses three preset density difference levels. The smallest one prevents the procedure to act on small differences due to noise between subsequent signal values. A second density difference level determines a zone around the isodensity value. If the measured density lies in this zone, the next step will be a step in the mean direction. This zone around the isodensity line will be called the isodensity region.

Within the isodensity region a step is always a 1 mm step in the mean direction. Every time a step outside the isodensity region is taken in a direction not coinciding with the mean direction, the measured density is compared with the previous one. If this local density difference is smaller than the third preset density difference level, the next step will be a 1 mm step. If greater, a step not in the mean direction will be a 0.5 mm step. This step is in the high gradient region.

Let DRCTN=0 indicate anticlockwise direction and DRCTN=1 the clockwise one (B, Fig. 2). Movement of the measuring light spot into the inner area sets the variable HIGH to 1; when entering the outer area HIGH is set to 0. When a step moved the spot away from its isodensity value, the necessary change in direction for the next step is given by HIGH+DRCTN (C, Fig. 2).

If a previous step moved the spot correctly, the next one is a step in the mean direction of the last 10 steps rounded to the nearest 45°.

Outside the isodensity region, the next step direction will be rotated 45° towards the isodensity line. If the spot then moves towards the isodensity value, this step will be repeated until the isodensity value is reached or passed. However, if the spot moves parallel to or diverges from the isodensity value, the next step direction will be again rotated 45° to the previous one (Fig. 3).

After 4 times repeating this turning the step direction has reversed and the measuring spot tends to move in circles. The variable AGAIN counts the number of consecutively increasing or decreasing step directions; after 4 times AGAIN equals 5 (Fig. 3). Then all following steps are taken in the last direction. However, if after 10 steps the spot still moves away from the isodensity line, the 45° turning process restarts.

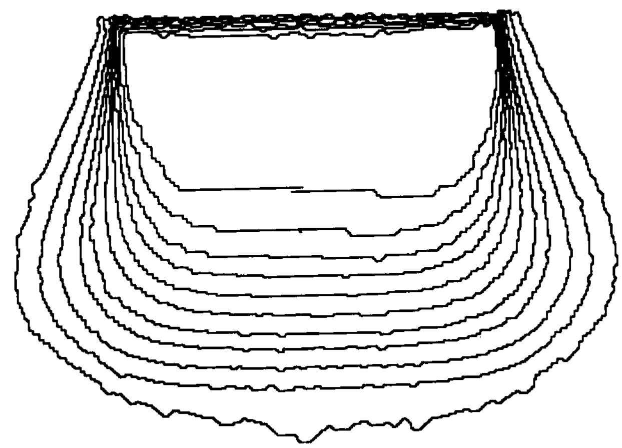

Fig. 5. Isodensity curves at 20 MeV electron radiation (field 10 cm × 10 cm) drawn by the tracking procedure. The isodensity tracking was started on the central axis at the positions of the 90, 80, ..., 10, 5 and 3 per cent depth dose. Note the following characteristics: The beginning and the end of a tracked curve do not necessarily coincide, cf. the 90 per cent line, due to introduction of an isodensity region along the isodensity line. The 3 per cent line shows some meandering in the low gradient region inside the beam.

The completion of the isocurve is detected by testing, after each step, whether or not the spot has entered a small region around the starting position.

More details can be found in the flowchart of the tracking procedure (Fig. 4).

Results and Discussion

The tracking procedure has two advantages as compared with other techniques. The tracking speed is maximal and a direct coupling with a drawing board is possible, because all steps have a small or zero divergence from the isodensity line. An X-Y pen recorder is thus not needed, which reduces the costs of the whole equipment substantially.

The combination of global movement and mean direction gives the procedure a remarkable capacity to handle irregularities like film stains or isodensity lines starting from a film edge at the entrance or exit side of the beam. Meandering of the isodensity line occurs only in regions with very low density gradients (Fig. 5).

A single set of values for the different density difference levels and the number of last steps to retain for the mean direction suffices for all density patterns tested. Since the density differences are all relative to the isodensity value, the accuracy of the isodensity curve obtained is to a high extent independent of the gain of the densitometer, provided the latter is sufficiently high.

SUMMARY

Using a microprocessor a method for plotting isodensity lines in film dosimetry is described. The procedure moves the measuring spot directly along an isodensity line, using information obtained in preceding steps to determine the next step. For registration of the curves no X-Y pen recorder is needed. The essentials of the procedure together with a flowchart are given.

ACKNOWLEDGEMENT

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HASKARD D. L.: An automatic X-ray isodose plotter. Phys. Med. Biol. 20 (1975), 645.