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A TRACKING SCANNER

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[redacted]

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[Following is a translation of an article by V. A. Garmash, V. S. Nereverzen-Orlov and V. M. Tsirlin entitled "Ustroystvo sledyashchey razvertki" (English version above) in Izvestiya Akademii Nauk SSSR, OTN, Energetika i Avtomatika (News of the Academy of Sciences, USSR, Technical Sciences Section, Energetics and Automatics), No 1, Moscow, Jan-Feb 1961, pp 166-170.]

A number of works [1-3*] have been devoted to the process of identification by man of shapes, in particular of images, by a modelling of that process and by the creation of specialized devices which enable automatic identification of presented images.

In creating devices for the purpose of identification, special attention must be devoted to problems in the detection and analysis of contours of an image [4*]. The problem of detection of contours can be solved in a great many ways. In particular, by using a scanner in two mutually perpendicular directions one can obtain a contour image [5*] But more description of the contour is required for identification of an object by its contour, on which the logical part of the identifying device can make a definite decision. In this

* See Literature page 8.

case direct tracking of the contour of the image evidently offers the best possibilities, since in this case its description is obtained by simpler means. This operation can be performed by a tracking scanner. Mention of a tracking scanner has already been made in discussion according to Loeb's paper [6*], but there have been no other references to it in the literature up to the present time.

<u>The operating principle of the tracking scanner.</u> The tracking scanner is a device which enables automatic movement of a scanning spot along a contour that is being tracked. In so doing it proves possible to separate the current coordinates of the scanning spot, and this enables one to obtain an analytical expression of the function, a graph of which is the contour being tracked.

The problem of obtaining steady movement along the contour is reduced to: 1) establishing an operating regime for the device in which the position of the scanning spot on the contour is steady; 2) providing for movement of the spot along the contour in a given direction.

If the scanning point is forced to move about a circle in such a way that it crosses the edge of the contour and shifts the center of the circle to the point where the circle and contour intersect, for example, in the transition of the scanning point from white to black, the problem posed will then be solved, since in this case the center of the circle will move on the contour in one direction and the position of the scanning circle will be steady on the edge of the contour. It follows from examination of Figure 1 that if the center of the scanning circle does not lie on the contour the vector of the elementary displacement a can be broken down into two compounds: the tangential a_1, which displaces the center of the circle along the contour, and the normal a_2, returning the center of the scanning circle on the contour. The trajectory of movement of the center of the scanning circle will describe a broken line here, wound on the contour, obtainable by subsequent adding of the vectors of the elementary displacements a.

This principle of tracking the contour has been

*See <u>Literature</u> page 8.

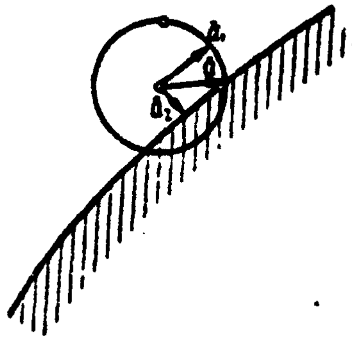

Fig. 1

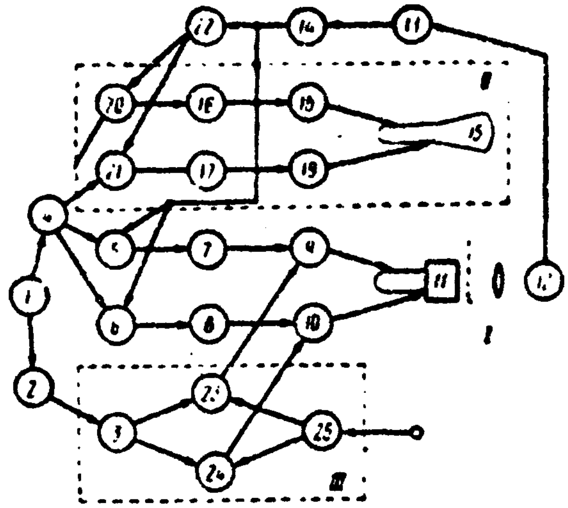

Fig. 2

adopted as the basis of the device now being described.

Block diagram of the tracking scanning device. A block diagram of the device is given in Figure 2 and consists of the tracking scanner I proper, a device II which serves for the conversion of scales and a device III which is used in the measurement of angles.

The sinusoidal voltage from the output of generator 1 across the phase inverter 2 with regulated phase shift is transferred to cascade 3, forming sinusoidal and cosinusoidal oscillations which are used further on to create the circular motion of the scanning beam on the screen of the counting tube. The same voltages are transmitted to a cascade 4 analogous to cascade 3, to the outputs of which switches 5 and 6 are connected to take readings of the instantaneous values of the paraphase voltages, the vectoral sum of which is proportional to the vector of the elementary displacement a. The readings of the instantaneous values of the sinusoidal voltages are integrated by elements 7 and 8, the signal from the output of which, amplified by cascades 9 and 10, is given to the counting tube 11.

The scanning beam, having completed its circular motion, is projected from the screen of the counting tube 11 by optical means onto the contour of the image, and having passed through or been reflected by them, strikes the photomultiplier 12. The signals obtained on the output of the photomultiplier are amplified by video amplifier 13 and given to cascade 14, the purpose of which is to shape a short impulse regulating the taking of readings of the instantaneous values of the paraphase voltages at a moment of time corresponding to the intersection of the contour by the scanning beam, at the transition from white to black, for example.

The phase inverter 2 serves for compensation for the effect of delays arising in the channels for amplification and shaping of signals. Compensation for the effect of these delays is accomplished by increasing the total delays to the magnitude of the period of revolution of the beam on the scanning circle.

The second part of the circuit enables the contour of the image being investigated to be reproduced on the control tube 15 with the possibility of change of scales along the two axes of the coordinates defined by the deflecting system of tube 15 and by turning of the image contour in the coordinate plane. This part of the block diagram does not differ at all from the corresponding part of the block diagram proper of tracking scanner 1, described above. Sudden change in scale along the two axes of the coordinates is accomplished at the expense of change in the constants of the time of integration of elements 16 and 17, and a smooth change, by change in the amplification factor of amplifiers 18 and 19. Turning of the image contour on the control tube, representing the turning of all the elements of the contour on one and the same angle, is accomplished by introducing a controlled delay 22 of the signal, taking readings of the instantaneous values of the paraphase voltages with the help of keys 21 and 20.

The third part of the circuit is used in measuring angles in places where there are breaks in the contour, and consists of two amplifiers 23 and 24 with variable amplification factors regulated by a Kipp relay 25 with a pulse length short of the period of the frequency of the paraphase voltages.

Description of separate units in the circuit. In the device built according to the above block diagram the most interesting features are: 1) a limiter of circuit 14 shaping short impulses regulating the taking of readings of the instantaneous values of the paraphase voltages; 2) switches 5, 6, 20 and 21 which accomplish the taking of these readings; 3) cascades with variable amplification, used in the measurement of angles in breaks of the contour.

By virtue of the fact that the counting tube has a finite afterglow time, the video amplifier a finite pass band and the scanning point finite dimensions, the pulses of the photocurrent on the output of the video amplifier represent, not rectangular pulses, but trapezoidal pulses with smoothed fronts. Since during movement of the scanning circle its center fluctuates around the contour, impulses of varying length are obtained. All this has forced rejection of ordinary circuits which produce a limitation at the mean integral level and use of the circuit producing a limitation at a level that is a mean relative to the maximum and minimum values of the photocurrent of Figure 3. In this circuit the diodes D_1 and D_2 are used for bilateral peak detection of the supplied signal. The arithmetic mean

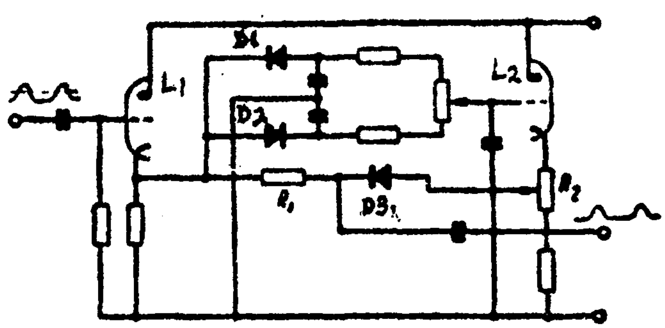

Fig. 3

value of the voltages obtained at the output of these detectors, amplified by the cathode repeater (L_2) is given as a reference to the limiter, assembled according to the circuit of the diode switch and consisting of resistor R_1 and diode D_3. The voltage obtained on the output of this switch is given to the circuit which shapes short pulses. The resistor R_2 is used to select the limitation threshold.

Switches 5, 6, 20 and 21, used to take readings of the instantaneous values of the paraphase voltages, must have two-way conductance. As a two-way switch (Fig. 4) two semiconductor triodes were used, switched in so that the emitter of one is joined to the collector of the other, while on one pair of emitters the collector is the input and on the other the output. The regulating negative pulse with a duration of 5 msec and an amplitude in the order of 30 V is supplied to the base of the triodes. The maximum amplitude of the sinusoidal voltage led in the input of the switches does not exceed 5 V.

Results of testing the model. In the constructed device the frequency of the paraphase voltages was 10 kc, the diameter of the scanning circle 1.5 mm at a beam width of 0.4 mm, which corresponded to a linear velocity of motion of the beam along the contour of 5 m/sec. Such a selection of frequency was brought about by the fact

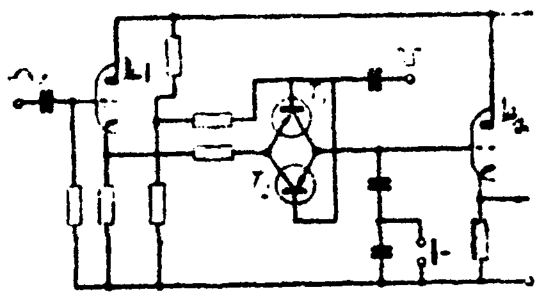

Fig. 4

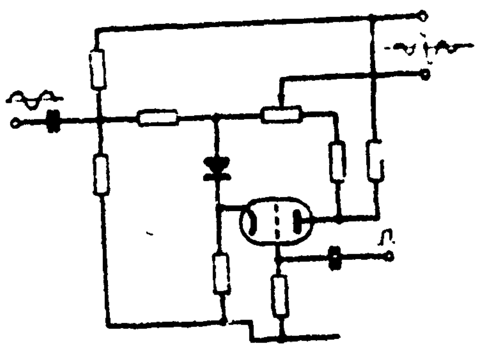

Fig. 5

that the frequency should be low enough to simplify debugging the model, and on the other band it was desirable to have a coalescent image on the monitor. The speed of operation of the system can be readily increased, however, by one or two times.

Very widely differing coherent images were studied during the change of their dimensions from the diameter of the scanning circle to dimensions of 5 cm. In this the maximum size was set by the diameter of the transmitting tube (7LO1M). When the scanning beam strikes images with dimensions smaller than the radius of the scanning circle they are not passed around by the scanning beam along the outside contour but are disposed within the scanning circle. In this border case the image is turned into a "point" but the scanning beam follows the image nevertheless.

It was established in the experiments that the beam does not transfer to an adjacent contour if the distance between the contours is not less than 2-3 diameters of the scanning circle, and in the opposite case the contours are considered as contiguous.

Extremely varied images cut out of paper were investigated -- convex from wires with a diameter of not less than 1 mm, as well as some formed by a combination of these images.

The apexes of the angles were rounded off by part of the circle with a radius that was about equal to the elementary displacement.

When the scanning circle turned out to be outside the contour, the inclusion of a necessary scan along the spiral until finding the place where the beam struck the nearest contour was assumed.

<u>Some applications of the tracking scanner.</u> The development and building of the tracking scanner described above was undertaken for the purpose of creating a reading machine, on which a quasi-logical method of separating letters of the Russian alphabet into classes was based. The essence of this method was that, when the letters were passed around on their outer contour, indexes of the points in places of the breaks were determined, in which the succession of values of the indexes of these points(without considering points with

an index of two) obtained during a single passage around the letters forms coded combinations which are also assumed in the principle of the classification. In this the classification of letters within classes, obtained by the quasi-logical method, is accomplished by means of the supplementary logic which has developed the signals of this tracking scanner.

In connection with the fact that the tracking scanner has constant linear velocity of motion along an arbitrary contour, it appears possible to classify these contours by their length.

The feature of the tracking scanner of passing around the proposed image on the contour can be used for contour television and phototelegraphy.

In conclusion, the authors thank A. A. Kharkevich for the attention he gave this work.

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