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STRUCTURAL MODEL OF HALFTONE IMAGE AND IMAGE SEGMENTATION EXPERIMENTS

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Abstract: The structural model of gray-scale picture is offered. The structural model supposes the selection of objects in the image, thus their description is invariant in relation to affine transformations. Object form is exhaustive its description of. Object form is defined by its contour and the optical density function, which is certain within its contour bounds. The determination of halftone picture contour is proposed, as a sequence, consisting of straight line segments and curve arcs, and the straight line segments and the curve arcs are the critical lines of surface which corresponds to the halftone picture. An example, how to use the structural model of halftone picture for the medical preparations image processing got on the method of Kyrlyan, is considered.

Key words: structural analysis of halftone picture, contour, row model, segmentation

ACM Classification Keywords: I.5.1 Models, I.3.5 Computational Geometry and Object Modeling.

Introduction

Visual information, particularly halftone pictures processing is one of the most difficult artificial intelligence problems and, at the same time, more and more urgent for the practical use in the most different branches of science and technologies.

The raster mode of halftone pictures is presently used in artificial intelligence means.

To process the raster half-tone pictures, the heavy computational resources are needed.

The raster half-tone pictures processing, for example, objects identification, which have different values of affine transformations - a scale, position, rotation, require the heavy computational resources or in general view are impossible.

In modern visual halftone information processing such concepts as *object contours* are not utillized practically (except for the object contours of halftone image preliminary turned into binary one).

The ability to segment a picture in the eyeshot, to stand out objects, which differ against a background by optical density, color, texture, other, is one of basic and the most natural feature of human visual perception. The form which is defined by a contour - border between an object and background is the basic attribute of any object. A contour, in same queue, is accepted by a human as a sequence of line segments and curve arcs. The form of half-tone and color objects is determined, in addition, by the function of optical density taking into account a color, texture within a contour each of objects. These human visual perception features are reproduced in the offered structural model for halftone image.

A structural model enables to present arbitrary images as regular description which consists of background and object descriptions.

Task of adduction to the structural model of arbitrary images, set in a raster mode, distorted hindrances in general case yet not decided. However in separate, numerous enough cases, bringing images over to the structural model allows substantially to promote speed and quality of visual information processing that, in same queue, provides the high-quality functioning of utilizing these facilities of information technologies. The objects of halftone picture, transformed in a structural mode, invariant in relation to affine transformations , by the best appearance befit as basic data for processing by the methods, based on growing pyramidal networks [Gladun,1] and theory of recognition and memory [Rabinovich,2]

Structural Model of Halftone Image

The structural model of half-tone image corresponds to the known representations about visual perception mechanisms. Objects, located on an image background, which have been determined by the two-dimensional function of optical density, are the basic structural display elements. Objects, in same queue, have been determined by the contours which bound objects and by the two-dimensional optical density function, within the bounds of object. Contours are the closed sequences which are formed by the segments of lines and by the curve arcs.

Under an image it is understand a part of plane, bounded with some geometrical figure, usually by a rectangle, which the value of optical density is defined for every point of. In other words, a rectangle with the sizes of X,Y on a plane is the function domain of $\rho = f(x,y)$, $(0 \le x \le X \,;\, 0 \le y \le Y)$. It is possible to put some surface of $z = f(x,y)$ in correspondence to this function.

Let us present some information over from an area analytical geometry in space [Korn,Korn,3]. The set of points P(x,y,z), the co-ordinates of which satisfy the system of equations

$$x=x(u,v),\ y=y(u,v),\ z=z(u,v) \tag{1}$$

at the suitable values of actual parameters of u,v, is named ***a continuous surface***, if right parts of equations are the continuous functions of parameters. It is possible to define a surface as the equation

$$j(x,y,z)=0 \text{ or } z = f(x,y).$$

A surface can have more than one cavity. *A continuous surface*, consisting of one cavity and not having self-intersections (multiple points) is named as the simple surface. It is having in mind, that simple surfaces are bilateral (one-sided surfaces, such as a sheet of Mebiusa, are eliminated).

The point of surface (1) is named ***a regular point***, if at some parametric surface representation the function (1) has in a sufficient closeness to the examined point continuous partial first derivatives and, at least, one of determinants

$$\begin{vmatrix} \frac{\partial x}{\partial u} & \frac{\partial y}{\partial u} \\ \frac{\partial x}{\partial v} & \frac{\partial y}{\partial v} \end{vmatrix}, \quad \begin{vmatrix} \frac{\partial y}{\partial u} & \frac{\partial z}{\partial u} \\ \frac{\partial y}{\partial v} & \frac{\partial z}{\partial v} \end{vmatrix}, \quad \begin{vmatrix} \frac{\partial z}{\partial u} & \frac{\partial x}{\partial u} \\ \frac{\partial z}{\partial v} & \frac{\partial x}{\partial v} \end{vmatrix}$$

is different from a zero. The simple surface piece, bounded with the closed curve, is named *regular*, if all of its internal points are regular. Bilateral simple (closed or unclosed) surface, composed of the finite number regular pieces with common regular arcs and points is named *a regular surface*.

Thus, regular unclosed surface in space of Oxyz, which consists of simple pieces of surface, can be put in correspondence to every halftone picture. It takes a place the next contingency for the surface, which corresponds a halftone picture. One and only one value of function r(x,y) corresponds every value of co-ordinates (x,y), that a perpendicular to the plane of image in any point x,y crosses an imaginary surface one and only one time.

The every piece external contour (border) of regular surface is the closed sequence of regular curve arcs and line segments. The contour points are not the regular points of simple surfaces pieces. The contour points are boundary points of simple surfaces pieces. The contour points form the special lines of surfaces which are boundaries, dividing the different pieces of simple surfaces. Unlike binary images the points of which can have two values of optical density only - black or white, the areas of half-tone pictures can have different change laws of optical density. Accordingly, an amount of different from each other nearby pieces of simple surfaces, as a rule, is more than two. So, contours of gray-scale picture can't be, in general case, the simply connected sequences, consisting of regular curve arcs and line segments, and consist of branches, connecting graph junctions, which form graph. The branches are the special lines of image. The contour points, except graph junctions, are the regular points of branches. Graph junctions are the special points of contour and all of image. Branches and graph junctions together with the law of change of optical closeness of every piece simple a surface fully determine a regular surface and proper by it area of image. In many practical cases the contours of gray-scale picture are the simply connected sequences of regular curve arcs and line segments, when simple, not contact with each other objects are located on background, that simplifies the task of structural analysis substantially.

It is always possible to select areas in a gray-scale picture, having permanent, or changing on a certain law value of optical density. So, a gray-scale picture can be represented as some area of regular surface, consisting of regular pieces of simple surfaces, thus every object of image corresponds to one or a few pieces of simple surfaces.

Every simple surface piece is fully determined some function of two arguments and contour. Within the boundary of every simple surface piece the law of change an optical density can be represented as a n degree polynomial function. A contour is the closed sequence of branches – line segments and curve arcs, and every branch can be represented as a n degree polynomial function. The representation of simple surface piece as a set of polynomial functions is invariant in relation to affine transformations. Consequently, the offered half-tone image representation is invariant in relation to affine transformations.

Digital Line Model of Arbitrary Gray-scale Picture

Let the grate of N×M, having discreteness value of *t,* is overlapped the image plane Oxy. That is the vertical lines of the grate {0,N}, distance *t* between them, are parallel to Ox axis. The horizontal lines of the grate {0,M}, distance *t* between them also, are parallel to Oy axis. The grate cells correspond image pixels, having integer co-ordinates *n,m* (n→{0,N}, *m*→{0,M}), thus $x = n \cdot t$; $y = m \cdot t$. Discrete, digital presentation of image substantially differs from the mathematical model of halftone picture. Discrete image elements are pixels, having finite sizes, unlike infinitely small points, used in a mathematical model. The lines of discrete image are usually formed with pixels, having finite sizes. At the same time contour lines of mathematical model do not have a thickness.

To eliminate the contradictions arising up when using the halftone picture structural model for discrete image, let represent image, as two-dimensional cell complex [Kovalevskiy, 4].

An *D*-dimensional cell complex is a structure consisting of abstract elements called cells. Each cell is assigned an integer value from 0 to *D* called its dimension. There is a bounding relation imposed onto the cells: a cell of a lower dimension may bind some cells of a higher dimension. An example of a two-dimensional complex is shown in Fig. 1. In this case pixels are two-dimensional elements. For every pixel a value of optical density r is the basic determining pixel attribute.

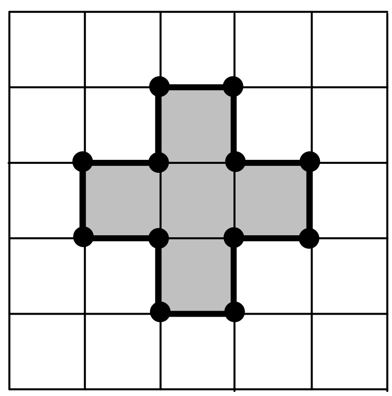

Fig.1

The pixels are represented in Fig. 2 as the interiors of the squares, the cracks as the sides of the squares and the points, i.e. the 0-cells, are the end points of the cracks and simultaneously the corners of the pixels.

The *boundary* (*crack boundary*), of object contour is the set of all boundary cracks and all end points of these cracks. A boundary contains no pixels and is therefore a „thin“ set, whose area is zero. Contour of object (Fig. 2) in this case is the connected closed sequence of *contour cracks*, boundary between object pixels and background.

As shown in [2], representation of discrete image as a cell complex gives a lot of advantages; in particular, the contour of object becomes a thin curve with a zero area. The images of objects in discrete space can be presented as areas with some set function of optical density, bounded by the contour lines.

Let $\rho_m(n)$; (n = 0,N) – is the optical density function of horizontal pixel row number m (m = 0,M), and $\rho_n(m)$; (n = 0,N) – is the optical density function of vertical pixel line number n (n = 0,N). The regular and critical points in regular surfaces can be detected by means of structural analysis of $\rho_m(n)$ and $\rho_n(m)$ functions for all of vertical and horizontal picture rows [Kalmykov 5]. It ensues from determination of regular surface, that a point of surface is regular, if it is the regular point of horizontal and vertical lines of crossing. It ensues from determination of regular surface, that a point of surface is regular, if it is the regular point of horizontal and vertical crossing rows. If the point of surface is a critical point at least one of rows - horizontal and/or vertical crossing rows, such point is the critical, boundary point of regular surface that is the area of halftone picture.

The halftone picture areas boundary points (i.e. his regular surface) form the contour lines. The contour lines, in same queue, contain regular and critical points. The next operations must be executed to realize the developed method of halftone picture structural analysis.

1. The critical points of regular surfaces (i.e. areas of image) detecting.

2. The image critical lines (contours) construction, that are bounded objects, using the critical points of regular surfaces.

3. The contour structural elements – line segments and curve arcs detecting.

On the fig. 2 an example of halftone image structural analysis, using row model, is presented, namely contours of gray-scale picture selection. The next operations are showed over an image. The optical density function graphs for each vertical and horizontal rows of image are built, the examples of which are represented on the fig. 2 c,d. For every graph the sequence of elements which he consists of is determined, - digital line segments and digital curve arcs. The boundary points of the graph elements are its critical points of this row and all of halftone picture. The critical points of image are selected on the fig. 2b as a white color. The critical points belong to the halftone picture contour lines. The halftone picture contours are built, using the critical points. On the fig. 2e the contours in a raster mode, formed of the separate special points, are presented, and corresponded contours in a vector mode - fig. 2f.

Image Processing Experiments Using Row Model of Gray-scale Processing Picture

The digital image processing on the basis structural row model will be considered using as examples of the images of medical preparations, got on the Kirlian method. The images of medical preparations contain objects the form of which is very changeable, but, at the same time, there is diagnostic information exactly in a form, specialists to determine confidently enough at a visual estimation.

As a rule, such images are distorted by noise. The medical preparation images are using decision making in the medical diagnostic systems. Images which are got in the process of functioning of such systems, far not always there can be enough high quality that considerably reduces possibility of their rapid and complete perception by experts at the reasonable time.

But only the large quantity of such images to be analyzed, there can be the got new knowledge's the health state of population about. The processing and decision-making time, similarly as well as the amount of experts in the medical diagnostic systems, as a rule, are limited. It is impossible to process such volumes of visual information without automation, to be high quality processing.

Images, got on the Kirlian method (farther Kirlian image), are pictures, executed on the special film, size of A4, on which luminescences are registered from each of ten fingers (fig.3).

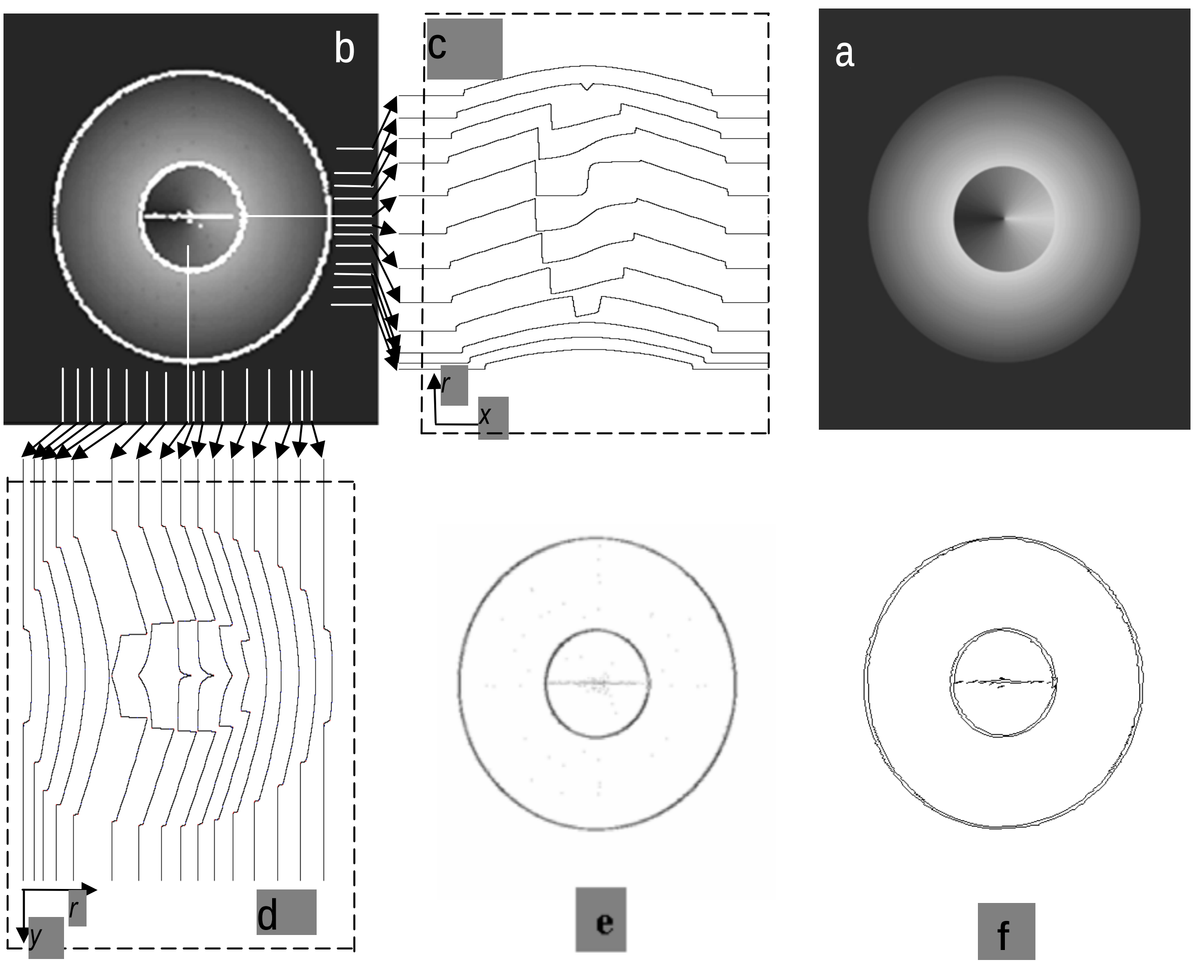

Fig.2. Contours detection on the halftone picture is executed by the programs, realizing the row model of image, and contours processing: a - model halftone picture; b - the same image with the detected critical points; c – the curves of optical density - *r* - horizontal lines; d - curves of optical density - *r* - vertical lines; e - contours images, formed of separate critical points; f - connected contours, consisting of line segments.

The images are of very bad quality: background variations, many hindrances which on intensity and size are comparable with objects, objects form and intensity instability and so on. Although on processing content these images would be considered binary, however, even such images binarization task cannot be considered easy, not to mention about the objects selection and identification tasks. There is the software for processing of Kirlian images, got on the special devices separately for every finger [Korotkov, 5]. However the use of such devices complicates diagnostics, as the organism state can substantially change himself for the recording time each of ten fingers luminescence in consecutive order.

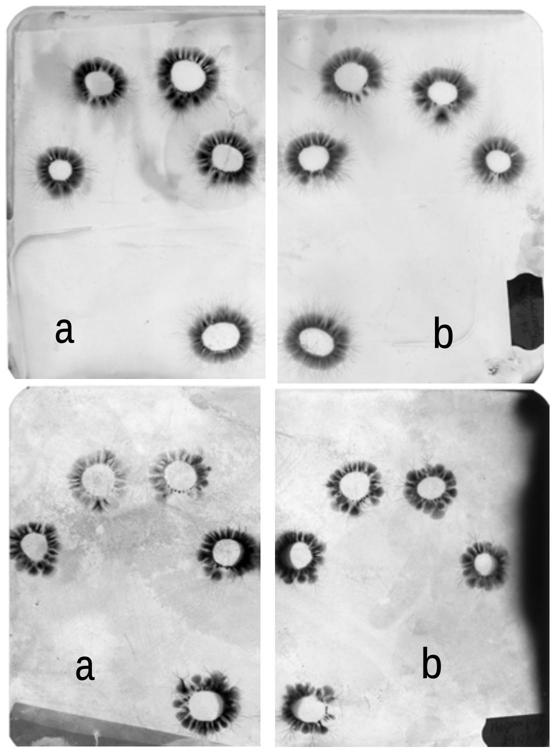

Fig. 3. Examples of Kirlian images: fingers emissions: a)- left, b) - right hands

M_o, m_f is mean values of objects brightness and background respectively; o_{min}, o_{max}, f_{min}, f_{max} are minimum and maximal brightness values of objects and background respectively.

To utilize the available bundled software for the Kirlian images, which all hand fingers (fig. 3) are simultaneously registered on, it is preliminary necessary to segment the images and define the turn corner of every finger luminescence in relation to a vertical line.

The developed software utilizes the halftone picture row model and it is intended for automatic segmentation of Kirlian images. The next operations are executed while Kirlian images processing.

The optical density histogram of the Kirlian image to be processed must be built (fig.4). Minimum objects brightness value of o_{min}, as minimum image brightness value, maximal background brightness value of f_{max}, as a maximal image brightness value is determined on a histogram. Objects mean brightness value of M_o as first maximum, while brightness values increase since a zero, and background mean brightness *of* M_f, as the first maximum while brightness values decrease since maximal (255) are determined.

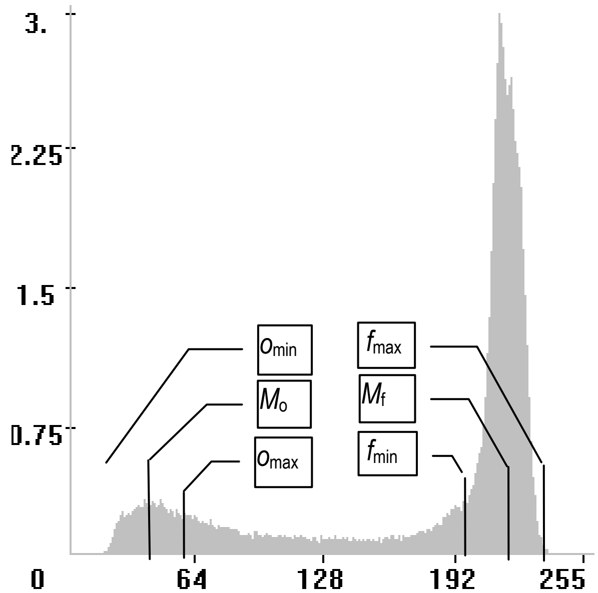

Fig. 4. Histogram of the image brightness (optical density). The values of brightness are built along abscise axis. The values, proportional the pixel amounts for this value of brightness along ordinate axes.

Background brightness minimum value as $f_{min}= M_f -(f_{max}- M_f)$ and objects brightness maximal value as $o_{max}= M_o +(M_f - o_{min})$ are calculated taking into account the next supposition. The random distribution of brightness values are symmetric as for background pixels, so for objects pixels.

– The next function for the image $v_b(m,n) = \left| \begin{array}{l} f_{min}, \text{for } r(m,n) \geq f_{min}; \\ o_{max}, \text{for } r(m,n) \leq o_{max}. \end{array} \right.$ is calculated. This function is not the binarization function, as pixels, having intermediate brightness values *of* $omax<r(m,n)<fmin$ are not taken into account in the calculation process. Such pixels do not matter for the objects detection on an image, at least, for the decision of tasks on Kirlian images processing.

This transformation is the nonlinear change of quantum levels amount from 256 to 3 and allows to a great extent to eliminate influencing of noise in the image. The examples of function *of* $vb(m,n)$ are represented on fig.5 as the polyline. Numbers 1,4,5,8,9,12,13,16 mark the critical image points, which belong to the background. Numbers 2,3,6,7,10,11,14,15 mark the critical image points which belong to the objects.

The internal and, if necessary, external object contours are built, using the selected critical points (fig.5). If contours are selected, the objects are detected successfully.

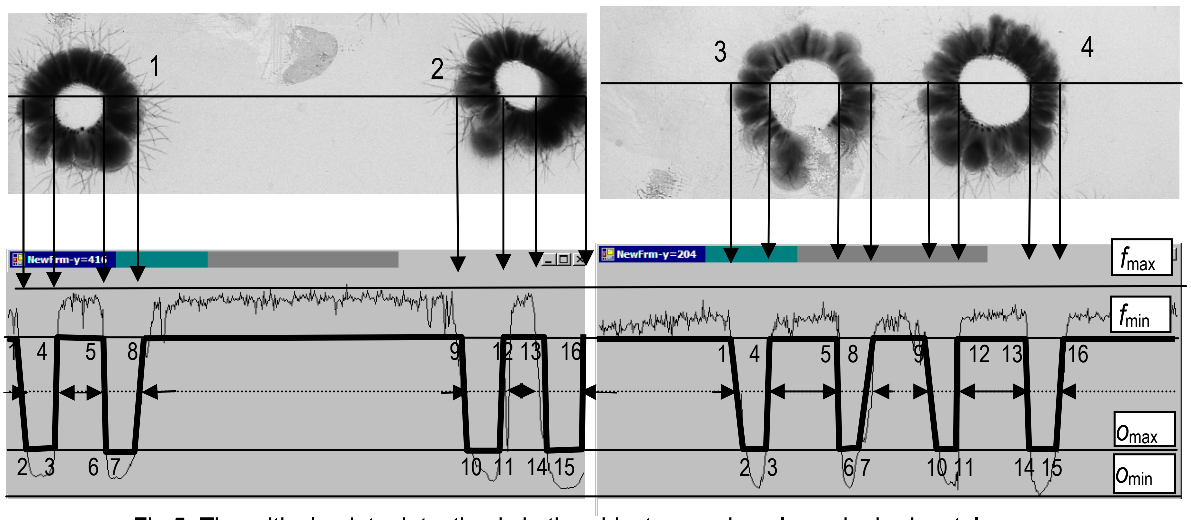

Fig.5. The critical points detection is in the objects crossing places by horizontal rows.

Objects positions (fingers emission) in relation to the palm center are detected. Internal contours are approximated as ellipses, the turn corner of every finger is detected, the finger emission images are turned to finger vertical position accordance (fig.6) and the resulting image files are formed.

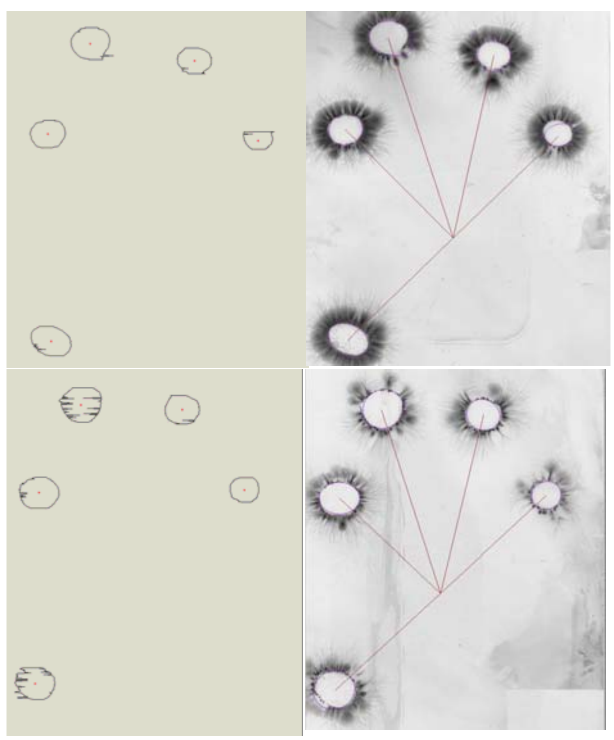

Fig.6. Internal object contours of (on the left).
Approximation of contours as ellipses (on the right).

Conclusion

1. The offered structural model allows halftone picture objects representations to be invariant to affine transformations.

2. The experiments confirmed possibility to process the half-tone images, which are different from each other such affine transformations as scale, rotation, location, using structural model.

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