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Computation of equidistant curve for the image with blurred contours

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Abstract

The task of edge restoration is important aspect of automatic information processing systems. We have developed algorithm for automatic computation of equidistant curve on the image with blurred contours. The algorithm is based on the use of linear operators on matrices. First we introduce the basic notation and mathematical model of blurred image. Then we describe developed mathematical tool to accomplish this task. We present block diagram of the algorithm and proposed restrictions on its application. We have tested our approach on the set of test images and it has shown promising results on the task of equidistant curve computation for the image with blurred contours.

Introduction

Currently, in the automated monitoring and analysis systems used computer vision systems. These systems allow creating partial or full automation of the analysis process, minimize the influence of the human factor and improve work efficiency. Independent problem of computer vision is the search and selection of boundaries of objects on images. In consequence of various factors, such as: filtering; defocusing; use is non plenoptic cameras or the result of the movement in the frame creates the effect of blurring the boundaries of objects.

The works D. Mumford and other [1-3] addressed issues restoration borders when piecewise constant and piecewise smooth optimal approximations for using the Mumford and Shah model. These numerical approaches are based on a discrete functional for image segmentation. The algorithms used a searching of contour on blurred region, but not always allow highlight the inner boundary of the object.

In the works M. Kass, A. Witkin, D. Terzopoulos [4] proposed method "snake" to find the boundaries of blurred images. This algorithm is an energy-minimizing spline guided by external constraint forces and influenced by image forces that pull it toward features such as lines and edges. "Snake" based on the active contour model. Scale-space continuation can be used to enlarge the capture region surrounding a feature. The algorithm is effective to find the boundaries, even blurring the boundary between the regions, and not the inner curve.

In the works V. Katkovnik, K. Egiazarian, J. Astola [5] is presented an approach to restoration and deblurring. In the absence of information about the kernel blur, the recovery process is much more complicated.

The purpose of this paper is to develop algorithm for automatic computation of equidistant curve for the image with blurred contours.

The rest of the paper is organized as follows. Section 1 describes the notation and restrictions for using algorithm. Section 2 describes the proposed algorithm. This is followed by a description of the basic idea of the proposed approach. Experimental results are given in Section 3 followed by the Conclusion section.

I. Notation and restrictions

We introduce the concepts and notation required to describe: let $Z^2 = Z \times Z$ is cartesian square of the set of all integers Z ; for the any aggregate $\Delta \subset Z^2$ $\overline{\Delta} = Z^2 \setminus \Delta$. Let $t=1$ or $t=2$. If (i,j), $(k,l) \in Z^2$, then $x(t)y$ $(x[t]y, x]t[y)$ when $(i-k)^2 + (j-l)^2 = t$ (properly, $\le t, > t$). On each non-empty aggregate $\Delta \subset Z^2$ we define a binary relation $[\Delta, t]$ as follows: for any $x, y \in \Delta$ $x[\Delta, t]y$ if and only if, when there is a finite sequence $x_1, x_2, \ldots, x_n$ elements of aggregate Δ such that $x[t]x_1[t]x_2[t]\ldots[t]x_n[t]y$. It is understood that $[\Delta, t]$ equivalence relation. Consequently, aggregate Δ It splits equivalence classes in this respect, which will take the name t – a aggregate of components Δ. Let's call Δ t – connected set, if aggregate is empty or has a single t components (which coincides with Δ). We note two facts: 1) simple connectedness the aggregate pull, double connectedness, and the converse is not true; 2) singleton set simple connectedness, as well as a double connectedness..

Let $\Theta \subset \Delta \subset Z^2$, and the aggregate Θ nonempty and t – connectedness. Then Θ is contained in one of the t components of Δ [6], denote $C_t(\Delta, \Theta)$. In case of simple connectedness the aggregate Θ, ie at $\Theta = \{x\}$ instead $C_t(\Delta, \{x\})$ the denote $C_t(\Delta, x)$. If aggregate $\Delta \subset Z^2$ with sufficiently large natural n aggregate $\Omega_n = \{(i,j) \in Z^2 : \max(|i|, |j|) \ge n\}$, register the simple connectedness, is contained in $\overline{\Delta}$. Consequently, defined «outer boundary» single component $C_1(\overline{\Delta}, \Omega_n)$ aggregate $\overline{\Delta}$, which will be denoted $E(\Delta)$. Since $E(\Delta)$ – is single infinite set in simple connectedness the aggregate $\overline{\Delta}$, it is independent of the choice of values n, for which $\Omega_n \subset \overline{\Delta}$. Let us $J(\Delta) = \overline{\Delta} \setminus E(\Delta)$ assume – the union of all «outer boundary» single component $\overline{\Delta}$; obviously, the set course $J(\Delta)$. Finite aggregate $\Theta \subset Z^2$ it is closed Jordan curve discrete (CJCD), if in event double connectedness, it contains at least four elements, with each time $x \in \Theta$ aggregate $\{y \in \Theta \setminus \{x\} : x[2]y\}$ double-element. Then, for any set $\Delta \subset Z^2$ the denote $F(\Delta)$ the set of all points $x \in \overline{\Delta}$, for which there is an element $y \in \Delta$ such that $x(1)y$. If Δ, Θ – finite subset Z^2, in the case $\Delta \subset J(\Theta)$ we say that a multiplicity of Θ covers many Δ aggregate.

Let used finite aggregate $\Delta \subset Z^2$, for which $J(\Delta) \neq 0$. Designed in [6] algorithm allows to find out whether in Δ there exists at least one CJCD covering set $J(\Delta)$, and secondly, in the case of the existence of such CJCD allocate Δ CJCD Θ covering corresponds to the assumption $J(\Delta)$ and intuitive notions of "equidistant curve" set (Figure 1).

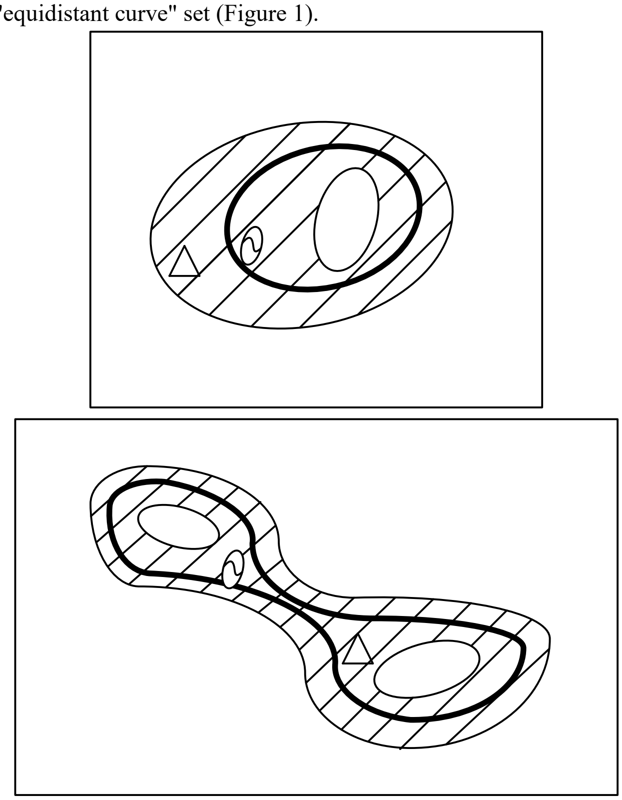

Figure 1. Example «equidistant curve»

For any finite aggregate $\Delta \subset Z^2$ take to $A_0^i(\Delta) = \Delta$, $A_1^i(\Delta) = \Delta \setminus (F(J(\Delta)) \setminus F(E(\Delta)))$, $A_n^i = A_1^i(A_{n-1}^i(\Delta))$, $n = 2,3,...$. Since the finite set Δ, and $A_{n+1}^i(\Delta) \subset A_n^i(\Delta)$, $n = 0,1,...$, exists number $n \geq 0$ such that $A_{n+1}^i(\Delta) = A_n^i(\Delta)$. In this case, take to the designation $A^i(\Delta) = A_n^i(\Delta)$ (the set $A^i(\Delta)$ does not depend on the number of n satisfies the equation $A_{n+1}^i(\Delta) = A_n^i(\Delta)$). Similarly, for the given operator $A_n^e(\Delta)$, $n = 0,1,...$ and $A^e(\Delta)$ (To do this, replace i on e, $J(\Delta)$ on $E(\Delta)$ and $E(\Delta)$ on $J(\Delta)$).

Let Θ - CJCD, $x \in \Theta$. Property CJCD establishes the existence of two and only two elements $y, z \in \Theta$, other than the point of the x and being with her in respect of [6]. This pair of elements that uniquely defines the point $u, v \in \Theta$ such that $u[2]y \neq u \neq x$, $v[2]z \neq v \neq x$. Let $U_\Theta(x) = \{u, y, x, z, v\}$; when traversing CJCD Θ elements extend $U_\Theta(x)$ in said plurality or inverse order (depending on the direction of rotation). It can be shown that for every $x \in \Theta$ number of elements of the set $U_\Theta(x)$ equal $\min(n;5)$, when n – number of set Θ. In describing the allocation algorithm average lines (AAAL) more convenient to use not $U_\Theta(x)$, the set $V_\Theta(x) = \Theta \setminus U_\Theta(x)$. For any CJCD Θ and each set of $\varphi \subset \Theta$ (cases $\varphi \neq 0$ and $\varphi = \Theta$ are not excluded) take to designation $H_\Theta(\varphi, x) = \{x\}$, if $x \in \Theta \setminus \varphi$, $H_\Theta(\varphi, x) = F(\{x\}) \cap J(\Theta)$ if $x \in \varphi$ we take $H_\Theta(\varphi) = \bigcup_{x \in \Theta} H_\Theta(\varphi, x)$. Always $H_\Theta(\varphi, x) \neq 0$.

Description AAAL. Let Δ_o – any finite aggregate in Z^2, $J(\Delta_o) \neq 0$. At the first stage we define the set $\Theta_0 = A^e(A^i(\Delta))$. Check whether Θ_0 CJCD [6], Θ_0 – CJCD $\Leftrightarrow$ the set $J(\Theta_0)$ simple connectedness, and $F(J(\Theta_0)) \cap F(E(\Theta_0)) = \Theta_0$. In case of a negative check result, in Δ_0 there is no CJCD, embracing $J(\Delta_o)$ [6], ie no solution. Suppose, that Θ_0 – CJCD; and Θ_0 is cover $J(\Delta_o)$. We start counting steps of the algorithm after determining Θ_0. For any $n \geq 1$ his $(2n-1)$ step is to find the set $\Delta_n = \Delta_{n-1} \setminus (F(J(\Delta_{n-1})) \setminus \Theta_{n-1})$, and $(2n)$ step – the initial determination of the set $\xi_{n-1} = \{x \in \Theta_{n-1} : F(\{x\}) \cap J(\Theta_{n-1}) \subset \Delta_n\}$, then sets φ_{n-1} all points $x \in \xi_{n-1}$ such that for any $y \in V_{\Theta_{n-1}}(x)$ set $H_{\Theta_{n-1}}(\xi_{n-1}, x) \cup H_{\Theta_{n-1}}(\xi_{n-1}, y)$ no double connectedness, and the set $\Theta_n = A_1^e(H_{\Theta_{n-1}}(\varphi_{n-1}))$. It can be proved, the set Θ_n is CJCD, embracing $J(\Delta_0)$, and $J(\Theta_n) \subset J(\Theta_{n-1})$, $n = 1,2,...$ Since the set $J(\Delta_0)$ of course, there exists a number $n \geq 0$ such that $J(\Theta_k) = J(\Theta_n)$ for all $k \geq n$, and in the case of $n \geq 1$ $J(\Theta_{n-1}) \neq J(\Theta_n)$. This element n will have the same properties, and in the set Θ_k (instead $J(\Theta_k)$). We take the " equidistant curve " $\widetilde{\Theta}$ the set Δ_0 the curve Θ_n; in other words, once found in a series of curves $\Theta_0, \Theta_1, \Theta_2,...$ meet two consecutive identical, calculation is stopped and taken $\widetilde{\Theta}$ as the last of these CJCD.

In practice, only be considered discrete sets that make up some of the limited subset Z^2. Let us assume for such the set

$\Omega = Z^2 \cap ([1;N]\times[1;M])$, when M and N - given natural numbers. Take to designation: $\Omega_0 = \{(i,j)\in\Omega : i=1$ or $i=M$, or $j=1$, or $j=N\}$ (Ω_0 – «border» discrete rectangular area Ω); $\Omega_1 = \Omega \setminus \Omega_0$. In the given grounds shall apply only to the AAAL sets $\Delta_0 \subset \Omega_1$. Let us prove an auxiliary result:

Lemma. Let $\Delta, \Theta \subset \Omega_1$, when Θ – CJCD. Then each of the sets $J(\Delta)$, $F(J(\Delta))$, $F(E(\Delta))$, $A_n^i(\Delta)$, $A_n^e(\Delta)\,(n=0,1,...)$, $A^i(\Delta)$, $A^e(\Delta)$, $H_\Theta(\varphi,x)$, $H_\Theta(\varphi)$, $V_\Theta(x)\,(x\in\Theta, \varphi\subset\Theta)$ contained in Ω_1, the set $\overline{\Omega_1}$ – in $E(\Delta)$, and the set $F(\Delta)$ – in Ω.

Lemma proving. Because of $\overline{\Omega_1} \subset \overline{\Delta}$ and the apparent simple connectedness $\overline{\Omega_1}$, contained in $E(\Delta)$. Because of $J(\Delta)\cap E(\Delta)=0$, then $J(\Delta)=\Omega_1$. We show that $F(J(\Delta))\subset\Delta$. Suppose it is not so, ie there is an element $x\in F(J(\Delta))\setminus\Delta$. Then there exists an element of $y\in J(\Delta)$ such that $x(1)y$. Since $x\notin J(\Delta)\cup\Delta$, then $x\in E(\Delta)$. Effect affiliation $y\in\overline{\Delta}$, we obtain affiliation $y\in E(\Delta)$, which contradicts the equality $J(\Delta)\cap E(\Delta)=0$. Consequently, $F(J(\Delta))\subset\Delta\subset\Omega_1$. Replacing of reasoning $E(\Delta)$ on $J(\Delta)$ and $J(\Delta)$ on $E(\Delta)$, prove and inclusion $F(E(\Delta))\subset\Delta\subset\Omega_1$. On the definition of the sets $A_n^i(\Delta)$, $A_n^e(\Delta)$, $A^i(\Delta)$, $A^e(\Delta)$ It follows that each of them is contained in Δ, and hence a Ω_1. Similarly, $V_\Theta(x)\subset\Theta\subset\Omega_1$. The sets $H_\Theta(\varphi,x)$ has the form $\{x\}$ or $F(\{x\})\cap J(\Delta)$, when $x\in\Theta$. In the first case it is contained in Θ, and therefore in, a Ω_1. Similarly, in the second case: $H_\Theta(\varphi,x)\subset J(\Delta)\subset\Omega_1$. Hence, $H_\Theta(\varphi)=\bigcup_{x\in\Theta} H_\Theta(\varphi,x)\subset\Omega_1$. Prove inclusion $F(\Delta)\subset\Omega$. Let $x\in F(\Delta)$, there is a point $y\in\Delta$ such that $x(1)y$. Because of $y\in\Omega_1$, then $x\in\Omega$.

Analysis AAAL this lemmas shows that when the "initial conditions" $\Delta_0\subset\Omega_1$ almost all the sets arising in the process of applying AAAL, are contained in, Ω, and the set Θ_n, Δ_n, ξ_n, φ_n, $H_\Theta(\xi_n,x)$, $H_{\Theta_n}(\varphi_n)$, $V_{\Theta_n}(x)$ $(n=0,1,2,....)$ and some other – even in Ω_1. The exceptions are the sets $E(\Delta)$, are in the process of calculation will be replaced by sets $\Omega\cap E(\Delta)$. The correctness of such a replacement is provided by the fact that during the entire procedure, computing the operator E applies only to Δ subsets of Ω_1 with subsequent application to a sets $E(\Delta)$ of operators F. Then, by the lemma $\overline{\Omega_1}\subset E(\Delta)$, and is easy to see that the proposed algorithm α_6 for constructing the set $F(\varepsilon)$ when $\varepsilon=\Omega\cap E(\Delta)$ lower when it gives a sets $F(E(\Delta))$. It is also important to note that nowhere in the calculation when a use of the sets $F(\Delta)$, when $\Delta\subset\Omega_1$, operator F not used. Thus, in the construction of the "equidistant curve" of the set $\Delta_0\in\Omega_1$ we have to deal only with subsets Ω. Therefore, it becomes possible to create an implementation AAAL, that do not operate with the sets $\Delta\subset\Omega$, and used "matrix images" that make this much easier. Accept data sets Δ mean matrix $\mu(\Delta)$ of the elements of $M\times N$ which (a_{ij}) are defined by the equation $a_{ij}=1$ if $(i,j)\in\Delta$ and $a_{ij}=0$ when the equation $(i,j)\notin\Delta$.

II. Proposed algorithm

Let the steps subalgorithms characters $\alpha_1,\alpha_2,...,\alpha_{17}$ – when components AAAL. All matrices have a size $M\times N$; elements of the matrix are denoted by the same as the matrix itself, but a small letter with two indices. The result of applying the algorithm α_i in the input ... we denote $\alpha_i(...)$.

1. The algorithm is the intersection of sets Δ and ε.

Let $A=\mu(\Delta)$, $B=\mu(\varepsilon)$, $C=\mu(\Delta\cap\varepsilon)=\alpha_1(A,B)$. Then $c_{ij}=a_{ij}b_{ij}$.

2. The algorithm is the union of sets Δ and ε.

The elements of the matrix $C=\mu(\Delta\cup\varepsilon)=\alpha_2(A,B)$ calculated by the formula $c_{ij}=sign(a_{ij}+b_{ij})$ ($sign(x)=1,0,-1$ at $x>0$, $x=0$, $x<0$ respectively).

3. The algorithm is deducting from the set Δ set ε.

The elements of the matrix $C=\mu(\Delta\setminus\varepsilon)=\alpha_3(A,B)$: $c_{ij}=a_{ij}(1-b_{ij})$.

4. The selection algorithm single component $C_1(\Delta,x)$ the set Δ, includes the element x.

Let $x=(k,l)$ (because of $x\in\Delta$, at the intersection k of l row and column of the matrix $\mu(\Delta)$ is a unit). The algorithm uses a variable matrix A.

Step 1. Assignment $A:=\mu(\Delta)$, and $a_{kl}:=2$.

Step 2. If in the matrix A no of twos turn to step 3. Otherwise, choose any item $a_{ij}=2$ and assign it a value 3. If the matrix A contains at least one element $a_{mn}=1$ for which the $m=i$, $n=j\pm1$ or $m=i\pm1$, $n=j$, every such component is assigned a value 2. Perform step up to the disappearance of the matrices A of all of twos.

Step 3. Computation the elements of the matrix $B=\mu(C_1(\Delta,x))=\alpha_4(\mu(\Delta),(k,l))$ the use formula $b_{ij}=\max(a_{ij}-2;0)$.

5. . The selection algorithm two component $C_2(\Delta,x)$ the set Δ, includes the element x.

The algorithm repeats the algorithm 4, but with the extension conditions $m=i$, $n=j\pm1$ или $m=i\pm1$, $n=j$, which takes the form $m=i$, $n=j\pm1$ или $m=i\pm1$, $n=j$, or $m=i\pm1$, $n=j\pm1$.

For using algorithms α_4, α_5 when $\Delta \cap \Omega_0 \neq 0$ may occur in the calculation of variables a_{ij}, for which $i=0$ or $i=M+1$, or $j=0$, or $j=N+1$. These variables should be considered as zero.

6. The algorithm for finding the set $F(\varepsilon)$, when $\varepsilon \subset \Omega_1$ or $\bar{\varepsilon} \subset \Omega_1$.

Let $A=\mu(\varepsilon)$, $B=\mu(F(\varepsilon))=\alpha_6(A)$. The elements of the matrix B calculated by the formula $b_{ij}=(1-a_{ij})sign(a_{i,j-1}+a_{i,j+1}+a_{i-1,j}+a_{i+1,j})$.

7. The algorithm for finding the set $\Omega \cap E(\Delta)$ at $\Delta \subset \Omega_1$.

Let $A=\mu(\Delta)$, $\varepsilon=\Omega \setminus \Delta$, $B=\mu(\varepsilon)$ (then $b_{ij}=1-a_{ij}$). Since $b_{11}=1$, defined set of $C_1(\varepsilon,(1;1))=\Omega \cap E(\Delta)$. Then, $\mu(\Omega \cap E(\Delta))=\alpha_7(A)=\alpha_4(B,(1;1))$.

8. The algorithm for finding the set $J(\Delta)$ at $\Delta \subset \Omega_1$.

Let $J(\Delta)=\overline{\Delta \cup E(\Delta)}$. By Lemma, $J(\Delta) \subset \Omega_1$, then $J(\Delta)=\Omega \setminus (\Delta \cup (\Omega \cap E(\Delta)))$. Let $A=\mu(\Delta)$, $B=\alpha_7(A)=\mu(\Omega \cap E(\Delta))$ and, the set Δ и $\Omega \cap E(\Delta)$ disjoins, we obtain $\mu(\Delta \cup (\Omega \cap E(\Delta)))=A+B$. Having designation $C=\mu(J(\Delta))=\alpha_8(A)$, we obtain the relation $c_{ij}=1-a_{ij}-b_{ij}$.

9. The algorithm for finding the set $A_1^i(\Delta)$ at $\Delta \subset \Omega_1$.

Let $A=\mu(\Delta)$, $B=\mu(A_1^i(\Delta))=\alpha_9(A)$. Then,

$$B=\alpha_3(A,\mu(F(J(\Delta))\setminus F(E(\Delta))))= \\ =\alpha_3(A,\alpha_3(\alpha_6(\alpha_8(A)),\alpha_6(\alpha_7(A)))).$$

10. The algorithm for finding the set $A^i(\Delta)$ at $\Delta \subset \Omega_1$.

Let $C:=\mu(A^i(\Delta))=\alpha_{10}(\mu(\Delta))$.

step 1. Assign $A:=\mu(\Delta)$.

step 2. Let $B:=\alpha_9(A)$. If $B \neq A$, assign $A:=\alpha_9(B)$. Otherwise, go to step 4.

step 3. If $A \neq B$ return to step 2, and if $A=B$ go to step 4.

Шаг 4. Assign $C:=A$.

11. The algorithm for finding the set $A_1^e(\Delta)$ at $\Delta \subset \Omega_1$.

It is obtained by replacing in the algorithm α_9 superscript i to subscript e in 8,7,11 on 7,8,9 respectively, sets $J(\Delta)$ and $E(\Delta)$ – each other.

12. The algorithm for finding the set $A^e(\Delta)$ at $\Delta \subset \Omega_1$.

It is obtained by replacing in the algorithm α_{10} superscript i, 9, 10 on e, 11, 12.

13. The algorithm for allocation CJCD $\Theta \subset \Omega_1$ the set in $V_\Theta(x), x \in \Theta$.

Let $A=\mu(\Theta)$, $x=(k,l)$ (then $a_{kl}=1$). Assign $a_{kl}:=0$. From paragraph I CJCD, of eight elements a_{ij}, where, $i=k$, $j=l \pm 1$ or $a_{kl}=1$, $a_{kl}=1$, or $i=k \pm 1$, $j=l \pm 1$, two equal to unity. Assign them a_{mn} and a_{pq}, is reset and the elements. Now, there exists only one item $a_{rs}=1$ for which, $r=m$, $s=n \pm 1$ or $r=m \pm 1$, $s=n$, or $r=m \pm 1$, $s=n \pm 1$, and the only element $a_{uv}=1$ such that $u=p$, $v=q \pm 1$ or $u=p \pm 1$, $v=q$, or $u=p \pm 1$, $v=q \pm 1$. For them also perform reassignment $a_{rs}:=0$, $a_{uv}:=0$. Received after this transformation matrix is the result of $\mu(V_\Theta(x))=\alpha_{13}(A,(k,l))$.

14. The algorithm for finding the set $\xi_\Theta(\Delta)=\{x \in \Theta : F(\{x\} \cap J(\Theta)) \subset \Delta\}$, where $\Theta, \Delta \subset \Omega_1$, Θ – CJCD.

Let $A=\mu(\Theta)$, $B=\mu(\Delta)$, $C=\mu(J(\Theta))=\alpha_8(A)$, $D=\mu(\xi_\Theta(\Delta))=\alpha_{14}(A,B)$. For each point $(i,j) \in \Theta (\Leftrightarrow a_{ij}=1)$ let

$$d_{ij}=1-sign(c_{i,j-1}(1-b_{i,j-1})+c_{i,j+1}(1-b_{i,j+1})+ \\ +c_{i-1,j}(1-b_{i-1,j})+c_{i+1,j}(1-b_{i+1,j}))$$

. The rest of the matrix D determines the implication $a_{ij}=0 \Rightarrow d_{ij}=0$.

15. The algorithm for finding the set $H_\Theta(\varphi,x)$, где Θ – CJCD, $\varphi \subset \Theta \subset \Omega_1$, $x \in \Theta$. Let $A=\mu(\Theta)$, $B=\mu(\varphi)$, $C=\mu(J(\Theta))=\alpha_8(A)$, $x=(k,l)$ (then $a_{kl}=1$), $D=\mu(H_\Theta(\varphi,x))=\alpha_{15}(A,B,(k,l))$. If $b_{kl}=0$, d_{kl} It is the only element of the matrix D equal to 1. In case $b_{kl}=1$ assign $d_{ij}=1$ if and only if $i=k$, $j=l \pm 1$ or $i=k \pm 1$, $j=l$, and $c_{ij}=1$.

16. The algorithm for finding the set $H_\Theta(\varphi)$, where Θ – CJCD, $\varphi \subset \Theta \subset \Omega_1$.

Let $A=\mu(\Theta)$, $B=\mu(\varphi)$, $C=\mu(\Theta \setminus \varphi)$, et. $a_{ij}=1 \Rightarrow c_{ij}=1-b_{ij}$; $a_{ij}=0 \Rightarrow c_{ij}=0$. The matrix $D=C+\sum_{b_{ij}=1} \alpha_{15}(A,B,(i,j))$. The matrix $G=\mu(H_\Theta(\varphi))=\alpha_{16}(A,B)$ has elements $g_{ij}=sign(d_{ij})$.

17. The algorithm for finding the set $\varphi_\Theta(\xi)$ for all points $x \in \xi$ such that for $y \in V_\Theta(x)$ every set $H_\Theta(\xi,x) \cup H_\Theta(\xi,y)$ is not two-component. For this Θ – CJCD, $\xi \subset \Theta \subset \Omega_1$.

Let $A=\mu(\Theta)$, $B=\mu(\xi)$. Fixing an arbitrary unit cell b_{kl} the matrix B, find the matrix $C=\alpha_{13}(A,(k,l))$, $D=\alpha_{15}(A,B,(k,l))$ and select any element of $d_{mn}=1$ the matrix D. If for every point (i,j) such that $c_{ij}=1$, the matrix $G=\alpha_2(D,\alpha_{15}(A,B,(i,j)))$ and $\alpha_5(G,(m,n))$ do not match, we let $h_{kl}:=1$, and otherwise $h_{kl}:=0$. This will identify all items h_{kl} the matrix $H=\mu(\varphi_\Theta(\xi))=\alpha_{17}(A,B)$, corresponding to the condition $b_{kl}=1$. If $b_{kl}=0$ accepted $h_{kl}:=0$.

Algorithm. The above partial algorithms allow to briefly describe the procedure AAAL, consisting of the following three steps. Let $\Delta_0 \subset \Omega_1$, $A = \mu(\Delta_0)$.

Step 1. Decision matrix $B = \alpha_{12}(\alpha_{10}(A))$, $C = \alpha_8(B)$, $D = \alpha_1(\alpha_6(\alpha_7(B)), \alpha_6(\alpha_8(B)))$, $G = \alpha_4(C,(k,l))$; for this (k,l) we can take any point for which $c_{kl} = 1$. If $D = B$, $G = C$, go to step 2. Otherwise, the calculation ends with and the conclusion that it is impossible to allocate Δ_0 "equidistant curve". The block diagram is shown in Figure 2.

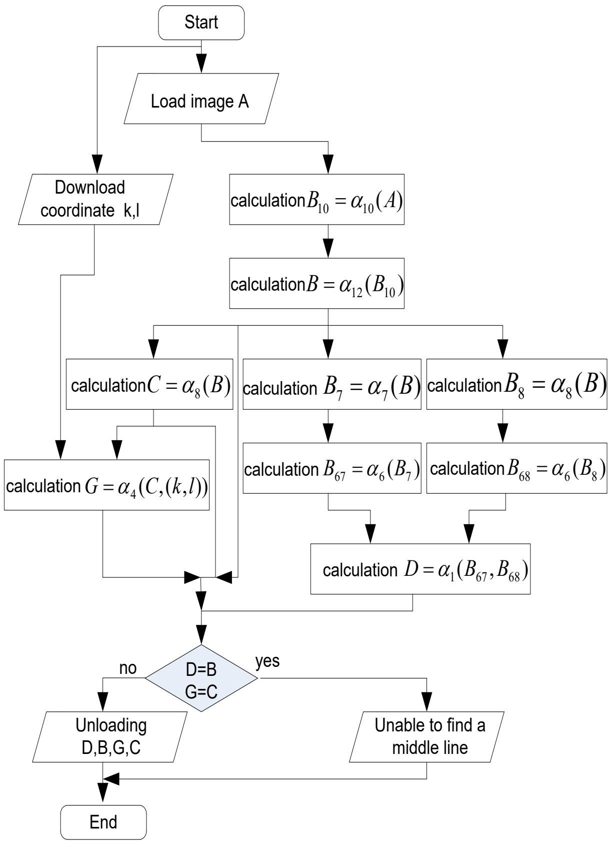

Figure 2. The block diagram first step algorithm

Step 2: Let $A := \alpha_3(A, \alpha_3(\alpha_6(\alpha_8(A)), B))$, $L := \alpha_{14}(B, A)$, $P := \alpha_{17}(B, L)$, $R := \alpha_{11}(\alpha_{16}(B, P))$. If $R = B$ as matrix image «equidistant curve» $\widetilde{\Theta}$ the set Δ_0 We take a matrix B that completes the calculation.

Step 3. Let $R \neq B$. Then we accept $B := R$ and return to step 2. The block diagram is shown in Figure 3.

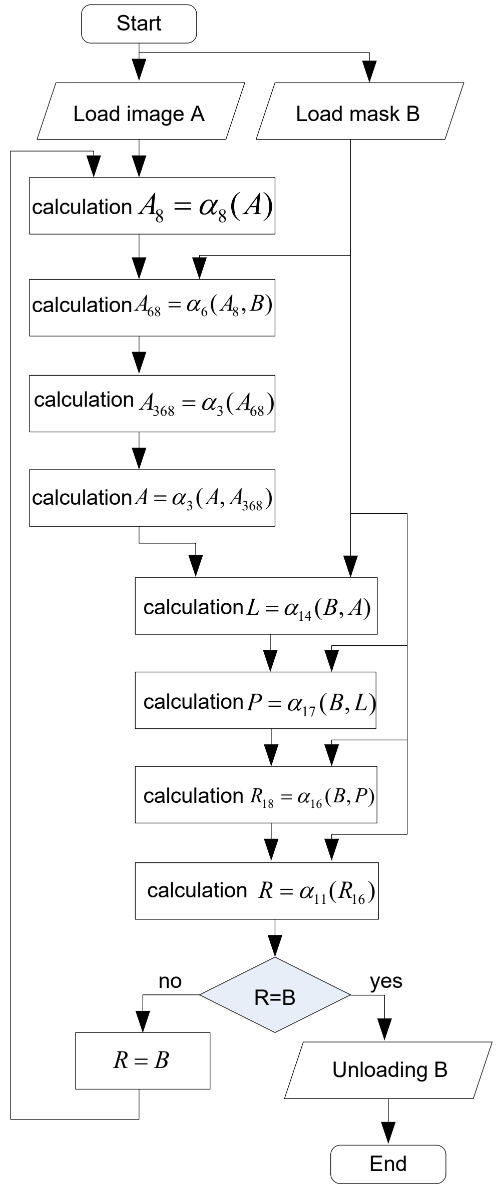

Figure 3. The block diagram of the second and third step algorithm

III The test results of the algorithm

The effectiveness of the proposed method ArfAAL shown on the test images in Figure 4. The figure shows a binary image of the objects of simple forms with a punctured area and complex form or more punctured areas. Image size is 100 by 100 pixels.

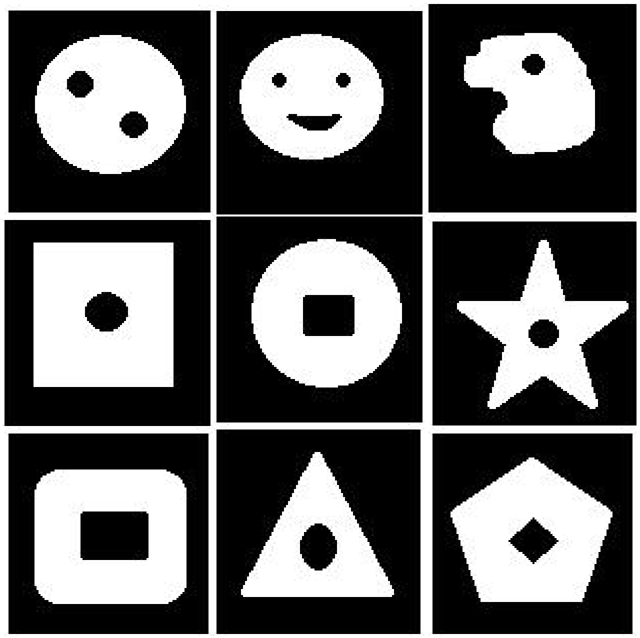

Figure 4. The test images

Figure 5 shows the result of separation «equidistant curve» on the image.

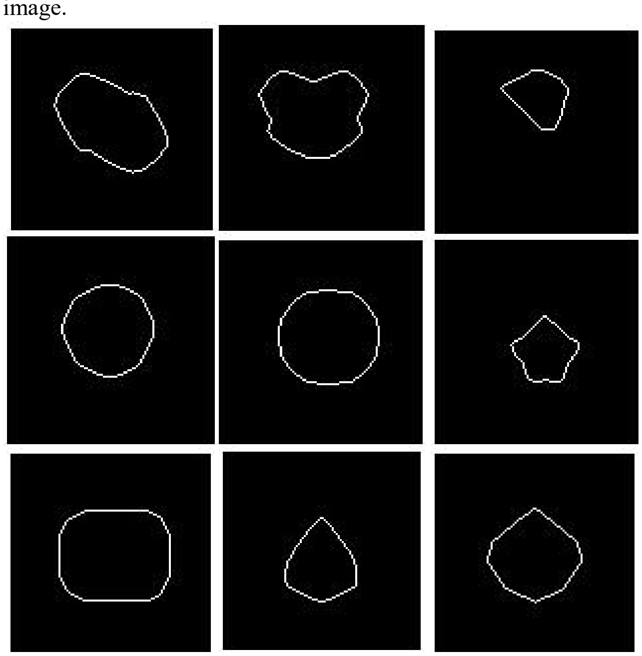

Figure 5. The result of separation «equidistant curve» on the image

On the figure 7 show the results of processing on the test images. The proposed algorithm able to determine of separation «equidistant curve» on the image.
Analysis of efficiency of the algorithm was performed on a set of medical images. For the analysis of medical image data we use data research microscope of blood cells. The images presented of the color data of RGB format obtained using a digital microscope. When receiving the test data we observed the blurring objects. At the same time the boundaries of some objects have strong blurred.

Figure 6 shows an example of blood cells data analysis. Determination of blurred areas was carried out with the use of the threshold processing. The threshold value was adjusted manually for each image. Another way for determine the contours, may be used approach proposed on the work [6]. As a result of the use of the algorithm, we identified the external border of the objects. Figure 7 shows an example of the objects boundaries definition.

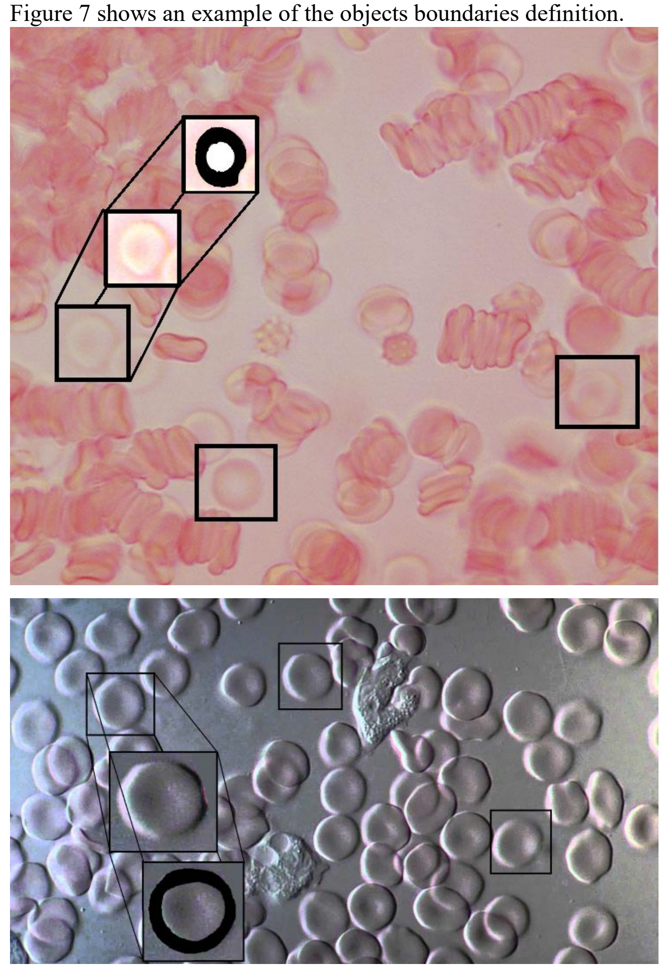

Figure 6. The test medical images

Conclusion

We proposed method for automatic computation of equidistant curve on the image with blurred contours. The algorithm is based on the use of linear operators on matrices. We received promising results on the task of equidistant curve computation for the image with blurred contours.

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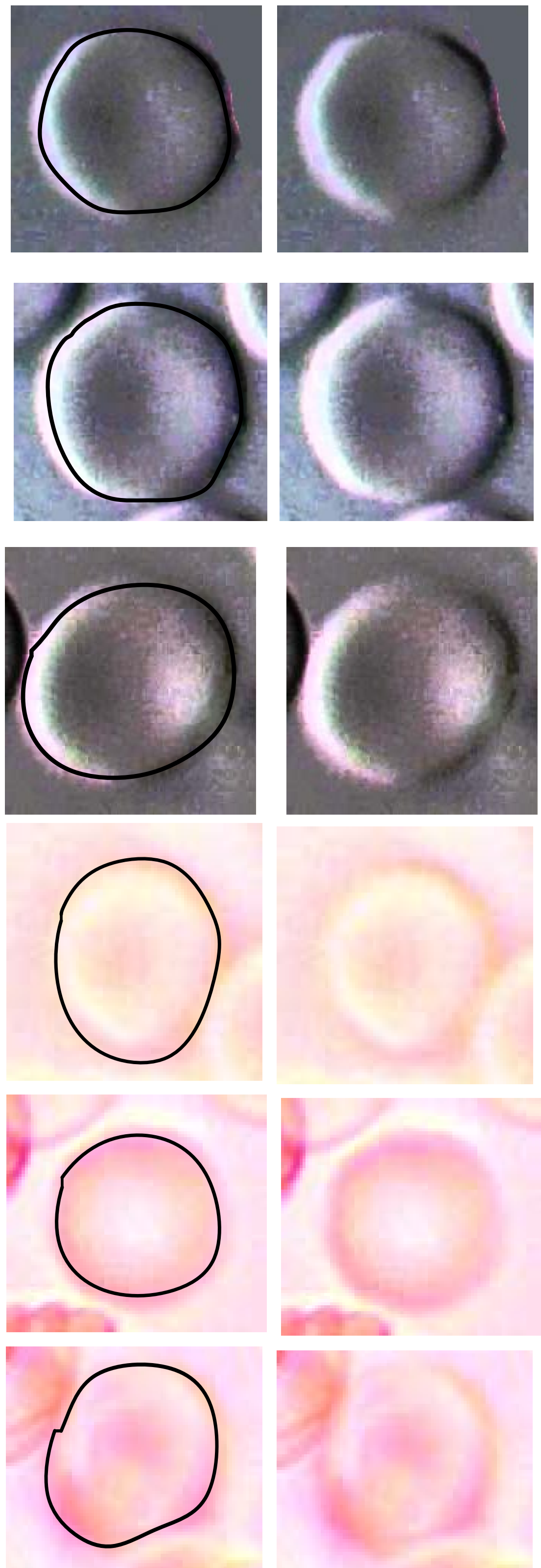

Figure 7. The result of separation «equidistant curve» on the image

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