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The Distance Regularized Level Set Evolution (DRLSE) model is sensitive to initial contour and weak boundary images. Meanwhile it is easy to leak from the weak edges and the curve sometimes converges slowly. To these issues an improved level set evolution method is proposed in the paper which combines target gray level statistical information with image gradient information. The boundary stopping function in the model of DRLSE is replaced by a target information function based on image information. And the constant coefficient associated with the weighted area was modified as an adaptive variable sign coefficient to deal with slow convergence and weak edge leakage. Experiments show that this method is free of initial contour. Besides it reduces the time of image segmentation and improves the quality of segmentation.

level set distance regularized active contour model image segmentation

1

10

1-3

11-12

13-15

4-5

6-8

Snake

⁹

Kass

1988

Osher

Sethian

1988

¹⁰

2016-08-16

2016-12-27

16 17

CV Kimmel¹⁸
GAC
Li⁷

$$p(s) = \begin{cases} \frac{1}{2\pi^2} (1 - \cos 2\pi s) & s \leq 1 \\ \frac{1}{2} (s-1)^2 & s > 1 \end{cases} \quad (2)$$

DRLSE¹⁹ DRLSE

$$\delta_\varepsilon \phi = \begin{cases} \frac{1}{2\varepsilon} \left(1 + \cos\left(\frac{\pi\phi}{\varepsilon}\right) \right) & |\phi| \leq \varepsilon \\ 0 & |\phi| > \varepsilon \end{cases} \quad (3)$$

$$H_\varepsilon \phi = \begin{cases} \frac{1}{2} \left(1 + \frac{\phi}{\varepsilon} + \frac{1}{\pi} \sin\left(\frac{\pi\phi}{\varepsilon}\right) \right) & |\phi| \leq \varepsilon \\ 1 & \phi > \varepsilon \\ 0 & \phi < -\varepsilon \end{cases} \quad (4)$$

20

$$g = \frac{1}{1 + |\nabla G_\sigma * I|^2} \quad (5)$$

DRLSE

$$\frac{\partial E}{\partial \phi} = -\mu \operatorname{div} d_p |\nabla \phi| \nabla \phi - \lambda \delta_\varepsilon \phi \operatorname{div} \left(g \frac{\nabla \phi}{|\nabla \phi|} \right) - \alpha g H'_\varepsilon \phi \quad (6)$$

$$d_p |\nabla \phi| = \frac{p' |\nabla \phi|}{|\nabla \phi|} \quad (6)$$

2

$\Omega \subset R^2$ $I: \Omega \rightarrow R$

19

$$\frac{\partial \phi}{\partial t} = -\frac{\partial E}{\partial \phi} = \mu \operatorname{div} d_p |\nabla \phi| \nabla \phi + \lambda \delta_\varepsilon \phi \operatorname{div} \left(g \frac{\nabla \phi}{|\nabla \phi|} \right) + \alpha g \delta_\varepsilon \phi \quad (7)$$

$$H'_\varepsilon \phi = \delta_\varepsilon \phi = \frac{H'_\varepsilon \phi}{\delta_\varepsilon \phi} = \delta_\varepsilon \phi \quad (8)$$

$$E(\phi) = \mu \int_\Omega p(|\nabla \phi|) dx + \lambda \int_\Omega g \delta_\varepsilon \phi |\nabla \phi| dx + \alpha \int_\Omega g H'_\varepsilon \phi dx \quad (1)$$

1 1

$$\frac{\partial \phi_{k+1}}{\partial t} = \frac{\phi_{k+1} - \phi_k}{\Delta t} = L \phi_k \quad (8)$$

$$L \phi_k = \frac{\phi_{k+1} - \phi_k}{\Delta t} \quad (7)$$

2

$$\phi_{k+1} = \phi_k + \Delta t L \phi_k \quad (9)$$

inside DRSLE $\delta_\varepsilon \phi$ Dirac $H'_\varepsilon \phi$ Heav- $\mu \lambda \alpha$ p

$$\phi_0(x) = \begin{cases} -c_0 & \text{if } x \in R_0 \\ c_0 & \text{if } x \in R_0^c \end{cases} \quad (10)$$

10 c_0 R_0

3 DRLSE

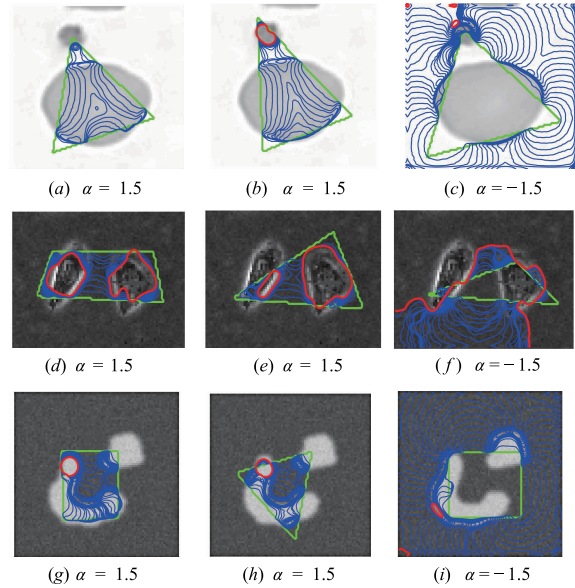
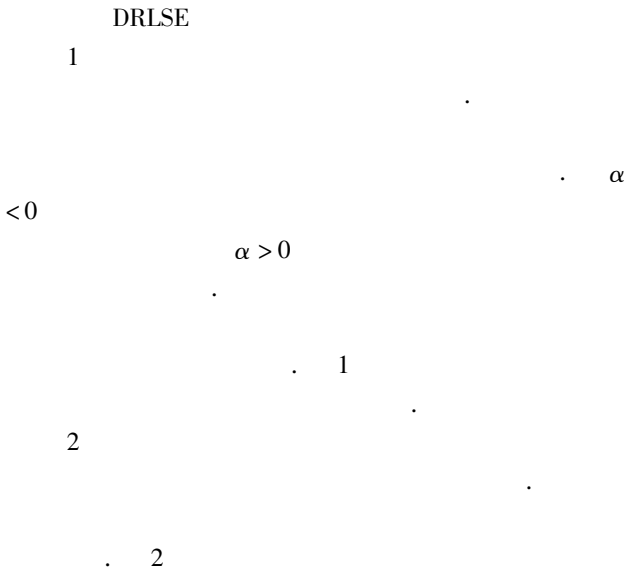


图1 初始轮廓曲线与目标交叉

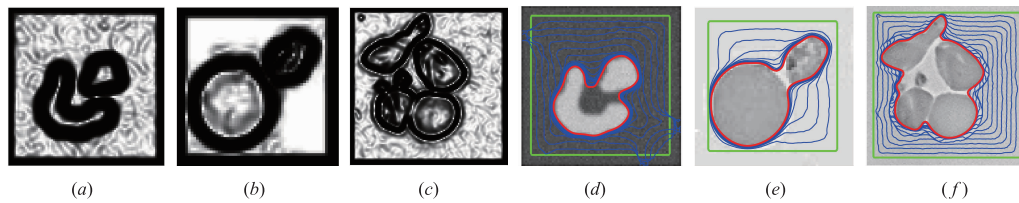
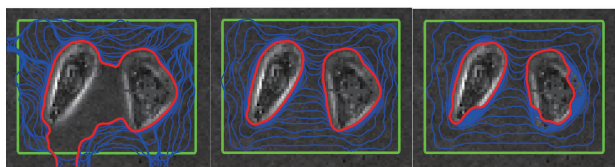
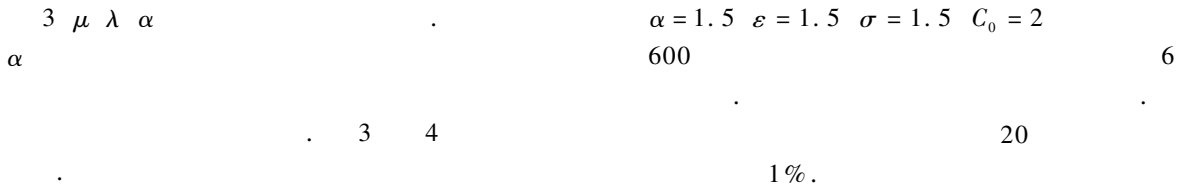


图2 目标距离靠近的分割效果



(a) $\alpha=0.8$, 陷入虚假边界; (b) $\alpha=1.5$, 合理的参数; (c) $\alpha=2.5$, 边界泄漏现象

图3 DRLSE演化与 α 的关系

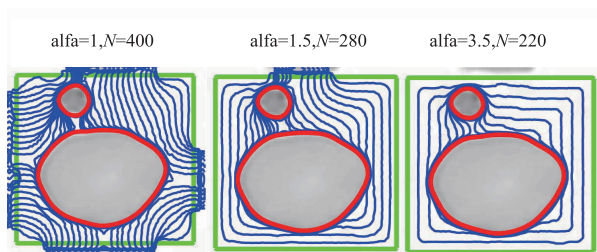


图4 DRLSE演化速度与 α 的关系, N 指迭代次数

DRLSE $\Delta t = 1 \quad \mu = 0.2 \quad \lambda = 5$

4

DELSE

$$\frac{\partial \phi}{\partial t} = \mu \operatorname{div} \left(d_p \frac{\nabla \phi}{|\nabla \phi|} \right) + \lambda \delta_\varepsilon \phi \operatorname{div} \left(g \frac{\nabla \phi}{|\nabla \phi|} \right) + \alpha I v I \delta_\varepsilon \phi \quad (11)$$

$$I \quad (11) \quad v$$

$$v I = \frac{2}{\pi} \arctan \left(\frac{G_\sigma * I - 255 \cdot T_\sigma}{\varepsilon_1} \right) \quad (12)$$

$$12 \quad T_\sigma \quad \varepsilon_1$$

I_σ
 T_σ
 αI
 $b = 2, 5$
 $b = 4$
 α
 α
 N
 $\lambda = 10 \quad b = 2 \quad \varepsilon_1 = 10$
 $T_\sigma = (u_1 + u_2) / 2$
 $4.2 \quad v \quad I$
 $DRLSE$
 $\alpha I = \frac{2 + \sqrt{s} G_\sigma * I}{b}$ 13
 $13 \quad s$
 $std2 \quad b$
4.1 αI
 $std2$
 $12 \quad 7$
 T_σ
 $G_\sigma * I - 255$
 $\varepsilon_1 \quad \epsilonpsilon1$
 αI
 $DRLSE$
 $\alpha > 0$
 $\alpha < 0$

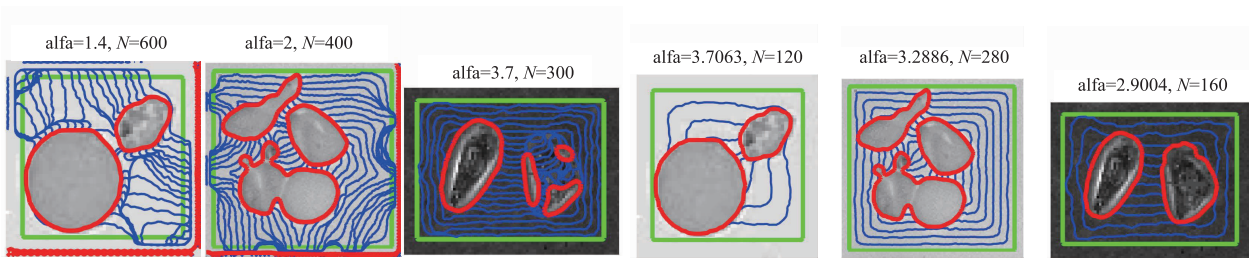


图5 α 设置不合理，陷入虚假边界或边界泄漏现象

图6 α 自适应方法，避免陷入虚假边界或边界泄漏，同时保持合理的演化速度

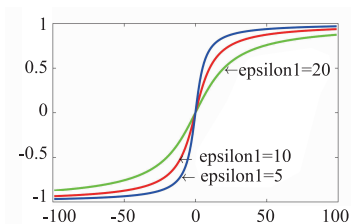


图7 图像目标信息函数



(a) 合成原图

(b) 目标符号函数示意图

(c) 收缩及膨胀示意图

图8 收缩及膨胀演化示意图

$\alpha I \cdot v I$

8

8 a

8 b

8 c

4.3

$$1 \begin{cases} \Delta t = 1 & \mu = 0.2 \\ \lambda = 10 & \varepsilon = 1.5 \\ b = 2 & \varepsilon_1 = 10 \\ c_0 = 2 \end{cases}$$

20

30

1%

2

g

3

Roi

$v I$

αI

4

5

1%

6

5

9 10 11

N

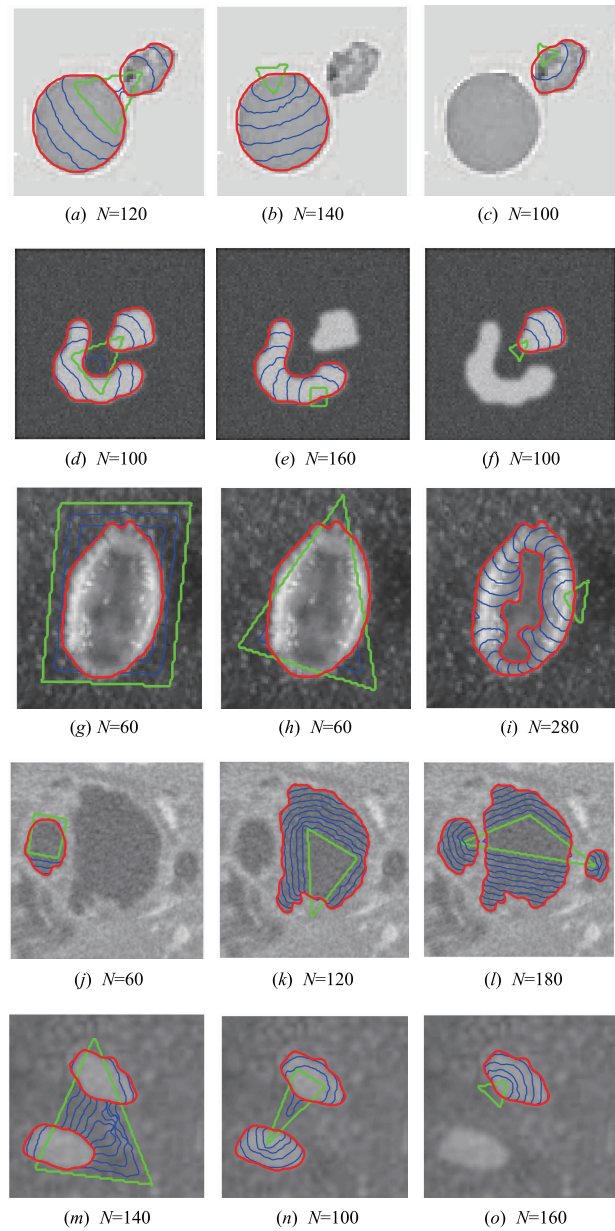


图9 不同的初始轮廓、演化过程及分割结果

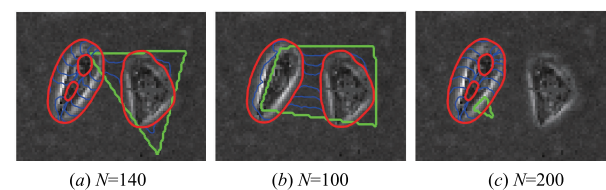


图10 参数 $\sigma=2.0$ ，不同的初始轮廓、演化过程及分割结果

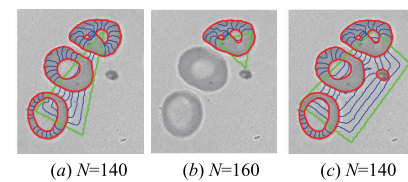


图11 有空洞目标的演化过程及分割结果

4.4

12

11

DRLSE

4

s DRLSE

3

. T

4.3

αI

0

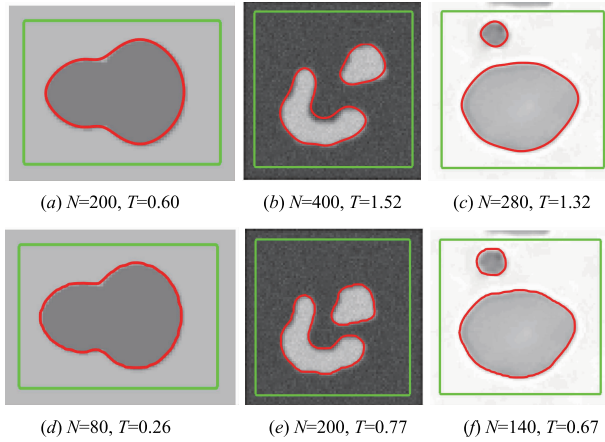


图12 迭代次数及时间比较: (a)~(c)为DRLSE模型, (d)~(f)为本文模型

± 1 .

$v I 0$

5

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