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1.

16

208

b b_1

b_2 b b_1 b_2

A

$A_{ij}=-\int\frac{\nabla\phi_i}{I_i}\bullet\frac{\nabla\phi_j}{I_j}dxdy$， A_{ij} j i φ_i i

I_i φ_j j I_j

$\nabla\phi_i$， $\nabla\phi_j$ φ_i φ_j

$f(\sigma)$ b σ $f(\sigma)$ b

$\Delta b=\frac{df(\sigma)}{d\sigma}\cdot\Delta\sigma$， Δσ Δb

Ag b

g

$F(g)==\frac{\lambda}{2}\|Ag-b\|_2^2+\alpha_1\|\nabla g-v\|_1+\alpha_0\|\varepsilon(v)\|_1$， $\alpha_1\|\nabla g-v\|_1$

$\alpha_0\|\varepsilon(v)\|_1$ α_1 α_0

λ $\frac{1}{2}\|Ag-b\|_2^2$

$\overline{g}=\arg\min_g F(g)$；

$\overline{g}=\arg\min_g F(g)$ $\min_{g,v}\max_{p\in P,q\in Q}\langle\nabla g-v,p\rangle+\langle\varepsilon(v),q\rangle+\frac{\lambda}{2}\|Ag-b\|_2^2$，

P $\{p\ (p_1,p_2)\ |\ \|p\|_\infty\le\alpha_1\}$ $Q=\left\{q=\begin{pmatrix}q_{11},q_{12}\\q_{21},q_{22}\end{pmatrix}\Big|\|q\|_\infty\le\alpha_0\right\}$；

$\overline{g}=\arg\min_g F(g)$ p λ

9) g^{k+1} v^{k+1}

g

(Electrical Tomography ET) 20 80

(Electrical Resistance Tomography ERT) (Electrical Impedance Tomography EIT) (Electrical Capacitance Tomography ECT) (Electrical Magnetic Tomography EMT)

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Tikhonov

Ag b A b g

$$F(g) = = \frac{\lambda}{2} \| Ag - b \|_2^2 + \alpha_1 \| \nabla g - v \|_1 + \alpha_0 \| \varepsilon(v) \|_1$$

λ ( ) $\|Ag-b\|_2^2$ (

) $\alpha_1\|\nabla g - v\|_1 + \alpha_0\|\varepsilon(v)\|_1$ α_1 α_0

$$\overline{g} = \arg\min_g F(g)$$

1. b A

b b_1 b_2

2. , Ag b

3.

4. $\overline{g} = \arg\min_g F(g)$

5. $\overline{g} = \arg\min_g F(g)$,

6.

Tikhonov

Tikhonov

1

2

3 Tikhonov

4 (Relative Error RE)
(Correlation Coefficient CC)

5(a) RE CC (b)
RE CC

1 2 3 4 5

1

2
16 5 2 1
3 4

3
Tikhonov

((a) (c))
((d) (f)) Tikhonov
Tikhonov

Tikhonov

$\min_{g}\{F(g)\}=\min_{g}\{\|Ag-b\|_2^2\}$ F(g)

F (g)

$F(g)=\frac{1}{2}\|Ag-b\|_2^2+\lambda R(g)$ λ $\|Ag-b\|_2^2$ R(g)

Tikhonov Tikhonov

$$F(g)=\frac{1}{2}\|Ag-b\|_2^2+\lambda\|g\|_2^2$$

L_2

$F(g)=\frac{1}{2}\|Ag-b\|_2^2+\lambda\int_{\Omega}|\nabla g|\mathrm{d}x$ L_1

16

208 b b_1

b_2 b b_1 b_2

A

$A_{ij}=-\int\frac{\nabla\phi_i}{I_i}\bullet\frac{\nabla\phi_j}{I_j}dxdy$ A_{ij} j i φ_i i

I_i φ_j j I_j

φ_i φ_j

f(σ) b σ f(σ)

b $\Delta b=\frac{\mathrm{d}f(\sigma)}{\mathrm{d}\sigma}\cdot\Delta\sigma$, Δσ Δ

b

Ag b g

$F(g)==\frac{\lambda}{2}\|Ag-b\|_2^2+\alpha_1\|\nabla g-v\|_1+\alpha_0\|\varepsilon(v)\|_1$ $\alpha_1\|\nabla g-v\|_1$

$\alpha_0\|\varepsilon(v)\|_1$ α_1 α_0

λ $\frac{1}{2}\|Ag-b\|_2^2$

$\overline{g} = \arg\min_{g} F(g)$ 。

$\overline{g} = \arg\min_{g} F(g)$ ：$\min_{g,v}\max_{p\in P,q\in Q}\langle \nabla g - v, p\rangle + \langle \varepsilon(v), q\rangle + \frac{\lambda}{2}\| Ag - b\|_2^2$

P {p (p$_1$,p$_2$)|||p||$_\infty \le \alpha_1$} $Q = \left\{ q = \begin{pmatrix} q_{11}, q_{12} \\ q_{21}, q_{22} \end{pmatrix} \Big| \|q\|_\infty \le \alpha_0 \right\}$ 。

$\overline{g} = \arg\min_{g} F(g)$

1) w 0, v 0, $\overline{v} = 0, p = 0, \overline{p} = 0$, q 0, g_0 0, τ 1/L, σ 1/L

2) $p^{k+1} = \mathrm{proj}_P(p^k + \sigma(\nabla \overline{g}^k - \overline{v}^k))$

3) $q^{k+1} = \mathrm{proj}_Q(q^k + \sigma(\varepsilon(\overline{v}^k)))$；

4) $w^{k+1} = \mathrm{prox}^{\sigma}(w^k + \sigma(A\overline{g}^k - b))$；

5) $g^{k+1} = g^k + \tau(\mathrm{div}\nabla p^{k+1} - A^T w^{k+1})$；

6) v^{k+1} $v^k + \tau(p^{k+1} + \mathrm{div}\,\varepsilon q^{k+1})$

7) $\overline{g}^{k+1} = 2g^{k+1} - g^k$

8) $\overline{v}^{k+1} = 2v^{k+1} - v^k$；

9) g^{k+1} v^{k+1}

3 Tikhonov Tikhonov Tikhonov

RE CC

(1) (2) RE CC

RE CC 5

$$\mathrm{RE} = \frac{\|\sigma - \sigma^*\|_2^2}{\|\sigma^*\|_2^2} \quad (1)$$

$$\mathrm{CC} = \frac{\sum_{i=1}^{t}(\sigma_i - \overline{\sigma})(\sigma_i^* - \overline{\sigma}^*)}{\sqrt{\sum_{i=1}^{t}(\sigma_i - \overline{\sigma})^2 \sum_{i=1}^{t}(\sigma_i^* - \overline{\sigma}^*)^2}} \quad (2)$$

σ σ^* t $\overline{\sigma}$ $\overline{\sigma}^*$ σ σ^* σ_i σ_i^* σ σ^* i

4 RE CC Tikhonov ((a) (c))

RE CC

((d) (f)) RE CC

((a) (c)) (

(d) (f))

0 2.5 5 7.5 10

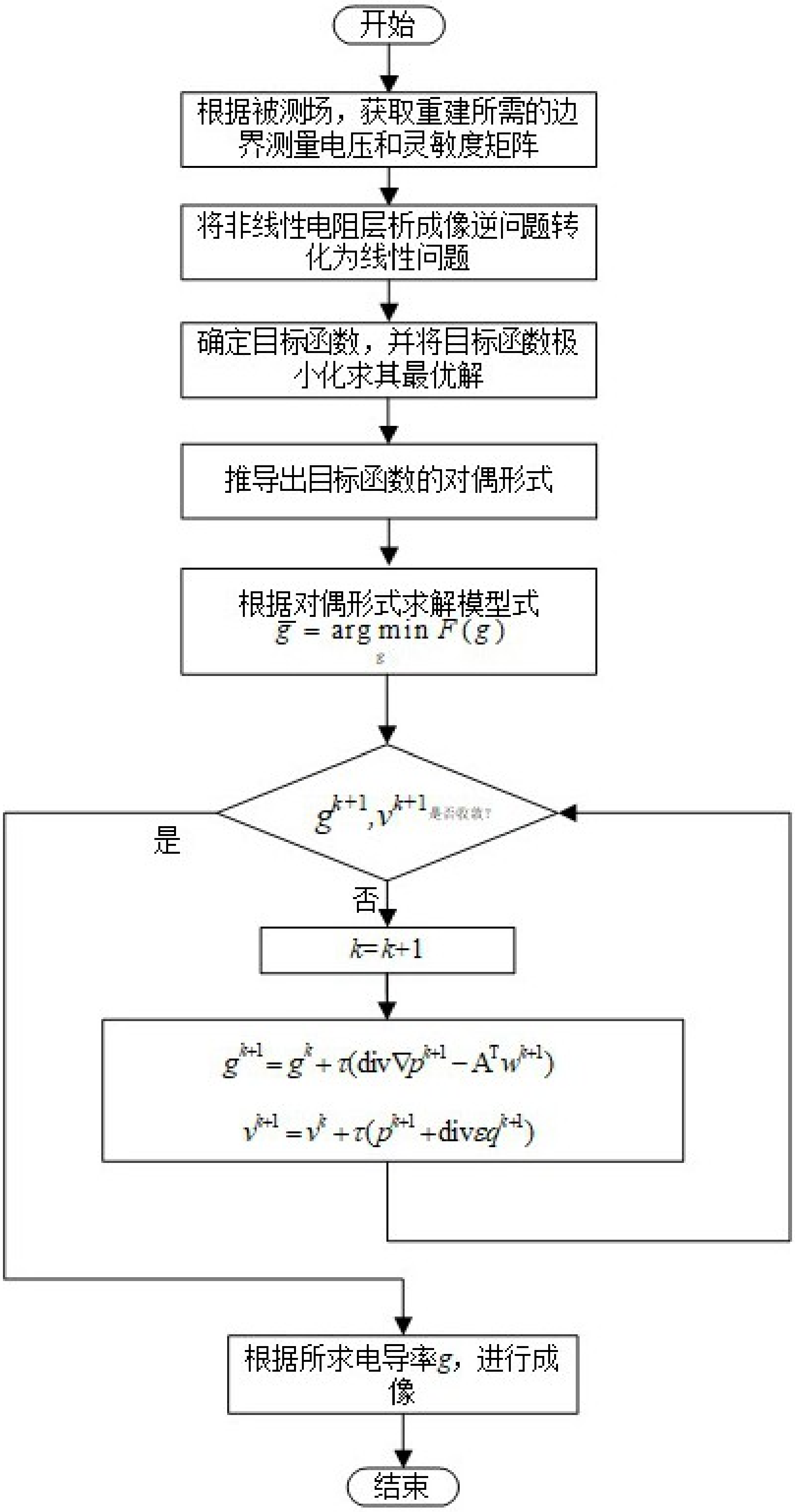
(a) (e) 5

RE CC RE CC Tikhonov

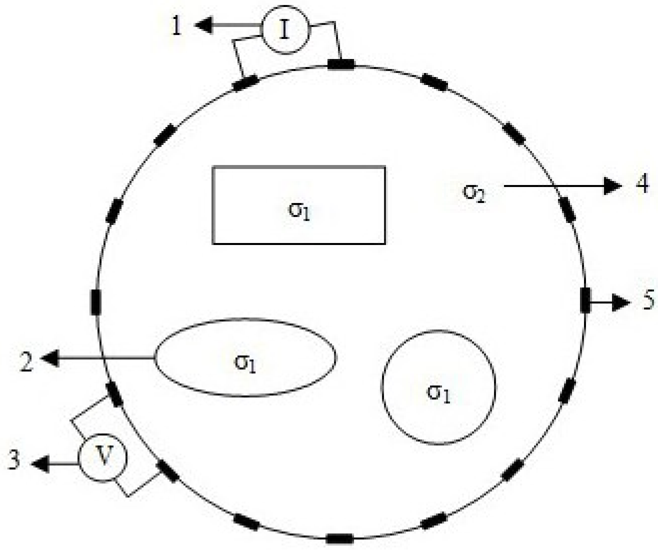
(a) 5(a) RE

CC

(e) RE CC 5(b)


开始
根据被测场，获取重建所需的边界测量电压和灵敏度矩阵
将非线性电阻层析成像逆问题转化为线性问题
确定目标函数，并将目标函数极小化求其最优解
推导出目标函数的对偶形式
根据对偶形式求解模型式
$\bar{g} = \arg\min_{g} F(g)$
g^{k+1}, v^{k+1} 是否收敛?
是
否
$k=k+1$
$g^{k+1} = g^{k} + \tau(\mathrm{div}\nabla p^{k+1} - A^{T} w^{k+1})$
$v^{k+1} = v^{k} + \tau(p^{k+1} + \mathrm{div}\varepsilon q^{k+1})$
根据所求电导率g，进行成像
结束

1



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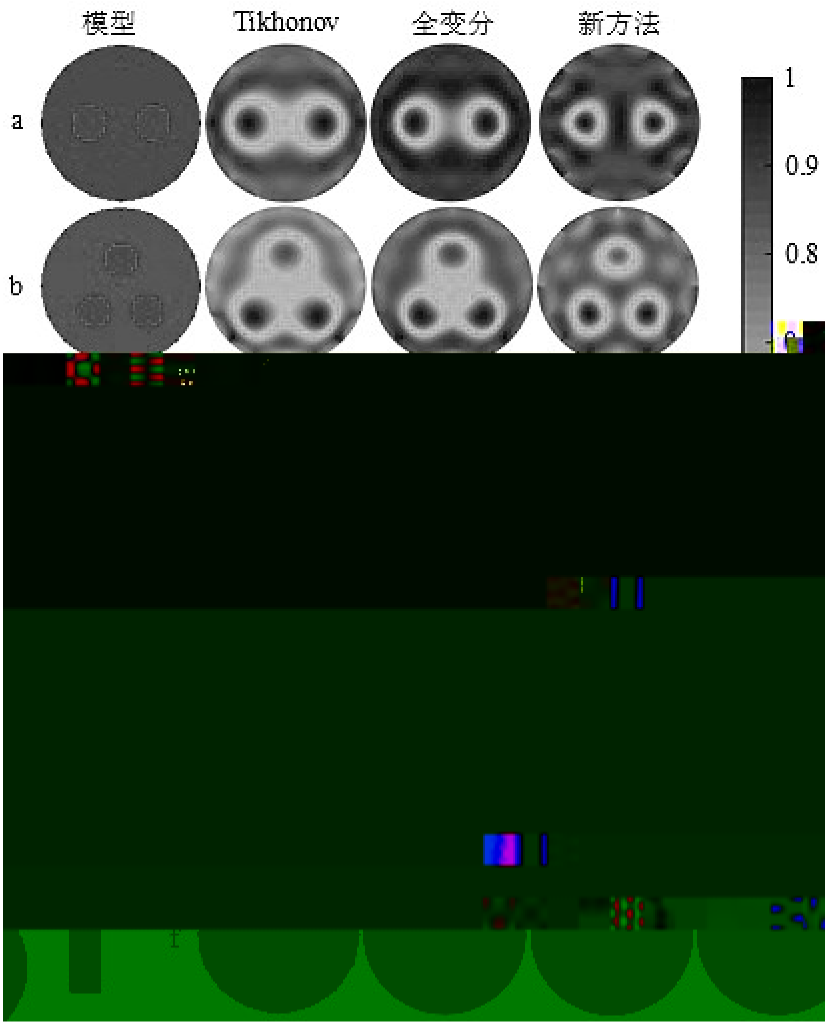
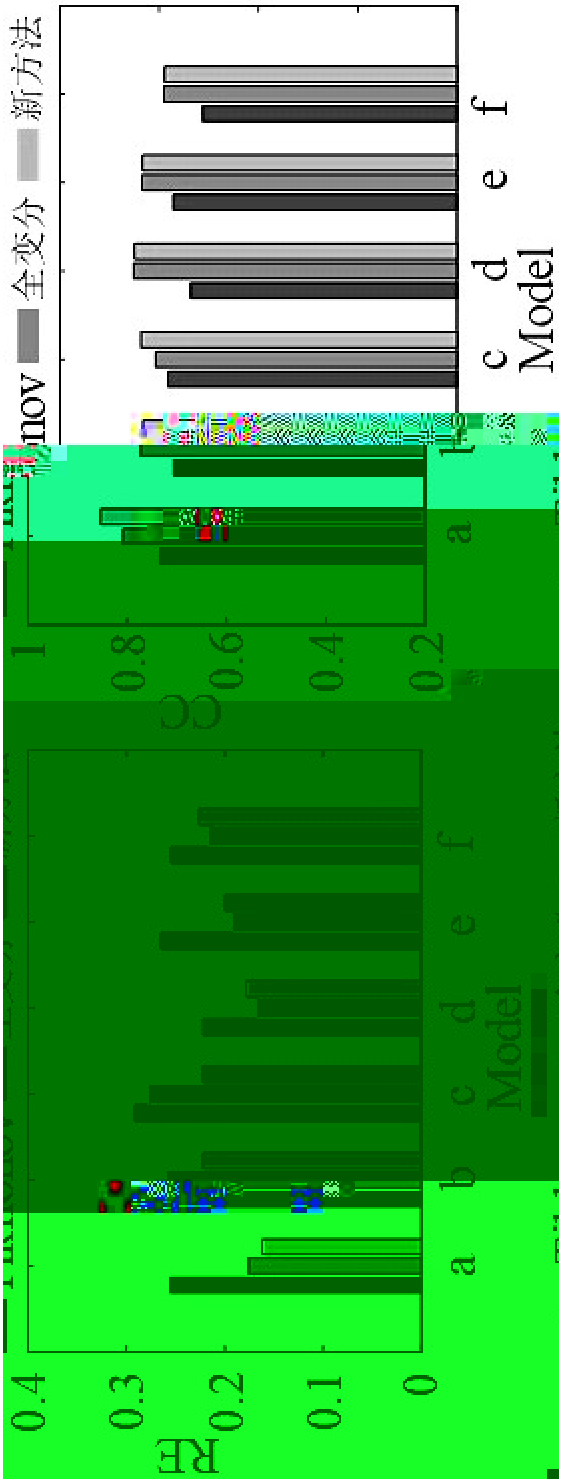
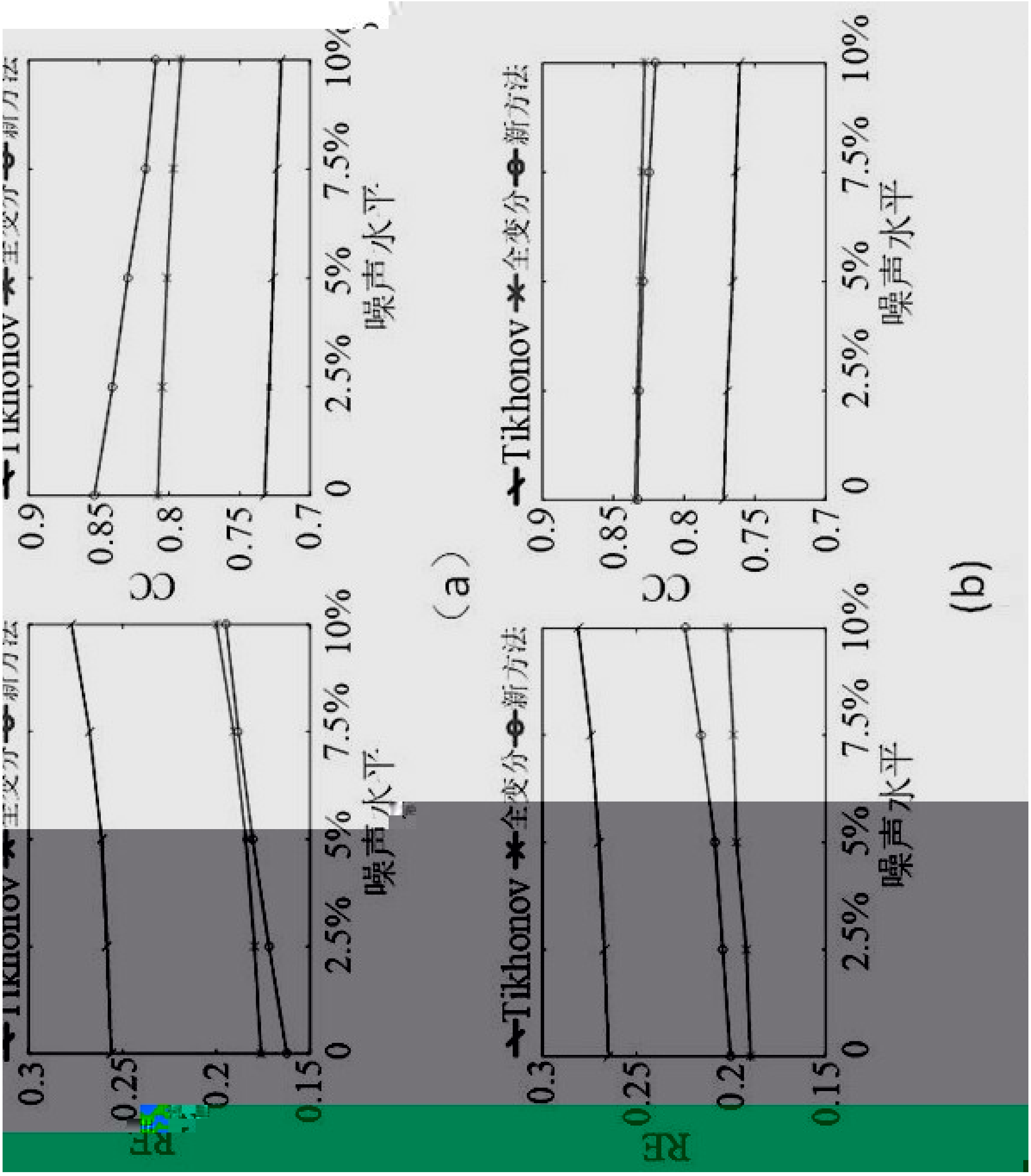


3



4



Tikhonov
全变分
新方法
噪声水平
CC
RE
0 2.5% 5% 7.5% 10%
0.9 0.85 0.8 0.75 0.7
0.3 0.25 0.2 0.15
（a）
(b)

5