HIGH CONTRAST IMAGE
RECONSTRUCTION USING LEVEL SET
TECHNIQUE_ APPLICATION FOR EIT
LUNG DATA

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CONTENT

- Level set representation of structures (shapes)

- Level set based/ shape based reconstruction algorithm (LSRM)

- First clinical results of the LSRM (2011)

- What we improved (2013)

- Simulated and clinical results (EIT human lung data)

- Conclusion
Many applications deal with the reconstruction and optimization of geometries (shapes, topologies);

however,

there is no natural a-priori information on shapes or topological structures of the solution (number of connected components, star-shapedness, convexity, ...).
SOLUTION

flexible representations of the shapes needed!

LEVEL SET technique can do this for us!

History:
- Osher & Sethian, JCP 1987.
**Level Set Representation**

\[ C = \{(x, y) \mid \varphi(x, y) = 0\} \]

Level set function is a **Signed distance function**

- **Inside** \( C \) \( \varphi < 0 \)
- **Outside** \( C \) \( \varphi > 0 \)

\( C = \) boundary of an open domain
ADVANTAGES

• Automatically detects interior contours!

• Works very well for concave objects

• Allows for automatic change of topology
WHAT WE PROPOSED IN 2011

LEVEL SET-BASED RECONSTRUCTION ALGORITHM USING DIFFERENCE SOLVER

L2 NORM based update equation
LEVEL SET-BASED RECONSTRUCTION ALGORITHM

Error function:

\[ \Delta \Phi(\Psi) = \| y - F(\Phi(\Psi)) \|^m + \| \Phi(\Psi) - \Phi(\hat{\Psi}) \|_R^n \]

where \( m, n = 1 \) (L1 norm) or 2 (L2 norm),

We need to minimize the above error function to find the best estimate of \( x \), which is the solution of inverse problem.
SHAPE BASED RECONSTRUCTION ALGORITHM (L2 NORM) - FIRST CLINICAL RESULTS (2011)

Lung Healthy Patients (8 patients)

Acute Lung Injury Patients (18 patients)
What we improved (2013)

- Problem:
  L2 norms are sensitive to spatial noise and data outliers!

- Solution:
  Redefine the cost functional based on L1 norms, instead of L2 norms.

  \[
  \Delta \Phi(\Psi) = |y - F(\Phi(\Psi))|_1 + |\Phi(\Psi) - \Phi(\hat{\Psi})|_1
  \]

- Difficulty:
  Minimization of the L1 norm based cost functional is not computationally easy!

Primal-Dual Interior Point Method
1977 (idea), 1998 (vauhkonen et al.)
1990 (idea) by Cheney et al.
1996 (idea), 2010 (Borsic et al.)
1996 (idea), 2012 (Borsic et al.)
1996 (idea), 2013 (Our proposed method)

No noise and No outliers

Added Zero-mean Gaussian Noise

Presence of Strong Outlier

Noise + Outliers

EIT Human Lung Data
CONCLUSION

- The level set based reconstruction method (LSRM) is suitable for EIT real data of breathing.
- The level set strategy allows for topological changes of quite complicated interfaces.
- The LSRM using L1 norms produces high contrast, high quality reconstructed images.
THANK YOU
Positive end-expiratory pressure (PEEP) trial

- Patient with healthy lungs

Frame 1
Left lung
Right lung

Frame 2

Frame 3

Frame 4

Frame 5

Area (Number of pixels)

Frames

Incremental PEEP
Decremental PEEP

Total lungs area

Right lung
Left lung
Patient with acute lung injury (ALI)

PEEP TRIAL

Frame 1
Frame 2
Frame 3
Frame 4
Frame 5

Right lung (collapsed)
Left lung

Incremental PEEP
Decremental PEEP

Frames

Total lungs area