Unsupervised localization of heart and lung region in EIT images: a validation study

Damien Ferrario¹, Andy Adler¹,², Josep Solà¹, Stephan Böhm¹ and Marc Bodenstein³

¹CSEM - Centre Suisse d’Electronique et de Microtechnique, Switzerland
²Systems and Computer Engineering, Carleton University, Ottawa, Canada
³Department of Anesthesiology, Johannes Gutenberg-University Mainz, Germany
Unsupervised localization of heart and lung region in EIT images: a validation study

Goal
Propose and evaluate an unsupervised method to detect pixels in a sequence of EIT images depicting functional information of heart and lungs (H&L).

Plan
1. Database
2. EIT morphological reconstruction
3. Unsupervised localization of H&L on EIT images
4. Assessment of H&L localization
5. Results and conclusion
1. Database: simultaneous CT and EIT recordings

Retrospective analysis of CT and EIT

- Same pig
- Ventilated pigs: 5, 15 and 45 mbar

How to compare CT and EIT images?

DB provided by Marc Bodenstein, Mainz University
2. EIT morphological reconstruction

RAW EIT Data → Morphological reconstruction → EIT images

CT volume images → Manual slice selection → Manual detection

EIT and CT images have now the same shape
2. EIT morphological reconstruction

3) Interpolate EIT image

RAW EIT Data → Morphological reconstruction → Interpolation → Physical correspondence

CT volume images → Manual slice selection → Manual detection

EIT and CT images have same resolution
Can be compared pixel by pixel
3. Unsupervised detection of H&L activity

Lungs ROI detection

⇒ The threshold allows to choose the size of the lungs ROI
3. Unsupervised detection of H&L activity

Allowing to zoom on pixels with more respiration

Threshold: 0.2

Threshold: 0.6

Threshold: 0.75
3. Unsupervised detection of H&L activity

Allowing to zoom on pixels with more respiration

Threshold: 0.2
Threshold: 0.6
Threshold: 0.75
3. Unsupervised detection of H&L activity

Cardiac frequency estimation

lungs pixels:

not lungs pixels:

difference:

⇒ Cardiac frequency is then the frequency with the biggest amplitude
3. Unsupervised detection of H&L activity

Heart ROI detection

- Compute harmonic energy at cardiac frequency for each pixel

- Heart ROI is detected similarly to the lungs detection

⇒ The threshold allows to choose the size of the heart ROI
3. Unsupervised detection of H&L activity

Allowing to zoom on pixels with more cardiac activity
4. Assessment of H&L detection performance

Reference CT images were manually segmented by an expert:
4. Assessment of H&L detection performance

Are pixels with high activity in the corresponding organ?

Precision: \[ precision = \frac{TP}{TP + FP} \]

If all pixels are in the segmented organ precision is 100%
5. Results

In total:
- 7 pigs at 3 PEEP conditions (5, 15, 45 mbar): 21 test.
- 20/21 tests were precise for the heart and 21/21 for lungs.
5. Results

One single animal showed unsuccessful heart detection
5. Conclusion

➢ Proposed automatic algorithm to detect H&L regions in EIT images was evaluated and showed a performant detection in almost all cases.

➢ Validates EIT images as an accurate representation of physiological activity in the thorax.

➢ Show the potential of EIT to specifically monitor organs or regions of interest.
5. Conclusion

Importance of accurate anatomical models for EIT reconstruction!

<table>
<thead>
<tr>
<th></th>
<th>Respiration activity</th>
<th>Cardiac Activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Round shape</td>
<td><img src="image1" alt="Respiration Activity" /></td>
<td><img src="image2" alt="Cardiac Activity" /></td>
</tr>
<tr>
<td>Pig shape</td>
<td><img src="image3" alt="Respiration Activity" /></td>
<td><img src="image4" alt="Cardiac Activity" /></td>
</tr>
</tbody>
</table>
Questions

Thank you!
2. EIT morphological reconstruction
3. Unsupervised detection of H&L activity

Lungs ROI detection

⇒ changing the size of the threshold allows to choose the size of the lungs ROI