A FULLY AUTOMATED COMPLETE SEGMENTATION SCHEME FOR MAMMOGRAMS

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Summary

- **Fully-automated** procedure (i.e. no manually defined thresholds are used)
- **Improved** technique for **pectoral muscle segmentation**
- **New** proposed technique for **nipple detection**
Why mammography?

- Breast cancer:
  - The 2\textsuperscript{nd} most common type of cancer
  - The 5\textsuperscript{th} most common cause of cancer-related death

- Mammography:
  - Proved to be the most effective and reliable screening method for early breast cancer detection

DSPo9 - Tzikopoulos et al. - A fully automated complete segmentation scheme for mammograms
Typical Mammogram

- Medio-lateral oblique view
But:

- Too many mammograms generated by population screening must be interpreted by a small number of radiologists
- Abnormalities are often camouflaged
- All the above lead to significant rate of missed breast cancer
Role of the CAD systems

- Computer Aided Diagnosis (CAD) systems
  - Reduce increasing workload
  - Improve accuracy

- CAD systems:
  - Perform computerized mammographic analysis
  - All of them require as a first stage the segmentation of each mammogram into its representative anatomical regions
    - Breast border
    - Pectoral muscle
    - Nipple
Mammogram segmentation (1)

DSP09 - Tzikopoulos et al. - A fully automated complete segmentation scheme for mammograms
Mammogram segmentation (2)

- **Breast Border**
  - Necessary for a typical CAD system
  - Identify also noisy regions (artifacts)
Mammogram segmentation (3)

- Pectoral Muscle
  - Visible only in MLO mammograms
  - False Positive reduction in automatic mass detection
  - Excluded for further processing (density estimation)

DSP09 - Tzikopoulos et al. - A fully automated complete segmentation scheme for mammograms
Mammogram segmentation (4)

- **Nipple Location**
  - It can serve as a key-point
  - Registration point for comparison (asymmetries)
  - Starting point for cancer detection
Dataset used

- Mini-MIAS database
  - Available freely online
  - 161 pairs of MLO mammograms
  - Spatial resolution: 0.4mm/pixel
  - Bit depth: 8 bits, 256 gray levels
Image Preprocessing

- Image orientation
- Noise estimation
  - High intensity noise
  - Tape artifacts
- Image filtering
  - Median filtering
Breast Boundary (1)

- Existing method, relying on the idea that the skin-air boundary is the smoothest section of identical pixels near the breast edge

- Method
  - Threshold the image
  - Extract boundary region
  - Fit a polynomial
  - Estimate the fitting error
  - Final estimate automatically chosen is the one producing the least error

- Divide whole image to zones and use different threshold values for each zone
Breast Boundary (2)

- **Evaluation**
  - Manual segmentation ground truth [Wirth 05]
  - Compare it with the automatic method
  - Metrics used
    - Tannimoto Coefficient
    - Dice Similarity Coefficient

\[
TC = \frac{N(A \cap B)}{N(A \cup B)}
\]

\[
DSC = \frac{2N(A \cap B)}{N(A) + N(B)}
\]
Breast Boundary (3)

- Comparing ground truth segmentation with the detection algorithm:
  - Comparison region: **10mm’s** around ground truth boundary
  - Mean values: TC 0.900, DSC 0.945 (optimal: 1)

- **But**: Inefficient detection of nipple, when in profile, because of sharp corners
Pectoral Muscle (1)

- 2 basic steps procedure
  [Kwok 04]
  - Straight Line Estimation
  - Iterative Cliff Detection
Pectoral Muscle (2) - Improvements

- Region enclosing:
  - Performed at the end of the process, if the bottom end is not aligned with the left edge of the image
  - Existing: extend the bottom end by a straight line parallel to the initial straight line estimation
Pectoral Muscle (3) - Improvements

- Region enclosing:
  - Proposed: extend the bottom end by a straight line parallel to the straight line, that best fits the already detected estimate
  - Idea: use the updated estimate, not the initial one
Nipple Detection (1)

- Motivation:
  - Nipple not detected, when in profile
- Use the already detected boundary, in order to find the nipple, if visible
Nipple Detection (2)

- Define a **search area of 10mm’s width**
- **Threshold** using values derived by the breast boundary detection procedure

DSP09 - Tzikopoulos et al. - A fully automated complete segmentation scheme for mammograms
Nipple Detection (3)

- Try to fit an ellipse
  - Moving center across the boundary detected
  - Variable semi-major and semi-minor axis (2mm’s - 10mm’s)

- False-positive reduction:
  - Mask derived by maximum value of thresholds (contains no noise) should contain at least one pixel of the nipple
Nipple Detection (4)

- Evaluation
  - Truth Table

<table>
<thead>
<tr>
<th></th>
<th>Nipple</th>
<th>Not Visible</th>
<th>Visible</th>
</tr>
</thead>
<tbody>
<tr>
<td>Not Detected</td>
<td>189</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Detected</td>
<td>15</td>
<td>88</td>
<td></td>
</tr>
</tbody>
</table>

- Manual annotation by an expert radiologist
- **118** mammograms with a visible nipple
  - Nipple *correctly* detected in **88** of them
  - In **30** of them no nipple detected
    - **25** of them was partly in profile, already detected by breast boundary algorithm
- **204** mammograms with no nipple in profile
  - In **15** of them was nipple detected, due to high level of noise
Nipple Detection (5)

- Evaluation
  - Estimate new values of metrics
  - Mean values:
    - TC : 0.900 (0.079) -> 0.903 (0.078)
    - DSC : 0.945 (0.055) -> 0.947 (0.055)
  - The increase may not be large, but:
    - The boundary changes only when nipple detected (103 images)
    - The area, where the boundary changes is too small compared to the whole boundary of the image
Final Conclusions (1)

- **Preprocessing**: Successful
- **Implemented breast boundary detection**: Acceptable results, according to specific measures and careful observation by radiologist
- **Pectoral muscle segmentation**: Acceptable and further improved through the modification we propose
- **New nipple detection technique**: Serves as an improvement for the already known breast boundary and serves as a key-point for the further processing of the image.
Final Conclusions (2)

FULLY AUTOMATED COMPLETE SEGMENTATION SCHEME
Acknowledgements

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Discussion

- Thank you for your interest

- Questions?