Computer-Aided Diagnosis for Microcalcifications in Mammograms

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Digital Images

- The first digital images were created by microprocessor for a space program and medical research in the 1960s.
- One picture is worth more than ten thousand words!
Breast Cancer Worldwide

- The World Health Organization (WHO) estimates that more than about 1.5 million people will be diagnosed with breast cancer this year worldwide.
- It is estimated that about 39,840 women and 390 men in US will die from it.

Breast Cancer in Thailand

- In Thailand, breast cancer is runner-up found in women and increasing found each year.
- It is estimated that 4,665 women will die from it in 2010 and the rest has to take painful radiation/chemo treatments or breast removal surgery.
Breast cancer is a progressive disease that an earlier stage means a higher survival rate (95%).
Unfortunately, its cause is not certainly known and early stage breast cancer has no pain/symptom notice for the patient.
Mammography, a low-dosage x-ray compressed-breast imaging, is currently the best screening and diagnostic tool for early stage breast cancer.

Microcalcification cluster is a calcium deposit which is an important sign of breast cancer in an early stage appearing on mammograms.
It looks like small grains of salt.
Among other abnormalities such as mass or spiculated lesion, μCa++ appears only in mammograms (25%) and it can not be found by touch.
Most of malignant lesions associate with cluster of microcalcifications.
A large number of routine mammography is performed each year but the number of the specialist fails to keep up with demand. Low quality image and human fatigue or overseeing may cause a false diagnosis. Double reading can pick up 15% more cancer. CAD, based on Digital Image Processing and Pattern Recognition, is used as “a second pair of eyes” helping a radiologist in reading and interpreting mammograms and increases a survival possibility.

**Performance of CADs**

- Mammogram ROIs
  - \( \mu \text{Ca}^{++} \) Detection
  - \( \mu \text{Ca}^{++} \) Classification
  - Benign/Malignant

- Detection (\( \mu \text{Ca}^{++} \) or not?)
  - Classification (Breast cancer or not?)
  - Automatic Diagnosis Result
### Positive and Negative Results

- **Positive** result means the diagnosis as “Disease presents.”
- **Negative** result means the diagnosis as “No disease.”

<table>
<thead>
<tr>
<th></th>
<th>Disease</th>
<th>No Disease</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Diagnosis</td>
<td>TP</td>
<td>FP</td>
</tr>
<tr>
<td>Negative Diagnosis</td>
<td>FN</td>
<td>TN</td>
</tr>
</tbody>
</table>

\[
\text{Specificity} = \frac{FP}{FP + TN} = 1
\]

\[
\text{Sensitivity} = \frac{TP}{TP + FN} = 1
\]

- False Alarm, UNNECESSARY BIOPSY!
- Missed detection, BREAST CANCER!

### PART I

**Low-level Image Processing:**

**Microcalcification Detection**
Challenge for Mammograms

- The CAD challenge is described as the more difficult than “finding a polar bear in a blizzard.”
- Where is the bear on a background of lots of things that look like the bear?

Where Are Microcalcifications?

- Ambiguity from NOISES
- Very Small Size
- Low Contrast to BACKGROUND
Mammographic Analysis: Microcalcifications

Microcalcification cluster looks like:
- Many bright small spots.
- Vary in shape, e.g. rounded or elongated
- The smallest microcalcification is approximately 0.1mm-0.5mm in size.
- The cluster is defined within 1 cm².

Wavelet-decomposition Based Method
Background Suppression

\[ I(y) \]

Input Signal

Output Signal

Noise Elimination

\[ I(y) \]

Input Signal

Output Signal
Using wavelet packet decomposition to remove low-frequency background and spatial $\mu$Ca++ edge to choose high-frequency subband.

Microcalcification Detection (cont’d)

For full-field mammograms, the results show 82% sensitivity and 7 false-positive/image.
PART II

Middle-level Image Processing:

Nomal Mammogram Detection

Problem Analysis for Microcalcification Detection

The previous CADs detected clustered-microcalcifications;
- based on abnormal features (characteristics of microcalcification)
- Testing in selected suspicious ROIs from mammograms,
  - True positive fraction is about 80%-90%
  - A few false-positive-per-image is claimed.

However, the current reports state that, in practical CAD with full-field mammograms, just 15-34% of this positive reading are proven malignancies.

Why?
Normal Mammograms

False positive is high because
- Mammography is a regular exam for concerned women aged more than 30 years old. Each year there is a large number of mammography. However, most of them is normal cases. **Normal mammogram is a majority of mammogram.**
- The previous CADs often perform on normal mammograms without microcalcification presents. Although there is less missed detection (FN), there is a lot of false alarm (FP).

Normal Vs. Abnormal

Moreover, for abnormal mammogram with microcalcification cluster presents,
- Normal area is still a majority of mammogram (more than 90%).
- The previous CADs perform on many normal ROIs inevitably.
Normal Mammogram Detection

Full-field Mammograms

Normal Mammogram Detection  \[ \mu \text{Ca}^{++} \text{ Detection} \]

Abnormal

"First Look"

\[ \mu \text{Ca}^{++} \text{ Classification} \]

Easy Normal  Benign/Malignant

"Second Opinion"

Normal Screening

100% TPF

Fatty mammogram.  Dense mammogram.

Breast anatomy

- Mammogram consists of images of fat, glandular, blood vessels, fibrous tissues and/or any abnormalities.
- The background of breast tissue looks like a low-contrast cloud with a bright linear tree-structure branched from the nipple.
- The overall intensity is various up to the patient and the imaging.

Mammographic Analysis: Breast Tissues

- Mammogram consists of images of fat, glandular, blood vessels, fibrous tissues and/or any abnormalities.
- The background of breast tissue looks like a low-contrast cloud with a bright linear tree-structure branched from the nipple.
- The overall intensity is various up to the patient and the imaging.
Normal Mammogram Detection Method

- Full-field Mammograms
- Normal Feature Extraction
- Feature Selection
- Feature Pre-processing
- Classification
- Normal/Abnormal

Normal Mammogram Feature Extraction

- Normal mammograms are observed to contain linear structures raising the local brightness in low-contrast clouded images.
- Breast background has much various pattern and density up to patient and x-ray imaging process.
- A large set of 86 normal mammogram features are extracted to represent all normal mammogram characteristics.
Normal Mammogram Features

86 Normal Features
- 18 Curvilinear Features
- 16 Texture Features
- 32 Gabor Features
- 20 Multiresolution Features

Normal Case Classification

- Normal mammogram features has a high variance (from various pattern).
- Support vector machine learning is used to optimize to separation (largest margin between two classes).
Normal Mammogram Detection Results

<table>
<thead>
<tr>
<th>TN</th>
<th>FP</th>
<th>TP</th>
<th>FN</th>
</tr>
</thead>
<tbody>
<tr>
<td>222</td>
<td>28</td>
<td>224</td>
<td>26</td>
</tr>
</tbody>
</table>

89% 90%

- The specificity is improved to 89%, while keeping the high sensitivity at 90% (compared to the others with average rate of 83%).

PART III

High-level Image Processing:

Microcalcification Classification
Good and Bad Microcalcifications?

$\mu$Ca++ types are categorized by their shape, size, number, distribution, and density.

- Malignant
  - dot-like or elongated form
  - tiny size
  - very numerous number
  - clustered distribution
  - differ in density

- Benign
  - round with sharply outline
  - larger size
  - solitary or numerous number
  - diffuse distribution
  - very fine and dense density

2D Image Projection

Intensity is related to x-ray attenuation and thickness.

$\mu$Ca++s

fat and fibroglandular

air

$x$-ray source

breast

intensity

$I = I_0 e^{\mu T}$
2D to 3D is Better

To rearrange the cluster into 3D space before classifying is possible by using two-view correspondence and its x-ray attenuation.

Two-view Matching Features

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1. **CC view**
2. **Input images**
3. **Image pair matching**
4. **Feature extraction**
5. **Classification**
6. **Benign / Malignant**

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**CC** view and **MLO** view
Stereo Mammograms

- **CC**
  - X-ray source
  - Parallel compression plate
  - Chest wall
  - Image receptor
  - Nipple direction
  - Known: \( x, y, x', y', \theta \)

- **MLO**
  - X-ray source
  - Parallel compression plate
  - Chest wall
  - Image receptor
  - Nipple direction
  - Rotation
  - \( x', y', \theta \)

- **Known:** \( Z \)
- **Optimized stereo-matching based on stereo position and relative intensity**
- **Unknown:** \( Z \)

Microcalcification Classification Results

The results show **85.71% true-positive fraction** and **71.43% true-negative fraction**.

<table>
<thead>
<tr>
<th></th>
<th>Sensitivity (%)</th>
<th>Specificity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CC</td>
<td>71.43</td>
<td>57.14</td>
</tr>
<tr>
<td>MLO</td>
<td>85.71</td>
<td>42.86</td>
</tr>
<tr>
<td>CC-MLO</td>
<td>85.71</td>
<td>71.43</td>
</tr>
</tbody>
</table>
Conclusions

CADs for automatic screening and classification of microcalcification cluster are introduced. It consists of “first look” and “second opinion” + 3D strategies is proposed to improve both “specificity” and “sensitivity” of the CADs.

1. Are you normal?
2. If not, where is $\mu\text{Ca}++$s?
3. See in 3D whether it is bad or not?

Other Medical Images
- Pap smear images for cervical cells
- Ultrasound images for horse tendinitis
- Nevirapine strip test for HIV/AIDS drug measurement
- PET/CT images for lung tumors
- PET brain images
- X-ray dental images
- Tonsillitis images
- 3D fetal ultrasound images
- Fundus images
Thank you for your attention.

Q&A