Detectability of malignant mass models in 2D mammograms: exploration as a function of size, background glandularity & local detectability index

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Welcome in Ghent !!!!!!

Don’t miss this front door view.
Outline

• Introduction
• Motivation
• 3D breast cancer models
• Insertion framework
• 4AFC observer study
• Results
• Conclusion
Introduction

- X-ray mammography: modality of choice for breast cancer detection.

- New digital mammography technologies would benefit from further optimization at the different stages of acquisition, processing and display.

From the Annual Report of the Screening Organisations, 2011
Question

- What is the impact of FFDM technologies/techniques on the clinical detection task?

- How should we use these systems to improve breast cancer detection rates?
Hypothesis

Seen the success of threshold contrasts of calcification like objects in the CDMAM phantom used for ‘tuning’ digital mammography, it may be very valuable to find relevant threshold contrasts for masses, to be used where masses are the critical issue.

NHS report, June 2010 by K. Young

Illustration from the Leuven QA team
Motivation for the simulation study

• Clinical trials
  • Time consuming
  • Collection of large data sets
  • Ethical issues on multi-exposure
  • Development pace of image technology

• Virtual trials: “fast” assessment of new technologies/techniques on detection task
  • Tissue modelling
  • System modelling
  • Post processing/display
  • Observer studies
Objective

To create a data set of virtual 3D malignant mass lesions for projection into raw data of 2D mammograms

To make a (reference) data set of hybrid images

To apply that data set (a first time) to investigate the detectability of the masses,
• as a function of size,
• as a function of background glandularity and local detectability index

To retrieve detectability characteristics to be used as a reference
Method

• Creation of task-specific models, namely 3D ill-defined masses and spiculated masses
• Selection of normal mammograms
• Using a simulation platform to project the lesions into the mammograms (physically correct)
• Define and measure/apply the controlling parameters of
  ➢ simulated lesions
    (e.g. size, linear attenuation coefficient of mass)
  ➢ real background tissue
    (e.g. local glandularity, local detectability index)
• Work out of a 4AFC study with human observers (physicists)
• Determine contrast thresholds
Implementation
3D mass models

- Validated realistic simulated breast mass models

<table>
<thead>
<tr>
<th>Diffusion limited aggregation mass*</th>
<th><img src="image1.png" alt="Image" /></th>
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<tbody>
<tr>
<td>• irregular shape</td>
<td><img src="image2.png" alt="Image" /></td>
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<tr>
<td>• ill-defined/lobulated margin</td>
<td><img src="image3.png" alt="Image" /></td>
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<tr>
<th>Segmented MRI core mass with simulated spiculations**</th>
<th><img src="image4.png" alt="Image" /></th>
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</thead>
<tbody>
<tr>
<td>• irregular shape</td>
<td><img src="image5.png" alt="Image" /></td>
</tr>
<tr>
<td>• spiculated margin</td>
<td><img src="image6.png" alt="Image" /></td>
</tr>
</tbody>
</table>


** Shaheen E. et al., The simulation of 3D mass models in 2D digital mammography and breast tomosynthesis, Med Phys, 41(8), 2014.
Classification of normal mammograms

- Collection of normal (raw) mammograms from screening patients
  - A radiologist double checked the cases
- Automated search and analysis of the mammogram for candidate insertion locations
- Measurement of local detectability index
  \[ d' = \frac{\sqrt{2\pi} C \int_0^\infty S^2(u) MTF^2(u) VTF^2(u) u \, du}{\sqrt{\int_0^\infty S^2(u) MTF^2(u) VTF^4(u) NNPS(u) u \, du}} \]
- Measurement of local glandularity in ROIs of 300x300 pixels with VOLPARA

Local average density map
Insertion framework

- Validated physics-based insertion framework
- Repeat insertion with size scaled version of masses

Insertion results

$SF=1$

$SF=0.75$

$SF=0.5$

$SF=0.25$

10-6-20
4AFC observer study: ROI selection

- 61 ROIs with glandularity < 15%
- 61 ROIs with 15% < glandularity < 30%
- 20 ROIs with glandularity > 30%
4AFC observer study: background selection

- 5 ill-defined DLA masses, 5 spiculated masses

- Mass in-plane size \( \sim 8-11\text{mm} \):
  - measured by an expert radiologist after insertion in a very fatty and homogenous background.

- Digitally scaled masses in all 3 dimensions
  - to create masses of \( \sim 6-8\text{ mm}, \sim 4-6\text{ mm}, \sim 2-3\text{ mm} \) in-plane size.

- Mass thickness (in z-direction):
  - \( \sim 7.6-11\text{mm} \) for ill-defined margin masses and \( \sim 4.5-6.2\text{ mm} \) spiculated masses.
Contrast measurements of the mass models

- Study on Siemens Mammomat Inspiration system
- Calculated in the hybrid images

\[ C\% = \frac{PV_0 - PV_B}{PV_B} \]
4AFC observer study

- 142 segments x (normal size + 3 resizes), twice by each observer
  -> 1136 images/observer
- 6 observers: medical physicists
- Analysis: percentage correct, confidence interval using bootstrapping
Results

View on the Friday Market (Vrijdagmarkt)

10-6-2015
4AFC study result

- PC vs Mass in-plane size

![Graph showing the relationship between percentage correct reading and mass size (mm) for different mass categories (ill-defined mass, spiculated mass) with low, medium, and high grades.](chart.png)
4AFC study result

- PC vs Thickness of the Mass

![Graph showing the relationship between percentage correct and mass thickness in the Z direction (mm). The graph includes data points for different categories such as low, med, high g% ill-defined masses, and low, med g% spiculated masses.](image-url)
Percentage correct vs. contrast of mass

- Ill-defined DLA masses
Percentage correct vs. contrast of mass

- Spiculated masses

![Graph showing the percentage correct vs. contrast of mass with different SF values: SF=1, SF=0.75, SF=0.5, SF=0.25.](image)
Contrast-detail-curve

• Threshold contrast to achieve 82% PC or detectability index of 2.61
Background effect on observer ranking

- Ill-defined DLA masses

Correct answer by
Green: >4 observer
Blue: 3 or 4 observers
Red: <3 observers
Background effect on observer ranking

- Spiculated masses

Correct answer by
Green: >4 observer
Blue: 3 or 4 observers
Red: <3 observers
Conclusions

• A fully functional virtual trial framework with automated generation of task-specific datasets.

• Detectability of the masses decreased as the glandularity of the background increases or the size of the mass decreases.

• Detectability of spiculated masses were systematically lower compared to ill-defined masses.

• Contrast threshold curves for detectability of masses in mammographic background.
What next

• Images could be re-read under different conditions
  – Processing
  – Display and ambient light setting
  – Time constraints

• Images could be re-read by different observers

• Images scored by humans can be used to validate a model observer
• COMADIS project of the IWT (Belgium)
  – Thanks to the team in Barco (T. Kimpe et al.)
• Thanks to all the readers!
Please enjoy your stay in Ghent!

Tonight’s reality