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INESC TEC and Faculdade de Engenharia, Universidade do Porto, Portugal

Breast Cancer: from surgery planning to surgery grading

Breast Cancer Workshop
April 7th, 2015, Porto, Portugal
INESC TEC (INESC TECHNOLOGY & SCIENCE) – coordinated by INESC Porto

CPES – Centre for Power and Energy Systems
CITE – Centre for Innovation, Technology and Entrepreneurship
CESE – Centre for Enterprise Systems Engineering
CEGI – Centre for Industrial Engineering and Management

CAP – Centre for Applied Photonics

**CTM** – Centre for Telecommunications and Multimedia
C-BER – Centre for Biomedical Engineering Research
CROB – Centre for Robotics and Intelligent Systems

CSIG – Centre for Information Systems and Computer Graphics
LIAAD – Laboratory of Artificial Intelligence and Decision Support
CRACS – Centre for Research in Advanced Computing Systems
HASLab – High-Assurance Software Laboratory

ASSOCIATE UNIT

CISTER - Research Centre in Real-Time and Embedded Computing Systems
Breast Research Group

- Image Processing
- Machine Learning

Screening and Diagnosis

Surgery Planning
(before surgery)

Surgery evaluation
(after surgery)
PICTURE Project

Patient Information Combined for the Assessment of Specific Surgical Outcomes in Breast Cancer
Surgery Planning (before surgery)

The Clinical Need

• When a woman faces a breast cancer diagnosis, and surgery is proposed, there are several options available.

• The cosmetic outcome of surgery is a function of many factors including tumour size and location, the volume of the breast, its density, and the dose and distribution of radiotherapy.
Surgery Planning

3-D simulation of breast surgery facilitates presurgical planning

• Facilitates informed patient-physician discussion of strategies so together they can:
  – Carefully consider the surgery
  – Plan to use the most appropriate pain relief techniques
  – Etc.
Surgery Planning
Surgery Planning

• The Challenge: data integration
Surgery Planning

• 3D Reconstruction from Kinect RGB-D images

Data Acquisition

- Kinect
  - Light weight
  - Hand held
  - Low cost

Preprocessing

- Colour and Depth transformation to common coordinate system using factory calibration data

Registration

- Coarse Registration
- Fine Registration
Surgery Planning

- 3D Reconstruction from Kinect RGB-D images
Surgery Planning

• 3D Reconstruction from Kinect RGB-D images

**Colour inconsistency correction**

- **RGB – Kinect**
- **PC before correction**
- **RGB – 2D HD**
- **PC after correction**

**Colour correction using 2D HD image**

\[ f_R(x) = \frac{\sigma_{2D}}{\sigma_K} (x - \mu_K) + \mu_{2D} \]
Surgery Planning

Parametric Breast Model Fitting

[A] [B]

12
Surgery Planning
Breast Research Group

- **Image Processing**
- **Machine Learning**

**Screening and Diagnosis**

**Surgery Planning**
(before surgery)

**Surgery evaluation**
(after surgery)
The Clinical Need

In breast-conserving surgery, there is evidence that approximately 30% of women receive a suboptimal or poor aesthetic outcome; however there is currently no standardised method of identifying these women.
Surgery evaluation (after surgery)

**Training**
- Training Images
- Image Features
- Model Design
- Learned model

**Testing**
- Test Image
- Image Features
- Learned model
- Prediction
Assessment of Contributing Factors to the cosmetic outcome

Using a Delphi methodology, a consensus overall evaluation was made by the clinical partners. This provided a set of patients with a reference to reproduce through objective features.
Objective criteria in 2D and 3D images

- Define **quantities** (‘features’ or ‘attributes’) in the image ‘correlated’ with the factors identified by the panel of experts
  - 2D and 3D features
- **Automate** the measurement
  - Automatic detection of fiducial points
2D Features

- 14 asymmetry features
2D Features

• 8 colour features

- Measure the dissimilarity between the colour of the two breasts
  - Compute the histogram of colours for each breast
  - Compare histograms
    - EMD (earth movers distance)
    - Chi-square
2D Features

• 8 scar features

- Scar visibility as a local (colour) change
- Breast divided in sectors
  - Corresponding sectors are compared
BCCT.core Software

• Software
From 2D to 3D

**Automate** the measurement

- Automatic detection of fiducial points
  - Extension of techniques previously developed for 2D to 3D data
  - Automatic detection of the
    - Breast contour
    - Nipples
    - Incisura Jugularis
From 2D to 3D

**Automate** the measurement

– Automatic detection of fiducial points
  • Extension of techniques previously developed for 2D to 3D data
  • Automatic detection of the
    – Breast contour
    – Nipples
    – Incisura jugularis
From 2D to 3D

- Define quantities (‘features’ or ‘attributes’) in the image ‘correlated’ with the factors identified by the panel of experts (2D and 3D features)

- Volume Computation

\[ V_{(Volume \ of \ half \ an \ Ellipsoide)} = \left(\frac{2}{3}\right) \pi \ a \ b \ c \]

\[ \text{given, } a = 0.8, b = 0.4, c = 0.6; \]
\[ V \approx 0.402125 \]
\[ V_{estimated} \approx 0.400666 \]
Automatic Assessment of Aesthetic Criteria in 2D and 3D

– Research Machine Learning methods specifically adapted to the problem of predicting **ordinal classes**.
  • Excellent, good, fair, poor

– Research Machine Learning methods with high **interpretability**
  • Facilitate understanding the connection between the **causes** and the **effects**
Automatic Assessment of Aesthetic Criteria in 2D and 3D

- Scorecards
- Adaboost
Automatic Assessment of Aesthetic Criteria in 2D and 3D

- **Scorecards**

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>Points</th>
</tr>
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<tbody>
<tr>
<td>LENGTH OF CREDIT HISTORY IN MONTHS</td>
<td></td>
</tr>
<tr>
<td>Below 12 months</td>
<td>12</td>
</tr>
<tr>
<td>12-23</td>
<td>35</td>
</tr>
<tr>
<td>24-47</td>
<td>60</td>
</tr>
<tr>
<td>48 or more</td>
<td>75</td>
</tr>
<tr>
<td>NUMBER OF CREDIT ACCOUNTS WITH BALANCE &gt; 0</td>
<td></td>
</tr>
<tr>
<td>0-1</td>
<td>65</td>
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<tr>
<td>2</td>
<td>55</td>
</tr>
<tr>
<td>3-4</td>
<td>50</td>
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<tr>
<td>5-7</td>
<td>40</td>
</tr>
<tr>
<td>8+</td>
<td>30</td>
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</table>
## Automatic Assessment of Aesthetic Criteria in 2D and 3D

### Scorecards

<table>
<thead>
<tr>
<th>Scar Visibility Index</th>
<th>Nipple Retraction</th>
<th>Shape Consistency</th>
<th>Color Asymmetry Index</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>B</strong></td>
<td><strong>Range</strong></td>
<td><strong>Points</strong></td>
<td><strong>B</strong></td>
</tr>
<tr>
<td>1</td>
<td>[0; 1[</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>2</td>
<td>[1; 2.5[</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>3</td>
<td>[2.5; 5.5[</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>&gt; 5.5</td>
<td>7</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>&gt; 2</td>
<td>35</td>
<td>6</td>
</tr>
</tbody>
</table>
### Automatic Assessment of Aesthetic Criteria in 2D and 3D

- **Scorecards**
  - Several alternatives exist to compute both the discretization scheme and the *weighting factors* which can or cannot include expert domain knowledge.
  - Generalization from Binary to Ordinal Data Settings

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<td>1</td>
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<td>4</td>
</tr>
<tr>
<td>5</td>
<td>[1.5; 2[</td>
<td>15</td>
<td>5</td>
</tr>
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<td>35</td>
<td>7</td>
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</table>
Automatic Assessment of Aesthetic Criteria in 2D and 3D

- **Scorecards::Weighting Strategies**
  - Weight of Evidence coding; 1-out-of-K coding; **Differential-coding**

- **Scorecards::Ordinal Data**
  - Integrated a ordinal data classifier (based on a single binary classifier reduction technique)

### Scorecards vs. oLDA and AdaBoost: Mean Absolute Error

<table>
<thead>
<tr>
<th>Datasets</th>
<th>Scorecard</th>
<th>oLDA</th>
<th>Conventional AdaBoost</th>
</tr>
</thead>
<tbody>
<tr>
<td>BALANCE</td>
<td>0.06</td>
<td>0.05</td>
<td>0.23</td>
</tr>
<tr>
<td>ERA</td>
<td>1.26</td>
<td>1.28</td>
<td>1.48</td>
</tr>
<tr>
<td>ESL</td>
<td>0.34</td>
<td>0.33</td>
<td>0.62</td>
</tr>
<tr>
<td>LEV</td>
<td>0.40</td>
<td>0.44</td>
<td>0.60</td>
</tr>
<tr>
<td>SWD</td>
<td>0.46</td>
<td>0.47</td>
<td>0.53</td>
</tr>
<tr>
<td>BCCT</td>
<td>0.55</td>
<td>0.64</td>
<td>0.38</td>
</tr>
</tbody>
</table>

**Differential Scorecards for Binary and Ordinal data (Pedro F. B. Silva, Jaime S. Cardoso), In Intelligent Data Analysis, 2015 (to appear)**
Automatic Assessment of Aesthetic Criteria in 2D and 3D

**oAdaboost** - AdaBoost variant for Ordinal Data Classification

- Adaboost
Automatic Assessment of Aesthetic Criteria in 2D and 3D

**oAdaboost** - AdaBoost variant for Ordinal Data Classification

- Extension of the (binary) Adaboost for Ordinal Data Classification
  - Grows several Adaboosts simultaneously to solve the multiclass (ordinal) data problem;
  - Order is imposed during the boosting process, allowing us to attain a better ensemble.
Automatic Assessment of Aesthetic Criteria in 2D and 3D

oAdaBoost

<table>
<thead>
<tr>
<th>Dataset</th>
<th>oADABoost</th>
<th>AdaBoost.M1</th>
<th>AdaBoost.M1W</th>
<th>AdaBoost.OR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle</td>
<td>6.87(2.61)</td>
<td>39.58(3.07)</td>
<td>55.03(1.28)</td>
<td>16.16(3.79)</td>
</tr>
<tr>
<td>Non-mon.</td>
<td>66.30(3.14)</td>
<td>69.99(2.38)</td>
<td>60.97(4.97)</td>
<td>76.26(1.79)</td>
</tr>
<tr>
<td>ERA</td>
<td>75.09(3.87)</td>
<td>78.19(2.32)</td>
<td>77.94(3.50)</td>
<td>78.10(2.31)</td>
</tr>
<tr>
<td>ESL</td>
<td>33.02(6.08)</td>
<td>56.97(2.89)</td>
<td>46.77(6.05)</td>
<td>44.86(5.48)</td>
</tr>
<tr>
<td>LEV</td>
<td>37.63(4.44)</td>
<td>57.60(2.85)</td>
<td>42.14(4.72)</td>
<td>50.34(4.19)</td>
</tr>
<tr>
<td>SWD</td>
<td>43.09(5.01)</td>
<td>48.20(3.90)</td>
<td>48.26(5.13)</td>
<td>48.20(3.90)</td>
</tr>
<tr>
<td>Balance</td>
<td>2.57(2.14)</td>
<td>28.23(4.24)</td>
<td>8.29(2.40)</td>
<td>16.78(7.99)</td>
</tr>
<tr>
<td>BCCT</td>
<td>12.80(2.76)</td>
<td>37.01(2.81)</td>
<td>37.82(5.04)</td>
<td>31.94(3.01)</td>
</tr>
</tbody>
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<td>0.55(0.01)</td>
<td>0.16(0.04)</td>
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<tr>
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<td>0.99(0.07)</td>
<td>1.30(0.08)</td>
<td>1.19(0.14)</td>
<td>1.03(0.04)</td>
</tr>
<tr>
<td>ERA</td>
<td>1.24(0.10)</td>
<td>1.43(0.07)</td>
<td>1.44(0.12)</td>
<td>1.43(0.07)</td>
</tr>
<tr>
<td>ESL</td>
<td>0.35(0.07)</td>
<td>0.73(0.06)</td>
<td>0.56(0.08)</td>
<td>0.51(0.07)</td>
</tr>
<tr>
<td>LEV</td>
<td>0.41(0.05)</td>
<td>0.71(0.03)</td>
<td>0.46(0.06)</td>
<td>0.57(0.05)</td>
</tr>
<tr>
<td>SWD</td>
<td>0.45(0.05)</td>
<td>0.50(0.04)</td>
<td>0.54(0.06)</td>
<td>0.50(0.04)</td>
</tr>
<tr>
<td>Balance</td>
<td>0.03(0.02)</td>
<td>0.49(0.09)</td>
<td>0.08(0.02)</td>
<td>0.18(0.09)</td>
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<tr>
<td>BCCT</td>
<td>0.13(0.03)</td>
<td>0.38(0.03)</td>
<td>0.40(0.07)</td>
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○,• statistically significant improvement or degradation.

oAdaBoost: An AdaBoost variant for Ordinal Classification

(John Costa, Jaime S. Cardoso), In Proceedings of the International Conference on Pattern Recognition Applications and Methods (ICPRAM), 2015 Best Student Paper Award
• Thank you!
• Questions?

Breast Research Group

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