Jaime S. Cardoso
Assistant Professor
jaime.cardoso@inescporto.pt
http://www.inescporto.pt/~jsc/

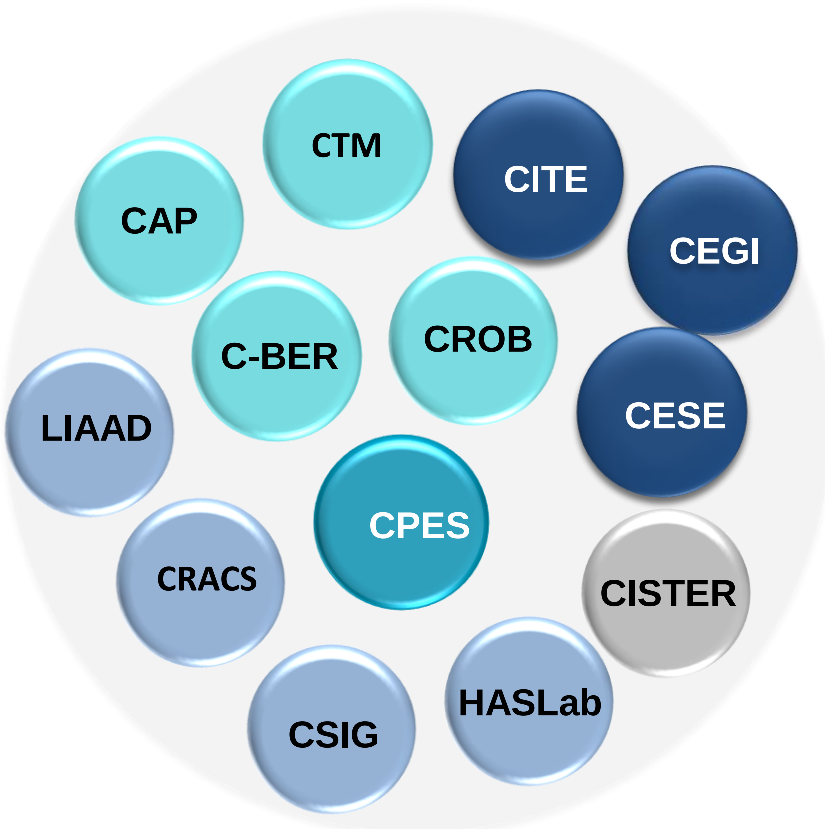
http://medicalresearch.inescporto.pt/breastresearch/

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

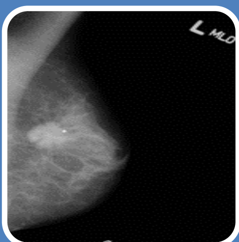
ASSOCIATE UNIT

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

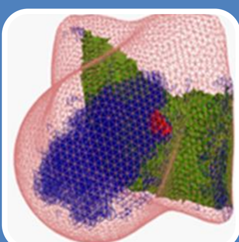
Breast Research Group

Image Processing

Machine Learning



Screening and Diagnosis



Surgery Planning (before surgery)

Surgery evaluation (after surgery)

INESCTEC
TECNOLOGIA E CIÊNCIA
LABORATÓRIO ASSOCIADO

U.PORTO
FMUP FACULDADE DE MEDICINA
UNIVERSIDADE DO PORTO

SÃO JOÃO

Champalimaud Foundation

PICTURE Project

Picture

Patient Information Combined for the Assessment of Specific Surgical

Outcomes in Breast Cancer

INESCTEC
TECNOLOGIA E CIÊNCIA
LABORATÓRIO ASSOCIADO

Champalimaud Foundation

UCL

LUMC

KING'S College LONDON

Royal Free London NHS
NHS Foundation Trust

PHILIPS

Surgery Planning (before surgery)

The Clinical Need

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

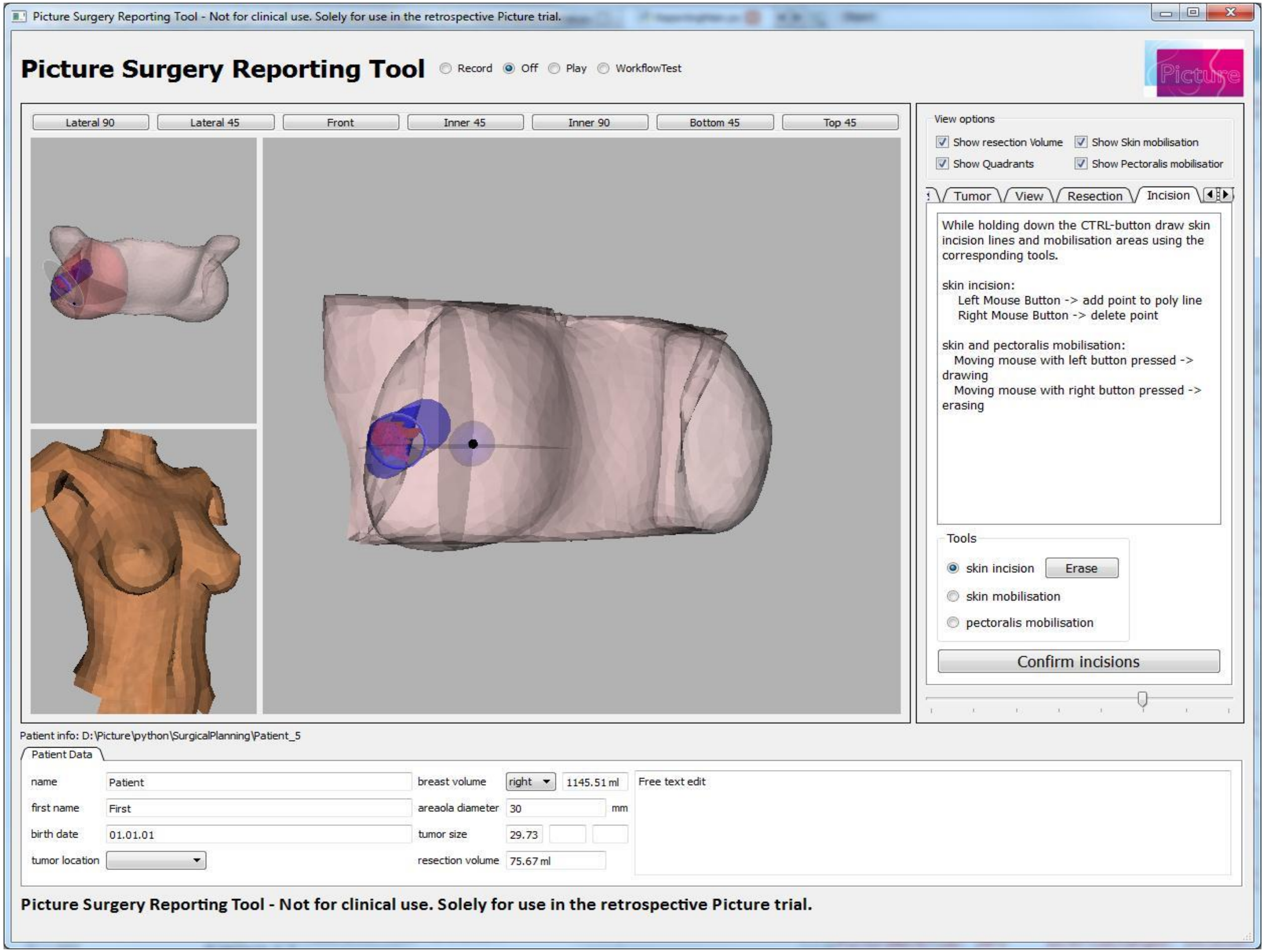
- The cosmetic outcome of surgery is a function of many factors including tumour size and location, the volume of the breast, its density, and the dose and distribution of radiotherapy.

Surgery Planning

3-D simulation of breast surgery facilitates presurgical planning

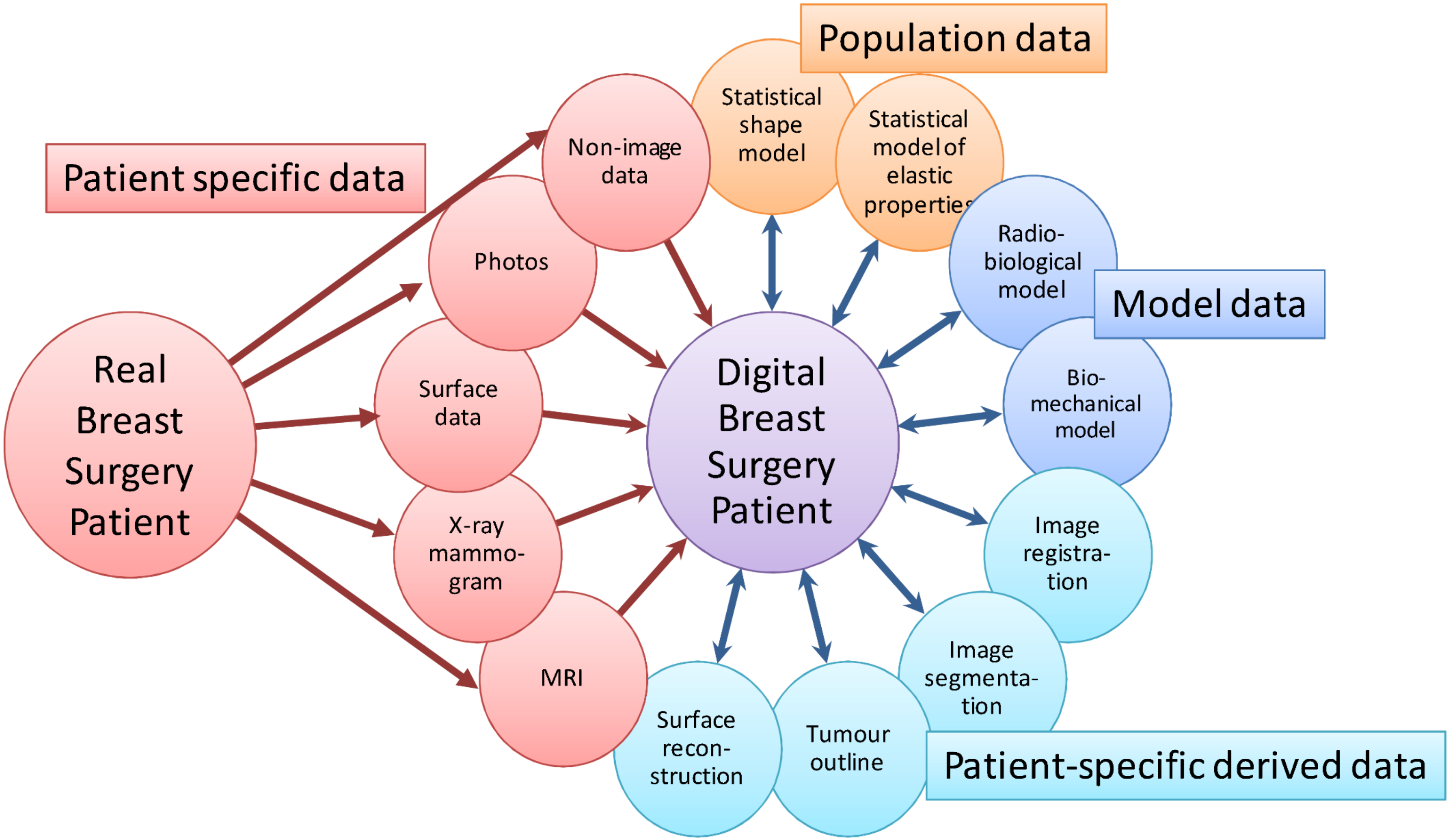
- Facilitates informed patient-physician discussion of strategies so together they can:
  - Carefully consider the surgery
  - Plan to use the most appropriate pain relief techniques
  - Etc.

Surgery Planning



Surgery Planning

- **The Challenge: data integration**



Surgery Planning

- 3D Reconstruction from Kinect RGB-D images

Data Acquisition

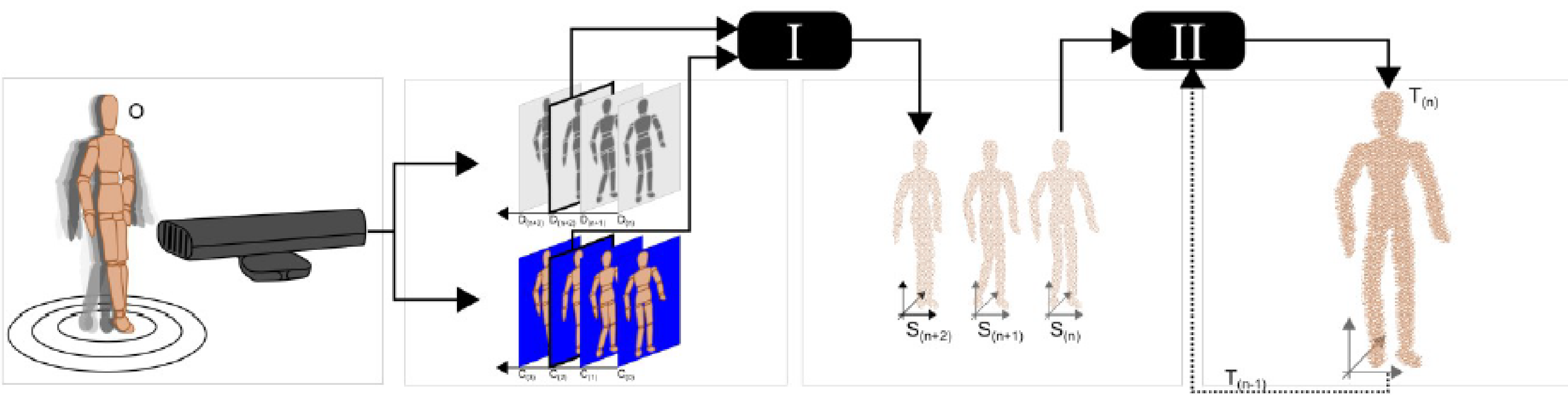
- Kinect
  - Light weight
  - Hand held
  - Low cost

Preprocessing

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

Registration

- Coarse Registration
- Fine Registration

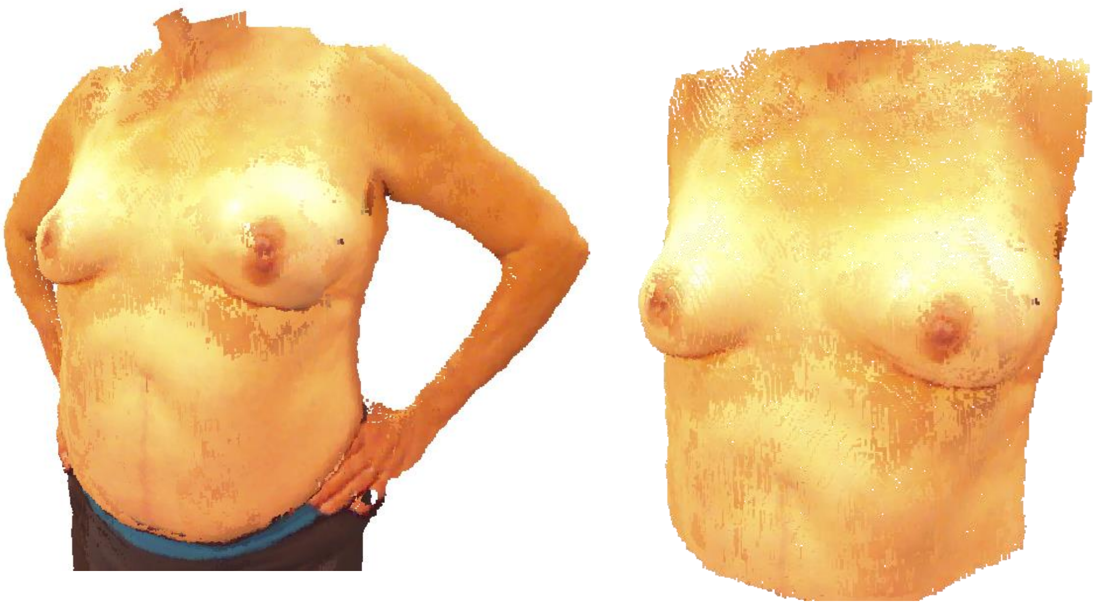


RGB-D images | Coloured Point clouds | Coloured Point cloud

Surgery Planning

- 3D Reconstruction from Kinect RGB-D images

Kinect Data



3D Scanner Data

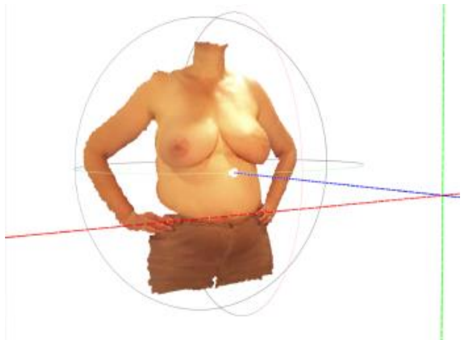
Surgery Planning

- 3D Reconstruction from Kinect RGB-D images

Colour inconsistency correction

RGB – Kinect

PC before correction

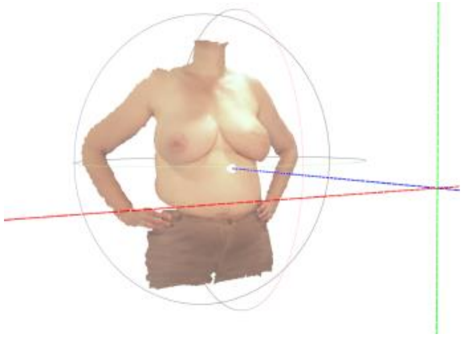


Colour correction using 2D HD image

$$f_R(x) = \frac{\sigma_{2D}}{\sigma_K}(x - \mu_K) + \mu_{2D}$$

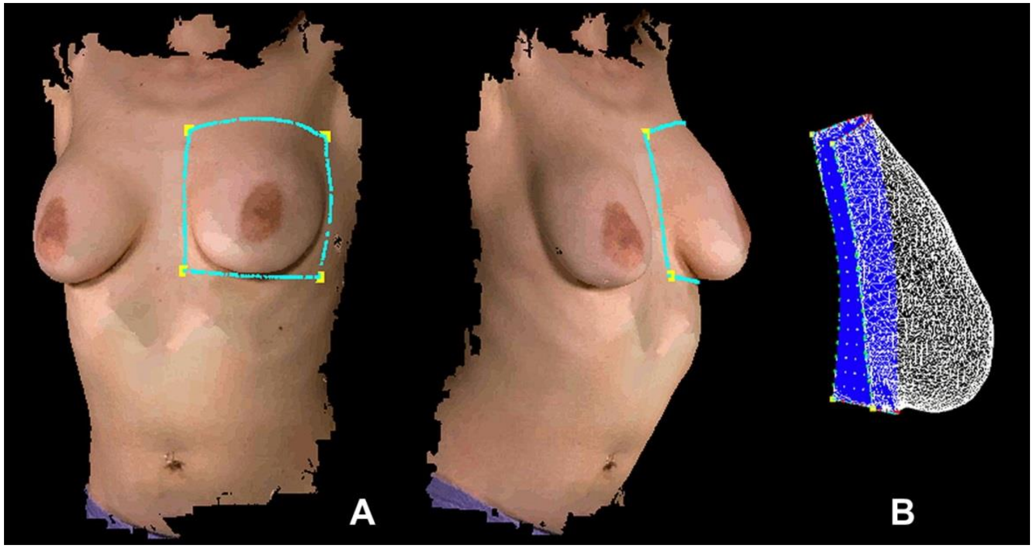
RGB – 2D HD

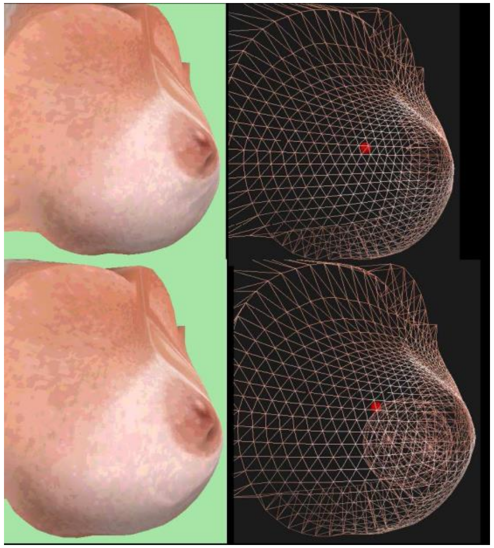
PC after correction



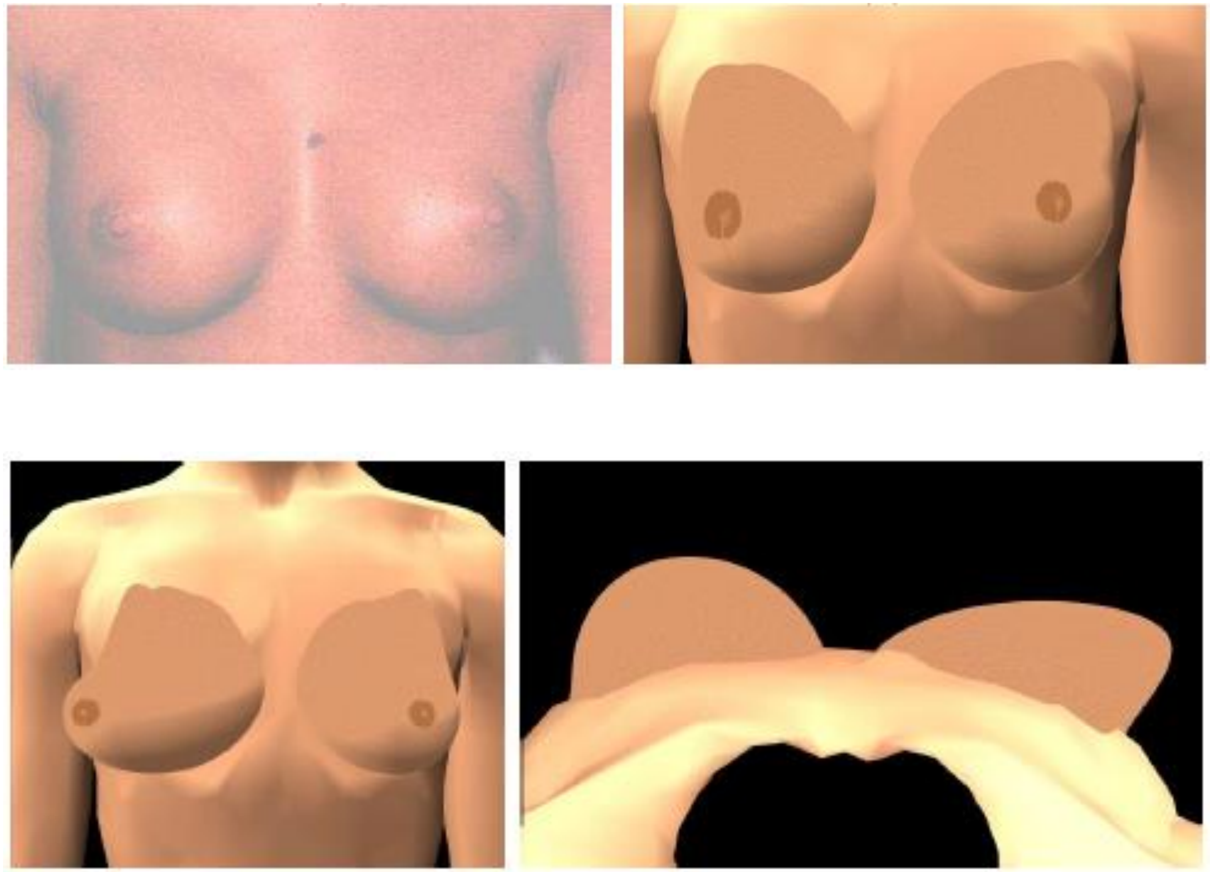
Surgery Planning

Parametric Breast Model Fitting





Surgery Planning

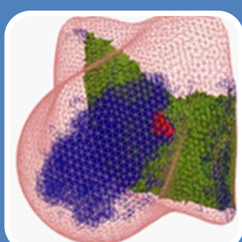


Breast Research Group

Image Processing

Machine Learning

Screening and Diagnosis



Surgery Planning (before surgery)

Surgery evaluation (after surgery)

INESCTEC
TECNOLOGIA E CIÊNCIA
LABORATÓRIO ASSOCIADO

U.PORTO
FMUP FACULDADE DE MEDICINA UNIVERSIDADE DO PORTO

SÃO JOÃO

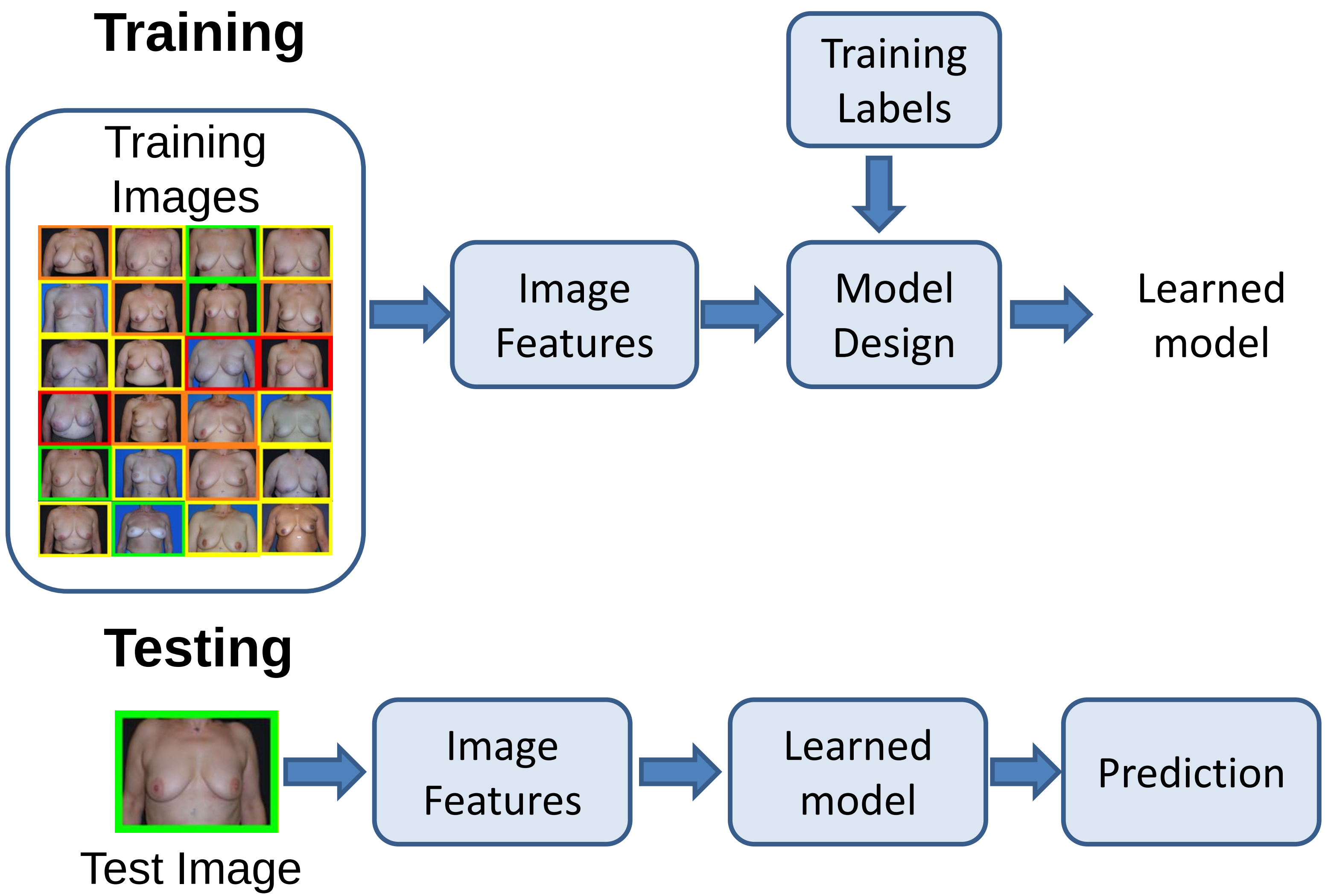
Champalimaud Foundation

Surgery evaluation (after surgery)

The Clinical Need

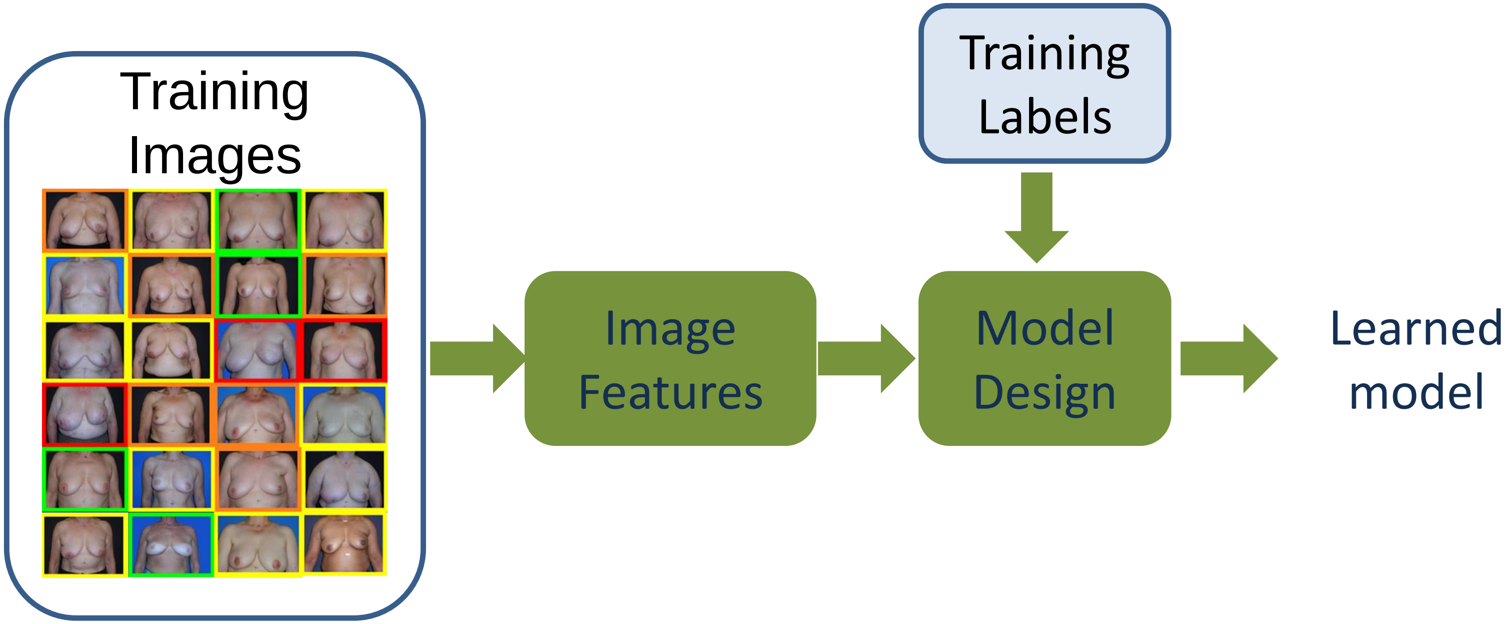
In breast-conserving surgery, there is evidence that approximately 30% of women receive a suboptimal or poor aesthetic outcome; however there is currently no standardised method of identifying these women.

Surgery evaluation (after surgery)



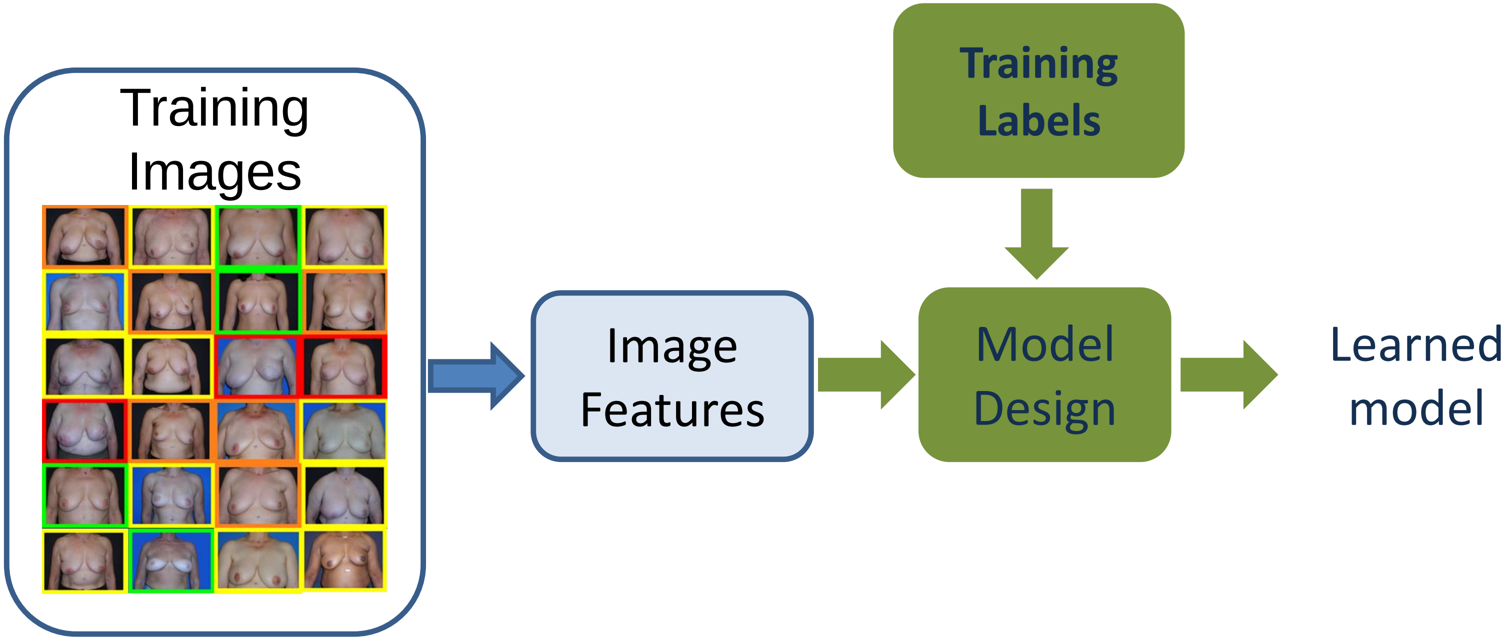
Assessment of Contributing Factors to the cosmetic outcome

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.



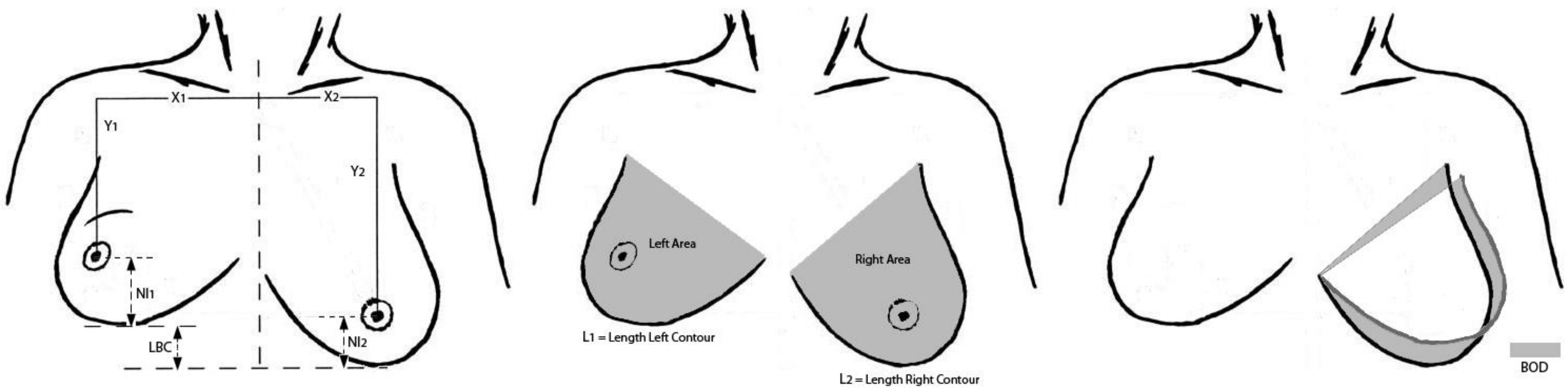
Objective criteria in 2D and 3D images

- 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



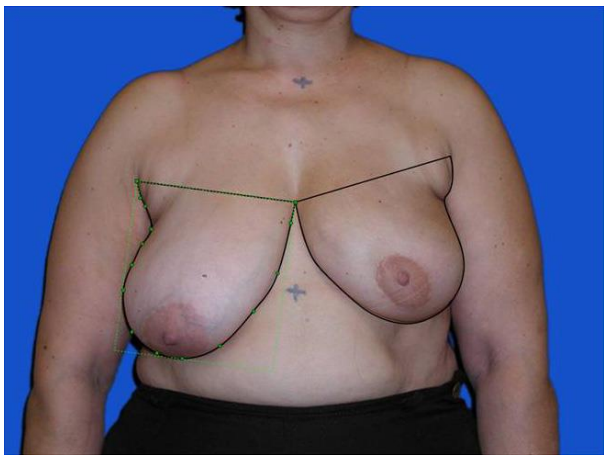
2D Features

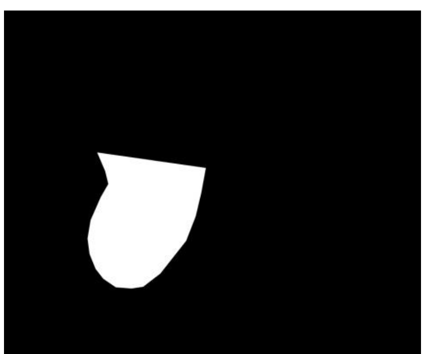
- 14 asymmetry features

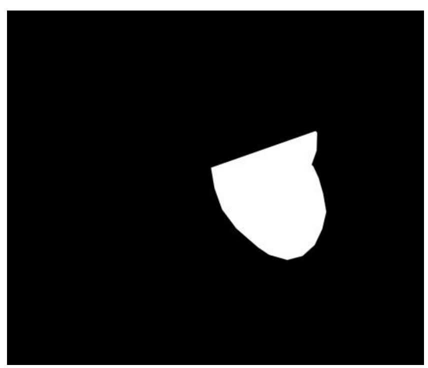


2D Features

- 8 colour features



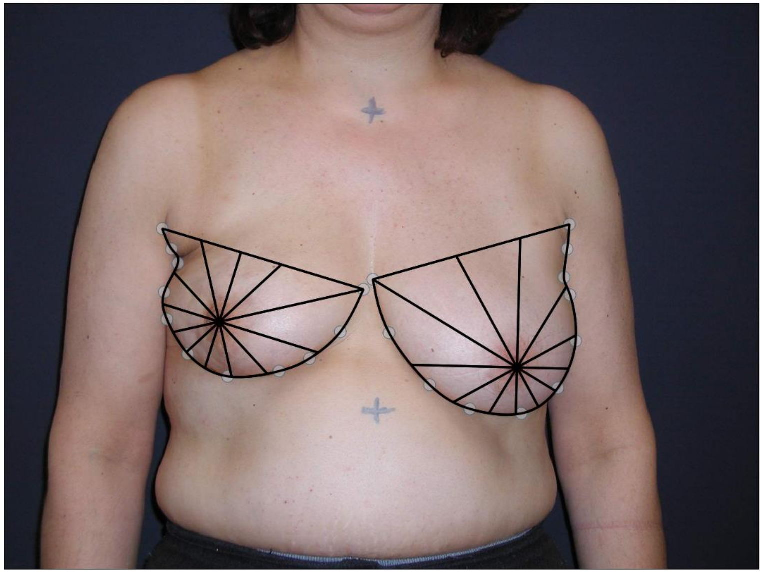




- **Measure the dissimilarity between the colour of the two breasts**
  - **Compute the histogram of colours for each breast**
  - **Compare histograms**
    - **EMD (earth movers distance)**
    - **Chi-square**

2D Features

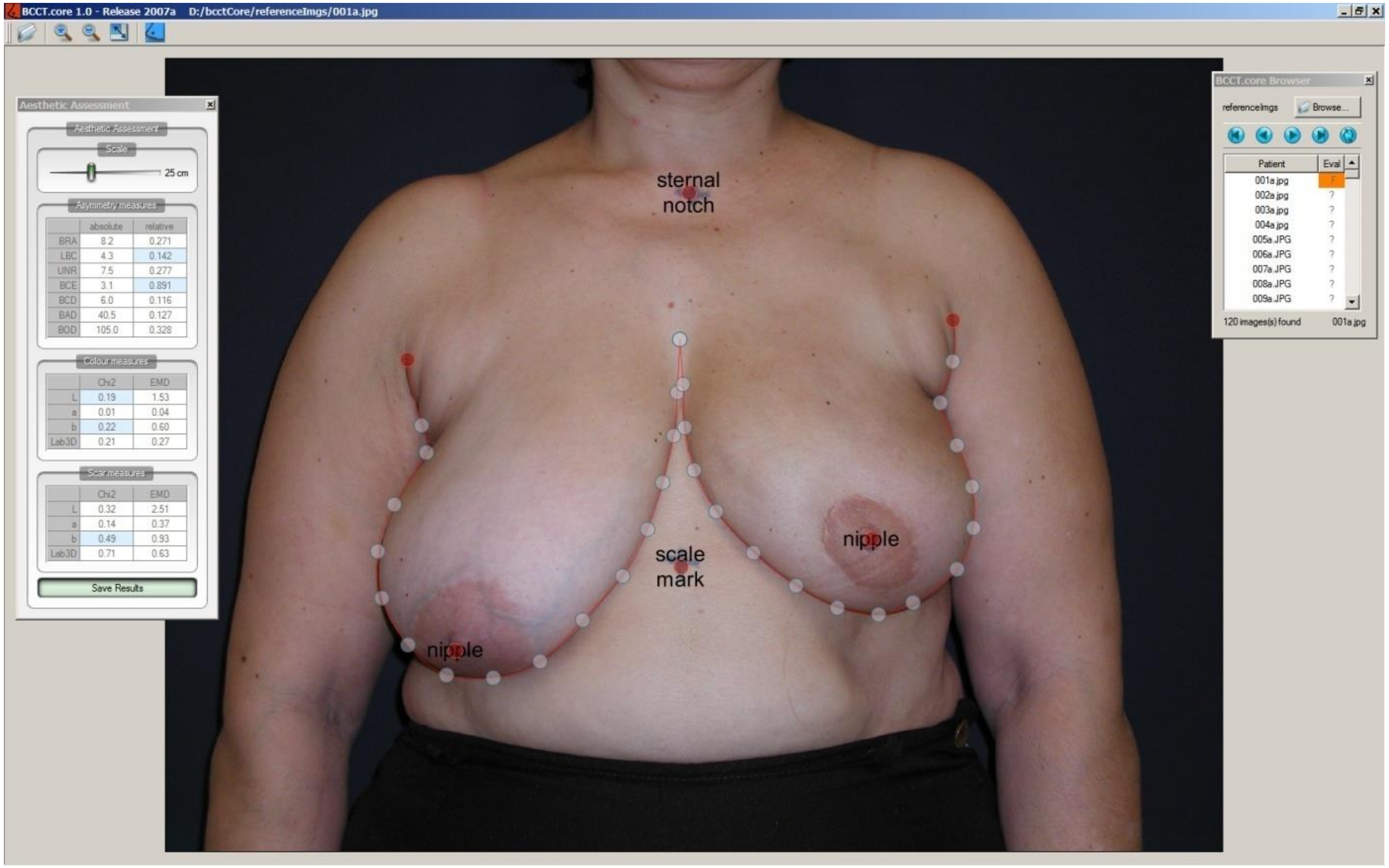
- 8 scar features



- **Scar visibility as a local (colour) change**
- **Breast divided in sectors**
  - **Corresponding sectors are compared**

BCCT.core Software

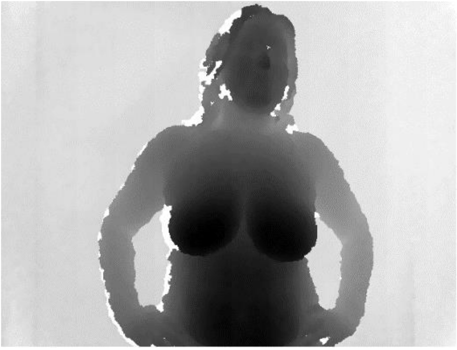
- Software
- http://medicalresearch.inescporto.pt/breastresearch/index.php/Get_BCCT.core

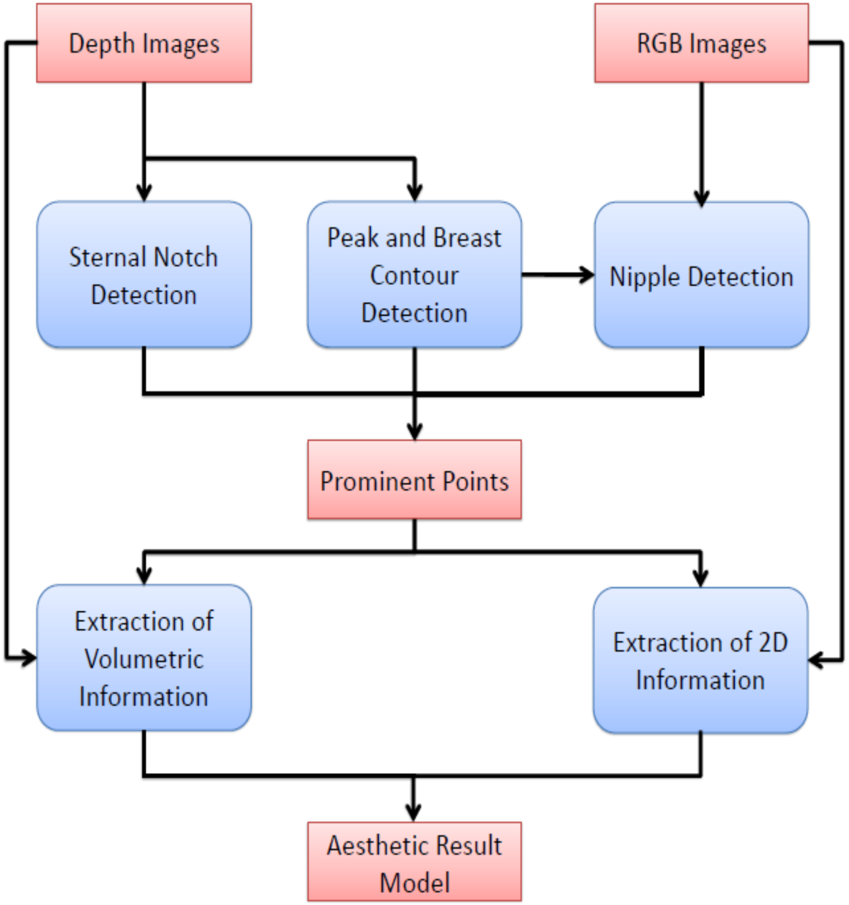


From 2D to 3D

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

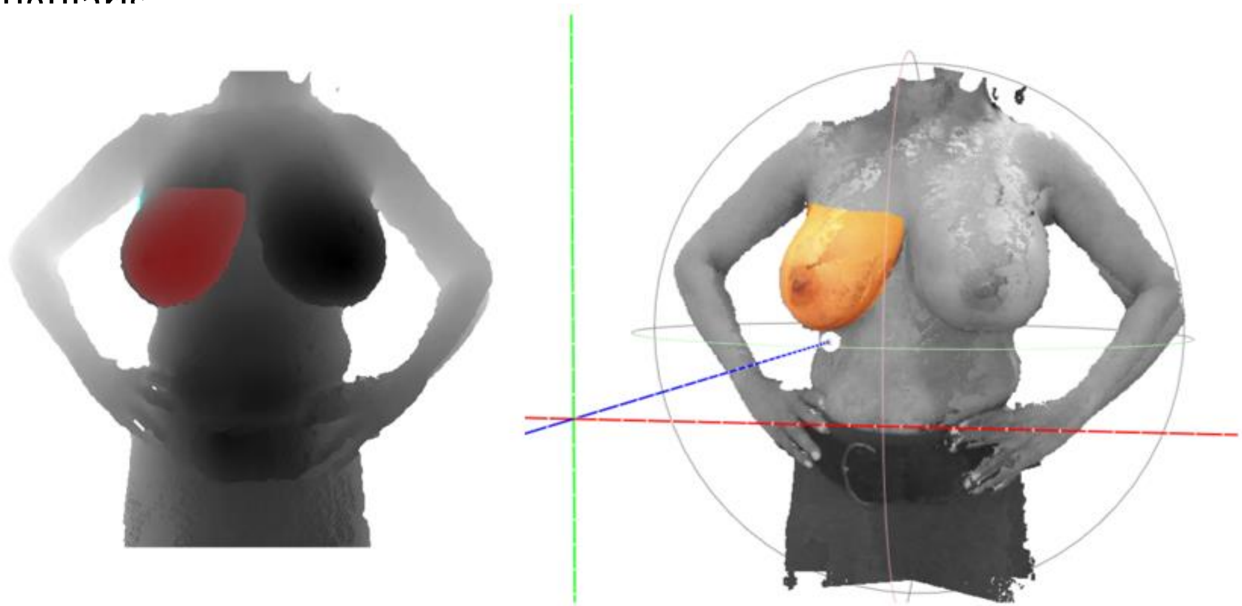




From 2D to 3D

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

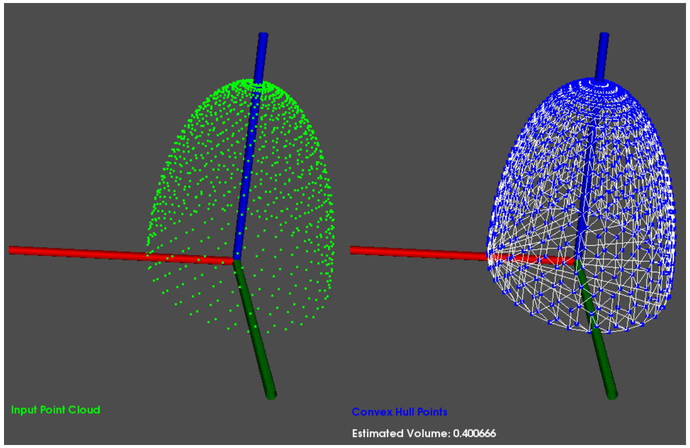


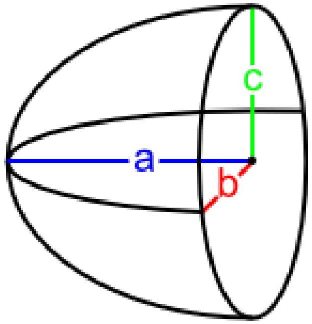
a) b)

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





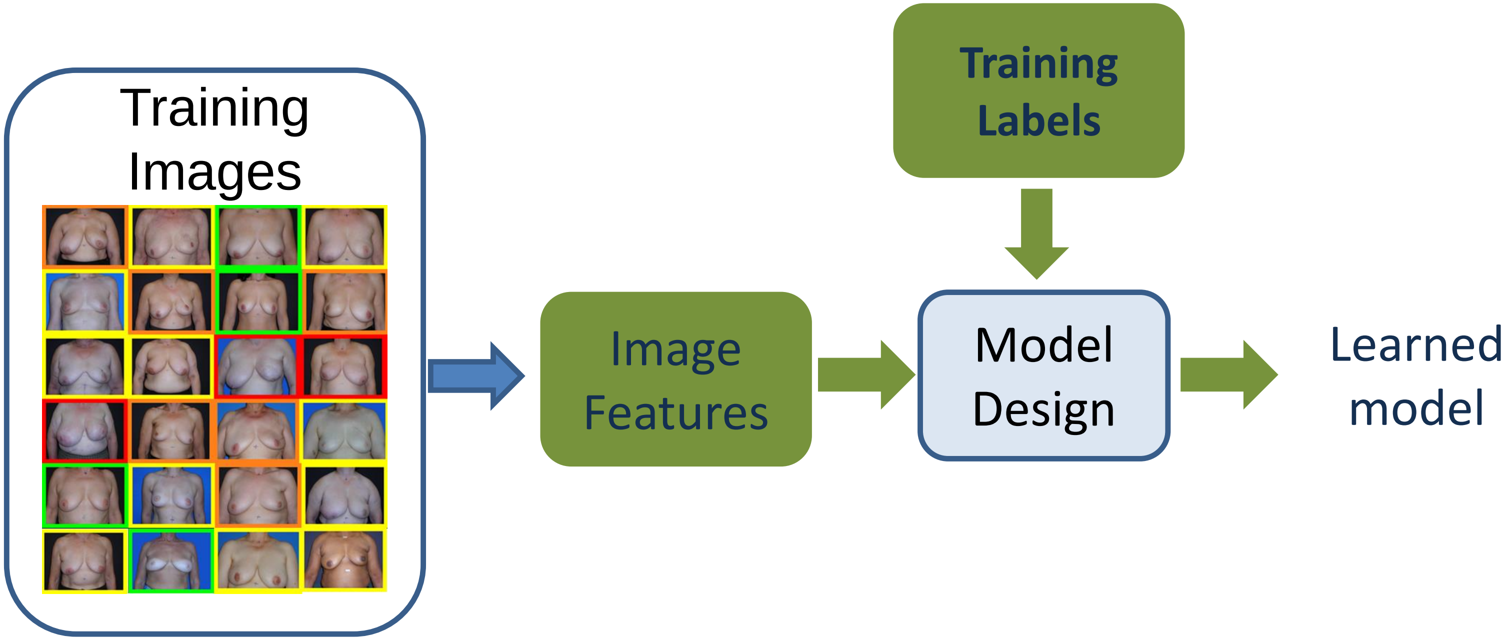
$$V_{(Volume\ of\ half\ an\ Ellipsoide)} = \left(\frac{2}{3}\right)\pi\, a\, b\, c$$

$$given, a = 0.8, b = 0.4, c = 0.6;$$
$$V \approx 0.402125$$

$$V_{\text{estimated}} \approx 0.400666$$

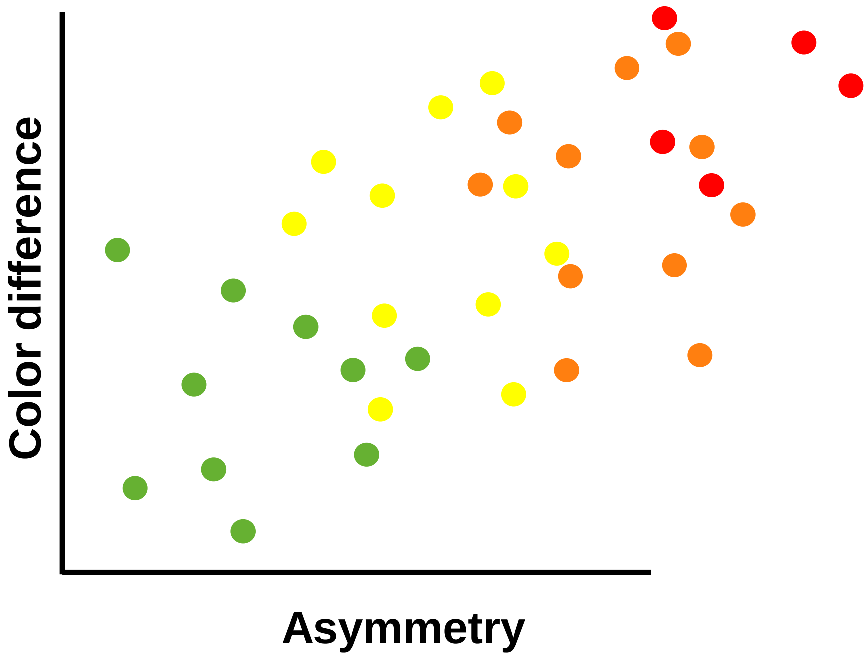
Automatic Assessment of Aesthetic Criteria in 2D and 3D

- 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**

CHARACTERISTIC	Points
LENGTH OF CREDIT HISTORY IN MONTHS	
Below 12 months	12
12-23	35
24-47	60
48 or more	75
NUMBER OF CREDIT ACCOUNTS WITH BALANCE > 0	
0-1	65
2	55
3-4	50
5-7	40
8+	30

Automatic Assessment of Aesthetic Criteria in 2D and 3D

- **Scorecards**

Scar Visibility Index			Nipple Retraction			Shape Consistency			Color Asymmetry Index		
B	Range	**Points**	B	Range	**Points**	B	Value	**Points**	B	Range	**Points**
1	[0; 1[	1	1	]0,0.5]	5	1	[0,1]	20	1	[0,0.05]	1
2	[1; 2.5[	3	2	]0.5,0.75]	6	2	]1,3]	8	2	]0.05,0.1]	5
3	[2.5; 5.5[	5	3	]0.75,1]	8	3	]3,4]	5	3	]0.1,0.2]	10
4	> 5.5	7	4	]1,1.5]	10	4	> 4	1	4	]0.2,0.3]	15
			5	]1.5,2]	15				5	]0.3,0.5]	20
			6	> 2	35				6	]0.5,0.8]	40
									7	]0.8,1]	100

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**

Scar Visibility Index			Nipple Retraction			Shape Consistency			Color Asymmetry Index		
B	Range	**Points**	B	Range	**Points**	B	Value	**Points**	B	Range	**Points**
1	[0; 1[	1	1	]0,0.5]	5	1	[0,1]	20	1	[0,0.05]	1
2	[1; 2.5[	3	2	]0.5,0.75]	6	2	]1,3]	8	2	]0.05,0.1]	5
3	[2.5; 5.5[	5	3	]0.75,1]	8	3	]3,4]	5	3	]0.1,0.2]	10
4	> 5.5	7	4	]1,1.5]	10	4	> 4	1	4	]0.2,0.3]	15
			5	]1.5,2]	15				5	]0.3,0.5]	20
			6	> 2	35				6	]0.5,0.8]	40
									7	]0.8,1]	100

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)**

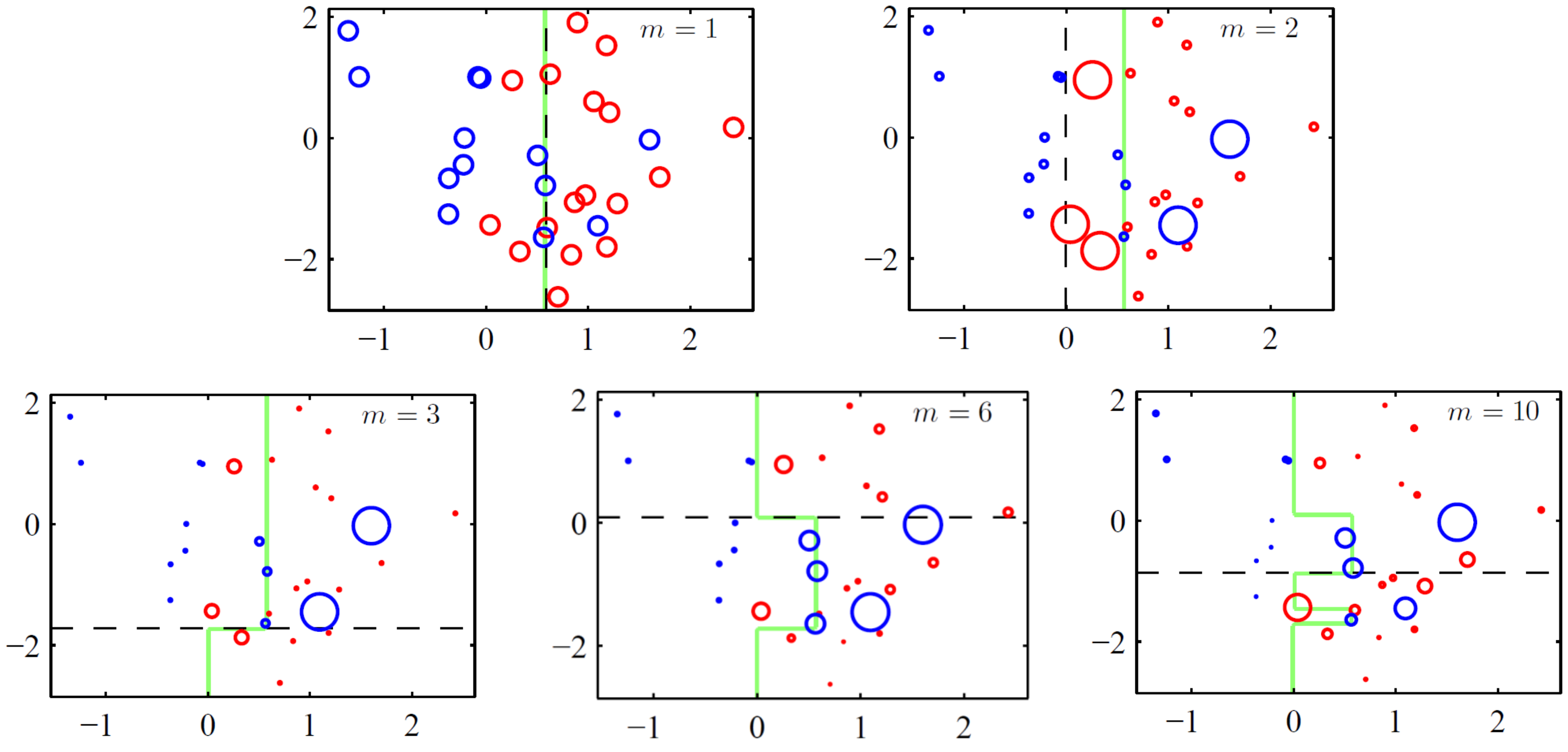
Scorecards vs. oLDA and AdaBoost: Mean Absolute Error

	Scorecard		oLDA	Conventional AdaBoost
Datasets	oRLS	oSVM		
BALANCE	0.06	0.00	0.05	0.23
ERA	1.26	1.30	1.28	1.48
ESL	0.34	0.35	0.33	0.62
LEV	0.40	0.42	0.44	0.60
SWD	0.46	0.44	0.47	0.53
BCCT	0.55	0.53	0.64	0.38

Differential Scorecards for Binary and Ordinal data (Pedro F. B. Silva, Jaime S. Cardoso),
In Intelligent Data Analysis, 2015 (to appear)

oAdaboost - AdaBoost variant for Ordinal Data Classification

- Adaboost



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

(a) Percentage of incorrect classifications: mean (standard deviation)

Dataset	oADABOOST	ADABOOST.M1	ADABOOST.M1W	ADABOOST.OR
Circle	6.87(2.61)	39.58(3.07) •	55.03(1.28) •	16.16(3.79) •
Non-mon.	66.30(3.14)	69.99(2.38) •	60.97(4.97) ∘	76.26(1.79) •
ERA	75.09(3.87)	78.19(2.32)	77.94(3.50)	78.10(2.31)
ESL	33.02(6.08)	56.97(2.89) •	46.77(6.05) •	44.86(5.48) •
LEV	37.63(4.44)	57.60(2.85) •	42.14(4.72) •	50.34(4.19) •
SWD	43.09(5.01)	48.20(3.90) •	48.26(5.13) •	48.20(3.90) •
Balance	2.57(2.14)	28.23(4.24) •	8.29(2.40) •	16.78(7.99) •
BCCT	12.80(2.76)	37.01(2.81) •	37.82(5.04) •	31.94(3.01) •

(b) Mean Absolute Error: mean (standard deviation)

Dataset	oADABOOST	ADABOOST.M1	ADABOOST.M1W	ADABOOST.OR
Circle	0.07(0.03)	0.44(0.03) •	0.55(0.01) •	0.16(0.04) •
Non-Mon.	0.99(0.07)	1.30(0.08) •	1.19(0.14) •	1.03(0.04)
ERA	1.24(0.10)	1.43(0.07) •	1.44(0.12) •	1.43(0.07) •
ESL	0.35(0.07)	0.73(0.06) •	0.56(0.08) •	0.51(0.07) •
LEV	0.41(0.05)	0.71(0.03) •	0.46(0.06) •	0.57(0.05) •
SWD	0.45(0.05)	0.50(0.04) •	0.54(0.06) •	0.50(0.04) •
Balance	0.03(0.02)	0.49(0.09) •	0.08(0.02) •	0.18(0.09) •
BCCT	0.13(0.03)	0.38(0.03) •	0.40(0.07) •	0.33(0.03) •

∘,• statistically significant improvement or degradation.

oAdaBoost: An AdaBoost variant for Ordinal Classification
(Joao 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

http://medicalresearch.inescporto.pt/

http://vcmi.inescporto.pt/

Contact: Jaime S. Cardoso

jaime.cardoso@inesctec.pt

http://www.inescporto.pt/~jsc/

INESC TEC
Campus da FEUP, Rua Dr. Roberto Frias
4200-465 Porto, Portugal