Predicting Malignancy from Mammography Findings and Image Guided Core Biopsies

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Pedro Miguel Ferreira

Nuno A. Fonseca
Inês Dutra
Ryan Woods
Elizabeth Burnside

CRACS INESCTEC
FACULDADE DE CIÊNCIAS UNIVERSIDADE DO PORTO
U.PORTO
WISCONSIN UNIVERSITY OF WISCONSIN-MADISON

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Outline

- Breast Cancer
- Objectives
- Dataset
- Methodology
- Results and Analysis
- *MammoClass* (online application)
- Conclusions and Future Work

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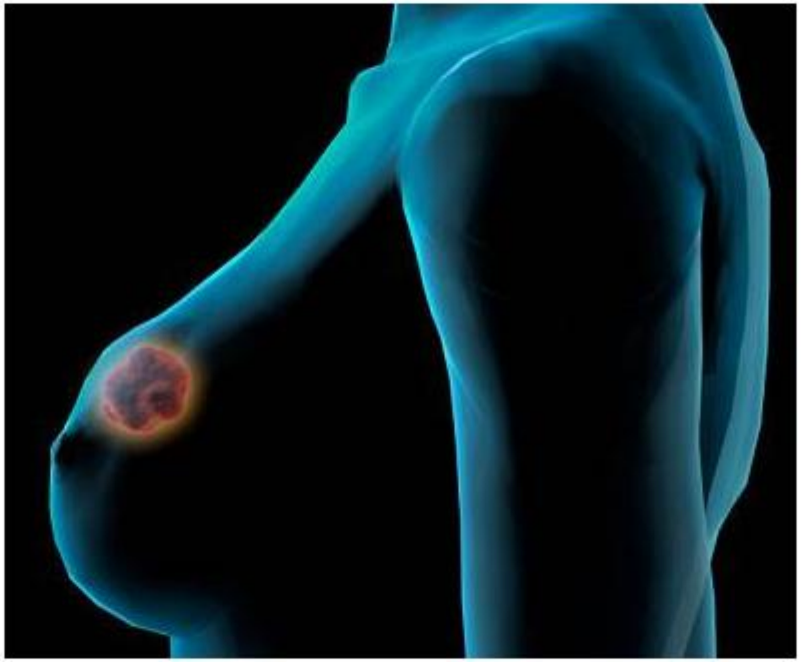
Breast Cancer



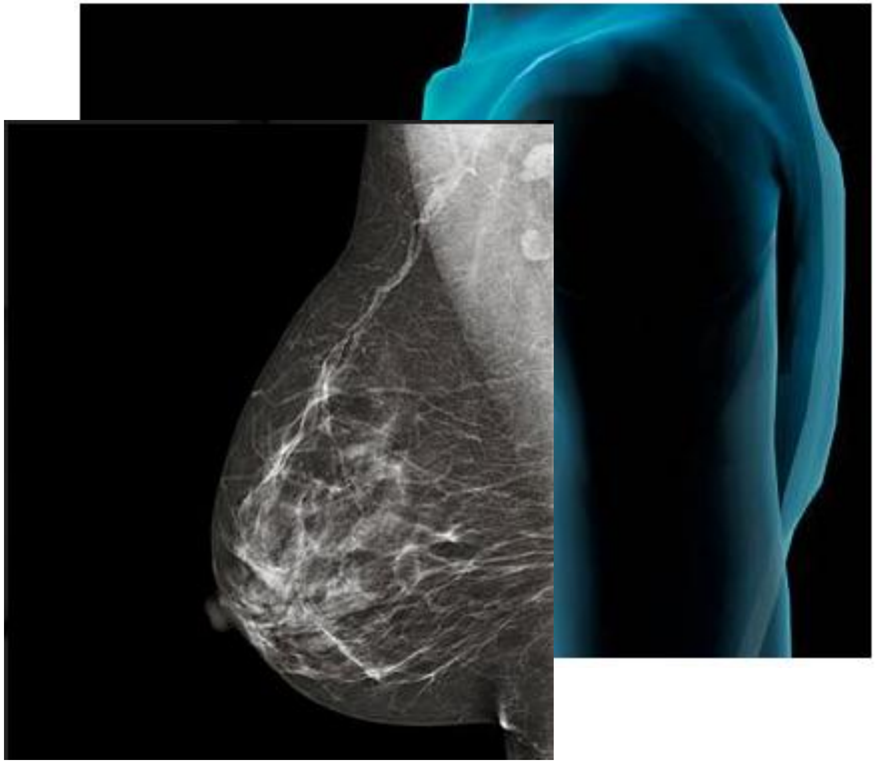
- USA:
  - 1 woman dies of breast cancer every 13 minutes
  - In 2011:
    - 230.480 invasive cancers
    - 39.520 (≈ 17%) expected to die

Source: *U. S. Breast Cancer Statistics* – accessed June 2013

- Portugal:
  - Per year:
    - 4500 new cases
    - 1500 deaths (33%)

Source: *Liga Portuguesa Contra o Cancro* – accessed June 2013

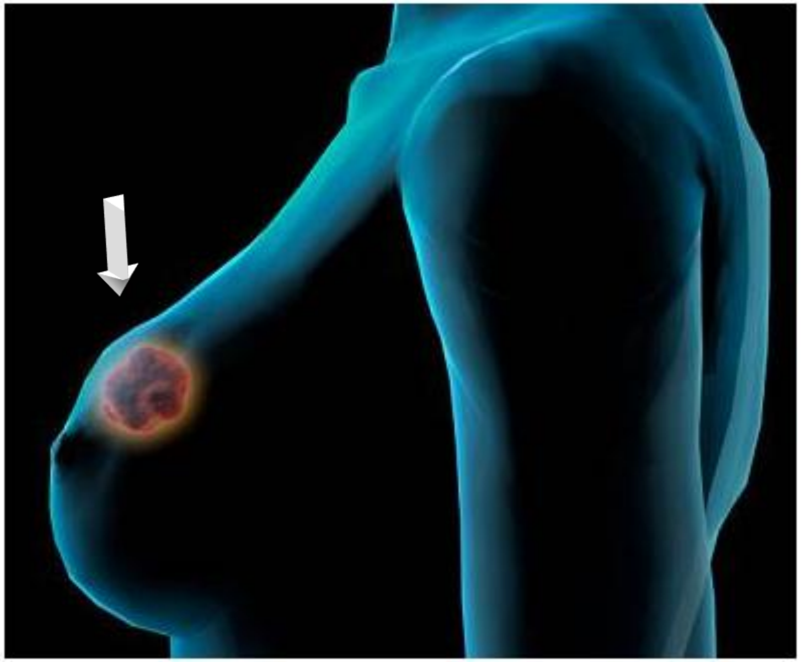
Breast Screening Programs



- Reduction of death rate in 30%
- **Mammography**:

  The cheapest and most eficient method to detect cancer in a preclinical stage

Mammography

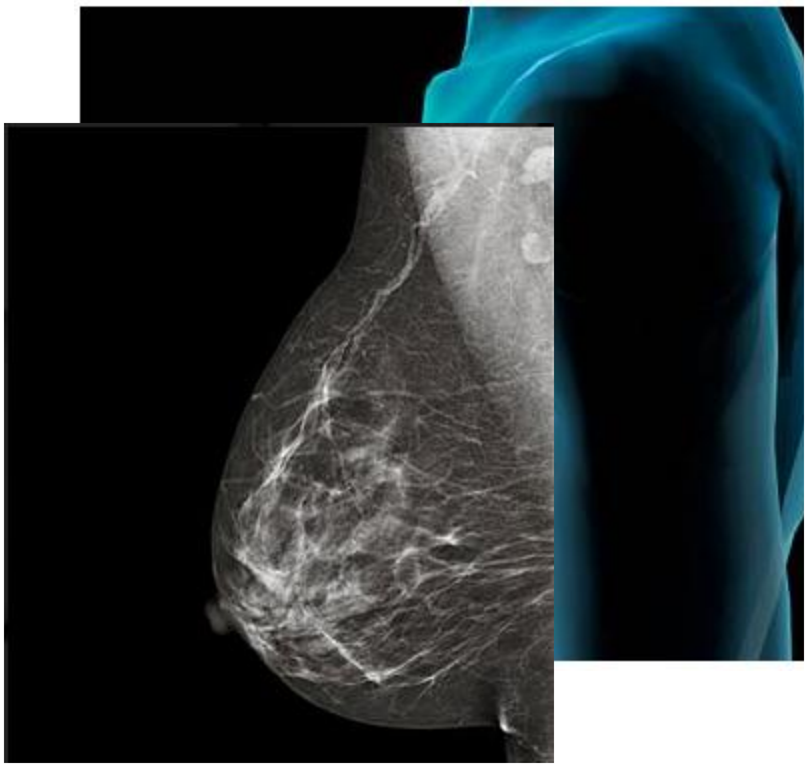


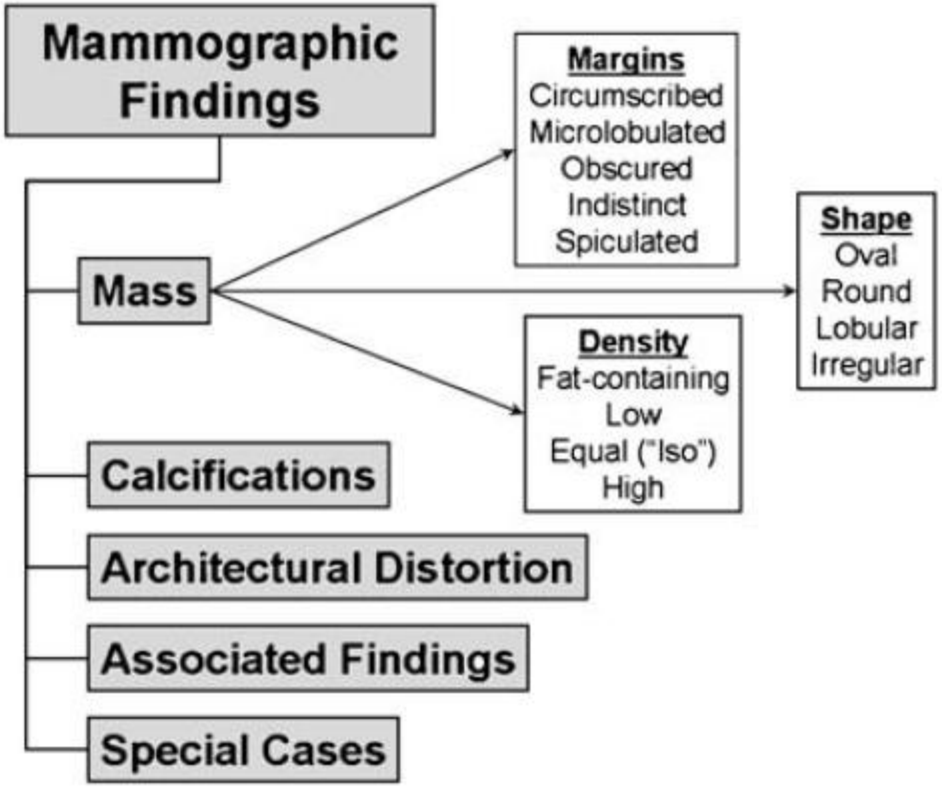
Nodule/Mass:

Solid lesion with more than 1 cm of width and usually well defined.

Also known as tumour.

Mammography





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- in P. Ferreira, et al., “**Studying the relevance of Breast Imaging Features**”, in Proc. International Conference on Health Informatics (HEALTHINF), 2011.

Objectives

- Build classifiers capable of predicting **mass density** and **malignancy** from a reduced set of mammography findings

- Reduce the number of unnecessary biopsies

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Dataset

- Source:
  - Ryan Woods (M.D.)
  - Elizabeth Burnside (M.D.)

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- 348 cases
- Each case refers to a breast nodule **retrospectively** classified according to BI-RADS® system
- From mammographies results
- Collected between October 2005 and December 2007

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Attributes

13 attributes

age_at_mammo
CLOCKFACE_LOCATION_OR_REGION
MASS_SHAPE
MASS_MARGINS
SIDE
DEPTH
MASS_MARGINS_worst
QUADRANT_LOCATION_def
SIZE
OVERALL_BREAST_COMPOSITION
Density_num
retro_density
outcome_num

118 (33.9%) malignant (+)

230 (66.1%) benign (-)

Masses classification

Prospective

- **Classification** of feature **mass density just by one radiologist**:
  - low density;
  - iso-dense;
  - high density;
- **Brief** and superficial medical **report** (at the time of imaging);
- **Classification under stress**.

mass density

density_num

Retrospective

- **Classification** by a **group of experienced physicians** that **re-assess** all **exams**;
- **Review of mass density classification** made by radiologist (prospective study);
- **Classification without stress**;
- **Reference standard** for **mass density**.

mass density

retro_density

Masses classification

348 cases (**retrospectively** classified)

180

(≈ 52%)

(**prospectively** classified)

168

(≈ 48%)

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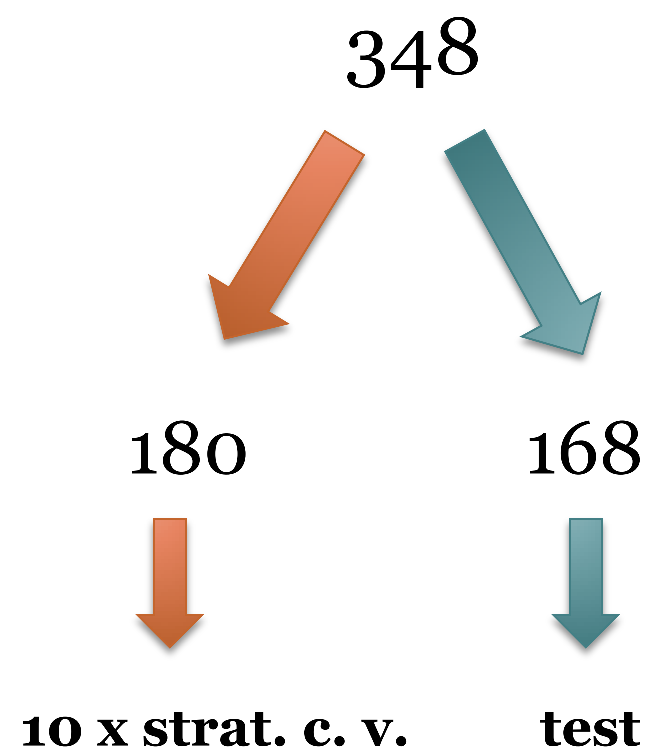
Methodology

- WEKA

- Paired Corrected T-Tester
  - **Significance level: 0.05**



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Methodology – Experiments

10 x stratified. c. v.

180

- $\mathbf{E_1}$ – Predicting malignancy with *retro_density*
- $\mathbf{E_2}$ – Predicting malignancy with *density_num*
- $\mathbf{E_3}$ – Predicting malignancy without mass density

- $\mathbf{E_4}$ – Predicting *retro_density**
- $\mathbf{E_5}$ – Predicting *density_num**

* in all experiments the *low* and *iso* densities were merged into a single class

Methodology – Algorithms applied

- ZeroR (baseline classifier)
- OneR
- DTNB
- PART

rules

- J48
- DecisionStump
- RandomForest
- SimpleCart
- NBTree

trees

- NaiveBayes
- BayesNet (TAN)

bayes

- SMO

functions

internal parameter variation

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Results

348

180

168

10 x strat. c.v.

test

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Results – Experiments

10 x stratified. c. v.

180

Predicting malignancy with retro_density

Predicting retro_density

Exp.	Algorithm	CCI	K	F	AUROC
E1	SMO	**85.6**±7.3	**0.69**±0.16	**0.80**±0.11	**0.84**±0.08
E1	DTNB	81.6±8.2	0.60±0.18	0.74±0.13	0.88±0.07
E1	NaiveBayes	81.3±9.5	0.61±0.20	0.76±0.12	0.88±0.08
E1	J48	80.7±9.3	0.59±0.20	0.75±0.13	0.79±0.11
E2	SMO	**83.9**±7.7	**0.66**±0.17	**0.78**±0.11	**0.82**±0.08
E2	NaiveBayes	80.3±9.3	0.59±0.19	0.75±0.12	0.87±0.09
E2	DTNB	79.8±9.5	0.56±0.21	0.72±0.15	0.86±0.09
E2	J48	75.4±9.5	0.47±0.21	0.65±0.15	0.73±0.12
E3	SMO	**83.8**±7.7	**0.65**±0.17	**0.78**±0.11	**0.82**±0.09
E3	J48	76.3±9.9	0.49±0.22	0.67±0.15	0.76±0.13
E3	NaiveBayes	76.2±9.9	0.51±0.20	0.71±0.13	0.85±0.09
E3	DTNB	75.7±9.0	0.48±0.19	0.67±0.13	**0.81**±0.10
E4	SMO	**81.3**±8.2	**0.52**±0.21	**0.64**±0.17	**0.75**±0.11
E4	J48	74.4±8.8	0.32±0.24	0.47±0.21	0.67±0.15
E4	DTNB	73.5±10.0	0.34±0.24	0.51±0.19	**0.76**±0.12
E4	NaiveBayes	72.8±9.9	0.37±0.23	0.56±0.18	0.77±0.11
E5	NaiveBayes	**67.2**±12.1	**0.33**±0.25	**0.62**±0.15	**0.72**±0.14
E5	SMO	**66.8**±10.7	**0.31**±0.22	0.55±0.16	0.65±0.11
E5	J48	63.6±10.1	0.26±0.21	0.56±0.15	0.62±0.13
E5	DTNB	62.1±11.9	0.22±0.24	0.54±0.16	0.64±0.14

Results – Experiments

Predicting density

180

Results - Experiments

10 x stratified. c. v.

- **E_4** – Predicting *retro_density*

SVM's

CCI: 81.3% (+/-8.2)

Sens: 0.57 (+/- 0.20)

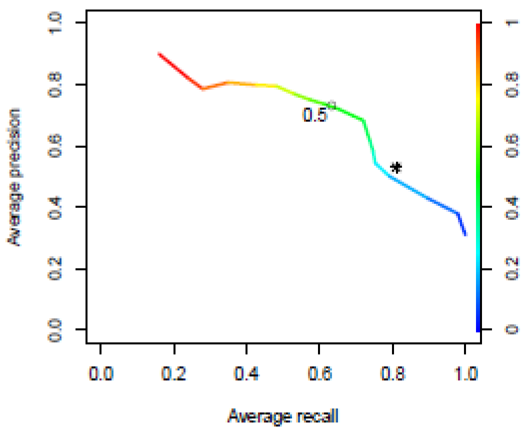
Spec: 0.92 (+/- 0.07)

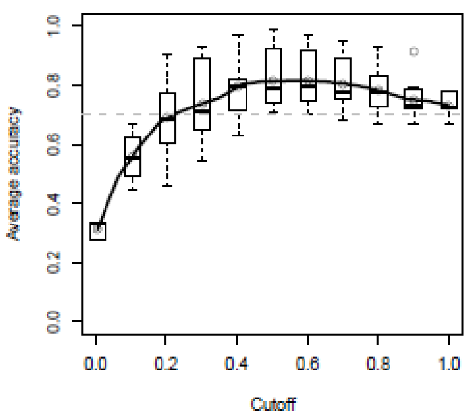
F: 0.64 (+/- 0.17)

Radiologist's accuracy = 70 %

Classifier ≈ 81 %

high density





168

Results - Experiments

TEST

- **E_6** – Predicting *retro_density*

(model E_4 applied)

SVM's

CCI: 84.5%

Sens: 0.57

Spec: 0.90

F: 0.55

180

SVM's

CCI: 81.3% (+/-8.2)

Sens: 0.57 (+/- 0.20)

Spec: 0.92 (+/- 0.07)

F: 0.64 (+/- 0.17)

Results – Experiments

Predicting malignancy

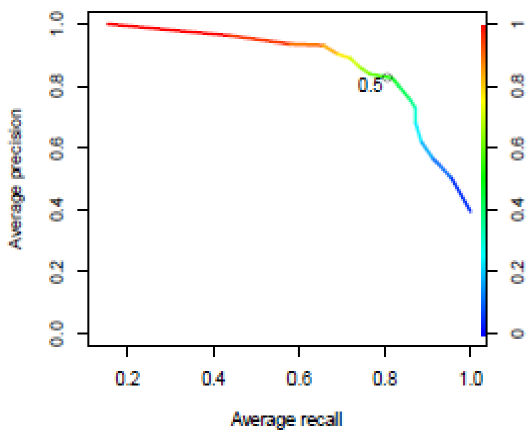
180

Results - Experiments

10 x stratified. c. v.

- **E_1** – Predicting malignancy with *retro_density*

malignant



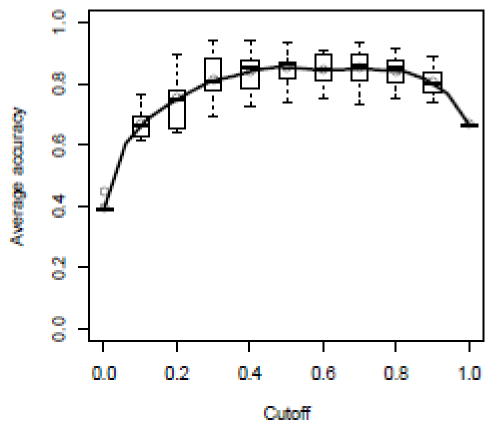
SVM's

CCI: 85.6% (+/-7.3)

Sens: 0.78 (+/- 0.15)

Spec: 0.91 (+/- 0.07)

F: 0.80 (+/- 0.11)



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Results - Experiments

180

SVM's

CCI: 85.6% (+/-7.3)
Sens: 0.78 (+/- 0.15)
Spec: 0.91 (+/- 0.07)
F: 0.80 (+/- 0.11)

TEST

- **E_8** – Predicting malignancy with *retro_density*

(model E_1 applied)

SVM's

CCI: 81.0%
Sens: 0.57
Spec: 0.90
F: 0.63

with **real** values of **retro_density**

SVM's

CCI: 80.4%
Sens: 0.57
Spec: 0.89
F: 0.62

with **predicted** values of **retro_density** by classifier **E_6**

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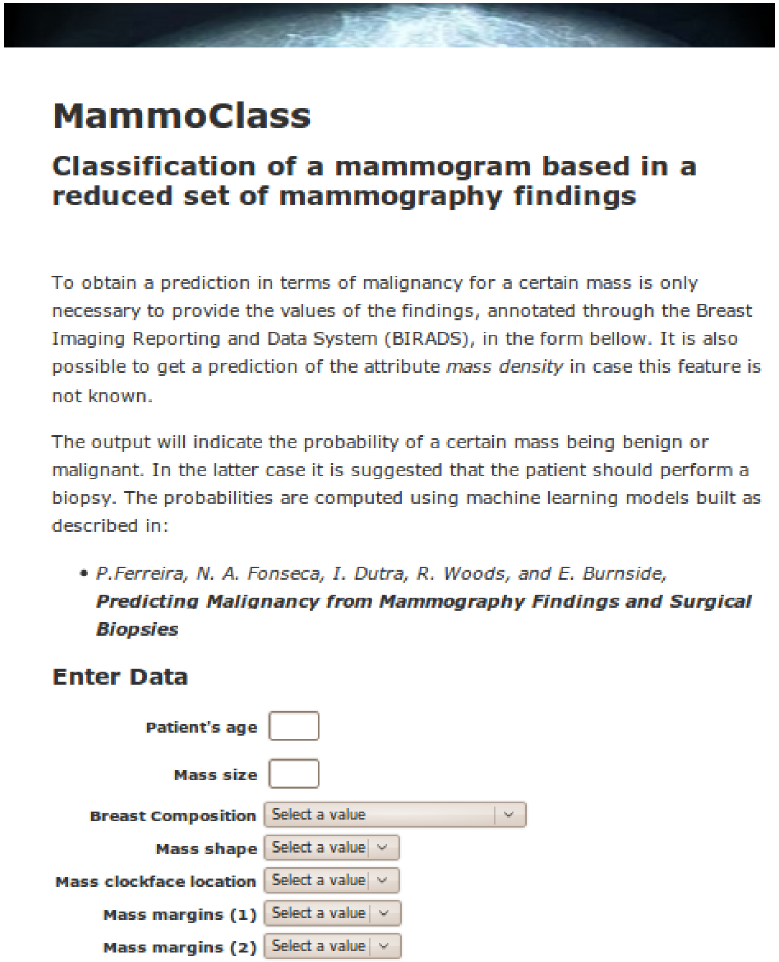
MammoClass

- Online application freely available at:
  - http://cracs.fc.up.pt/mammoclass/



MammoClass

Classification of a mammogram based in a reduced set of mammography findings

To obtain a prediction in terms of malignancy for a certain mass is only necessary to provide the values of the findings, annotated through the Breast Imaging Reporting and Data System (BIRADS), in the form bellow. It is also possible to get a prediction of the attribute *mass density* in case this feature is not known.

The output will indicate the probability of a certain mass being benign or malignant. In the latter case it is suggested that the patient should perform a biopsy. The probabilities are computed using machine learning models built as described in:

- *P.Ferreira, N. A. Fonseca, I. Dutra, R. Woods, and E. Burnside,* ***Predicting Malignancy from Mammography Findings and Surgical Biopsies***

Enter Data

Patient's age

Mass size

Breast Composition: Select a value

Mass shape: Select a value

Mass clockface location: Select a value

Mass margins (1): Select a value

Mass margins (2): Select a value

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Conclusions and Future Work

a) We built **models** that **predict malignancy and mass density** based on mammography findings;

b) Machine learning **classifiers** to **predict mass density** may **aid radiologists** during the prospective mass classification

c) One of our classifiers can **predict malignancy even in the absence of mass density**, since we can **fill up** this **attribute** using our **mass density predictor.**

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Conclusions and Future Work

a) **Apply** other machine learning techniques based on **statistical relational learning**;

b) Investigate how **other features** can affect malignancy or are related to the other attributes.

Future Work – Challenges

- Correct **classification of BIRADS** categories:

BIRADS 5 ⇨ 39 instances
BIRADS 4 ⇨ 131 instances
BIRADS 0 ⇨ 178 instances

} 348 cases

- **Problems**:
  - **multi-class** problem
  - classes **not balanced**

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Future Work – Challenges

- Correct **classification of BIRADS** categories:

BIRADS 5	⇨ 39 instances	348 cases
BIRADS 4	⇨ 131 instances	
BIRADS 0	⇨ 178 instances	

- **Approaches**:
  - oversampling
  - undersampling
  - **nested cross-validation** on 348 cases (best results so far)
  - cost-sensitive learning (to be applied)

Future Work – Challenges

- Correct **classification of BIRADS categories:**

BIRADS 5	39 instances	348 cases
BIRADS 4	131 instances	
BIRADS 0	178 instances	

- **nested cross-validation** on 348 cases (best results so far)

PPV = 0.57 (**B5**)
PPV = **0.42** (**B4**)
PPV = 0.57 (**B0**)

PPV = 0.67 (**B5**)
PPV = 0.06 (**B4**)
PPV = 0.09 (B3)

- in G. Kennedy, et al., "**Predictive value of BI-RADS classification for breast imaging in women under age 50**", in Breast Cancer Res Treat, 2011.

Thank you!

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FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA EDUCAÇÃO E CIÊNCIA

http://cracs.fc.up.pt/mammoclass

pedroferreira@dcc.fc.up.pt
nunofonseca@acm.org
ines@dcc.fc.up.pt
rwoods@gmail.com
eburnside@uwhealth.org

Appendices

Data distribution

- 348

348	retro_density		Total
outcome_num	high	iso	
malignant	59 (70.2%)	59 (22.3%)	118 (33.9%)
benign	25 (29.8%)	205 (77.7%)	230 (66.1%)
Total	84 (24.1%)	264 (75.9%)	

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Data distribution

- 180

180	*retro_density*		Total
outcome_num	*high*	*iso*	
malignant	42 (75.0%)	29 (23.4%)	**71 (39.4%)**
benign	14 (25.0%)	95 (76.6%)	**109 (60.6%)**
Total	**56 (31.1%)**	**124 (68.9%)**	

180	*density_num*		Total
outcome_num	*high*	*iso*	
malignant	51 (63.0%)	20 (20.2%)	**71 (39.4%)**
benign	30 (37.0%)	79 (79.8%)	**109 (60.6%)**
Total	**81 (45.0%)**	**99 (55.0%)**	

Data distribution

- 168

168	retro_density		Total
outcome_num	high	iso	
malignant	17 (60.7%)	30 (21.4%)	**47 (28.0%)**
benign	11 (39.3%)	110 (78.6%)	**121 (72.0%)**
Total	**28 (16.7%)**	**140 (83.3%)**	