Applications of Computational Intelligence to Medicine and Health

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Contents

- Motivation and main lines
- Brain Image biomarkers
- Vessel Image segmentation
- Clinical Decision Systems
- Future directions

Motivation

- Computational Intelligence
  - Classification
  - Optimization
  - Reasoning (fuzzy, etc)
- Main application
  - Computer Assisted Diagnosis
  - Signal/Image processing
    - Interactive/assisted segmentation
    - Biomarkers

Motivation

- Biomarkers
  - Signal features
  - Locations in image/anatomical space
  - Biomedical meaning
    - Agreement with medical expertise
  - Classification accuracy
    - Predictive validation

Motivation

- Computer Assisted Diagnosis
  - Classification/regression
    - Based on signal/image
  - Speeding processing of huge amounts of data
  - Auxiliary tool
  - Multiple type evidences
    - Ontology based Reasoning

Motivation

- Interactive segmentation
  - High variability
    - Data imaging
    - Biological structures
  - Aids to manual segmentation
    - Active learning
  - Automated segmentation
    - Filtering + classification

Main work lines

- Brain image processing (MRI) CAD
  - Alzheimer disease
    - Public data: OASIS
    - Private data: Hospital Santiago, Vitoria
  - Bipolar disorder
    - Private data: Hospital Santiago, Vitoria
  - Schizophrenia
    - Private data
  - Cocaine addiction
    - (UJI group Neuroimage)

Main work lines

- Vessel image segmentation
  - Abdominal Aortic Aneuryms
    - Private data (Biodonostia, Vicomtech-IK4)
  - Retinal image segmentation
    - Public data

Main Lines

- Breast-cancer
  - Ontology-based clinical decision systems
  - Multi-source modality information
  - Vicomtech-IK4, projects MIND, LIFE

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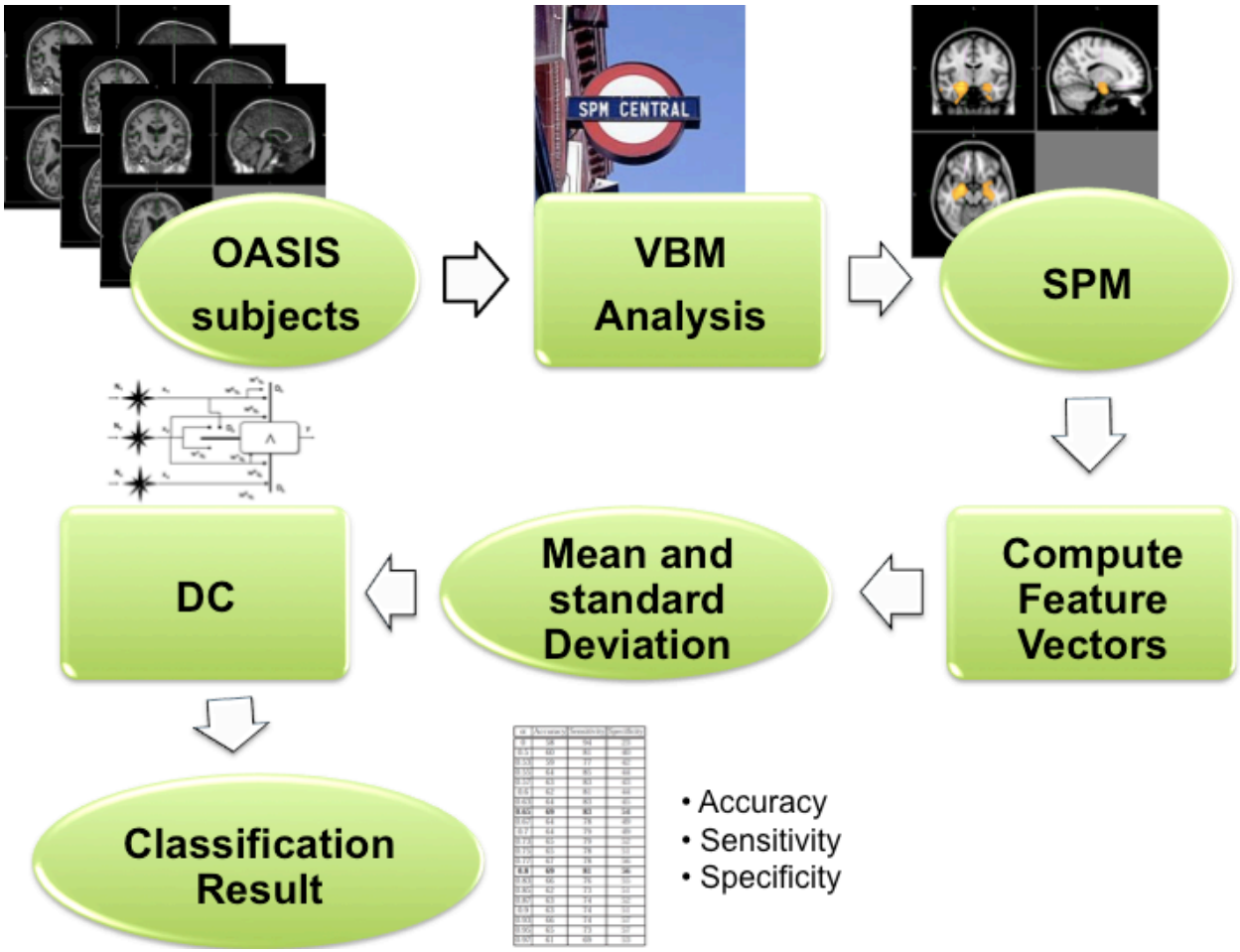
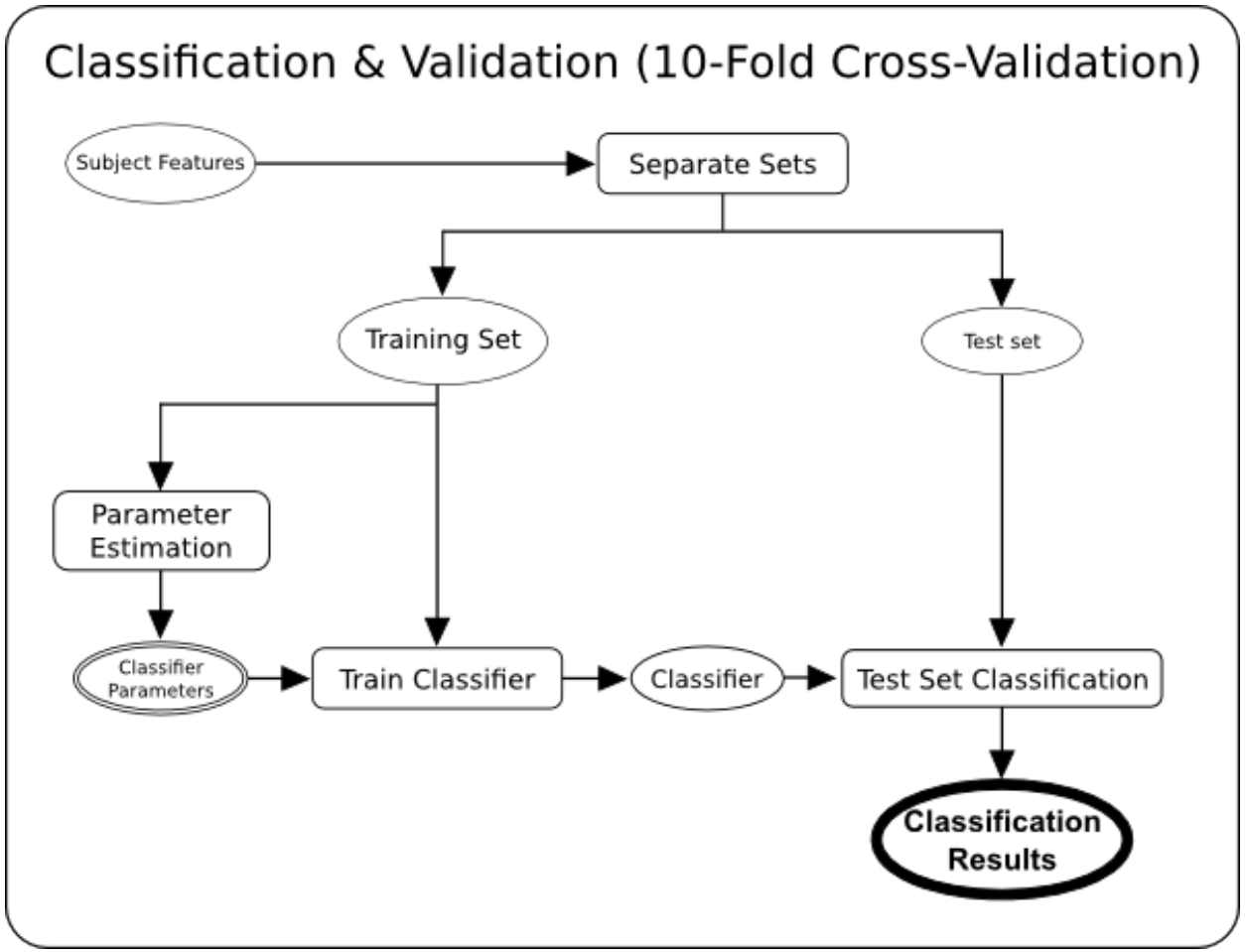
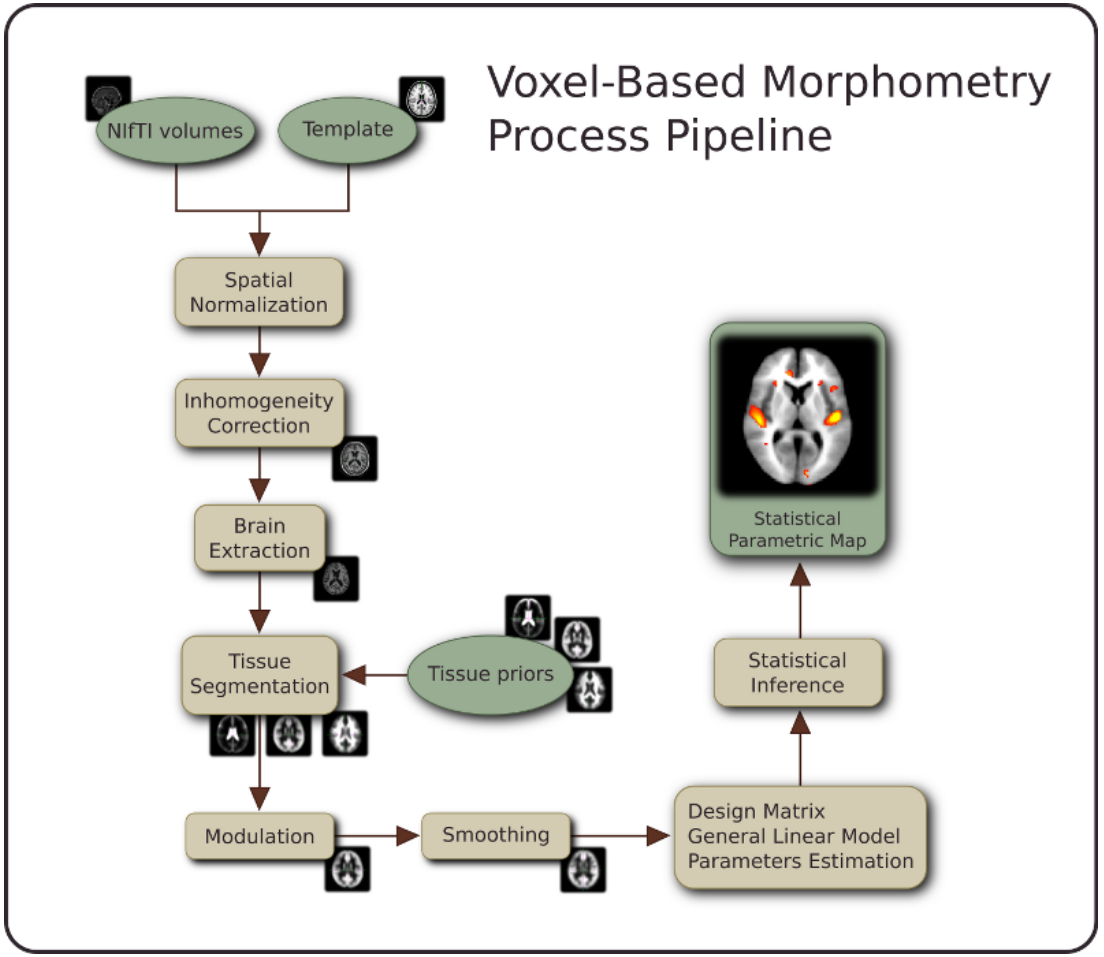
Brain image biomarkers

- MRI imaging modalities
  - Anatomical, diffusion, functional
- Classification approach
  - Feature selection
    - Significant voxel sites
  - Classification validation experiments
    - Discriminant / predictive value of features
  - Visualization and biomedical interpretation
    - Atlas localization

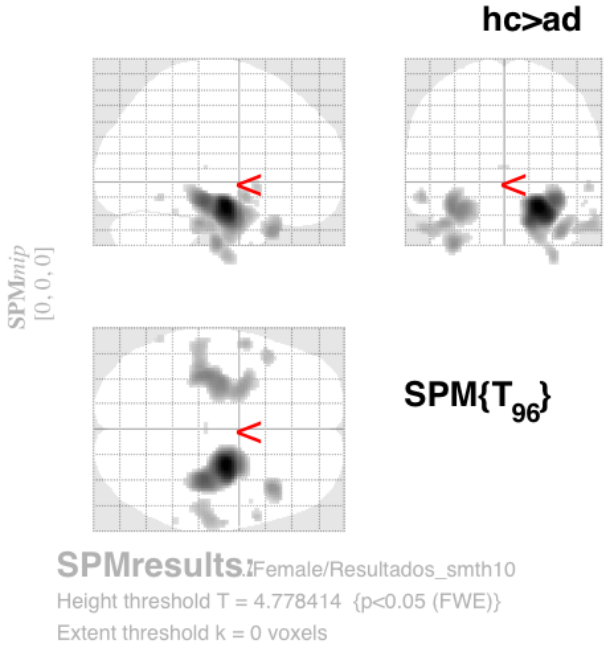

OASIS subjects
SPM CENTRAL
VBM Analysis
SPM
Compute Feature Vectors
Mean and standard Deviation
DC
Classification Result
• Accuracy
• Sensitivity
• Specificity


Classification & Validation (10-Fold Cross-Validation)
Subject Features
Separate Sets
Training Set
Test set
Parameter Estimation
Classifier Parameters
Train Classifier
Classifier
Test Set Classification
Classification Results


Voxel-Based Morphometry
Process Pipeline
NIfTI volumes
Template
Spatial Normalization
Inhomogeneity Correction
Brain Extraction
Tissue Segmentation
Tissue priors
Modulation
Smoothing
Design Matrix
General Linear Model
Parameters Estimation
Statistical Inference
Statistical Parametric Map

- OASIS reduced database

	Very mild to mild AD	CS
No. of subjects	49	49
Age	78.08 (66-96)	77.77 (65-94)
Education	2.63 (1-5)	2.87 (1-5)
Socioeconomic status	2.94 (1-5)	2.88 (1-5)
CDR (0.5 / 1 / 2)	31 / 17 / 1	0
MMSE	24 (15-30)	28.96 (26-30)



Classif.	Accuracy	Sensitivity	Specificity
linear SVM	0.78	0.72	0.88
rbf SVM	**0.81**	0.75	0.89
MLP-BP	0.78	0.69	0.88
RBF	0.66	0.65	0.68
PNN	0.78	0.62	0.94
LVQ1	**0.81**	0.72	0.90
LVQ2	**0.83**	0.74	0.92
Indep-linear-SVM	0.74	0.51	0.97
Indep-rbf-SVM	0.75	0.56	0.95
linear-AB-SVM	0.71	0.54	0.88
rbf-AB-SVM	0.79	0.78	0.80
rbf-DAB-SVM	**0.85**	0.78	0.92

Table 3: Results over the MSD features computed from the OASIS data for AD detection

VBM cluster localizations for feature extraction

A Savio; MT Garcia-Sebastian; D Chyzhyk; C Hernandez; M Graña; A Sistiaga; A Lopez de Munain; J Villanua
Neurocognitive disorder detection based on Feature Vectors extracted from VBM analysis of structural MRI
Computers in Biology and Medicine 41 (2011), pp. 600-610

Classifier	Accuracy	Sensitivity	Specificity
Linear RVM	0.69	0.67	0.70
rbf RVM	0.77	0.75	0.80
Linear RVM - SVM	0.82	0.66	0.88
rbf RVM - Linear SVM	0.85	0.74	0.90
rbf RVM - rbf SVM	0.85	0.70	0.92
rbf RVM - LVQ1	0.87	0.73	0.92
rbf RVM - LVQ2	0.78	0.76	0.80
rbf RVM - rbf RVM	0.80	0.70	0.86
rbf RVM - 1NN	0.85	0.72	0.91
linear SVM	0.78	0.72	0.88
rbf SVM	0.81	0.75	0.89
MLP-BP	0.78	0.69	0.88
RBF	0.66	0.65	0.68
PNN	0.78	0.62	0.94
LVQ1	0.81	0.72	0.90
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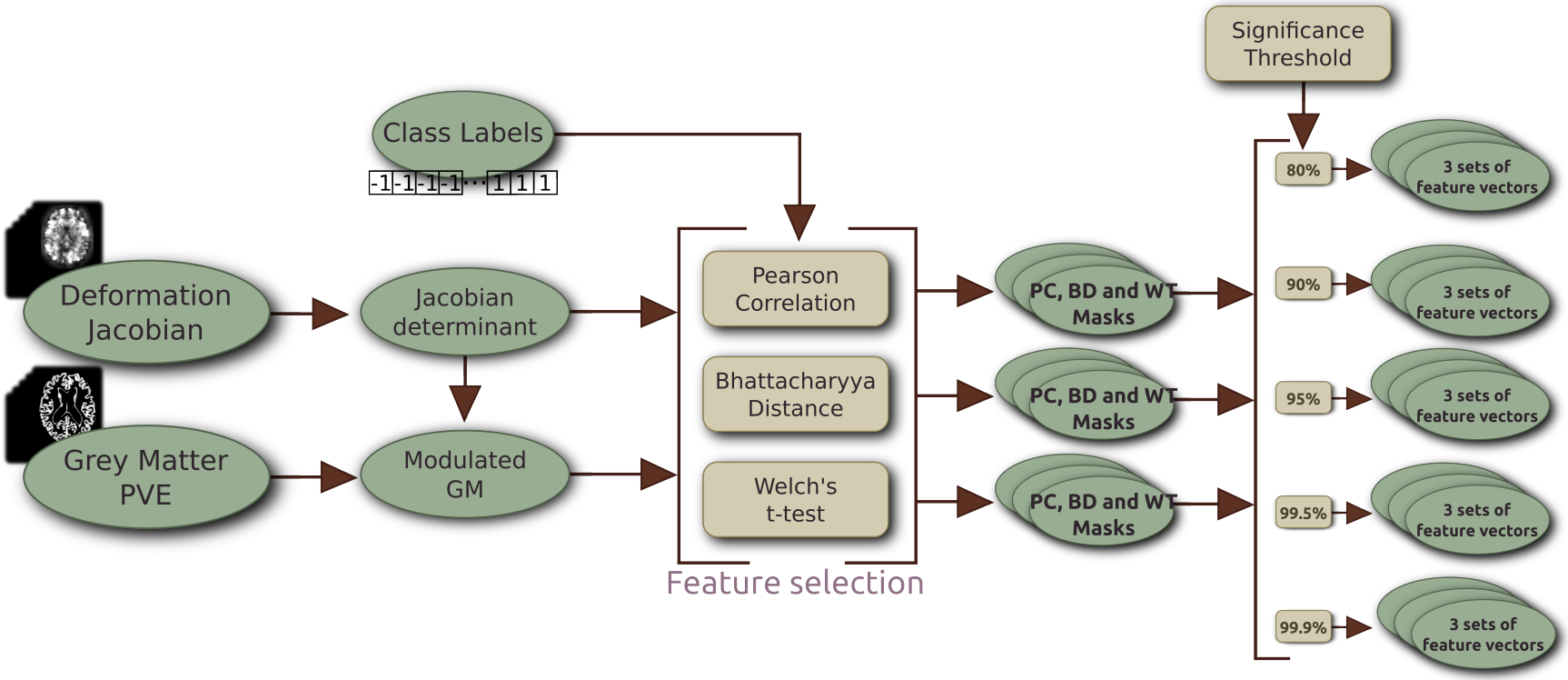
Indep-rbf-SVM	0.75	0.56	0.95
linear-AB-SVM	0.71	0.54	0.88
rbf-AB-SVM	0.79	0.78	0.80
rbf-DAB-SVM	0.85	0.78	0.92

Table 2: RVM results (MSD data).

Maite Termenon, Manuel Graña A two stage sequential ensemble applied to the classification of Alzheimer's Disease based on MRI features Neural Processing Letters (2012) 35(1): 1-12

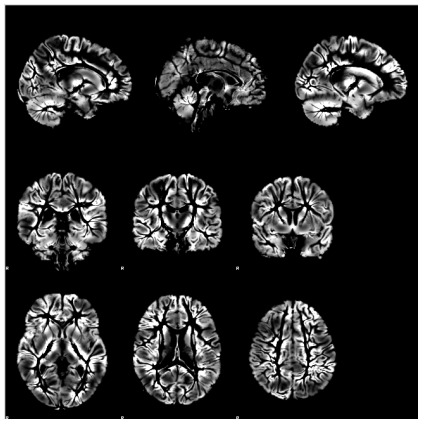
Method	NE	α	σ	Accuracy	Sensitivity	Specificity
DC	-	-	-	58	94	23
DC shrinking	-	-	-	**69**	81	56
PCA - DC	1	-	-	68.25	85.5	51
LICA - DC	1	7	-	**72**	88	56
Kernel - DC	-	-	0.2512	55	98	12
Kernel - PCA - DC	8	-	0.0794	66.5	96	37
Kernel - LICA - DC	3	2	0.5012	**74.25**	96	52.5

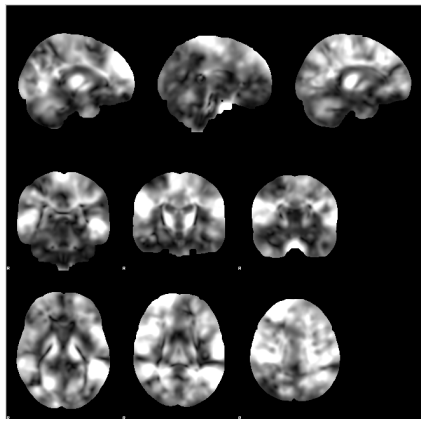
Darya Chyzhyk, Manuel Graña, Alexandre Savio, Josu Maiora
Hybrid Dendritic Computing with Kernel-LICA applied to Alzheimer's Disease detection in MRI. Neurocomputing, 2012, 75(1), pp. 72-77



Deformation Based Feature Selection for Computer Aided Diagnosis of Alzheimer's Disease
A. Savio, M. Graña, Expert Systems with Applications, 2012

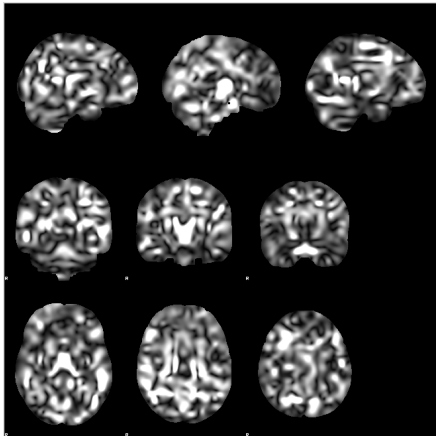
Modulated GM

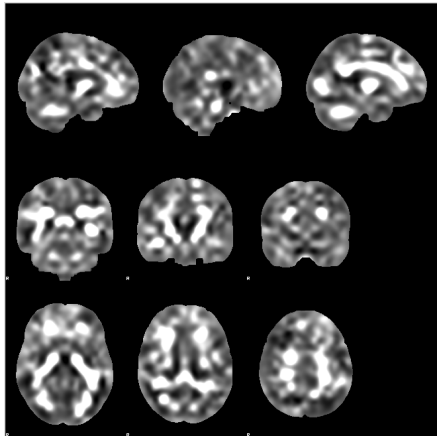




Displacement norm

Geodesic anysotropy



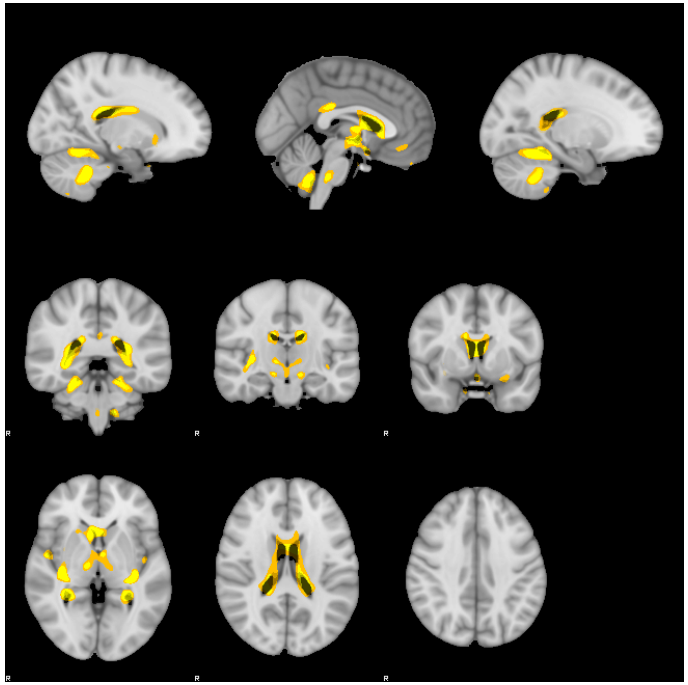


Jacobian map

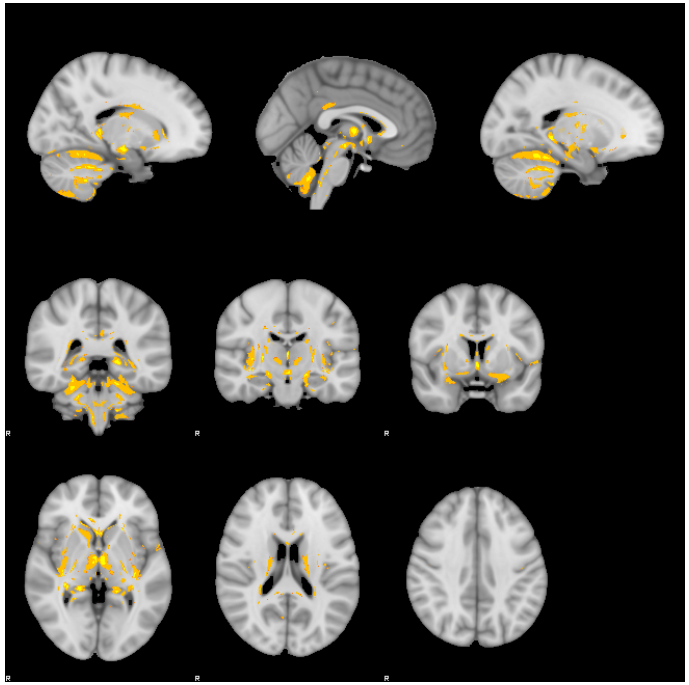
Oasis database

		Without Dementia			*With Dementia*			
Age Group	*Total n*	*n*	*Mean age*	*M/F**	*n*	*Mean age*	*M/F**	*CDR 0.5/1/2*
<20	19	19	18.53	10/9	0		0/0	0/0/0
20s	119	119	22.82	51/68	0		0/0	0/0/0
30s	16	16	33.38	11/5	0		0/0	0/0/0
40s	31	31	45.58	10/21	0		0/0	0/0/0
50s	33	33	54.36	11/22	0		0/0	0/0/0
60s	40	25	64.88	7/18	15	66.13	6/9	12/3/0
70s	83	35	73.37	10/25	48	74.42	20/28	32/15/1
80s	62	30	84.07	8/22	32	82.88	13/19	22/9/1
≥90	13	8	91.00	1/7	5	92.00	2/3	4/1/0
Total	416	316		119/197	100		41/59	70/28/2

		Accuracy	Precision	Recall	AUC
	jacs	88.10 (0.00)	50.76 (1.70)	58.33 (3.73)	92.32 (1.53)
	norms	88.10 (2.75)	84.14 (6.12)	58.33 (8.98)	94.79 (2.53)
PC	modgm	**92.07 (1.12)**	**95.83 (5.89)**	**86.67 (4.71)**	**96.67 (0.44)**
	trace	89.43 (2.70)	79.55 (5.77)	65.00 (5.00)	94.27 (0.43)
	geodan	88.15 (2.25)	87.74 (3.96)	70.00 (0.00)	93.49 (1.04)
	jacs	91.27 (1.22)	86.44 (1.89)	**81.67 (7.45)**	95.36 (1.54)
	norms	89.89 (1.77)	82.62 (6.94)	79.67 (3.73)	93.12 (1.48)
BD	modgm	89.74 (1.77)	82.94 (4.14)	78.00 (5.00)	**97.37 (0.29)**
	trace	89.52 (1.78)	82.43 (4.15)	80.33 (7.45)	95.67 (1.08)
	geodan	**92.09 (2.60)**	**88.09 (5.33)**	80.00 (4.00)	95.37 (0.99)
	jacs	92.15 (3.07)	87.36 (6.67)	85.373 (6.87)	93.67 (0.39)
	norms	88.50 (0.89)	76.40 (3.62)	75.00 (4.00)	92.95 (0.87)
WT	modgm	91.43 (0.89)	**85.98 (1.55)**	83.33 (3.73)	94.54 (0.50)
	trace	**92.83 (0.91)**	85.62 (0.85)	86.33 (3.73)	94.32 (0.55)
	geodan	89.92 (1.78)	79.42 (4.85)	**94.67 (7.45)**	**95.00 (0.52)**



Voxel sites 95% Pearson correlation on Jacobian maps



Voxel sites 95% Pearson correlation on modulated GM

Critical issues

- Circularity
  - Strict separation of feature selection and training from test in validation
- Sample
  - Imbalance
  - Small size
    - Leave one out
- Biomedical meaning of findings

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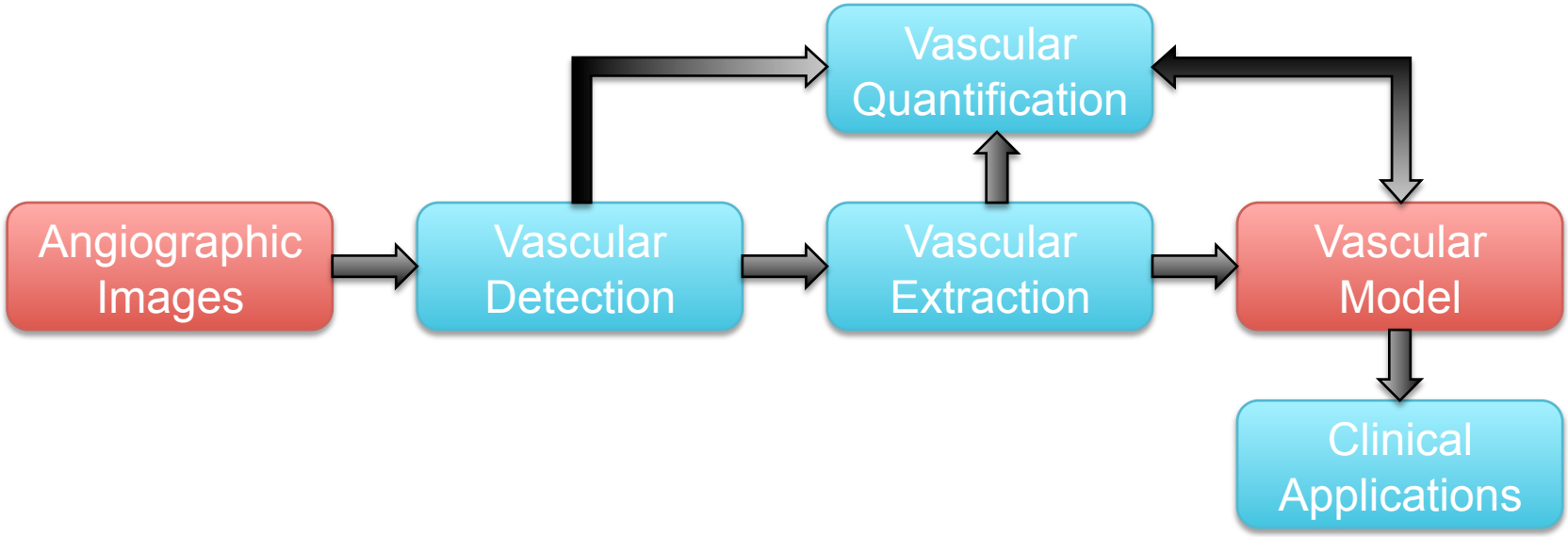
- Clinical Decision Systems
- Conclusions

Vessel image segmentation

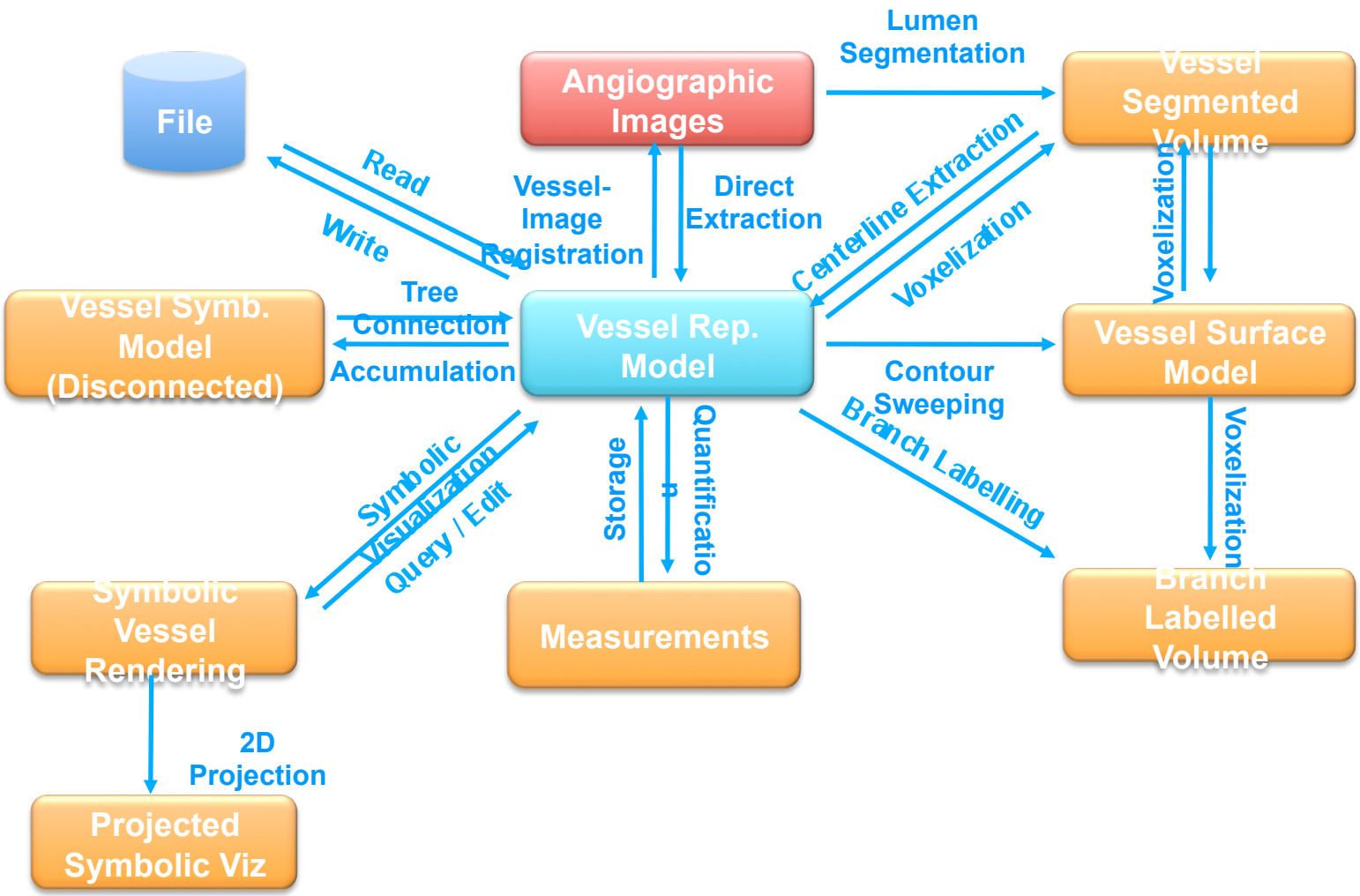
- Wide variety of applications and image modalities
- Focus on Abdominal Aortic Aneurysm
  - Monitoring of evolution of EVAR
  - Segmentation of thrombus
    - Filtering + machine learning
    - Interactive segmentation -- Active Learning

Computerized Tomography Angiography (CTA)

Magnetic Resonance Angiography (MRA)

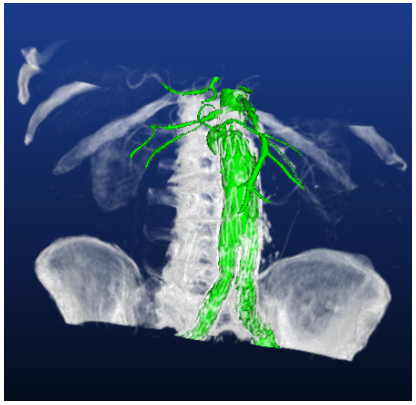


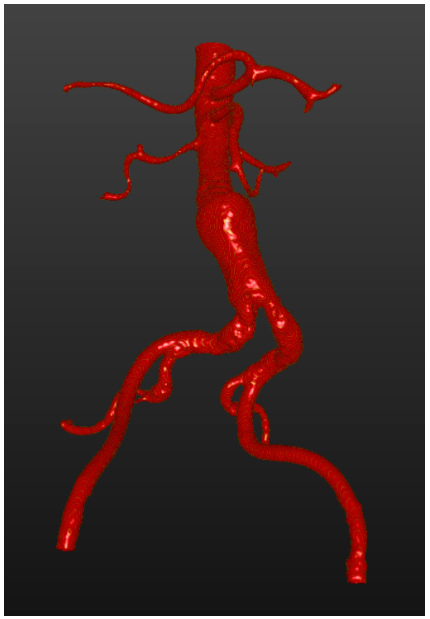
Vascular image processing pipeline, from Ivan Macia's PhD slides

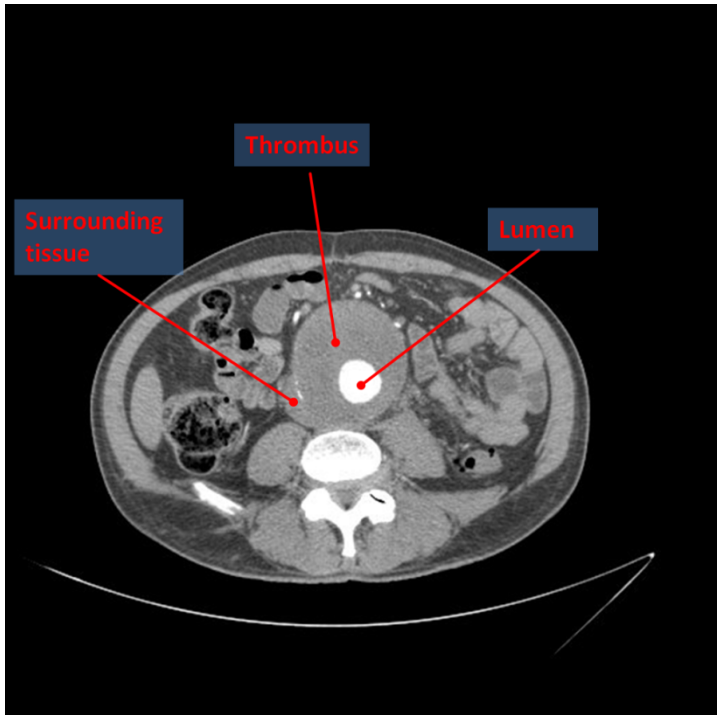


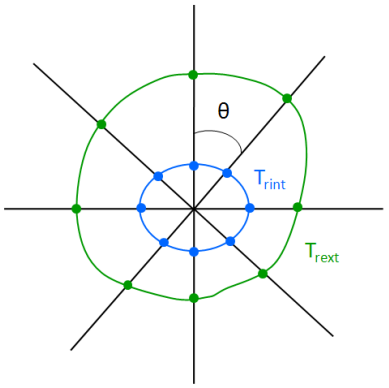
I Macia, M Graña; C Paloc,Knowledge Management in Image-based Analysis of Blood Vessel Structures Knowledge and Information Systems 30(2) (2012):457-491

Abdominal Aortic Aneurysm

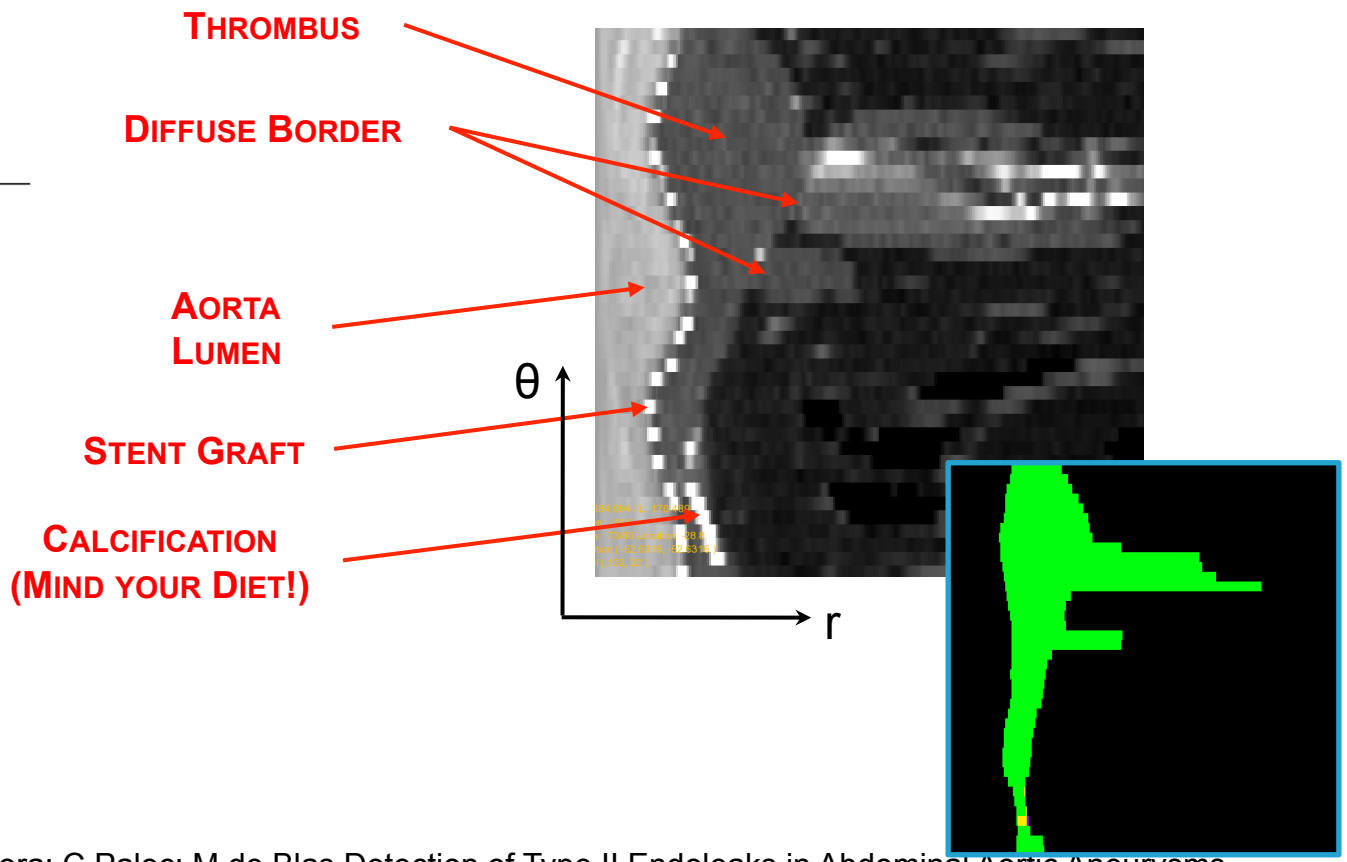






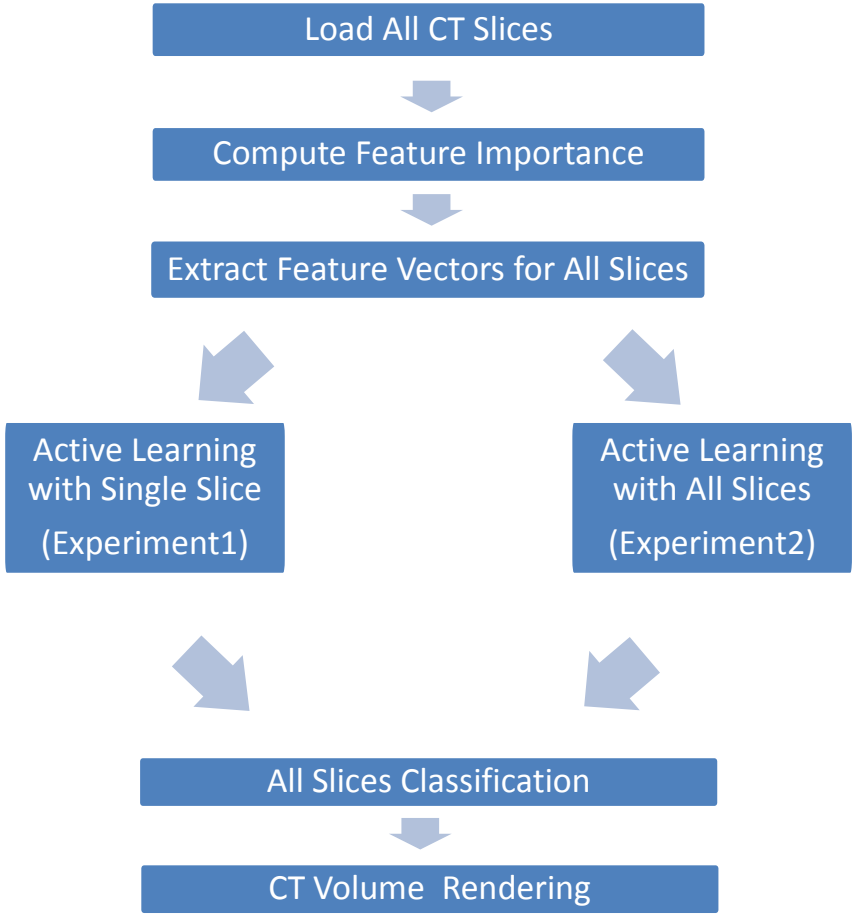


RADIAL MODEL

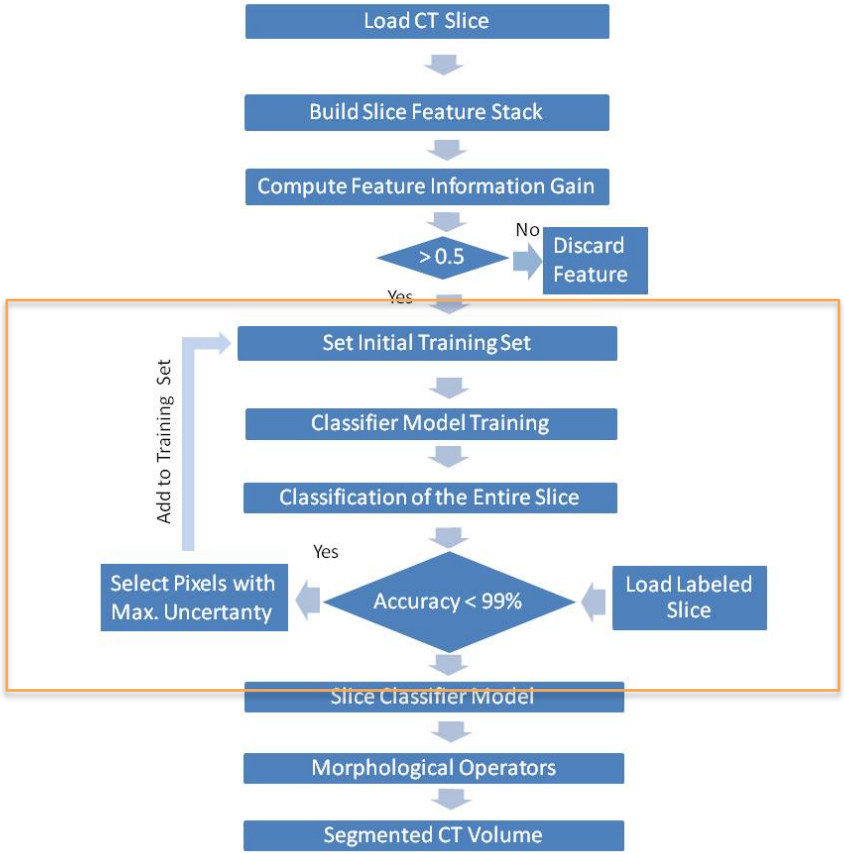


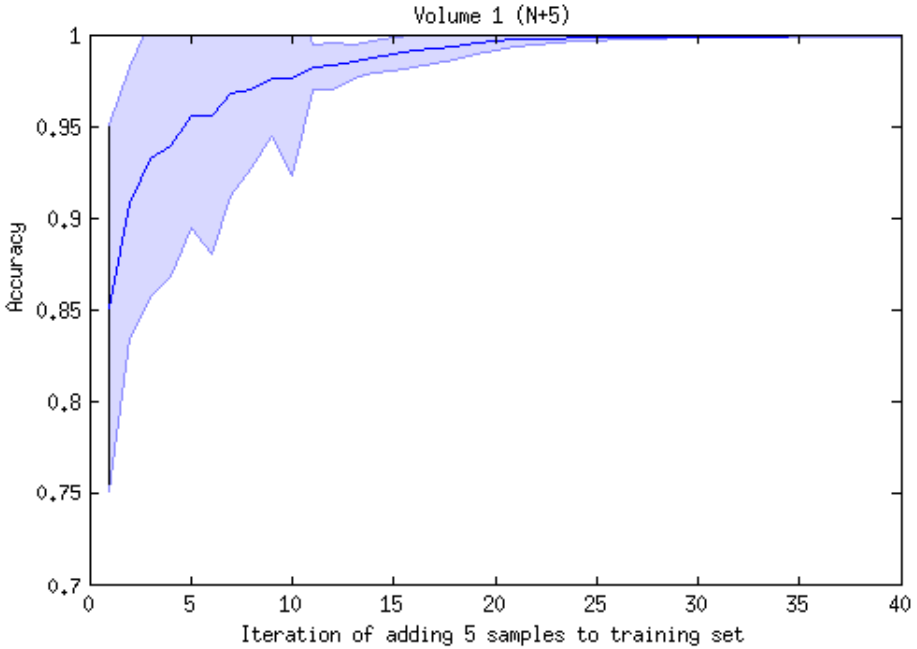
I Macia; M Graña; J Maiora; C Paloc; M de Blas Detection of Type II Endoleaks in Abdominal Aortic Aneurysms After Endovascular Repair
Computers in Biology and Medicine 41(10): 871-880

Active learning experiments J Maiora's PhD slides



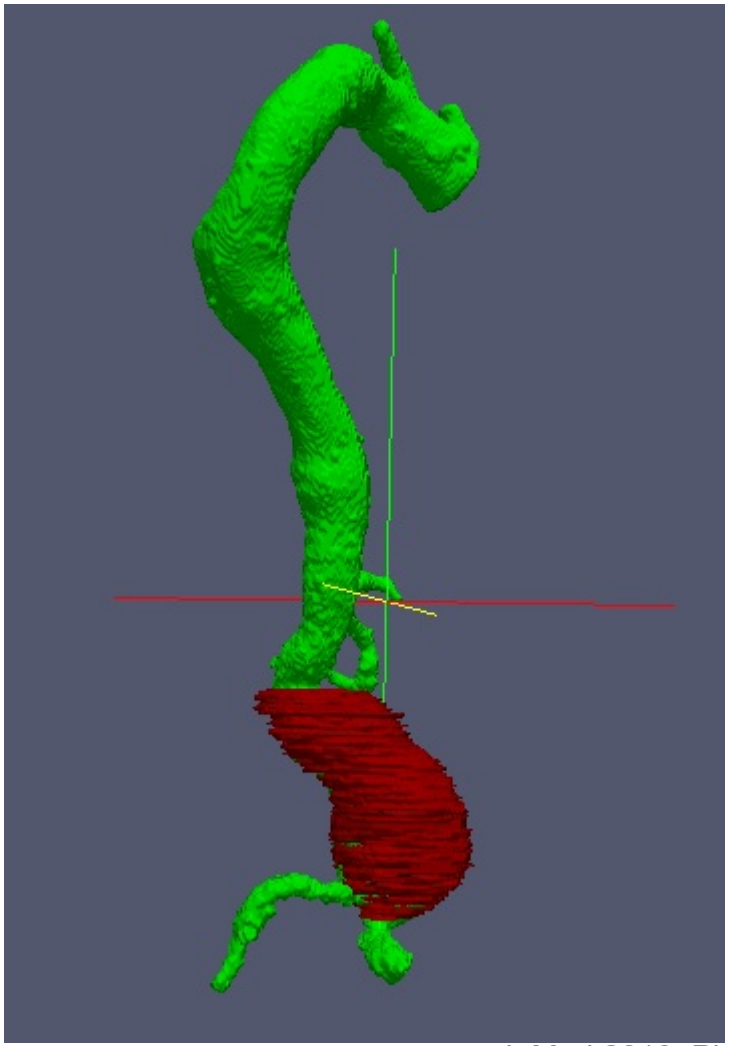
Active learning to build interactively classifiers for thrombus segmentation

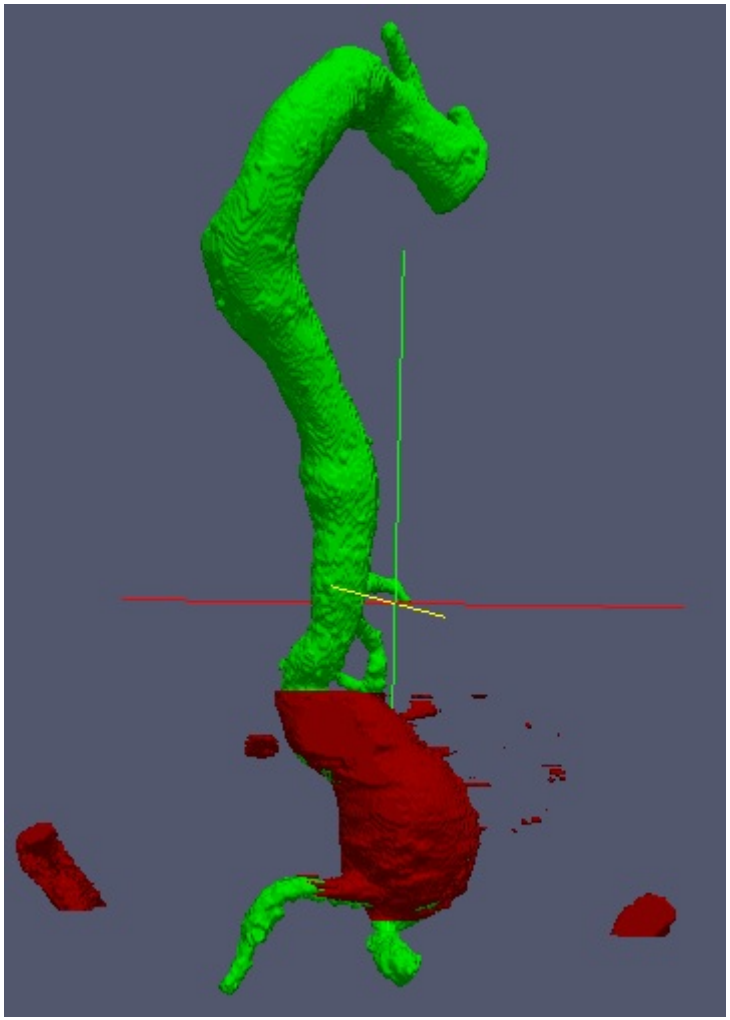




Accuracy of segmentation and its uncertainty in the interactive enrichment of the training data set for one volume, per slice.

Josu Maiora; Borja Ayerdi; Manuel Graña
Random Forest Active Learning for Computed Tomography Angiography Image Segmentation, Neurocomputing (in press)





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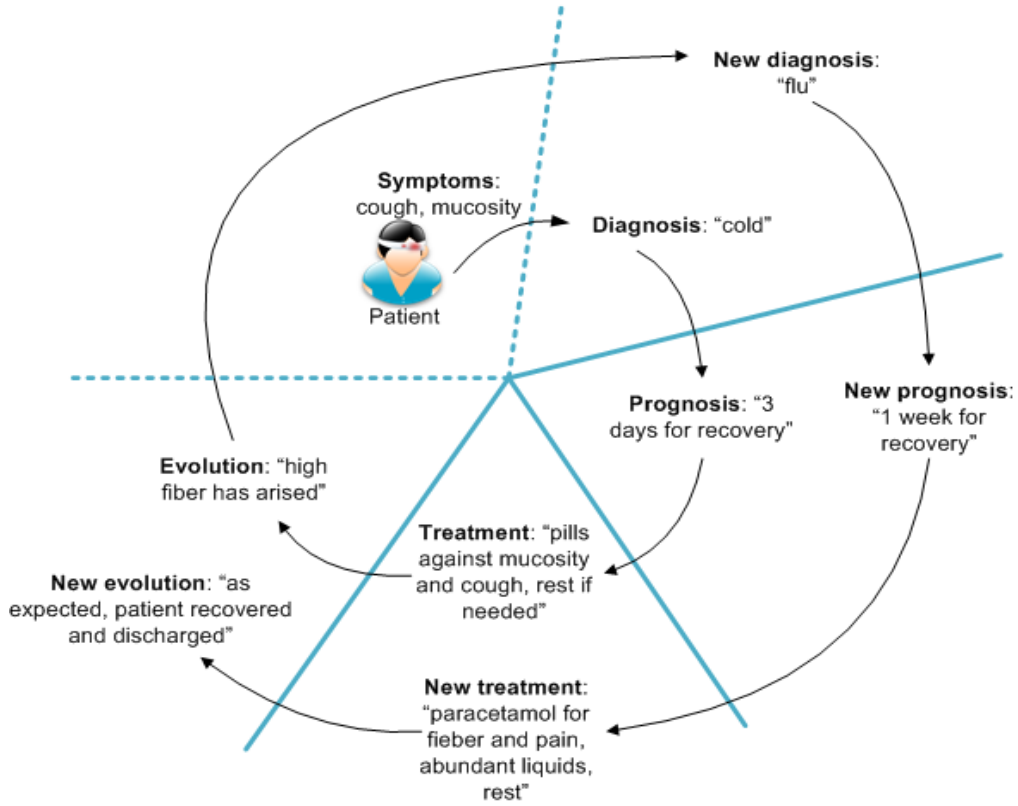
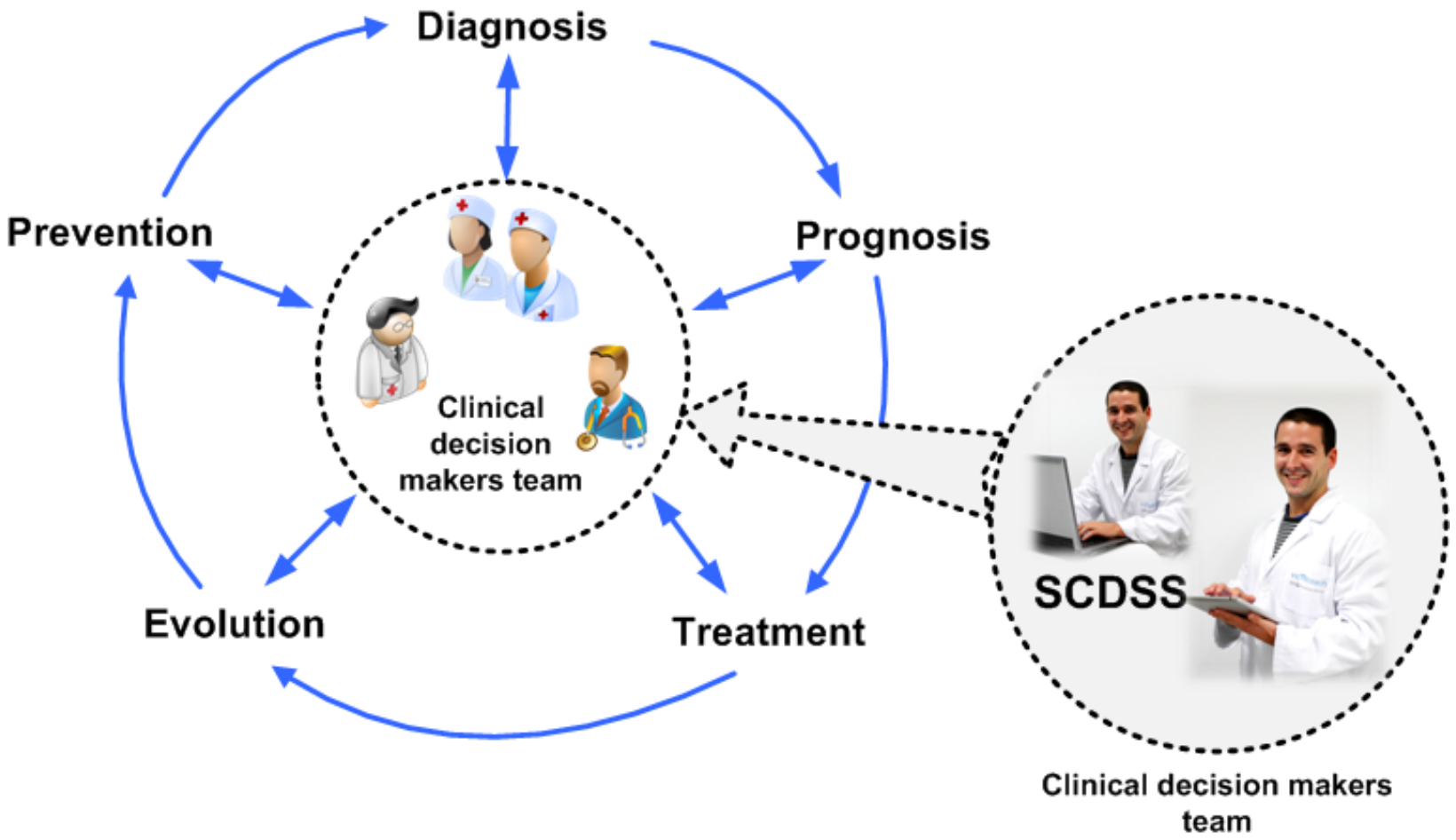
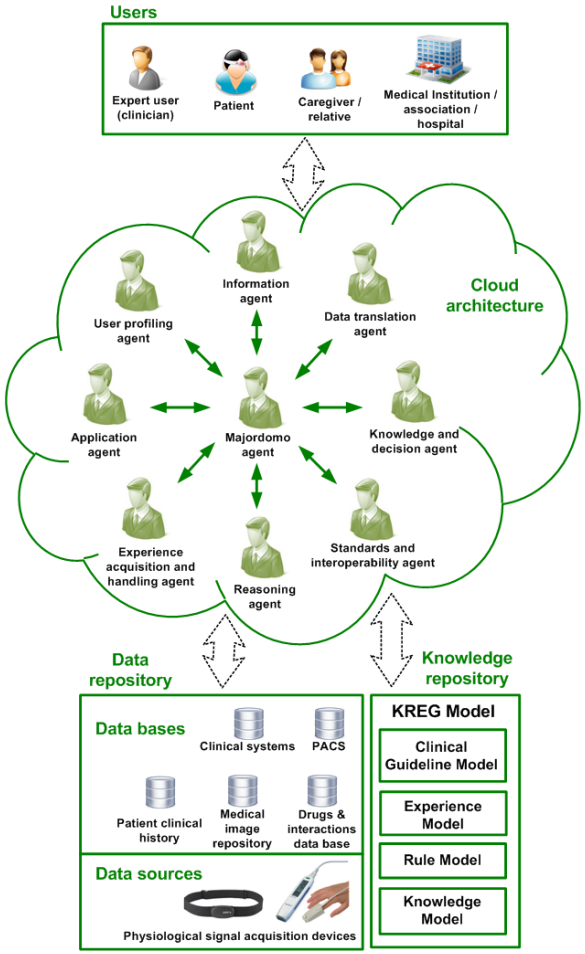
Clinical decision support



Bridging challenges of Clinical Decision Support Systems with a semantic approach. A case study on breast cancer.
Eider Sanchez, Carlos Toro, Arkaitz Artetxe, Manuel Graña, Cesar Sanin, Edward Szczerbicki, Eduardo Carrasco and Frank Guijarro Pattern Recognition Letters, 2013, in press online first

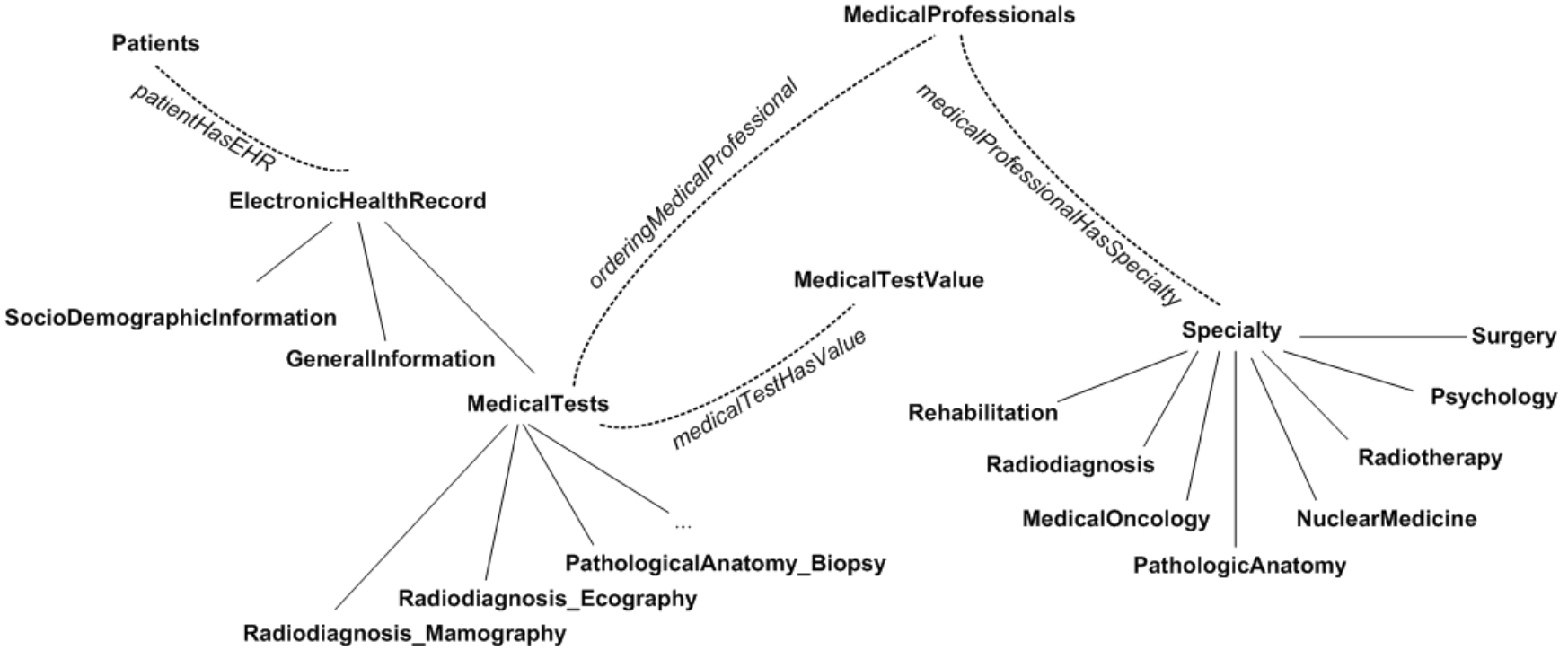
Clinical decision support



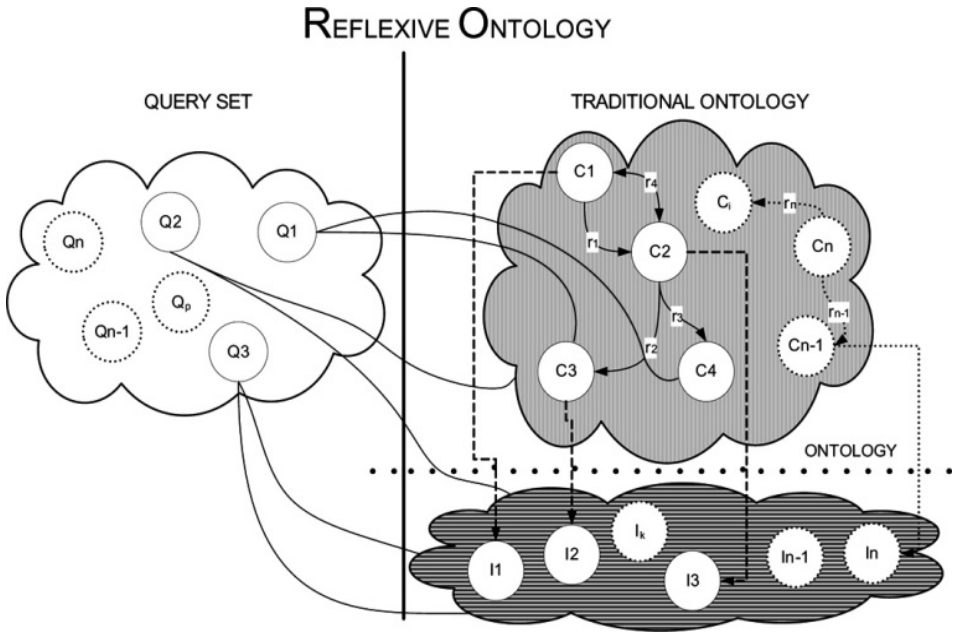


Eider Sanchez, Carlos Toro, Arkaitz Artetxe, Manuel Graña, Cesar Sanin, Edward Szczerbicki, Eduardo Carrasco and Frank Guijarro
Bridging challenges of Clinical Decision Support Systems with a semantic approach . A case study on breast cancer.
Pattern Recognition Letters (in press, online)

Breast cancer clinical process treatment ontology



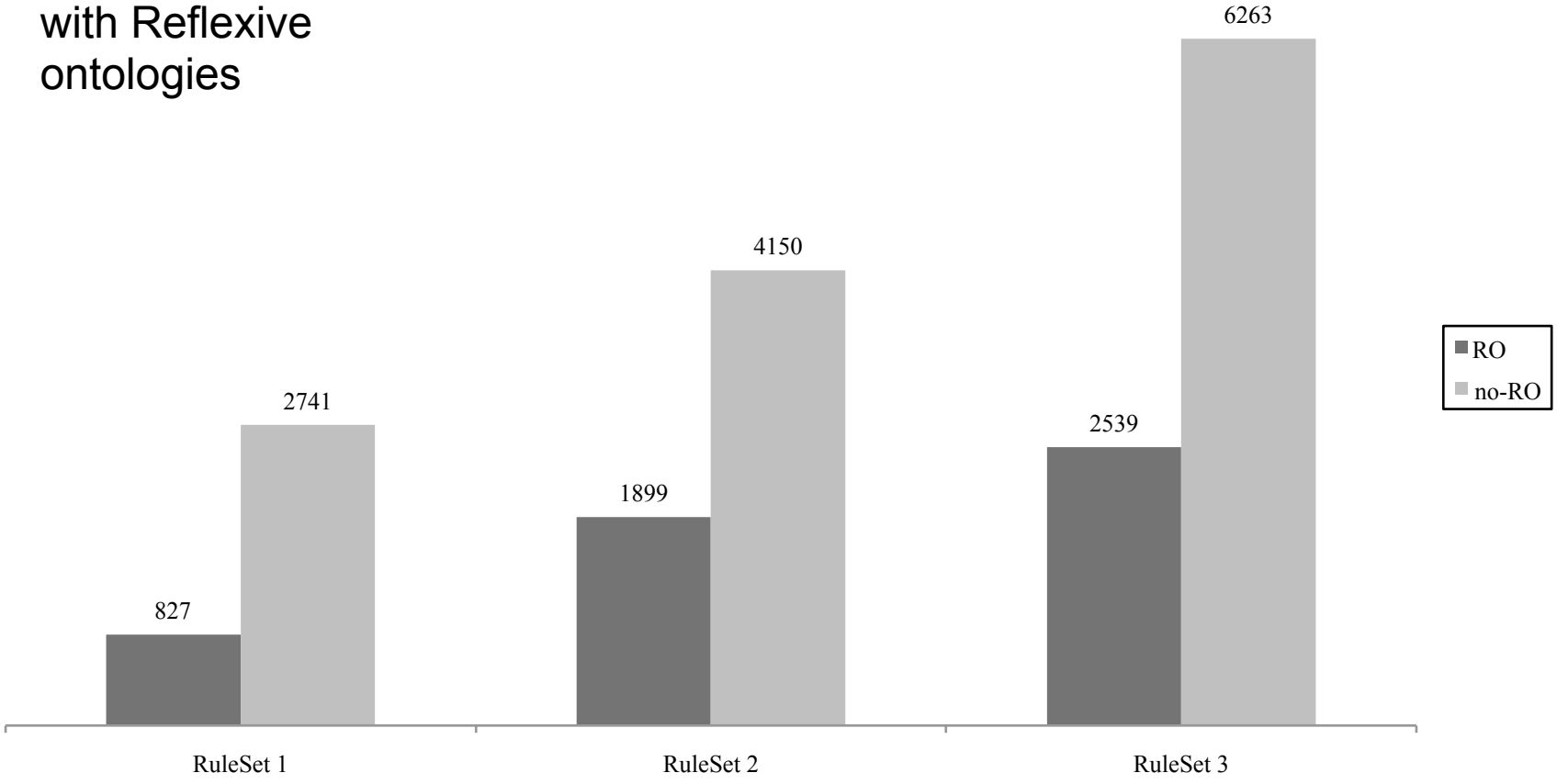
Reflexive ontologies



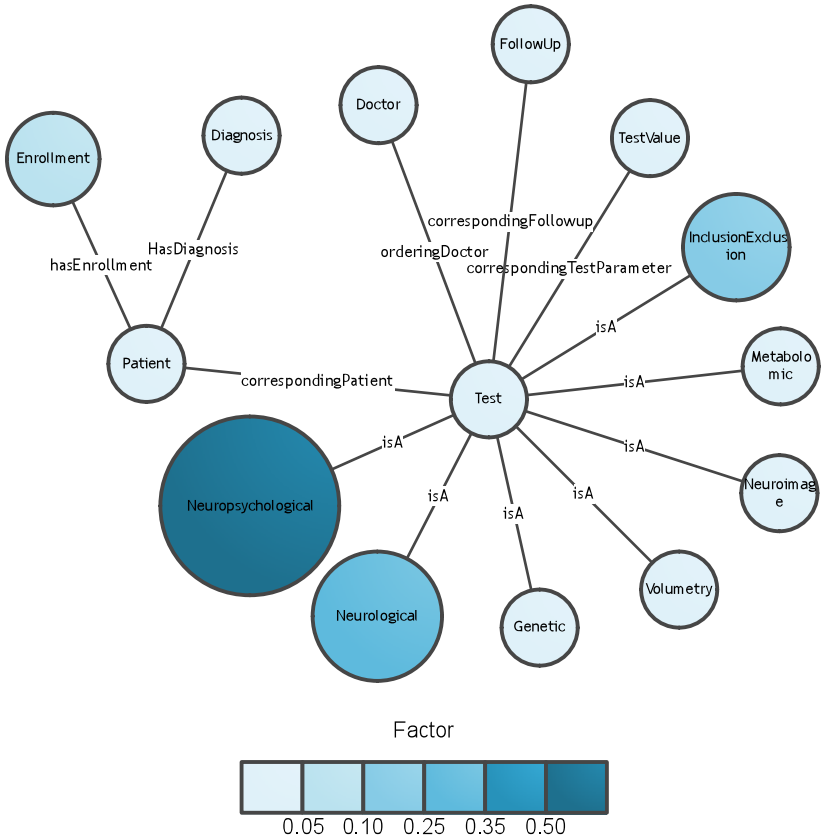
Toro, C., Sanín, C., Szczerbicki, E., Posada, J.: Reflexive Ontologies: Enhancing Ontologies with self-contained queries. In: Cybernetics and Systems: An International Journal 39, 171-189 (2008)

Reflexive ontologies

Speed up obtained with Reflexive ontologies



Reflexive ontologies



Distribution of frequency of rule invocation per domain in MIND project,

Impact of Reflexive Ontologies in Semantic Clinical Decision Support Systems
Arkaitz Artetxe, Eider Sanchez, Carlos Toro, Cesar Sanin, Edward Szczerbicki, Manuel Graña, Jorge Posada
Cybernetics and Systems, 44(2-3), pp 187-203 , 2012

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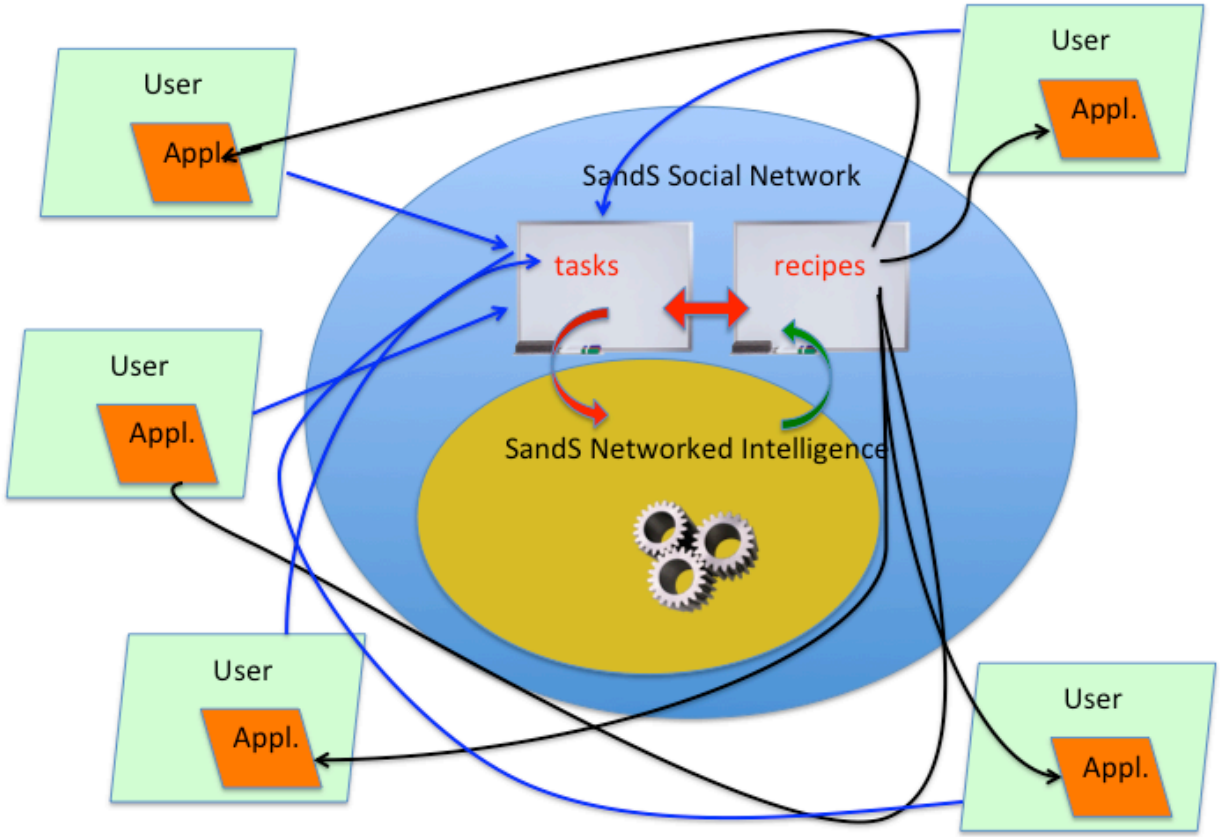
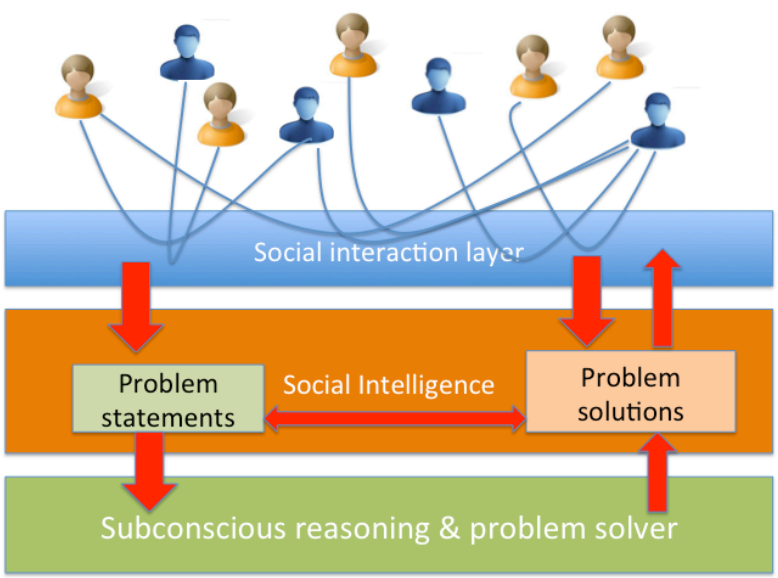
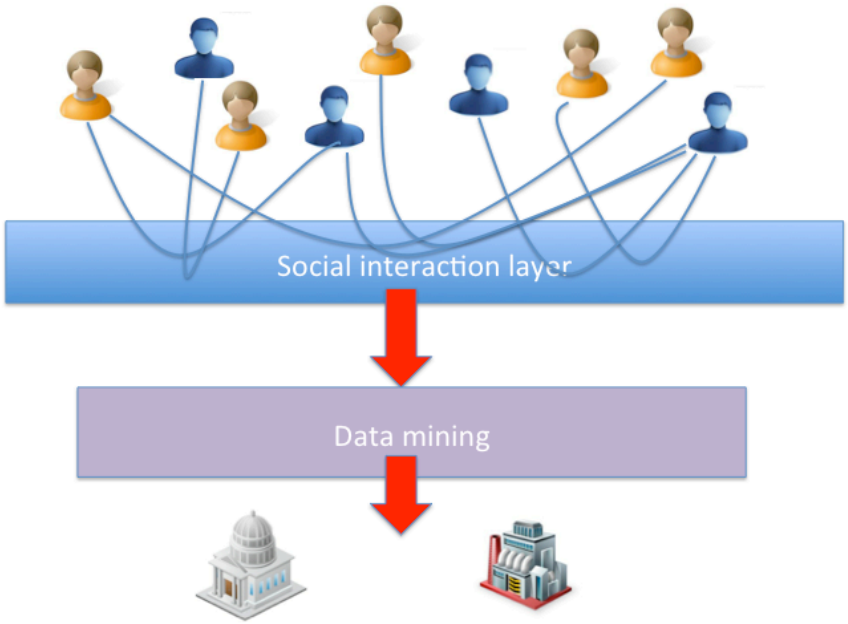
- ICT to the service of the health care
  - Social Networks + Comp. Int.
    - Exchanging information
    - Creating/maintaining social intelligence
  - (Serious) Games
    - Education
    - Training
    - Diffusion (viral)

Social Networks

- An unrelated instance: Social and Smart
  - Household Appliance users
  - Exchange of appliance recipes
  - Underlying intelligent layer
  - Involvement of appliance manufacturers


User
Appl.
User
Appl.
SandS Social Network
tasks
recipes
User
Appl.
SandS Networked Intelligence
User
Appl.
User
Appl.


Social interaction layer
Problem statements
Social Intelligence
Problem solutions
Subconscious reasoning & problem solver


Social interaction layer
Data mining

GIC team 2013

http://www.ehu.es/ccwintco/index.php/Miembros

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