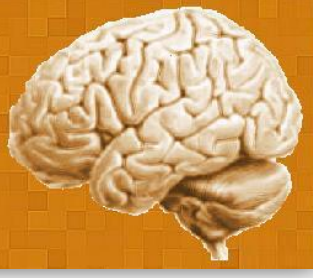
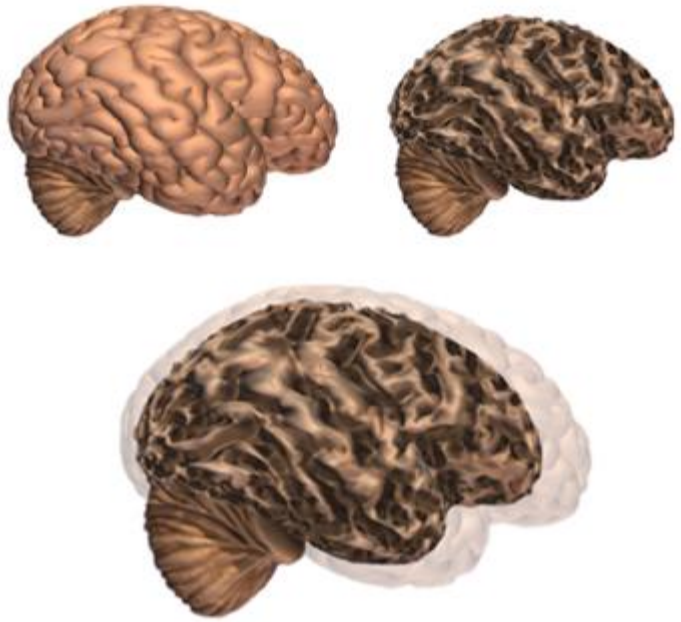
Partial Least Squares for feature extraction of SPECT images

F. Segovia, J. Ramírez, J.M. Górriz, R. Chaves,
D. Salas-Gonzalez, M. López, I. Álvarez, P. Padilla
and C.G. Puntonet

Contents

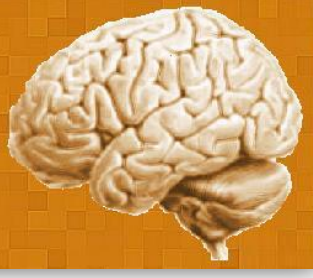


1. Introduction
   - Alzheimer's disease
   - Functional imaging
2. Materials and methods
   - SPECT database
   - Partial Least Squares
3. Experiments
   - A CAD system for AD
   - Feature extraction
   - Results
4. Conclusions



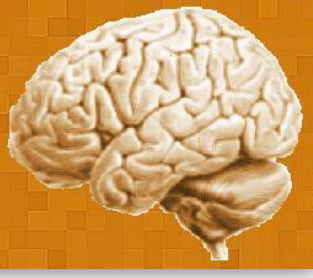
INTRODUCTION

Alzheimer’s disease



- Alzheimer's disease (AD) was first described by German psychiatrist and neuropathologist Alois Alzheimer in 1906 and was named after him.
- AD is the most common cause of dementia in the elderly that affects memory and cognitive functions and eventually causes the death.
- It mainly affects people over 60 years but some cases around 20 years old have been detected.

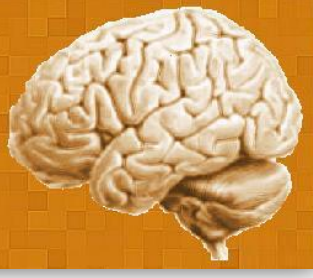
Alzheimer's disease



- With the growth of the older population in developed nations, the prevalence of AD is expected to triple over the next 50 years.
- AD has no cure and it is only possible to mitigate its effects.
- New drugs can slow the progression of the disease.

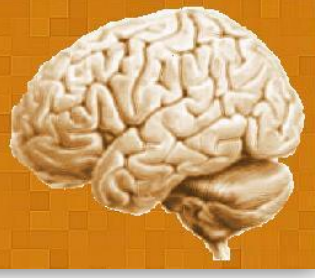
An early diagnosis is crucial

Alzheimer's disease



- 100% reliable diagnosis of AD is only possible after death.
- The in-live diagnosis is usually performed through:
  - Cognitive function assessment
  - Memory, attention, perception and language are evaluated
  - Standard tests:
    - Mini-Mental State Examination (MMSE)
    - Clinical Dementia Rating (CDR)
    - Global Deterioration Scale (GDS)

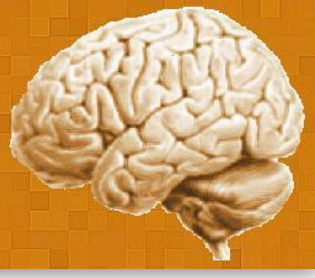
Functional imaging



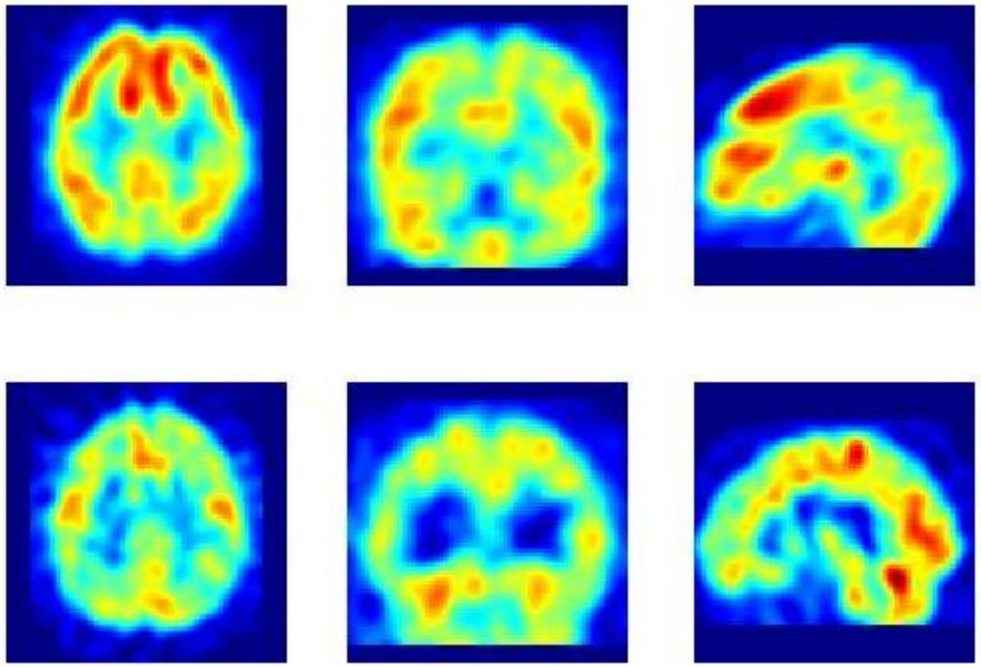
- Single Photon Emission Computed Tomography (SPECT) is a noninvasive, functional imaging modality that can be used to analyze the regional cerebral blood flow (rCBF) in patients.
- SPECT provides three-dimensional images with physiological functions contrary to other imaging modalities which produce images of anatomical structures.

- SPECT images are widely used in neurology to diagnose several dementias, such as AD

Functional imaging

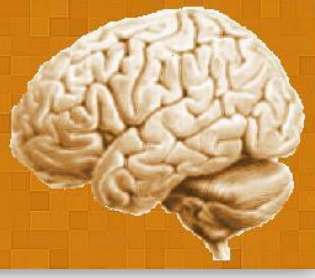


- Traditionally, experienced clinicians visually examine the images and look for areas of low activation.
- Visual examination is possible in patients with advanced AD but not in early stages of the disease



MATERIALS AND METHODS

SPECT database

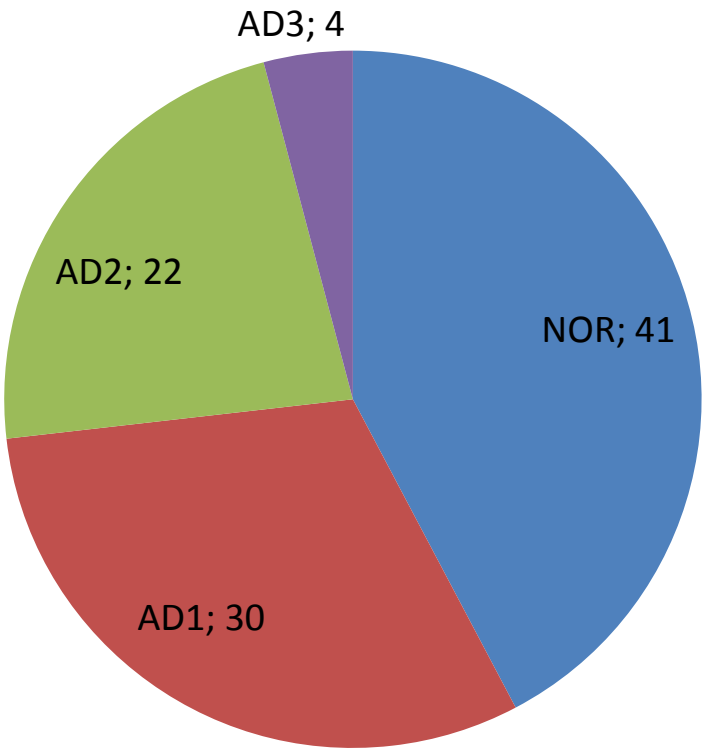


- We have used a database of 97 SPECT images in order to evaluate the proposed system.
- Images were collected during a recent study carried out by the “Virgen de las Nieves” hospital in Granada (Spain).
- The patients were injected with a gamma emitting ^{99m}Tc-ECD radiopharmeceutical.
- SPECT raw data was acquired by a three head gamma camera Picker Prism 3000
- The images of the brain were reconstructed from the projection data using the filtered backprojection (FBP) algorithm in combination with a Butterworth noise removal filter.

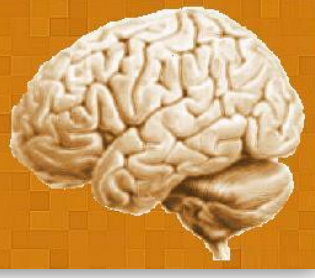
SPECT database

- The SPECT images are then spatially normalized using the SPM software.

- 95 x 69 x 79 voxels per subject.
- The intensities were also normalized for each image individually.
- The images were visually labeled by experts from the hospital.



Partial Least Squares

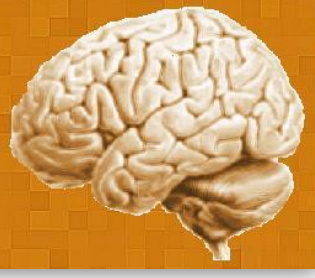


- PLS is a statistical method for modeling relations between sets of observed variables by means of latent variables. It creates orthogonal score vectors by maximizing the covariance between different sets of variables.

- It comprises of regression and classification tasks as well as dimension reduction techniques and modeling tools.

- The underlying assumption of all PLS methods is that the observed data is generated by a system or process which is driven by a small number of latent (not directly observed or measured) variables.

Partial Least Squares



- PLS can be applied as a discrimination tool and dimension reduction method similar to Principal Component Analysis (PCA).
- After relevant latent vectors are extracted, an appropriate classifier can be applied.
- Mathematically, PLS is a linear algorithm for modeling the relation between two data sets $\mathbf{X}$ and $\mathbf{Y}$

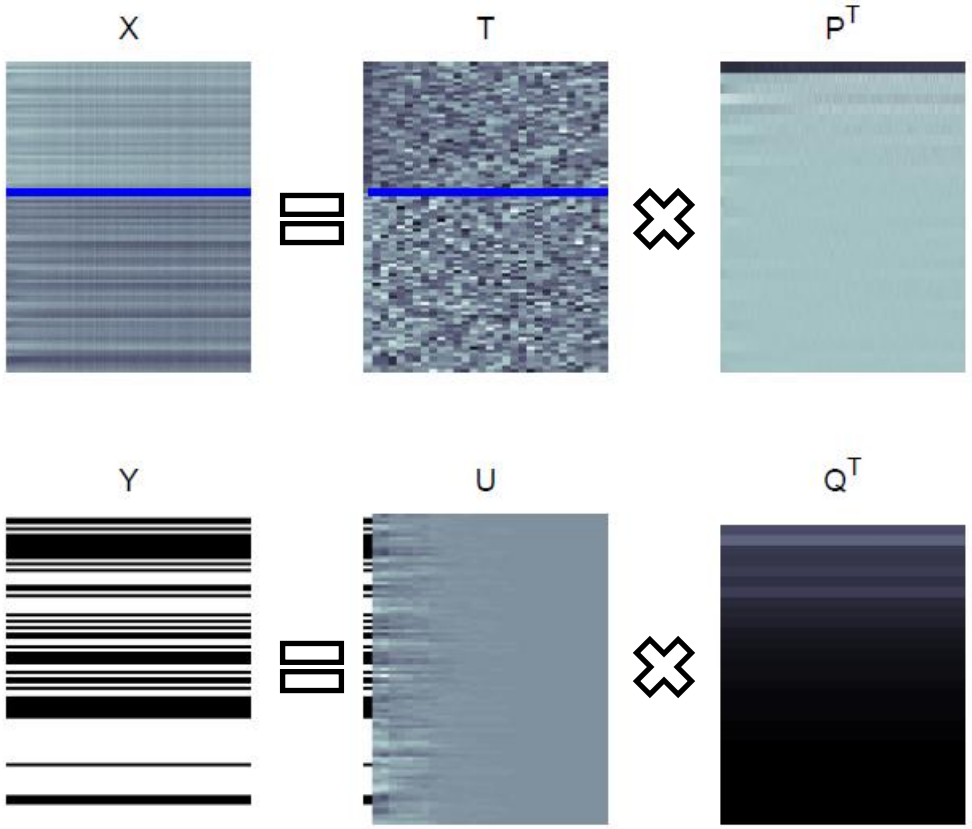
$$\mathbf{X} = \mathbf{T}\mathbf{P}^T + \mathbf{E}$$

$$\mathbf{Y} = \mathbf{U}\mathbf{Q}^T + \mathbf{F}$$

- We use the SIMPLS algorithm to implement PLS

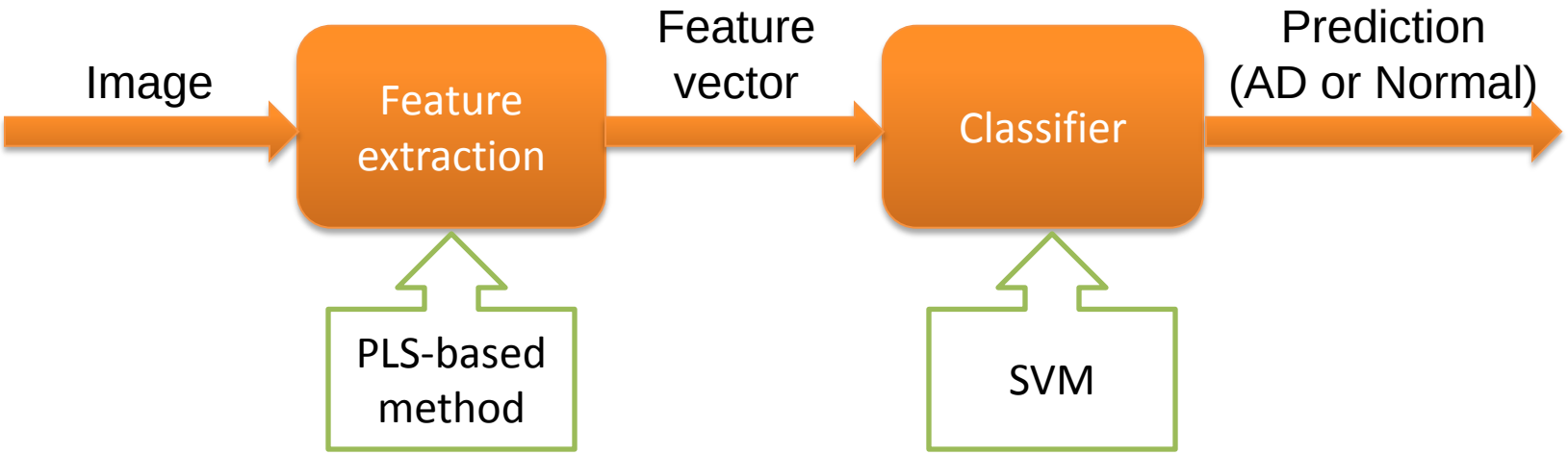
Partial Least Squares

- Note that score vectors (T) contains the most relevant information of the samples (X matrix).
- Loading vectors (P^T) does not contain relevant information for classification and may be discarded.



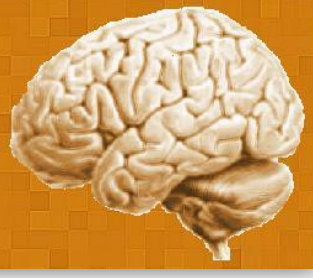
Experiments and results

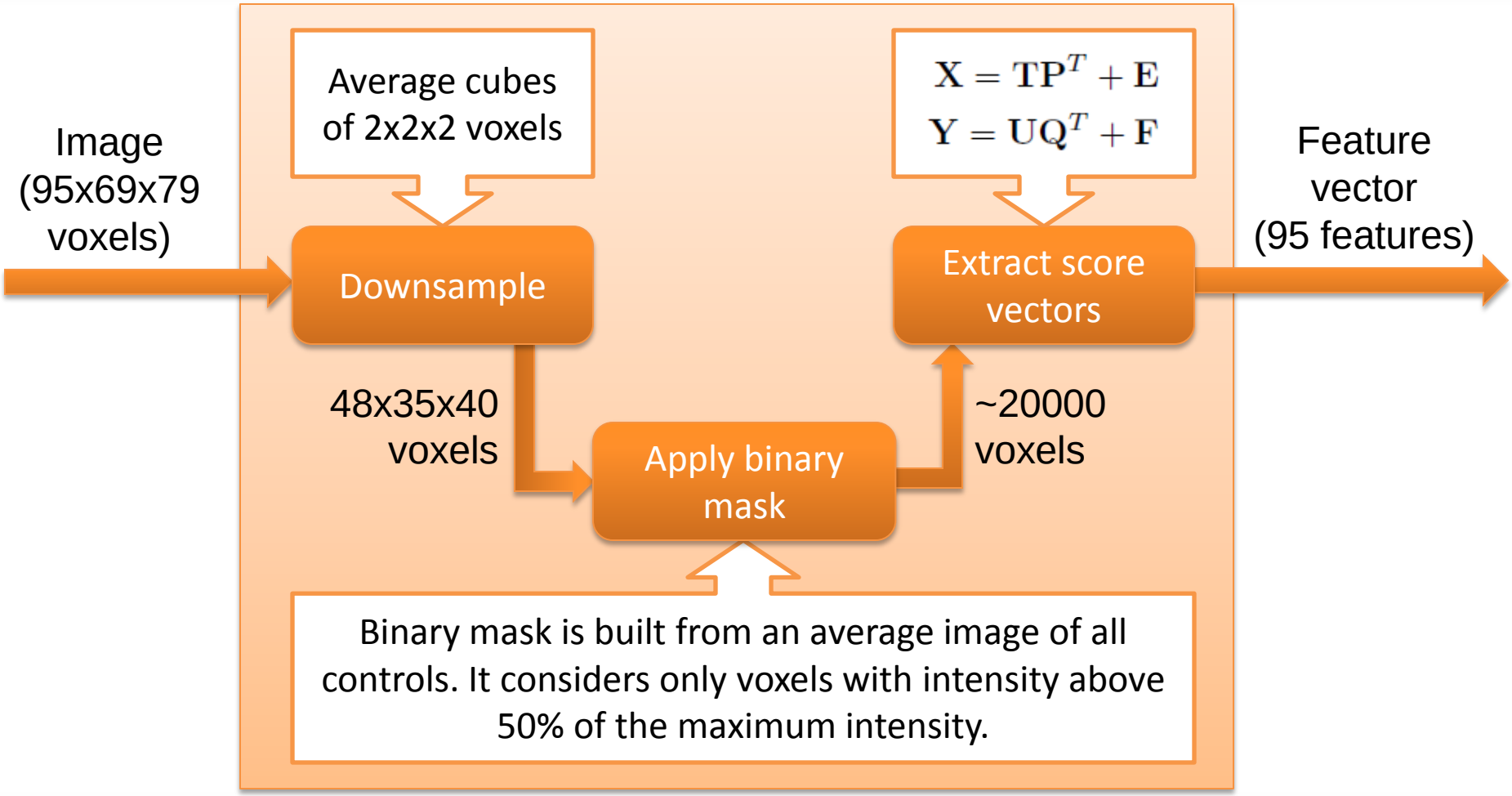
CAD system for Alzheimer's disease



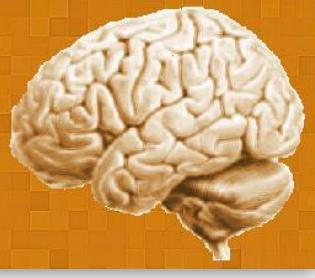
The main contribution of this work is the PLS-based method for feature extraction that allows achieving high accuracy rates in classification

Feature extraction





Extract score vectors



To extract score vector for an image, we use the other 96 images of the database and their labels

Leave one out strategy

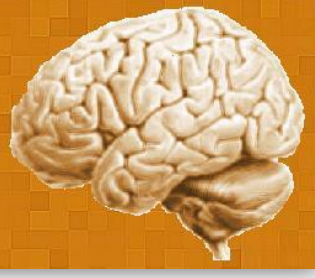
The algorithm provides a matrix of weights and from this we calculate the matrix of scores for the given image.

It prevents biased results by avoiding that the label of a given image is taken into account to compute its score vector.

Thus, in PLS equations:

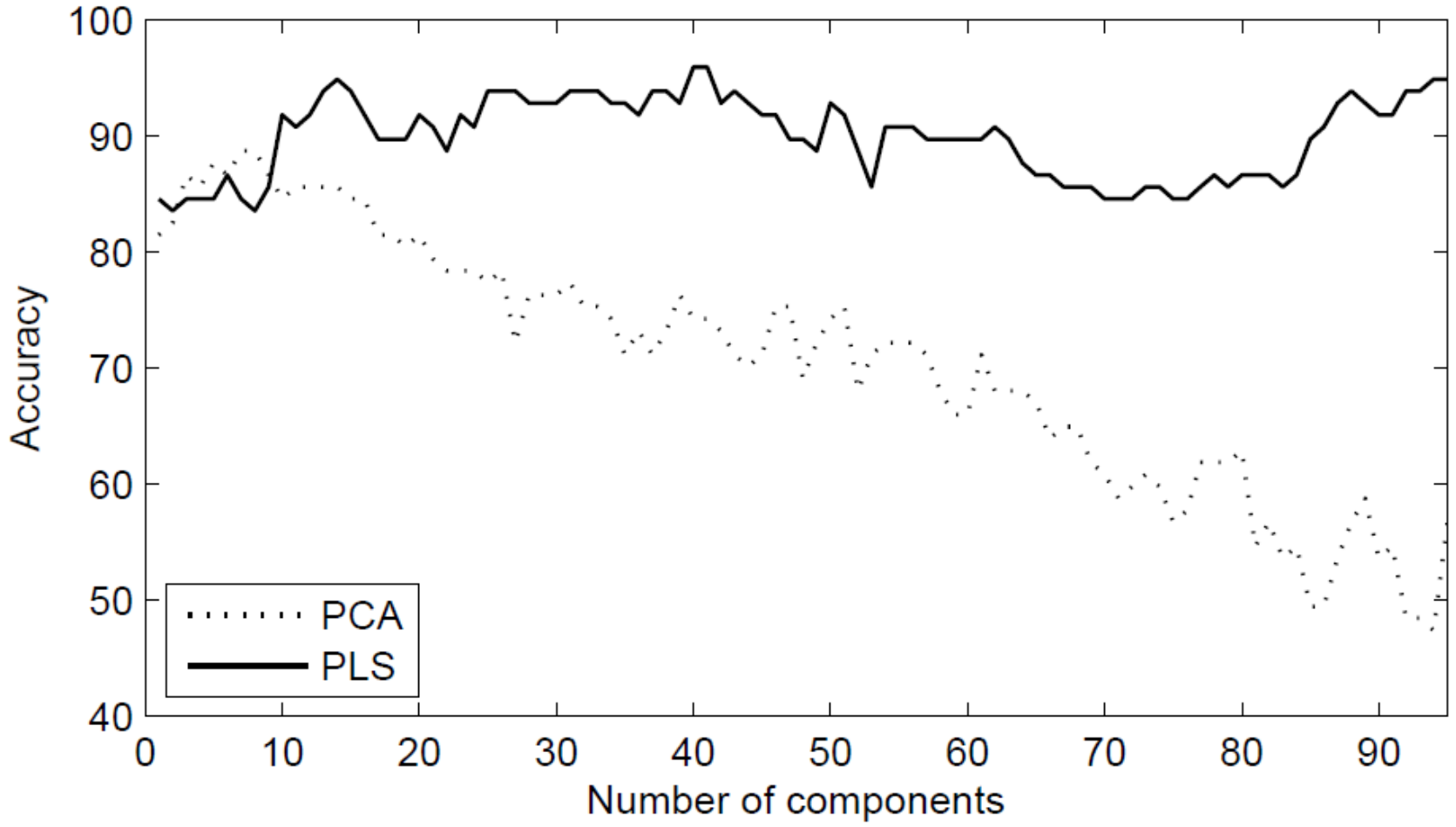
- X has 96 rows and ~20000 columns ← Images
- Y has 96 rows and 1 column ← Labels

Experiments

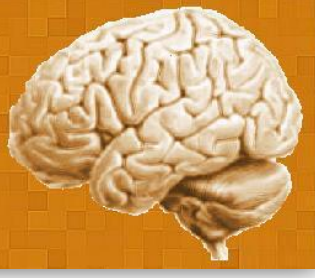


- After feature extraction step, there are 95 features per image.
- Since, features are sorted according to their importance (as in PCA), we can perform a further reduction of the number of features by truncating the feature vectors.
- We have compute the accuracy of a CAD system for Alzheimer's disease based on the feature extraction method described above using a leave-one-out cross-validation strategy.

Results


100
90
80
70
60
50
40
Accuracy
0
10
20
30
40
50
60
70
80
90
Number of components
PCA
PLS

Results



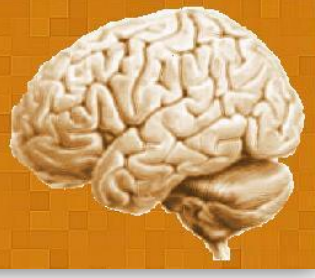
- The highest rates are obtained by using around 20 features:

	Accuracy	Sensitivity	Specificity
PCA	88.66%	87.50%	90.24%
PLS	95.88%	96.43%	95.12%

- In addition, the necessary trade-off between sensitivity and specificity is achieved.

Conclusions

Conclusions



- The main contributions of this works are:
  - A promising feature extraction method for SPECT images based on PLS.
  - A CAD system for Alzheimer's disease based on PLS and SVM that achieves accuracy rates higher than 95%

Thank you very much for your attention

Contact: fsegovia@ugr.es