Detection of Mild Cognitive Impairment using Image Differences and Clinical Features

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Outline

- Medical imaging
- Mild cognitive impairment (MCI)
- Computer aided diagnosis (CAD): data processing
- Brain image analysis methods
- The method proposed for the detection of MCI

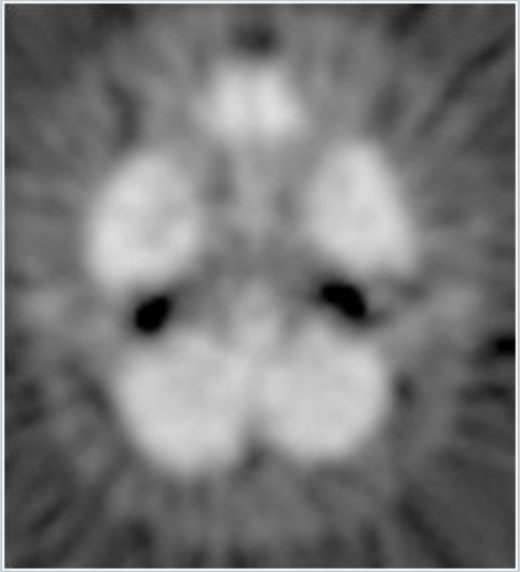
Medical imaging

- Medical imaging is the technique and process used to create images of the human body for clinical purposes or medical science.
- Imaging technologies:
  - Computed Tomography (CT)
  - Magnetic Resonance Imaging (MRI)
    - fMRI: function MRI
  - Doppler Ultrasound Imaging
  - Other techniques based on nuclear emission e.g:
    - PET: Positron Emission Tomography
    - SPECT: Single Photon Emission Computed Tomography

Medical imaging

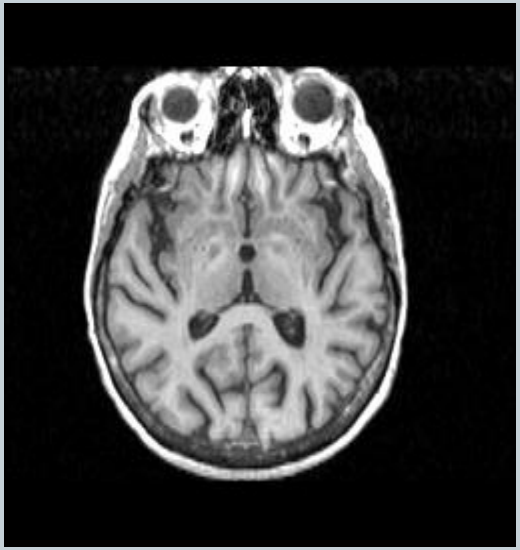
CT scan	MRI
	

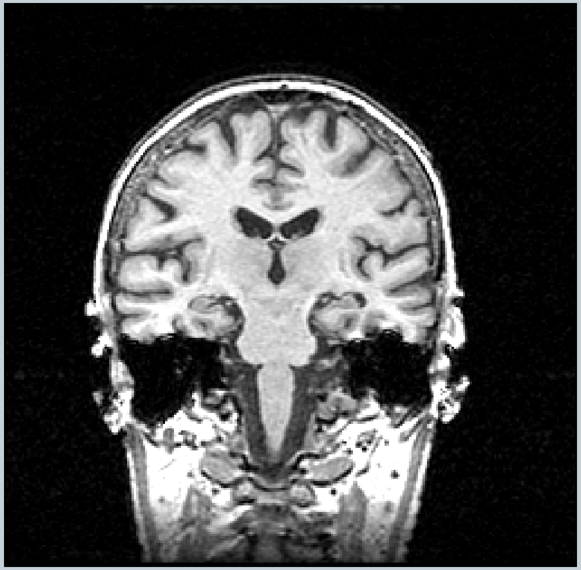
Medical imaging

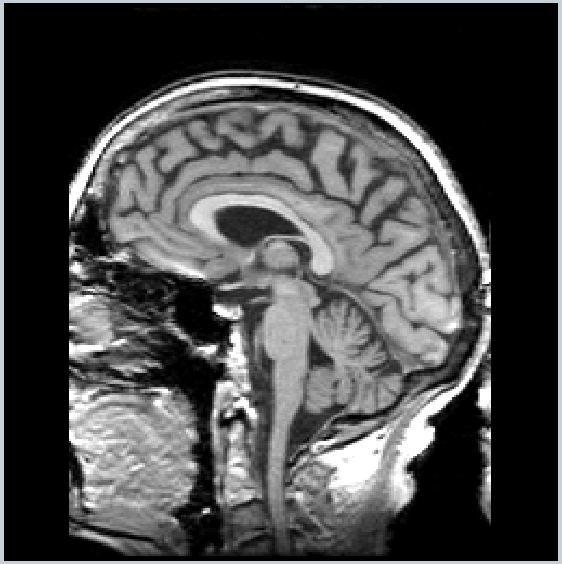
MRI	PET
	

Medical imaging

3D MRI images





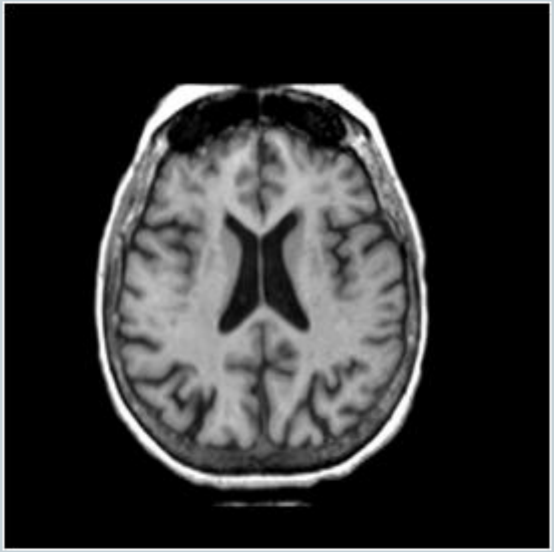
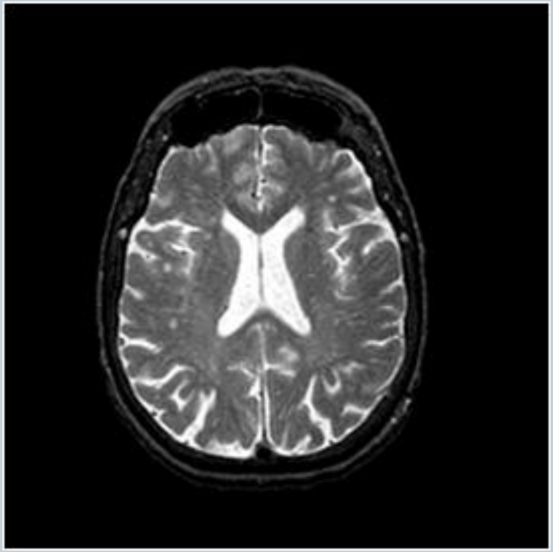


Medical imaging

- Terminology
  - T1 weighted image

    Every tissue in the human body has its own T1 and T2 value. “T1 weighted” is used to indicate an image where most of the contrast between tissues is due to differences in the T1 value.
  - T2 weighted image

Medical imaging

T1 weighted MRI	T2 weighted MRI
	

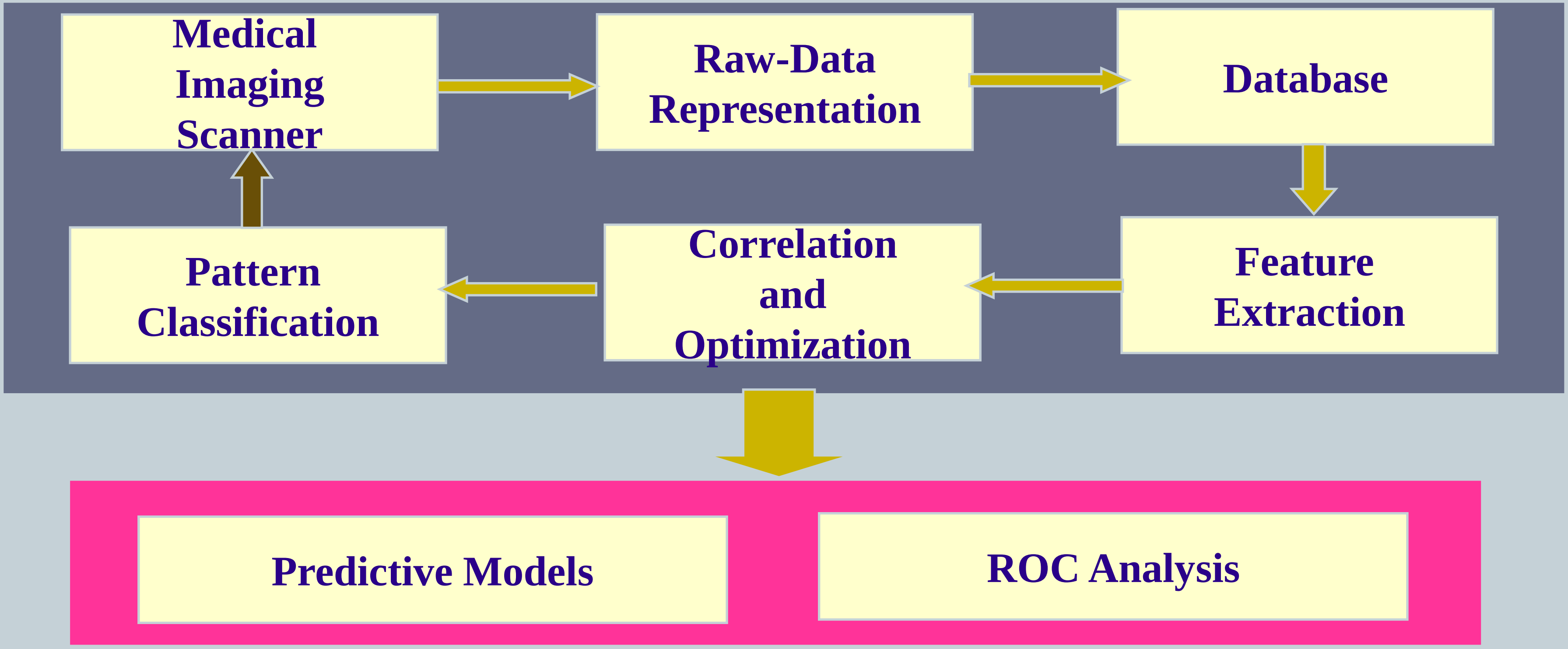
Mild cognitive impairment (MCI)

- MCI: a diagnosis given to individuals who have cognitive impairment beyond that expected for their age and education, but that do not interfere significantly with their daily activities.
- Alzheimer's disease (AD): the most common form of dementia.
- MCI is the transitional stage between normal aging and dementia.

MCI

- The intensity of grey matter (GM) decreases
- The intensity of white matter(WM) decreases
- The intensity of cerebrospinal fluid (CSF) increases

Computer aided diagnosis (CAD)

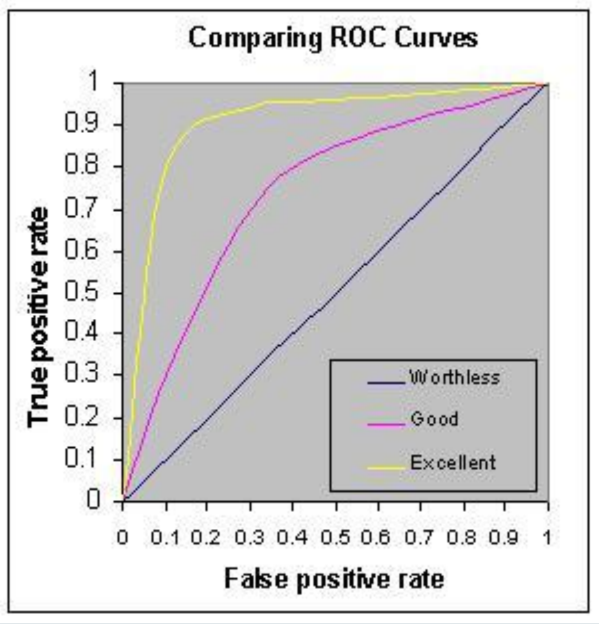


This figure is from the presentation "Medical Imaging Instrumentation & Image Analysis" by professor Atam P. Dhawan.

Computer aided diagnosis

- Receiver operating characteristic (ROC) curve

a graphical plot of the sensitivity, or true positive, vs. (1 - specificity), or false positive, for a binary classifier system as its discrimination threshold is varied.



	MCI	normal
Subjects reported as MCI	True positives	False positives
Subjects reported as normal	False negatives	True negatives

$$\text{sensitivity} = \frac{\text{number of True Positives}}{\text{number of True Positives} + \text{number of False Negatives}}$$

$$\text{specificity} = \frac{\text{number of True Negatives}}{\text{number of True Negatives} + \text{number of False Positives}}$$

Brain image analysis methods

- Gross volumetric measurement
  - pros: can measure the regional brain tissue atrophy in MCI patients
  - cons: specific brain regions have to be outlined manually
- Voxel-by-voxel measurement
  - can measure all the brain regions that demonstrate significant tissue loss
  - more efficient and accurate
- Pattern recognition
  - consider multiple atrophic regions related to characteristic of MCI
  - apply machine learning methods to differentiate between controls and MCI subjects

My research

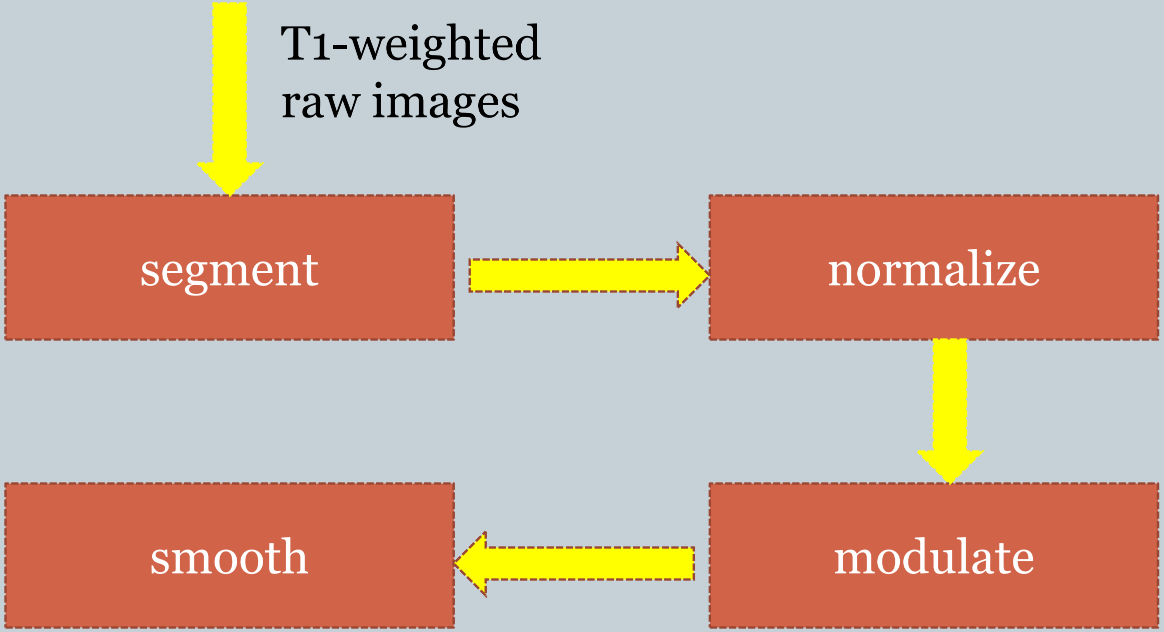
- Lin Li, Carl Lozar, Mark A. Eckert, Dheeraj Chahal, and James Z. Wang, "Online brain image database system for diagnosis of subtle brain injury," the 4th International Conference on Bioinformatics and Biomedical Engineering (iCBBE 2010), Chengdu, China, June 18-20, 2010, in press.
- Lin Li, Carl Lozar, Mark A. Eckert, Dheeraj Chahal, and James Z. Wang, "Detection of mild cognitive impairment using image differences and clinical features," the 10th IEEE International Conference on Bioinformatics and Bioengineering (BIBE 2010), Thomas Jefferson University, Philadelphia, PA, USA, May 31–June 3, 2010, in press.
- We present an approach which can identify the atrophic brain regions in MCI automatically by using the voxel-by-voxel differences of GM intensity between MRI scans of controls and MCI patients.
  - Provides high diagnostic accuracy (90%)
  - The first to use clinical features as covariates
  - The sample set is the largest one (89 MCI subjects and 80 controls)

Details

- Subjects
  - ✓ Participants were selected from the OASIS database.
  - ✓ Clinical Dementia Rating (CDR) of 0.5, 1, 2, (questionable or very mild-, mild-, or moderate-dementia) was used to establish a MCI classification. The controls exhibited the CDR values of 0 (no cognitive dementia)
  - ✓ the final sample for this study included 89 MCI subjects and 80 cognitively normal controls

Details

- Image processing



Details

- Statistical analysis

t-test was used to extract image differences between the controls and MCI subjects with respect to GM intensity of each voxel

$$t(u) = \frac{Avg(f(u))_1 - Avg(f(u))_2}{\sqrt{\frac{\sigma(f(u))_1^2}{N_1} + \frac{\sigma(f(u))_2^2}{N_2}}},$$

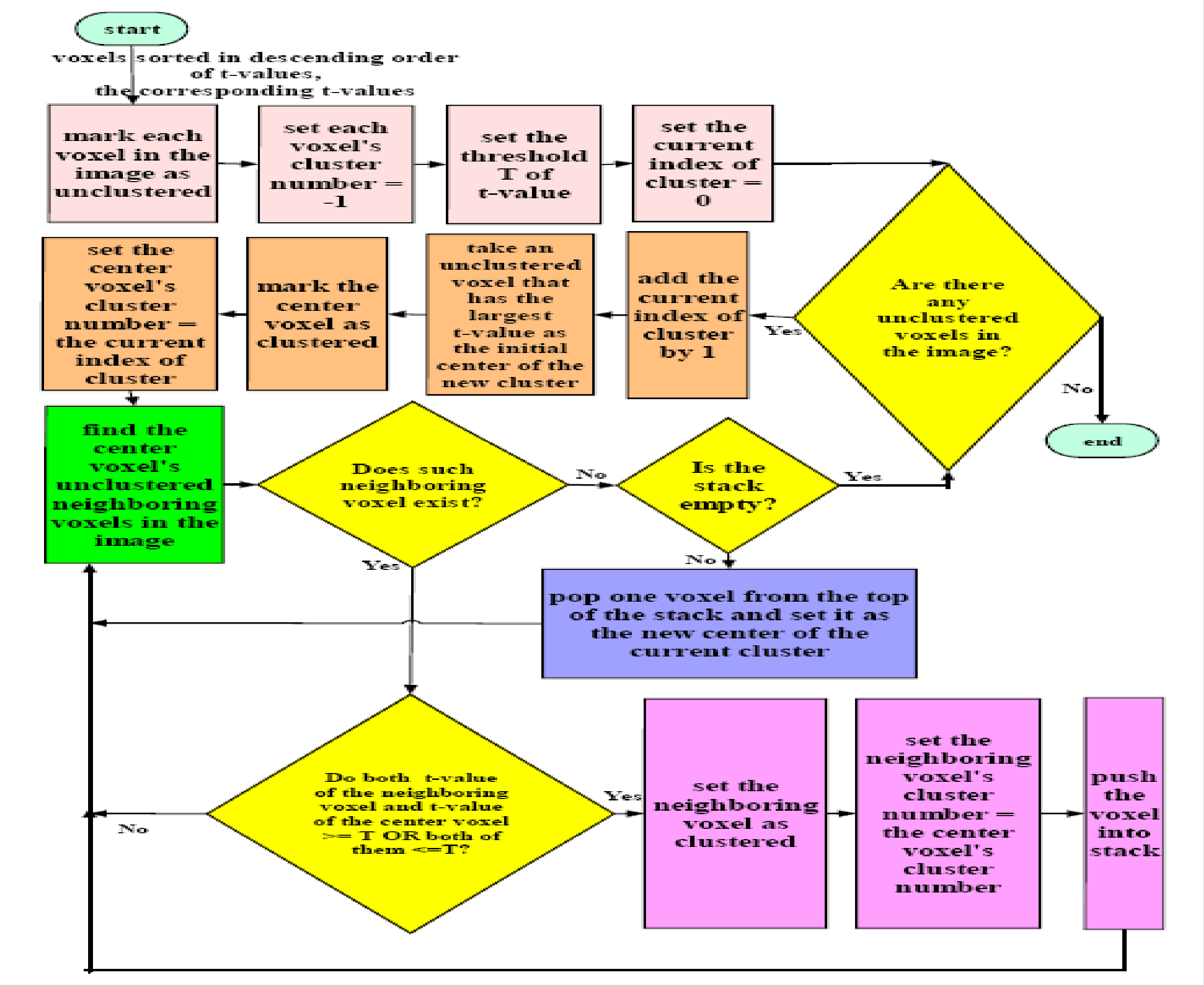
$$\sigma(f(u))_1^2 = \frac{\sum\left(f_i(u) - Avg(f(u))_1\right)^2}{N_1}$$

$$\sigma(f(u))_2^2 = \frac{\sum\left(f_j(u) - Avg(f(u))_2\right)^2}{N_2}.$$

Details

- Region segmentation
  - ✓ calculated t-values of all voxels (902629 voxels) and sorted voxels in descending order of the absolute values of the corresponding t-values
  - ✓ a threshold-based unseeded region growing algorithm to identify the regions of interest (ROIs)
  - ✓ chose 3.1 as the threshold of t-value

Details



start
voxels sorted in descending order of t-values, the corresponding t-values
mark each voxel in the image as unclustered
set each voxel's cluster number = -1
set the threshold T of t-value
set the current index of cluster = 0
Are there any unclustered voxels in the image?
No
end
Yes
add the current index of cluster by 1
take an unclustered voxel that has the largest t-value as the initial center of the new cluster
mark the center voxel as clustered
set the center voxel's cluster number = the current index of cluster
find the center voxel's unclustered neighboring voxels in the image
Does such neighboring voxel exist?
No
Is the stack empty?
Yes
No
pop one voxel from the top of the stack and set it as the new center of the current cluster
Yes
Do both t-value of the neighboring voxel and t-value of the center voxel >= T OR both of them <=T?
No
Yes
set the neighboring voxel as clustered
set the neighboring voxel's cluster number = the center voxel's cluster number
push the voxel into stack

Details

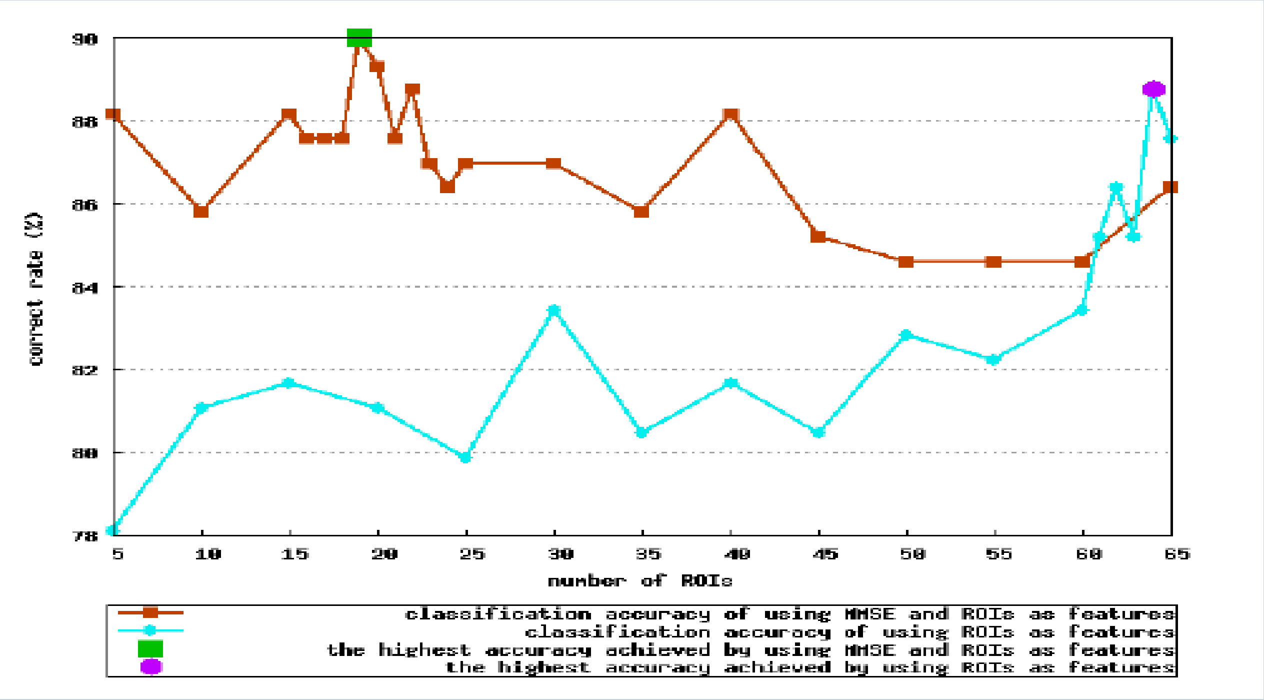
- Feature selection and classification
  - feature ranking method: the rank score was the t-value of the initial center voxel in each region
  - features:
    - GM intensity of the initial center voxels of the regions (the first 19 regions were selected)
    - clinical features: MMSE score
  - LIBSVM was used to train a classifier with the selected features
  - Leave-one-out cross-validation was used to evaluate the classifier's classification accuracy

Details

- Results

the classification accuracy was 90%

(sensitivity = 91.9%, specificity = 88.0%)

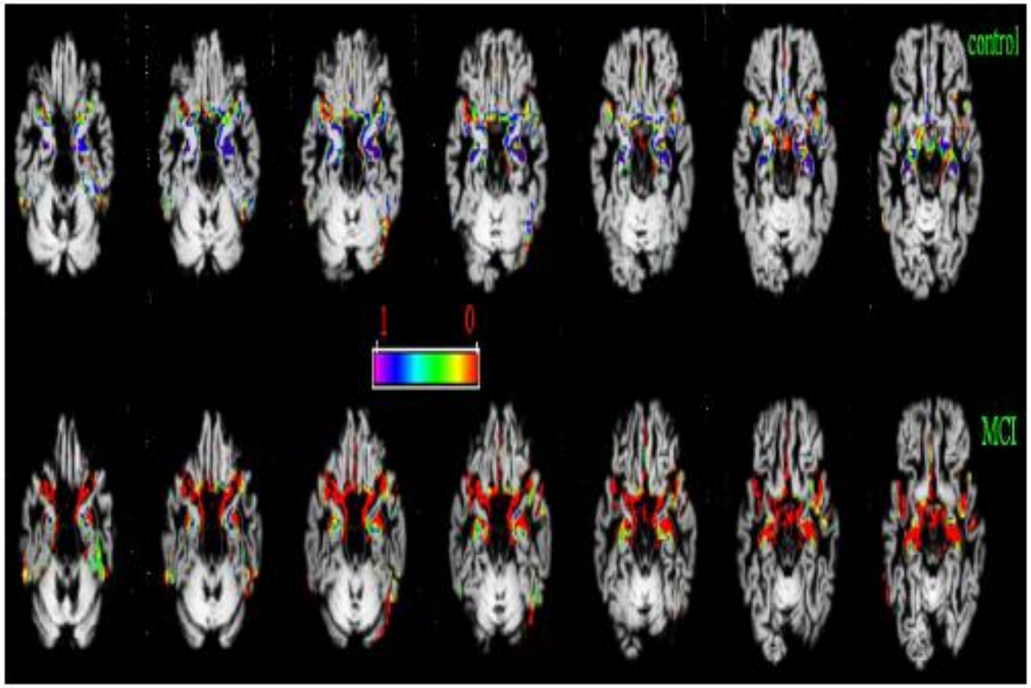


Details

- Results

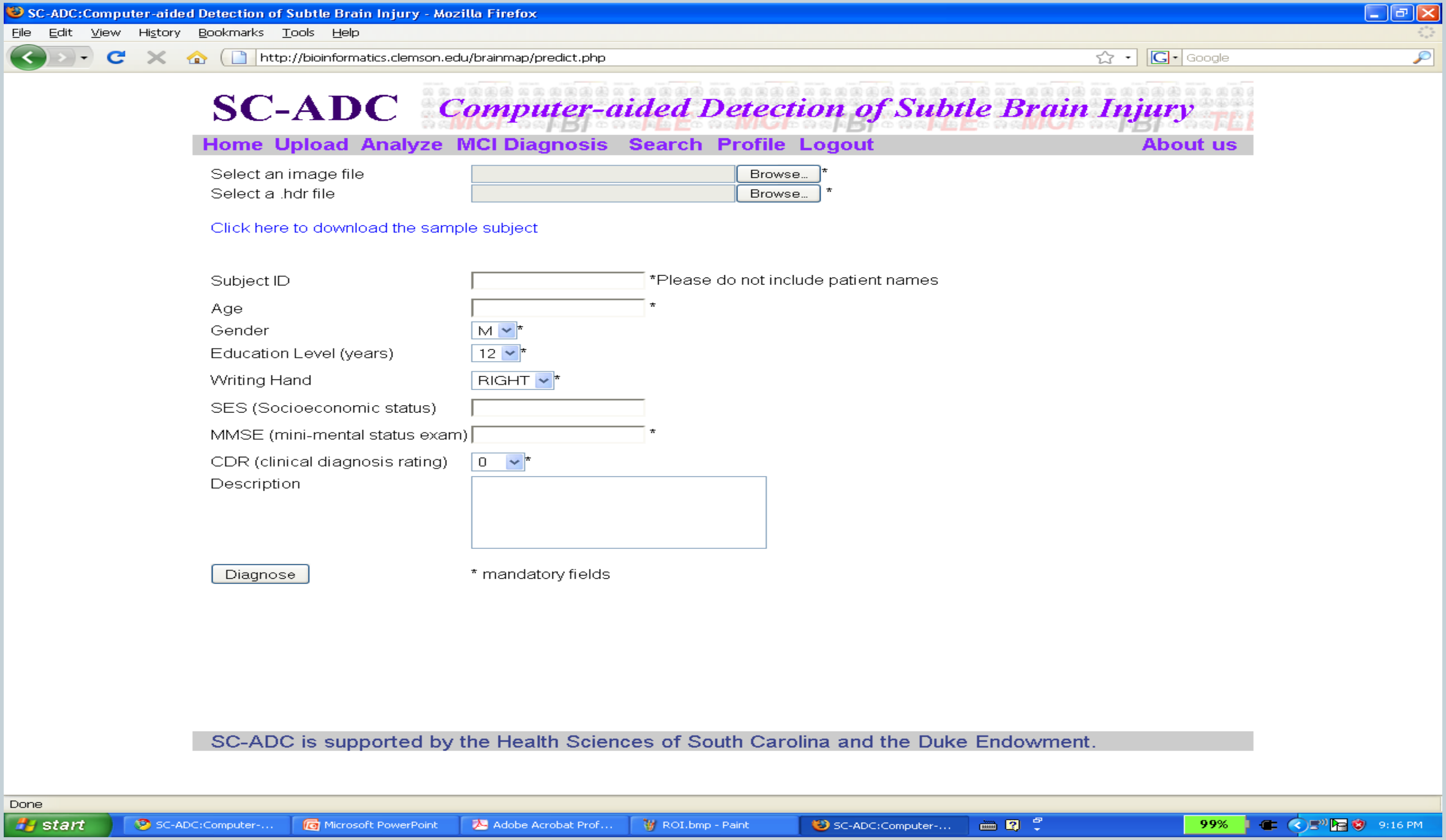
demonstrate GM atrophy pattern specific to MCI subjects, especially in the medial temporal lobe region

Subject	MCI	Control
Gender (F/M)	F	F
Writing hand (L/R)	R	R
Age	73	77
Years of education	4	1
SES	3	4
MMSE	27	29
CDR	0.5	0



Details

- The computer-aided diagnosis system



Thank you!