Detection of Mild Cognitive Impairment using Image Differences and Clinical Features

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• 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
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
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.

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

\[
specificity = \frac{\text{number of True Negatives}}{\text{number of True Negatives} + \text{number of False Positives}}
\]
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.
- 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)
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
• Image processing

- T1-weighted raw images
- Segment
- Normalize
- Smooth
- Modulate
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

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

\[
\sigma(f(u))^2_1 = \frac{\sum (f_i(u) - \text{Avg}(f(u))_1)^2}{N_1}
\]

\[
\sigma(f(u))^2_2 = \frac{\sum (f_j(u) - \text{Avg}(f(u))_2)^2}{N_2}
\]
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
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
• Results

the classification accuracy was 90%
(sensitivity = 91.9%, specificity = 88.0%)
Results demonstrate GM atrophy pattern specific to MCI subjects, especially in the medial temporal lobe region.
The computer-aided diagnosis system

The computer-aided detection of subtle brain injury (SC-ADC) system is designed to assist in the early detection of brain injuries. Its interface includes options for uploading and analyzing images and includes fields for demographic and clinical information. The system is supported by the Health Sciences of South Carolina and the Duke Endowment.
Thank you!