XXXIII cycle Ph.D. course in Physics:

Final year report

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My research field

My research field is data analysis applied to medical physics, more in detail I am analyzing PET-amyloid brain images in the context of Alzheimer Disease (AD).

The β-amyloid(Aβ) accumulation in brain tissue is related to the the neurodegenerative process which leads to AD. The positron emission tomography (PET) provides us images which we can use to evaluate amyloid burden in the brain tissue.

Currently, in clinical practice, the Aβ burden is evaluated with a dichotomous rating (POS/NEG) by visual analysis.
This approach is limiting: the accumulation of Aβ is a progressive and continuous process: about 20% of patients are borderline and so dichotomous rating is not suitable.

The generic aim of my research is to go beyond dichotomous assessment using Aβ quantification methods (such as ELBA, SUVr, TDr) to evaluate quantitatively amyloid burden. Quantification consists in associating a number that is representative of the amyloid load and is therefore optimal to describe a continuous and progressive process such as the accumulation of Aβ.

My research activity

Preparatory work: normative database

I made a SQL-database consisting of 872 patients: for each subject we have at least a late PET-amyloid image, age, sex, acquistion date, center of provenance and the clinical visual assessment.

Then I have made a pipeline to register (using ANTS-Registration software) and quantify these PET images. Then I have updated registered images, related transformations and quantification data (SUVr, ELBA) in the database.

Aim 1. Smooth out semi-quantification variability

PET images are not, in general, acquired with the same machinery, nor they are reconstructed in the same way. Then different images may have different quality. Quantification could be dependent by images quality and so data could be not comparable to each other. My goal is to obtain normative subsets within which PET images are comparable in quality, and so quantification data will also be comparable to each other.

In order to achieve this, I have quantified images quality and then I have clustered images in two subsets using a hierarchical bottom up clustering approach.
I am also currently working on a classifier to put any new images in the appropriate subset.

Aim 2. Data driven atlas versus clinical atlas comparison

I collaborated at a computational level to the creation of a clinical brain atlas (collaboration with IRCCS, San Martino, Genova): we have divided brain into regions relevant to AD from an anatomical point of view.

I am working to obtain a data-driven brain atlas, which is completely agnostic from a clinical and anatomical point of view. I am using different clustering techniques to divide the brain into regions that are geometrically compact and equivalent in terms of the information they carry.

It will be very important to compare these two different atlases: if they will be different there may will be other relevant information not strictly related to amyloid burden which is relevant to AD symptoms.

Furthermore, it will also be very interesting to implement the regional quantification on the data-driven atlas, which I will briefly explain in the following section.

Aim 3. Regional quantification and amyloid-PET accumulation pattern

Regional quantification means the assessment of amyloid load on different regions of the brain. Regional quantification is important because it provides more information with respect to the average amyloid load.

I've done a preliminary analysis on 183 images that seems to indicate the presence of different Aβ accumulation patterns. My aim is to identify, if they exist, different amyloid accumulation patterns, and classify patients according to them. Finally, the clinical implications between accumulation modality and AD symptoms will be investigated.

Courses attended during last year

- MLCC Summer School Genova, June 17-21 ,MLCC2019 , 3 CFU
- Statistic and Probability, Parodi, Passaggio, Kulikovskiy, PhD course 3 CFU

List of given exams during my PhD

- Teoria dei Campi, Camillo Imbimbo, Master Degree course, 6 CFU
- Summer School of Cosmology, International Center of Theoretical Physics, Trieste 18-29 June 2018, 3 CFU
- Very high energy asptrophysics, Fabrizio Tavecchio, Phd course, 3 CFU

List of published papers

- "Analysis of the Angular Dependence of Time Delay in Gravitational Lensing"; Nicola Alchera, Marco Bonici, Roberta Cardinale, Alba Domi, Nicola Maggiore, Chiara Righi, Silvano Tosi; Symmery 2018,10(7),246, https://doi.org/10.3390/sym10070246
- "Towards a New Proposal for the Time Delay in Gravitational Lensing"; Nicola Alchera, Marco Bonici, Nicola Maggiore; Symmetry 2017, 9(10), 202; https://doi.org/10.3390/sym9100202

Conference and Workshops

- On 30 January 2019 I took part Aim Kick-off meeting at Pisa University
- On 13 April 2018 I had a Talk at UniVersum Conference in Bologna. The title of the talk was: Analysis of the Angular Dependence of Time Delay in Gravitational Lensing.