Shape analysis of brain structures

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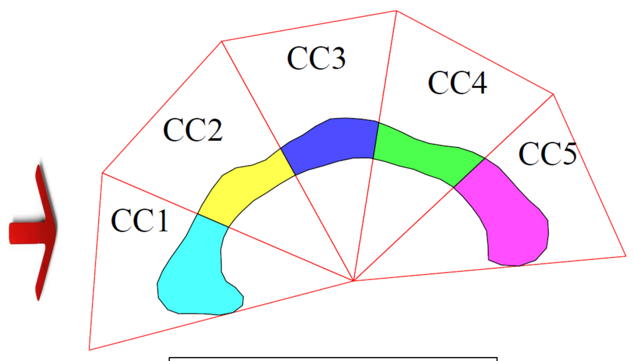
Problem

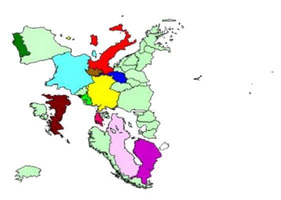
Is it possible to establish a correlation between motorical and neuropsychological changes and the local shape changes of the brain structure *corpus callosum* based on

- Clinical assessments and
- Mid-sagittal brain Magnetic Resonance scans?

The *corpus callosum* is the largest bundle of transversal white nerve fibers in the brain and local shape variations can be associated with certain clinical manifestations.



Regional subdivisoins of corpus callosum [1].



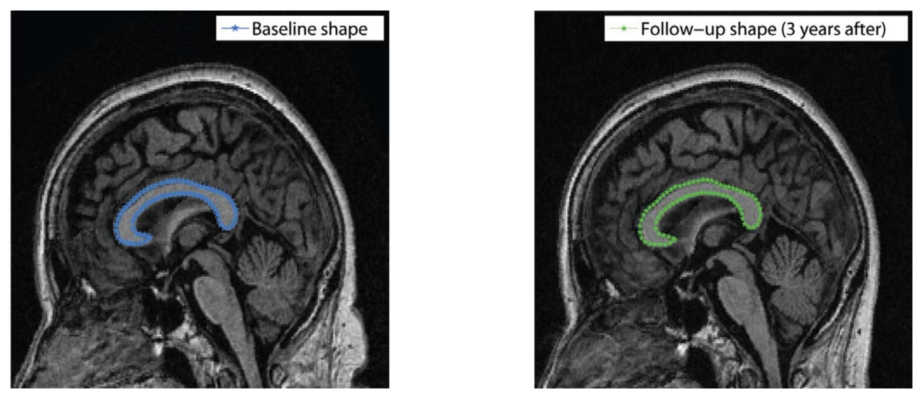
The data that lay out the foundation for the analysis comes from **LADIS** (Leukoaraiosis And DISability):

- Collaboration between 11 European hospitals and health centers with the purpose of studying Age-Related White Matter Changes (ARWMC).
- 978 persons aged 65 to 84 were subjected to tests twice with three years in between (baseline and follow-up).

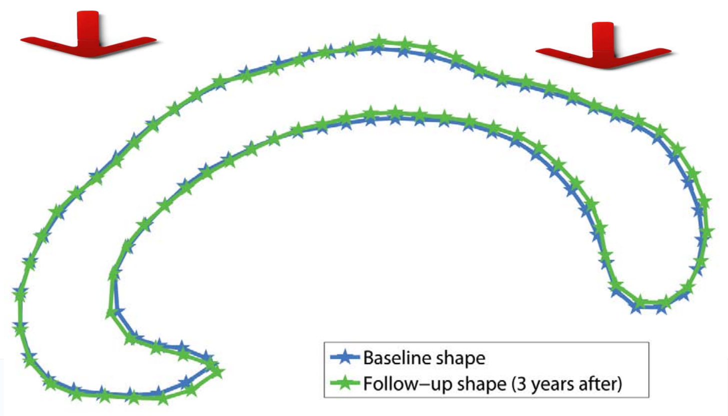
Over 500 Clinical assessments, including:

- Memory
- Walking speed
- Verbal Fluency
- Geriatric depression scale
- Executive motor skills
- Age
- Gender

Mid-sagittal MR scans exist for each test person:



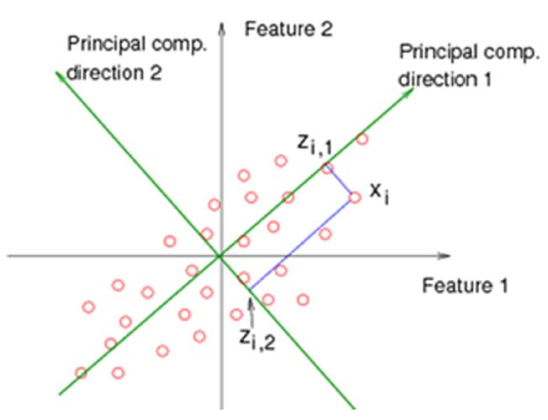
Each MR scan has been annotated with 78 landmarks signifying the outer contour of the corpus callosum.



Analysis

Regular Principal Component Analysis (PCA):

An advantage of using PCA is that one can project the entire set of data onto the principal component directions that describe the highest amount of variation throughout the dataset. PCA is a method of orthogonal subspace projection.

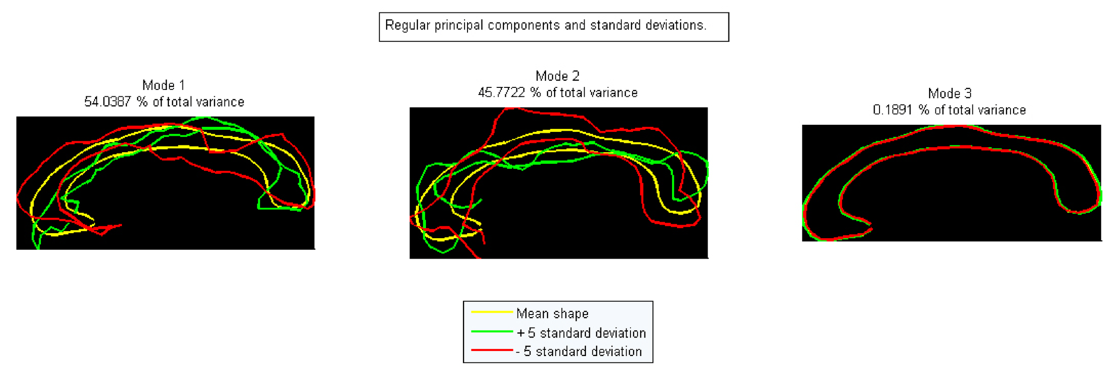


Left figure shows random data (red dots) distributed along feature 1 and 2. Projecting each observation x_i onto the subspace of the orthogonal principal component directions will reduce the dimensionality of the entire dataset. The so-scalled *scores* are denoted by *z* [2].

All variance in distribution of the landmarks making out the corpus callosum outline is contained within the principal components.

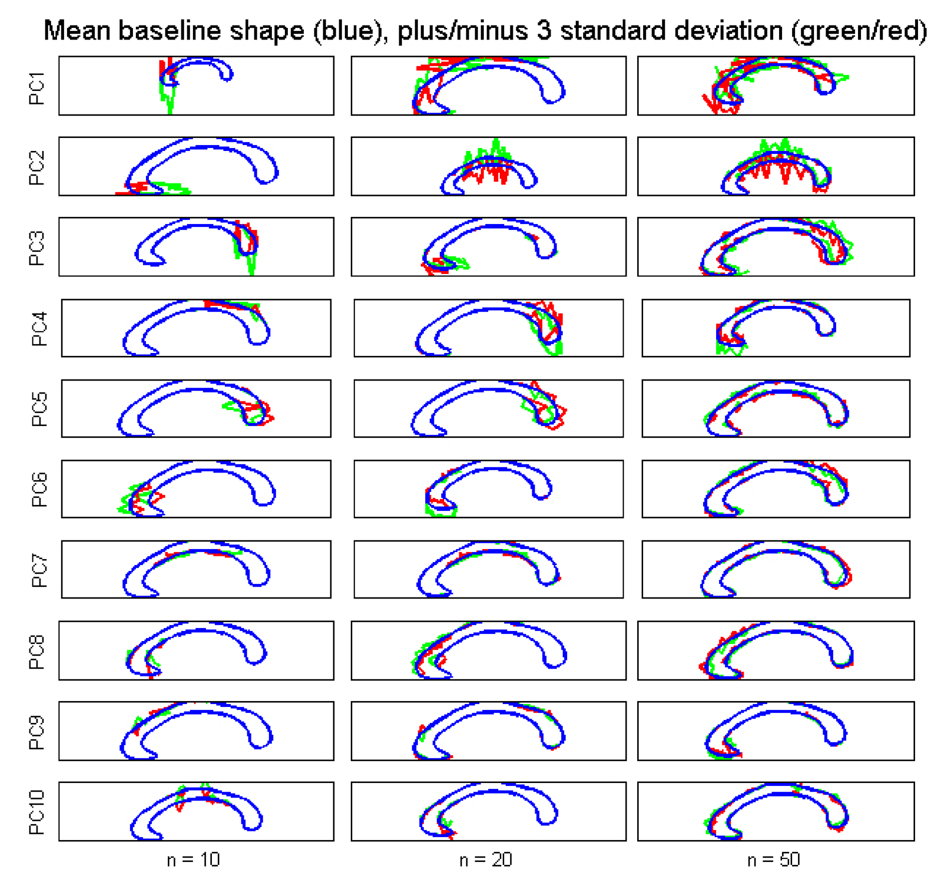
Sparse Principal Component Analysis (SPCA):

By adjusting the number of landmarks that will contribute to the analysis as well as choosing certain principal components to be set to zero, local changes in shape from baseline to follow-up can be detected. Contrary to regular PCA, the principal components of SPCA does not cover the entire variation in the dataset and thus, gives way for local shape change detection.



Mean corpus callosum shape as well as the ± 5 standard deviation perturbed shapes computed from the regular PCA.

Mean baseline shape (blue), plus/minus 3 standard deviation (green/red)

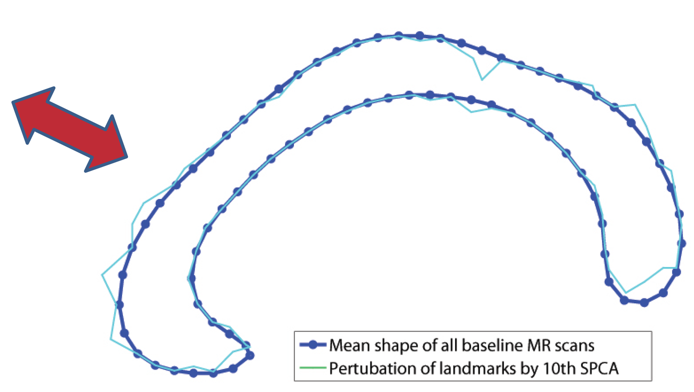


Mean corpus callosum shape as well as the ± 3 standard deviation perturbed shapes computed from SPCA. *n* signifies the number of landmarks considered in each analysis.

Discussion & Conclusion

Regression Analysis:

- Large number of test persons leads to even larger number of MR scans. Each scan is annotated with 78 landmarks.
- Large number of clinical assessments.
- The analysis aims at detecting if there is significant correlation between the local corpus callosum shape changes and the changes in the clinical assessments.



Why use Sparse Principal Component Analysis?

- If regular PCA had been used, each component would describe changes in every landmark position, whereas, by using SPCA and keeping only one or a few components non-zero, we can describe the shape changes of interest based on only a small part of the data. This gives rise to powerful local shape change analysis.
- SPCA allows one to consider datasets of vast amounts of variables and observations by projection of the data onto orthogonal subspaces and thus, allowing for regression analysis within these much lower dimensional subspaces.

Is there a potential for predicting the risk of developing neurodegenerative diseases such as

- Alzheimer's Disease,
- Parkinson's Disease,
- dementia

based on brain MR scans and clinical assessments? The analytical work in the present thesis is ongoing and contributes to detection of correlation between the temporal changes in clinical assessments and shape.

References:

1. Image from C. Ryberg, M.B. Stegmann, K. Sjöstrand, E. Rostrup, F. Barkhof, F. Fazekas, and G. Waldemar. Corpus Callosum Partitioning Schemes and Their Eect on Callosal Morphometry. *Proc. International Society of Magnetic Resonance in Medicine-ISMRM 2006, Seattle, Washington, USA.*
2. Image from course notes from STAT 897D – Applied Data Mining at The Pennsylvania State University.

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