CT Brain Perfusion Studies

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Outline

- Motivation
- Infarct location
- Perfusion and hemodynamical maps
- Int.eu.grid integration
- Future Work
Introduction

- Collaboration between IFCA (CSIC-UC) and Hospital Universitario Marqués de Valdecilla at Santander (HUMV) radiologists.
  - Previous collaboration
- Development of a tool for assisted diagnosis for brain stroke using hemodynamic parameters maps
- Vendor independent parameters calculation testing several methods
- Integration in int.eu.grid
Brain stroke is one of the most important death and disability causes in the EU and USA.

Currently available treatments could help to reduce the extension of the problem

- CT Perfusion techniques can help using the acquired images to generate brain maps showing relevant hemodynamical parameters:
  - MTT Mean Transition Time
  - BV Blood Volume
  - BF Blood Flow

- But need accurate identification of the ischemic lesion

Other relevant information for diagnosis is needed: like angiography
WHAT’S STROKE?
One million strokes occurring per year in the European Union.

NINDS trial demonstrated usefulness of thrombolytic treatment of stroke in selected patients rescuing the ischemic penumbra.

Thrombolytic treatment has an associated risk of cerebral hemorrhage up to 20%.
WHAT’S STROKE?
- **Core:** part of the ischemic region that is irreversibly injured

- **Penumbra:** area of the brain underperfused and in danger of infarcting.
CT perfusion plays a major role by demonstrating salvageable brain tissue and extension of cerebral core infarction.

And... WHAT’S CT PERFUSION??
ANALYSIS

- Attenuation proportional to blood (= contrast) in brain tissue.

- Time attenuation curve of reference:
  - artery (ACA, MCA)
  - vein
Deconvolution (MTT)

Parametric maps

$\text{CBV} = \frac{\text{AUC pixel parench}}{\text{AUC pixel artery}}$

$\text{CBF} = \frac{\text{CBV}}{\text{MTT}}$
MAIN CLINICAL APPLICATIONS

- **Vascular pathology**
  - *Acute ischemic stroke*
  - Chronic ischemia
  - Vasoespasm

- **Brain tumours**
¿Salvageable cerebral tissue??

**NECROSIS**

**PENUMBRA (CBF)**

**NECROSIS**

**NECROSIS**

**NECROSIS**

**NECROSIS**
Infarct location application

- Using the cerebral blood flow and the mean transit time generate a brain map showing:
  - The infarct core
  - The ischemic penumbra
- Implemented in Java (ij library for the images)
  - Using input from GE Perfusion application
  - Will use also our maps when finished
- The program fed with the parameter maps automatically calculates an output map
  - The medic can change the criteria
  - Also can define a good tissue region to use as reference
Now a java standalone GUI application

It is being ported to the grid as a plugin for the Migrating Desktop

Blood Volume Blood Flow Mean Transit Time
For DCE (Dynamic Contrast Enhancement) imaging using CT (aka CT Perfusion) a sequence of images (45) at the same location are taken in a given interval.

- Concentration Time Curves

The objective is to get the three parameters that are related by the central volume principle

- This is done voxel by voxel
CT Perfusion Application

- **Input:** (4*) 45 CT brain images in DICOM format
  - Using as reference an artery and a vein, three parameters are computed for each pixel:
    - blood flow (CBF),
    - blood volume (CBV) and
    - mean transition time (MTT).

- **Prototype in Matlab**
  - Using RegTools Toolbox by P.C. Hansen

- **Now implementing the algorithms in**
  - ANSI C
  - Java
We want to obtain $F$ and $R(t)$
- $C_{tiss}$ and $C_{art}$ are the tissue and artery concentrations
- $R(t)$ is the tissue residue function and it is used to calculate the MTT
- Numerical deconvolution process is very sensitive to noise in the measured data
  - Inherently ill-conditioned problem

If using Fourier Transform

$$C_{tiss}(w) = C_{art}(w)R(w)$$

$$R(w) = C_{tiss}(w) / C_{art}(w)$$
Singular Value Decomposition

- Discretize the convolution integral equation
  - System of linear equations
- \( A \) is a \( n \times n \) matrix and \( x \) and \( b \) are vectors
- Singular Value Decomposition (SVD)

\[
A \cdot x = b
\]

\[
x_i = F \cdot R(t_i)
\]

\[
A = U \cdot S \cdot V^T = \sum_{i=1}^{n} u_i s_i v_i^T
\]

\[
s_1 \geq s_2 \geq \ldots \geq s_n \geq 0
\]
Regularization Methods

- **TSVD**
  - Singular Value Decomposition (SVD)
    - Threshold or truncation index
    - The smaller singular values are eliminated
    - Limits the effects of noise
  - C implementation using SVDLibC
  - Java using JAMA

- **Tikhonov Regularization**
  - Prototype in Matlab
  - Java using JAMA
Selection of the regularization parameter

- Picard plots to estimate
- Currently using the L-Curve method
Interactive European Grid Project

Interactive: because researchers need answers in seconds, not in hours.

Grid: easy, intuitive, transparent BUT distributed, powerful, open.

For e-Science: Collaboration.

“providing transparently the researcher’s desktop with the power of a supercomputer, using distributed resources”

http://www.interactive-grid.eu

Coordinator: CSIC, Jesús Marco, IFCA, Santander, SPAIN [marco@ifca.unican.es]
Distributed Parallel (MPI) Interactive Computing and Storage at the Tera level

User Friendly Access through a Grid Interactive Desktop with powerful visualization and real simulation steering in real time

Supporting Virtual Organizations at all levels: setup, collaborative environment, grid enhancement of applications, execution and monitoring tools.
- Single sign-on / authorisation
- Platform independent
- Batch jobs
- MPI jobs
- Running interactive applications using java plugins or VNC
- Monitoring grid applications
- Flexible Application framework
- User profile management
- Easy application add on
- Local and grid file management

**Desktop tools:**
- Job Wizard
- Job Monitor
- Application Container and Plugin
- GridFTP Commander
- User Profile Manager
- Private Storage
- Management
- VNC/SSH console
The TSVD is already running in int.eu.grid
  ► Working on Tikhonov regularization

The infarct location Java application would be included in a MD visualization plugin that:
  ► Use DICOM images already at int.eu.grid SEs or register new ones (with anonymization)
  ► Would run the brain parameters map creation application using TSVD or Tikhonov
  ► Using them would create the core and penumbra map.
Other Future Work

- Implementing alternative techniques for getting the perfusion and hemodynamic parameters:
  - Frequencies filtering
  - Parametrical approaches
  - Bayesian

- Comparing all these techniques with simulated and real data
  - Using Monte Carlo simulations to check the methods robustness against different levels of SNR

- Adapting the application for other medical uses of CT perfusion:
  - Brain tumors