Application of the Grid to Pharmacokinetic Modelling of Contrast Agents in Abdominal Imaging

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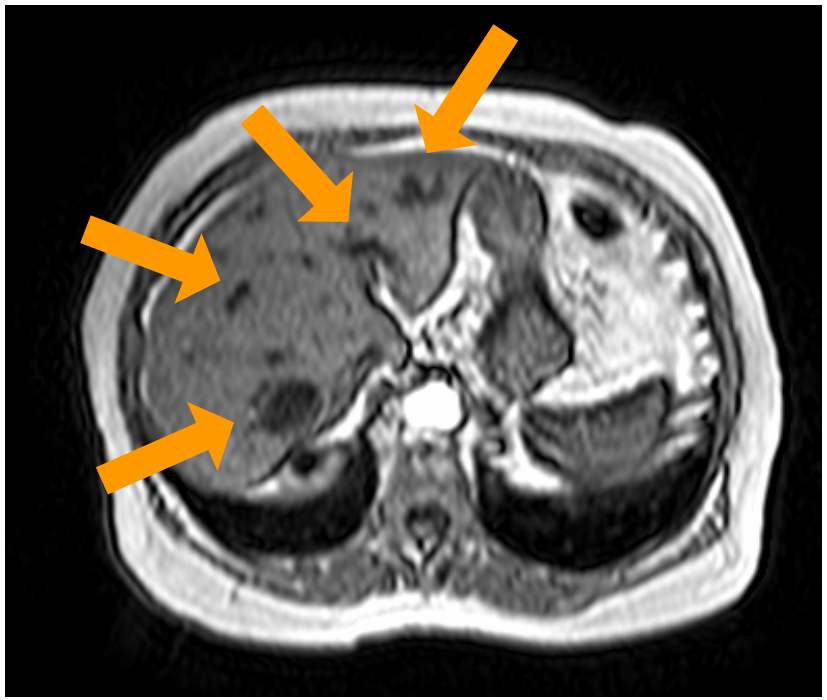
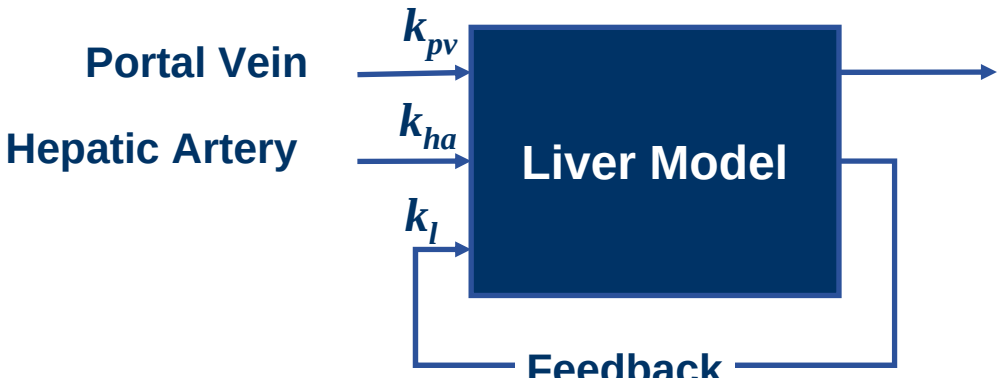
Analysing the Nature of Tumours

- The Liver is a Key Organ of the Abdomen in Oncology.
- Angiogenesis is Quite an Important Marker of Tumour Aggressiveness and Response to Therapy.
- Dynamic Contrast Enhanced Magnetic Resonance Imaging (DCE-MRI) is Extensively Used for the Detection of Primary and Metastatic Hepatic Tumours.
- However, the Assessment of Early Stages of the Malignancy and Other Diseases like Cirrhosis Require the Quantitative Evaluation of the Hepatic Arterial Supply.



Quantitative Modelling of the Blood Perfusion

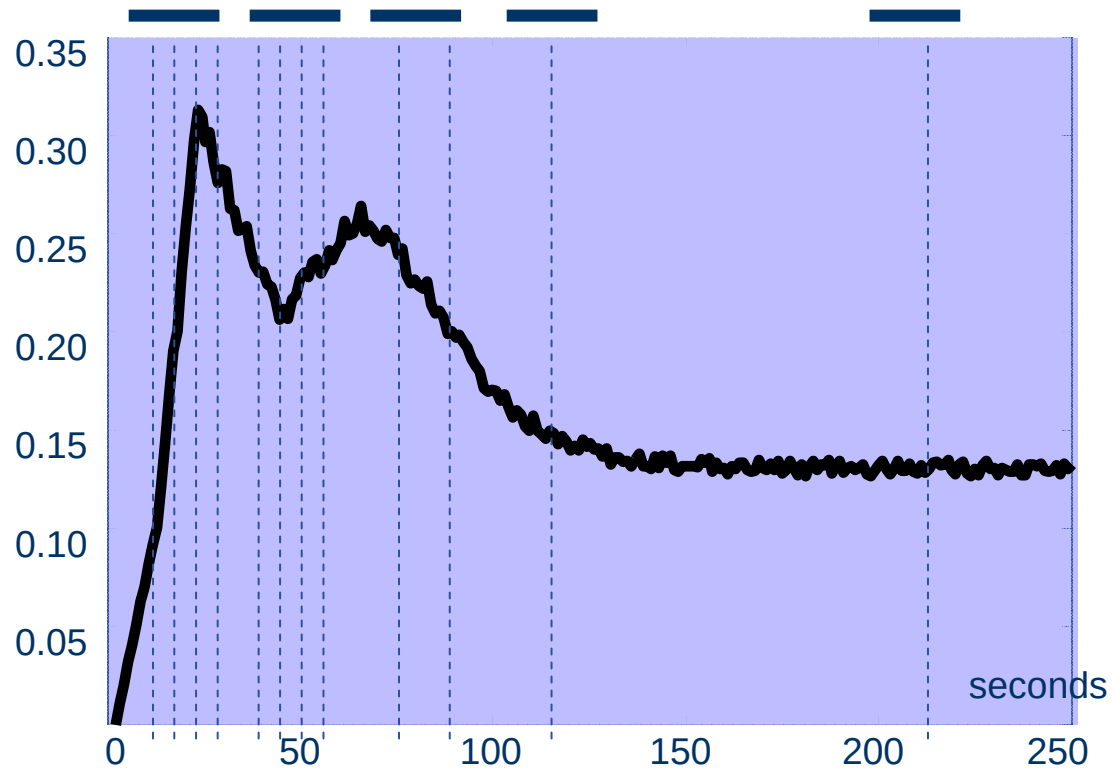
- The Objective is the Characterization of the Tissular Nature by the Analysis of the Evolution of Contrast in a Time Series.
- Different Tissues Define Different Constants for Recycling And Flow Rate of the Physical Models.
- Those Constants can be used for the Creation of Parametric Images.



$$C_L(t) = \int_0^t \left(k_{ai} C_a(x) + k_{pi} C_p(x-\tau) \right) e^{-k_{Lo}(t-x)} dx$$

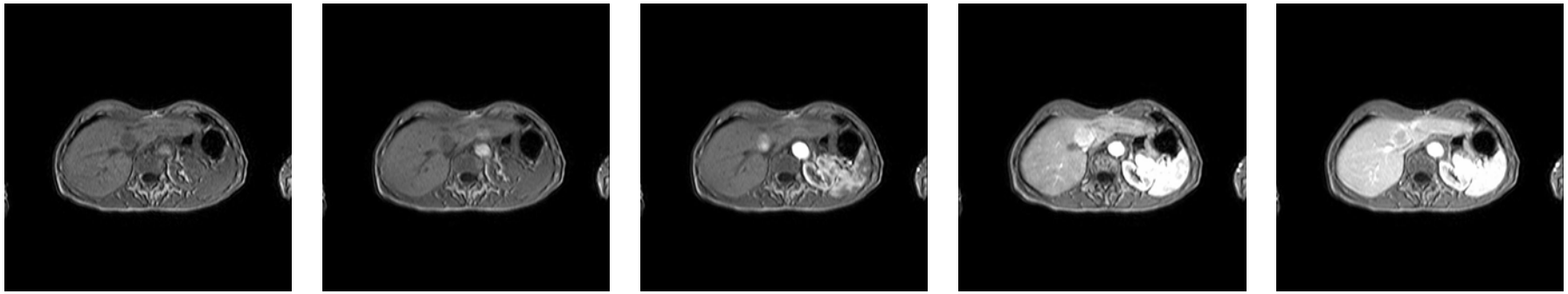
Data Acquisition and Problems

- **Description**
  - The Process Requires Obtaining a Sequence of DCE-MRI Volumetric Images.
  - Different Images are Obtained in Different Breath-holds.
  - The Movement of the Abdomen is Unavoidable and Relevant When Voxels have Sub-millimetrical Dimensions.
  - Before Analyzing the Variation of Each Voxel, Images Must be Co-registered to Minimize Deformation due to Different Breath Holds.



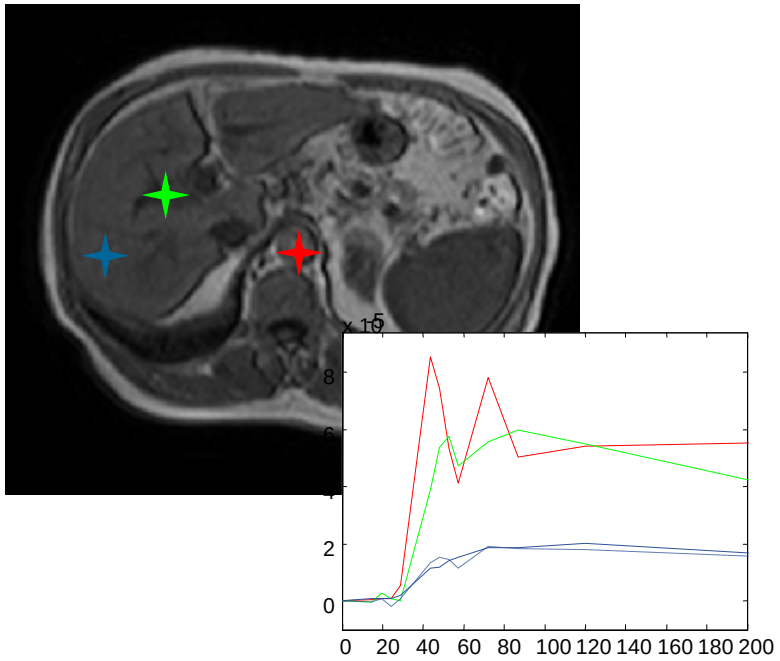
Technical Issues

- **Acquisition of Data**
  - 13 DICOM 3D Studies of 24 Slices at Different Timesteps.
- **Data Pre-processing**
  - Anonymisation of the DICOM Images and Conversion to Raw Format (Analyze).
  - Cropping of Blank Areas to Reduce Overhead in the Co-registration Process.
  - Co-registration with Respect to Reference Image Using Deformable Methods (Around 100-140h).
  - Slice re-ordering to Produce 24 studies of 13 Slices.



Technical Issues

- **Model Estimation**
  - Identification of Portal Vein and Hepatic Artery.
  - Optimisation of the Nonlinear Model Through Least Squares.
  - The Equation is Solved For Each Time Value for Each Voxel of the 3D Images (k_{ai}, k_{pi} and k_{lo} are the Unknowns).



$$C_L(t)=\sum_{i=0}^{n-1}\left(\left(\frac{p_i(t_{i+1})}{k_{Lo}}-\frac{p_i'(t_{i+1})}{k_{Lo}^2}-\frac{p_i''(t_{i+1})}{k_{Lo}^3}-\frac{p_i'''(t_{i+1})}{k_{Lo}^4}\right)e^{-k_{Lo}(t-t_{i+1})}-\left(\frac{p_i(t_i)}{k_{Lo}}-\frac{p_i'(t_i)}{k_{Lo}^2}-\frac{p_i''(t_i)}{k_{Lo}^3}-\frac{p_i'''(t_i)}{k_{Lo}^4}\right)e^{-k_{Lo}(t-t_i)}\right)$$

  - Computation of the Parametrical Image (Function of k_{ai}, k_{pi} and k_{lo}).

Objectives of the Grid Application

- **Performance**
  - Use of the Grid to Provide the Computational Power.

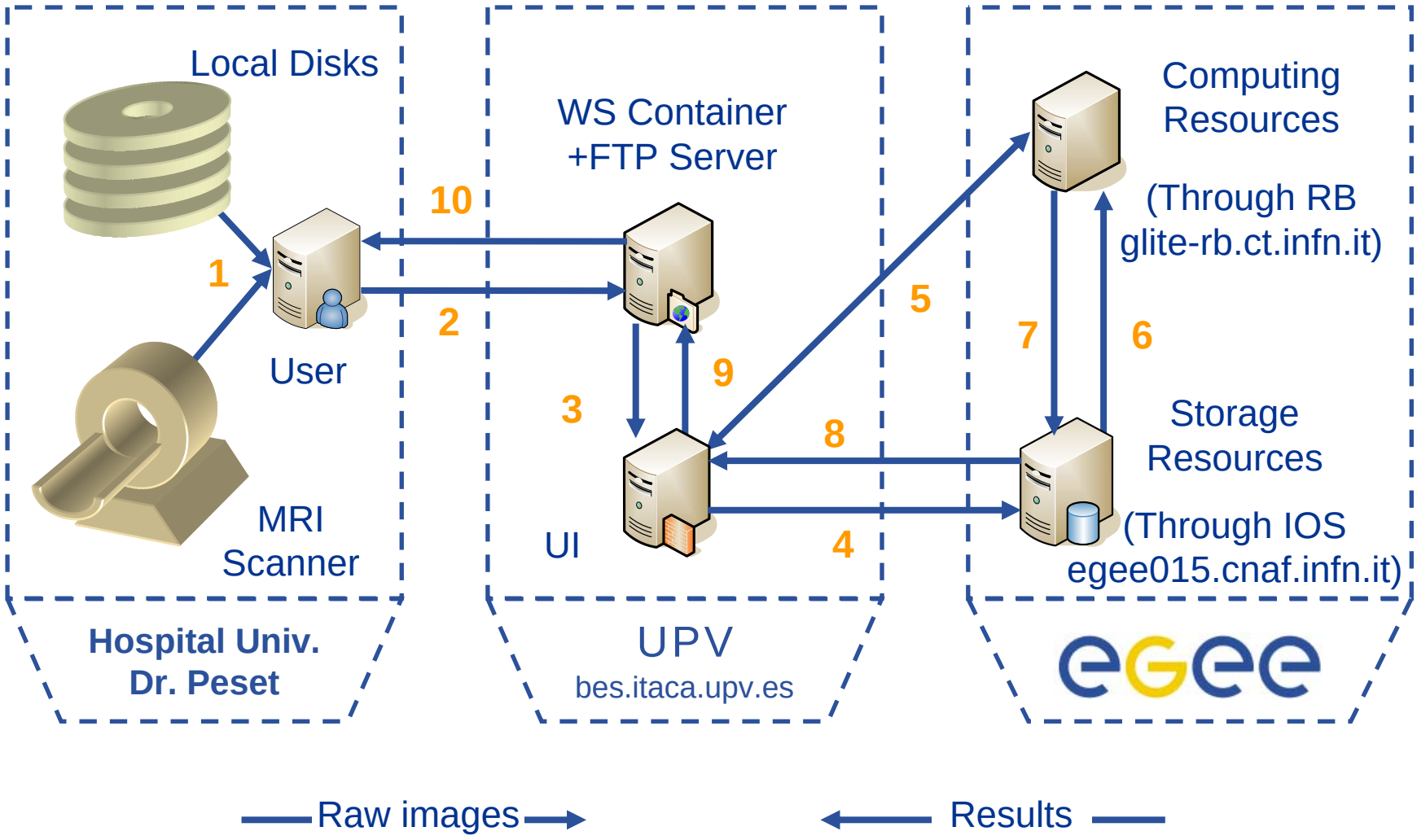
  >> Use a Large Grid Infrastructure
- **Usability**
  - Reduce the Complexity of Grids by Using a Friendly Interface.
  - Provide an Interface Open to its Integration in Other Applications.

  >> Implement a Web-services Based Portal.
- **Security**
  - Deal with the Risks of Using Remote Resources.

  >> Anonymise and Access Control Need for gLite.
- **Reliability**
  - Production Capability.

  >>Provide Intelligence on Selecting the Sites.

Application Structure

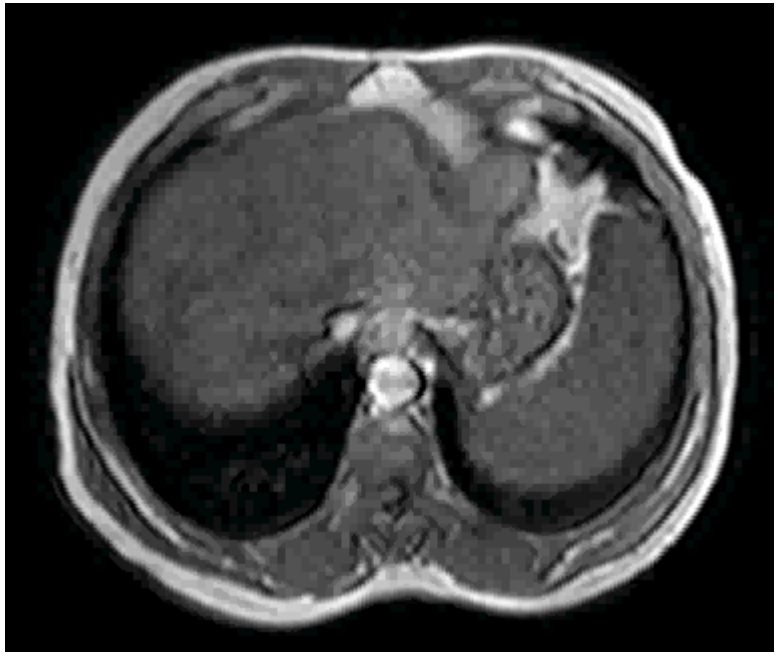


Application Tasks

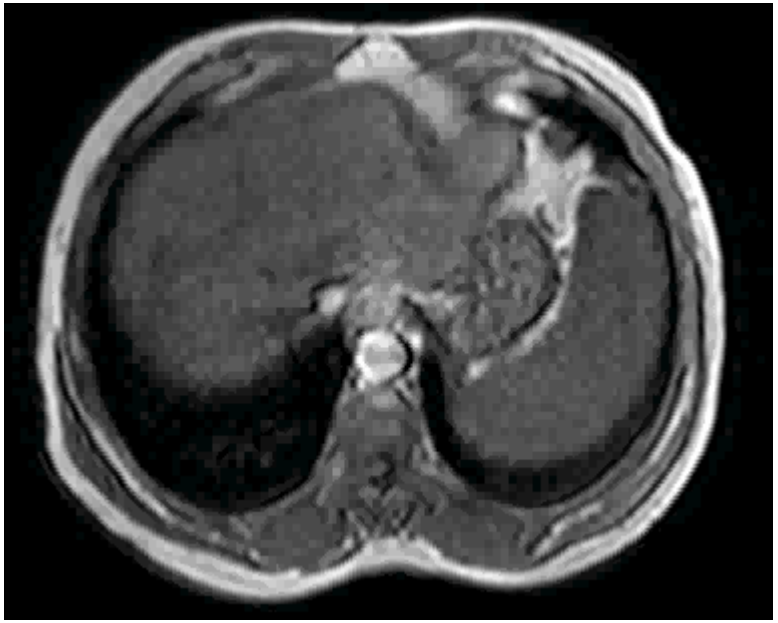
- **A Graphical User Interface has been Created.**
- **The Gui Calls the Web Services to Implement**
  - Creating the Proxy on the Grid.
  - Transferring the data into the Grid Storage Area.
  - Select the ranges of the parameters to test:
    - Maximum Step Length for the Gradient Descent Optimisator.
    - Maximum Number of Iterations for the Optimiser.
    - Initial Scaling Factor.
    - Initial Angle for Deformation.
  - Create the JDLs and Define the Arguments for the Scripts of Each Job
    - One Job per Registration and per Combination of Parameters.
  - Monitoring of the Evolution of a Set of Jobs.
  - Downloading the Output of all the Jobs in a Group with a Single Click.

Results: Co-registration

Before Co-registration

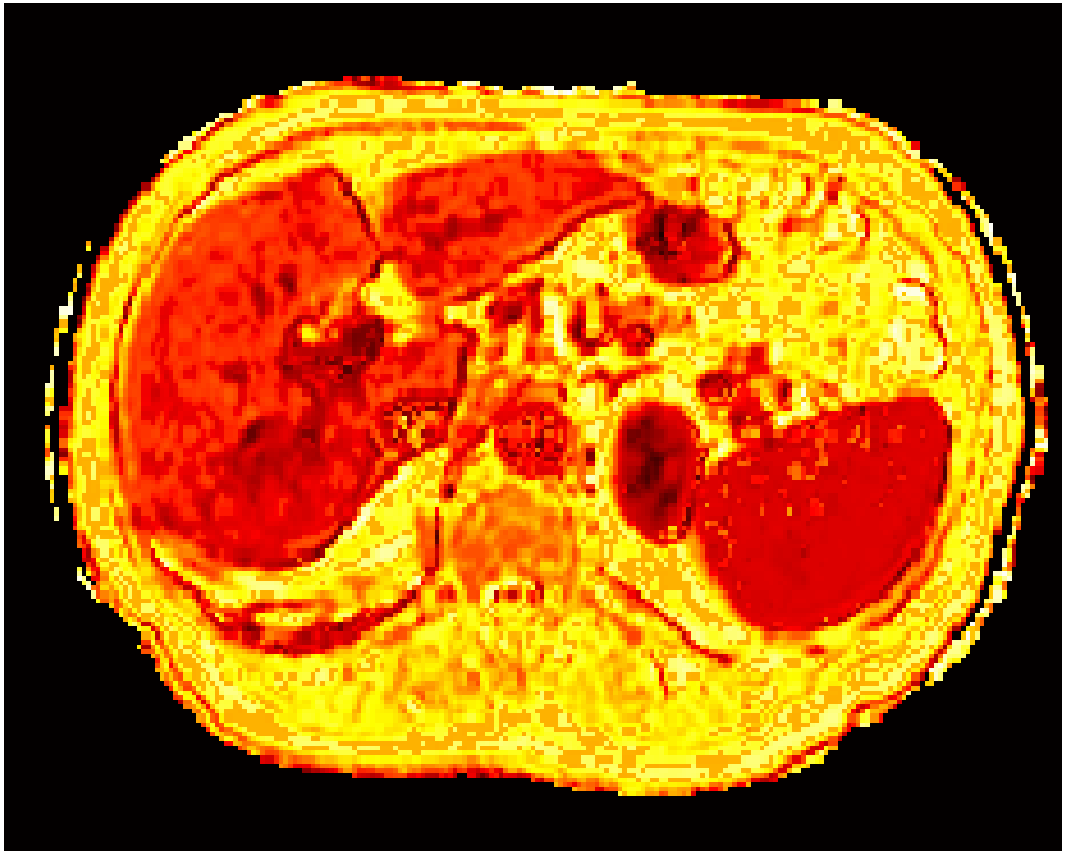


After Co-registration



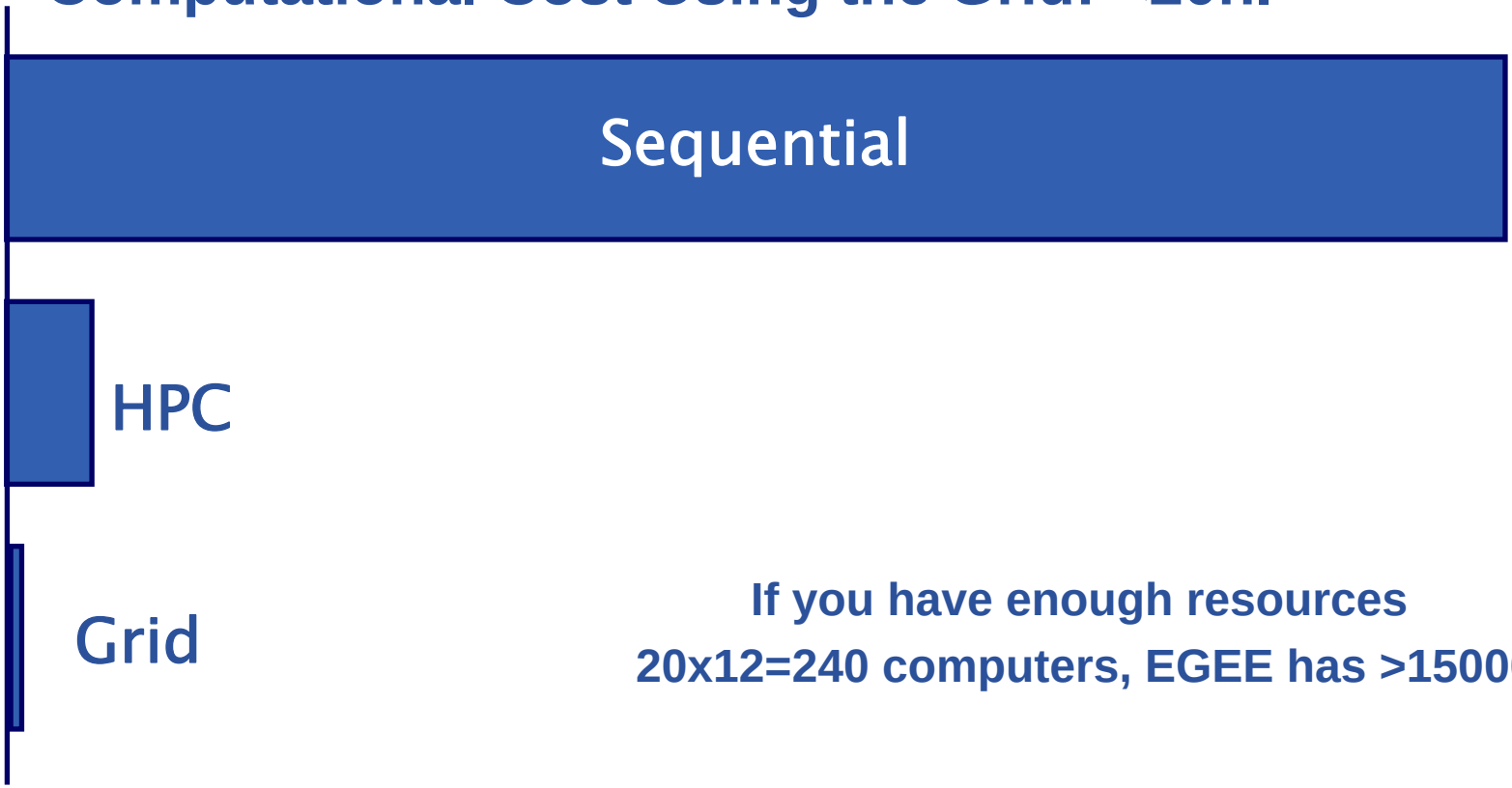
Results: Parametrical Images

- The Evolution of the Concentration of Contrast on Each 3D Pixel (Voxel) Defines the K-Coefficients.
- Klo (Output on the Liver) Gives the Image:



Results: Performance

- **Cost of 20 Patients: 2623h (Co-registration + Parametric Image).**
- **Cost using a 20-procs Computing Farm: 146h.**
- **Computational Cost Using the Grid: <20h.**



If you have enough resources
20x12=240 computers, EGEE has >15000

Conclusions and Future Plans

- **The problem has a Clear Need for the grid**
  - The Computing Requirements for a Reduced Clinical Trial of 20 Patients Exceeds the Conventional Computational Capabilities of Either a Hospital or a Research Team.
  - There is a Need for a Production Platform 24x7 (users).
  - Added Value of gLite: Need for Access Control in Data and Metadata.
- **The Grid Resources can Easily be Exploited from any Computer Through a Web Service.**
- **Future Plans**
  - Short term: Extend the Clinical Trial up to 50 Patients (this will Require About 4000 CPU hours).
  - Extension to Other Areas
    - The Analysis of Diffusion and Correlation to Vessel Growing has Potential Impact in Most Other Tumoral Localisations.
    - It Also has Relevance in the Study of Adverse Reaction in Infertility Treatments.

More Information

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