Comparison of European Grid Projects

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Project:

GEMSS

Area:

Applications

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1. Introduction

1.1. Objective and Structure

This document is one of thirteen templates that have common goal to gather information related to main European Grid Projects in order to make their accurate comparison in the framework of GRIDSTART initiative. We believe that the participation of particular projects members in preparation of this document will allow comparing all activities in a credible and exhaustive way.

The proposed structure of the description consists of two parts. The former is concerned with the general overview and architecture together with the contents of layers (the first template). The latter includes the main components of the Grid infrastructure (remaining 12 templates). Since information regarding the project architecture is to be quite general, more detailed description should be provided in the review of the main aspects of the Grid infrastructure. In order to prepare uniform description for each project, we identify the important issues that have to, should or can be included into particular components. Common issues for all components and these specific for this component are briefly described in the next section.

We ask you to proceed according to this schema. However, a feedback is obviously welcome. For some projects the document has been partially completed on the basis of descriptions found at the official web pages. In this case, we ask you to revise already filled in sections, correct and complete them if necessary.

You should take into consideration future plans while you fill in particular sections. Actually they are even more important then the current state of the project components. If you are not going to design some elements in the scope of the project at all, please, note it in the proper section.

1.2. Uniform description

All the descriptions of the Grid infrastructure components are divided into three parts: **General** section includes main requirements and functionality, **Details** section relates to the issues specific for particular component and **External** defines its connections with other components and users.

As it was mentioned above, some of the issues are common for all components or at least repeat for many of them. Such issues, appearing for many or even all areas are shortly characterized below.

In **<u>General</u>** section:

Main requirements determine the objectives and requirements of the workpackage or the software module responsible for the design of functionality related to the particular domain of the Grid infrastructure.

Functionality contains a set of operations provided by the project in the given area.

In **<u>External</u>** section:

Interfaces define services, SDKs, APIs and so forth which can be used in order to access the functionality of the component.

Low level Grid middleware is the middleware providing basic Grid functionality as for example Globus or UNICORE.

Relations with other components determine components that utilize or are utilized by component being described as well as data and information flow between them.

Issues that are specific for this particular domain of the Grid infrastructure are presented in the sequel. Some of them, which we consider to be clear, have been skipped, however, if they turn out to be vague, please, contact the authors of this document (ariel@man.poznan.pl).

The **Details** section should contain a description of applications being developed or Grid-enabled in the scope of the project.

These applications should be listed in the **Applications** paragraph.

Application domain defines application kind in the context of its purpose. We consider domains such as simulation, visualization, optimization, data-mining etc.

On the other hand **application type** take into account its architecture, for example, MPI, workflow, massively parallel etc.

Potential users may include scientists, engineers, administrators or others.

Application scenarios describe possible manners of computer programs utilization. They may contain the methods for application running, controlling and monitoring and after the application has been finished, the methods for getting results and paying for use.

2. Applications

2.1. General

The Medical Service Applications provide simulation and image processing services via the GEMSS test-bed. The components cover a range of different Grid-requirements and complexity. This document can only present a snapshot of the current situation. The GEMSS design is still being discussed by the partners and not all issues have been finalized yet.

- **Applications**

  Medical Service Applications
  - Maxillo-facial surgery simulation
  - Quasi real-time neurosurgery support by non-linear registration
  - Near real-time cranial radiosurgery simulation
  - Inhaled drug delivery simulation
  - Compartment modeling approach for the cardiovascular system
  - Image reconstruction service

- **Main requirements**

  See Deliverable GEMSS-WP1-D1.1

- **Functionality**

  All applications involve several of the following steps:
  - Data acquisition (CT, MRI, SPECT images, or image data bases)
  - Digital model preparation (image pre-processing, segmentation, registration, meshing)
  - Mesh processing (quality checking, topological checking, boundary conditions for simulation)
  - 3D iterative image reconstruction from projections
  - Simulation (finite element modeling, computational fluid dynamics)

- Visualisation, analysis, result reporting

2.2. Details

- **Application domain**

Medical application services:

Maxillo-facial surgery simulation (GEMSS-WP4-ST4.1)

This subtask is concerned with pre-operative planning for maxillofacial surgery. The surgery relies on distractors attached to a head mounted halo frame that can be used to exert forces on the midface and change its shape. Tools for computing the facial outcome are based on the Finite Element Method (FEM). Pre-operative planning involves 'playing' with different what-if scenarios, and fast response times are required if the tool is to be acceptable in a clinical planning environment. The Grid will be used to compute results of sufficient accuracy and reliability for clinical use, using an anatomically detailed Finite Element model. Pre- and post-processing tools for image registration, segmentation, mesh manipulation (i.e. halo positioning, bone cutting) and visualisation will be created. Performance comparisons with other compute scenarios will be undertaken.

Quasi real-time Neurosurgery support by non-linear image registration (GEMSS-WP4-ST4.2)

Assistance for image-guided surgical planning by correction of the brain shift phenomenon is the focus of this subtask. The occurrence of surgically induced deformations invalidates positional information about functionally relevant areas acquired from functional MRI (fMRI) data. This problem is addressed by non-linear registration of pre-operative fMR images to intra-operative MRI, or to intra-operative 3D ultrasound data. The current time taken to perform the brain shift correction is about 4 h (Intel Pentium III, single processor), but to be useful in surgical intervention require a maximum processing time of approx. 10 min. Reduced computation time is the role of the Grid, and the registration procedure is suited to this environment since it is readily parallelisable on shared or distributed memory HPC platforms. Performance comparisons with other compute scenarios will be undertaken.

Near real-time Cranial Radiosurgery Simulation (GEMSS-WP4-ST4.3)

This sub task is concerned with a Monte Carlo provision for radiosurgery treatment planning. Accurate focusing of radiation to the treatment site requires a combination of stereotactic localisation and accurate modeling of the radiation dose distribution within the head. The best description of the radiation distribution can be obtained using complex, compute intense Monte-Carlo computer simulations. The need to treat patients as soon as possible after the stereotactic frame is fitted means that rapid computations of these distributions are needed. The use of an efficient parallel Monte-Carlo code running on the Grid will enable high accuracy treatments to be planned and executed within existing time constraints. The accuracy of the treatment plans and the response time of the GRID system will be evaluated.

Inhaled Drug Delivery Simulation (GEMSS-WP4-ST4.4)

This component of GEMSS is a comprehensive simulation tool for the study of new lung treatments and drug delivery to the lungs. It involves a respiratory simulation that integrates medical images, mesh generation, Computational Fluid Dynamics (CFD), compartment modelling of the lungs, and the simulation of inhalation devices. The fluid dynamics elements are very computationally demanding and enable the simulation to derive significant benefit from the Grid. The simulation results are used to inform the user of the requirements for targeted delivery of medication to the lung and systemic circulation.

Compartmental modeling approach for the Cardiovascular System (GEMSS-WP4-ST4.5)

Simulation of the cardiovascular system is a valuable tool in the development of prostheses. Its role in surgical planning offers the opportunity to answer 'what if' questions. There is a need for improved description of boundary conditions. Specification of this Grid compliant simulation tool includes description of the delivery modality for the segmentation and integrated compartmental tools. Mesh generation software applied to the cardiovascular environment will be exercised, and appropriate boundary condition descriptors for the interface between fully three-dimensional and lower level compartments will be produced and integrated into the software environment. Numerical results for system simulations will be compared with *in vitro* and *in vivo* data

Image reconstruction service (GEMSS-WP4-ST4.6)

Visualisation of the distribution of radio-pharmaceuticals by Single Photon Emission Computed Tomography provides valuable complementary information to the representation of anatomy from high-resolution imaging modalities such as x-ray CT and magnetic resonance imaging. Modern fully 3D iterative reconstruction algorithms provide enhanced image reconstruction for the whole image volume, by considering principal 3D effects of data acquisition. Accurate design of the system matrix based on empirical calibration data, allows inherent correction of spatially invariant line of response function, and first order scatter correction. In this subtask, Grid technology will be employed to enable the use of advanced 3D image reconstruction software for improved healthcare within a clinical environment by relying on transparent access to remote parallel computing hardware. The work will focus on adapting current algorithms to meet the requirements of the Grid. In this context, the reconstruction service offers great potential for integration into a tele-consulting environment.

- **Application type (architecture)**
  See GEMSS-WP1-D1.2

- **Potential users**
  Four distinct user types, each with their own individual application end-user characteristics:
    - Industrial product development, possibly supported by engineering consultants.
    - Clinical treatment planning and outcome prediction for individual patients.
    - Education and training of medical practitioners and other staff.

- Research to support development and validation of core applications.

- **Hardware requirements**
  See GEMSS-WP1-D1.1

  Computational power

  Memory

  Storage capacity

  Scalability

  Other

- **Application scenarios**
  See GEMSS-WP1-ST1.1
  The potential users outlined above require different exploitation paths (in terms of technical and business opportunities) within GEMSS. Each has different access requirements and different expectations for short- and long-term payback from its usage:
  - *Engineering* and industrial consultancy users may seek rapid financial return from the use of GEMSS. These users are familiar with engineering software and simulation, are often expert users, and are already aware of the benefits in the product design cycle.
  - *Clinical* users hope to see improved treatment for their patients, but are unlikely to experience cost savings directly as a result. Since clinicians are spenders rather than income generators, the challenge will be to justify increased costs per patient to pay for Grid-accessible decision support tools, in terms of the wider socio-economic benefits achieved through better treatment.
  - *Educational* users can benefit from improved understanding generated by the facility to answer 'what if' questions in a model environment, or from using the environment for training or evaluation.
  - *Research* users will pay for the service only indirectly, probably through external funding. Nevertheless they are an important category of user because they provide the validation and credibility for the application, as well as being the primary developers of new functionality. There is often overlap between research and industrial or clinical users.

  Running

  Controlling

  Monitoring

Obtaining results

Charging

2.3.External

- **Utilization of components**