GRID INFRASTRUCTURE FOR SATELLITE DATA PROCESSING IN UKRAINE

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Abstract. In this paper conceptual foundations for the development of Grid systems that aimed for satellite data processing are discussed. The state of the art of development of such Grid systems is analyzed, and a model of Grid system for satellite data processing is proposed. An experience obtained within the development of the Grid system for satellite data processing in the Space Research Institute of NASU-NSAU is discussed.

Keywords: Grid system, satellite data processing, Grid services.

ACM Classification Keywords: H.3.4 Systems and Software - Distributed systems, H.3.3 Information Search and Retrieval.

1 Introduction

Grid systems, originated by Ian Foster [[1], are becoming standard solutions for enabling remote computations execution and distributed data access and processing in environments of the different level of scalability.

The aim of Grid system could be formulated as connecting data, processing powers and algorithms that distributed over the network for solving particular problems. Grid system should be universal up to some degree, so these problems should not be hardcoded during its development. Instead, a set of problems being solved in a Grid environment must be open for modifications and addition of new ones. This goal is achieved by introducing standard interfaces for communicating between different kinds of Grid resources and clients.

Space agencies all over the world are successfully working on development of Grid technology for their application areas. This is due to the fact that Earth observation (EO) domain is characterized by the acquisition of large amounts of data from satellites and distributed nature of data. Furthermore, the single EO product and the data after its initial processing may easily exceed the gigabyte size. Thus, problems of storing, indexing for quick retrieval on application's demand as well as distributed computing arise within the above mentioned area. Grid technology can provide comprehensive solutions for this problem.

In this paper a brief overview of Grid systems for satellite data processing is given. Common approaches and conceptual foundations of development of Earth Observation Grid system are defined. A model of Grid system for satellite data processing is proposed and verified based on a test-bed of Grid system for satellite data processing that was developed in the Space Research Institute of the National Academy of Sciences of Ukraine and the National Space Agency of Ukraine.

2 Overview of Grid Systems for Satellite Data Processing

Nowadays Grid technology is widely applied for the solution of various problems in many domains [[2]. These applications span a wide spectrum. In this section we give a brief overview of Grid systems that are used for satellite data processing.

Earth Science GRID on Demand project [http://eogrid.esrin.esa.int/] is being developed by European Space Agency (ESA) and European Space Research Institute (ESRIN). GRID is considered as a comfortable "open platform" for handling computing resources, data, tools, etc., and not limited to only high performing computing. Online access to different data is enabled within this project, in particular to data provided by various instruments of Envisat satellite [http://envisat.esa.int/], the SEVIRI instrument onboard MSG (the Meteosat Second Generation) satellite, ozone profiles derived from GOME instrument, etc. One of the most important applications is the analysis of long-term data. For example, the analysis of 8 years of GOME on-board temperatures (overall 525 Gb of data) took less than 2 days on 40 computer elements of ESRIN "Grid-on-demand" structure (overall 38460 files were processed).

Grid Web Portal provides access to the "Grid-on-demand" [http://eogrid.esrin.esa.int/] resources enabling:

— Personal certification

— Time /space selection of data, directly from the ESA catalogue

— Data transfer from ESA data storages

— Job selection, launching and live status

— Visualization in OpenGIS Web Map and Google Earth

— Access to user products and documentation

Nowadays “Grid-on-demand” infrastructure consists of more than 150 working nodes with ability to store and handle of about 70 Gb of data. As middleware Globus Toolkit 2.4 and LCG/EGEE components are being used.

Japan Aerospace eXploration Agency (JAXA) [[3] and KEIO University started to establish “Digital Asia” system aimed at semi-real time data processing and analyzing. They use GRID environment to accumulate knowledge and know-how to process remote sensing data. The problems of radiometric rectification and composition of remotely sensed data are being solved.

National Aeronautics and Space Administration (NASA) have created Information Power Grid (IPG) [[4] targeting an operational Grid environment incorporating major computing and data resources at multiple NASA sites in order to provide an infrastructure capable of routinely addressing larger scale, more diverse, and more transient problems than is possible today. One of the problems being solved is development of techniques for satellite data fusion. Nowadays IPG have approximately 600 CPU nodes of Computing resources and 30-100 Terabytes of archival information/data storage resources.

Spatial Information Grid (SIG), a research project supported by 863 projects of China government, is a series of special grid researches in the filed of Earth Observation. SIG has been designed to be the tested of grid middleware research and grid-enable spatial information services and applications. There are 12 data centers have been involved SIG. The Web Portal has been developed in order to provide access to SIG resources (http://159.226.224.52:6140/Grid/application/index_en.jsp). This portal enables geo-data discover and processing, work monitoring, and grid resources (all service/job/node etc.) management.

3 Why EO Domain requires Grid

In particular, EO domain is characterized by the acquisition of large amounts of data from satellites. For example, an image acquired from ETM+ instrument from the Landsat-7 satellite is approximately 700 megabytes in size. NASA is planning to launch National Polar-orbiting Operational Environmental Satellite System (NPOESS) project [[5] that in 5 years will generate approximately 1 petabytes of information.

In general EO domain is characterized by:

— large amounts of data acquired from different satellites in different spectral bands that need to be integrated with aerial and in-situ components and maps;

— thematic problems solving require the use of data from multiple sources which in turn leads to the need of use complex data fusion and data mining techniques;

— long-term archives need to be created with uniform access to them.

To enable processing and management of such volumes of data sets and information flows an appropriate infrastructure is needed that will support the following functionality:

— access to distributed resources (data/services/network/computing/storage);

— high flexibility, to foster data fusion and assimilation (meteo, models, global changes, etc.);

— portal enabling easy and homogeneous accessibility;

— virtual organisation (VO) Management;

— collaborative work (e.g. sharing of data sources, tools, means, models, algorithms);

— seamless integration of resources and processes;

— allow processing of large historical archives;

— avoid unauthorised access to/use of resources.

Grid technology is an appropriate solution for solving such kind of problems.

4 The Architecture of Systems for Satellite Data Processing

Based on the existing systems and the systems that are currently being developed, it is possible to identify principal components (sub-systems) and informational flows within a system for satellite data processing (Fig. 1).

Data Storage Sub-System is intended for gathering data from multiple sources, i.e. aerial and space-borne data, in-situ data, etc. Usually, the storage system is organized as multi-layer system each level being characterized by different frequencies of data use. We will consider three-level architecture that consists of an operational archive, a short-term data archive, and a long-time archive. The operational archive contains information that was obtained recently, and there is a higher possibility of accessing this kind of data by users. To store such data hard-discs are usually used enabling minimum access time to data. The short-term archive contains data that were obtained weeks or some months ago. To store these data tape-drives are used. The long-term archive contains data obtained years ago. In some cases such kind of archives can be not automated. They can also use high level of data compression and slow recorders. Time access to these archives can be of hours or days. Such three-level architecture of data storage system is implemented in archives of NASA (USA), DLR (Germany), JAXA (Japan). Two-level architecture is used in the State Research & Productive Center "Pryroda" (Ukraine).

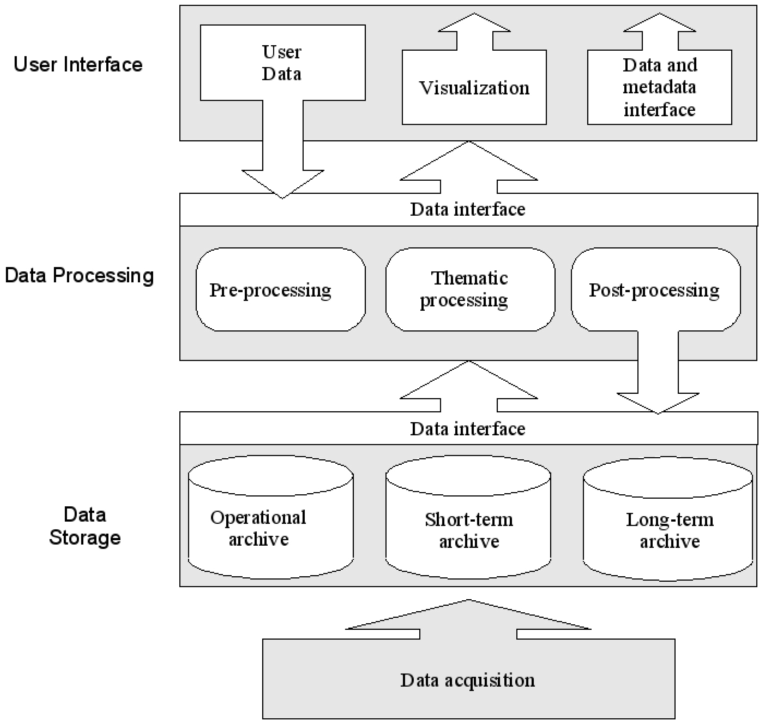

Fig. 1. Three-level architecture of system for satellite data processing

Data Processing Sub-System is intended for data pre-processing (e.g. radiometric and geometric correction of space images, filtering, etc.) and thematic problems solving based on different models and data integration from multiple sources.

User Interface Sub-System is a front-end component that allows end-users to interact with the system. This system is intended for delivering products and services (e.g. raw data and different levels of processed data delivery) to end-users on regular basis or based on their request.

5 Grid Infrastructure for Satellite Data Processing in Space Research Institute of NASU-NSAU

5.1 Grid Infrastructure

A Grid system for satellite data processing that integrates resources of the Space Research Institute of NASU-NSAU, the Institute of Cybernetics of NASU, and the State Research & Productive Center "Pryroda" has been developed. The Grid system consists of two computational SCIT-clusters (the Institute of Cybernetics), a cluster of the Space Research Institute, and an archive of the Meteosat satellite images acquiring from the data center "Pryroda". The developed infrastructure also includes works-stations and network data storage elements. Figure 2 illustrates the overall system architecture.

The developed Grid system provides both informational and computational resources of Space Research Institute and Institute of Cybernetics. The computational resources compromise SCIT-1 (48 processors Intel Xeon) and SCIT-2 (64 processors Intel Itanium2) clusters belonging to the Institute of Cybernetics, and the cluster of the Space Research Institute that is used as testing environment. An interface between Grid system and the computational resources is enabled by Grid Resource Allocation and Management (GRAM) service of Globus

Toolkit 4. GRAM enables translation of RSL-XML format that is used for job submission request in Globus Toolkit 4 in a format of local job scheduling systems (PBS, Condor, LFS, etc.). Globus provides a set of adapters for standard local job scheduling systems, and tools enabling the development of new adapters. The cluster of thq Space Research Institute uses Torque job scheduling system that is PBS-compatible. In contrast, the SCIT-clusters use its own job scheduling system. That is why, a new adapter was developed in order to integrate these resources in the Grid system.

Up to this moment informational resources consist of archive where data acquired from the “Pryroda” centre and from Internet are stored. In the near future we are planning to provide access to the Meteosat Second Generation (MSG) satellite through DVB technology. The developed archive provides FTP and GridFTP interfaces. Currently, a multi-level data access OGSA-DAI interface is under development which will enable complex distributed requests execution and results combination.

A workflow in the Grid system consisting in job submissions, data transfers, proxy certificates renewal, etc., is controlled by scripts, written in Karajan language [[6]. Karajan is developed as workflow description language for Grid environments and possesses many useful features, such as transparent scheduling and job submission, declarative parallelism and easy extendibility by Java.

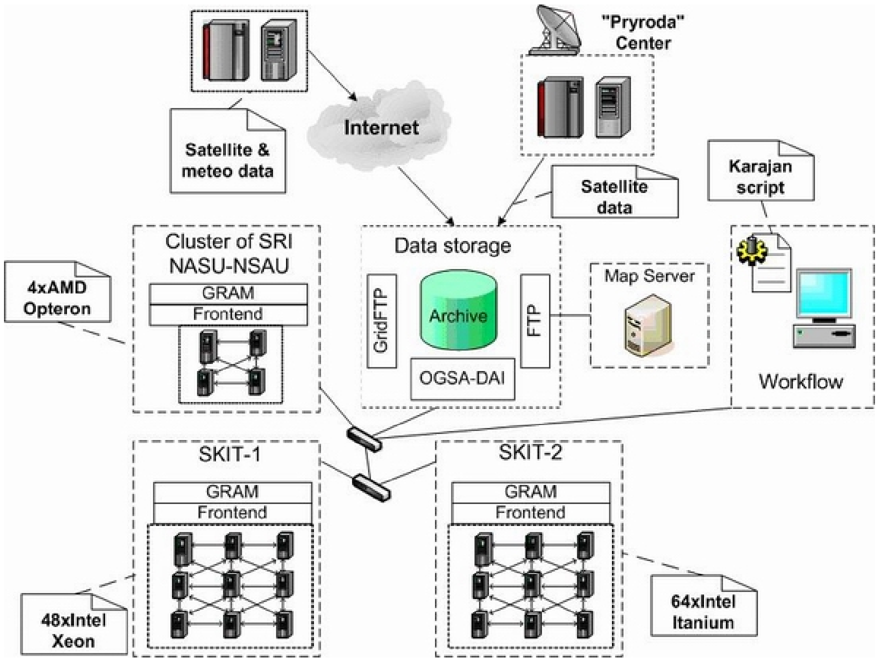

Fig. 2. Current Grid system infrastructure developed in the Space Research Institute of NASU-NSAU

5.2 Applied Services

The developed Grid system is currently used to process various satellite data, such as data acquired by the Meteosat satellite and the MODIS instrument onboard the Terra satellite.

Meteosat data in infrared spectrum are used in order to extract a cloud mask using Markov Random Field segmentation algorithm [[7] (Fig. 3). Image processing is done in three steps. First step consists in image filtration (namely, noise detection and removal) that is done using modified version of median filter [[8]. The second step is the segmentation of the image. The third step is post-processing and preparation of the data to be visualized by a map-server. The last step includes geo-reference of raw image and cloud mask, images re-projection, cloud boundary transformation in vector format, metadata creation for visualization. All these algorithms are implemented in the form of Web services available on http://www.dos.ikd.kiev.ua.

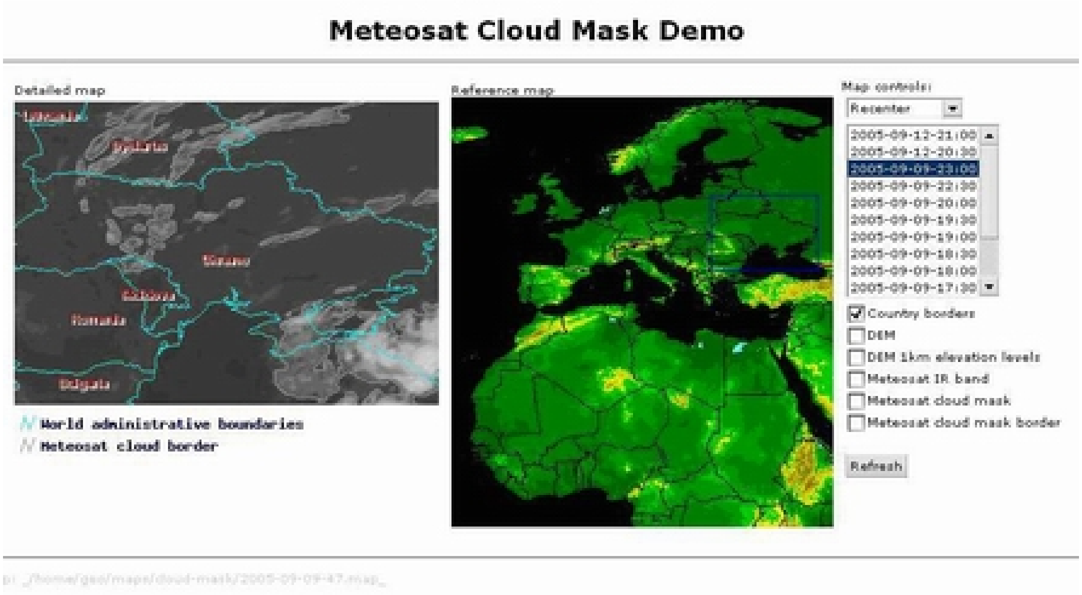

Fig. 3. Visualization of the Meteosat data processing

MODIS data are used for water quality monitoring in Dnieper river estuary. For this problem solving additional information is required such as in-situ measurements and a number of meteorological parameters, which are acquired using meteorological simulations. For this purpose we use WRF (Weather Research & Forecasting) mesoscale meteorological model [[9]. In order to provide initial and boundary conditions we use data produced by global meteorological model, namely Global Forecast System (GFS), and in-situ measurements. Currently we provide every 6 hours 3-day forecasts for the territory of Ukraine (Fig. 4).

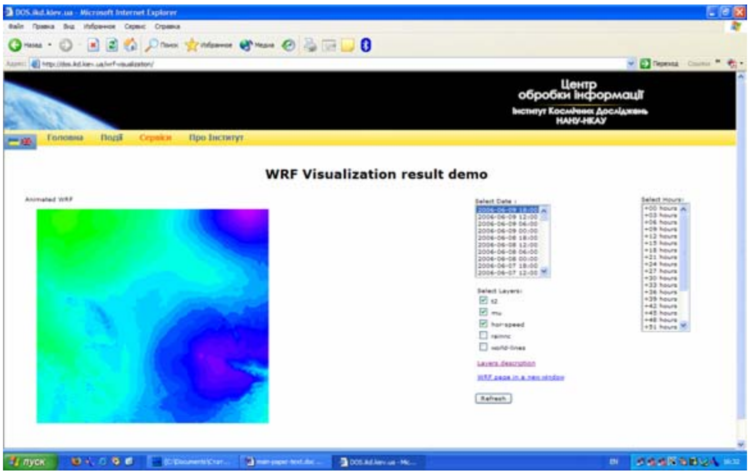

Fig. 4. WRF model visualization

The visualization of resulting data is done with the use of open-source UMN MapServer [[10] software that supports OGC (Open Geospatial Consortium) [[11] standards for spatial data representation.

6 Grid Infrastructure Simulation

Simulation is a common and useful approach for designing complex distributed systems with no exception to Grid. By using models one can decrease TCO (total cost ownership) and save funds on initial installation. Grid systems simulation requires appropriate software usage. The simulation of a Grid testbed in the Space Research Institute was performed by using GridSim [[12] modeling software. Different job scheduling algorithms were analyzed for independent tasks and for data-sharing tasks.

We used GridSim due to its ability to simulate common components of distributed systems such as heterogeneous resources, users, applications and Grid specific components including resource brokers and schedulers for single and multiple administrative domains. Within GridSim package resources can be modeled using time- and space-sharing modes, thus representing workstations, SMP systems and clusters. There are other available Grid simulation packages, such as MicroGrid [[13] and SimGrid [[14]. However, GridSim is more flexible in model design, and does not impose additional requirements, such as Globus Toolkit installation.

Figure 5 illustrates GridSim class diagram where only redefined methods are depicted. New methods were added in order to extend basic GridSim functionality for our simulations. For example, Broker class was extended for Grid infrastructure resource brokering, GRIDTopology class for Grid infrastructure resource description and presentation.

GridSim model of the developed Grid system was used to estimate different job scheduling algorithms. Two common use cases were examined:

— a large group of independent tasks

— a set of tasks that are using common data

The first use case in comparison corresponds to the ideal parallel algorithm. All branches in algorithm can be executed independently in any order. This is a common situation in Monte-Carlo simulation or pixelwise image processing. The problems of scheduling for independent tasks are well investigated [[15]. However, these investigations stay in the field of homogeneous and static heterogeneous distributed computational systems. In turns, dynamic and heterogeneous Grid environments require some modifications to existing scheduling algorithms to take advantage of full utilization of system resources. The proposed algorithm is based on weighted factoring algorithm [[16]. The proposed modifications lie in using dynamic information about system's state to take into account side load on computational resources. Fig. 6a illustrates the performance of modified algorithm (bold line) comparing with traditional weighted factoring (thin line).

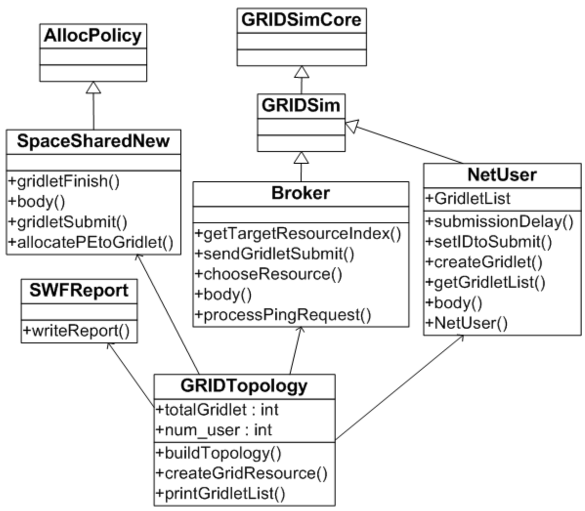

Fig. 5. GridSim Class Diagram

On each iteration of the modified algorithm a set of tasks from the group is assigned to some computational resource. The size of set is estimated as follows:

$$k_i(t) = \alpha\hat{\omega}_i(t)K(t) ,$$

where α is granularity parameter of algorithm, $\hat{\omega}_i(t)$ is the last-known load of computational resource, and $K(t)$ is a number of uncompleted tasks at a given time.

The last-known load $\hat{\omega}_i(t)$ is non-actual by its nature. There are always some lag between present moment and the moment when the information was last updated. The proposed algorithm is quite sensitive to these lags. The performance gain over unmodified version of the algorithm is lost when this parameter grows.

The second use case is a generalization of independent tasks case. The job now consists of tasks that need the same data of considerable size (transfer time of these data is comparable to total task execution time). The data granules are stored on the servers over the network. Each server has some limited bandwidth that separated between different transfers. The developed algorithm introduces fit measure U that shows a quality of assignment of some task to specific resource:

$$U=F+Q.$$

In this expression F is the measure of unbalance and shows how balanced is the use of system resources (computational and network channels) by particular task, and Q is the measure of system resources utilization.

Fig 6b illustrates the performance of developed algorithm (bold line) comparing with random and round-robin schedulers (thin lines).

7 Conclusions

Nowadays, there is a strong interest of scientific communities from different domains in the development of distributed systems for complex problems solving with the use of high-performance computing. Grid represents an appropriate technology that enables integration and management of geographically distributed informational and computational resources. In the last years leading organizations of the NASU are involved in the research and development of Grid-based computing systems, and the first results have been already achieved. In the near future it is planned to integrate Ukrainian resources in a single infrastructure based on the high-speed network. And this infrastructure should be based on recent developments in Grid technology, high-speed networks, and multi-processors platforms.

The Grid infrastructure for satellite data processing that has been developed in the Space Research Institute of NASU-NSAU will become Ukrainian segment of the GEOSS/GMES system.

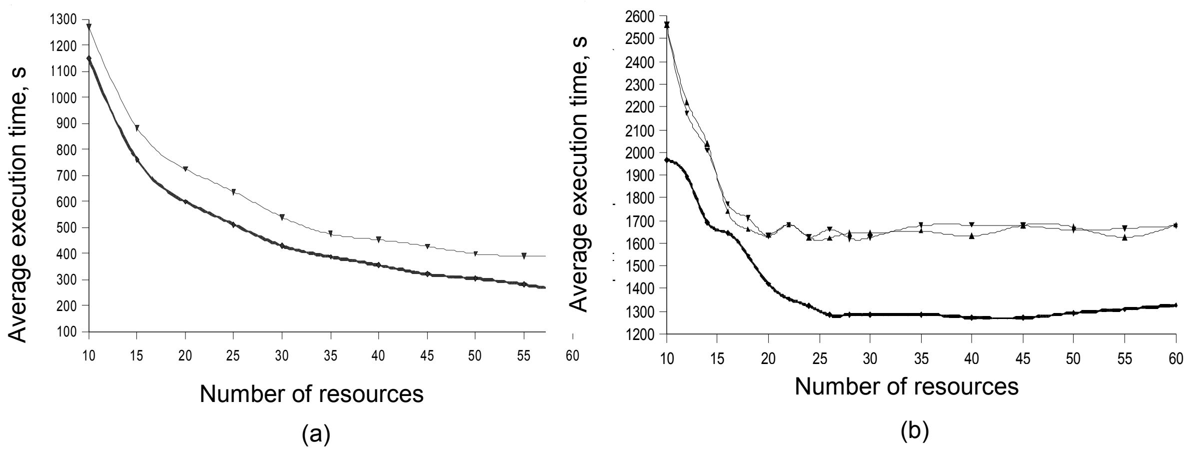

Fig. 6. Average task execution time for independent tasks (a) and data-sharing tasks (b) depending on number of resources in Grid system

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DISTRIBUTED VISUALIZATION SYSTEMS IN REMOTE SENSING DATA PROCESSING GRID

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Abstract: *Implementation of GEOSS/GMES initiative requires creation and integration of service providers, most of which provide geospatial data output from Grid system to interactive user. In this paper approaches of DOS-centers (service providers) integration used in Ukrainian segment of GEOSS/GMES will be considered and template solutions for geospatial data visualization subsystems will be suggested. Developed patterns are implemented in DOS center of Space Research Institute of National Academy of Science of Ukraine and National Space Agency of Ukraine (NASU-NSAU).*

Keywords: *data visualization.*

ACM Classification Keywords: *I.3.2 Graphics Systems - Distributed/network graphics, C.5.0 Computer system implementation – General.*

1 Introduction

Grid systems providing geospatial data are common and usually have complex visualization subsystems. Wide class of typical problems are weather prediction, satellite data processing can be solved in these systems, some of them are solved in DOS center of Space Research Institute of National Academy of NASU-NSAU. Different interfaces and architecture assumptions can make these Grid systems very hard for development and usage, lowering their value as the data source for decision making. Implementation of standards for data visualization, creation of common template solutions will simplify development and increase usability of these systems.