# Seamless Medical Image Processing on the Grid on the Example of Segmentation and Partition of the Airspaces

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***Abstract*—In this paper, we present method to process medical images on the grid in the seamless manner. The only software required on the client side is a web browser which is used to upload files, submit analysis and present results. The proposed solution is easy to deploy and use. It meets user requirements to focus on medical diagnosis rather than technical details. The proposed system is built based on the UNICORE grid middleware including recently developed UNICORE Portal. It is deployed on the Polish National Grid Infrastructure (PL-Grid). Due to the novel grid technology, the whole process is handled in the secure way without additional inconveniences. The developed infrastructure has been used to segment and partition the airspaces in a human head.**

***Keywords–Medical imaging; Segmentation; Grid computing; Web portal.***

## I. INTRODUCTION

The development in the imaging techniques makes analysis of the medical images important part of the medical doctor activities [1]. However, an automatic analysis of the images still cannot be trusted and the process depends on the doctor's experience and knowledge.

The number of different approaches and tools used for processing and analysis of the medical images is large which makes diagnoses more complicated [2]. Progress in the computer technology leads to more and more sophisticated and resources consuming applications. Usage of emerging technologies, such as clouds and grids, leads to the security and privacy issues which have to be addressed properly. In addition, access to the remote resources is still not easy and requires dedicated software which has to be installed on the user's computer.

Based on the grid technology, we have developed solution to process medical images in the seamless manner. With the web browser available on the user's computer it is possible to upload files, submit analysis and present results with no additional software needed. Due to the novel grid technology used, the whole process fulfills security requirements without additional inconveniences.

The analysis is based on the 3D CT images of the patient head. The traditional segmentation of the airspace is difficult and leads to uncertain results [3][4]. Therefore, we rely on the atlas based, non-linear registration paradigm that allows for high level automation of the whole volumetric processing.

The developed IT infrastructure [5][6] has been used to segment and partition the airspaces in a human head. In particular, the detailed analysis of the separated sinuses in terms of their shape, symmetry and anatomy deviations are detected. The computer analysis of the images requires significant computer resources and cannot be performed in the short time using typical desktop or workstation computer.

The paper is organized as follows: in Section II, we present algorithm used to to segment and partition the airspaces in a human head as well as overview of the computational infrastructure. Section III provides description of the grid middleware used. In Section IV the SinusMed application written in the Java language and installed on the high performance computing system together with the portal access is presented. The conclusions are presented in the Section V.

## II. IMPLEMENTATION

To address the problem, we have created a segmented and partitioned atlas model using healthy patient data. The aerial segments were separated using interactive tools with a guidance of skilled throat specialist. For every single patient data, we selected automatically the most suitable data from the series of measurements differing with the volume size and spatial orientation.

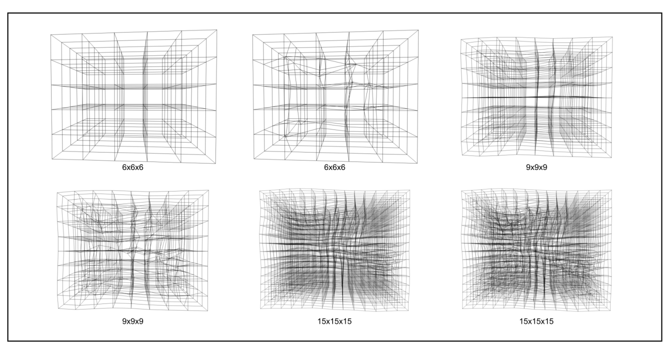


Figure 1. The schematic view on the detection of the airspaces through deformation.

After that, the registration phase of model CT data and selected volume begins. We apply the affine registration followed by the non-linear Free Form Deformation parametrized by B-splines. The resulting deformation field is applied to the

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segmented and labeled sinuses atlas to delineate the proposed partitioning of aerial spaces for a given patient. Due to the significant differences in anatomy, the result is used as a starting point for a final segmentation. The last stage consists of the volumetric tuning of every segment boundary using patients original data. The segmentation process as a sequence of the deformation fields starting form a rough estimate to more detailed approximation is presented in the Figure 1.

The whole process is time consuming. It can take several hours on a typical computer if a high resolution is required. Another problem is access to the atlas data. With the availability of new image data, the atlas can be extended leading to the better quality of the segmentation. This leads to a frequent updates and can be difficult while locally installed software is used. The ultimate solution is to use external resources to perform whole analysis.

Non-linear registration portion of the algorithm is parallelized on the level of optimizing position of a single control points of B-spline grid, with respect to energy function. The main challenge is that multiple threads can't work on a close control points, because each has an impact on energy function in a significant portion of adjacent voxels. In current implementation, the work manager spawns work to separate threads by finding non colliding areas that need to be registered. It is possible to allow slight overlay between these areas, since the effects of deformation by single control point are very slim on edges of these areas. We found that allowing control points to be as close as 3.5 units in index space is suitable. Each thread works locally and tries to minimize local energy function. After receiving results from the thread, the manager tries to allocate new job for that worker. Threads don't need to communicate with each other during local minimization. Spawning jobs and gathering results are the only points where threads communicate with manager.

The presented parallelization strategy does not scale to the larger number of threads. Therefore we are working on a new implementation that will make use of a multiple nodes of the most time consuming registration phase. As more atlas data with variant anatomical structures will be available, it will be natural to process input data against all atlases in parallel. Final result will be constructed from atlas that fits the input the best, i.e. requires the smallest deformation to achieve the same level of energy function.

The CT images uploaded to the remote storage can be analyzed using high performance systems with multiple processors. Such model allows to reduce processing time to several or even single minutes. In addition, the extensive repository of patient data can be built.

Since processing of patient data requires high level of the security and privacy, the grid technology is ultimate choice [5]. The grid middleware allows for an access to the distributed resources with secure manner. The tools vary and depend on the software used. The typical grid middleware has three tier architecture with the client layer exposed to the end user. The technology used ranges from the command line type of access through libraries, graphical clients up to a web interfaces. The web access is particularly important for the medical users, since they are focused on the analysis of the images rather than technical issues.

The web access to the remote resources have been developed by the numerous groups using different technologies, such as web gateways or web portals [7][8][9]. Unfortunately, most of them is complicated and requires extensive software stack. In result they are difficult to install and manage. The extensions such as introduction of new functionality or adoption to new application areas is especially time consuming. The ultimate solution is UNICORE, which provides whole software stack including web interface. What is also important, the UNICORE does not require significant effort to install and maintain.

## III. UNICORE INFRASTRUCTURE

Typical UNICORE [10][11] infrastructure consists of two groups of services. First one contains services UNICORE Registry, UVOS, Service Orchestrator and Workflow Engine. They are run at ICM with redundant instances of Registry and UVOS at WCSS site. Second group contains services which allows access to sites' resources. Those are UNICORE/X and UNICORE TSI together with the UFTPD for fast file transfer.

After UNICORE 7 has been released, there has been started migration to new main attribute source for UNICORE servers. This was mostly because of new features allowing users to access resources without complicated certificate setup. For that reason, new service called Unity IDM [12] was designed and developed. The goal is to replace UVOS in nearest future and to use it as the main authentication and authorization service in PL-Grid for UNICORE users.

The Rich Client based on the Eclipse Rich Client Platform is the main access tool for the users. The Rich Client is easy to install and configure, however for the unexperienced user this task is still too complicated. The UNICORE Portal is the recently added element to the UNICORE portfolio of client applications [13]. It is much different from the other, already existing, client software, as it is using two separate software components to realize the clients functionality: a thin web browser client (UNICORE unaware) and the Portal servlet which serves as a Grid gateway. Such design, typical for the Web applications, brings several challenges: the Portal application has to be used by multiple users simultaneously what requires proper context separation and careful management of resources (disk space, memory) which are much more constrained than in the standalone client case. The UNICORE Portal provides ready to be used interface for a generic jobs. This interface is a web version of the Generic Grid Bean available in the UNICORE Rich Client. The UNICORE portal allows for the development of a domain specific interfaces tuned for the particular use cases. This work still requires programming skills, but is much more easier compare to the other science gateways software stacks.

## IV. RESULTS

The described algorithm for the segmentation of airspaces has been implemented as a SinusMed application written in the Java language and installed on the high performance computing system. It has been parallelized using Java threads which allowed us to reduce computation time from hours to several minutes. Further parallelization is in progress and should lead to reduction of the analysis time to few minutes with hundreds of cores used.

The disk space and computational resources are provided by the Polish National Grid Infrastructure (PL-Grid) [6][14] which is open for research and education usage and is provided to the Polish research community free of charge.

The UNICORE Portal has been installed and integrated with the PL-Grid infrastructure as presented in the Figure 2. In particular, it has been integrated with the Unity authorization and authenticated system. Unity allows its users to enable authentication (or login) to their web services using various protocols, with different configurations for many relaying parties. The authentication can be performed using the built-in, feature-rich users database or can be delegated to one of the supported upstream identity providers (IdPs). The information obtained from the IdPs can be flexibly translated and merged with the local database (if needed) and re-exported using other protocols.

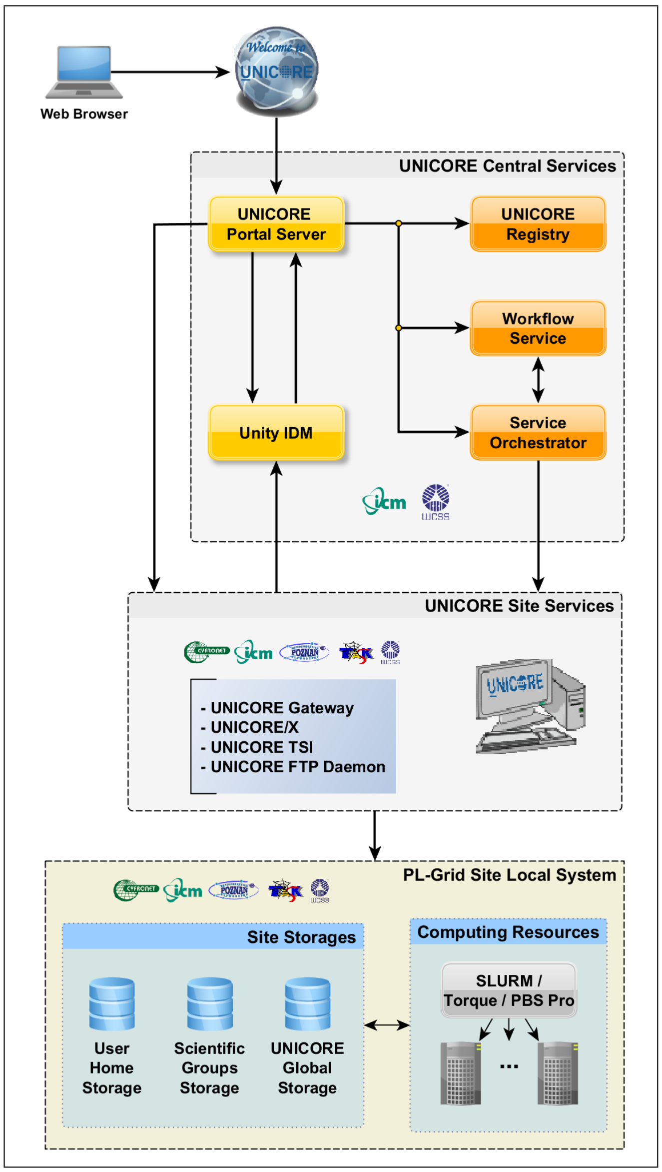


Figure 2. The UNICORE Portal Deployment in the PL-Grid.

In terms of the PL-Grid infrastructure, users using the UNICORE Portal or working with the standalone clients like UCC or URC, may use login and password provided during their registration in the PL-Grid portal. Those credentials are stored using central LDAP server. Unity binds to this server during authentication and reads user attributes and groups. This data is further processed by the Unity using input translation rules. The details of the authorization and authentication process in the PL-Grid are presented in the Figure 3. The main benefit is that user do not have to hassle with the certificates and the communication stays secure and trustworthy which is especially important while processing medical data.

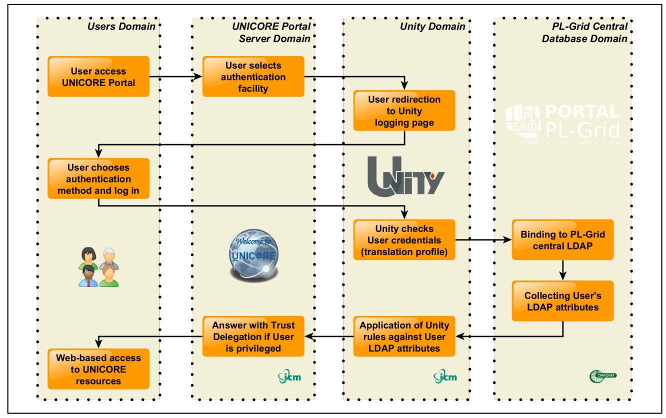


Figure 3. The communication flow between different infrastructure components during user authentication and authorization.

Unity is not yet another bundle of several, coupled together systems. It is a solution built from the ground up. All pieces perfectly fit together. Startup is fast, administration of all parts is performed in the same style and the whole solution is fully web and cloud ready.

Thanks to the the UNICORE Portal solution, user can submit a job, monitor it and see results from all UNICORE clients. Using the portal he can switch to simple mode where jobs for only one application type are displayed in the web browser.

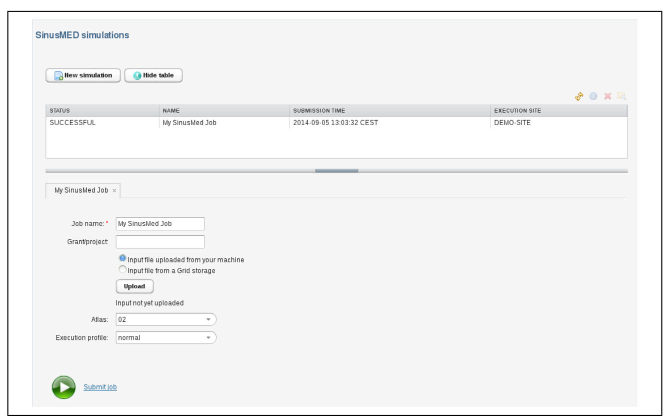


Figure 4. The interface to the SinusMed application: input data for the analysis.

The developed by us SinusMed extension to the UNICORE Portal allows to upload packed images in the DICOM-Dir format and process them on the grid. As presented in the Figure 4, the user has to select the atlas to be used and quality of the results. Than simulation is started using Submit button.

In return, the user obtains set of images with the paranasal sinuses areas marked. He can modify display parameters with the buttons and display different 2D layers with the navigation bar (see Figure 5).

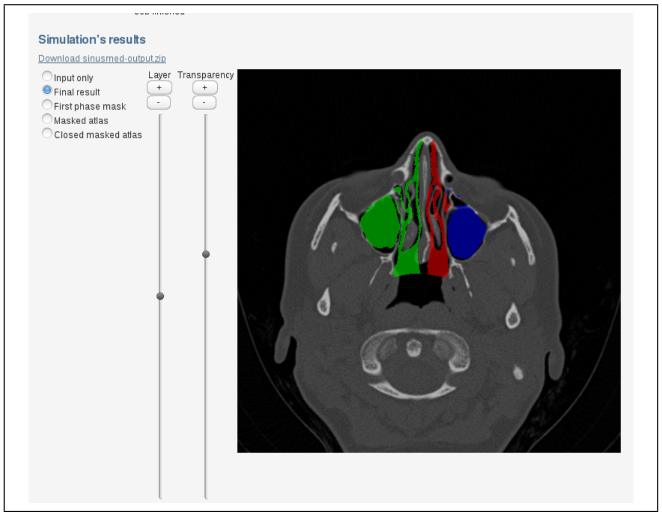


Figure 5. The interface to the SinusMed application deployed in the UNICORE Portal. The results of example analyses are presented.

The images are processed on the grid with the parallel application described above. It produces high quality images and allows for reliable determination of the important regions, their size and volume in the reasonable time. Since SinusMed application is parallelized, it can benefit from the multicore nodes available in the PL-Grid. The same time, the access is simple and no dedicated software is required on the client side.

## V. Conclusions

Presented example clearly shows that grid technology became mature enough to offer reliable, high quality services designed to suit requirements of a different scientific communities. In particular, web interface as well as automation of the processing of selected applications have been developed using UNICORE Portal. In result, the medical doctors can focus on the diagnosis instead of writing complicated scripts, transferring the files and mastering complicated IT infrastructure.

With the UNICORE Portal, creation of the application and domain specific solution become simple and straightforward. The software stack necessary to build full featured gateway is now small and easy to handle. Presented work shows, that based on the UNICORE framework service to support medical diagnosis can be bring to the users.

In the near future, we plan to extend system by additional functionality such as estimation of the key parameters of the segmented areas and extraction of the segmented objects for further processing. The database of the patient data will be used with the extensive search functionality and will be used to improve segmentation results and to aid doctors in the diagnosis process.

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