# SYSTEM FOR STORING AND ANALYZING EXPERIMENTAL MRI/fMRI DATA ON THE HYBRILIT HETEROGENEOUS PLATFORM

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The article presents the first results on the development of an information system on the HybriLIT heterogeneous platform for storing and analyzing data of magnetic resonance imaging (MRI) and functional magnetic resonance imaging (fMRI). The major objective of the given information system is to create a storage for MRI/fMRI data, as well as to automate the processes of its processing and analysis with the possibility of subsequent visualization of the results. To date, a system module for working with MRI/fMRI of the human brain has been developed and is ready for use, and this article describes its architecture. The module will be used, in particular, for organizing practical classes within the training course on neuroimaging. When deploying the corresponding specialized software, the module can also be used to process and analyze MRI/fMRI data of the brain of monkeys, mice and other laboratory animals. The work is performed within collaboration between the Laboratory of Radiation Biology and the Laboratory of Information Technologies at JINR.

Keywords: scientific data analysis, MRI, fMRI, neuroimaging, information system.

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## 1. Introduction

At present, MRI and fMRI are considered the most effective methods of neuroimaging [1]. The modern equipment allows conducting non-invasive experiments of these types for both humans and laboratory animals (monkeys, mice, etc.). The discovery of these methods has provided new opportunities for neurobiologists. In particular, the use of MRI/fMRI methods enables long-term research of the brain, human or laboratory animals. Thus, the task of mastering the skills of performing MRI/fMRI experiments and analyzing the data is actual for the Laboratory of Radiation Biology. For this reason, the Laboratory of Information Technologies has started working on the creation of a system for processing, analyzing, storing and visualizing experimental MRI/fMRI data on the HybriLIT heterogeneous platform [2]. Due to the similarity of data processing procedures of MRI/fMRI of the brain of a human and laboratory animals, the model of the workflow of MRI/fMRI data of the human brain [3] has been taken as a basis. At this stage, the system allows processing MRI/fMRI data of the human brain using the specialized software FreeSurfer and FSL. The module provides the possibility of expanding the functionality by deploying specialized software to process MRI/fMRI data of laboratory animals.

## 2. Workflow of data from MRI/fMRI experiments

During the MRI/fMRI experiment, the tomography signal is sent to the tomography operator's PC, where it is saved as a set of 2D(MRI)/3D(fMRI) DICOM files. The number of files equals to the number of "slices" – brain scans performed during the experiment. A unique number of a specific "slice" contained in the file is assigned to each file, and a metadata block with information about the experiment (data of the experiment, characteristics of the tomography settings, subject data, etc.) is added. This set of 2D/3D DICOM files is then transferred from the tomography operator's PC to other devices for storage and analysis in any convenient way (external drive or online).

Further, to be able to process and analyze 2D/3D DICOM data files using specialized software, this set should be converted into one 3D (MRI)/4D(fMRI) NIFTI file, while separating the metadata into a separate .txt file. Such conversion is carried out using special programs – converters. In our system, for example, the MRI Convert program is used for this purpose. The input is a set of 2D/3D DICOM files, and the output is an 3D/4D NIFTI file and a .txt file. The NIFTI file is used for further processing and analysis using specialized software. The .txt file is stored in the metadata base and enables the identification of the results of NIFTI file analysis with a specific experiment and a subject.

The result of processing and analyzing experimental data contained in the NIFTI file is a set of directories and files of different formats (depending on the selected specialized software). These results can be visualized using special visual editors – viewers (usually, each specialized program has its own viewer). For example, our system allows one to visualize the results of data processing by the FreeSurfer program using the FreeView viewer.

The schematic workflow of fMRI data is illustrated in Figure 1.

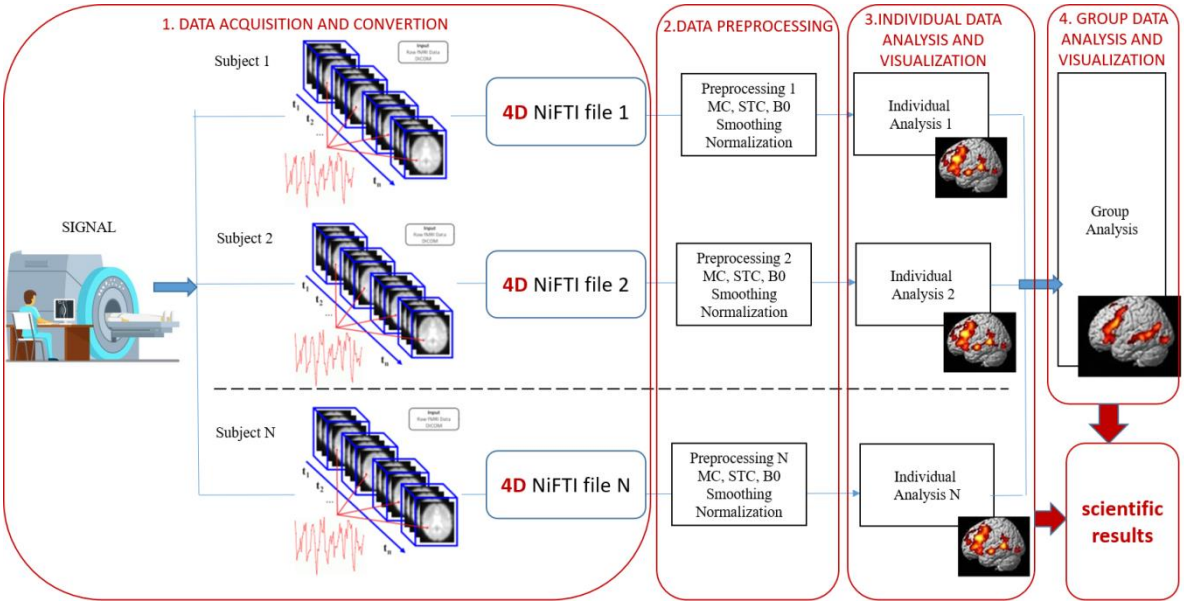


Fig. 1. Dataflow of fMRI processing and analysis

## 3. System on the HybriLIT heterogeneous platform

Within this project, the following software packages have been installed on the HybriLIT heterogeneous platform:

- MRIConvert [4] for converting the NIFTI file from the original set of DICOM files;
- FreeSurfer [5] for NIFTI file processing;
- FSL [6], alternative package for NIFTI file processing;
- FreeView (from the FreeSurfer package) for building images after NIFTI file processing.

All the software has been installed in the network file system such as CernVM File System (cvmfs) [7], and the corresponding modules have been prepared. Work with it is organized via the Modules package [8], using which the user can dynamically change the environment variables of the current session.

The principle of work is as follows, and it is shown in Figure 2:

- the user connects to the HybriLIT heterogeneous platform;
- using the commands of the Modules package, the user connects the required software and works with it interactively;
- when launching calculations via the SLURM scheduler, the user adds a command to connect the module to the script file, and when the task starts, the environment variables are defined on the work node.

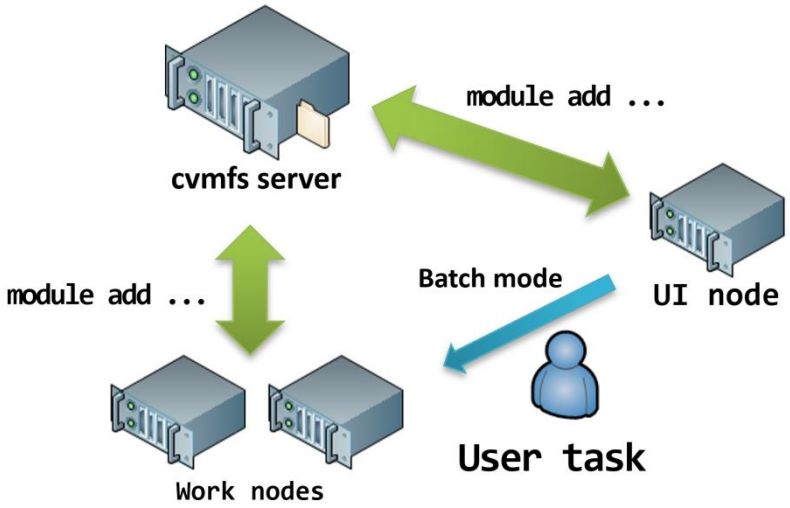


Fig. 2. Principle of working with the cvmfs file system and the Modules package

Figure 3 shows images built in FreeView after processing the initial data.

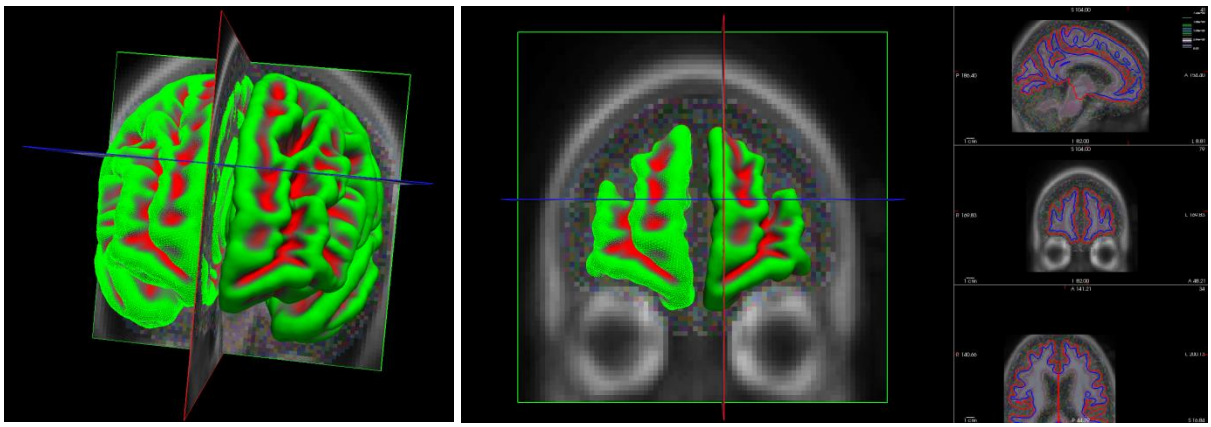

Fig. 3. Images built in FreeView after processing the initial data

Owing to the unified software and information environment on the HybriLIT heterogeneous platform, after debugging the workflow on the education and testing polygon, the user can perform calculations on the "Govorun" supercomputer, making minimal changes to the script files.

## Conclusion

The article describes the first stage of creating an information system for storing, processing, analyzing and visualizing experimental MRI/fMRI data on the HybriLIT heterogeneous platform. The architecture and functionality of the module for processing MRI/fMRI data of the human brain are presented. The module enables the processing of MRI/fMRI data with the most popular neuroimaging tools – FreeSurfer and FSL software, using the resources of the HybriLIT heterogeneous platform and the "Govorun" supercomputer of LIT JINR, Dubna. The module has been verified using real MRI/fMRI data.

The module will serve as a basis for expanding the system by adding functionality to process MRI/fMRI data of the brain of laboratory animals, with the provision of remote access to the system via a web interface. The module will also be used for the practical part of training courses on neuroimaging.

## References

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