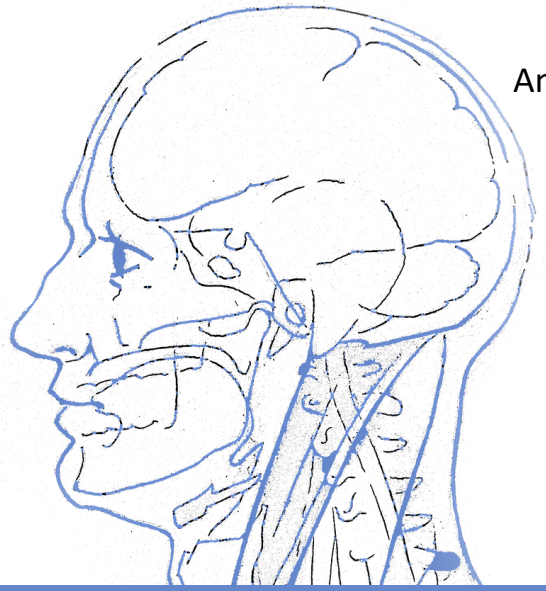
Polygon for visualization of brain computed tomography data

Anikina A.I.[1]

Andreev G.I.[3], Anikin I.V.[2], Belyackov D.V.[1], Grigorov G.G.[3], Kokorev A. A.[1], Streltsova O.I.[1], Zuev M.I.[1].

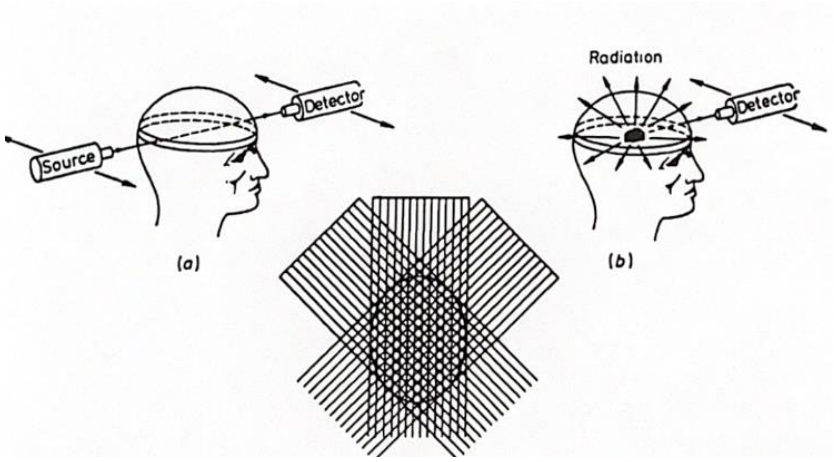
[1] *Meshcheryakov Laboratory of Information Technologies (MLIT, JINR)*
[2] *Bogoliubov Laboratory of Theoretical Physics (BLTP, JINR)*
[3] *Federal Medico-Biological Agency (FMBA)*



The task of image reconstruction

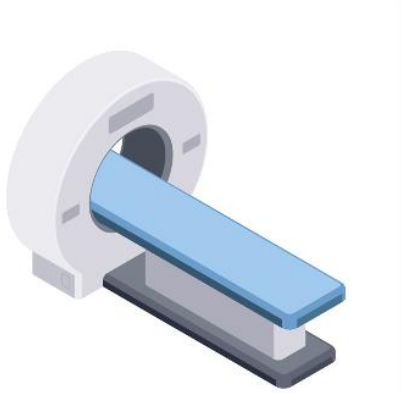
The task is to study the internal structure of subjects without breakings and cutting. The medical CT methods which exist nowadays suffer from many different difficulties (blurred zones on images). The practical application involves the analysis and visualization of CT data including **transmission (a)** and **emission (b)** processes.

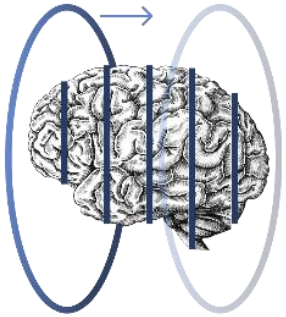
The purpose of project is the development of CT data visualization and possible improvements of CT images which should eliminate the blurred zones.

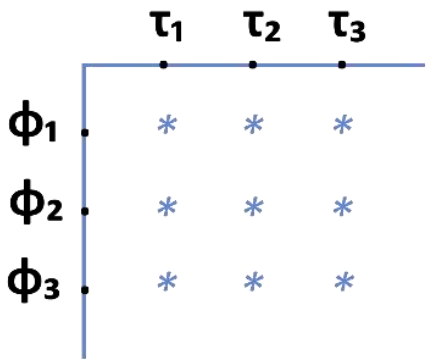


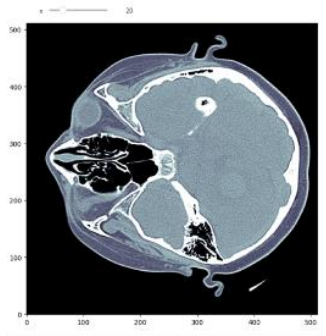
Scheme of reconstruction

CT machine → CT scan → Matrix of intensity ratio → Reconstruction of images









standard method leading the blurred zones

proposed method that should eliminate the blurred zones

In practice, the original slice function differs from the reconstructed forms. Our principal goal is to minimize the mentioned difference using a new mathematical method. To this aim, as a preliminary stage the corresponding polygon of CT-data analysis is planned to be created.

CT data workflow

Input data

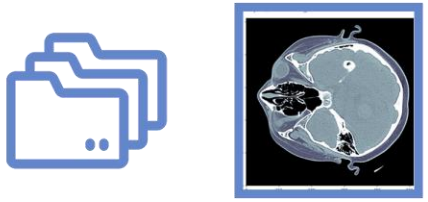
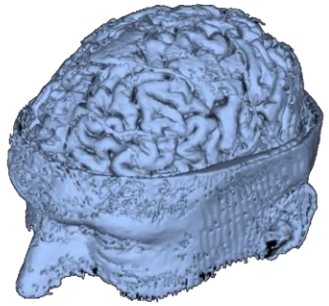


Image preprocessing

- Noise reduction
- Contrast enhancement
- Segmentation

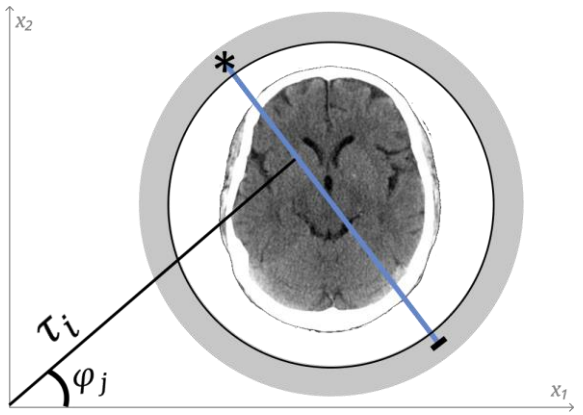
Visualization



The standard process of reconstruction

Let $f(\vec{x}; x_{3_k})$ be the original outset function that describes the given slice of the scanned object.

$$f_R^{st.}(\vec{x}; x_{3_k}) = \sum_{i=1}^{N}\sum_{j=1}^{M} \Delta\tau_i \Delta\varphi_j W_S(\tau_i, \varphi_j)\left[ln\ \frac{I}{I_0}(\tau, \varphi; \vec{x}, x_{3_k})\right]_{k;i,j}$$,where



$f_R^{st.}(\vec{x}; x_{3_k})$ is the reconstructed function; $\ln \frac{I}{I_0}(\tau, \varphi; \vec{x}, x_{3_k})$ gives the intensity ratio of incoming and outgoing X-rays; $W_S(\tau_i, \varphi_j)$ is the weight function of the standard procedure.

The problem of reconstruction: $f_R^{st.}(\vec{x}; x_{3_k}) \nsim f(\vec{x}; x_{3_k})$

The proposed approach

$$f_R^{prop.}(\vec{x}; x_{3_k}) = \sum_{i=1}^{N}\sum_{j=1}^{M} \Delta\tau_i \Delta\varphi_j \{W_S(\tau_i, \varphi_j) + W_A(\tau_i, \varphi_j)\}\left[ln\ \frac{I}{I_0}(\tau, \varphi; \vec{x}, x_{3_k})\right]_{k;i,j},$$

where $W_A(\tau_i, \varphi_j)$ is the weight function which reflects the extended and improved method of reconstruction.

The **principal aim** is to obtain that

$$f_R^{prop.}(\vec{x}; x_{3_k}) \sim f(\vec{x}; x_{3_k})$$

I. V. Anikin, "Universal inverse Radon transforms: Complexity of Radon transforms and the hybrid functions," [arXiv:2506.18911 [math.FA]];
I. V. Anikin, "Universal inverse Radon transforms: Inhomogeneity, angular restrictions and boundary," Mod. Phys. Lett. A (in press) [arXiv:2504.01744 [math.CA]]
I. V. Anikin and X. Chen, "Inverse Radon transforms: Analytical and Tikhonov-like regularizations of inversion," Mod. Phys. Lett. A 39, no.38, 2450181 (2024) [arXiv:2405.14897 [physics.comp-ph]].

The ML/DL/HPC ecosystem

Component for educational purposes (without GPUs)

For teaching students
https://studhub1.jinr.ru

For conducting workshops within the framework of JINR scientific events
https://studhub2.jinr.ru
https://studhub3.jinr.ru

Component for carrying out resource-intensive computations (with GPUs)

https://jhub1.jinr.ru
https://jhub2.jinr.ru

HPC component for scientific projects (with installed specialized libraries)

BioProject services
https://cell.jinr.ru
https://mostlit.jinr.ru
https://bio-dashboards.jinr.ru/morris

CVAT services
https://159.93.36.88:8080
https://159.93.36.67:8080

Jupyter Books infrastructure
https://studhub.jinr.ru:8080/jjbook
https://studhub.jinr.ru:8080/books
https://studhub.jinr.ru:8080/itschool2024

A polygon for visualization of brain CT data
https://hlit-th-ct.jinr.ru

A polygon for quantum computing
https://ampere05.jinr.ru

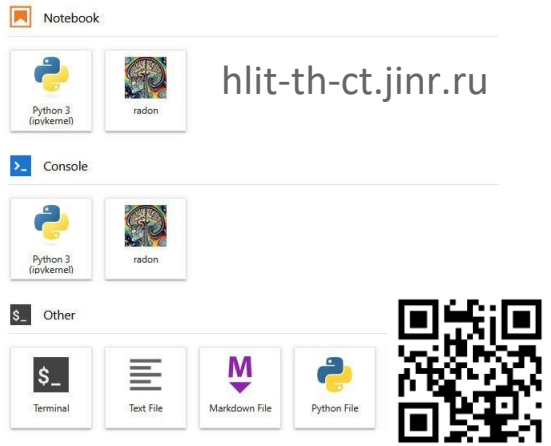
OpenCV, pandas, jupyter, Caffe, NumPy, scikit learn, JB, theano, Keras, PyTorch, TensorFlow, CVAT, ultralytics, kornia, Cirq, matplotlib, Numba, Joblib, FreeSurfer, PENNYLANE

Nipype: Neuroimaging in Python Pipelines and Interfaces

Polygon for visualization of brain CT data

Work tools for visualization

- **PyDicom** is a Python package used to read, modify, and write DICOM (Digital Imaging and Communications in Medicine) files, which are commonly used in medical imaging and related information. It provides a way to interact with DICOM datasets in a Pythonic way, allowing users to easily access and manipulate DICOM metadata and pixel data.
- **Nipype** (Neuroimaging in Python - Pipelines and Interfaces) is a Python-based open-source software package that offer users an incredible opportunity to analyze data using a variety of different algorithms and provides a uniform interface to neuroimaging software.
- **Pysurfer** is a Python library for visualizing cortical surface representations of neuroimaging data.



1

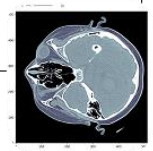
Mathematical modeling

- Ecosystem ML/DL/HPC
- SC Govorun

2

Visualization

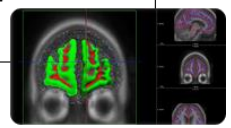
- Pydicom
- Nipype
- PySurfer

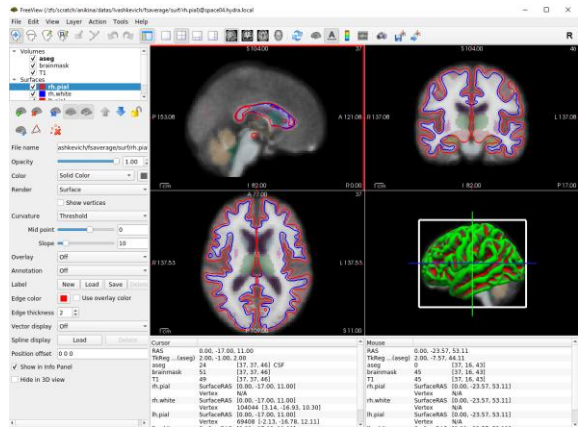


3

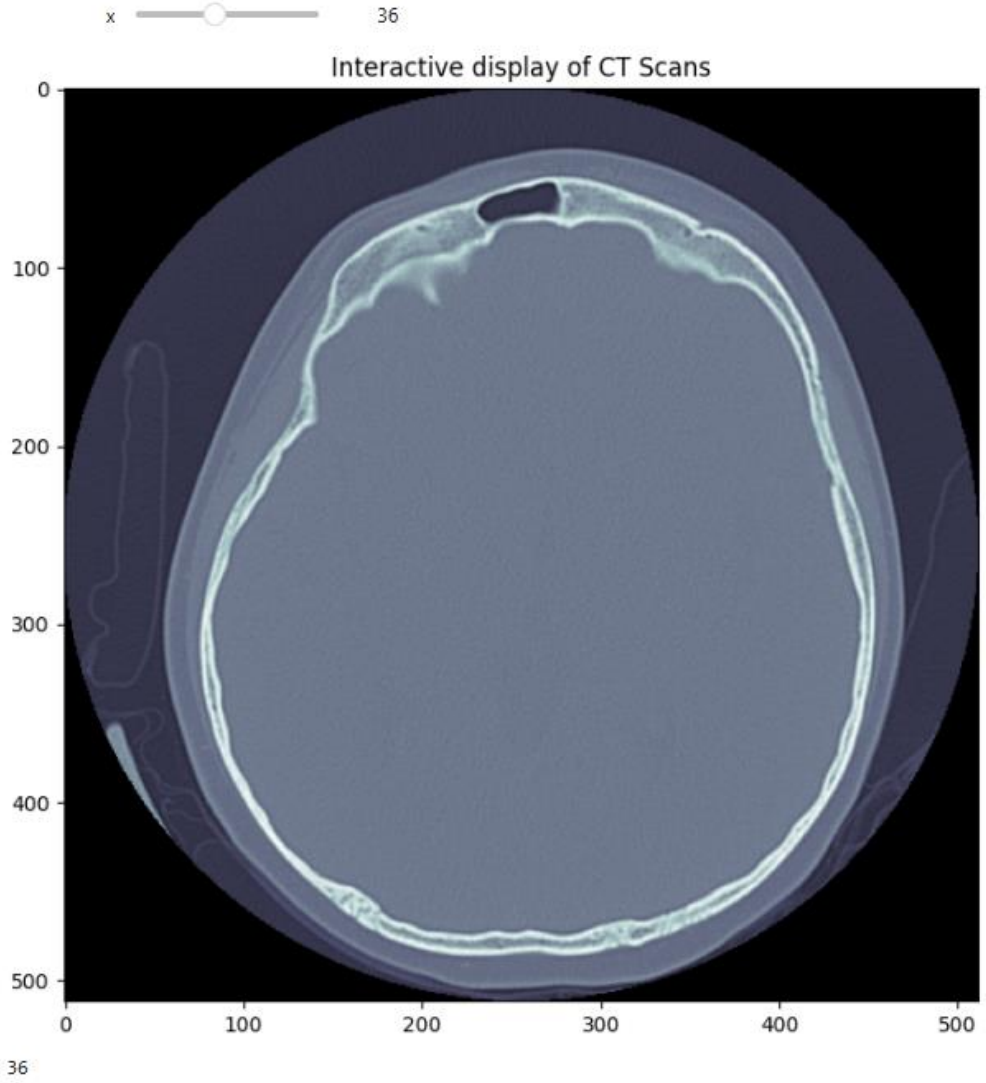
Software developer

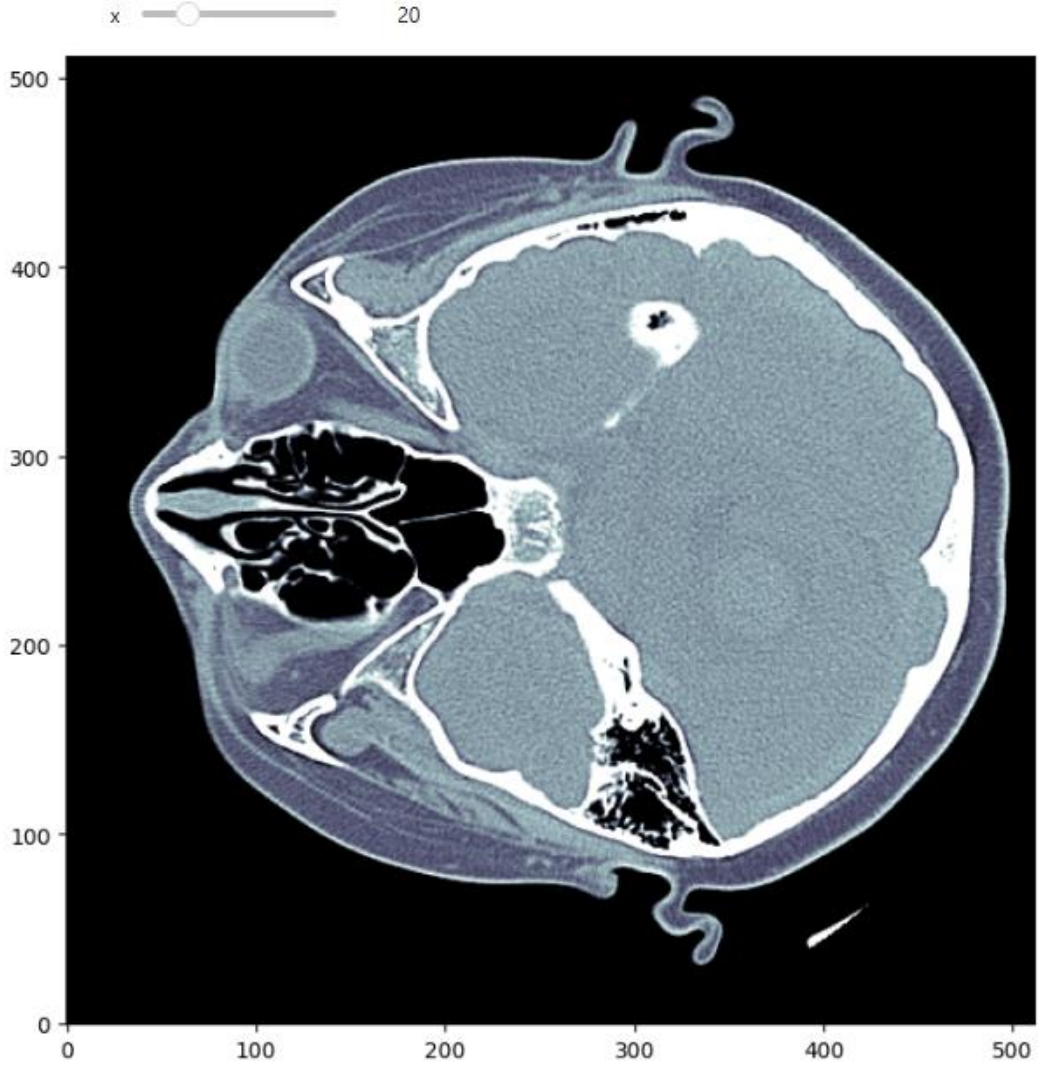
- MRI Convert
- FreeSurfer
- FreeView





Visualization of medical data





Data source: https://www.kaggle.com/datasets/trainingdatapro/computed-tomography-ct-of-the-brain

Conclusions

For the visualization of medical computed tomography data, the polygon based on heterogeneous platform “HybriLIT “ has been developed. The main purposes of polygon are

1) CT and MRI/fMRI data storage;
2) the visualized work with data in web-browser thanks for the possibility to work within JupyterLab interactive environment ;
3) the visualization of results using the special software;
4) the software development;
5) mathematical modeling.

In the further work, after implementation of new mathematical methods, visualization and medical data analysis the polygon has to help for the restoration of images. This is the principal goal which should minimize the blurred zones of images and the X-ray radiation of patients.

Thank you for attention!