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We create computational technologies for optimised healthcare

Navigating the challenges of processing distributed medical data

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Sano Centre for Computational Medicine

The Polish Open Science Conference 2024
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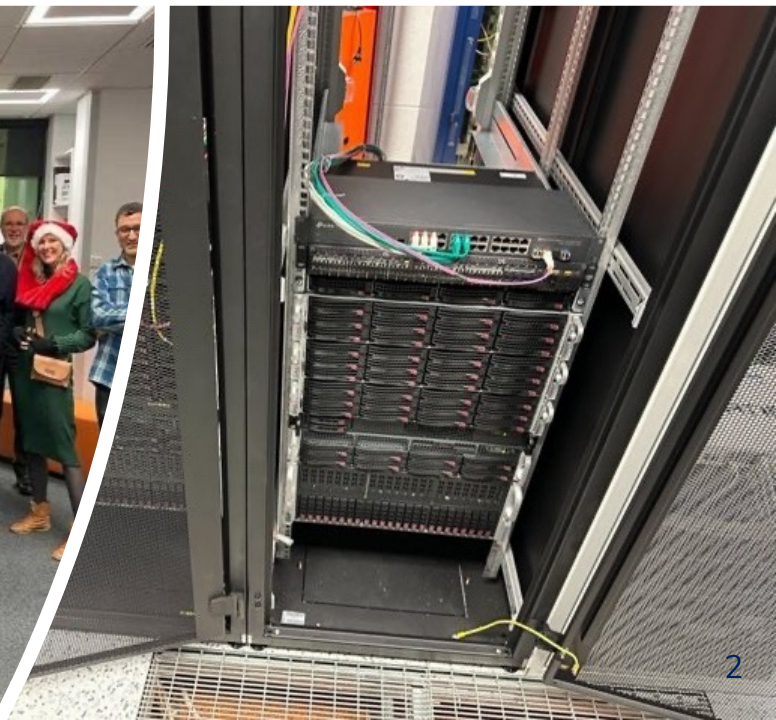
Sano – Centre for Computational Medicine



New research institution in Krakow

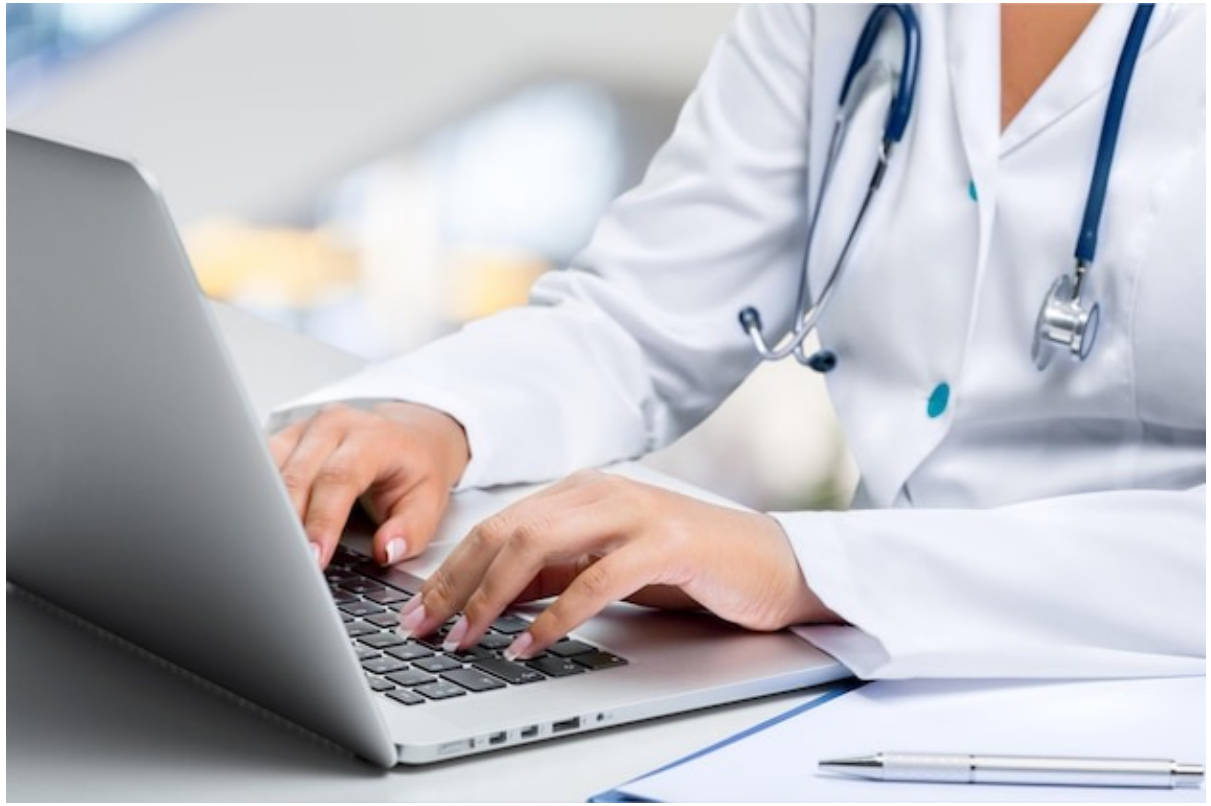
European Centre of Excellence

5 research Teams

90 People

Working with medical data: challenges and solutions

- Technological progress, coupled with ongoing digitization of various aspects of social life results in ever increasing quantities of digital data – the ability to process such data paves the way to further civilizational advancements.
- Ongoing digitization is particularly evident in the healthcare domain – with systems such as **e-recepty** (*e-prescriptions*), **e-skierowania** (*e-referrals*) or **Internetowe Konto Pacjenta** (*Online Patient Account*) providing evidence that modern IT solutions may substantially affect the work of healthcare providers and render benefits to the patient.
- We are still at an early stage of the e-health revolution – and we face new challenges related to further digitization of healthcare services, as well as development of AI-based systems to further assist doctors in planning and adminstering treatment.



Legal context

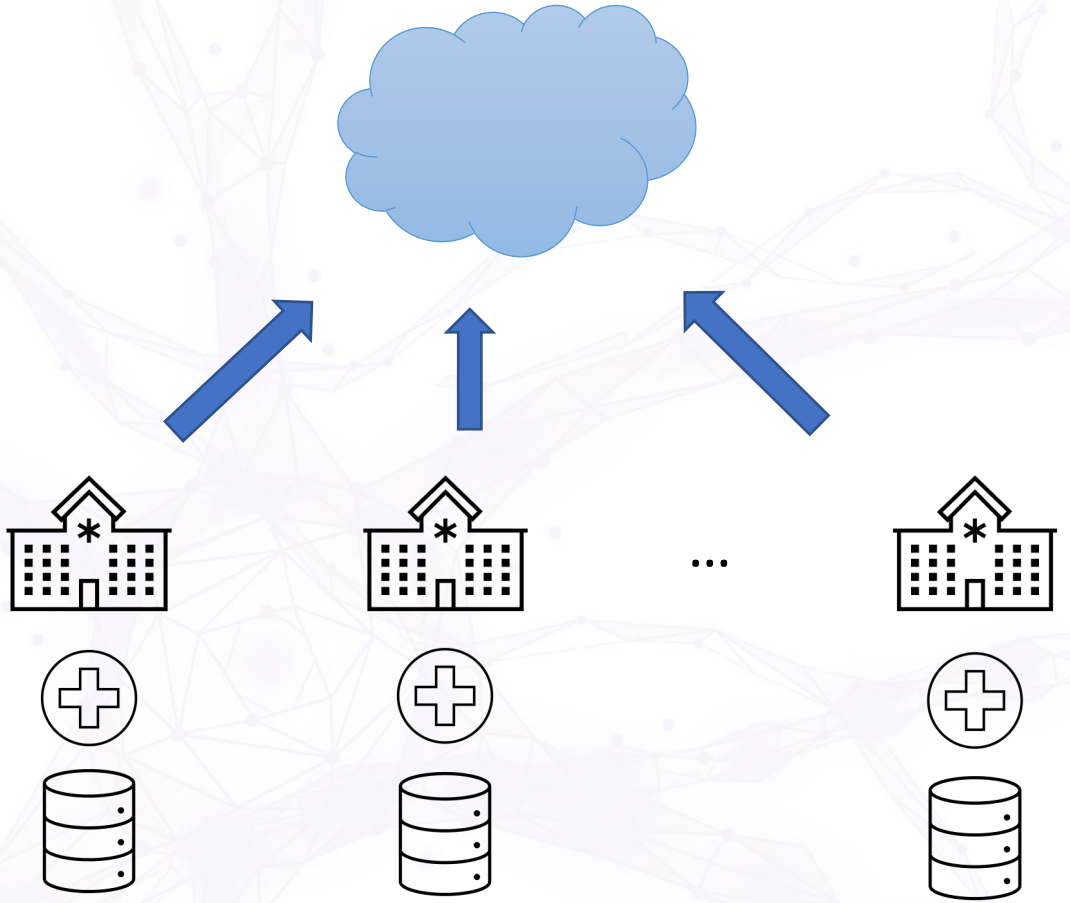
The legal framework related to using and sharing medical data is being revolutionized with the adoption of new legislation – including the **EU Data Governance Act** and **Data Act**, as well as the **EHDS** initiative, together with national projects

Key objectives include:

- Establishing centralized data registries and common EU-wide interchange formats,
- Safeguarding security of healthcare records,
- Ensuring patients remain in control of their data, enabling physicians to access it when required,
- Open possibilities for so-called secondary use of medical data (including for research)

Problem – accessing required data for research and development purposes

- Silos
  - Local data in hospitals
- Data heterogeneity
  - Various types of data, modalities, device configurations
  - Non uniform and not identically distributed data
- Metadata issues
- Slow adoption of central repositories – varying by country (Poland, Germany, Finland)



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Example 1

Federated Learning

Federated Learning - Definition

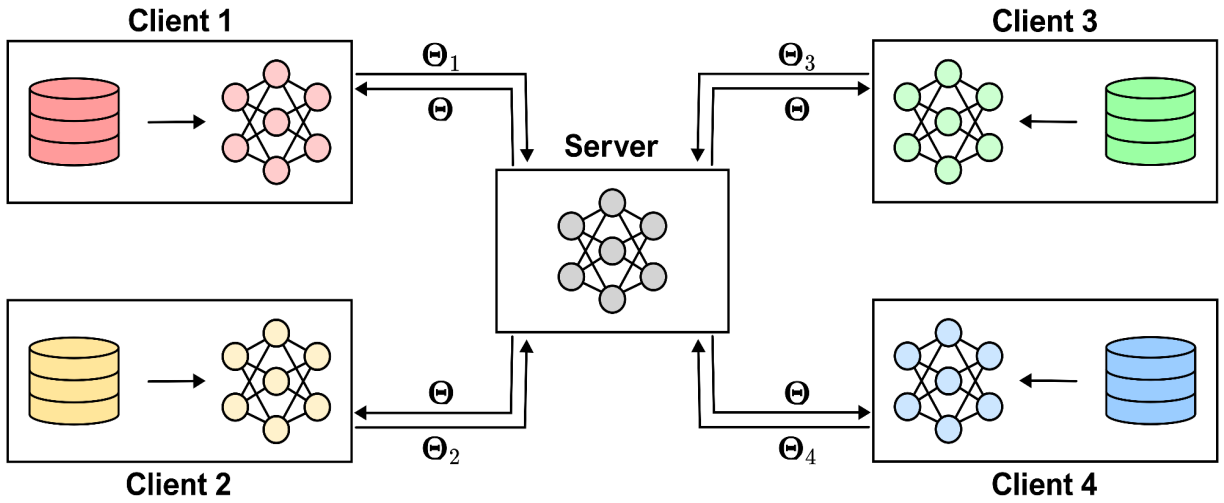


Figure 1: Federated learning scheme involving four institutions (Θ_c – parameters of client c local model, Θ – parameters of the global model).

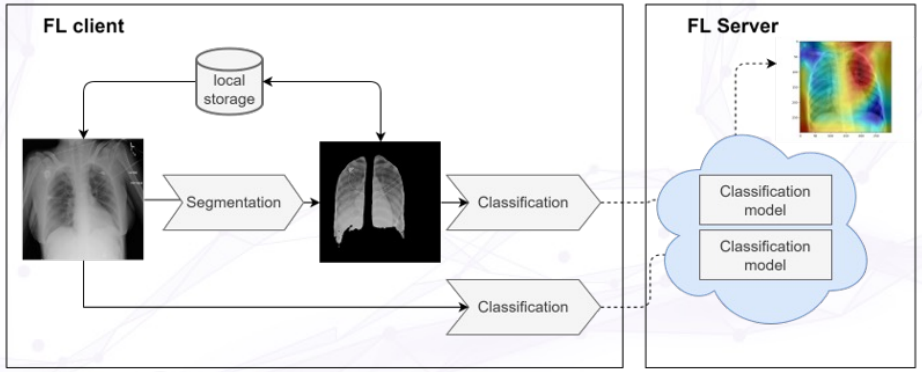
Global aggregation:

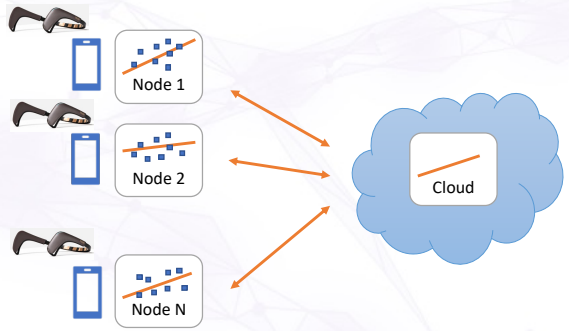
$$\Theta^{r+1} = \sum_{c=1}^{C} w_c \Theta_c^r ,$$

C – the number of selected clients, Θ_c^r – the parameters of client's c local model at federated round r, w_c – the aggregation weight.

Examples of Federated Learning projects at Sano

- Large-scale analysis of Chest X-Ray data (600 000 images) from multiple sources
  - Classification, segmentation
- Edge / cloud computing scenario
  - EEG signal from mobile sensors
  - Pilot project on dementia patients
- Transcriptomics data
  - Disease type classification based on genomics variants
  - NearData EU project
- Brain MRI data analysis:
  - Data translation of MRI data (between T1 and T2 weighted images)
  - Estimation of Brain Microstructural Parameters
- Experiments using
  - HPC - Cyfronet: Prometheus, Ares, Athena (GPU)
  - Cloud: Google Cloud Platform (10 GPU Instances)
- Software:
  - Flower.dev – Open Source
  - Pytorch





Data translation in MRI

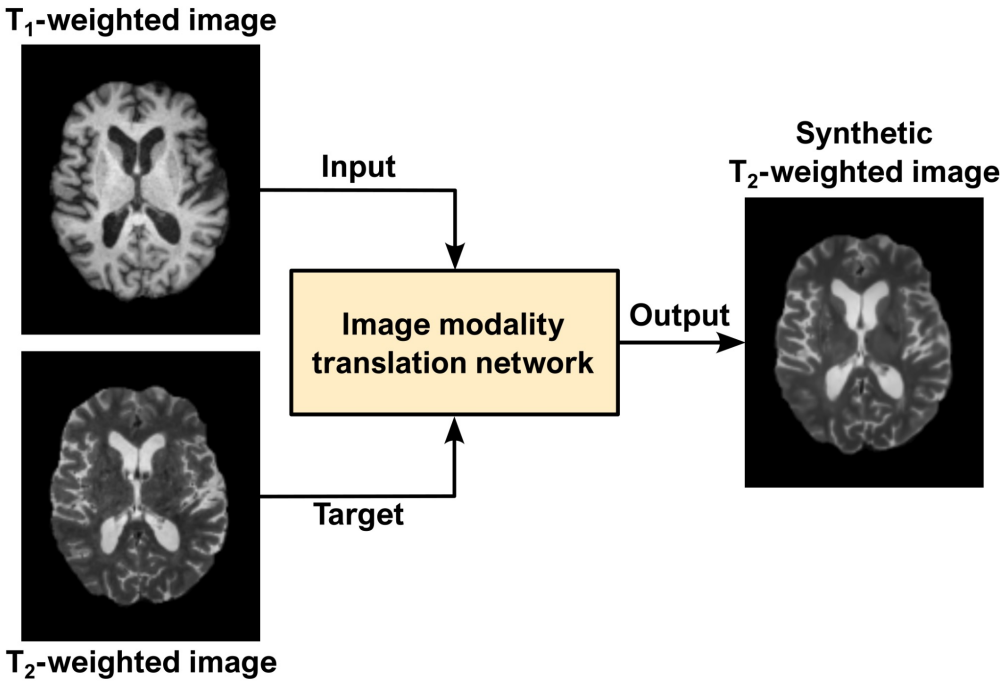


Figure 4: Visual representation of the translation process.

- Data translation is an area of research focused on generating images within and across medical imaging modalities.
- It simplifies clinical workflow by replacing infeasible imaging procedures due to time, labor or expense constraints.

- J. Fiszer, **D. Ciupek**, M. Malawski, T. Pięciak. *Image-to-image multi-contrast data synthesis from heterogeneous sources using a federated learning concept*.

Visual results

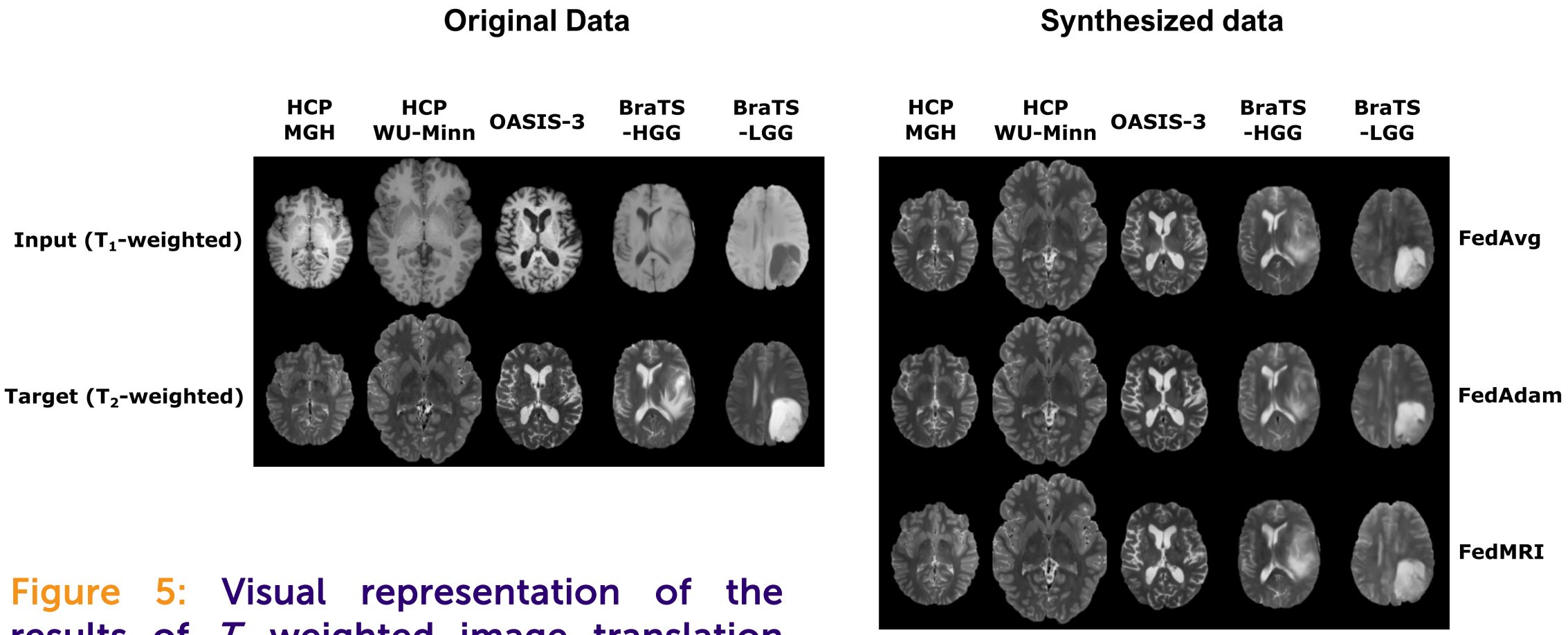


Figure 5: Visual representation of the results of T_2-weighted image translation after applying selected federated learning algorithms

J. Fiszer, **D. Ciupek**, M. Malawski, T. Pięciak. *Image-to-image multi-contrast data synthesis from heterogeneous sources using a federated learning concept*.

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Example 2

Open Data in In Silico Trials

Exploiting medical data for research: *in silico* clinical trials

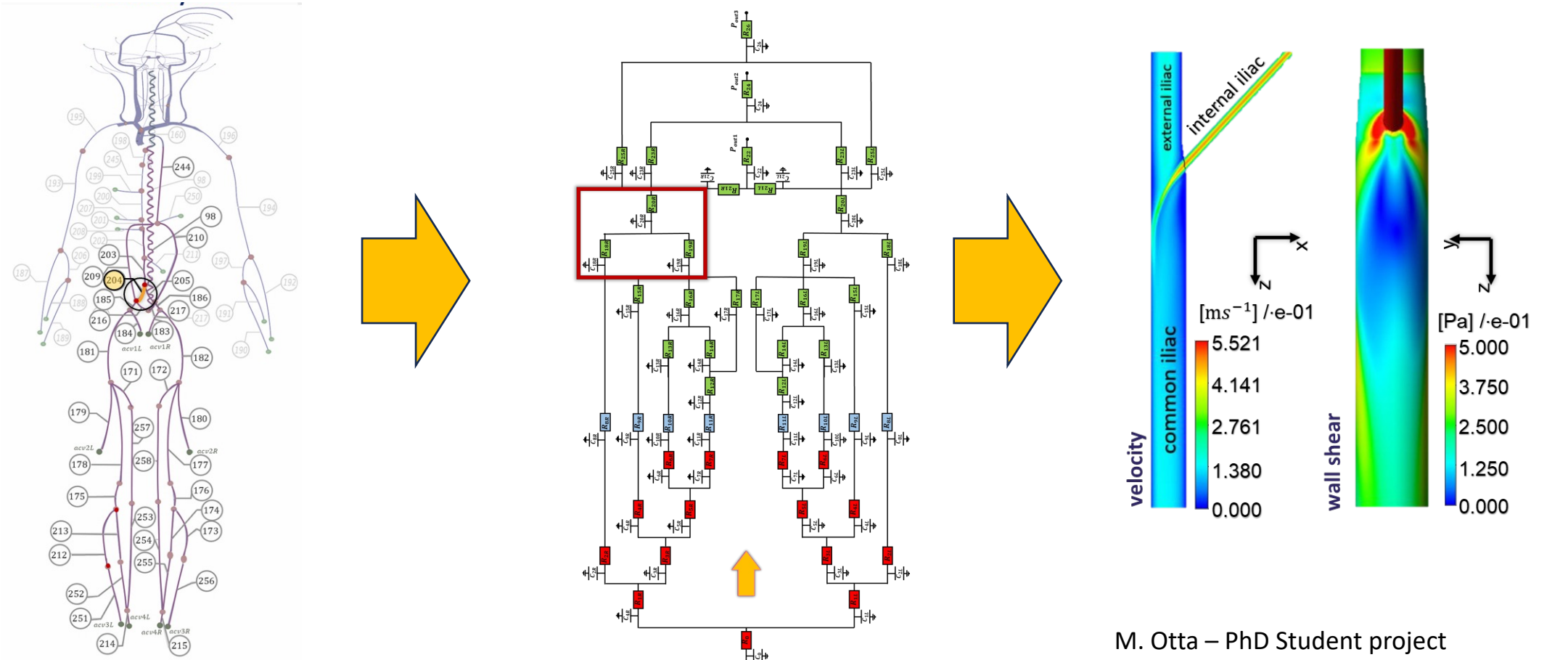
- InSilicoWorld is an international collaboration which aims to accelerate the uptake of modelling and simulation technologies.
- The project investigates a broad range of solutions targeting various medical specialities (endocrinology, orthopaedics, infectiology, neurology, oncology, cardiology) and diseases (osteoporosis, dynapenia-sarcopenia, tuberculosis, multiple sclerosis, mammary carcinoma, arterial stenosis, etc.)
- Sano participates in the project through its Extreme Scale Data and Computing team.

Our goal: to develop an advanced, easy to use simulation environment enabling *repeatability*, *replicability* and *reproducibility* of simulation results; and efficient access and usage of computation and storage resources.

SciProg lead: Piotr Nowakowski

Digital Twin / Virtual Human Twin (VHT)

- Digital, mathematical representation of human body
- VHT is an infrastructure that makes it easier to develop and validate digital twins.

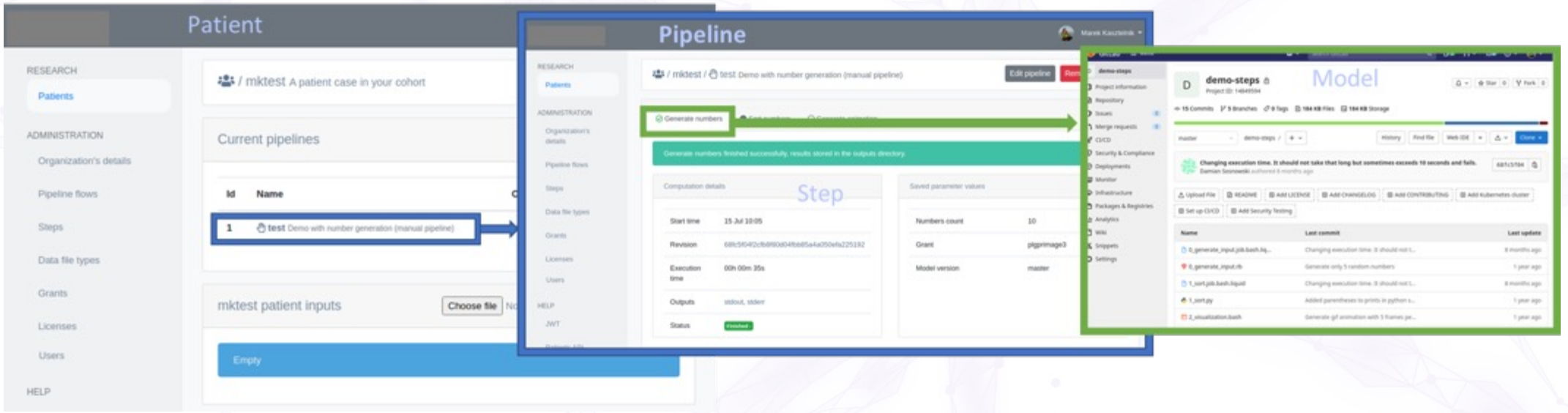


M. Otta – PhD Student project

In silico clinical trials – the ISW project

Integrating application models with HPC: the Model Execution Environment

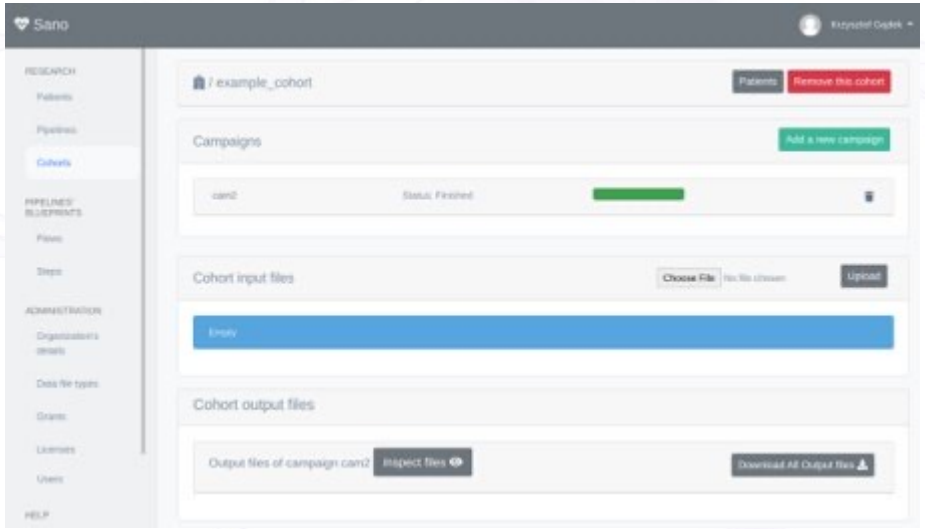
- **Patient** – virtual space to run different calculations on patient data.
- **Pipeline** – set of steps which should be executed on patient data.
- **Pipeline step** – specification of how the model should be run on HPC and what input data is required.
- **Model** – set of scripts/source code stored in a git repository. Git repository gives us the ability to store development history and run different model versions.

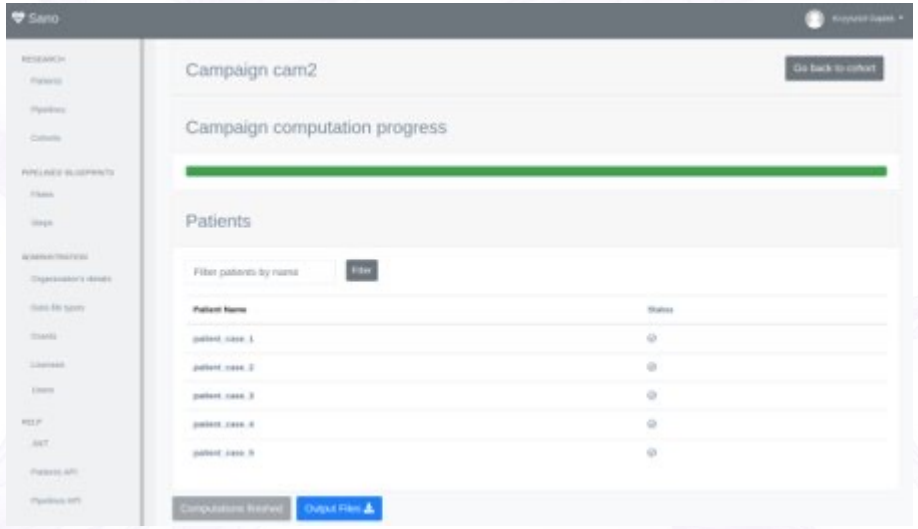


ISW: *in silico* clinical trials

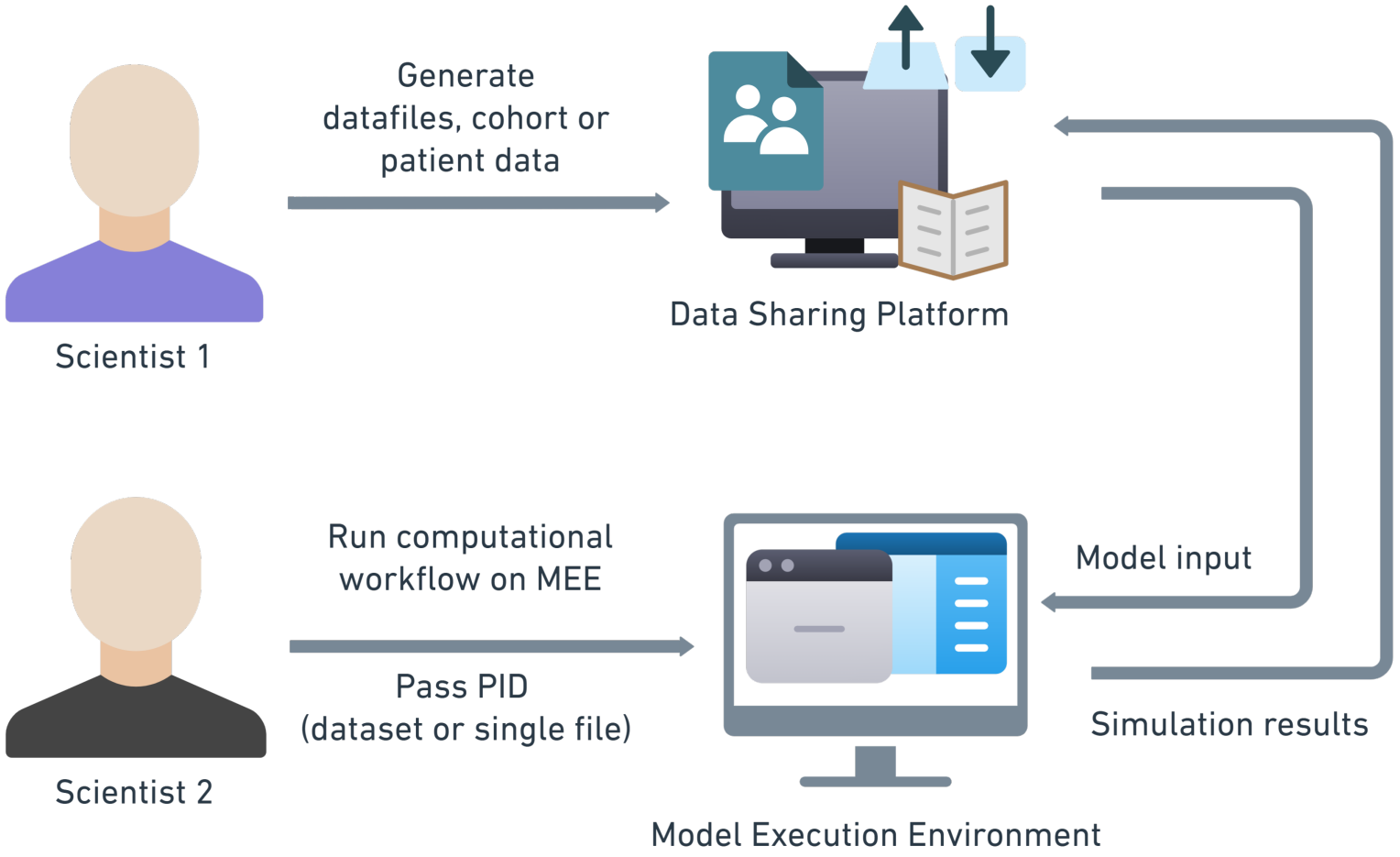
Cohort and campaign management

- The main feature, ensuring efficiency of ISW simulations in MEE are patient cohorts. The user is able to run multiple computational units (**Pipelines**) associated with specific patients with a single click of a button. Such bulk processing is known as a **Campaign**. The screenshots present a sample cohort of 5 patients and results of a simple campaign involving these patients. Every pipeline produces some output files, which are zipped into a single archive and exported for download.





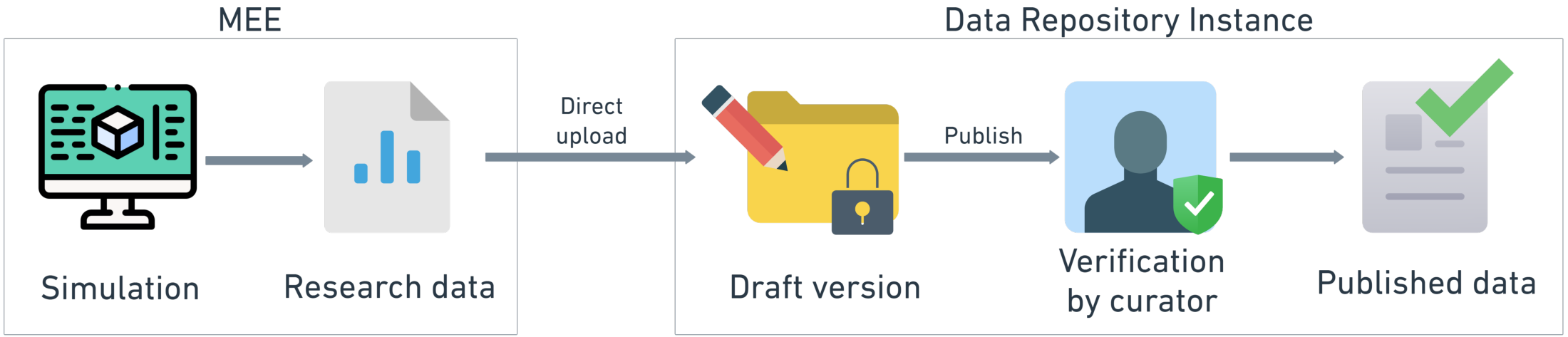
Accessing and publishing medical data in the ISW environment



- Data and model levels
- Data as required model input
- Sharing simulation results

Collaboration

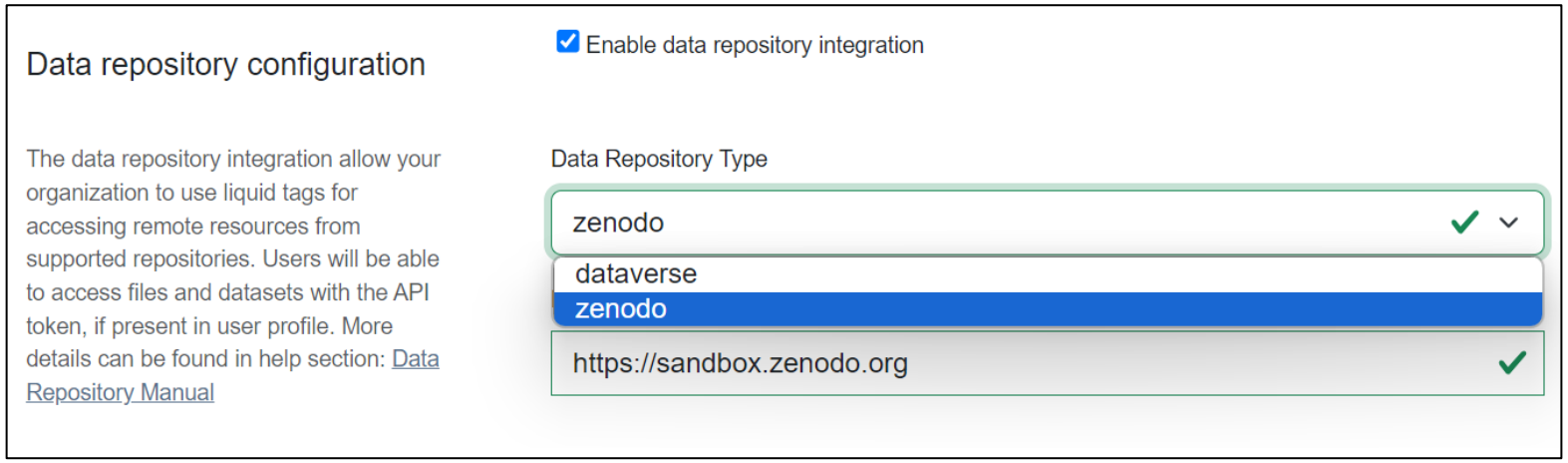
Collaboration scenario

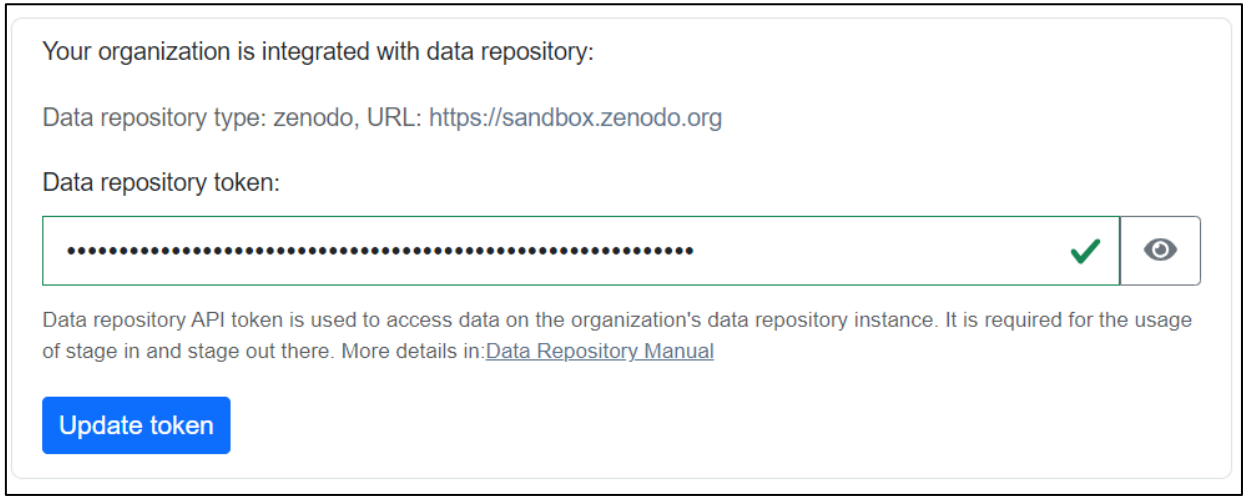


- Expose obtained data as draft version of dataset, ready for publication
- Automatically gather interesting results and extend collections stored in the data repository

Integration of data repositories

- Data repository instance can be configured for MEE organization (**admin**)

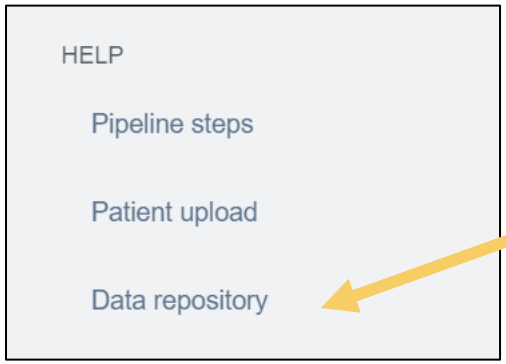




- Data repository access token can be configured for specific organization membership (**user**)

Accessing and publishing data

- Easy workflow adaptation to external data usage during your simulation
  - Download single file
  - Download dataset
  - Upload file to dataset or record



User guide for advanced tags

```
22  echo Download dataset from dataverse
23  echo --------------------START-----------------------------
24  dataset_doi={% value_of dataset_doi %}
25  file_doi={% value_of file_doi %}
26  {% dataverse_dataset_stage_in $dataset_doi %}
27  echo "Downloaded dataset"
28  {% dataverse_file_stage_in $file_doi %}
29  echo "Downloaded file"
30  echo --------------------END-------------------------------
31
32  find . -type f -name "*.txt" -exec cat {} + > merged.out
33
34
35  echo Uploading results
36  echo --------------------START-----------------------------
37  {% dataverse_file_stage_out merged.out $dataset_doi %}
38
39  {% dataverse_file_stage_out merged.out $dataset_doi {"description":"My
    description.","directoryLabel":"dataverse/subdir1","categories":["Data", "Dummy
    File"], "restrict":"false", "tabIngest":"false", "jshfdbv":"sjhfd"} %}
40
41  echo --------------------END-------------------------------
42  echo Finish
43
```

Usage inside step script

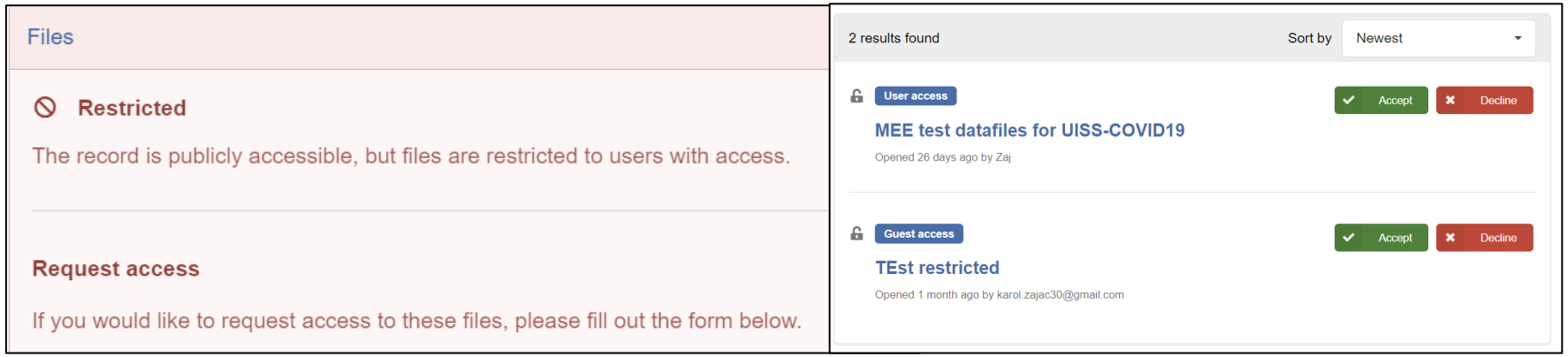
Future work: rule-based data sharing

- Initial research and work on rule-based sharing model
- Potential difficulties in model automation

  How to verify the data content to avoid **data abuse**?

  Dataset versioning – permanent access?

  How to use existing solutions?



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Request

Verification

Acceptance

Collection update

Conclusions:
Wide spectrum of data access modes

Type of data	Examples	Solutions	Examples of projects
Public datasets	Large Genomics databases	Big Data / Cloud solutions	Transcriptomics Atlas Pipeline in NearData Project
Private data	Medical imaging	Federated Learning	Applications to MRI Data
Research results	In-silico modeling and simulation data	Open Repositories	Model Execution Environment in InSilicoWorld Project

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Thank you!

https://sano.science

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