

Advances in Computational Medicine – Experiences from Creating Sano Centre of Excellence

Maciej Malawski

IRAP Conference
Warsaw, 13 Oct 2023



Sano Centre for Computational Medicine

New Research
Institution
in Krakow



Motto

Computational medicine deals with developing and applying new, advanced computing technologies to the problems of human health.

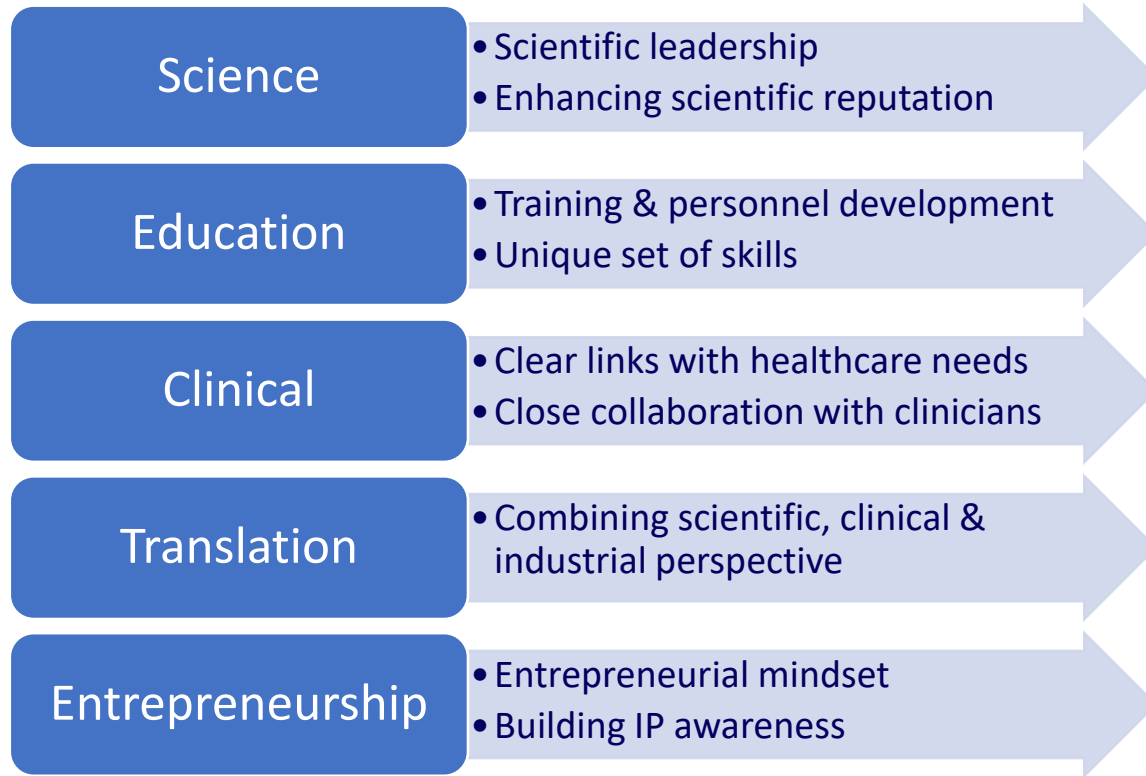
Given that "Sano" means "health", and that health is a key value to everyone, at Sano we believe that by advancing such technologies we can contribute to the common good.

Sano Organization

- International Research Foundation
(NGO, non-profit)
- Five Research Teams
- 40+ researchers
- Foundation Council (*supervisory, PL, DE, UK*)
- Scientific Committee
(*advisory, IT, NL, DE, PL, UK, US*)
- Management Board (*executive*)



Main objectives of Sano

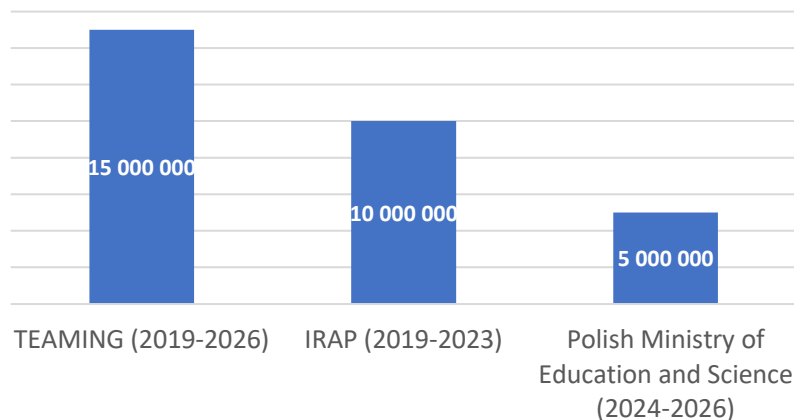




Funding



Sano Funding 2019-2026 (EUR)



IRAP

Strategic Partner: University of Sheffield

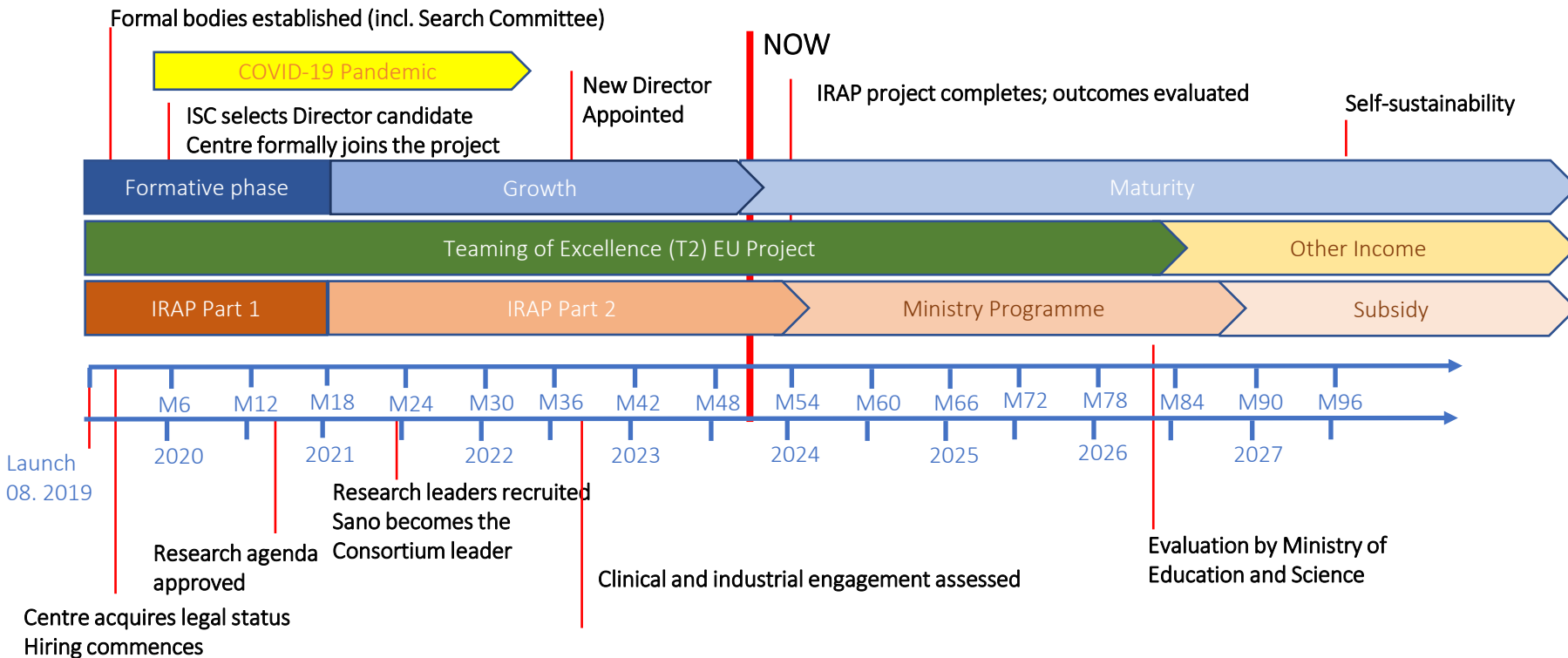
Applicants: Marco Viceconti, University of Bologna (ISC Chair), Marian Bubak, AGH University of Science and Technology (Scientific Affairs Director)

Director of Sano and IRAP Part 2 Manager: Maciej Malawski

Teaming Partners:



Sano Timeline



Sano in 2026:
<https://sano.science>

“We prevent and heal disease through the use of computing and data”

Board, Council and Committee



Management Board conducts the daily operations of the Foundation

Name	Role
Prof. Maciej Malawski	Director, President of the Management Board
Dr. Marian Bubak	Director for Scientific Affairs, Member of the Management Board

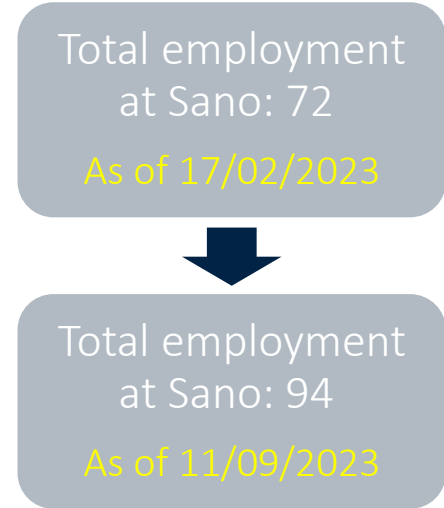
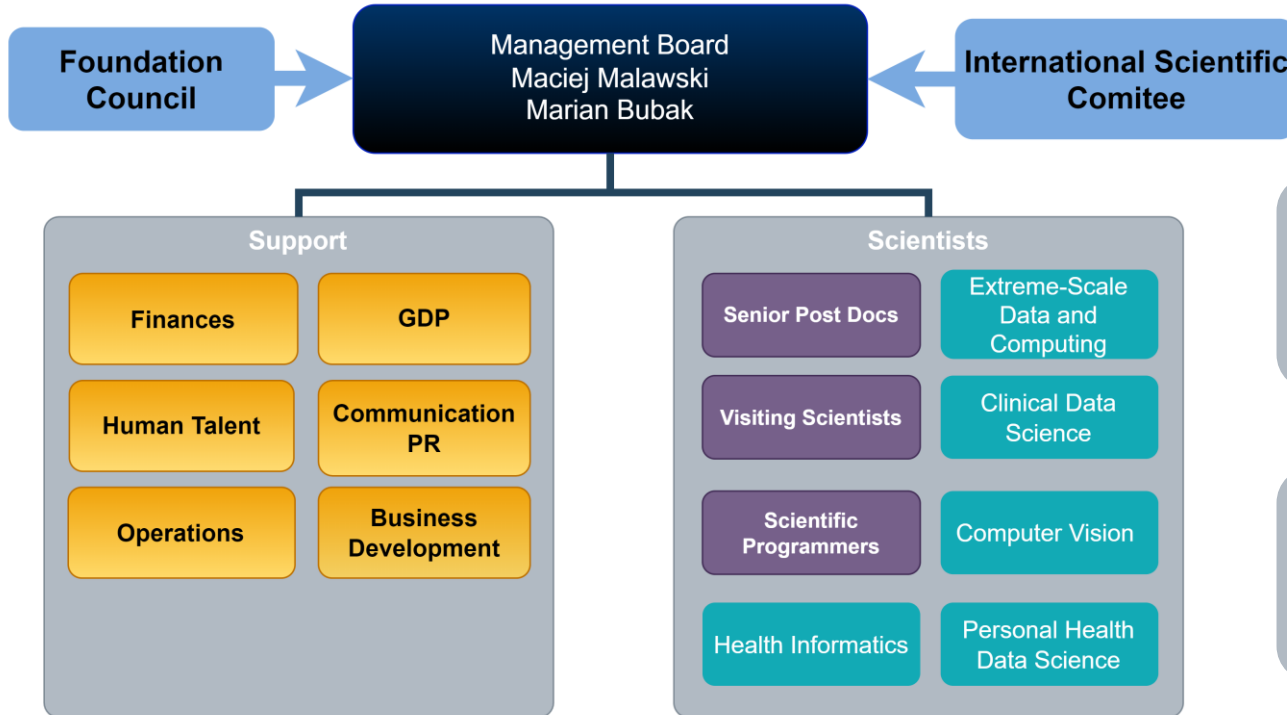
Foundation Council supervises Sano and appoints Management Board members

Name	Affiliation
Karol Krawentek	ACC Cyfronet AGH, PL
Dr. Tanja Bratan	Fraunhofer Institute ISI, DE
Dr. Andrew Narracott	University of Sheffield, UK
Dr. Olav Zimmermann	Forschungszentrum Jülich, DE
Kazimierz Murzyn President	Klaster LifeScience Kraków, PL

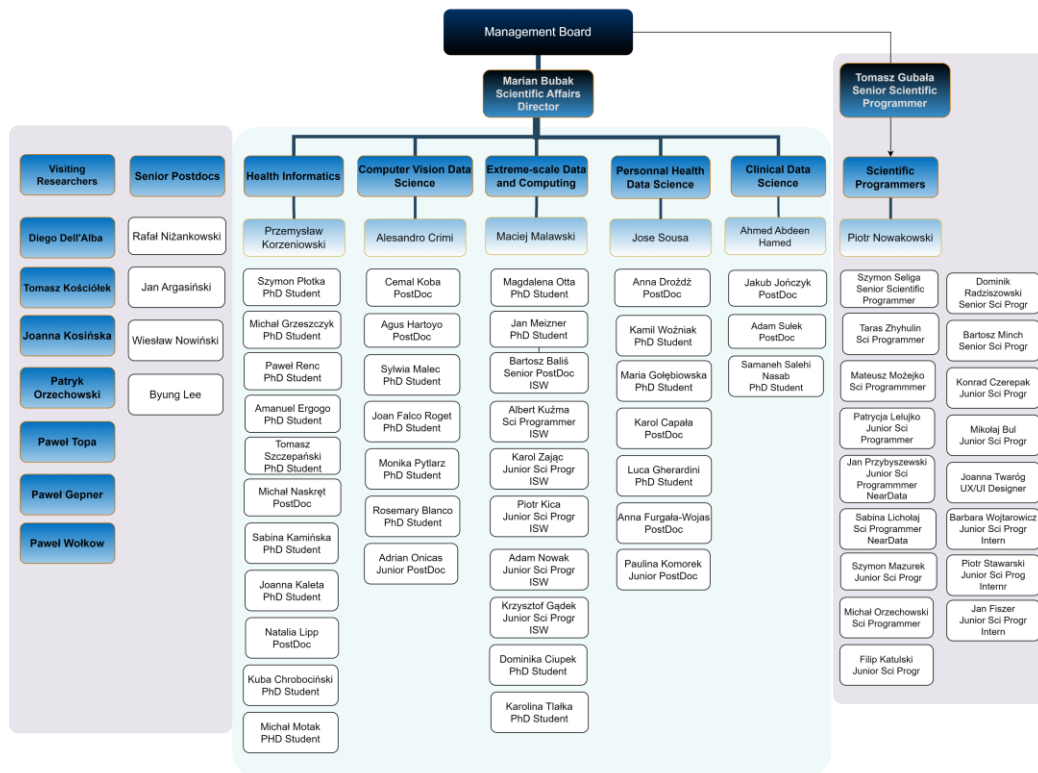
International Scientific Committee selects research team leaders, evaluates their achievements, and advises the Management Board in scientific matters

Name	Affiliation
Prof. Marco Viceconti, President	Università di Bologna, IT
Prof. Rod Hose	University of Sheffield, UK
Prof. Richard Clayton	University of Sheffield, UK
Prof. Marek Behr	Aachen University, DE
Prof. Holger Gohlke	Heinrich Heine University Düsseldorf, DE
Prof. Dieter Kranzlmüller	Ludwig-Maximilian University Munich, DE
Prof. Zbigniew Nawrat	Silesian Center for Heart Diseases in Zabrze, PL
Prof. Irena Rotermań-Konieczna	Jagiellonian University Medical College, PL
Prof. Jerzy Gąsowski	Jagiellonian University Medical College, PL
Prof. Knut Koschatzky	Fraunhofer Institute ISI, DE
Dr. Claire Chalopin	University of Leipzig, DE
Dr. Stefan Zachow	Zuse Institute Berlin, DE
Prof. Ewa Deelman	University of Southern California, USA
Prof. Peter Stoot	University of Amsterdam, NL
Prof. Jacek Kitowski	AGH University of Science and Technology, PL

Sano General Structure



Sano Research Personnel

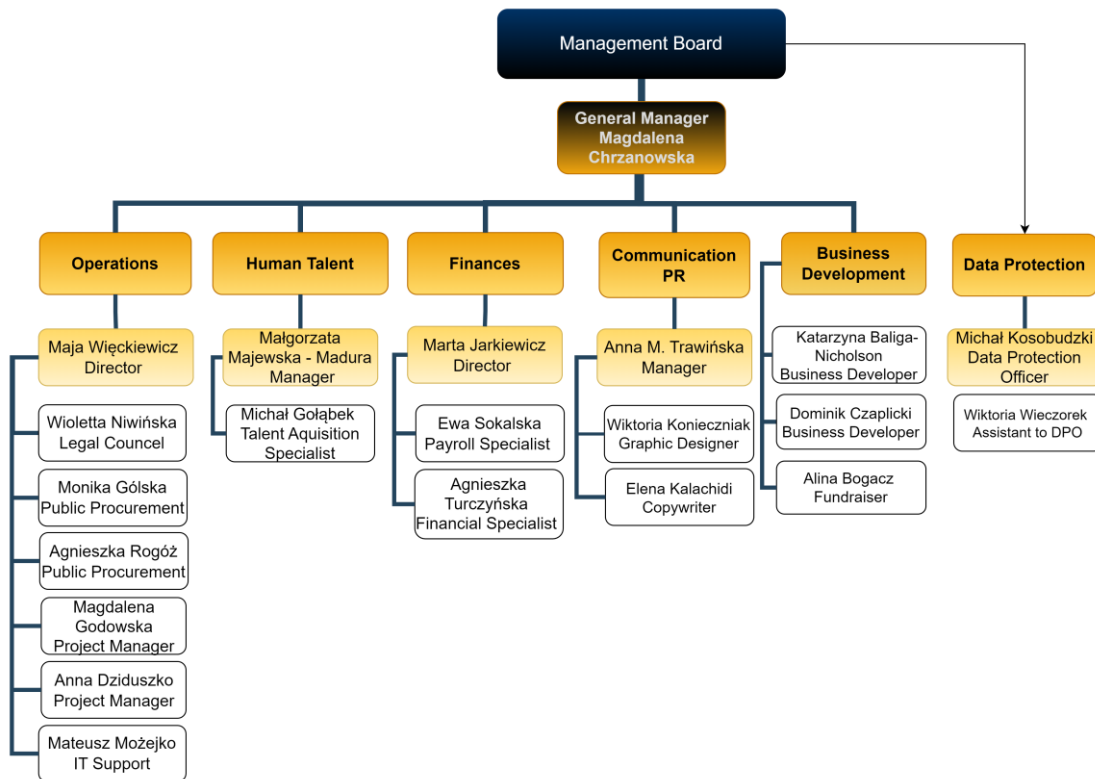


Researchers + scientific programmers: 66 (IRAP only) + 6 in other projects

- Scientific Affairs Director: 1
 - Group Leaders: 5
 - Senior Postdocs: 4
 - Visiting Scientists: 7
 - PhD Students: 21
 - Scientific Programmers: 19
 - Postdocs: 11
- 14 international members
 - 19 women

As of 31/08/2023

Support & Development Personnel



Support and development: 21 (incl. 2 IRAP technical brokers)

Sano Team



Culture
+
Competency



Sano Team



Office and lab space



- AGH Center of Energy
- Laboratory space
 - ✓ M15: 55 m²
 - ✓ M30: 522 m²



Infrastructural development and support activities



Computing Devices: Computer equipment, including desktop computers, laptops, and monitors.

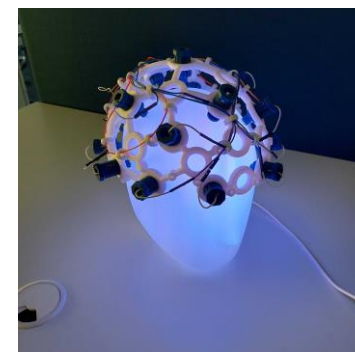
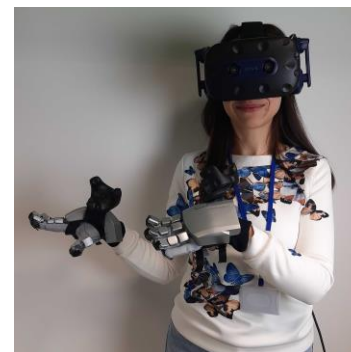
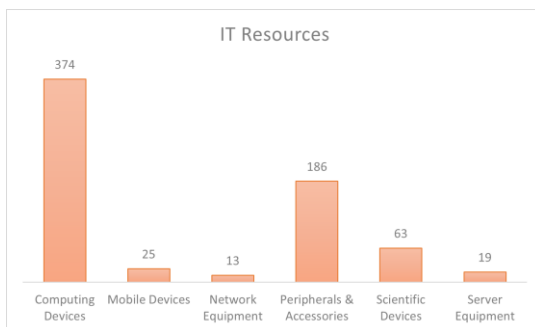
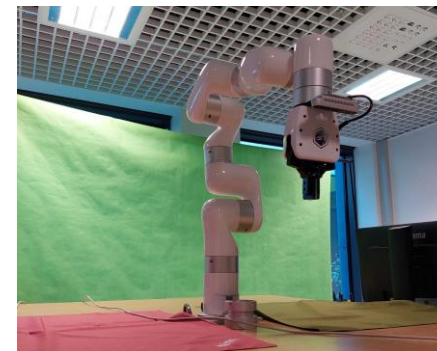
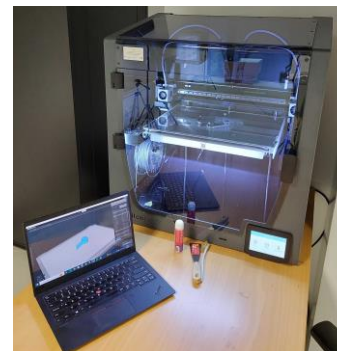
Mobile Devices: Mobile devices, such as smartphones and tablets.

Network Equipment: Network equipment, including routers, switches, and access points.

Peripherals & Accessories: Peripherals and accessories, like keyboards, mice, external hard drives, printers, and scanners.

Scientific Devices: Scientific devices, such as laboratory instruments, research equipment, and medical devices.

Server Equipment: Server equipment, including servers and storage solutions.

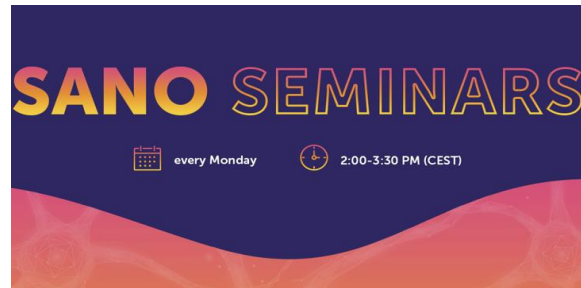


Events



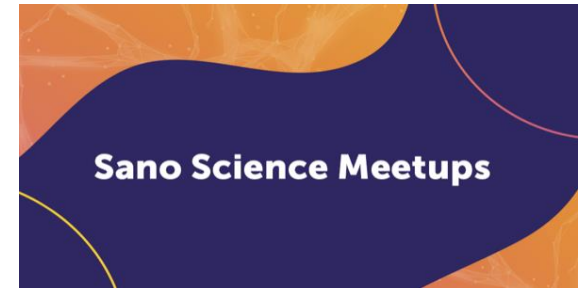
**LET'S TALK
ABOUT FUTURE
OF MEDICINE**

Coffee with Sano Science

A banner for a coffee event. The left side shows a close-up of hands holding several coffee cups. The right side has a dark blue background with a red-to-orange gradient wave at the bottom. The text is in white and yellow.

SANO SEMINARS

every Monday 2:00-3:30 PM (CEST)

A banner for Sano Seminars. The background is dark blue with a red-to-orange gradient wave at the bottom. The text "SANO SEMINARS" is in large, bold, yellow-outlined letters. Below it, a calendar icon is followed by "every Monday" and a clock icon is followed by "2:00-3:30 PM (CEST)".

Sano Science Meetups

A banner for Sano Science Meetups. The background is dark blue with a red-to-orange gradient wave at the bottom. The text "Sano Science Meetups" is in white, bold, sans-serif font.

**neuropizza:
meet, eat & talk**

sano BBL FS

A banner for neuropizza. The background is dark blue with a red-to-orange gradient wave at the bottom. The text "neuropizza: meet, eat & talk" is in white, bold, sans-serif font. At the bottom, there are logos for sano, BBL, and FS.

**AI Neuro Summer
School**

A banner for AI Neuro Summer School. The background is dark blue with a red-to-orange gradient wave at the bottom. The text "AI Neuro Summer School" is in white, bold, sans-serif font. Above the text is a white line-art illustration of a brain on a mountain peak with a volcano-like shape, surrounded by circles and lines.

Sano Summer Workshops

A banner for Sano Summer Workshops. The background is dark blue with a red-to-orange gradient wave at the bottom. The text "Sano Summer Workshops" is in white, bold, sans-serif font. Above the text is a colorful illustration of people working in a laboratory or office setting.

Sano Computational Medicine Seminars



- A mean to enhance knowledge and build a scientific network
- Started on 22 June 2020; total 103 seminars until 26th June 2023
- The seminars take place each Monday at 14.00 CET/CEST
- Most of seminars are recorded (teaching material) and possible to watch at Sano YouTube channel.
- The list of Sano Seminars is available at Sano website: <http://sano.science/seminars>

A promotional poster for a Sano seminar. The background is dark blue. In the top left corner is the Sano logo. The text "SANO SEMINARS" is written in large, bold, yellow and orange letters. Below this, the title "Digital Behaviour Change Interventions (DBCi): From design to implementation" is written in white. At the bottom left, there is a calendar icon, the date "14th November 2022", and a clock icon with the time "2:00-3:30 PM (CEST)". On the right side, there is a portrait of Aneta Lisowska, a woman with short brown hair, smiling. Below her portrait is a white box with her name "Aneta Lisowska" and her title "Senior PostDoc Researcher in Sano" in black text.

A promotional poster for a Sano seminar. The background is dark blue. In the top left corner is the Sano logo. The text "SANO SEMINARS" is written in large, bold, yellow and orange letters. Below this, the name "Roksana Wilk" is written in white, followed by her affiliation "Academic Computer Centre Cyfronet AGH, Krakow, PL" in smaller white text. At the bottom left, there is a calendar icon, the date "15th May 2023", and a clock icon with the time "2:00-3:30 PM (CEST)". On the right side, there is a circular portrait of Roksana Wilk, a woman with long dark hair, looking slightly to the side. The portrait has a yellow and orange border.

NEUROPIZZA event

- NEUROPIZZA is a brown bag seminar where people could discuss brain research, encompassing a wide range of fields from neuroscience, biology, psychology, medicine and biomedical engineering among others. The aim is to create a space for discussion.
- **Started on 3rd November 2021.**
- The event is created by Sano Centre and Brain and Behaviour Lab, Jagiellonian University.
- Since now, the total number of events: 30.
- Some of the meetings are available on YouTube channel as well.



Coffee with Sano



- **Coffee with Sano** is designed for those who are interested in modern trends in medicine.
- We invite people engrossed by topics of digital health, AI in medicine, personalized healthcare, medical innovations, MedTech startups to meet our researchers and scientists to discuss over a cup of coffee.
- More than 20 people gathered on the first Coffee with Sano meetup.
- The special guest: Ligia Kornowska, managing director of the largest hospital organization in Poland, the leader of “**AI in healthcare**” Coalition, coordinator of “AI&BD” stream of the Polish E-Health Strategy for 2021-26, co-initiator of GDPR code of conduct for healthcare.

The event poster features a black and white portrait of Ligia Kornowska on the left. The right side has a red-to-orange gradient background. It includes the Sano logo, the date "19th May 2023" with a calendar icon, the time "7:00PM-9:30PM (CEST)" with a clock icon, and the location "Fidrygalki ul. Urzędnicza 47, Kraków" with a location pin icon. The main title "LET'S TALK ABOUT FUTURE OF MEDICINE" is in large, bold, blue letters, and the subtitle "Coffee with Sano Science Guest – Ligia Kornowska" is in a smaller, bold, blue font below it.

 sano

19th May 2023 

7:00PM-9:30PM (CEST) 

Fidrygalki 
ul. Urzędnicza 47, Kraków

**LET'S TALK ABOUT
FUTURE OF MEDICINE**

**Coffee with Sano Science
Guest – Ligia Kornowska**

AI in medicine. Workshops for medical students and young doctors

- The first summer school on modern technologies in medicine, for young scientists, students and graduates of medical faculties.
- 2 days of intensive workshops and seminars with the best specialists involved in the design and implementation of modern technologies in medicine.
- Event website: workshops.sano.science



AI Neuro Summer School

- 2 editions in Lipari, Sicilia, Italy
- One-week event for neuroscience PhD students and PostDocs
- Event website: neuro.sano.science
- Co-organizer: The University of Pennsylvania
- Almost 100 participants in total



Securing long-term financial stability

Anticipated funding sources



National funding sources

- 18 proposals submitted to NCN, NCBR and FNP calls
- IRAP FENG submitted (30 000 000 PLN) – 5 years

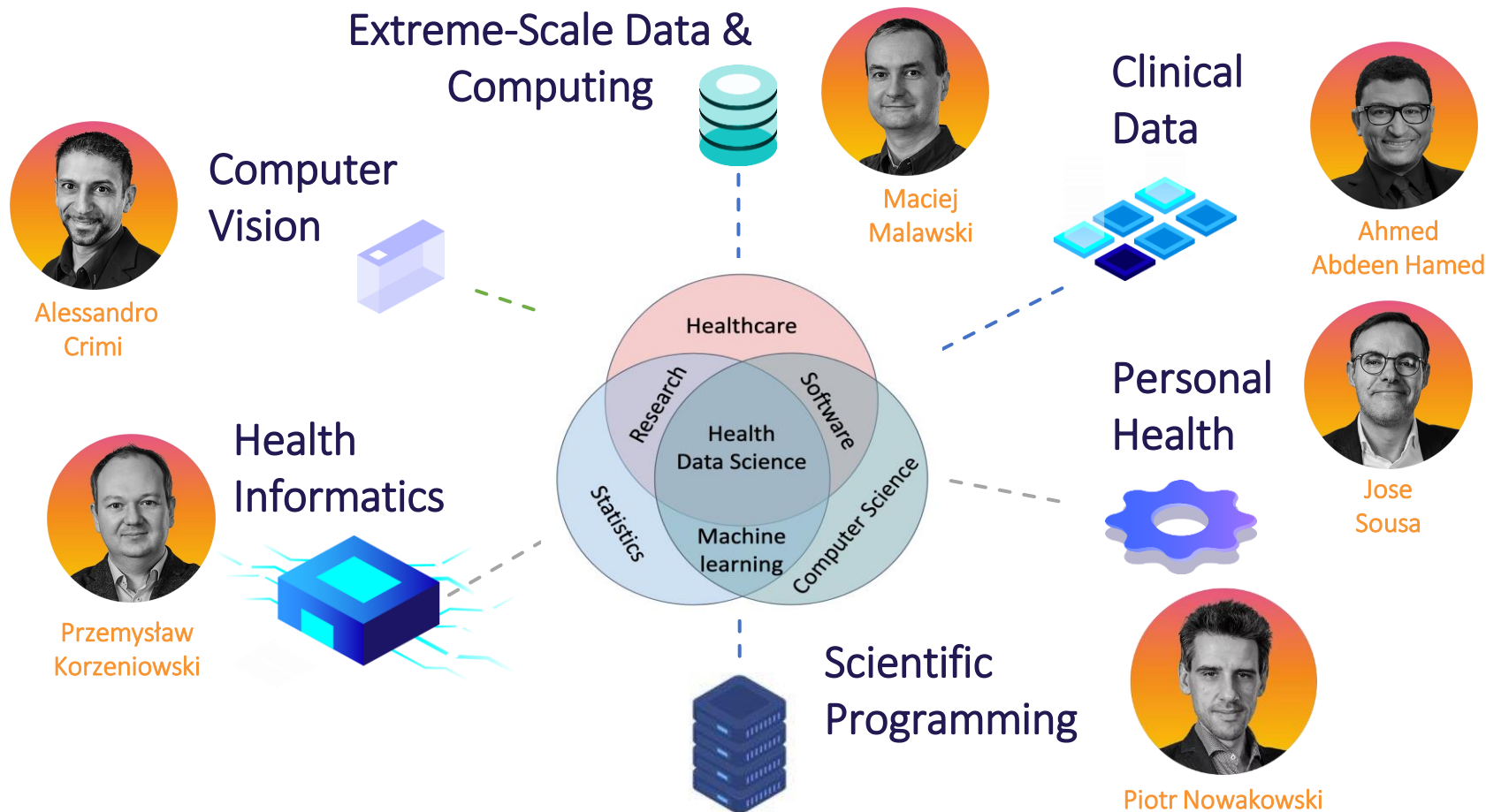
National statutory funding

- Application in 2026
- First round of statutory funding for years 2027-2030
- Amount of funding depending on the score obtained

International funding

- 26 proposals submitted (inc. Horizon Europe, DIGITAL, COST, ERA PerMed)
- 1.2 MEUR from H2020 and Horizon Europe

Sano Research Teams



Healthcare Informatics

Research Team



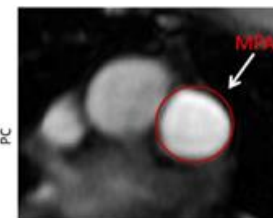
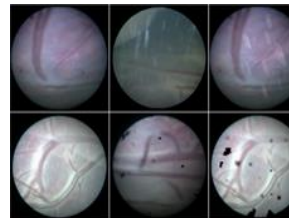
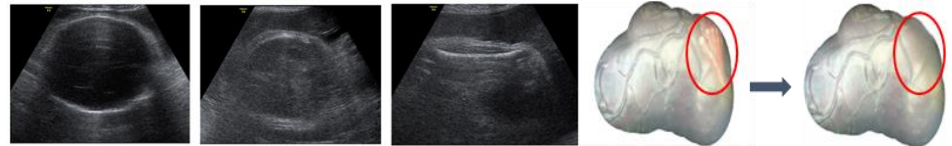
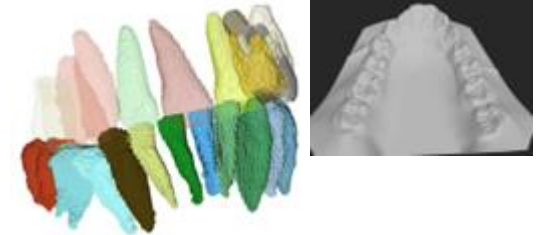
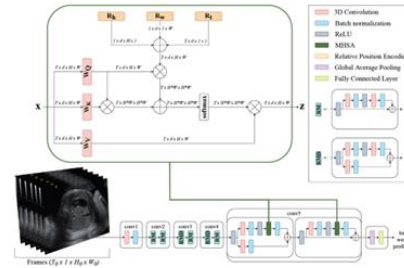
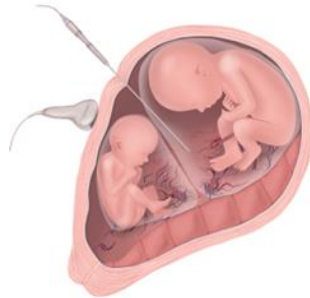
Przemysław
Korzeniowski

We focus on:

- Developing new diagnostic and therapeutic processes based on patient data to extract insights that can be used to **improve patient care and prevention**.
- Working on a new generation of medical communication and **incorporation of medical image analysis, virtual and augmented reality (VR/AR) and robotics** in existing and new medical workflows.

Team in numbers:

- 7 PhD Students
- 2 Postdocs



The results of different projects conducted in our team (details will follow in next slides)

Fetal Birth Weight Prediction using Multimodal data

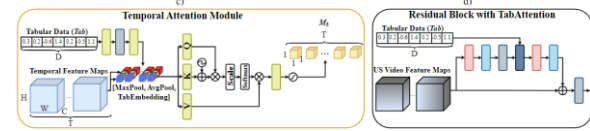
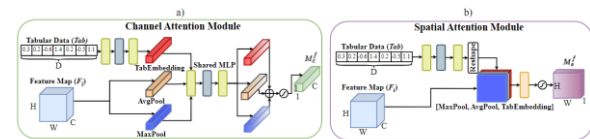
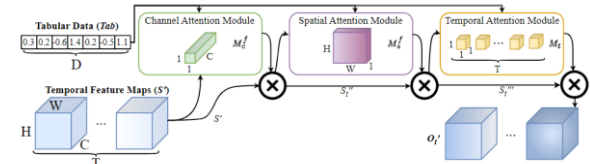
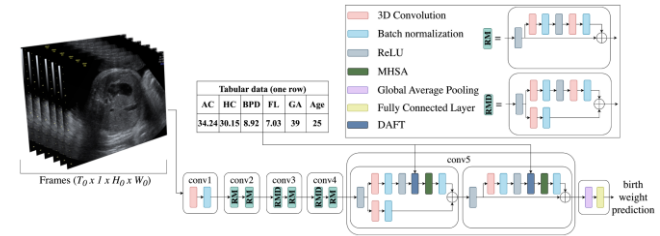
Szymon Płotka, Michał Grzeszczyk

Goal: Accurate prediction of fetal weight at birth is essential for effective perinatal care, particularly in the context of antenatal management, which involves determining the timing and mode of delivery.

Research results: We present a novel method that automatically predicts fetal birth weight by using fetal ultrasound video scans and clinical data. This method leverages tabular clinical data to evaluate 2D+t spatio-temporal features in fetal ultrasound video scans. Our results show that our method outperforms several state-of-the-art methods and estimates fetal birth weight with an accuracy comparable to human experts and can minimize the risk of errors inherent in manual measurements.

In cooperation with: Dr Robert Biskupski-Brawura-Samaha, I Klinika Położnictwa i Ginekologii, **Warsaw Medical University**

PhD project by Sz. Płotka - viva in Q4 2023 at University of Amsterdam under supervision of Clarisa I. Sanchez, Ivana Isgum and Arkadiusz Sitek



Legend: TabAttention, Batch Normalization, ReLU, Fully Connected, 3D Convolution, 2D Convolution, Signal, Addition, Position Encoding



BabyNet: residual transformer module for birth weight prediction on fetal ultrasound video.
 Płotka, S., Grzeszczyk, M. K., Brawura-Biskupski-Samaha, R., Gutaj, P., Lipa, M., Trzciniński, T., & Sitek, A.
 MICCAI 2022, Singapore (CORE A)



TabAttention: Learning Attention Conditionally on Tabular Data,
 Grzeszczyk, M. K., Płotka, S., Rebizant, B., Kosińska-Kaczyńska, K., Lipa, M., Brawura-Biskupski-Samaha, R., Korzeniowski, P., Trzciniński, T., & Sitek, A.
 MICCAI 2023, Vancouver, Canada (CORE A)

Virtual Reality Surgical Simulators

Przemysław Korzeniowski



Goal: Given the challenges of fetoscopic Spina Bifida repair, there's a growing need for effective training. Computer-based VR simulation systems present a solution, offering a safe and adaptable training platform without ethical concerns.

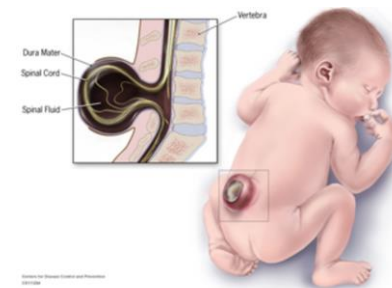
Result: A simulation validation study, involving feedback from 14 clinicians, rated the system's realism at 4.07 out of 5. Its applicability for SB-repair training and laparoscopic skill acquisition received scores of 4.63 and 4.80, respectively.

Next Steps: There's an intent to refine the simulator based on clinician feedback and then pursue broader clinical research, such as skill transferability and construct validity evaluations.

In cooperation with: Dr Robert Biskupski-Brawura-Samaha, I Klinika Położnictwa i Ginekologii, Warsaw Medical University



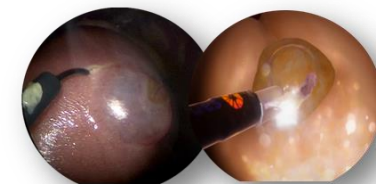
Validation study participants



Spina Bifida



Simulator setup with haptic laparoscopic interface



Real (on the left) and simulated surgery (on the right)



Computer Vision

Brain and More Lab



Alessandro Crimi

Brain and More Lab



We focus on three main areas:

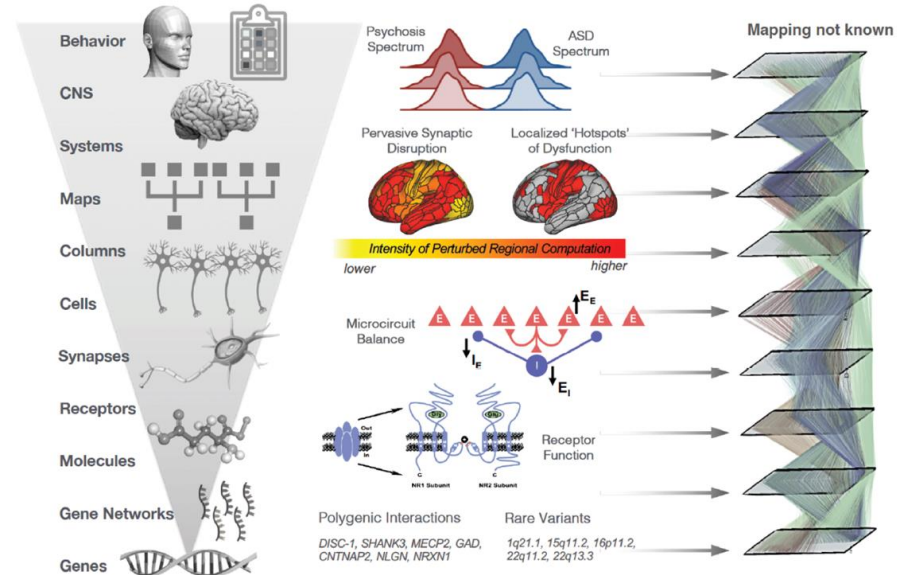
- Medical imaging (from histology/microscopy)
- Medical imaging (Neuroimaging)
- Brain Wearables (EEG, fNIRS, MEG, etc.)

In practice, we are interested in studying spanning all dimensions 2 disease (but open to others)

- Alzheimer/Dementia
- Brain tumors

My team in numbers:

- 1 Senior Scientist
- 4 PhD Students
- 3 Postdocs
- 2 Research Assistants
- 1 MSc Student
- 1 Dog

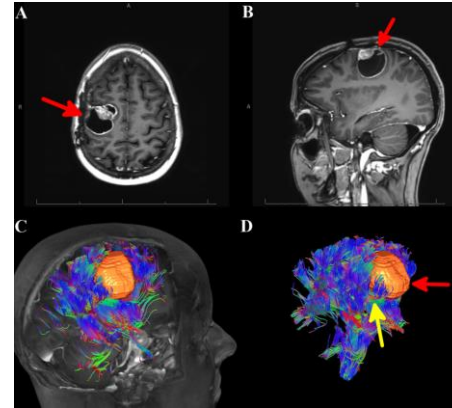


Brain tumor surgical planning and prediction

Joan Falco-Roget et al.



- A trained model is able to predict the brain connectivity of patients post-surgery and recovery
- Collaborations: University of Ghent for data, University of Messina and Padua for clinical support



"Bayesian Filtered Generation of Post-surgical Brain Connectomes on Tumor Patients" J. Roget Falco, F. Sambataro, A. Cacciola, A. Crimi

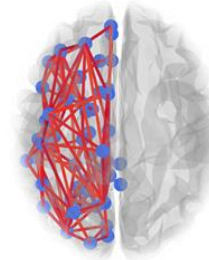
MICCAI 2022, Nature Communication

https://link.springer.com/chapter/10.1007/978-3-031-21083-9_8

"Structural Reorganization Following a Brain Tumor: A Machine Learning Study Considering Desynchronized Functional Oscillations"

Nature Communication (to submit minor revision)

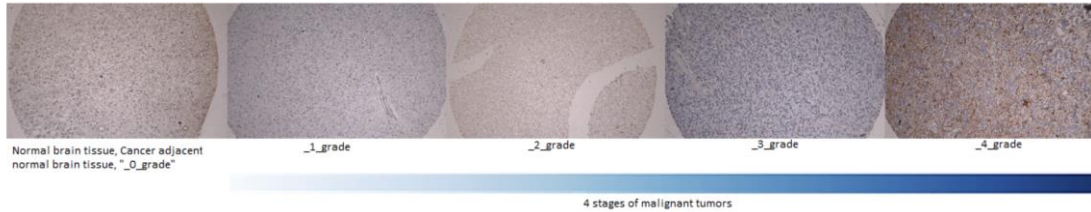
<https://www.biorxiv.org/content/10.1101/2022.11.14.516248v2.abstract>



Pre-surgery
planning
to avoid
aphasia/motor
deficit

Brain tumor classification and image translation

Monika Pytlarz et al.

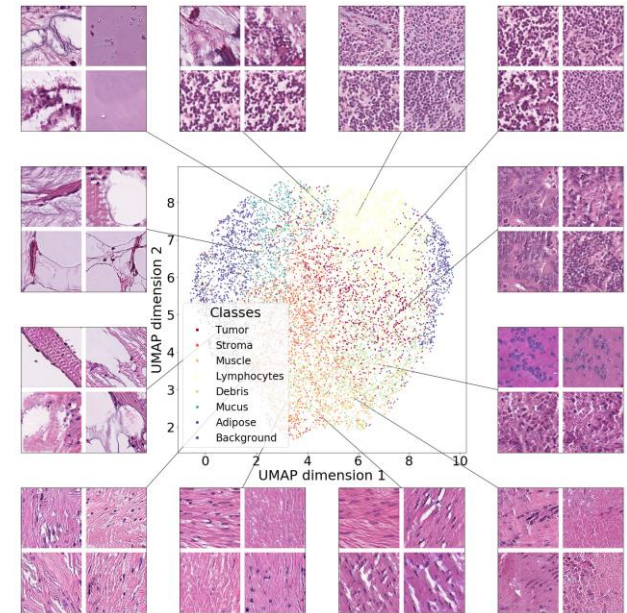


- A classification model is able to detect and classify the grade of a brain tumor within a biopsy
- Project is ruled out in collaboration with the Nencki institute for molecular neurobiology

Automated glioma multiclass tumor classification, M Pytlarz, K Wojnicki, P Pilanc, B Kaminska, A Crimi, SPIE 2023

[Deep Learning Glioma Grading with the Tumor Microenvironment Analysis Protocol for A Comprehensive Learning, Discovering, and Quantifying Microenvironmental Features](#)

M Pytlarz, K Wojnicki, P Pilanc, B Kaminska, A Crimi, Digital Imaging 2023



Extreme-Scale Data & Computing

Research Team



Maciej Malawski

Extreme-Scale Data & Computing

Goals: To apply the experience in large-scale computing systems to medical applications and to push the boundaries of current technologies when required by scale of data and computing demands

Topics of research agenda:

- Efficient processing of large data sets with the use of advanced computing infrastructures (HPC and Cloud).
- Development of tools for large-scale computing and data analysis
- Distributed and federated machine learning
- Performance evaluation and optimization of medical applications on emerging computing infrastructures.

The team in numbers:

- 4 PhD Students
- 5 MSc Students
- 5 Scientific programmers

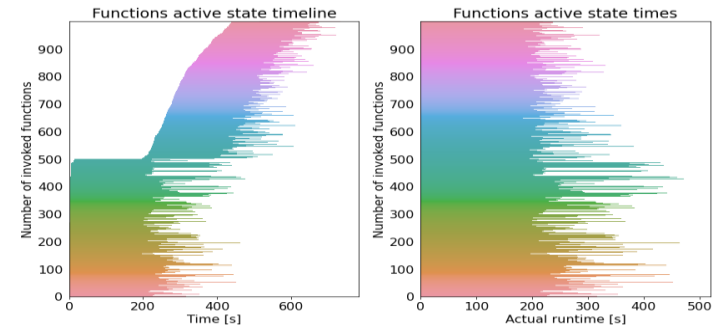
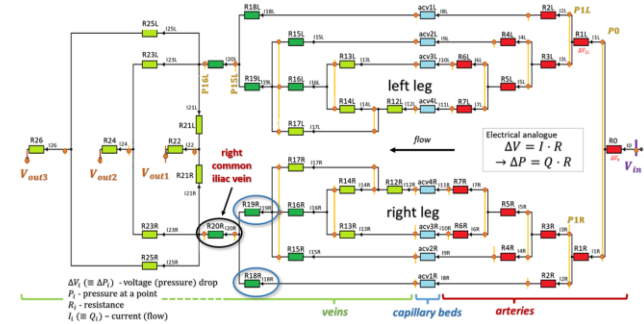


Verification, Validation, Uncertainty Quantification of simulation models

Magdalena Otta, Piotr Kica



- 0D, 1D, 3D models of cardiovascular systems
- Example: Venous modelling to inform treatment of patients presenting with lower limb thrombosis (PhD project with University of Sheffield)
- VVUQ, Sensitivity analysis - required in the regulatory process of model certification
- Large parameter studies
 - 50 000 parameters -> tasks
- CloudVVUQ library using serverless computing
- Total time to compute locally $\approx 76.1\text{h}$
- Total time to compute using Google Cloud $\approx 12.5\text{min}$
- <https://github.com/SanoScience/CloudVVUQ>



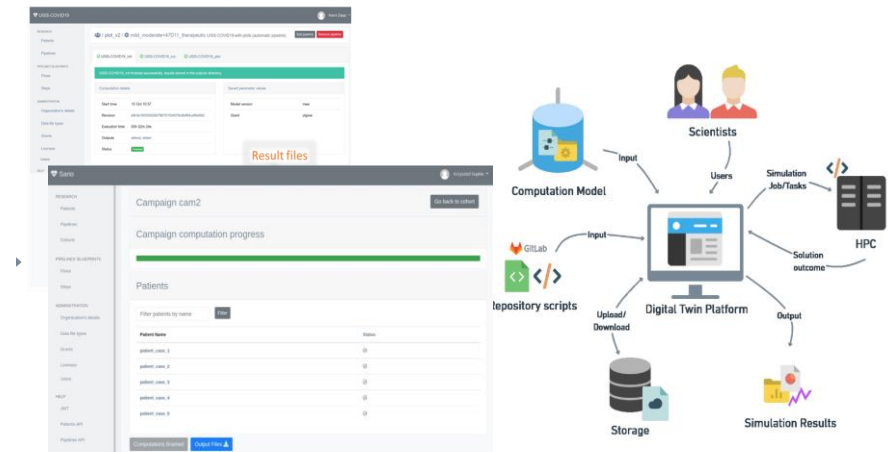
500 tasks running in parallel

Platform for Simulations of Digital Twins

Jan Meizner, Karol Zająć, Adam Nowak, Krzysztof Gądek,
Piotr Nowakowski



- Web-based system for management of multi-step computational pipelines on HPC systems
- Patient data-centered workflows:
 - Steps -> Pipelines -> Campaigns
 - Patients -> Cohorts
- Models implemented as software artifacts
 - Versioning: GitHub, GitLab
 - Comparison of results
 - **Reproducibility** -> Robust Science
- File management (HPC storage, Cloud storage)
- Usage in In Silico World EU Project
- Collaboration with Univ. Bologna, Univ. van Amsterdam, KU Leuven
- <https://mee.cyfronet.pl/>



Marek Kasztelnik, Piotr Nowakowski, Jan Meizner, Maciej Malawski, Adam Nowak, Krzysztof Gadek, Karol Zająć, Antonino Amedeo La Mattina, Marian Bubak: Digital Twin Simulation Development and Execution on HPC Infrastructures. ICCS (2) 2023: 18-32

Personal Health Data Science Team

Research Team



Jose Sousa, PhD

Personal Health Data Science

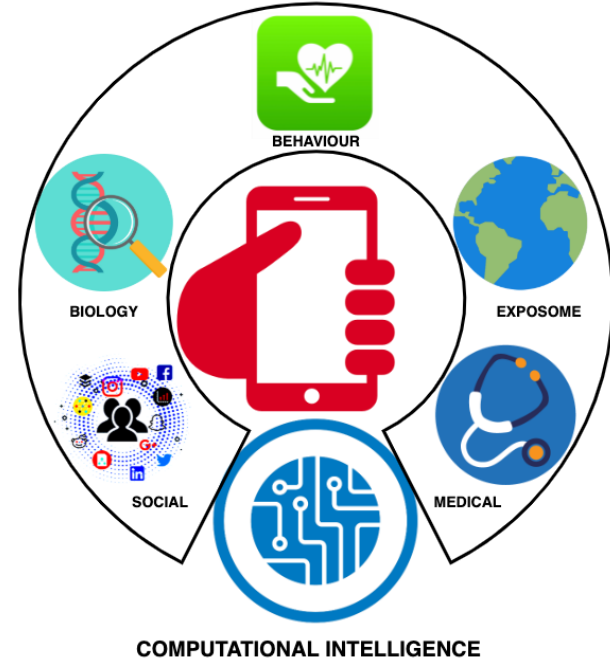
The group has a research vision of “Citizen-Before-Patient” (CB4P). We focus on the mission of “Empowering personal health decision making with actionable insights using a Computational Intelligence Architecture of Choice”.

The two main areas:

- Fundamental computational approaches aimed at emulating the intricate processes of both "System 1" and "System 2" decision-making in AI systems within a concept of a digital mind
- Foundational Disease models' development to support evidence-based health care decision making

My team in numbers:

- 4 PhD Students (1 external)
- 4 Postdocs
- 3 BSc



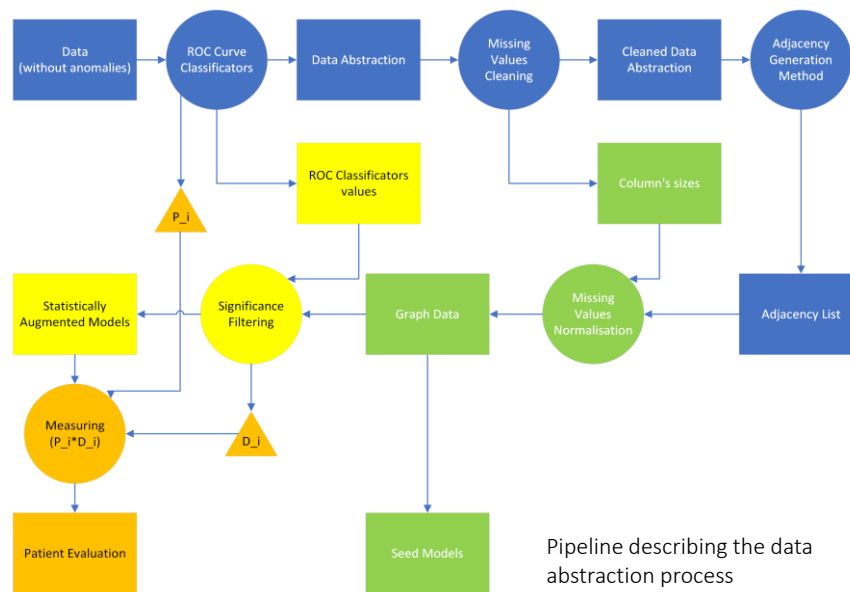
A small and incomplete dataset analyser

Alfredo Ibias, Varun Ravi Varma, Karol Capala, Luca Gherardini, Jose Sousa

- Personalized health often involves small datasets with missing data.
- Current Machine Learning methods struggle with such datasets due to high data volume requirements.
- SaNDA prioritizes explainability over efficiency due to dataset characteristics and domain importance.
- Evaluation against Random Forest (baseline for explainable methods) and gcForest (state-of-the-art for small datasets).
- SaNDA outperforms Random Forest with more missing data or fewer entries, but less favourable results on larger, well-curated datasets.
- Preferred over gcForest for explainability and privacy protection.
- Valuable for healthcare practitioners given data challenges in the field.

Keywords: Personalised Health, Small Data, Machine Learning, Data Science

<https://www.sciencedirect.com/science/article/pii/S0020025523006631>
Information Sciences, IF: 7



Pipeline describing the data abstraction process

CACTUS: a Comprehensive Abstraction and Classification Tool for Uncovering Structures

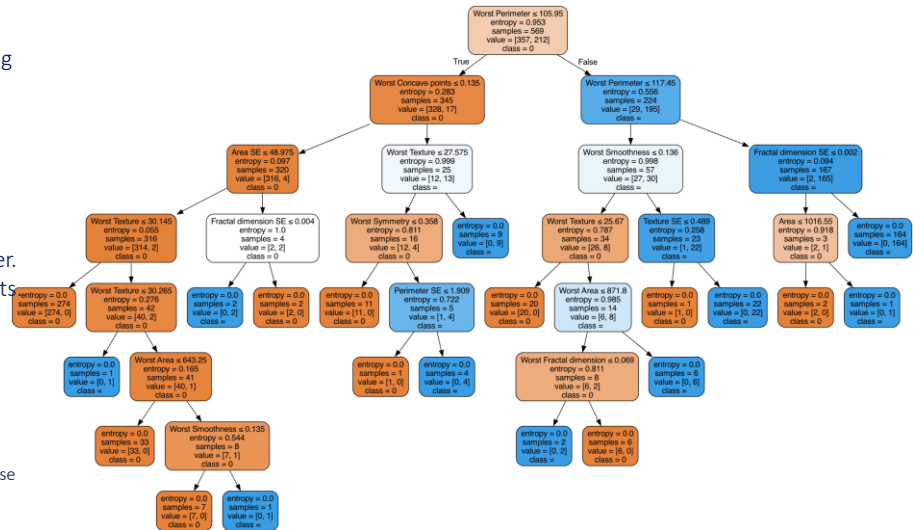
Luca Gherardini, Varun Ravi Varma, Karol Capała, Roger Woods, Jose Sousa

- Availability of large data sets drives current AI developments.
- Challenges exist for small data sets due to practicality, cost, and opacity of deep learning models.
- Proposal: Introduction of the Comprehensive Abstraction and Classification Tool for Uncovering Structures (CACTUS).
- CACTUS focuses on secure analytics using explainable AI.
- It enhances support for categorical attributes while preserving their original meaning.
- Optimizes memory usage and speeds up computation through parallelization.
- Displays attribute frequency in each class and ranks them based on discriminative power.
- Assessment conducted on Wisconsin diagnostic breast cancer and Thyroid0387 data sets

Keywords: Classification, Machine Learning, Explainable Artificial Intelligence

ArXiv, <https://doi.org/10.48550/arXiv.2308.12031>

(under review at ACM Transactions on Intelligent Systems and Technology, IF 10)
 (research supporting this work is under review at **IEEE Transactions on Pattern Analysis and Machine Intelligence**, “Noise Reduction through Abstractions and Its Possibilities for Machine Learning”, IF 24)



A decision tree for explainability

Clinical Data Science

Network Medicine & AI



Ahmed Abdeen Hamed

Clinical Data Science. Network Medicine & AI

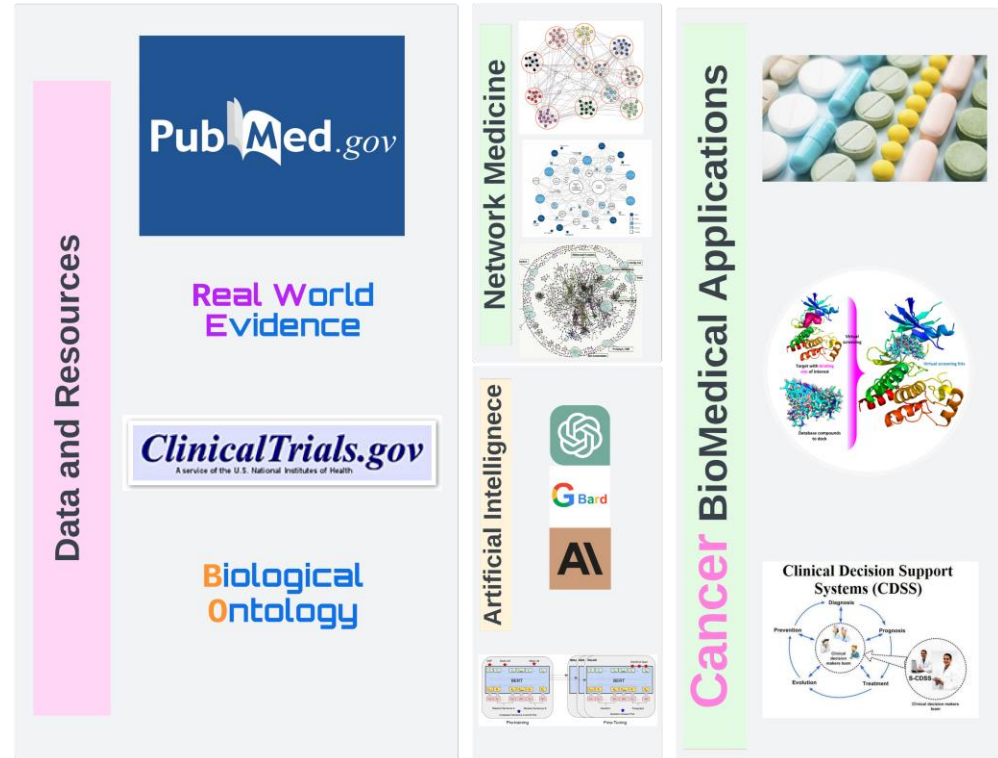


We focus on **Cancer Research** using computational two methods:

- Development of Innovative **Network Medicine** Approaches to Complex Disease Research and Management
- Development of **Generative AI** Methods to Improve Clinical Decision Support for Complex Disease Treatment

Team in numbers:

- 2 Master's students
- 3 PhD student (1 pending)
- 2 PostDoctoral Fellow



A Graphical Abstract Demonstrating the Scope of the CDS team: specialized in **Network Medicine** and **Artificial Intelligence** for **Cancer Research**

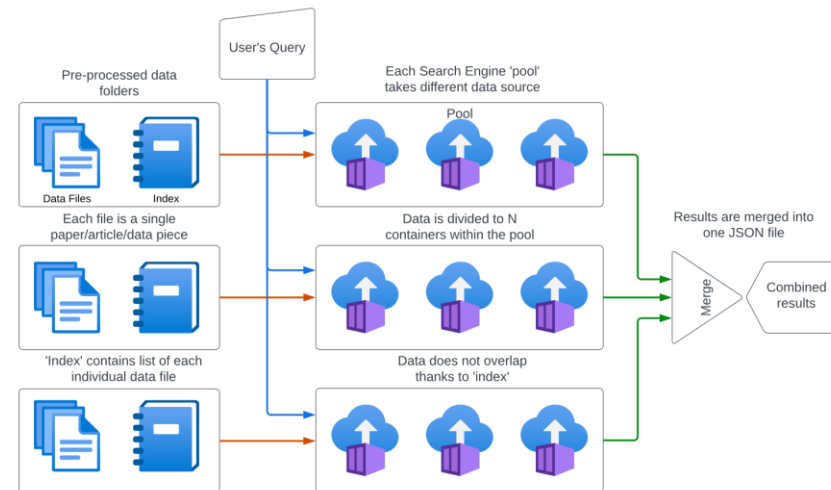
A Federated Search Workflow Engine for BioMedical and Drug Analytics

Filip Katulski et al.

Question: Can we optimize a highly scalable federated search engine architecture using High-Performance Computing (HPC) and Cloud enhancements to bridge gaps in diverse clinical and biomedical literature sources, ultimately facilitating better biomedical discoveries?

Features:

- A highly-scalable general-purpose search engine that can be instantiated biological, clinical and pharmaceutical discoveries
- Searching across multiple data sources for relevant documents. This could save researchers time and effort, as they would no longer need to manually search each data source individually.
- The engine has been instantiated in the research of Drug Repurposing using BioMedical Literature and Clinical Trials



The System Architecture of the Federated Search And Biomedical Engine

Precision Thermostability Prediction Using AlphaFold and GNN

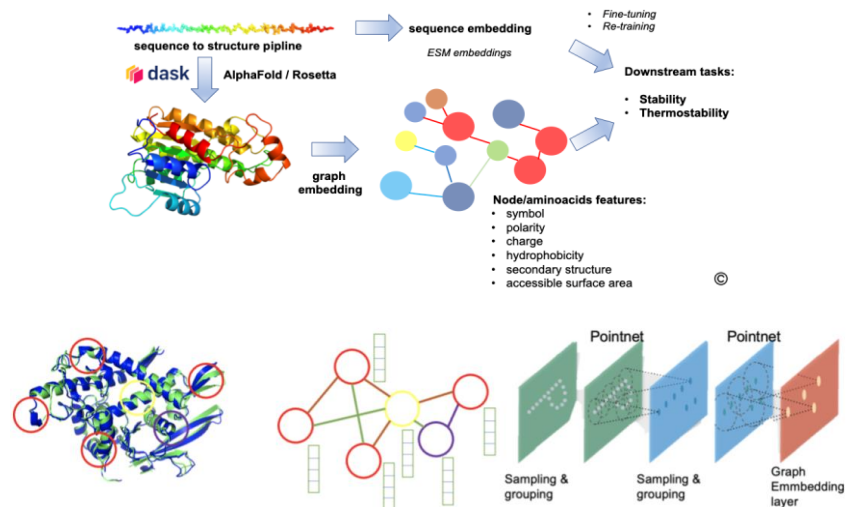
Adam Sufek, et al.

Question: Can We Accurately Predict Protein Thermostability to Enhance Drug Discovery for Biological Targets in Healthcare?

Features:

- Cutting-edge advanced graph neural networks (GNN).
- Data-driven approach: utilization of publicly available data sources for prediction.
- Superior model performance: GNN model outperforms PointNet++ with higher correlation ($R^2 \sim 0.6$).

Sulek, A, Jonczyk, J, Hamed, AA, "Language Models & Protein Stability: Predicting Protein Thermostability with Deep Learning Models", 2023 CompBioMed Conference, Garching, Germany



The virtual screening workflow of proteins using GNN

Scientific Programming Team

Support Team

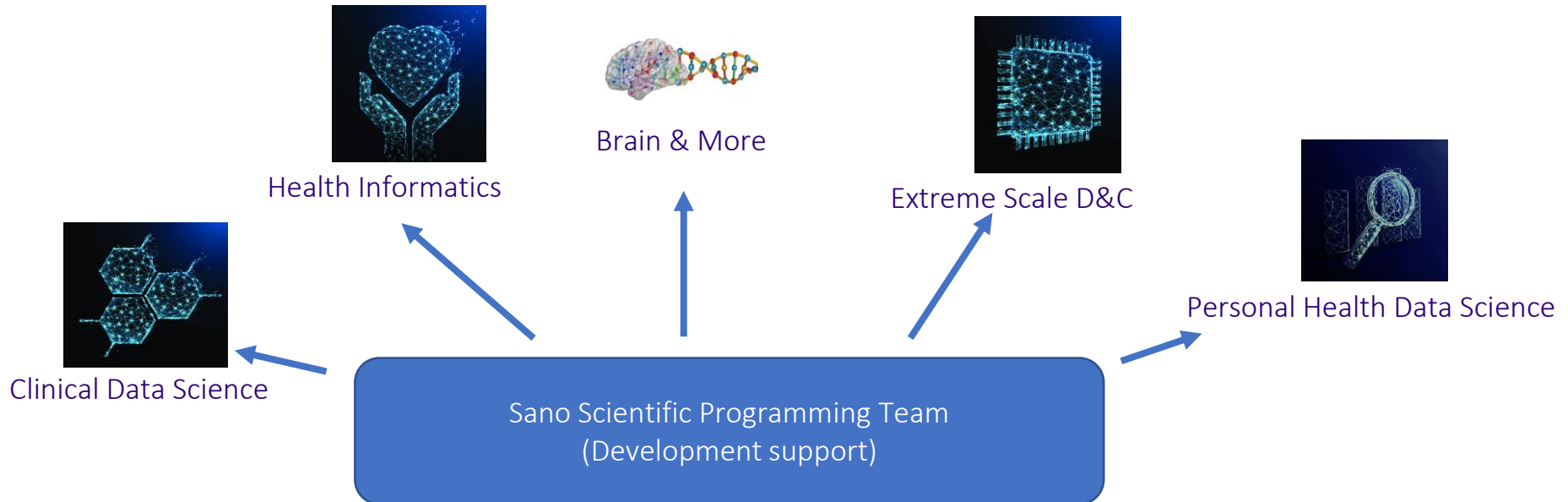
Scientific Programming Team



Each member of SPT is affiliated with one or more research teams, where they participate in development of artifacts, services and customized IT tools.

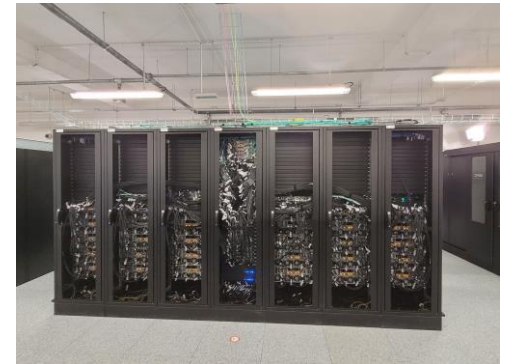
SPT members also work on research grant proposals, and have been quite successful in this regard

Successful GEMINI Horizon Europe proposal!

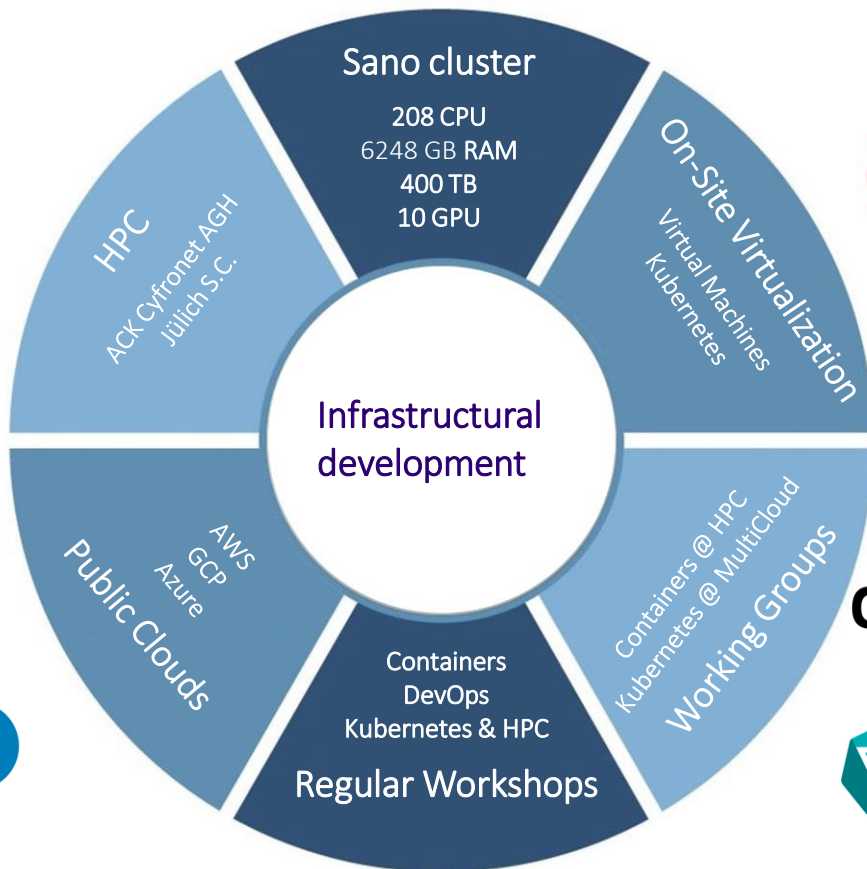
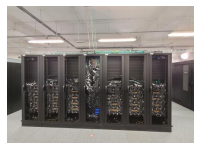


Access to infrastructure

- ✦ In 2022 Cyfronet launched Athena – a powerful cluster dedicated to GPGPU computations.
- ✦ With 7.71 PFlops of computational power, Athena placed 105th on the TOP500 list, making it the most powerful computing cluster in Poland.
- ✦ Taken together, the three main HPC systems at Cyfronet provide over 10 PFlops of computational power.
- ✦ However, properly accessing and utilizing this power requires IT knowledge, which is why the SPT team assists our users in deploying their computations on the available resources.



Infrastructural development and support activities



kubernetes



GitHub



docker



KubeVirt



Google Cloud Platform



Summary of achievements

Successes of Sano in numbers



- **90+** people in **4** years
- **5** teams, **21** PhD students, **11** PostDocs
- **3** EU Horizon projects, **2** commercial contracts
- **2** editions of Summer School
- **45** publications in journals, **29** conference papers
- **37** publications in journals on JCR List
- **18** conference papers on Ministry List



Centre for Computational
Medicine

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Republic
of Poland



Foundation for
Polish Science

European Union
European Regional
Development Fund

