Elettra
Sincrotrone
Trieste

Artificial Intelligence as an Operational Layer in a Research Infrastructure

Infrastructure, Chatbots, Agentic Systems and Publications at Elettra Sincrotrone Trieste

Roberto Pugliese, George Kourousias et al.

Elettra Sincrotrone Trieste

Outline

- ✓ Elettra AI since 1995
- ✓ Recent Projects and Strategy
- ✓ The Elettra Data Lake
- ✓ Data Lake Applications
- ✓ Elettra AI (gpt.elettra.eu)
- ✓ The Importance of Training
- ✓ AI Readiness Level
- ✓ Agentic Publications
- ✓ Autonomous Robotics
- ✓ The Largest Robot in the World
- ✓ CAIRNE and Call for Partners

Elettra: AI pioneers since 1995

- ✓ First intelligent system developed on the SuperESCA beamline.
- ✓ Technologies later adopted at ESRF (Grenoble).
- ✓ Automatic optimization of the synchrotron light beam.
- ✓ Elettra was already applying AI to optimize beam quality 30 years ago.

Automatic Alignment of a Synchrotron Radiation Source Beamline using Intelligent Systems

S. Olof Svensson[a], Roberto Pugliese[b]

[a]European Synchrotron Radiation Facility, BP220, F-38043 Grenoble Cedex, France
[b]Sincrotrone Trieste S.C.p.A., Strada Statale per Basovizza 14 km 163.5, 34012 Trieste, Italy

ABSTRACT

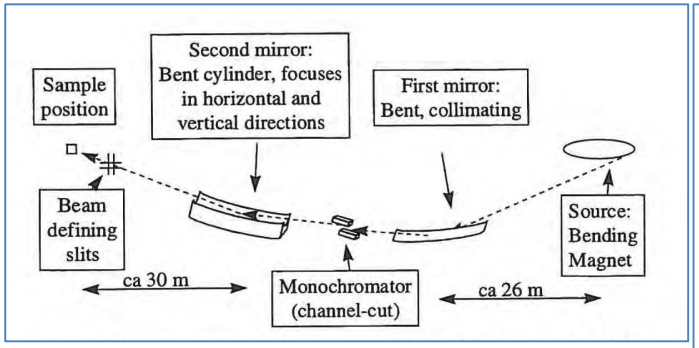
Synchrotron Radiation (SR) sources in general, and the new third generation SR sources in particular, deliver very intense X-ray beams with very low divergence. However, due to small shifts of the stored electron beam position caused by re-optimisation of the closed orbit after shutdowns, the beamlines must be regularly re-aligned in order to deliver optimum performance. Since the beamlines generally contain complicated optical elements, such as X-ray mirrors and monochromators, the alignment procedure is difficult and time-consuming.

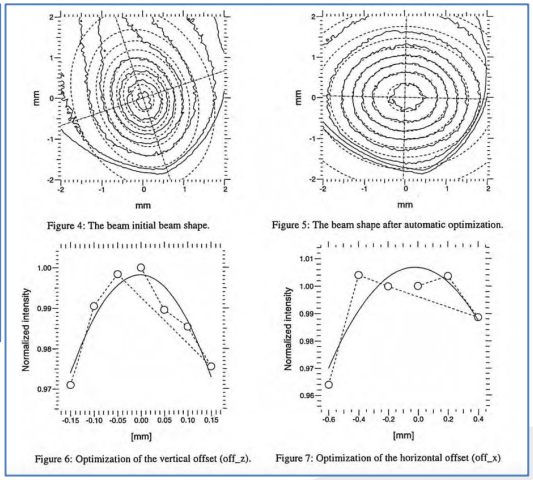
Automatic beamline alignment has been envisaged in order to more constantly keep optimal performance of the beamline. An Intelligent System approach has been chosen to face the complexity of X-ray beamline alignment. A knowledge-based system has been chosen for the development of the automatic alignment tools.

The developed tools have been applied to the Multi-wavelength Anomalous Dispersion (MAD) beamline of the European Synchrotron Radiation Facility (ESRF). The intensity and the spot shape at the sample position, obtained by using a small 2-D CCD detector, were optimized by automatically aligning the main optical element, a bent cylindrical mirror that focuses the beam in both horizontal and vertical directions.

The developed automatic alignment techniques have been shown to robustly optimize the intensity and the focal spot shape on the ESRF MAD beamline. A series of images of the beam shape showing the optimization will be presented.

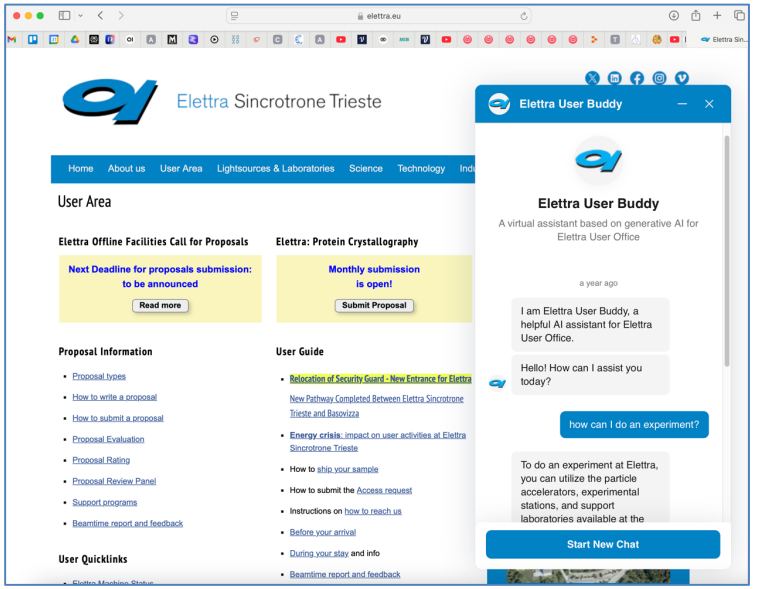
Keywords: Synchrotron Radiation, Intelligent Systems, Knowledge-based System, Optimization, Java

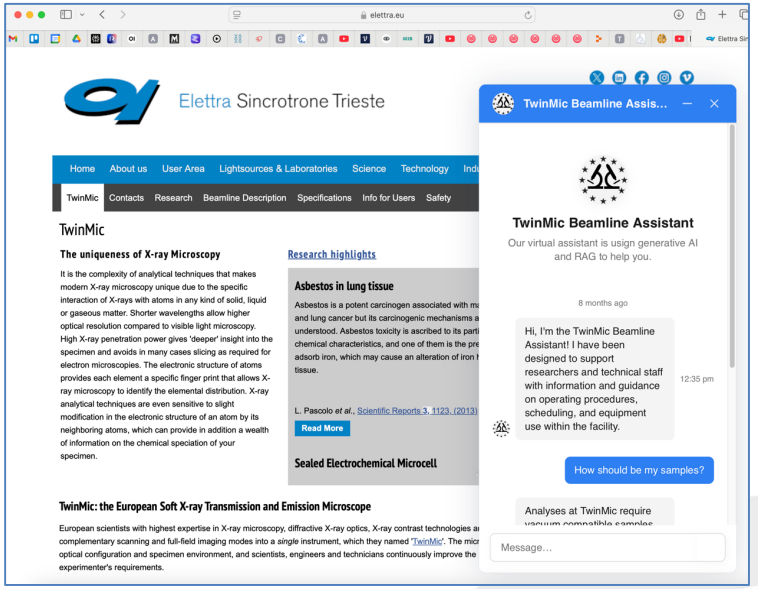




Recent projects and strategy

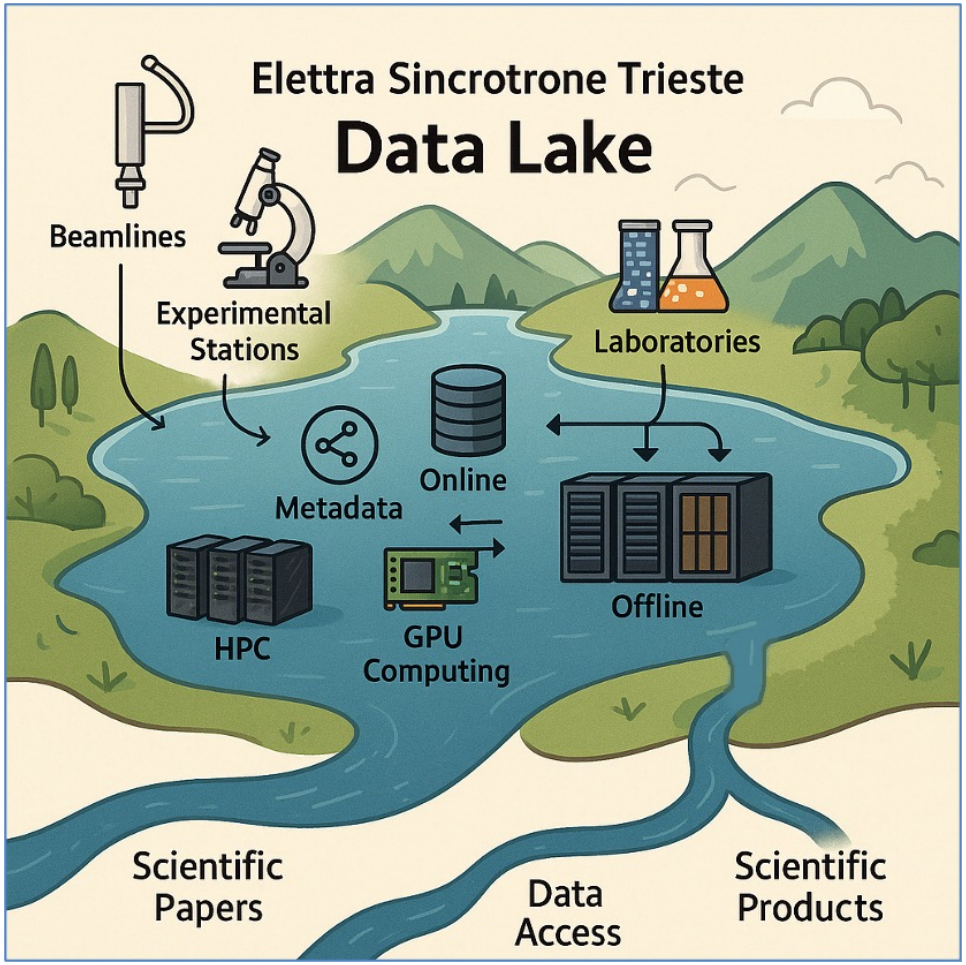
- ✓ AIPATH (2019-2020): AI roadmap, pilot cases, chatbots.
- ✓ EAI Project (2025-2027): AI services, LLM portal, policy.
- ✓ AI4UO: Support for research infrastructure user offices through virtual assistants.
- ✓ BEAM: AI applied to accelerator optimization (troubleshooting assistants, reinforcement learning for orbit optimization).
- ✓ Elettra develops operational AI solutions.



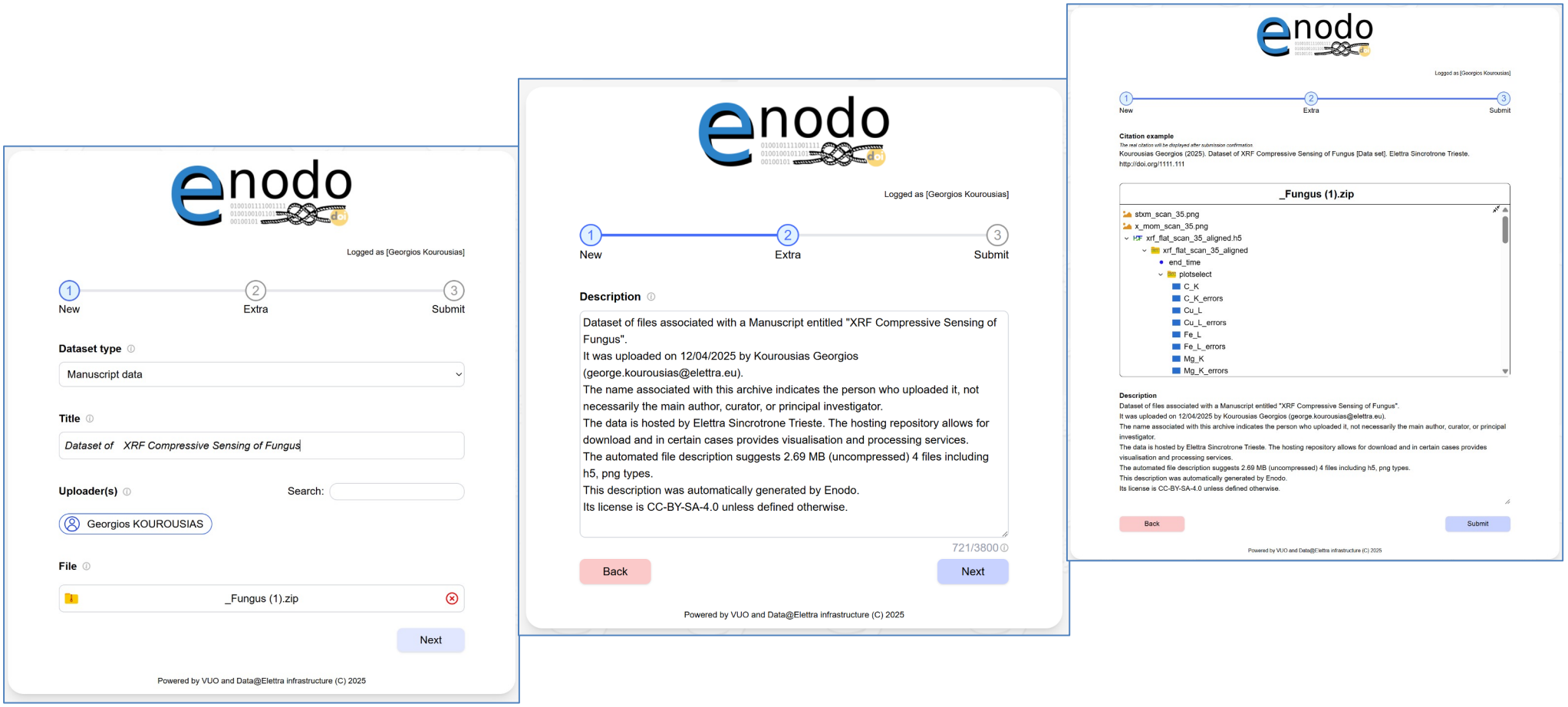


The Data Lake: The Foundation for All Modern AI

- ✓ AI means Data, Computing Power, and Algorithms.
- ✓ Scalable and secure lakehouse architecture.
- ✓ Interoperable scientific formats (TIFF, HDF5, CIF, etc.).
- ✓ Already operational, FAIR, and integrated with AI tools.
- ✓ Without data, AI doesn't exist. Our Data Lake is already ready, operational, and fueling our AI models.

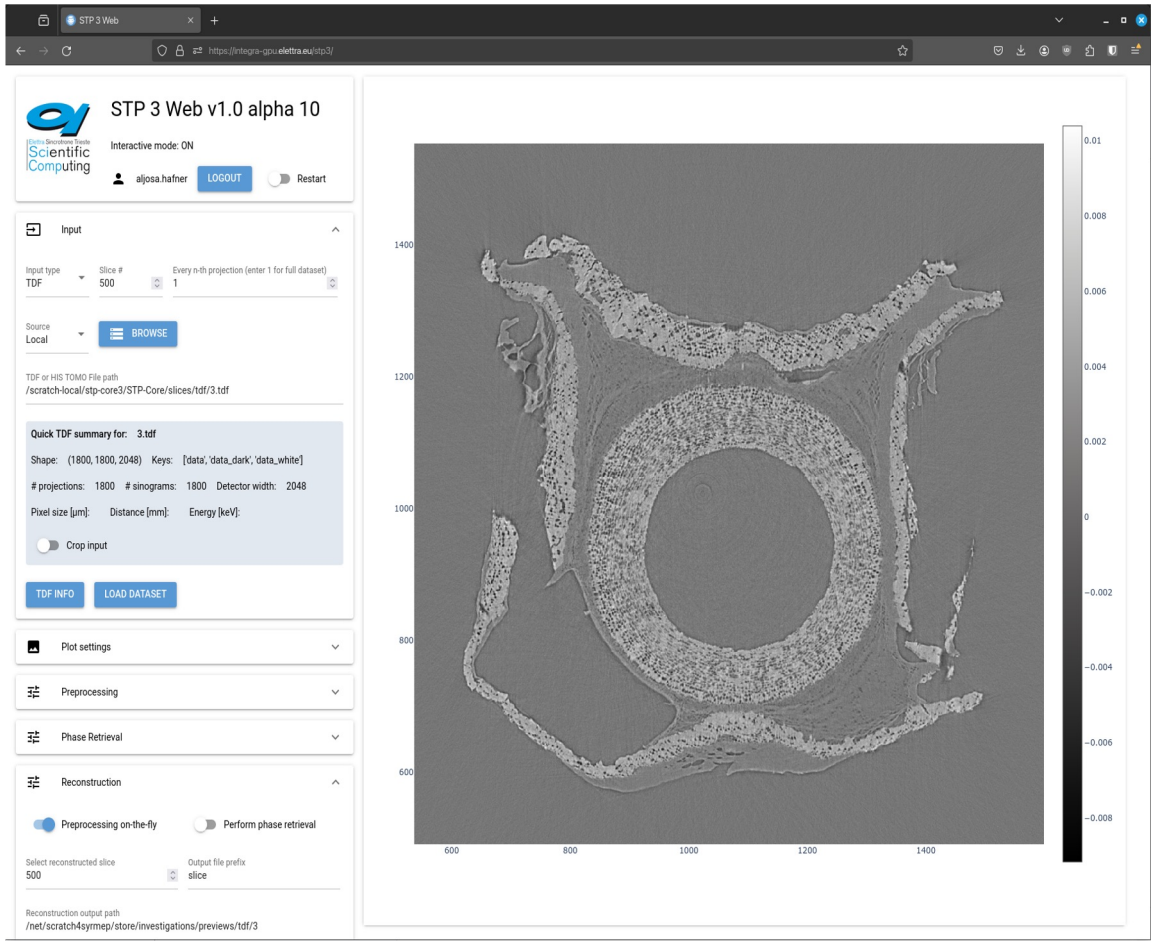


Datalake Applications: enodo.elettra.eu
LLMs for Automatic Data Description



AI for data processing and web visualization: STP3

- ✓ CT analysis.
- ✓ SYRMEP beamline.
- ✓ Modular Adaptive Processing Infrastructure (MAPI): ultra-high-performance architecture developed in-house.
- ✓ Extensive use of AI throughout the pipeline.



Elettra and the Health and Biotechnology sector

- ✓ Compressive Sensing for Elettra 2.0's SYRMEP_LS.
- ✓ Develop advanced compressive sensing techniques to optimize data acquisition on the SYRMEP_LS beamline (biomedical imaging).
- ✓ Improve diagnosis of asbestosis, mesothelioma, and lung cancer.
- ✓ Reduce scanning times and X-ray exposure. AI-driven sparse, dynamic, and conditional scans and in-painting algorithms for data reconstruction with intelligent masking of critical areas.
- ✓ Reduce acquisition times by up to 50-66%, improve image quality, and increase patient safety.
- ✓ Collaboration with healthcare organizations, universities, industry, and other research centers.

Elettra Sincrotrone Trieste

Compressive Sensing

Compressive sensing for dynamic XRF scanning

G Kourousias, F Billè, R Borghes, A Alborini, S Sala, R Alberti, A Gianoncelli

Scientific reports, 2020 • nature.com

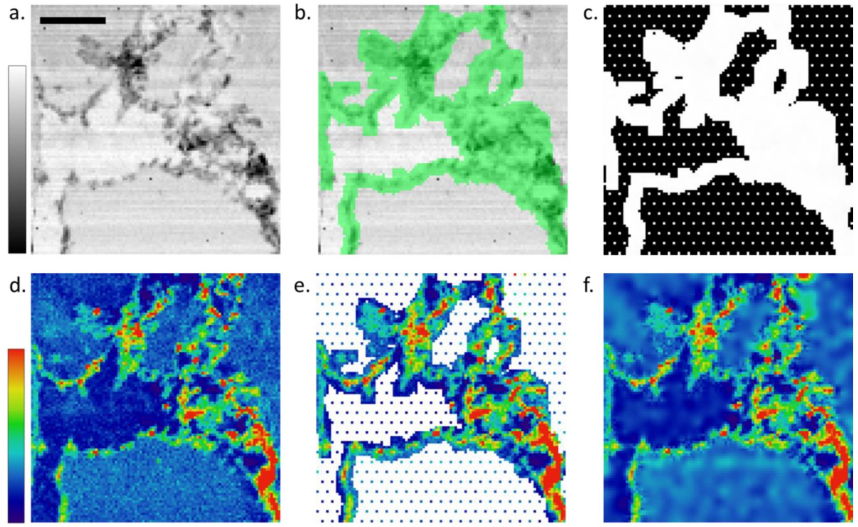


Figure 1. A rapidly acquired STXM map (a) (80µm x 80µm, 50x50 pixels, 20ms dwell time/pixel, scale bar=20µm) is used to create a mask (b) which is dense only in the regions of interest (green areas in c). A sub-sampled sparse XRF acquisition (e) is approximately 3 times faster than a full one (d). When the sparse is reconstructed through biharmonic in-painting (f) it can be processed with the usual XRF workflows producing similar results. In this specific case Panels d, e and f shows Si XRF signal collected at 1.95 keV on a foraminifera section over an area of 80µm x 80µm, with 1.6 µm step size and 3s acquisition time/pixel.

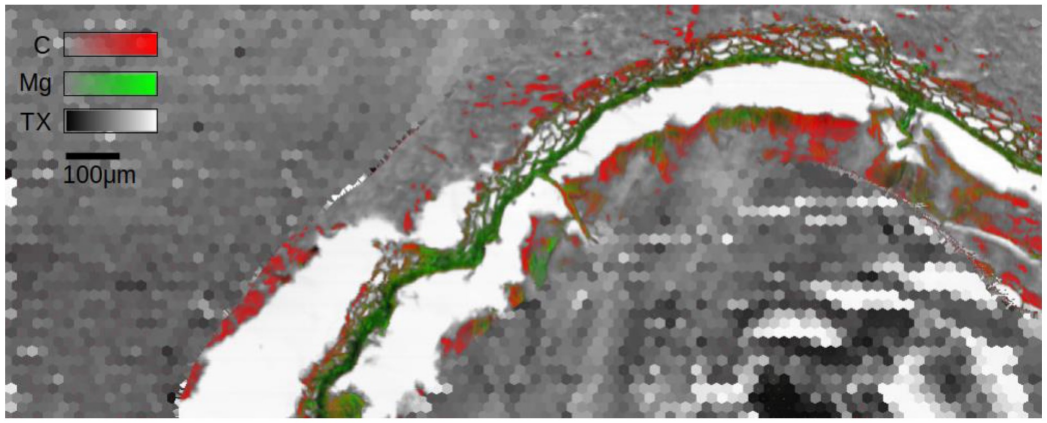


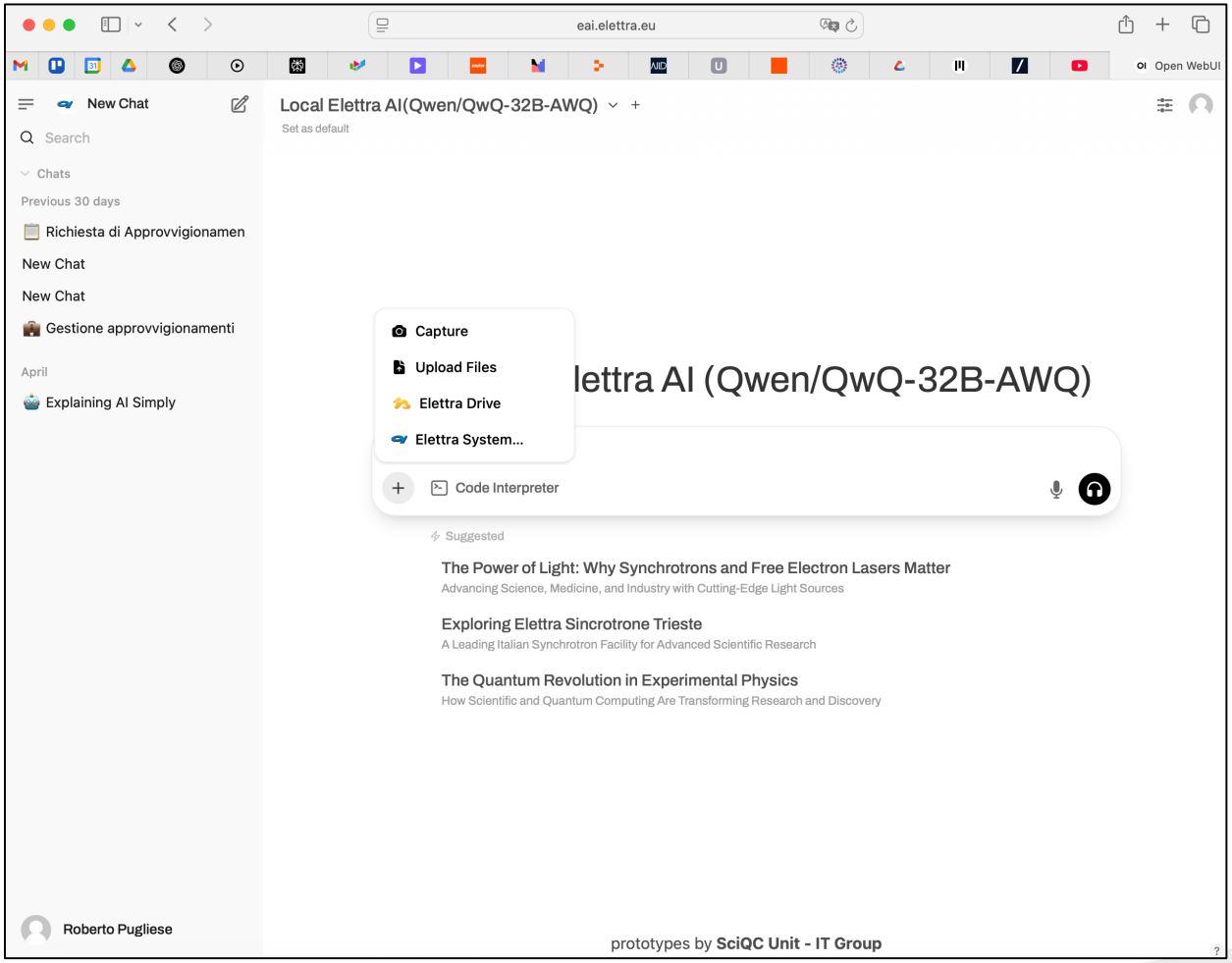
Figure 5. 0.4MPixel Sparse scan and Masking combined with a Conditional scan and multimodal acquisition on a cane root section sample. The STXM data (grey) (2000µm x 800µm) are acquired with a dense sampling (2µm step size) along the border of the cane root section while in a sparse way (20µm step size) in the remaining masked areas. The XRF data have been collected in a similar reduced manner (C in red, Mg in green) and are displayed overlapped with the STXM image. A traditional/complete acquisition (2µm step size) on the total area would require a measurement time 3 times longer.

AI to guide acquisition, reconstruction, for segmentation and recognition.

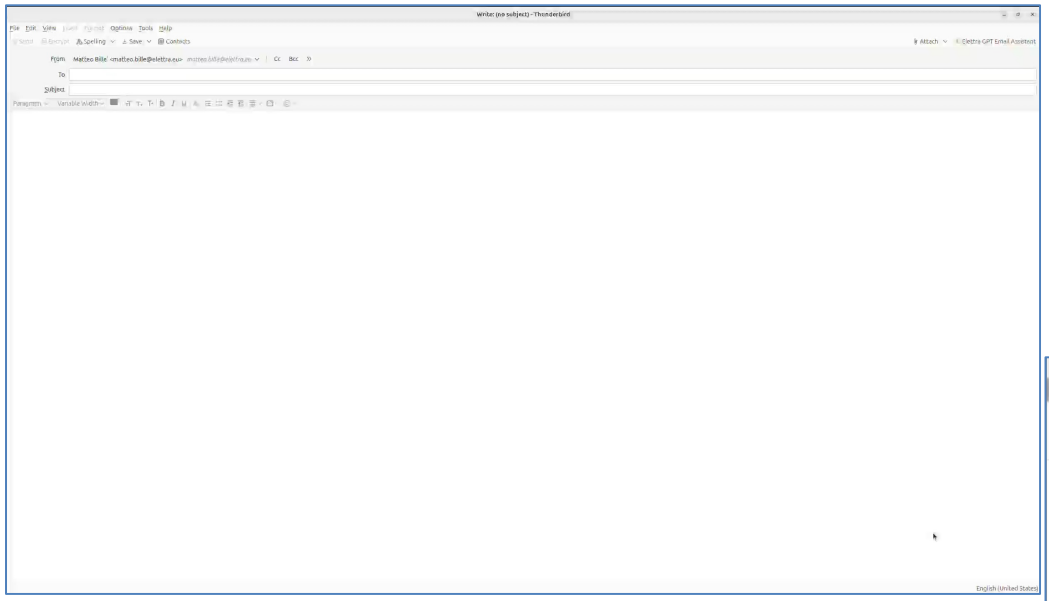
Elettra Sincrotrone Trieste

Elettra Artificial Intelligence

- ✓ We have the infrastructure needed to host and grow AI with full data sovereignty and control.
- ✓ Local GPUs, custom LLMs, RAG pipelines.

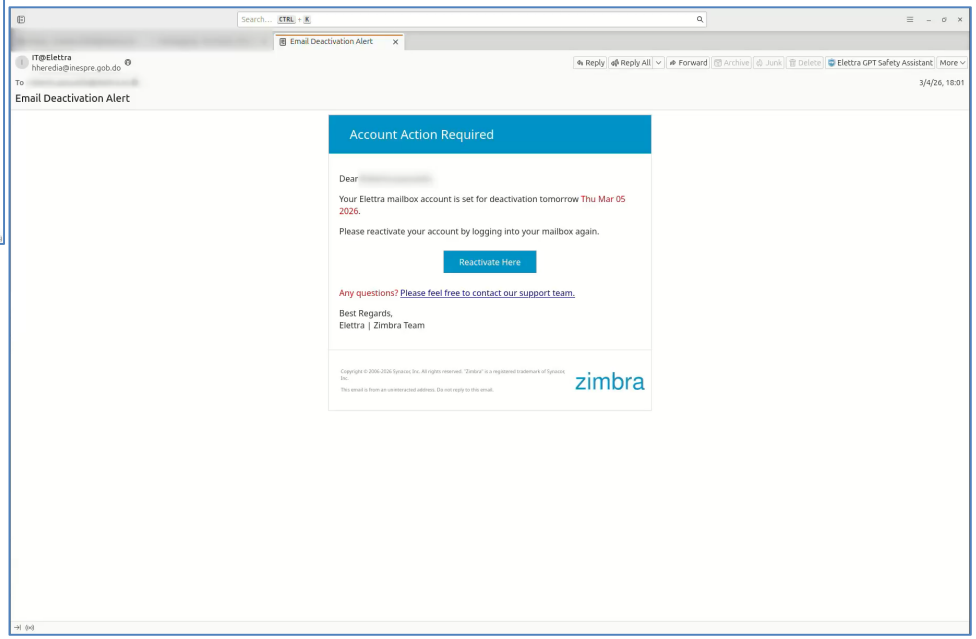


gpt.elettra.eu applications



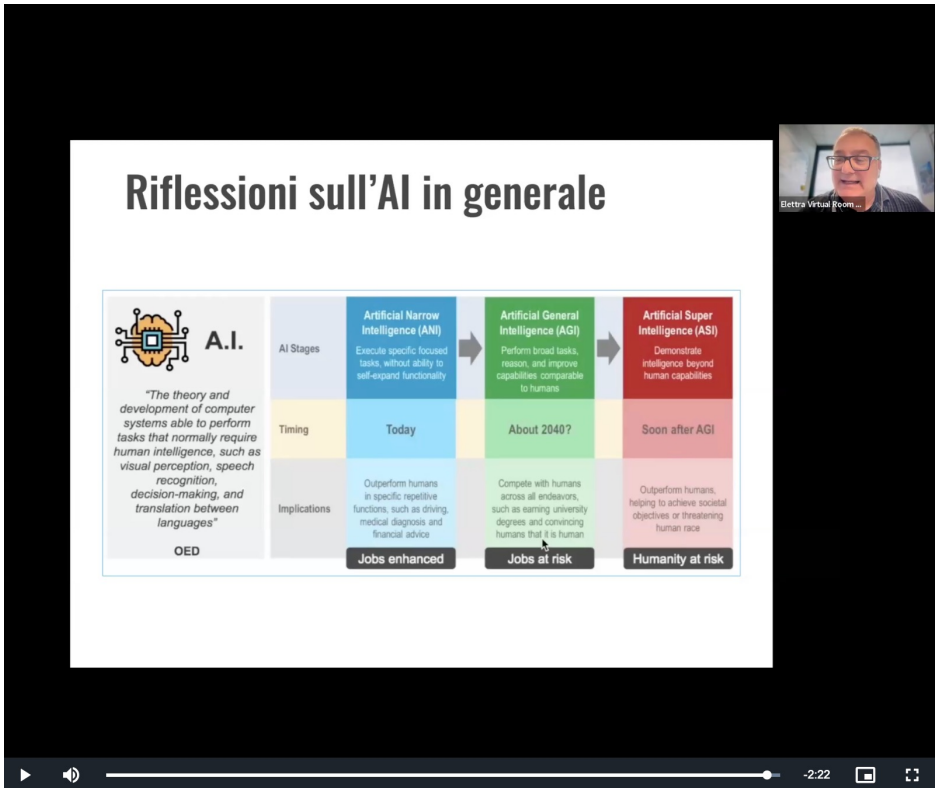
< email edit assistant

email cyersecurity assistant >



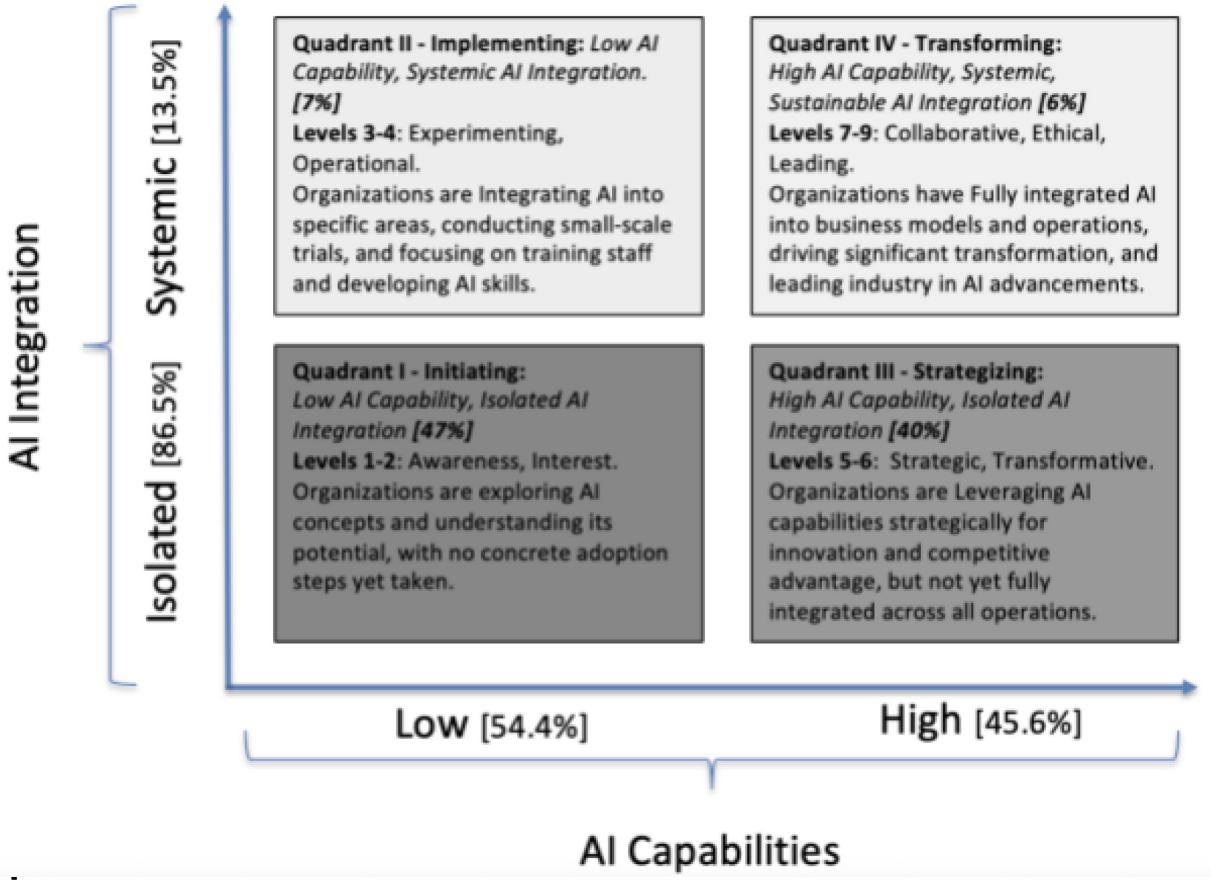
The importance of AI training

- ✓ 230 employees trained in the use of AI, particularly generative AI, starting in 2024.
- ✓ Three internal courses open to all staff.
- ✓ Excellent feedback and high participation.
- ✓ We have already sown AI culture internally. This creates fertile ground for innovation and widespread adoption.
- ✓ This generates ideas for pilot projects.



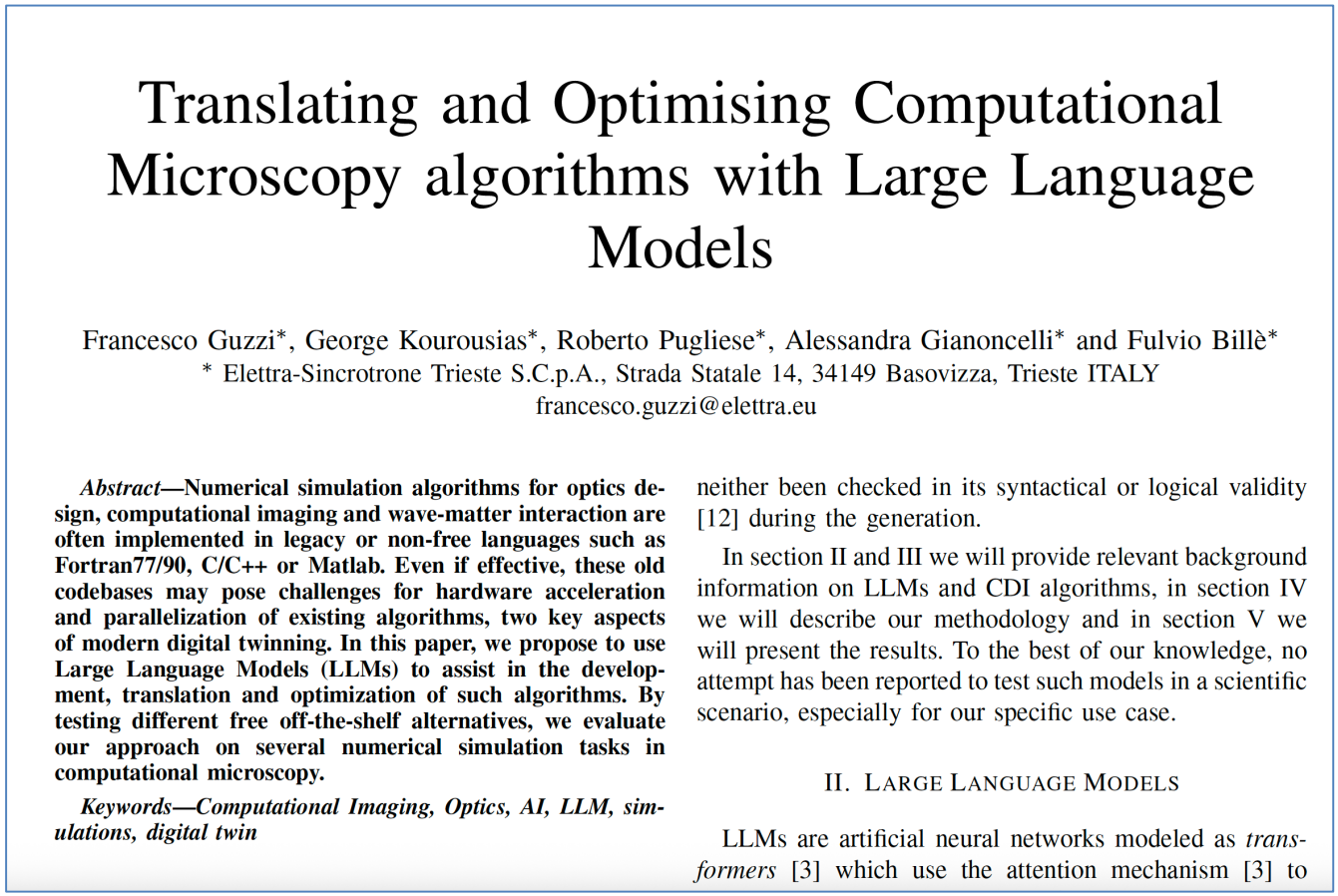
AIRL Model: AI Readiness Level

- ✓ AI Readiness Level (AIRL) model.
- ✓ Developed in collaboration with MIB School of TS
- ✓ Measures the AI maturity of Italian companies.
- ✓ Based on an empirica study with 237 managers.
- ✓ A useful tool for mapping and supporting AI adoption in the business world.



Research on LLM applications

- ✓ Elettra continues to research the practical applications of the LLM in coding.
- ✓ Elettra believes in the synergy between AI and quantum computing, which will have a significant impact on scientific computing.



Translating and Optimising Computational Microscopy algorithms with Large Language Models

Francesco Guzzi*, George Kourousias*, Roberto Pugliese*, Alessandra Gianoncelli* and Fulvio Billè*
* Elettra-Sincrotrone Trieste S.C.p.A., Strada Statale 14, 34149 Basovizza, Trieste ITALY
francesco.guzzi@elettra.eu

***Abstract*—Numerical simulation algorithms for optics design, computational imaging and wave-matter interaction are often implemented in legacy or non-free languages such as Fortran77/90, C/C++ or Matlab. Even if effective, these old codebases may pose challenges for hardware acceleration and parallelization of existing algorithms, two key aspects of modern digital twinning. In this paper, we propose to use Large Language Models (LLMs) to assist in the development, translation and optimization of such algorithms. By testing different free off-the-shelf alternatives, we evaluate our approach on several numerical simulation tasks in computational microscopy.**

***Keywords*—Computational Imaging, Optics, AI, LLM, simulations, digital twin**

neither been checked in its syntactical or logical validity [12] during the generation.

In section II and III we will provide relevant background information on LLMs and CDI algorithms, in section IV we will describe our methodology and in section V we will present the results. To the best of our knowledge, no attempt has been reported to test such models in a scientific scenario, especially for our specific use case.

II. Large Language Models

LLMs are artificial neural networks modeled as *transformers* [3] which use the attention mechanism [3] to

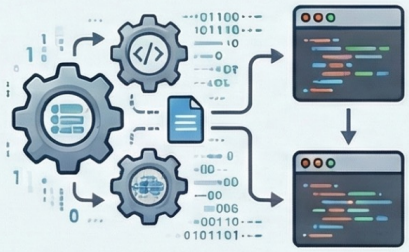
Elettra Sincrotrone Trieste

Agentic Publication: Future of Science

Reimagining Research: The Rise of Agentic Publications

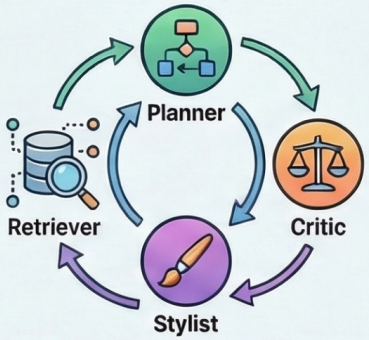
From Static PDF to Active AI Agent

STATIC PDF



Automated Transformation (Paper2Agent)

Multi-agent frameworks automatically convert papers and code into Model Context Protocol (MCP) servers with minimal human input.



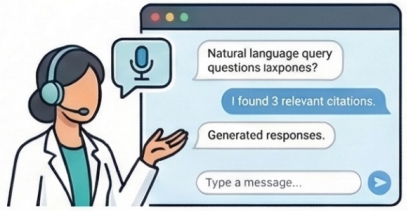
Collaborative Multi-Agent Pipelines

Specialized agents work together to verify claims, plan content, and generate publication-ready illustrations.

Continuous Knowledge Ingestion

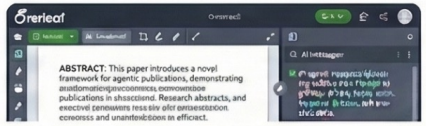
Unlike fixed documents, Agentic Publications support real-time data updates and version tracking as research progresses.

Interactive Scientific Application



Conversational Research Assistants

Researchers use natural language to query datasets, reproduce results, or synthesize findings across multiple papers.



Efficient Implementation

converted into active agents in **30 minutes to 3 hours** at a cost of approximately **$15.**

In-Editor Writing Support (PaperDebugger)

AI agents integrate directly into editors like Overieaf to provide inline critiques, literature lookups, and one-click edits.

Comparison: Traditional Manuscript vs. Agentic Publication (AP)

	Traditional Manuscript	Agentic Publication (AP)
Interactivity	Static Document	Dynamic Chat & API Access
Update Cycle	Months to Years	Continuous / Real-time
Accessibility	Human-readable only	Human and Machine-interpretable

Elettra and the Smart Factory

- ✓ Remote control systems and the use of telepresence robots have allowed us to remain operational even during the lockdown.
- ✓ Intelligent robotics:
- ✓ Autonomous systems based on ROS and SLAM, automatic docking, and intelligent navigation.
- ✓ Autonomous vehicles for indoor logistics based on AI and vision.
- ✓ Evolution towards humanoid systems for complex environments.

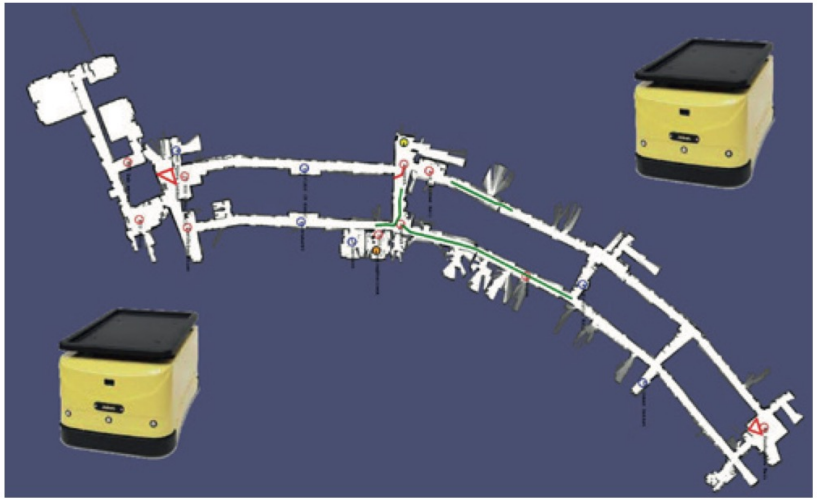
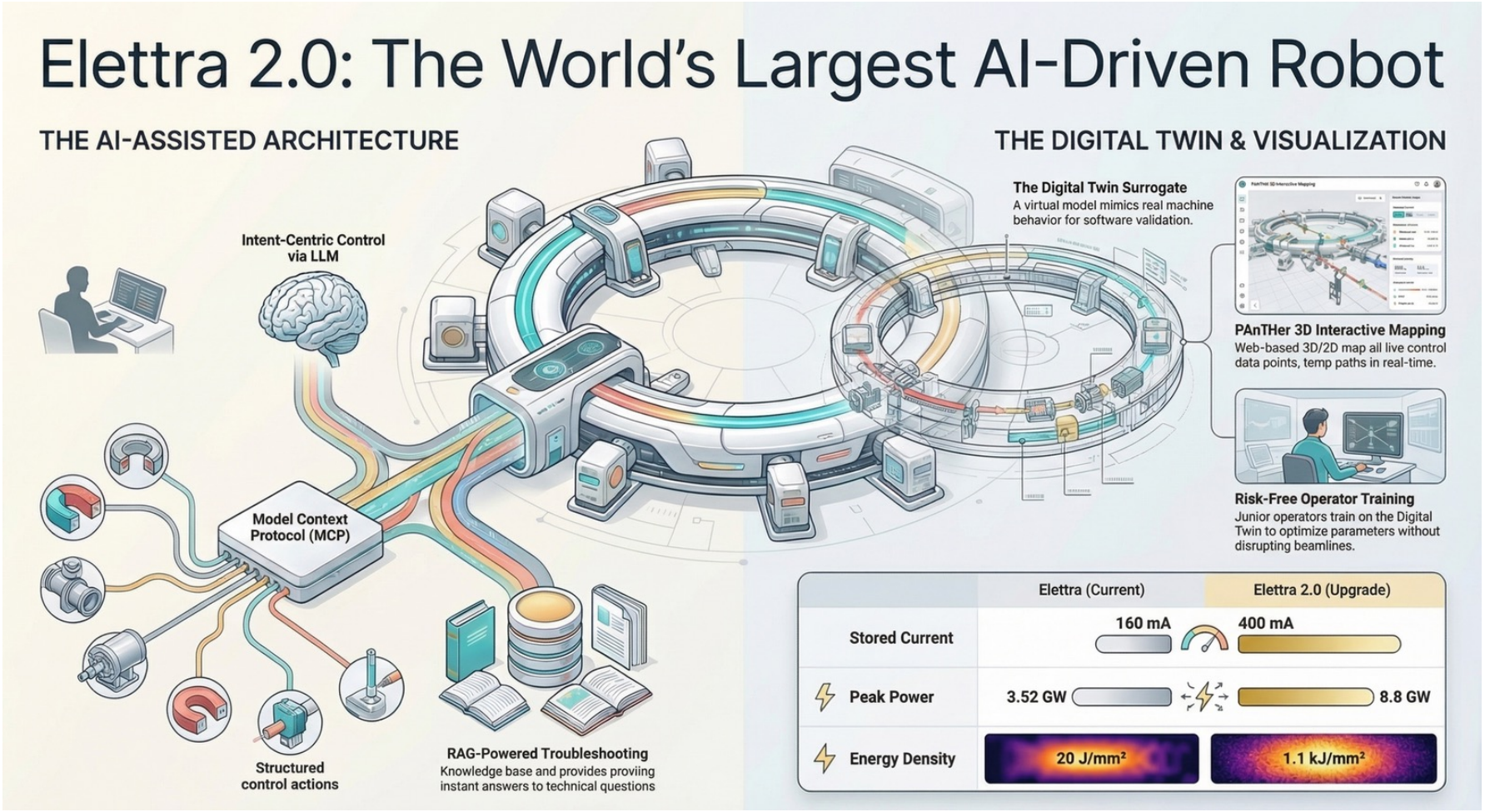


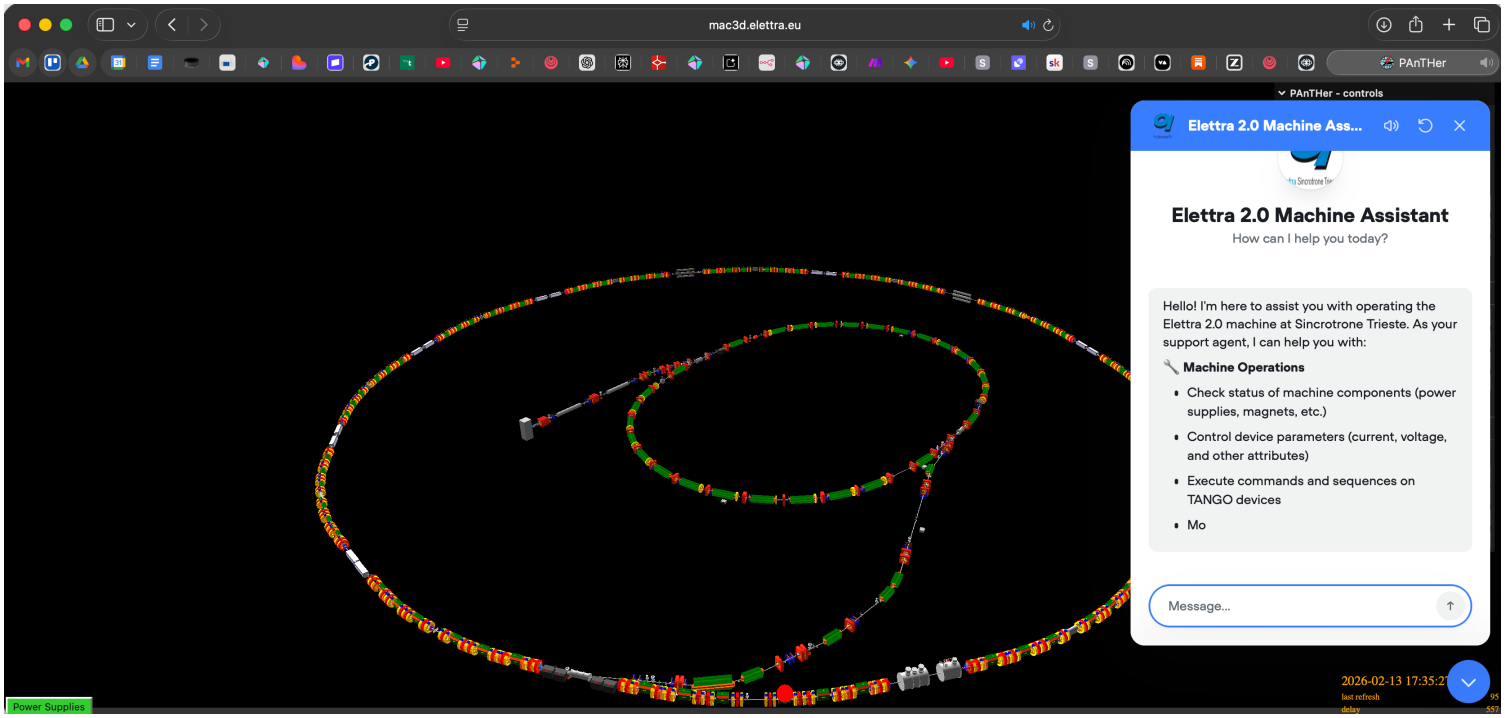
Figure 1: Lidar map of part of Elettra T2 building used for autonomous navigation for the robotic platform Jobot. This represents the state-of-the-art with goals, virtual walls and preferred paths can be defined to enable real and safe navigation.

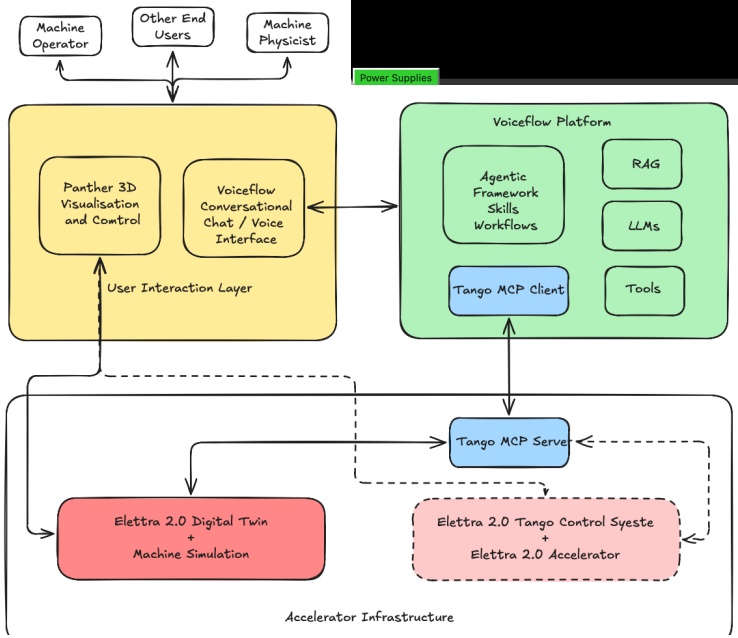
Elettra
Sincrotrone
Trieste

The Largest Robot in the World



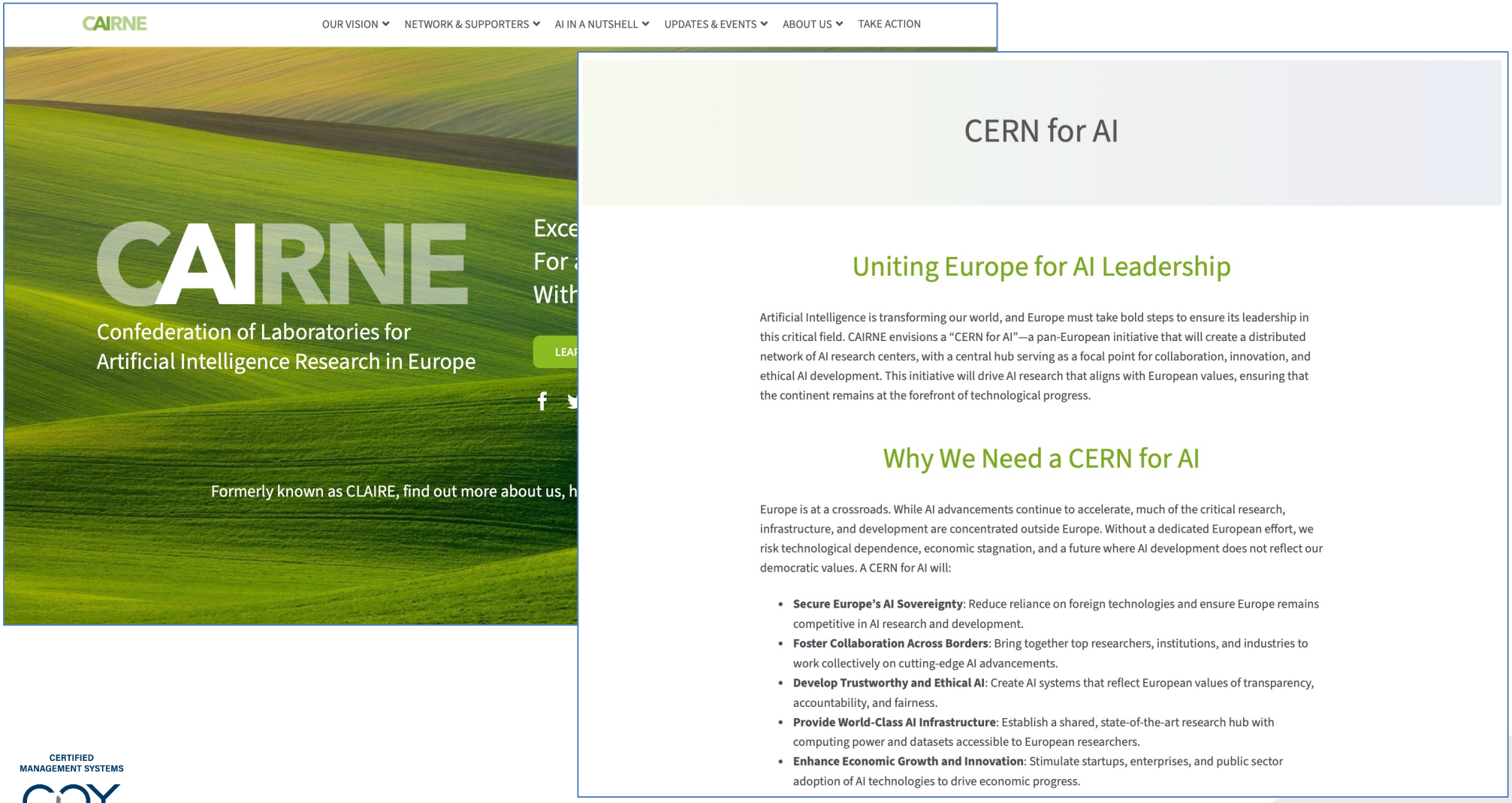
Architecture an Operator Training Interface





Elettra Sincrotrone Trieste

CERN for AI



Concluding remarks

- ✓ AI is a technology transforming all strategic sectors, spanning healthcare, industry, energy, and science, with a significant impact on competitiveness, sustainability, and attractiveness.
- ✓ AI stands for Data, Computing Power, and Algorithms. This is why Elettra has developed a FAIR Datalake, which is the foundation for fueling the development of AI algorithms.
- ✓ Elettra recently launched the EAI Project to refine its strategy and enable its employees to safely use generative AI tools that run locally to process internal and confidential documents securely and ethically (ISO27001, AI Act Compliant). This is achieved by investing in infrastructure and training.
- ✓ Elettra has an expandable infrastructure and advanced expertise in AI applications and AI training that it can make available to regional organizations.

Elettra Sincrotrone Trieste

CALL FOR PARTNERS:

Partner with us to build the future of scientific research.

1 AGENTDOC

Manuali Intelligenti basati su Agentic Publications

Documenti tecnici e protocolli operativi trasformati in sistemi interattivi guidati da agenti AI. Il contenuto diventa interrogabile e adattivo: gli utenti esplorano procedure e dati tramite interfacce conversazionali con LLM locali.

PMI tech · Università · Aziende e-learning · Sviluppatori AI

2 AI SHIELD

Cybersecurity Intelligente per Infrastrutture Scientifiche

Soluzioni avanzate di cybersecurity basate su AI per rilevamento automatico di phishing, anomalie di rete e intrusioni. Sistemi explainable AI e LLM locali proteggono grandi ecosistemi di dati scientifici secondo standard ISO 27001.

PMI cybersecurity · Università · Laboratori di ricerca

3 MEGACONTROL

Architetture MCP per Sistemi Hardware Complessi e Digital Twin

Nuove architetture software basate su Model Context Protocols per orchestrare sistemi hardware complessi con digital twin intelligenti. LLM integrati abilitano interfacce operative avanzate e Rapid Application Development per sistemi di controllo distribuiti.

PMI tech · Ingegneria sistemi · Contractor infrastrutture

Elettra Sincrotrone Trieste

CALL FOR PARTNERS:

Partner with us to build the future of scientific research.

4 **Q-MAT**

Quantum Materials Acceleration

Algoritmi quantistici e metodi ibridi quantum-classical integrati con dati sperimentali delle beamline di Elettra per accelerare la scoperta di nuovi materiali avanzati: proprietà elettroniche, magnetiche e strutturali identificate in tempi drasticamente ridotti.

Università · Aziende materiali avanzati · Lab quantum computing

5 **SECUREDATA**

Infrastrutture Avanzate per Big Data Sensibili

Pipeline distribuite, gestione avanzata di metadati e architetture modulari per grandi volumi di dati scientifici e sensibili. Integra Compressive Sensing per acquisizione efficiente, garantendo scalabilità, sicurezza e piena tracciabilità dei dataset.

PMI IT · Data engineering · Aziende tecnologie avanzate

6 **SINCROBOT++**

Robotica Intelligente per Logistica e Ispezione

Sistemi robotici autonomi basati su ROS per logistica, trasporto interno e ispezione tecnica in ambienti complessi. Computer vision, fleet management e integrazione con LLM consentono supervisione intelligente e nuove modalità di interazione uomo-robot.

PMI robotica · Università · Industria automazione


Elettra
Sincrotrone
Trieste
Thanks! Questions?
roberto.pugliese@elettra.eu
george.kouroussias@elettra.eu
www.elettra.eu