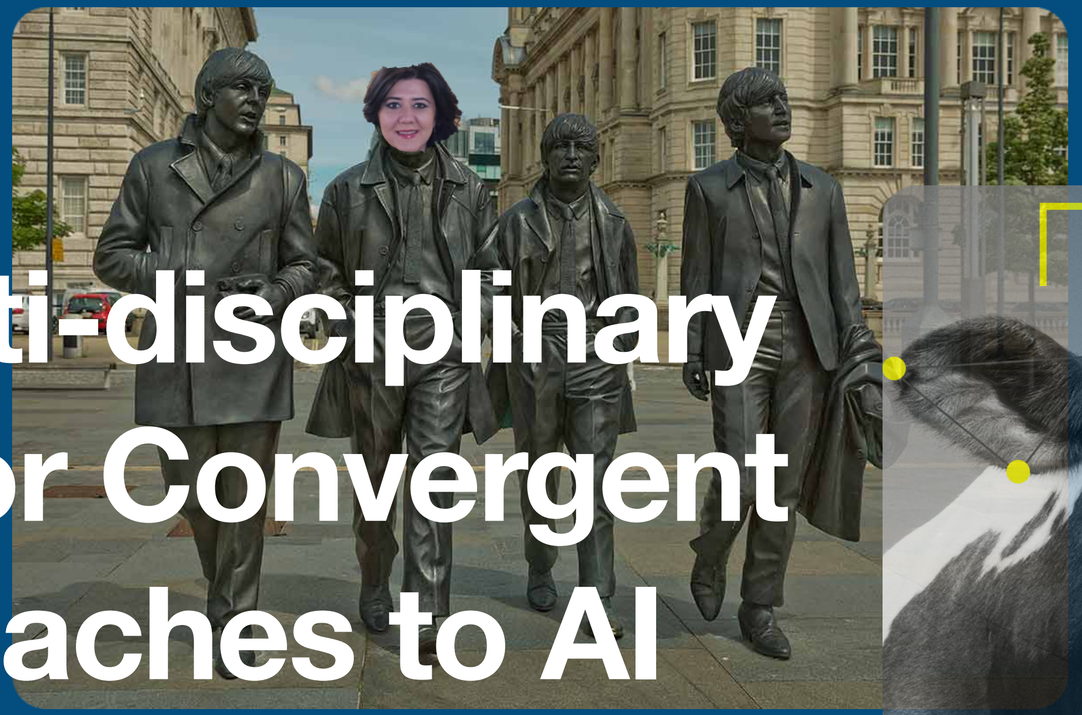
MUCCA Multi-disciplinary Use Cases for Convergent new Approaches to AI explainability



Stefano Giagu
Sapienza Università di Roma and INFN Roma

From GNNs to xAI School 2023
SPINE Liverpool and University of Liverpool - September, 21st, 2023

FUTURE AI RESEARCH

INFN
Istituto Nazionale di Fisica Nucleare

STVDIVM VRBIS

THE MUCCA PROJECT

- CHIST-ERA IV xAI H2020 EU grant 2.2021-7.2024
- **Ultimate goal:** quantifying strengths and solving weaknesses of state of the art and novel AI explainability methods
- **Strategy:** study explainability techniques in different use-cases intentionally chosen to be heterogeneous with respect to the types of data, learning tasks, scientific questions
- **Multidisciplinary Collaboration** that brings together researchers from different fields:
  - high energy physics
  - applied physics in medicine
  - applied physics in neuroscience
  - computer science

Three phases:

I - apply xAI techniques

II - identify possibile shortcomings of the techniques and find metrics to gauge explainability & interpretability

III - combine methods and knowledge to develop general procedures and engineering pipelines for xAI

MUCCA CONSORTIUM

project overarches multiple disciplines putting together world-experts from the respective fields

Istituto Nazionale Fisica Nucleare (IT) Rome group

Fundamental research with cutting edge technologies and instruments, applications in several fields (HEP, medicine imaging/diagnosis/prognosis/therapy)

University of Sofia St.Kl.Ohridski (BG) Faculty of Physics

extended expertise in detector development, firmware, experiment software in HEP

Sapienza University of Rome (IT) Departments of Physics, Physiology, and Information Engineering

HEP: data-analysis, detectors, simulation; AI: ML/DL methods in basic/applied research and industry, intelligent signal processing; Neurosciences: brain encoding of complex behaviours, ML in electrophysiology, multi-scale modelling approaches

Polytechnic University of Bucharest (RO) Department of Hydraulics, Hydraulic Equipment and Environmental Engineering

Complex Fluids and Microfluidics expertise: mucus/saliva rheology, reconstruction and simulation of respiratory airways, AI applications for airflow predictions in respiratory conducts

Medlea S.r.l.s (IT)

high tech startup, with an established track record in medical image analysis and high-performance simulation and capabilities of developing and deploying industry-standard software solutions

University of Liverpool (UK) Department of Physics

physics data analysis at hadron colliders experiments, simulation, ML and DL methods in HEP

Istituto Superiore di Sanità (IT)

expertise in neural networks modeling, cortical network dynamics, theory inspired data analysis

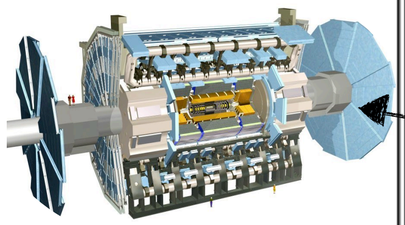
MUCCA's PEOPLE

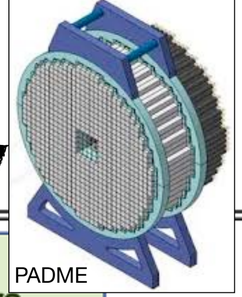
- Bucharest Poli.: **C. Balan**, D. Broboana, E. Chiriac, E. Magos, C. Patrascu, N. Tanase + students
- INFN: G. Bardella, A. Ciardiello (now Sapienza), T. Torda, **C. Voena**
- ISS: P. Del Giudice†, G. Gigante, **M. Mattia** + students
- Liverpool Univ.: J. Carmignani, **M. D'Onofrio**, C. Sebastiani + students
- MedLea srls: **S. Melchionna**, M. Pratim Borthakur
- Sapienza Univ.: S. Ferraina, **S. Giagu (MUCCA PIs)**, L. Rambelli (now Genova), S. Scardapane, A. Uncini + several students
- Sophia Univ.: **V. Kozhuharov**, G. Georgiev + students

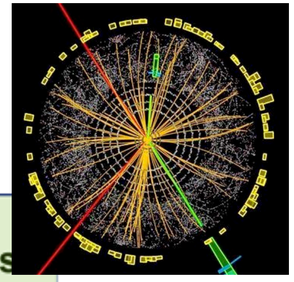
MUCCA WORK PLAN

Scientific outputs
Social impact

Samples and xAI-tools exchange
Management and communication exchange







Publication, Real-time application tools
Open doors days
Tools for detectors

WP1: HEP physics

Application of AI-methods to searches for new physics at ATLAS. Provide samples and tools to allow testing of xAI. Improve transparency, impact of systematics explainability. **Deliverables:** HEP publications, benchmarks use-cases, generalized tools.

WP2: HEP detectors

Application of AI-methods to calorimeter detectors (PADME). Provide simulation of electromagnetic showers, benchmarking and tools for xAI. **Deliverables:** samples and tools for xAI methods, reports.

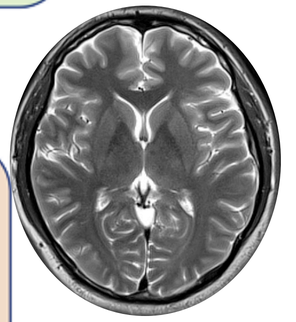
WP3: HEP real-time systems

Develop AI-based real-time selection algorithms for FPGAs at ATLAS. Use xAI methods for to understand complex systems. **Deliverables:** tools to transfer knowledge for xAI methods in real-time applications, publication.

School/Hackaton
publications

WP7: xAI-Tools

Survey of all available xAI methods relevant for use-cases; develop xAI usage pipelines; analysis of results.
Deliverables: document xAI procedures and engineering pipelines for general use. Kaggle challenge for exploitation.



WP4: Medical imaging

Develop xAI pipeline to segmentation of brains in magnetic resonance imaging. Use publicly available databases for xAI developments, focusing on explainability of training strategy. **Deliverables:** xAI algorithms and stability evaluation.

WP0: Management

Project and reports coordination, planning of meetings, networking and participation in public conferences. Dissemination, communication and exploitation of results (publications, reports, social media)

xAI tools,
Kaggle challenge

Brain-Computer Interfaces
Meetings stakeholders

WP6: Neuro-science

Test xAI techniques to uncover computational brain strategies on NHP and selection of dynamical neural models
Deliverables: reports on saliency maps from DNNs trials, quantification of quality and model selection.

WP5: Functional Imaging

Test xAI methodology in respiratory system. Analyse complex systems (passage of air and mucus, expected non-linear responses) to derive model and test xAI. **Deliverables:** prototype of xAI algorithm implementation, assessment of produced predictions.

Open doors days
Diagnostic tools

- **eight inter-disciplinary and inter-connected Work Packages**

PROJECT TIME LINE

official starting date 1.2.2021
project ends 7.2024

Description	Year 1				Year2				Year3				Y4	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
WP0 Project management, coordination														
T0.1 Project management and coordination														
T0.2 Coordination of the periodic technical and financial reporting														
T0.3 Planning of project meetings														
T0.4 Networking and participation in public conferences														
T0.5 Creation of a dissemination and communication plan														
T0.6 Plan for exploitation of project results														
WP1 HEP-1														
T1.1 HEP1-SUSY														
T1.2 HEP1-DARK														
T1.3 HEP1-BENCH														
WP2 HEP-2														
T2.1 Collection of experimental data														
T2.2 Simulation of electromagnetic showers														
T2.3 Reconstruction of charges and times														
T2.4 Shower reconstruction														
WP3 HEP-3														
T3.1 Preparation of the dataset														
T3.2 Implementation of baseline AI models														
T3.3 Syntesis of the baseline model in VHDL														
T3.4 Deployment of xAI methods														
T3.5 Dissemination and exploitation of results														

Description	Year 1				Year2				Year3				Y4	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
WP4 MED-1														
T4.1 Selection of AI algorithms														
T4.2 Application of state-of-the-art explainability algorithms														
T4.3 Test of new xAI algorithms														
T4.4 Stability of xAI algorithms														
WP5 MED-2														
T 5.1 Reconstruction on tomographic scans														
T5.2 Experiments and validation on air-mucus in idealized geometries														
T5.3 Experiments and validation on air-mucus in respiratory geometries														
T5.4 Test of xAI on simulation results														
WP6 NS-1														
T6.1 Uncover task-relevant neural spatio-temporal pattterns of neural activity														
T6.2 xAI-assisted selection of neural dynamic models														
WP7 XAI-TOOLS														
T7.1 xAI methods survey														
T7.2 xAI tools delivery to the use cases														
T7.3 Engineering pipelines for general xAI applications and documentation														

MUCCA: SUMMARY AND EXPECTED IMPACT

- **Status of the project:** some delay wrt the original plans due to Covid19 restrictions and delay in obtaining funding from one of the funding agencies (Italy MUR), nevertheless:
  - successfully implemented appropriate AI algorithms for all the use cases
  - performed an extensive survey and analysis of state-of-the art xAI methods and developed new ones, identified the most suitable ones to be used for the next phase of the project
- **Expected Results:** knowledge base and xAI tools (documentation and procedures/engineering pipelines)

Multiple level impact:

1. enable users to better understand AI models and diagnosis limitation using xAI
2. systematic understanding of which xAI methods better adapts to specific applications
3. skill development and training for young researcher