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

CHIST-ERA Project Seminar 2022
The MUCCA Project

**Ultimate Goal:** quantifying strengths and solving weaknesses of new and state of the art xAI methods

**Strategy:** study xAI in *heterogenous use cases* from High Energy Physics (HEP), medical imaging, diagnosis of pulmonary, tracheal and nasal disease, neuroscience

**Collaboration** that brings together researchers from different fields
- High Energy Physics
- Medicine
- Neuroscience
- Computer science

**Multidisciplinarity**

Three phases:
1. Apply xAI techniques
2. Identify shortcomings and metrics
3. Get new transparent algorithms
The Consortium

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

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)

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

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

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

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

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

Funding agency: INFN

Istituto Superiore di Sanità

Funding agency: MUR
The Work Plan

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 challenges.

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: HE 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.

WP4: Medical imaging
- Develop xAI pipelines 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.

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.

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.

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.

Scientific outputs
- Open doors days
- Tools for detectors

Social impact
- Publications, Real-time application tools
- School/Hackathon publications

Management and communication exchange
- Samples and xAI-tools exchange
Progress Report: HEP Uses Cases

**WP1:** developed AI algorithms (CNN, Graph NN), targeted to event classification and process discrimination, for new physics and dark matter searches at ATLAS. First review of suitable state-of-art xAI algorithms performed.

**WP2:** AI algorithms (CNN, autoencoder), successfully developed and applied to identify pulses, determining amplitude and time of arrival in close to reality simulated data of the PADME calorimeter.

**WP3:** developed complete pipeline for an AI based event selection algorithm to expand physics potential of the ATLAS experiment. CNN model with compression and simplification strategies to make easier to interpret, and faster to execute the AI model, for the conversion and implementation in the firmware of FPGA accelerators. Obtained CNN inference in 80/150ns/image.

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Progress Report: MED and NS Use Cases

**WP4**: Implemented AI models for the brain lesion segmentation in the Brats17 MRI dataset (Unet2D, Resnet 3D). Data augmentation techniques to enhance performances tested. Selected state-of-the-art xAI algorithms, under implementation.

**WP5**: procedure for the realization of the prototypes of the trachea bifurcation (reconstruction of the geometry from the CT scan, numerical code) completed. Study of the GNN model for the simulation of the air-flow.

**WP6**: designed and realized a specific CNN (fed by electrophysiological signals) based on a ResNet to uncover an inner decision value increasing in time as a linear ramp eventually allowing to predict at single-trial level the onset timing of overt movements. Test of various xAI algorithms underway.
Summary and Possible 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 agency, nevertheless we succeeded in:

- successfully implement appropriate AI algorithms for all the use cases
- perform an extensive survey and analysis of state-of-the art xAI methods by WP7
- identify suitable xAI algorithms for the next phase, that now are under implementation

Expected results: knowledge base and xAI tools (documentation/procedure/engineering pipelines)

Dissemination:
- scientific publication, conferences
- open access toolkit
- dedicated web site
- hackathons, festivals, challenges...

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