'Green' Machine Learning

Platform for green data analysis based on AI and real-time energy optimized federated learning

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CERN CAFEIN CERN CASO

CIPEA
CERN Innovation Programme
on Environmental Applications

Outline

- Introduction
- Background work and developments
- Project proposal description
- Project deliverables and schedule
- Project organization and financing
- Impact beyond CERN
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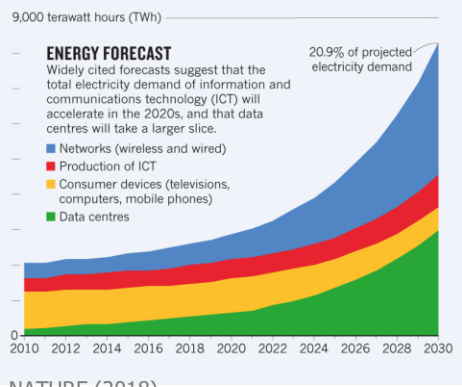
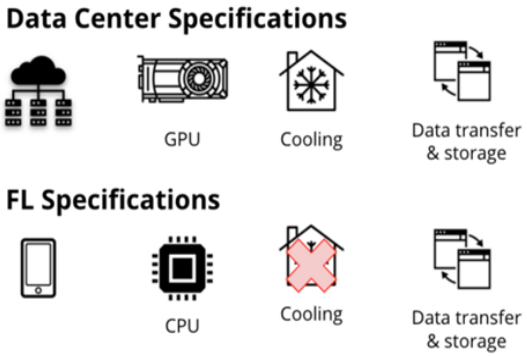
Federated learning (FL) vs. centralized analytics (CA)



NATURE (2018)

- **Large centralized data centers for AI and big-data analytics**
  - » Becoming more and more energy-hungry
  - » Responsible of about 15% of the equivalent global Green House Gas (GHG) emissions of the entire Information and Communication Technology (ICT) ecosystem
  - » Contribute to about 0.3 % of global CO2 emissions
  - » Will further increase in the years to come

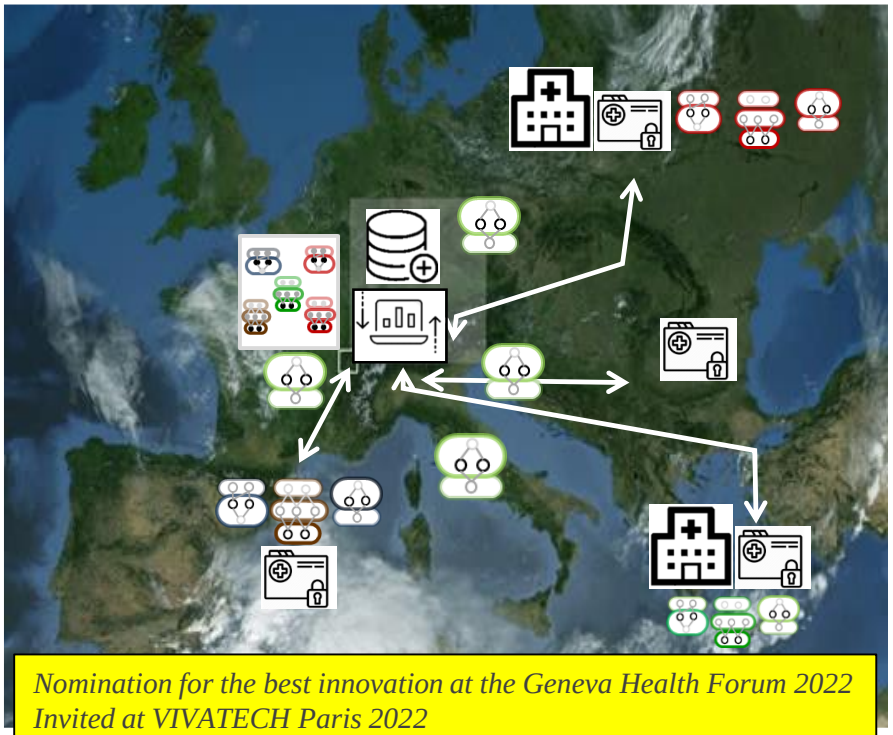
- **FL: emerging alternative to centralized analytics**
  - » It distributes the computing tasks across many devices characterized by a more efficient use of the energy (low carbon footprints)
  - » Optimizing accuracy & energy, can significantly reduce energy footprints
    - No need for a large centralized infrastructure for cooling or power delivery
  - » Ensuring privacy and security of data in local and distributed storage



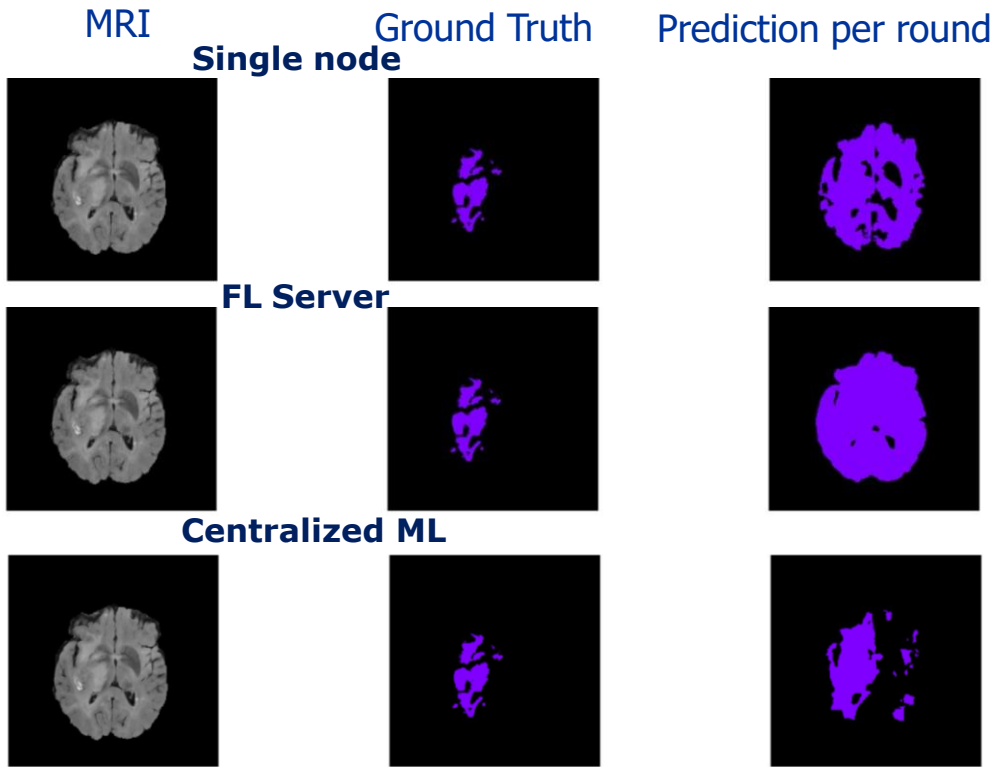
X. Qiu et al – a first look in the Carbon Footprint of FL (July 2021)

Background work and developments: CAFEIN platform

Computer-Aided Defects and Anomalies Detection, Identification and Classification system for Digital Images and Medical Data

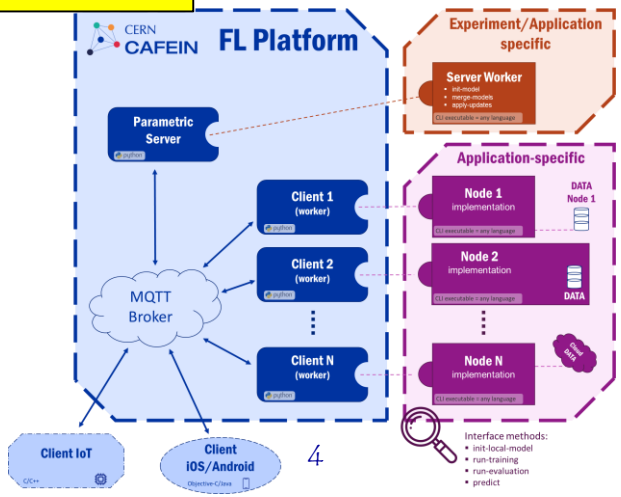


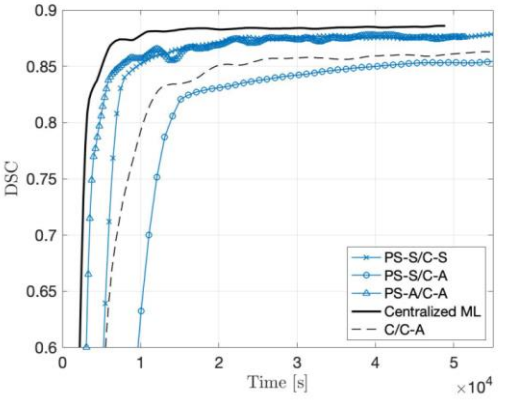
Nomination for the best innovation at the Geneva Health Forum 2022
Invited at VIVATECH Paris 2022



Federated Platform based at CERN (PS):

- **Robustness** of global models v. local models
- **Privacy** and **confidentiality** of data





Project Proposal Description:
Platform based on AI and real-time energy optimized federated learning

Explore novel greener AI solutions offered by FL techniques

Break down and analyze the main factors influencing the environmental footprint (energy and equivalent carbon footprint) of various FL algorithms compared with classical AI tools running in the data centers

Assess all the components of the learning process

FL network architecture, the communication efficiency, the response time, transmission occupancy bandwidth, storage, and computation resources

Showcase the benefits of the proposed solutions through a real-time platform that is based on an evolved implementation of CAFEIN equipped with a tool to:

Track the energy/greenhouse gas emission costs of FL on each learning round

Monitor and minimize the discrepancy between measured and predicted performances

Enable real-time decision towards energy-aware optimizations by distributing the FL computations across the devices depending on their energy source/cost and availability of green energy

Project Deliverables and Schedule

- **Initially we propose to test and validate the FL platform and the energy/greenhouse gas emission costs tool on the LHC superfluid helium loops I&C / compressor stations**
- **Algorithms will be trained across multiple decentralized edge devices (individual cooling loops controllers) or servers (LHC points)**
- **Without exchanging data will cooperatively train models to drive the diagnosis, reliability analysis and predictive maintenance**

Phase I

- ***T0 + 6 mts:*** *study, investigation, and definition of the implementation architecture and required developments*
- ***T0 + 12 mts:*** *development of the carbon tracker and implementation of the required local and centralized FL tools*
- ***T0 + 24 mts:*** *testing of the architecture and machine learning tools on simulated data*
- ***T0 + 36 mts:*** *field implementation, operation, optimization and performance evaluation (data analysis, diagnostic, prognosis, energy and CO2 optimization) and overall evaluation of CO2 emissions control and reduction*
- ***Proposal for scalability and larger impact applications***

Project Organization and Financing

CAFEIN main partners:

Centro Nazionale delle Ricerche (IT)

Politecnico di Milano (IT)

Possible implementation in TRUStroke project

Spain, Belgium, Italy and Slovenia hospitals

<u>Study, design and implementation of the platform</u>

1 PhD and 1 MSc students: 250 kCHF

HW and SW: 50 kCHF

(FL learning nodes in the LHC [min 4 LHC points] and GPU's)

Total: 300 kCHF over 3 years

Impact Beyond CERN

Phase II

- **Deployment to the whole cryogenic system of the LHC**
- **Implementation to other cryogenics facilities to train global models for diagnosis and maintenance of equipment**
  - » Without exchanging data
  - » Optimizing algorithms training with the energy/greenhouse gas emission costs tool
- **Make available to the society at large a Federated Learning Platform developed and operated by CERN to train global AI models while preserving privacy of the data and reducing energy/greenhouse gas emission costs**

Industry » Data driven fault analysis and optimized maintenance plans of the equipment to enhance the performances of industrial installations, thus further reducing energy and carbon footprint

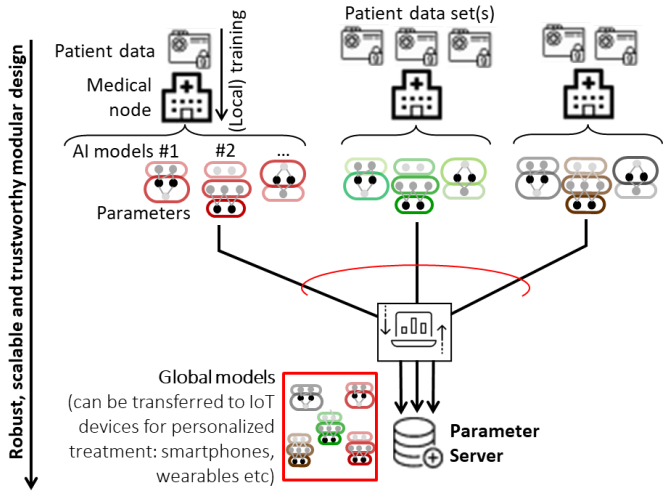
Clinicians » Medical data and images analysis to guide and support diagnosis, prognosis and therapies selection

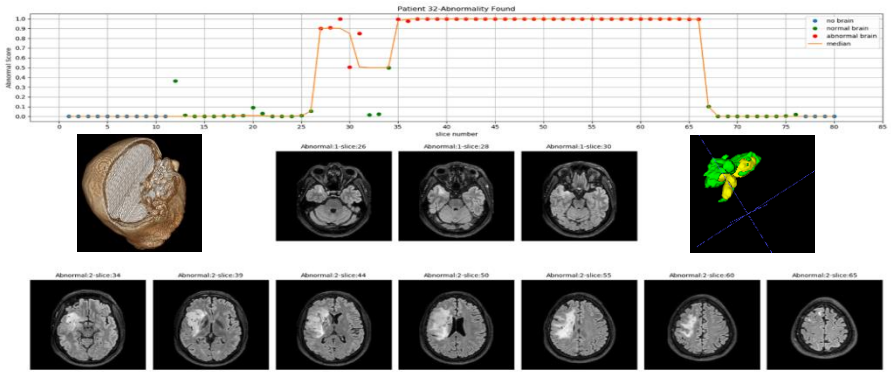
Clients
Patients » Enable multiple entities to collaboratively build AI based model without compromising data privacy and minimising the impact on the environment

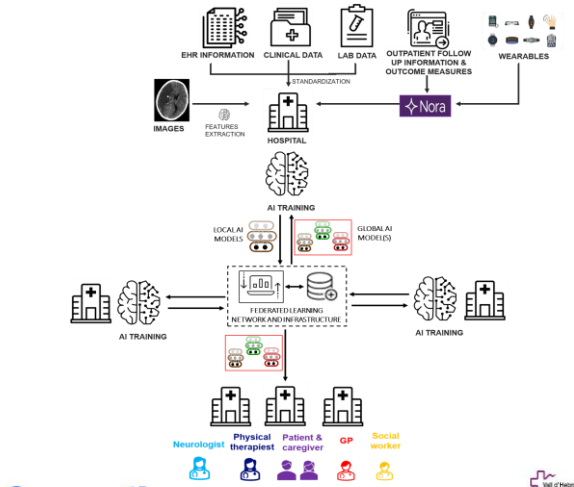
References: CAFEIN FL platform

BrainPath : KT funded / TRUSTroke: H2020

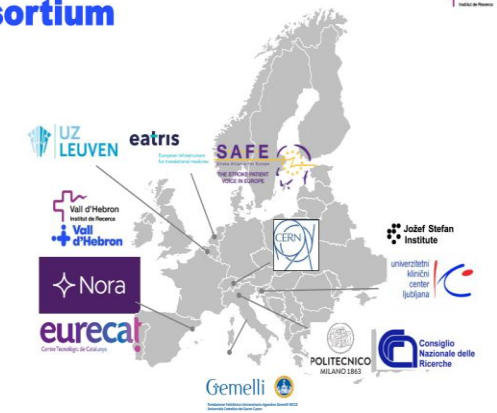
Federate Learning Platform for Brain Pathologies Screening / Trustworthy Prediction of Stroke Outcome on a Federated Learning Infrastructure







Consortium



CERN developed and hosted (P.S.)

Federated Learning infrastructure:

CAFEIN Project

- ✓ Robustness of global models versus local models
- ✓ Privacy and confidentiality of data
- ✓ Security and protection of data and models

TRUSTroke Project

- ✓ Enhanced collaboration and minimized administrative work
- ✓ Transfer of knowledge without data exchange

CIPEA Project

- ➢ Communication optimization and sustainability
- ➢ AI algorithms training optimization
- ➢ Environmental impact minimization

References: Projects, Publications, Awards

Projects:

- *CAFEIN: KT Funded – CERN / CNR (IT) / Politecnico di Milano (IT) / BRN University (CZ) / Athens University (GR) 2019 - 2021*
- *TRUSTroke: H2020 (stage 1 passed 9.5/10) – 7.5 Meuro – 13 Partners – 2023 - 2026*

Publications:

- *Decentralized Federated Learning for Healthcare Networks: A Case Study on Tumor Segmentation, B. Camajori Tedeschini, S. Savazzi, R. Stoklasa, L. Barbieri, I. Stathopoulos, M. Nicoli, L. Serio, January 2022, in IEEE Access, 10.1109/ACCESS.2017.DOI*
- *A Niching Augmented Evolutionary Algorithm for the Identification of Functional Dependencies in Complex Technical Infrastructures from Alarm Data, F. Antonello, P.Baraldi, L. Serio, E. Zio, IEEE SYSTEMS JOURNAL, 10.1109/JSYST.2022.3146014*

Thesis:

- *A deep-Learning based Method for the Detection of Defects from Images of Industrial Equipment – Andrea Perin - Politecnico di Milano – 2020*
- *Federated learning architectures and algorithms for diagnostic imaging in healthcare networks – Bernardo Camojori Tedeschini – 2021*
- *Development and use of deep learning algorithms for brain tumor diagnosis and classification based on MR images – Ioannis Stathopoulos – Athens University – exp. 2022*

Awards:

- *Nomination for the best innovation at the 2022 Geneva Health Forum*