Integrated **D**ata **A**nalysis **P**ipelines for Large-scale Data Management, **H**PC, and Machi**ne** Learning; DAPHNE daughter of river god Peneus (fountains, streams), chased by Apollo

[Louvre, Paris]

DAPHNE

https://daphne-eu.eu/

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DAPHNE: An Open and Extensible System Infrastructure for Integrated Data Analysis Pipelines

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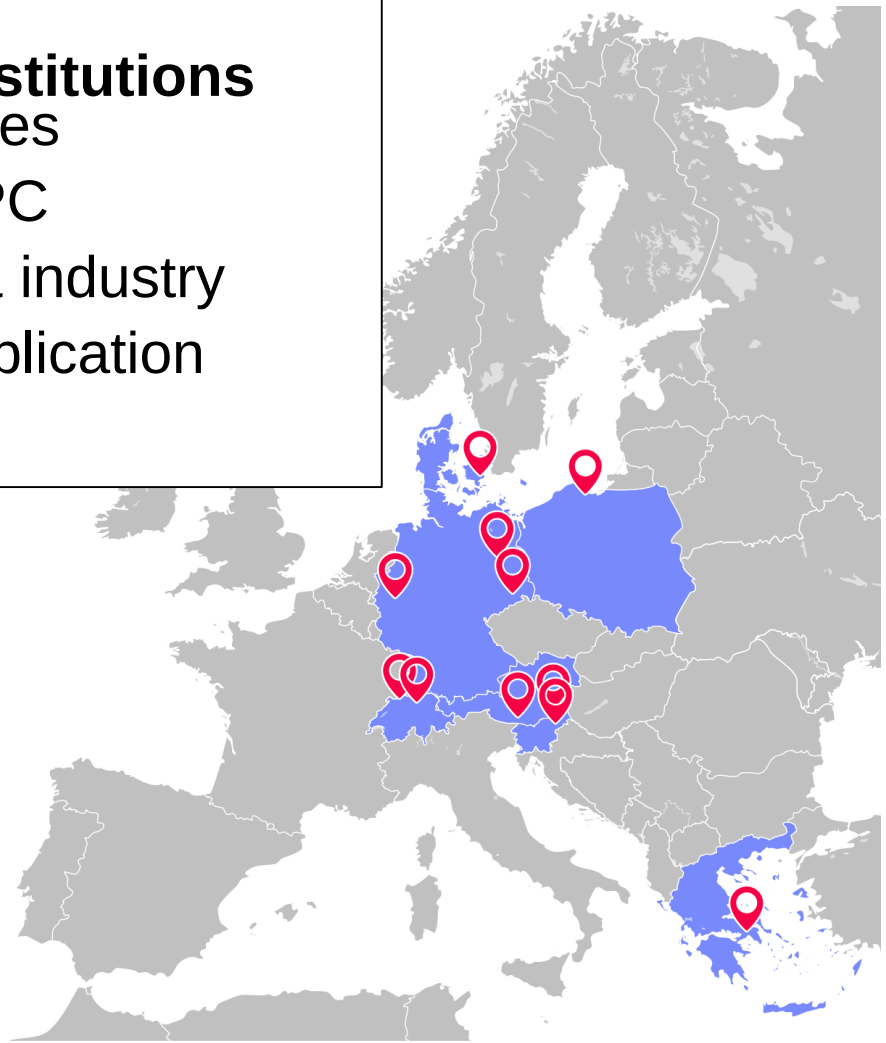
DATAWEEK 2023, June 13-15, Luleå, Sweden

Project Consortium

DAPHNE

14 partner institutions
from 7 countries

- DM, ML, HPC
- Academia & industry
- Different application domains



- Know-Center GmbH (**coordinator**), Austria
- AVL List GmbH, Austria
- Deutsches Zentrum fuer Luft- und Raumfahrt e.V., Germany
- Eidgenoessische Technische Hochschule Zuerich, Switzerland
- Hasso-Plattner-Institut for Digital Engineering gGmbH, Germany
- Institute of Communication and Computer Systems, Greece
- Infineon Technologies Austria AG, Austria
- , Intel Technology Poland sp. z o.o., Poland
- IT-Universitetet i København, Denmark
- Kompetenzzentrum Automobil- und Industrieelektronik GmbH, Austria
- Technische Universität Dresden, Germany
- Univerza v Mariboru, Slovenia
- Universitaet Basel, Switzerland
- Technische Universität Berlin

Integrated Data Analysis (IDA) Pipelines

DAPHNE

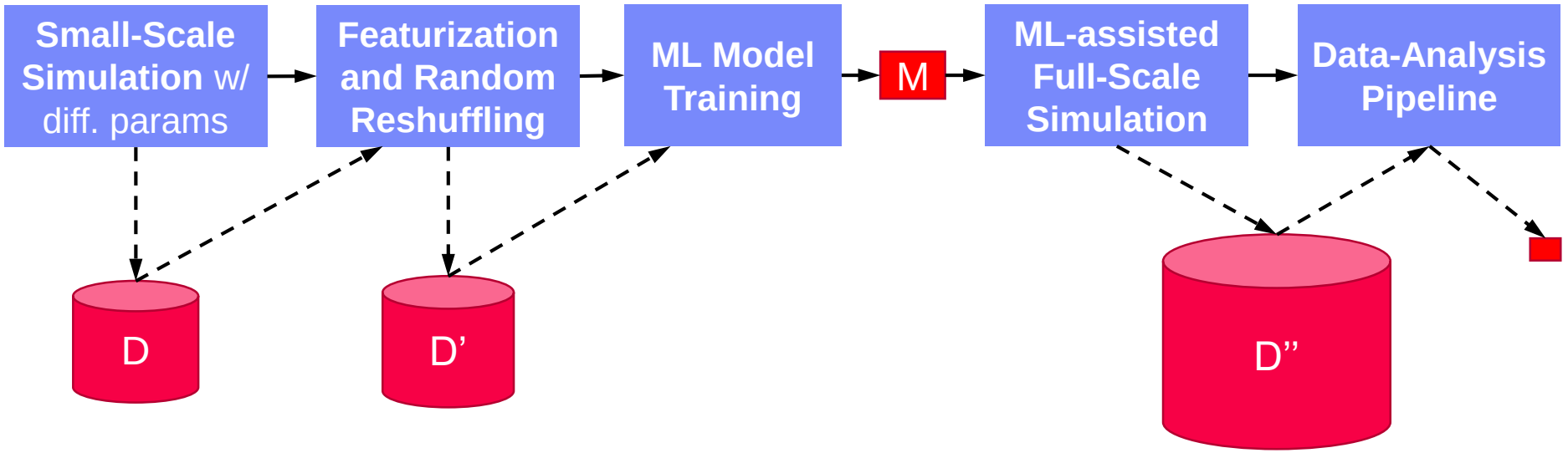
DM + **ML** + **HPC**

Data Management & query processing

Machine Learning training & scoring

High-Perf. Computing custom codes & simulations

Example: ML-assisted simulation



Challenges

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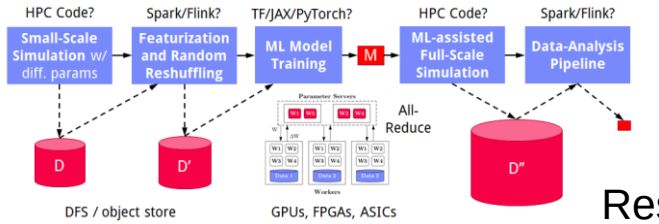
- **Deployment Challenges**

Dev Teams Programming Models

Different Systems/ Libraries



Cluster Under-utilization

Data/File Exchange

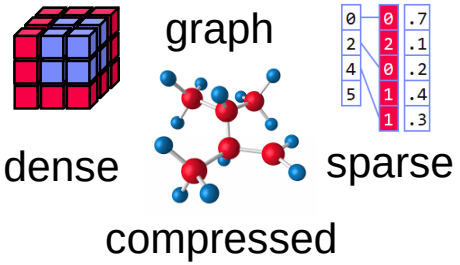
Resource Managers

➔ DAPHNE Overall Objective: Open and extensible system infrastructure

- **Hardware Challenges**
  - DM+ML+HPC share compilation and runtime techniques / converging cluster hardware
  - **End of Dennard scaling:** P = α CFV2 (power density 1)
  - **End of Moore's law**
  - **Amdahl's law:** sp = 1/s

➔ Increasing Specialization

#1 Data Representations



Sparsity Exploitation from Algorithms to HW

#2 Data Placement

Local vs **distributed**

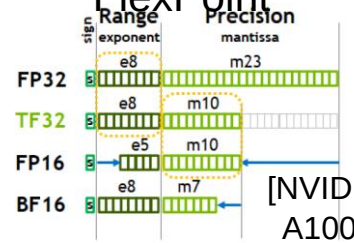
CPUs/ NUMA

GPUs

FPGAs/ ASICs

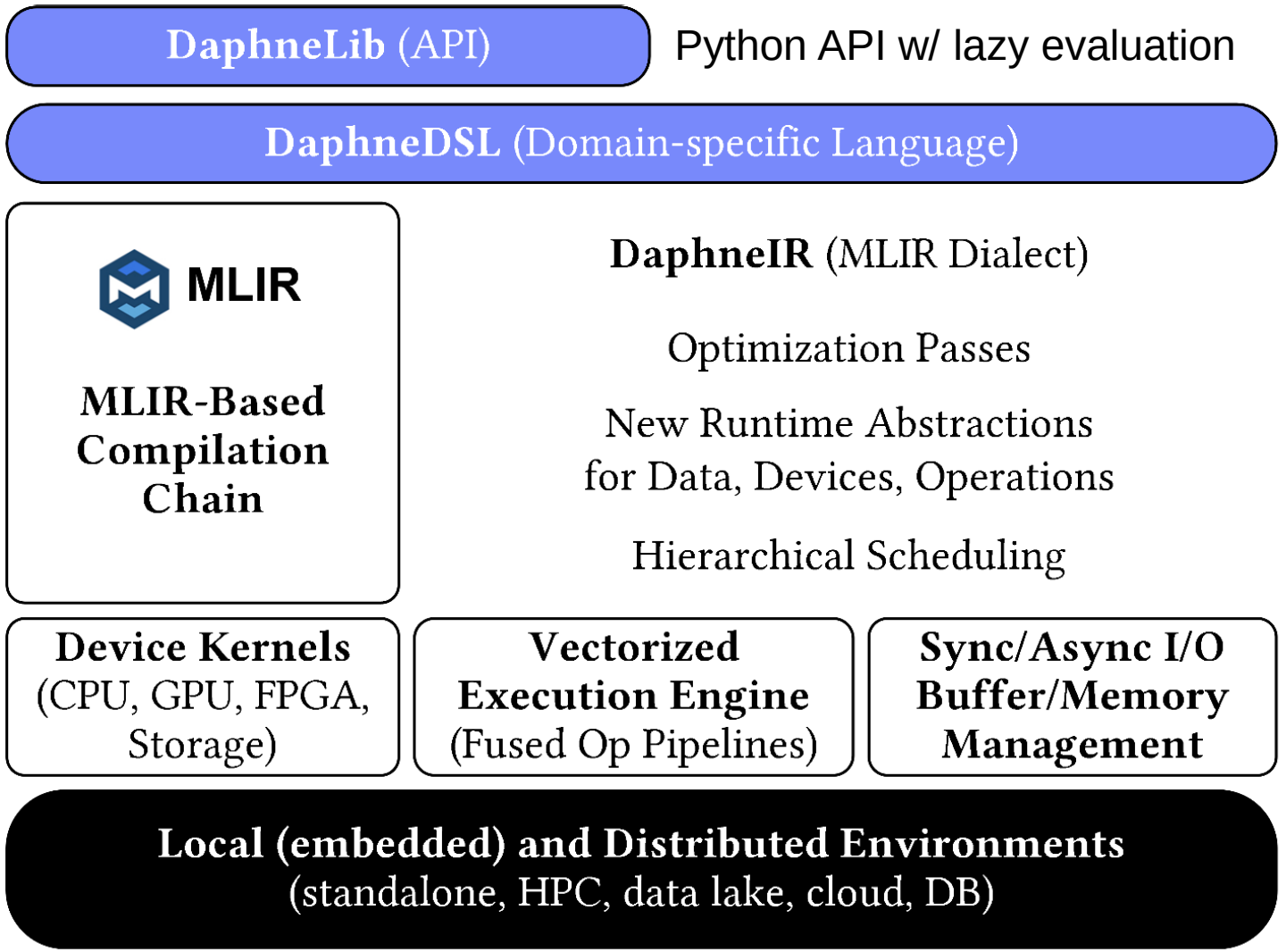
#3 Data (Value) Types

FP32, FP64, INT8, INT32, INT64, UINT8, BF16, TF32, FlexPoint



[NVIDIA A100]

System Architecture



Extensible Infrastructure

MLIR Dialects, Extension Catalog (new data types, kernels, scheduling algs)

Multi-level Compilation/ Runtime

Sideways Entry, DSL-level constraints (data formats & data/op placement)

Fine-grained Fusion and Parallelism

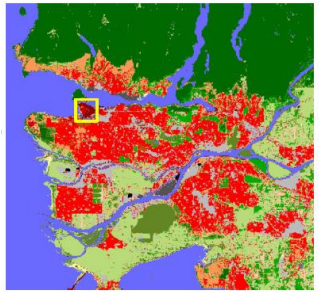
Integration w/ Resource Mgmt & Prog. Models

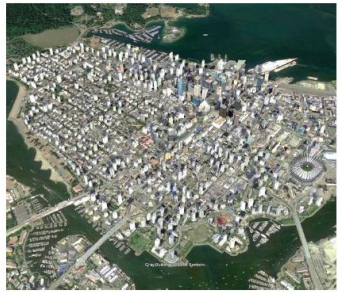
Example Use Cases

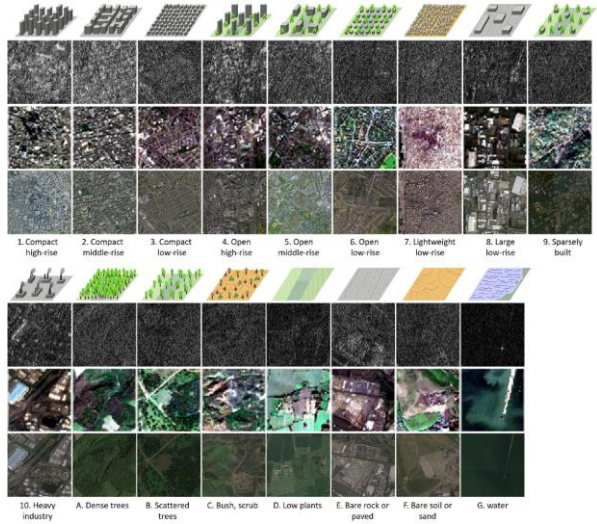
[Xiao Xiang Zhu et al: So2Sat LCZ42: A Benchmark Dataset for the Classification of Global Local Climate Zones. **GRSM 8(3) 2020**]

[So2Sat LC42: https://mediatum.ub.tum.de/1454690]

- **DLR Earth Observation**
  - **ESA Sentinel-1/2** datasets → 4PB/year
  - Training of local climate zone classifiers on **So2Sat LCZ42** (15 experts, 400K instances, 10 labels each, ~55GB HDF5)
  - **ML pipeline:** preprocessing, ResNet-20, climate models







- **IFAT Semiconductor Ion Beam Tuning**
- **KAI Semiconductor Material Degradation**
- **AVL Vehicle Development Process** (ejector geometries, KPIs)

- **ML-assisted simulations, data cleaning, augmentation**
- **Cleaning during exploratory query processing**

Automotive Use Cases

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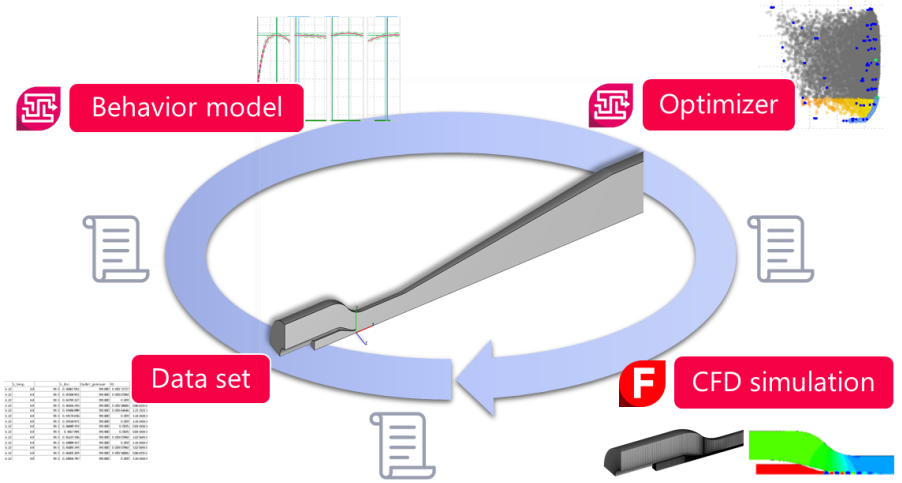
ICT51 - extreme data

AVL

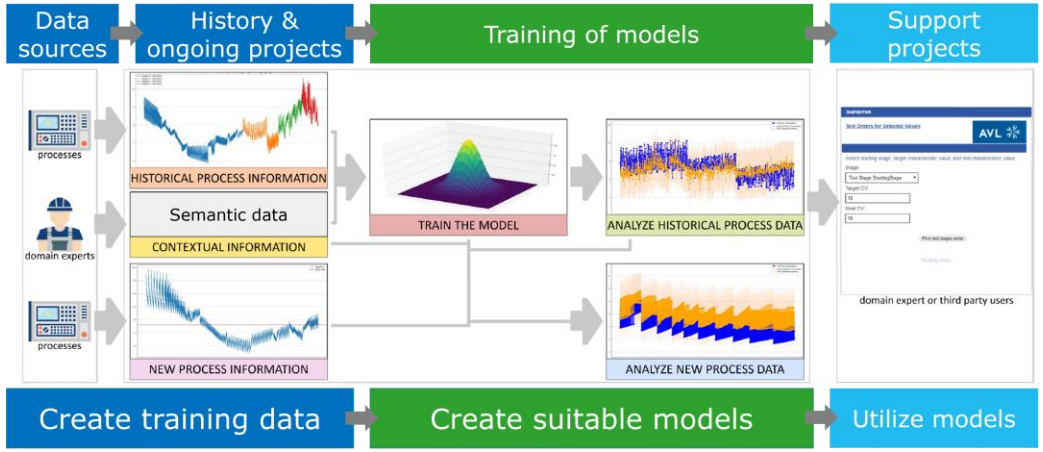
- Optimize ejector contour for target suction pressure
  - Geometric variables (lengths, diameters, radii) at different operating conditions
- Iterative process: searching param, set via CFD sim
- Volume: nightly optimization runs
- Value: combining physics-based (Active DoE) with Kernel Rich regression model (DAPHNE DSL)

Fuel cell: Ejector geometry optimization



ICT51 - extreme data

AVL

- Systematic data management
- Highly structured data
- Predict vehicle KPIs (e.g., fuel consumption)
- Volume: perform sim. to obtain values over time
- Value: align the values overt time across multiple dimensions to obtain synthetic time series (DAPHNE DSL & open API)

Synthetic data: automotive process mining