Empowering diagnosis and prognosis by using the Hybrid Artificial Intelligence paradigm embracing physics-based and data-driven approaches

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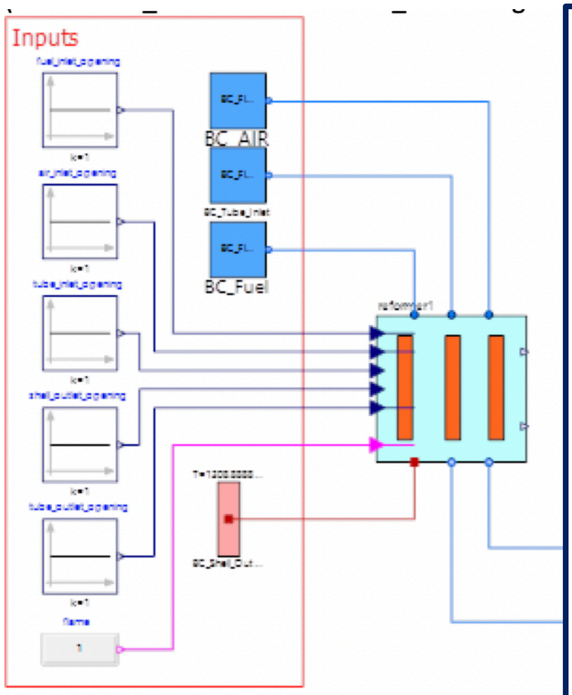
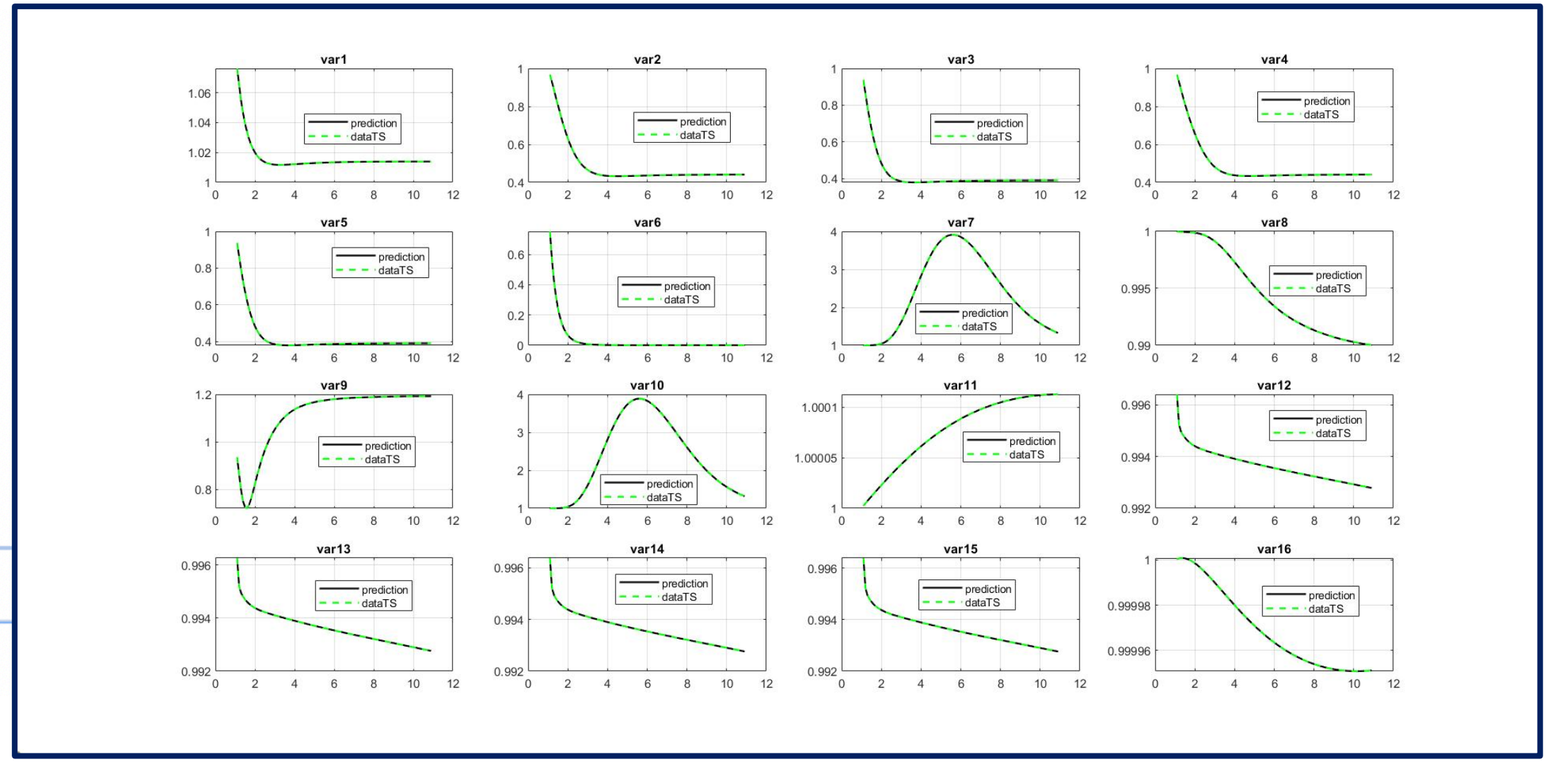
Introduction: a new performances-based engineering





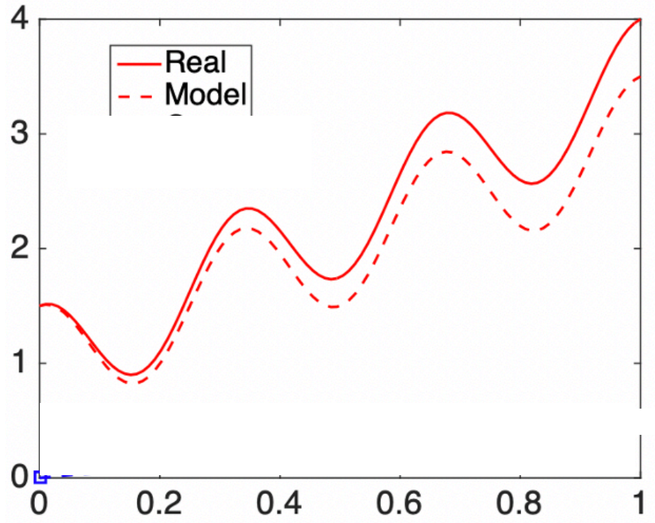
Complex	Learning	Diagnosis	Accurate
Large	Monitoring	Prognosis	Fast
Uncertain	Anticipating	Decision-making	Resilient

Models versus Data

- Physics-based

WEAKNESSES

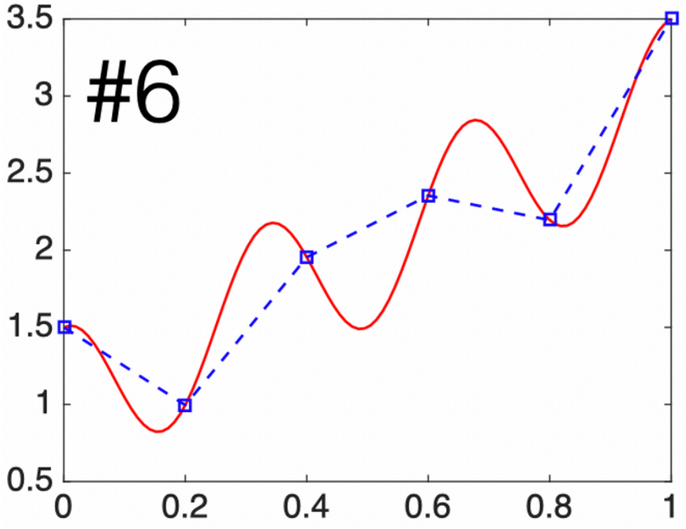
Variability
Uncertainty
Computing cost
…



- Data-based

WEAKNESSES

Amount of data ($)
Explanation
Certification
Extrapolation
…



The fundamental equation

Looking for the highest accuracy …

Reality

=

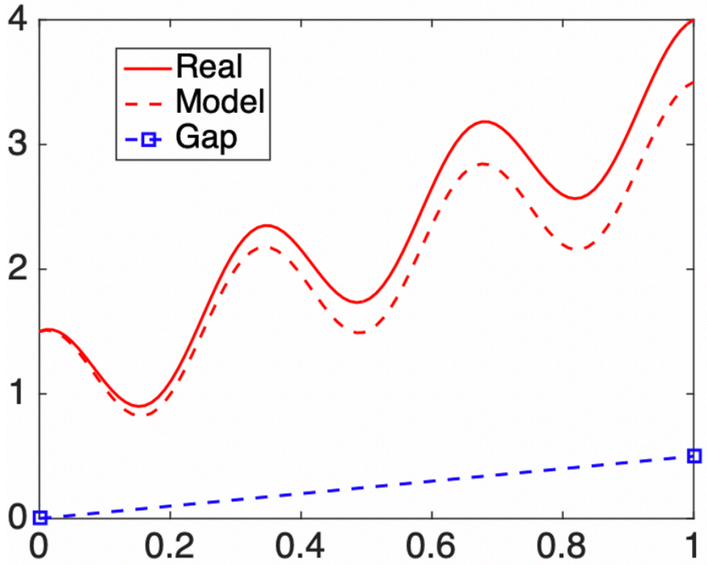
Physics-based model “The Art of Modelling”

+

The part of the reality that the model ignores “The Ignorance”

within the Hybrid paradigm

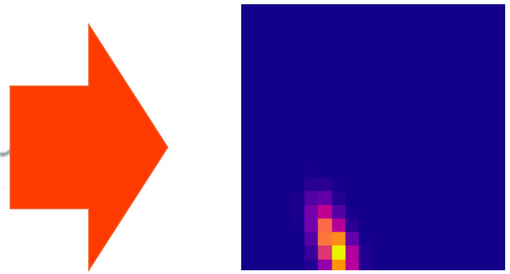
Accurate, fast, explainable
& frugal (cheap).
The right data, at the right scale,
the right place
and the right moment



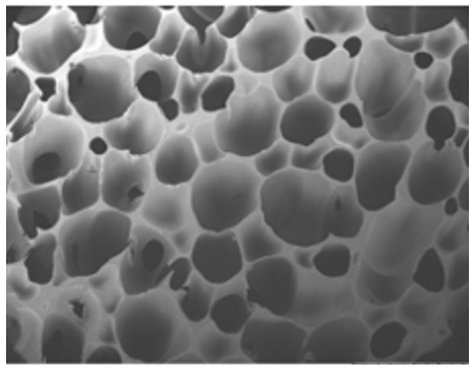
Data Inspector for efficient data description

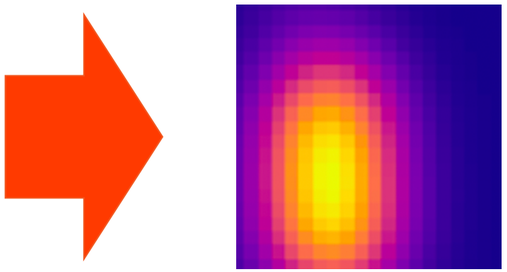
Topological Data Analysis - TDA

Time series



Complex images



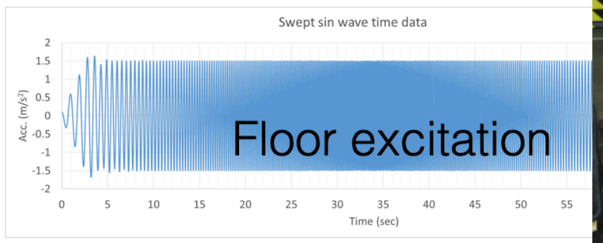


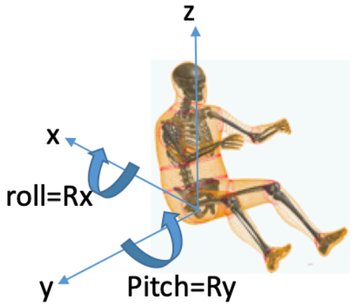
A sort of goal oriented

QR code / Passeport

but in a vector space

Human models

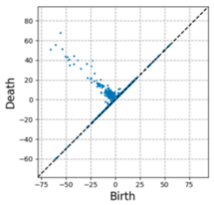


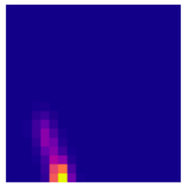


Tense, relax, …?

Data → **TDA**

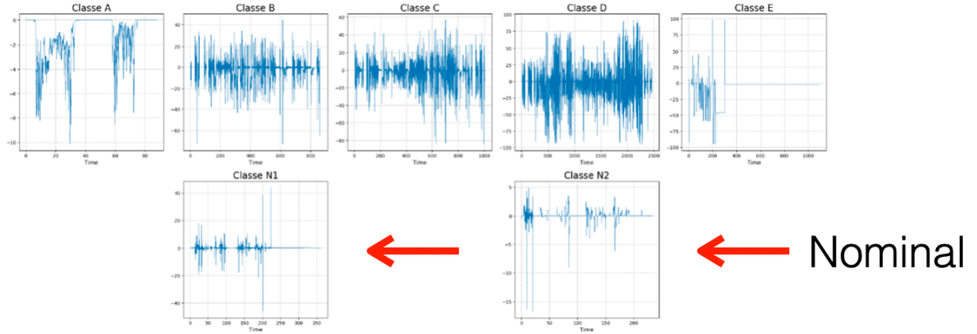
Barcode > Persistence diagram > persistence image > Behavioral classification

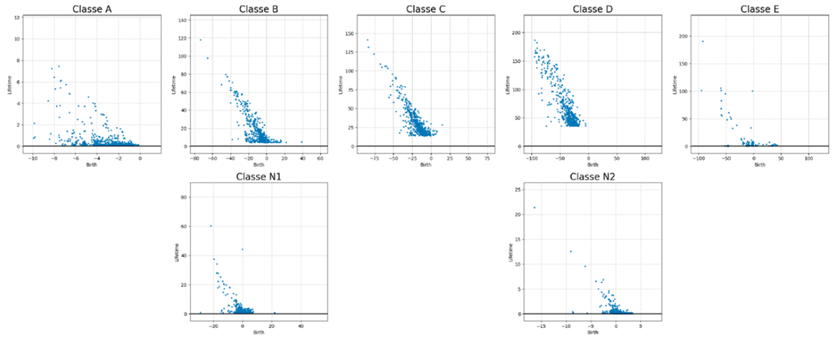


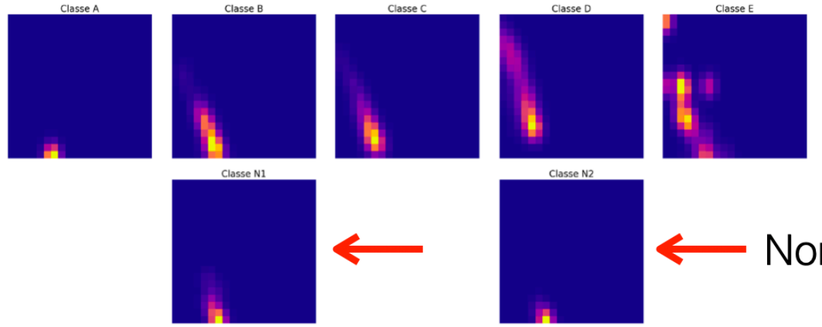


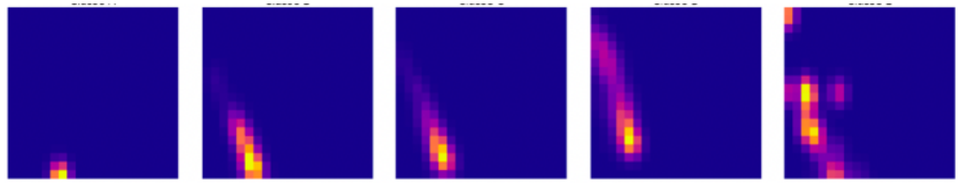
DIGITAL HUMAN LAB

Obtained accuracy > 96%

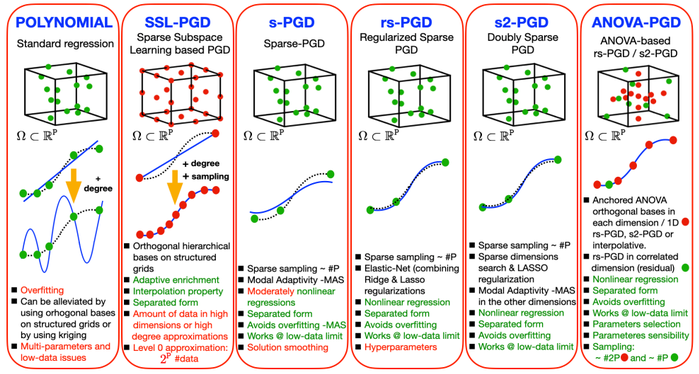








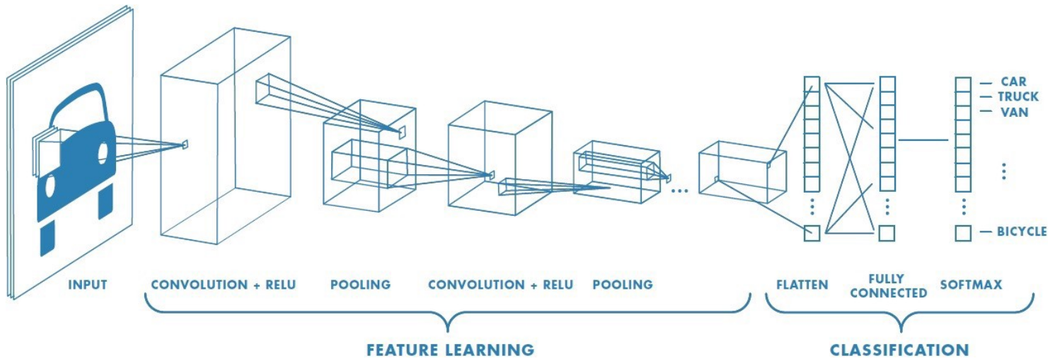
PGD



POD

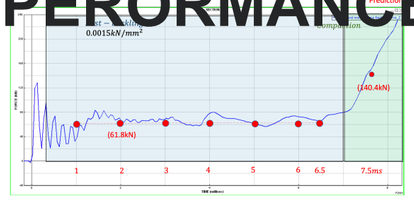
$$\alpha_1, \alpha_2, \cdots$$

(convolutional) Neural Network



PGD

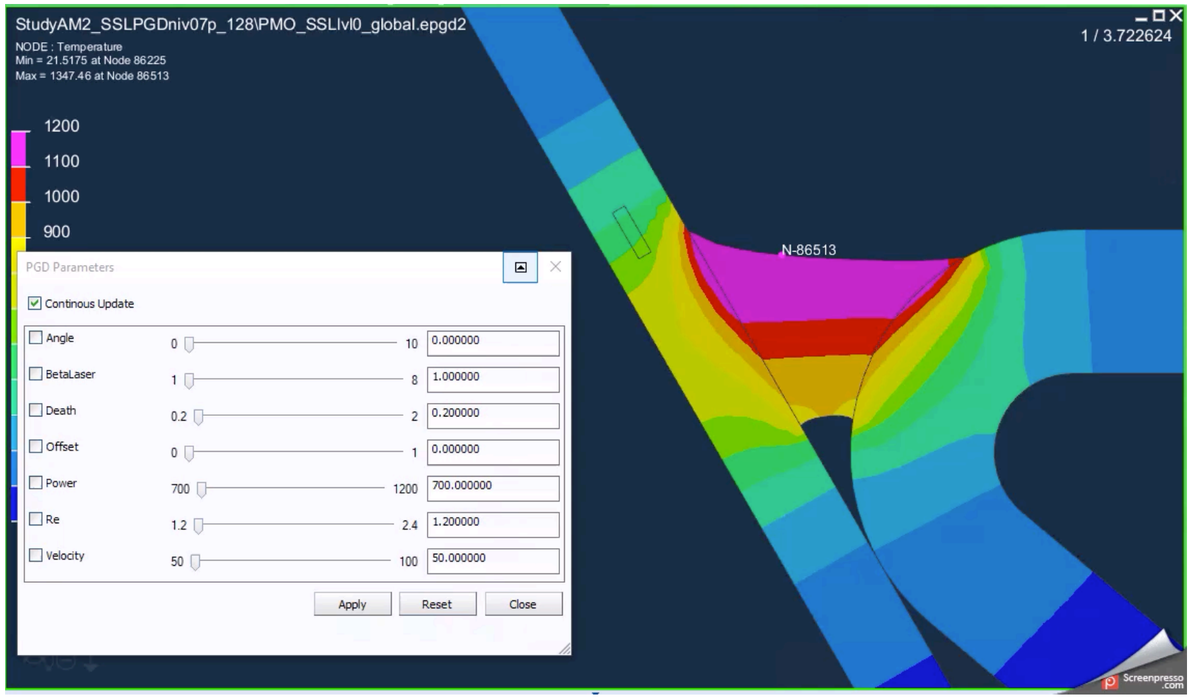
PERORMANCES



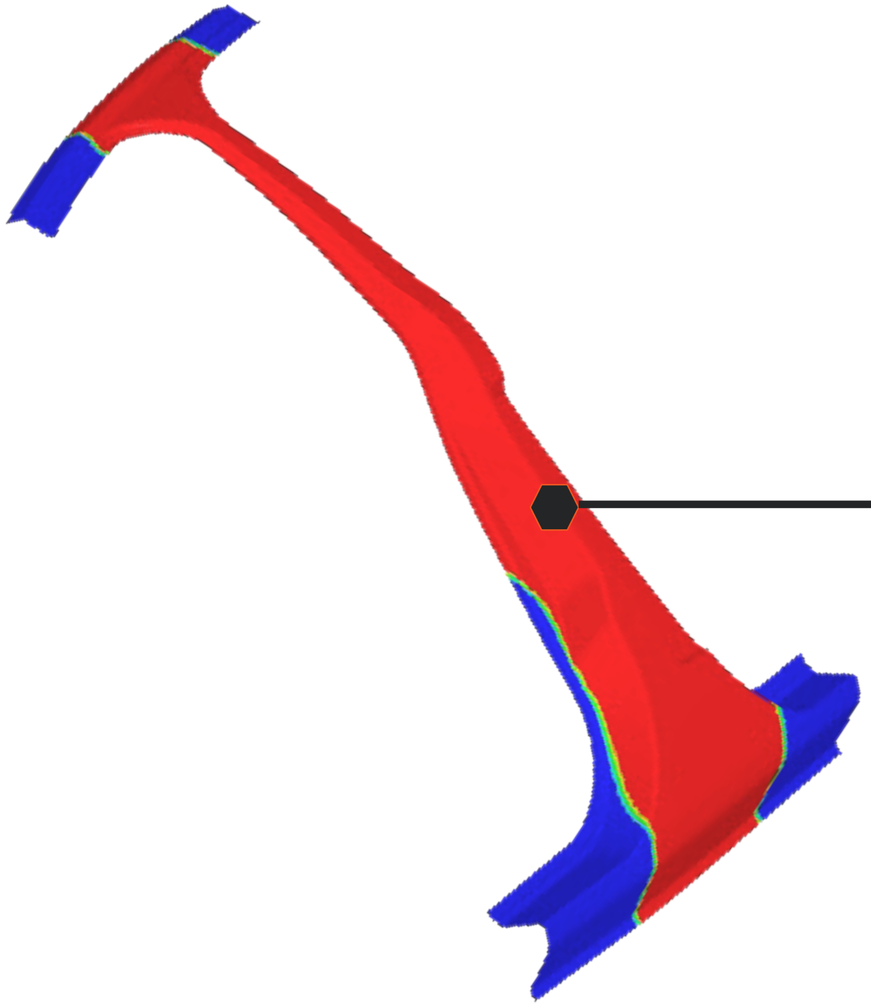
Looking for the highest efficiency

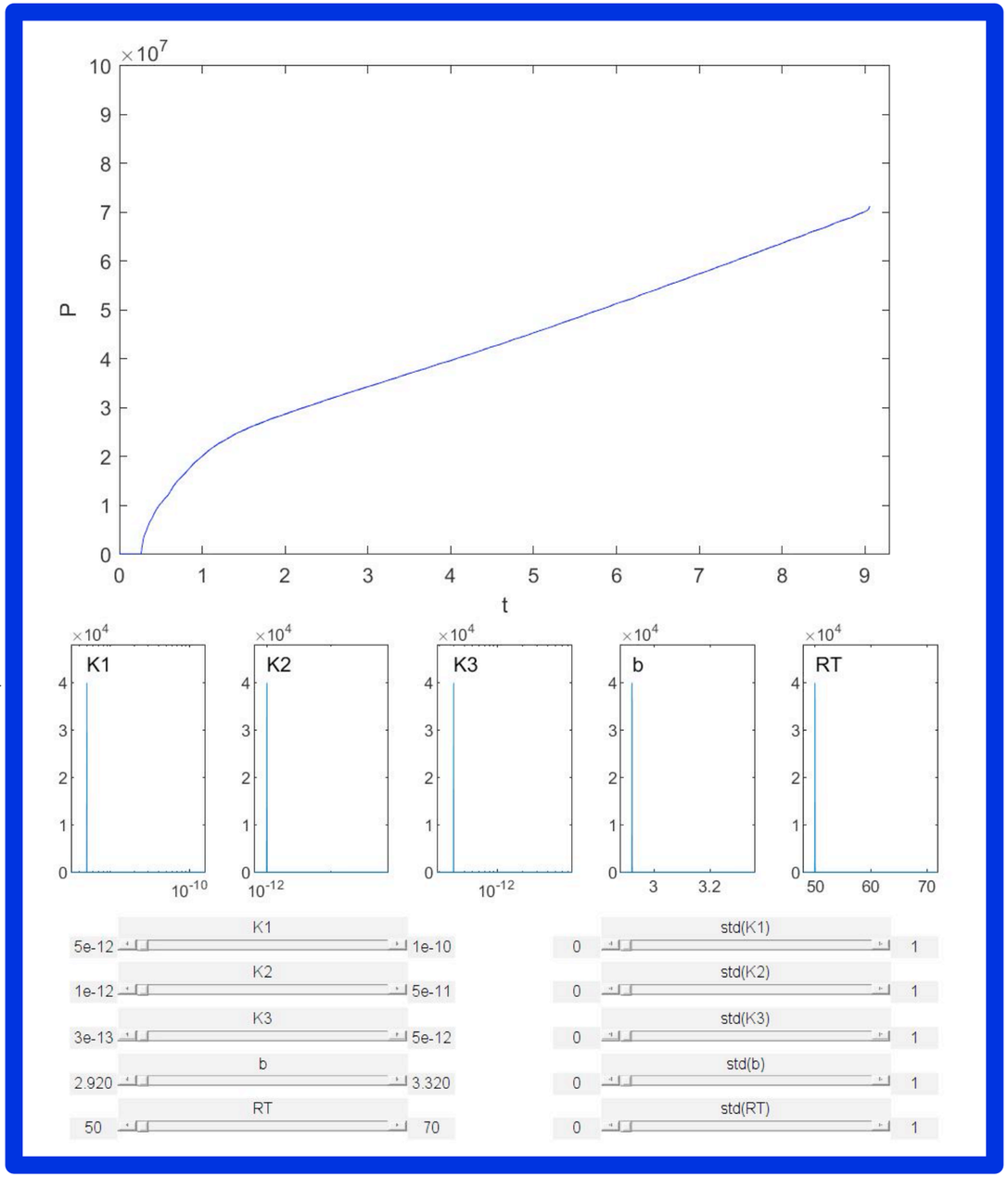
Physics-based models (Art of Modelling)
solved in real-time (Art of Simulation)

Model Order Reduction



Smart sensor with physics inside





Looking for the highest accuracy

Physics-Aware AI

Learning the ignorance
(gap between reality & model-based predictions)
… in real-time and from very few (smart) data
(what data, where and when)

Looking for the highest accuracy

Deep learning of thermodynamics-aware reduced-order models from data☆

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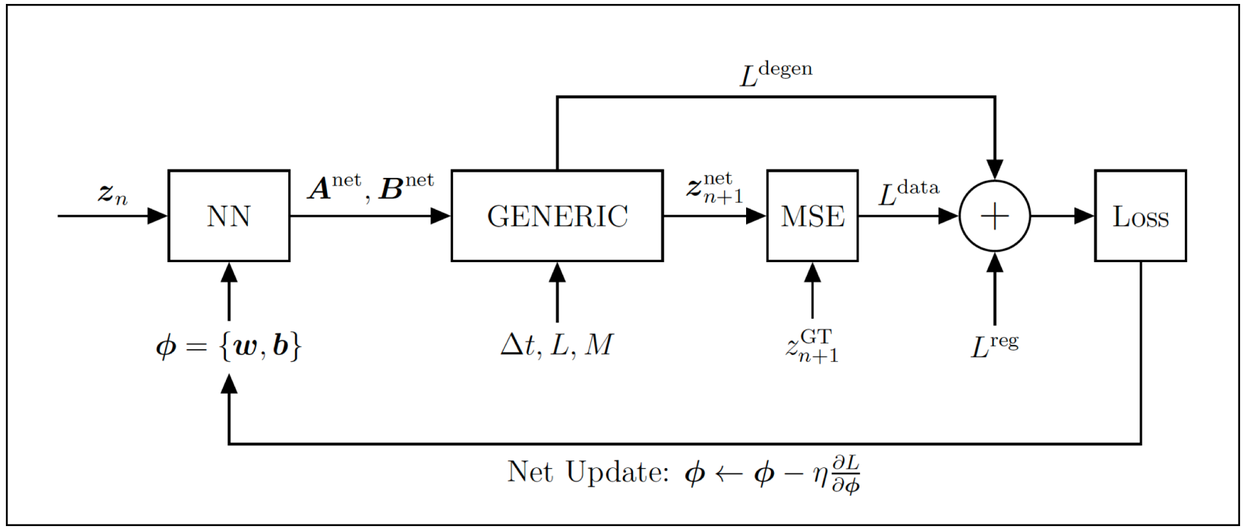

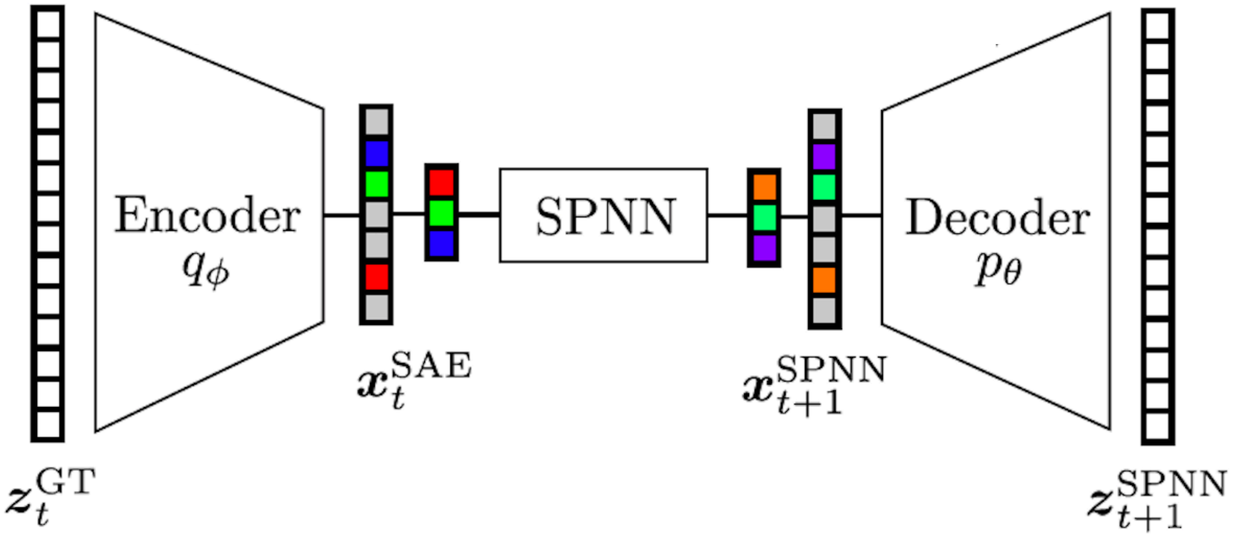

Physically sound, self-learning digital twins for sloshing fluids

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A CREATE Program on Intelligent Modelling for **De**cision-making in **C**ritica**l** U**r**ban Sys**t**e**m**s

DESCARTES

INTELLIGENT MODELLING FOR DECISION-MAKING IN CRITICAL URBAN SYSTEMS

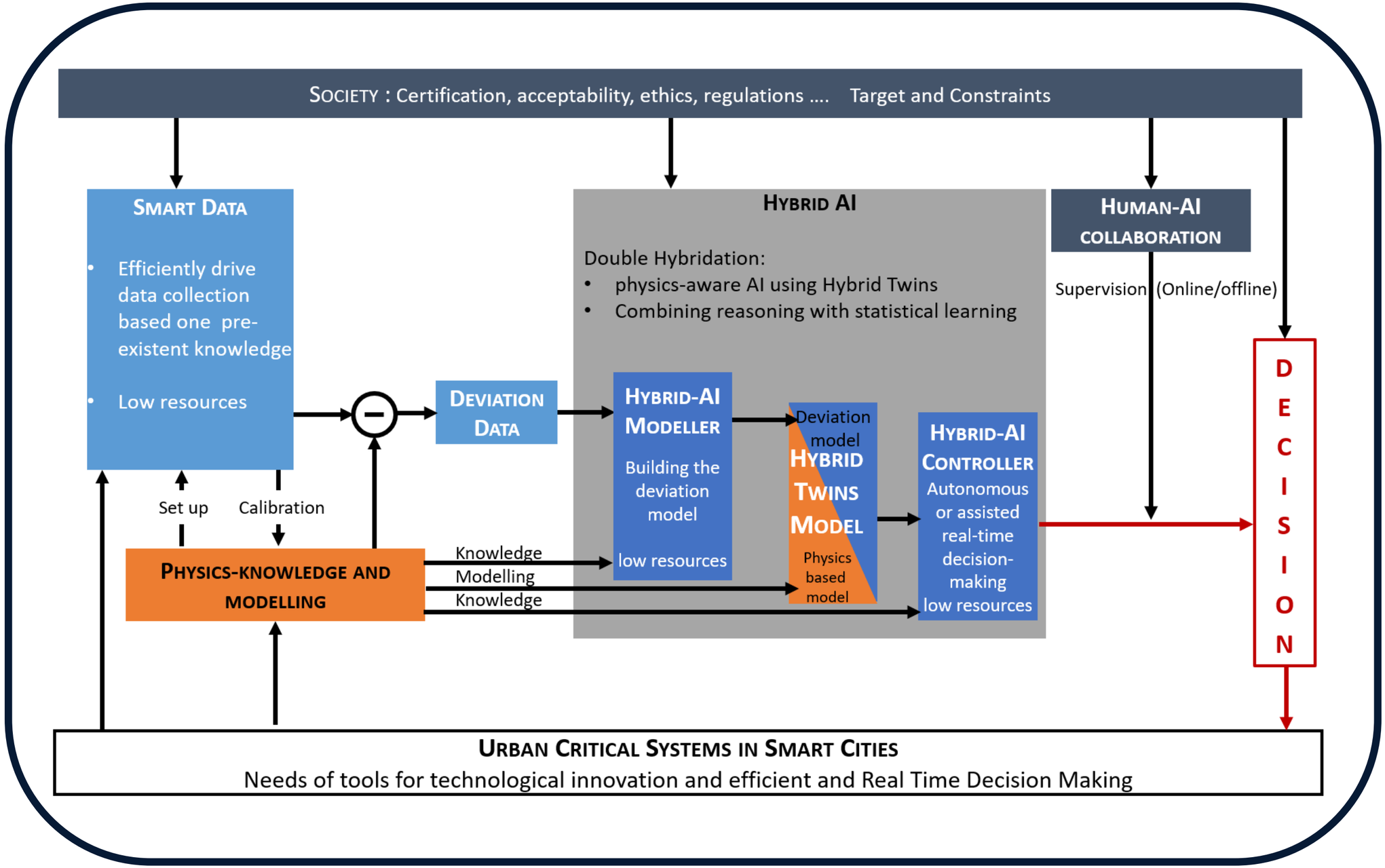
On René Descartes:

Widely known from his mantra *I think therefore I am* French Philosopher René Descartes (1596-1650) is generally considered as the founder of modern philosophy, as well as a precursor of modern science through his 'Mathesis Universalis'. DesCartes project is a tribute to the cartesian insights on intelligence, technology and ethics. His philosophy is stimulating for the development of AI in three aspects at least. First, the definition of intelligence. Second, the similarity and differences between humans and machines. Third, ethics in a time of uncertainty.

First, regarding what Intelligence is, Descartes is often considered as one of the precursors of Cognitive Science thanks to his theory of representation: He proposed a revolutionary account of the human mind. Second, one of his most important contributions to critical thought was his reflection on the similarities and differences between human minds and machines or 'automata ', which were very fashionable at his time. He argued that bodies could be compared to automata, as well as animals ('animaux-machines') but that, even if the human body works as a machine, or a clockwork, only rational humans have an ability to reason, understood as general reasoning. He is also considered as having set the theoretical framework for the Turing Test (or Imitation Game) in his Discourse on the Method' when stating that no machine can respond appropriately to what is said in its presence. Third, he suggested that the absence of certainty does not condemn us to act without ethics and proposed a provisional ethical framework (morale par provision) which could be used in times of uncertainty.

Akin to René Descartes, the DesCartes program is cross disciplinary, involving core science as well as human sciences, with (Artificial) "Intelligence" at its core.

The Hybrid AI



REMOTE SENSING

Boundary conditions

Global scale (large infrastructure):

- Structural Mech. models accurate enough
- No data (no sensors)

Local scale (damaged area):

- Remote sensing: drone (sensor @ right place)
- SoA NL models are not accurate enough
- Data is limited (environment, images+)

Model + Data: HAI modeller

Local 2 Global

Human / Society dimension:

- Online data analyses and expert-driven enhanced data collection
- HAI-Human collaboration –P2: Empowering offline diagnosis & prognosis (with economical, legal & ethical dimensions from P3 tools)

Added Value in Diagnosis & Prognosis:

- Less data (from sensors)
- High accuracy (in particular prognosis)
- Explainable
- Inefficiency of existing paradigms

Towards Intelligent Mobile Sensing In Smart City

Metrology in Harsh / Complex Environment
- Temperature, Humidity, Gas, etc.
- Industrial plant
- Civil Infrastructures

Objectives & Impact
- Safety of people, places and goods
- Well-being and Health
- Predictive maintenance
- Maintain of economy activities

Advanced materials, electronics and photonics
- Technologies and Process
- Quantum & nano 1D,2D
- Photonic technologies

Intelligent Mobile sensors / sensing
- Disruptive remote sensing and image
- Integration
- Unmanned Aerial Vehicles (UAV)
- Unmanned Underwater Vehicles (UUV)
- Alone / Network
- Autonomous in decision-making
- Autonomous in energy
- Communicating

Physics informed data collection for Smart Data

Hybrid AI model
- Physics law
- AI

IoT, (beyond) 5G, 6G
- New designs RF Devices, antennas
- Low latency
- Low consumption / energy
- Energy harvesting
- Embedded electronics

Propagation channels – Waves
- Earth / Ocean / Atmosphere / City
- EM, Optic, Acoustic
- Reconfigurable intelligent surface

Decision-making
- Real-time
- Edge / Cloud computing
- Neuromorphic