



ASOCIACIÓN NACIONAL DE **INGENIEROS DEL ICAI**







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Traditional engineering process





- Engineering activities mainly based on physical models/expert knowledge
- Models developed for each activity → low model share between activities
- Low use of operational data on models development.



Model Based Design



Based on

- **Digital Continuity of Models**.- model evolves not changing basic structure (keeping the interfaces)
- **Digital Continuity of Parameters.** centralized source of truth for the different parameters
- **Digital continuity of Requirements**.- digital thread with traceability from requirements and system architecture to component design and tests.





Digital Twin Definition

"A digital twin is a virtual representation of an object or system that spans its lifecycle, is updated from real-time data, and uses simulation, machine learning and reasoning to help decision-making."

Data Models & Physical models



Data Models

- Large Amount of data (few labelled)
- Most Data from "good"
 conditions
- Explainability issues

Knowledge Transfer

Physical Models

- Large experience
- Results "similar" to real ones
- Uncertainties related to parameters and boundary conditions

- ML to obtain boundary conditions
- Parameter estimation (Bayesian models)
 - Data Models trained with Digital Twin Results
- Models combining data knowledge and physical knowledge

Boundary conditions for Design & Maintenance





Applications

- Gearbox
- Wheelset
- Bearings



Data Models based on Digital Twin Results





Health Monitoring systems

- Applied to wheelset defects
- Very few data of deteriorated conditions
- High precision model of vehicle track interaction
- DT results used to train SVM based health monitor systems
- Output: defect magnitude (i.e. peak force created by a flat)



10

Passages

Experimental results

15

20

5

F ratio

0

Physical Model Parameter Estimation





- Improve knowledge of the parameters of physical models
- Methodology based on Bayesian Inference
- Evolution of parameters with time→ maintenance



Parameter estimation



Fitted results

Time [s]

Physic Informed Neural Nets



- Introduce physical knowledge in the NN
- Lower training requirements
- Train of the NN in situations where no data are available



Conclusions



- Digital Twins can be used to optimize different stages of the product (design, homologation, maintenance,...)
- System models can be developed using different tools:
 - Physical models
 - Data based models (NN)
 - PINN
- Data Transfer between models key to maximize accuracy /reduce development effort
 - Data can help to improve knowledge of parameters or boundary condition of physical models
 - Physical knowledge can be used to reduce training effort of data models (PINN, artificial data generated with DT)





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