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Can Machine Learning bring a revolution in EMC/SI/PI Design?

dr. Domenico Spina

INTRODUCTION

- EMC, SI and PI are crucial for modern circuits
  - Complex systems under several physical effects
  - Must be robust to external interferences and be integrated with other components (i.e. digital)

- New production technologies, increased complexity and high operational frequencies bring new challenges to EMC/SI/PI design!

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INTRODUCTION

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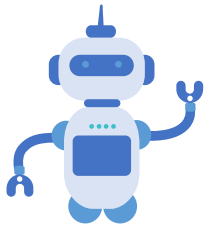
- What is the role of Machine Learning (ML)?



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MACHINE LEARNING FOR EMC/SI/PI

- What is ML?
  - ML is a set of methodologies in artificial intelligence (AI)
    - Mathematical techniques able to learn information from a set of data

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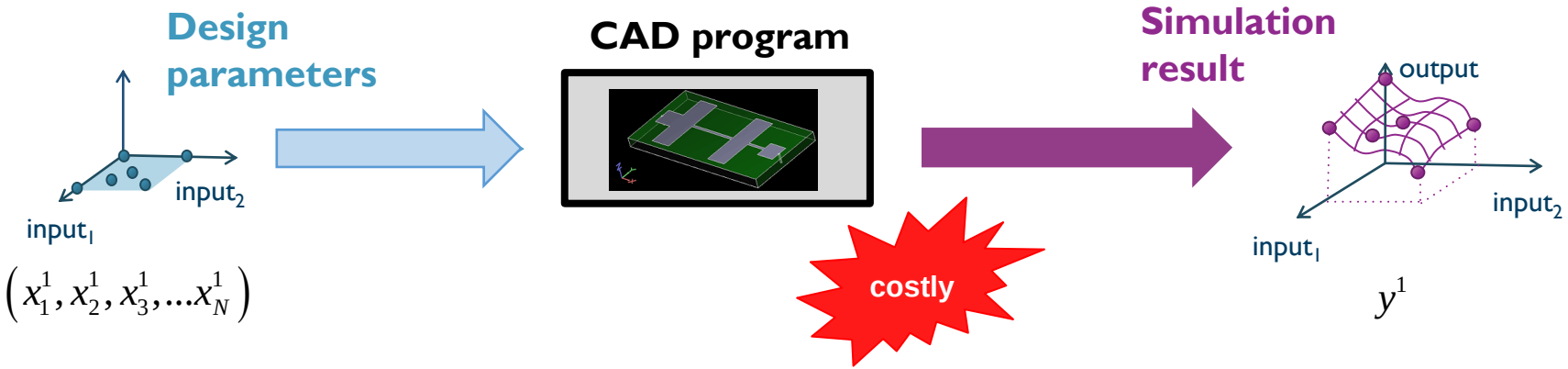
MACHINE LEARNING FOR EMC/SI/PI

Design Problem

1. Design an analog device/circuit in a simulation program (CAD)
2. Define design parameters
3. Tune value of design parameters until desired performance are reached



MACHINE LEARNING FOR EMC/SI/PI

- **Dataset**
  - Samples of design parameters and corresponding simulation results

$\left(x_1^1, x_2^1, x_3^1, \ldots x_N^1\right)$	y^1
$\left(x_1^2, x_2^2, x_3^2, \ldots x_N^2\right)$	y^2
⋮	⋮
$\left(x_1^M, x_2^M, x_3^M, \ldots x_N^M\right)$	y^M

Ready for ML!

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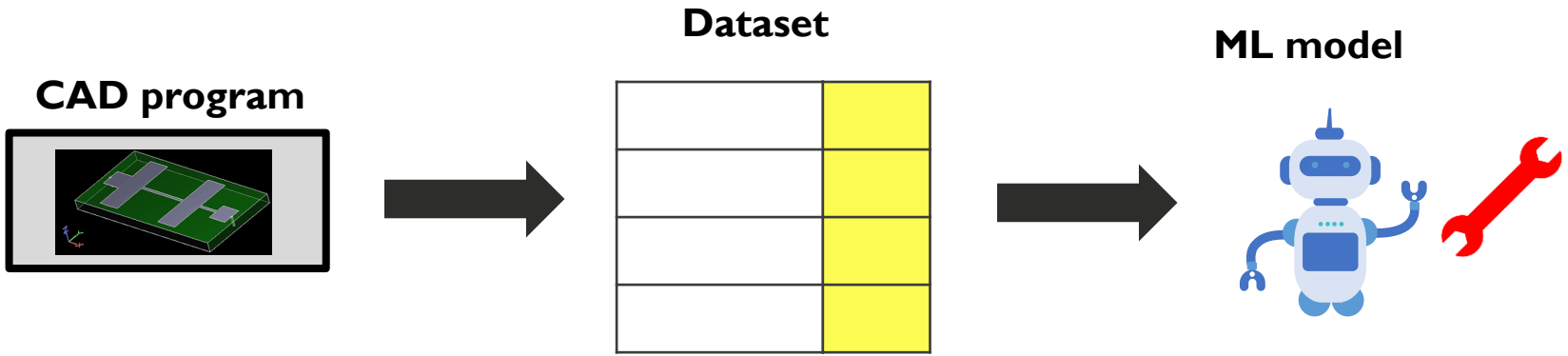
MACHINE LEARNING FOR EMC/SI/PI

1. Training

- Goal: tune model to learn relation between design parameters and performance metric



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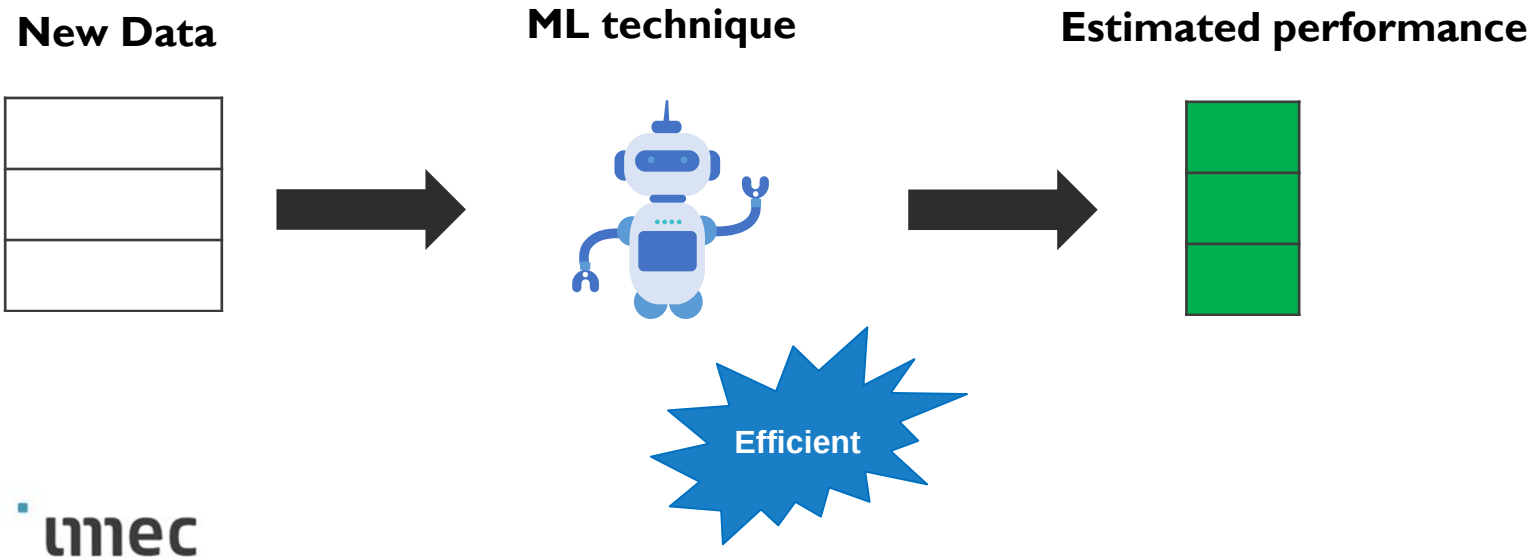
2. Application

- Feed new values of design parameters to ML model
- Model predicts performance of the system



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MACHINE LEARNING FOR EMC/SI/PI

- **ML Properties**
  - Able to describe complex systems
    - Resonance, nonlinear effects, crosstalk, ….

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MACHINE LEARNING FOR EMC/SI/PI

- **ML Properties**
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  - Accurate estimation (confidence bound)
  - Generalize well to unseen data

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MACHINE LEARNING FOR EMC/SI/PI

- **ML Properties**
  - Able to describe complex systems
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  - Accurate estimation (confidence bound)
  - Generalize well to unseen data
  - Able to handle large amount of data or design parameters

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MACHINE LEARNING FOR EMC/SI/PI

- **Examples of ML applications in analog design**
  - Scattering parameters modeling [Jin19, Torun20]
  - Transfer function extrapolation [Bhatti22]
  - Inverse problems [Xiao21, Wu22]
  - Optimization problems [Garbuglia22, Guo22, Touloupas22]
  - Eye Diagram worst case analysis: [Dolatsara21]
  - …….

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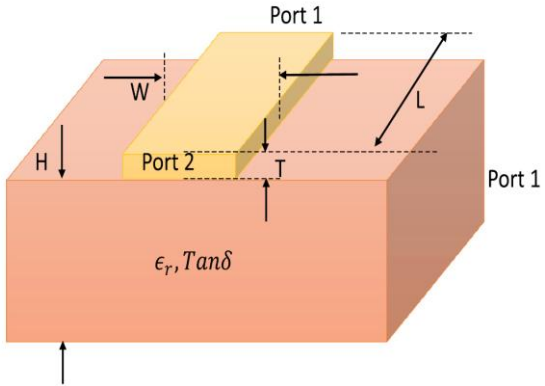
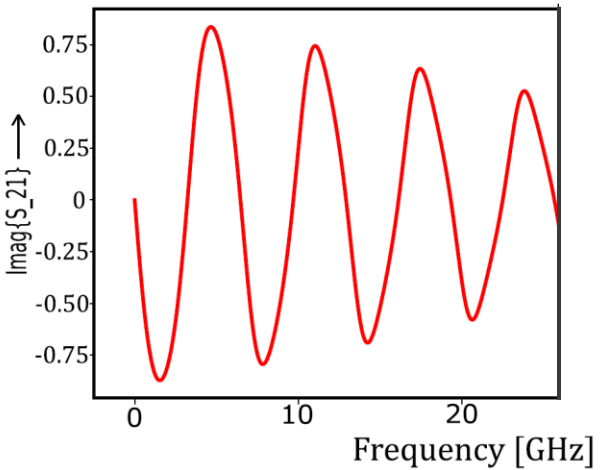
MACHINE LEARNING FOR EMC/SI/PI

APPLICATION EXAMPLE

- **Extrapolation S-parameters of a microstrip**
  - Neural Network trained to extrapolate S-parameter data [Bhatti22]





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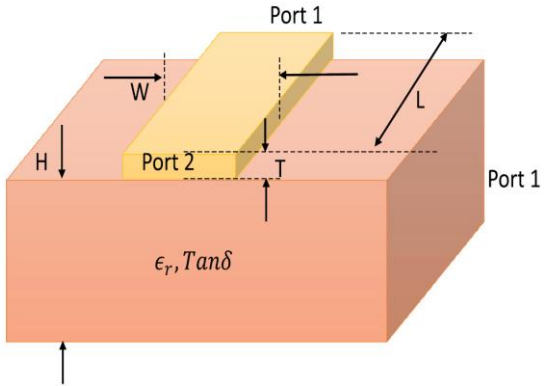

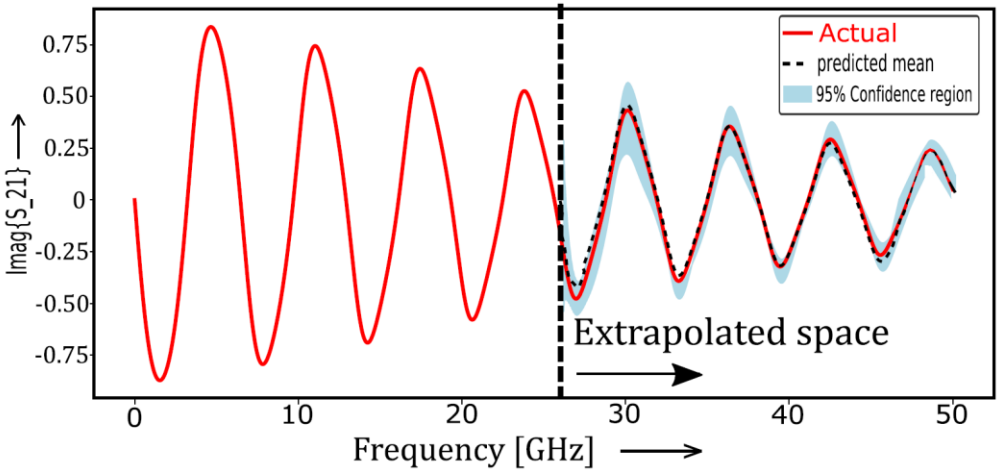

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MACHINE LEARNING FOR EMC/SI/PI

- **Problem**
  - High cost of generating a dataset for EMC/SI/PI problems
    - Expensive simulations or measurements
    - Many ML techniques require thousands of simulations (Deep Neural Networks)

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- **Goal**
  - Minimize number of simulations to build dataset→ Efficiency
  - Maximize the information → Accuracy

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- **Solution: Data–efficient ML**
  - Iteratively acquire new data in order to maximize information
  - Adapt ML model predictions according to new data

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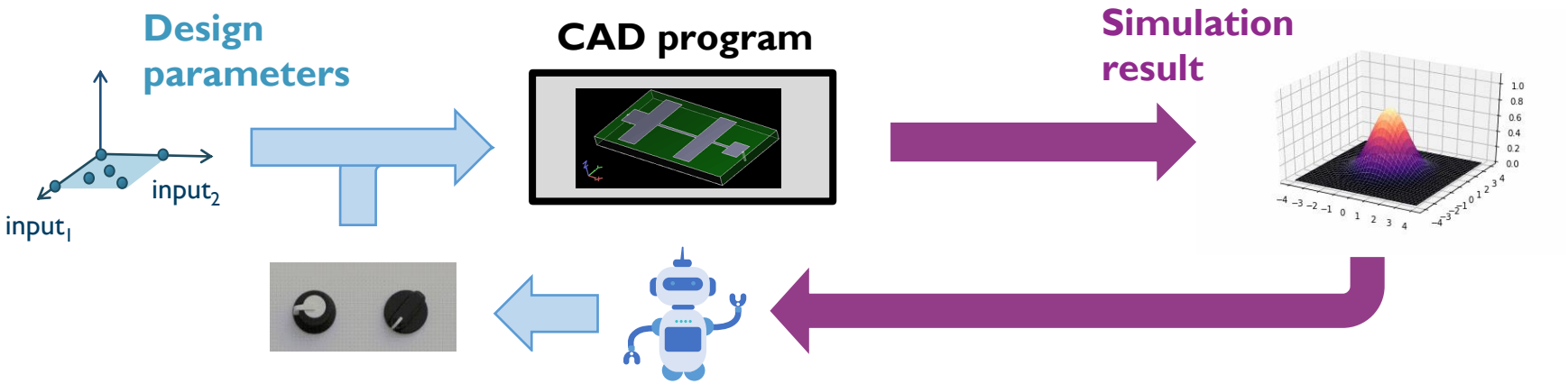
DATA-EFFICIENT MACHINE LEARNING

- **Data–efficient ML Framework**



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SUMO LAB: RESEARCH TOPICS

- **Our vision**
  - Increasing level of automation in analog circuit design
  - Enabling accurate and efficient characterization of high-frequency systems
  - Increasing efficiency design cycle
  - Discovering new design configurations

- **Main Research Area**
  - Data-efficient Modeling and Machine Learning
    - Bayesian inference

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MACHINE LEARNING FOR EMC/SI/PI

CONCLUSIONS

- **Can ML bring a revolution in EMC/SI/PI design?**

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MACHINE LEARNING FOR EMC/SI/PI

CONCLUSIONS

- **Can ML bring a revolution in EMC/SI/PI design? YES**

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MACHINE LEARNING FOR EMC/SI/PI

CONCLUSIONS

- **Can ML bring a revolution in EMC/SI/PI design? YES**

- What is needed
  - Include physic-based knowledge in ML
  - Comprehensive approach
    - ML for system- circuit- and device-level
  - Human-in-the-loop
    - Easy to use, interpretable results

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MACHINE LEARNING FOR EMC/SI/PI
CONCLUSIONS

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Cooperation between academia and industry is fundamental!

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Thanks for your attention!

Questions?

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