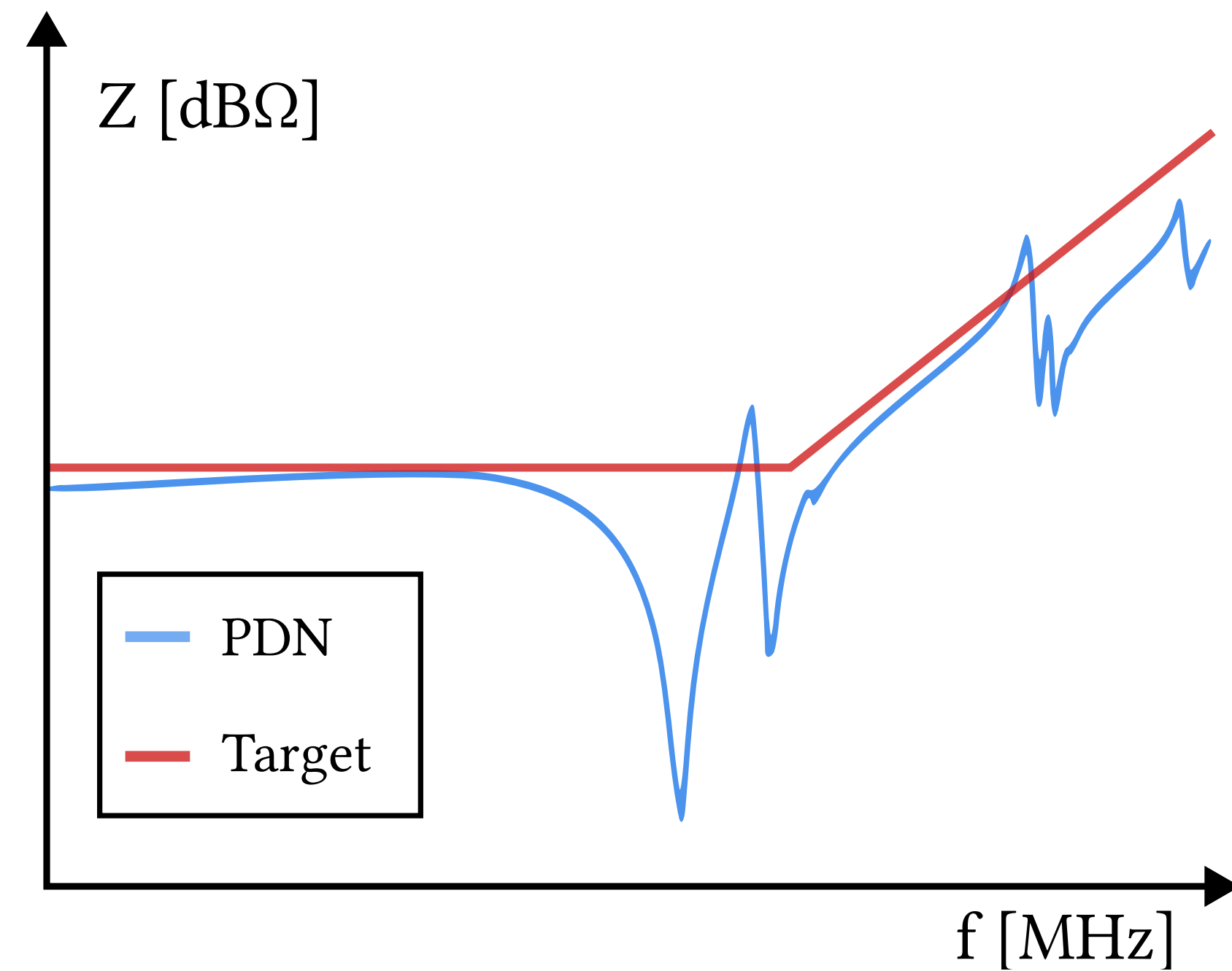


Data-Driven Power Integrity on Printed Circuit Boards

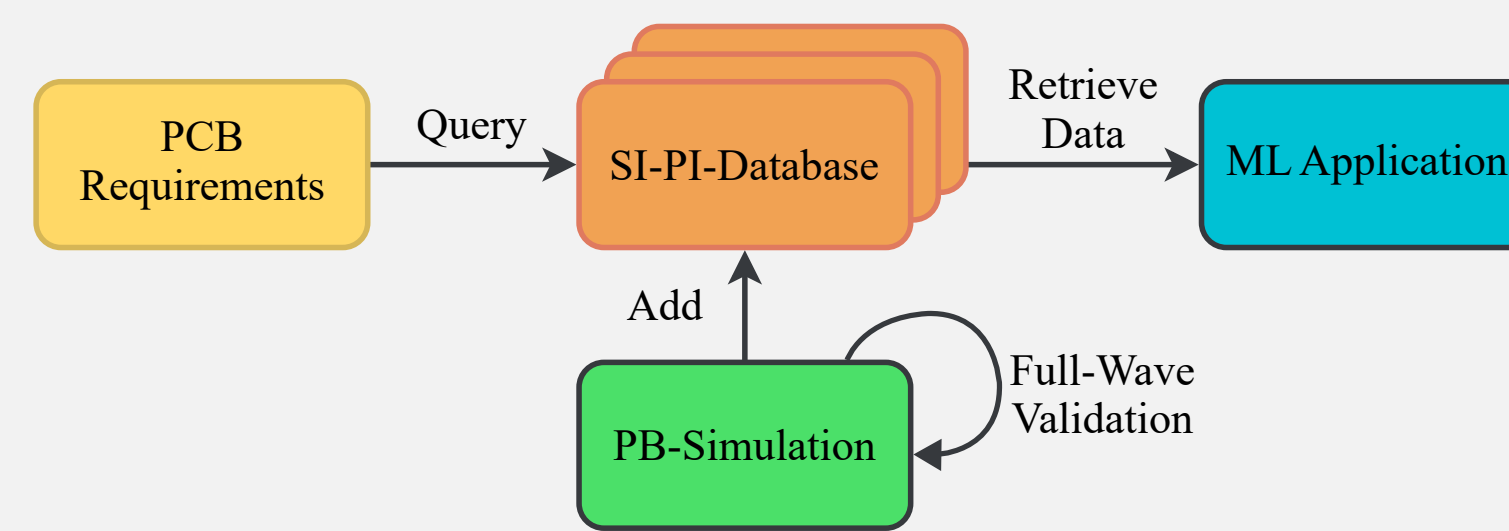
Power Integrity on Printed Circuit Boards

Target Impedance



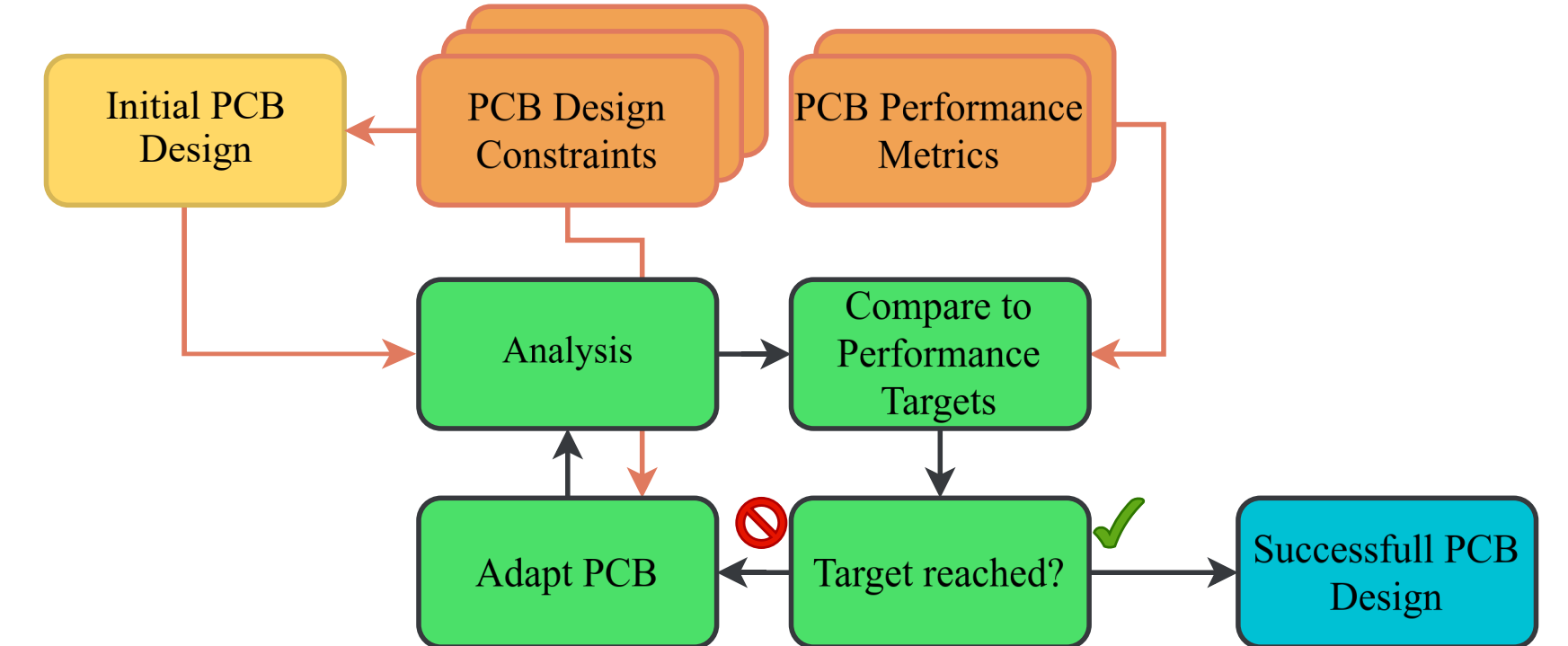
SI/PI-Database

- Centralized infrastructure for PCB simulations [5].
- Automation with fast physics-based simulations and full-wave validation.
- Unified pre-processing steps for ML applications.
- Encompasses over 80,000 individual simulations.
- <https://www.tet.tuhh.de/en/si-pi-database/>



Data-Driven Workflow

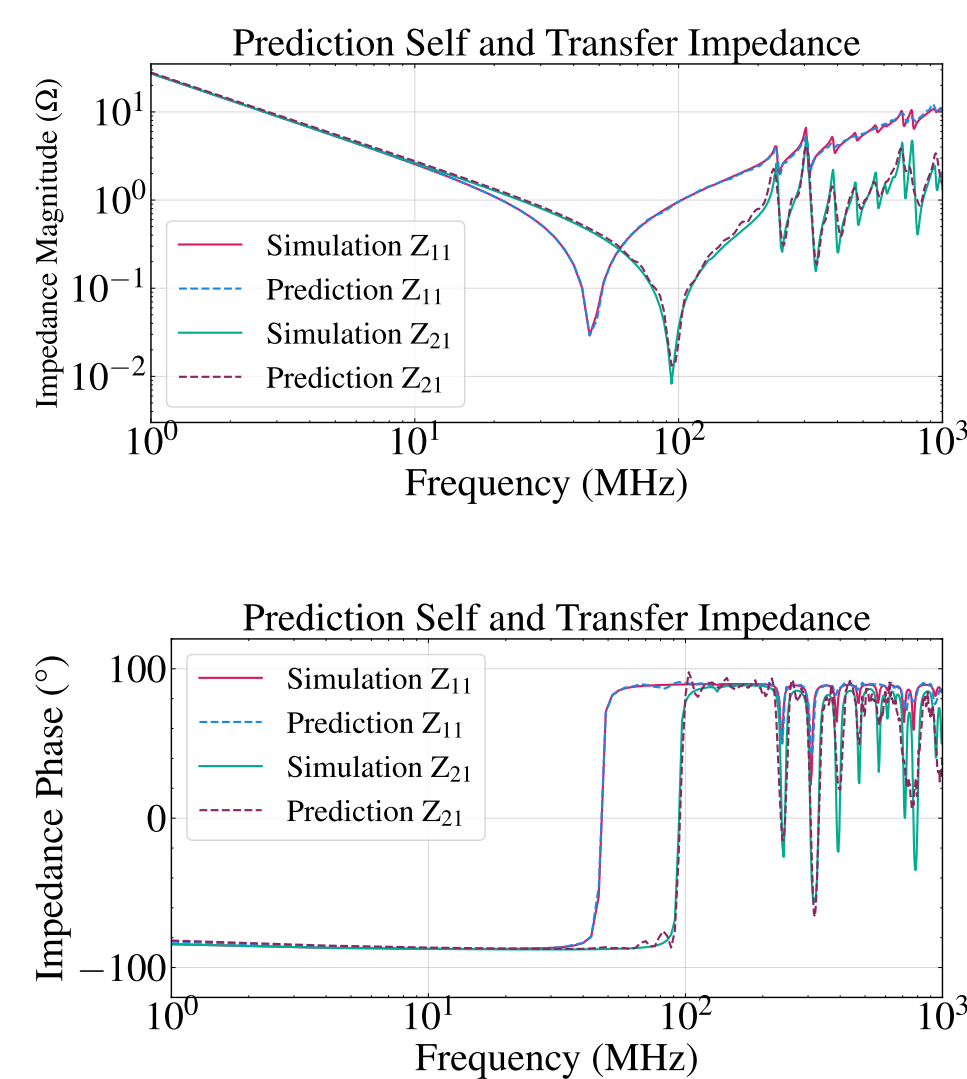
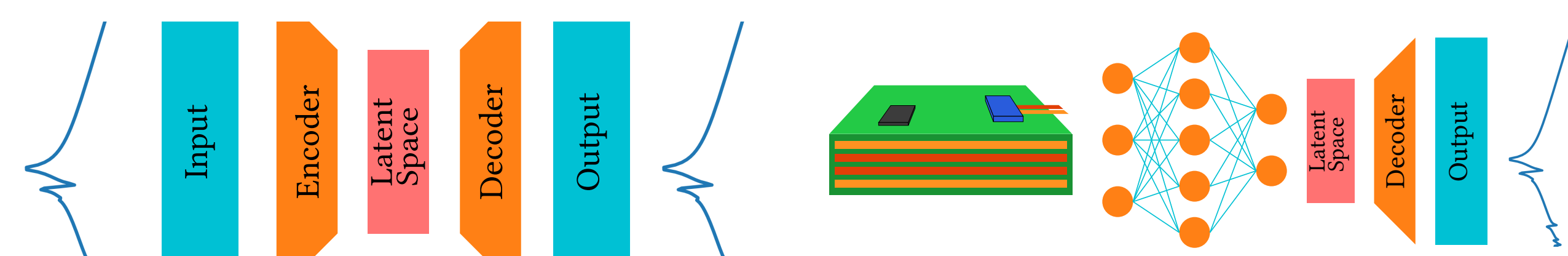
- Starting from previous design PCB is optimized over many iterations.
- Each iteration demands feedback of EM behavior.
- Simulation of modern, complex systems are computationally expensive.



Power Delivery Network Impedance Prediction

Motivation

- Full-wave simulations of modern PCBs take up several hours.
- ML model predicts EM-behavior in milliseconds → 1000x speed-up.
- Inference time is independent of input PCB size.
- Rapid exploration of large design spaces becomes feasible for complex designs.
- Publicly available training data is obtained from SI/PI-Database [3].



ML Impedance Prediction

- Autoencoder is trained on PCB impedance profiles [1][2].
- A compressed representation of the impedance profile is contained in the latent space.
- The encoder is replaced by a neural network that maps the PCB features to the latent space.
- The decoder reconstructs magnitude and phase of the impedance profile.

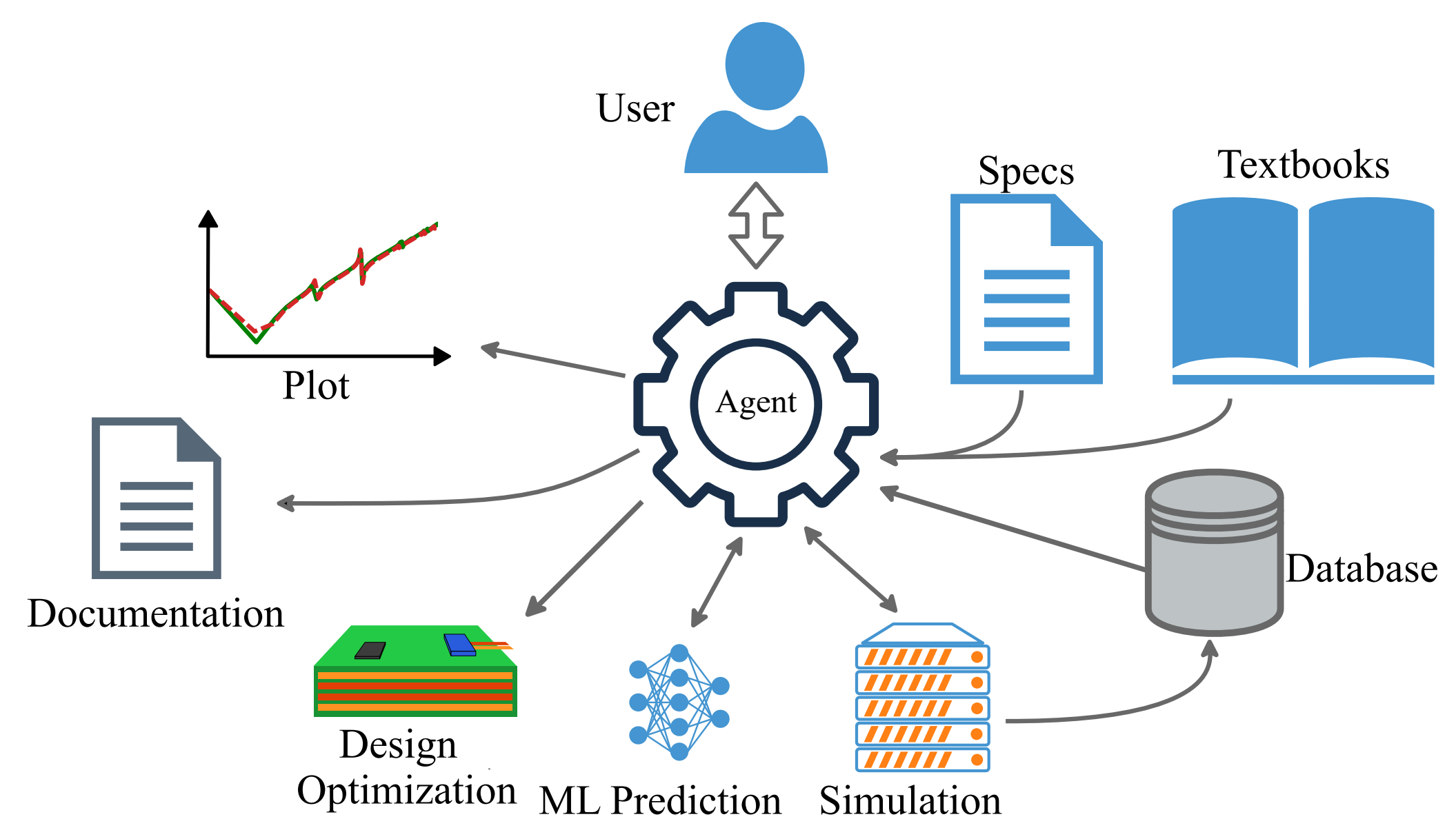
References

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- [2] Y. Hassab, J. Hessling, M. Schierholz, I. Erdin, J. Balachandran, and C. Schuster, "Impedance profile prediction and classification for PCB based PDN decoupling using autoencoders," in *DesignCon 2025*, Santa Clara, CA, USA, Jan. 2025.
- [3] Y. Hassab, M. Schierholz, and C. Schuster, "Application of Gaussian Process Regression for Data Efficient Prediction of PCB-Based Power Delivery Network Impedance Features," in *2024 IEEE 28th Workshop on Signal and Power Integrity (SPI)*, Lisbon, Portugal, May 2024. doi: 10.1109/SPI60975.2024.10539189.
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- [5] M. Schierholz *et al.*, "SI/PI-database of PCB-based interconnects for machine learning applications," *IEEE Access*, vol. 9, no. , pp. 34423–34432, 2021, doi: 10.1109/ACCESS.2021.3061788.

Agentic Power Integrity Framework

In the future PI Agents will use a variety of tools

- RAG: Retrieve design specs and query databases
- Simulation: Call simulations and ML-tools from user input and RAG results.
- Optimization: Propose design optimizations or identify issues.
- Plot: Visualize and document final results for human in the loop.

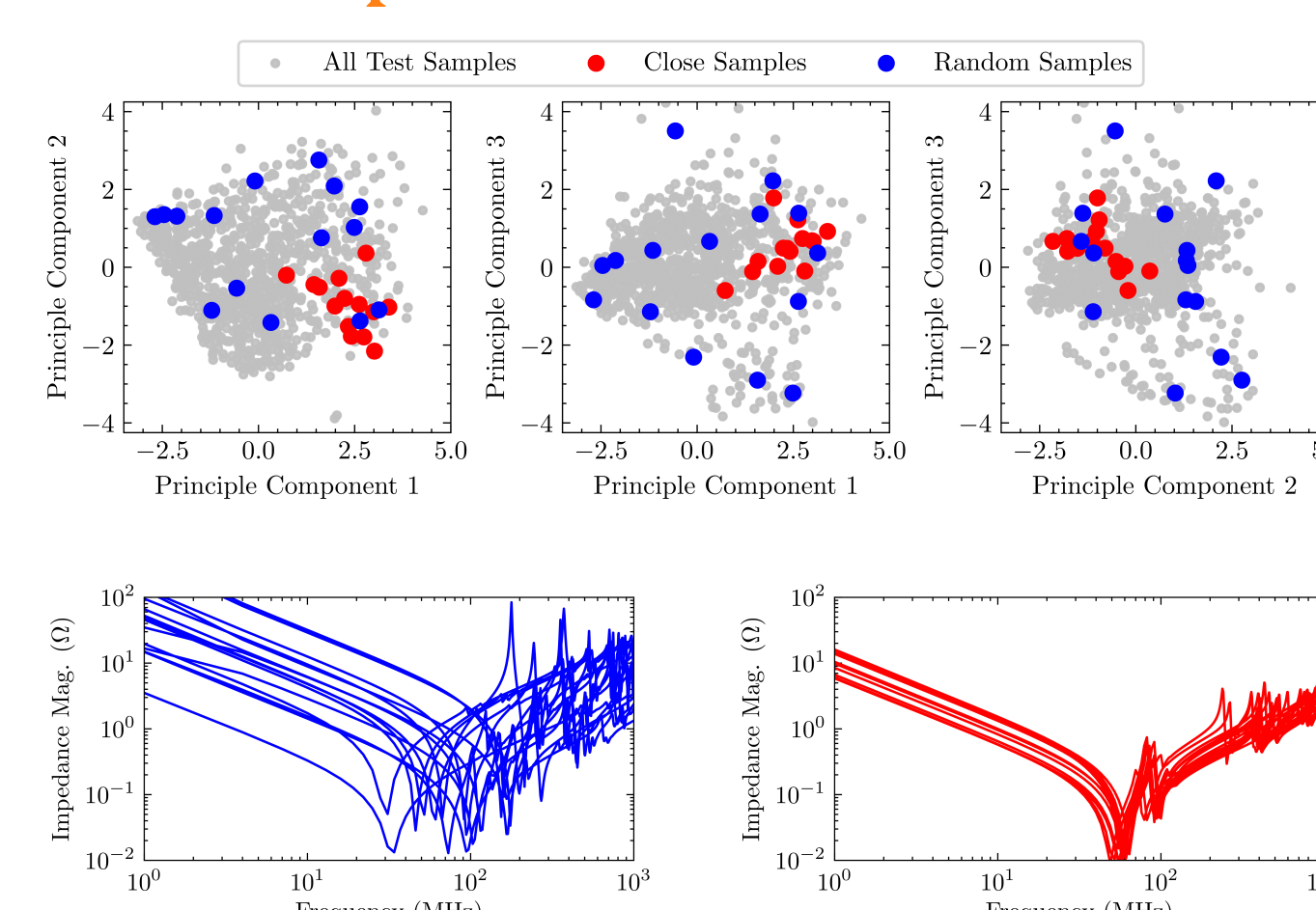


Latent Space Analysis

Latent Space Properties

- The autoencoder maps each PCB to the latent space.
- In the latent space similar PCBs are clustered.
- This enables to identify boards with related properties.
- If a query to the latent space yields a similar board, simulations could be bypassed.

Latent Space



Decoupling

