

Automation during the equipment design process

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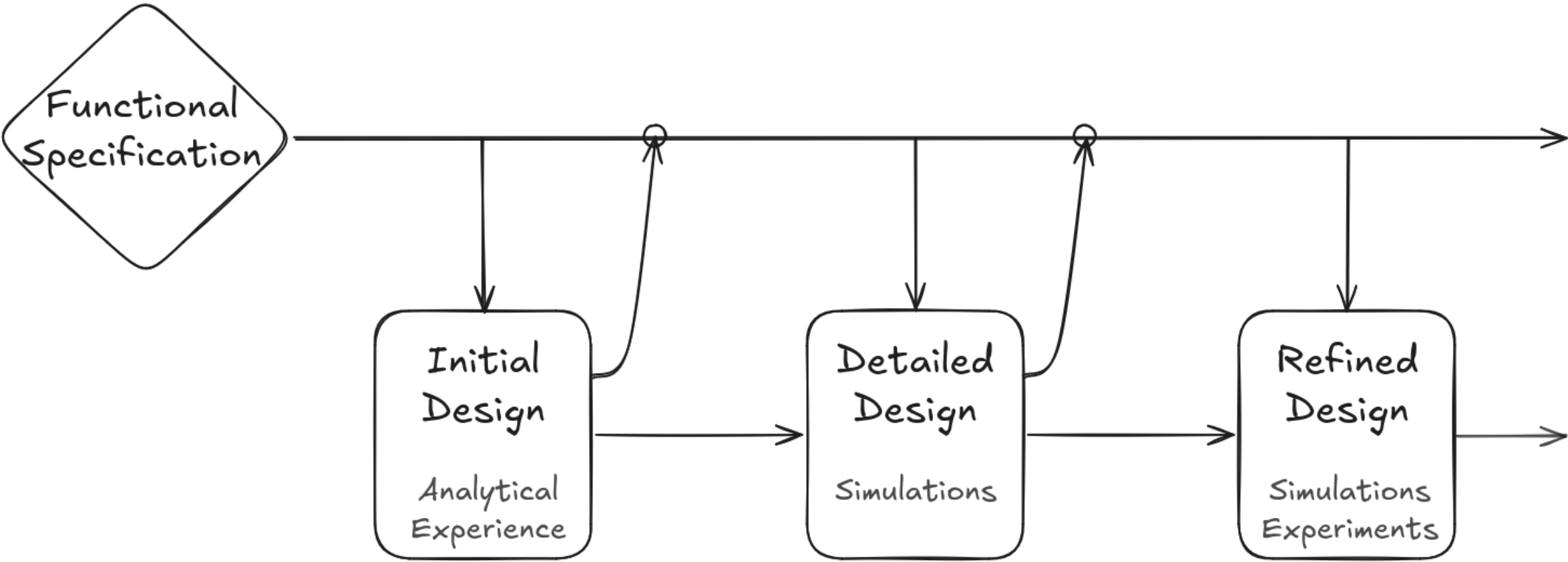
2024/12/12

Joint Accelerator Performance Workshop 2024

Montreux






General overview of design process



Simulations and design process

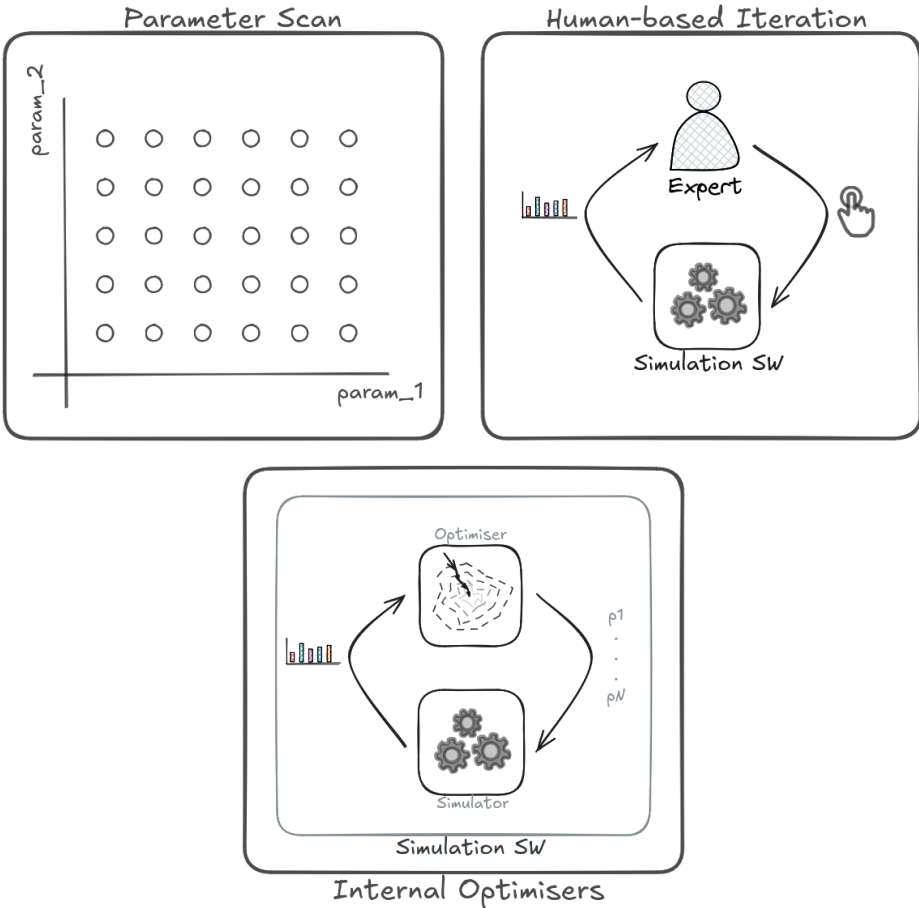
Simulations

- # 10 – 1000
-  seconds – days
~hours
-  usually commercial
-  static ~~###~~ ~~###~~ |
dynamic ||




 ⋮

Design Process



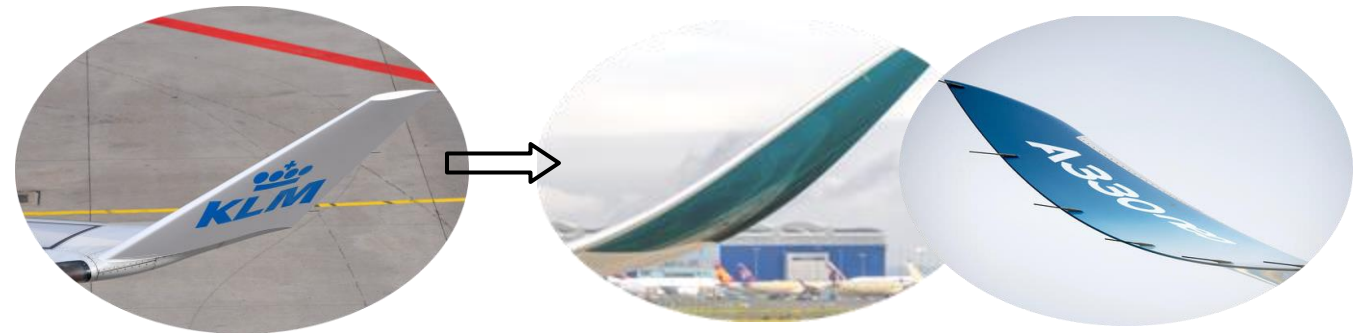
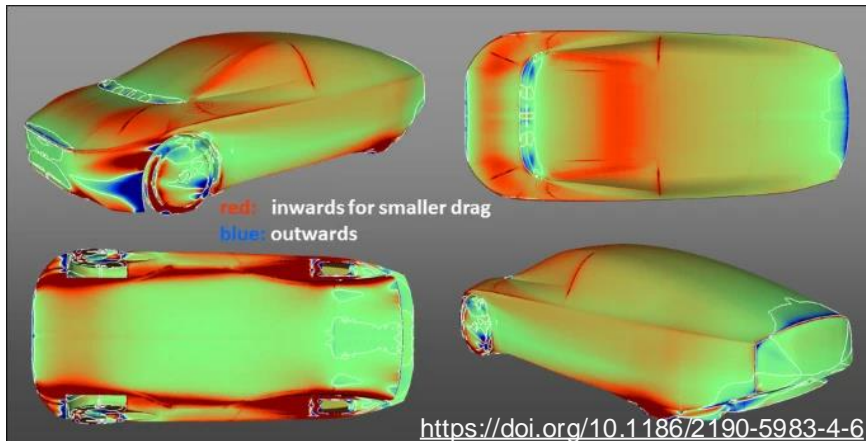
Optimisation, an alternative

Gradient-free (∇_p ✗)

- Sometimes provided by simulation software suite
- Low development cost: write interfacing with simulation software
- Useful when #parameters is low

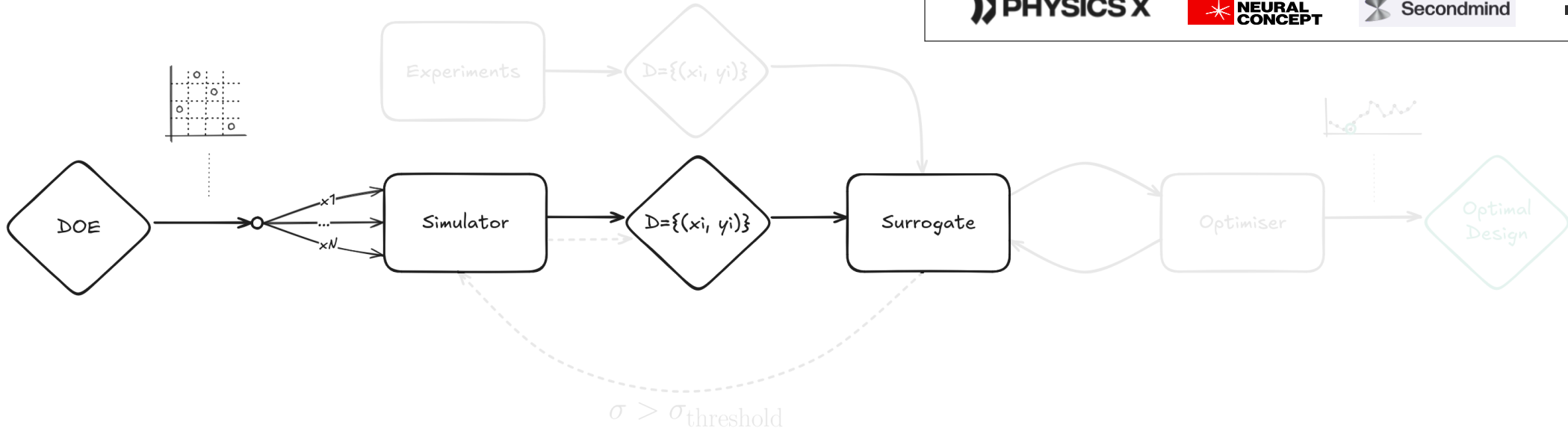
Gradient-based (∇_p needed)

- Scales well (gradient cost $\neq f(\#parameters)$)
- Design robustness (higher-order derivatives)
- Mesh refinement (tangent gradient)
- Seldom provided by simulation software
- High development cost (impl. differentiable sim.)



Surrogate-based design

Check out F. M. Velotti's talk on surrogates!
<https://indico.cern.ch/event/1439972/contributions/6159176>



robust exploration

- low computational cost
- fast iterations
- large exploration

multi-fidelity integration

- low-fidelity simulations
- high-fidelity simulations
- experimental data

prediction

- objective (target)
- constraints
- spatiotemporal quantities

Surrogate-based design: example

Surrogate-based design: example

Surrogate-based design: generative design

Surrogate-based design: example

Surrogate-based design: Ai.rplane

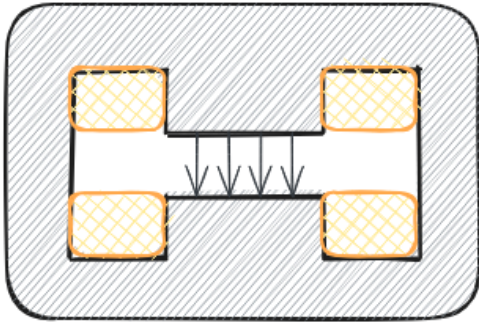
The screenshot displays the 'Ai.rplane' web interface. On the left, there are filter sections for 'Payload' (Weight: 4 kg, Maximum wingspan: 5.5 m) and 'Performance constraints' (Volume: 0.1 m³, Thrust available: 60 N, Cruise speed: 0-100 m/s). The central area features a contour plot of a design space with numbered points (1-18) and a 'Select' button. A QR code is visible in the top right. The URL 'airplane.physicsx.ai' is shown in the top right corner. A legend at the bottom indicates 'Example designs', 'Generated designs', and 'Uploaded designs'. A 'Courtesy of PhysicsX' watermark is present at the bottom center of the interface.

Digital twins

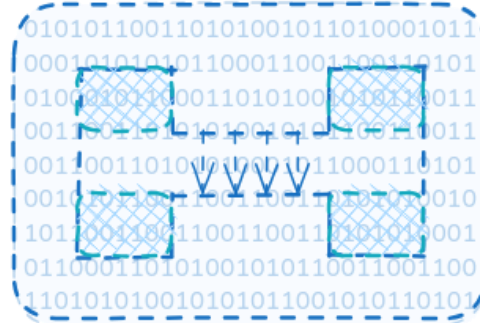
Check out Workshop for Digital Twins @ CERN!

<https://indico.cern.ch/event/1304817/>

real-world
physical system



digital model of
physical system



Only as useful as far as it can be executed.



Surrogate models are prime candidates!



Virtual Sensors



Forecasting



Optimisation & Control



Quality Control



What's needed

Challenges

People set in traditional ways

Little know-how of new techniques

Rigid simulation software (config-, interface-, script-ability, ...)

Potential Solutions


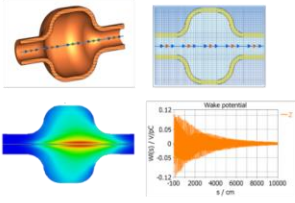
Pilot projects and dedicated resources

Collaboration with expert partners

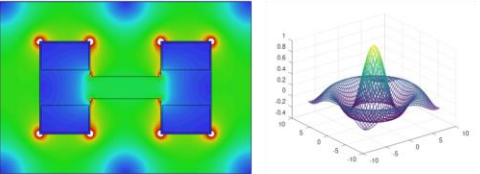
Explore SW capabilities; develop alternatives; harmonise processes

What's happening

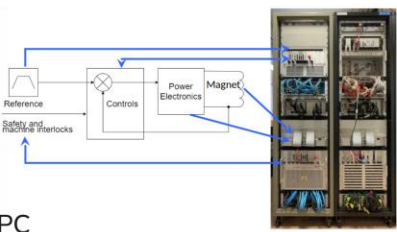
Tools

[1]  

BE-ABP

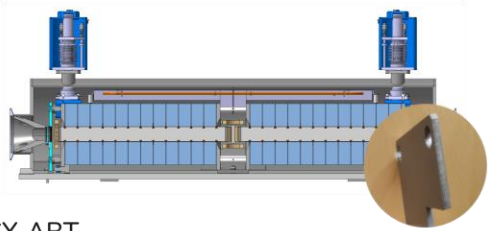
[2] 

TE-MSC

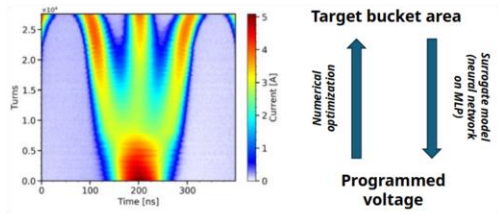
[3] 

SY-EPC

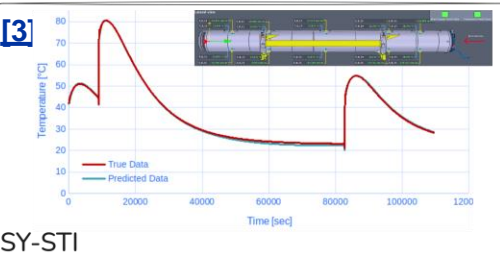
Digital Twins

[1] 

SY-ABT

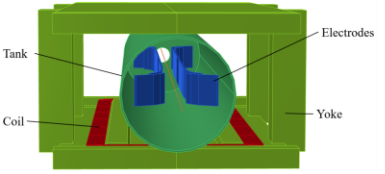
[2] 


SY-RF

[3] 

SY-STI

Automated Design

[4] 

SY-ABT 

Hopefully more!

Conclusion and Acknowledgments

Conclusion

- There is momentum in automation, digital twins, tool development, but still limited (especially in automated design)
- Industry is moving towards this approach – various startups in the field, partnerships with large tech & engineering companies
- We should explore and exploit surrogate models and automated design to improve efficiency and performance

Acknowledgments

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