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# DigiTwin

Digital twins for improved dynamic design



Engineering and  
Physical Sciences  
Research Council

## *Digital Twin Operational Platform for Connectivity and Accessibility using Flask Python*

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1st International Workshop on Model-Driven Engineering of Digital Twins

ModDiT'21

co-located with [MODELS 2021](#)

A WORLD  
**TOP 100**  
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# Outline

- Motivation
- Framework
- DTOP-Cristallo
  - Three-storey structure
  - Types of Simulations
- Git Repository
- Remarks



# Motivation

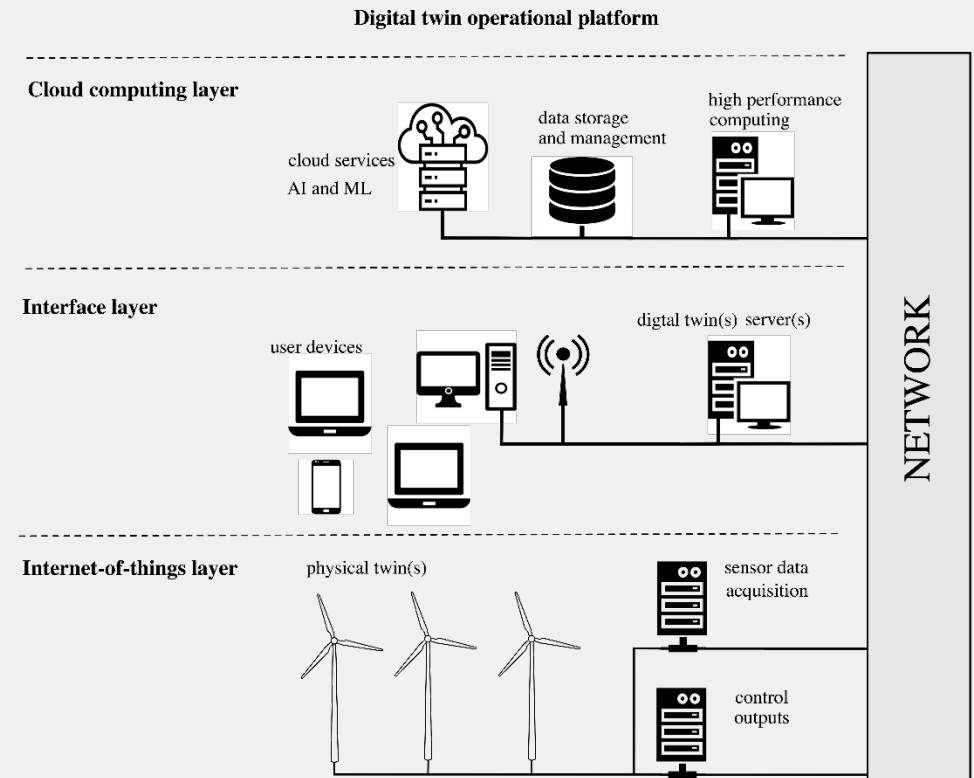
- Commercially available digital twins tend to be based on proprietary software
- Creates bespoke and rigid format
- Limiting for collaborative systems and multi-disciplinary design
- Complex and remote systems require added connectivity and accessibility options





# Connectivity Framework

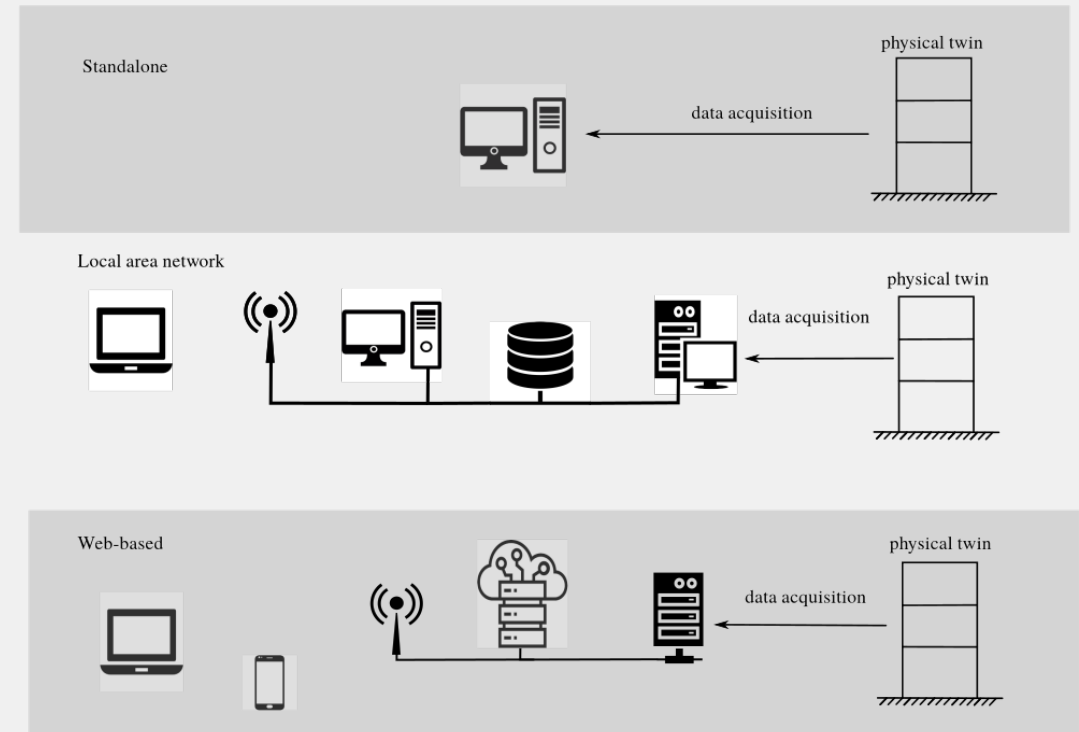
- Digital Twin is much more than a model
- Connections between PT, DT, User, and Resources
- Predominantly 3 layers of operation
- Broad viewpoint for engineering systems





# Accessibility Framework

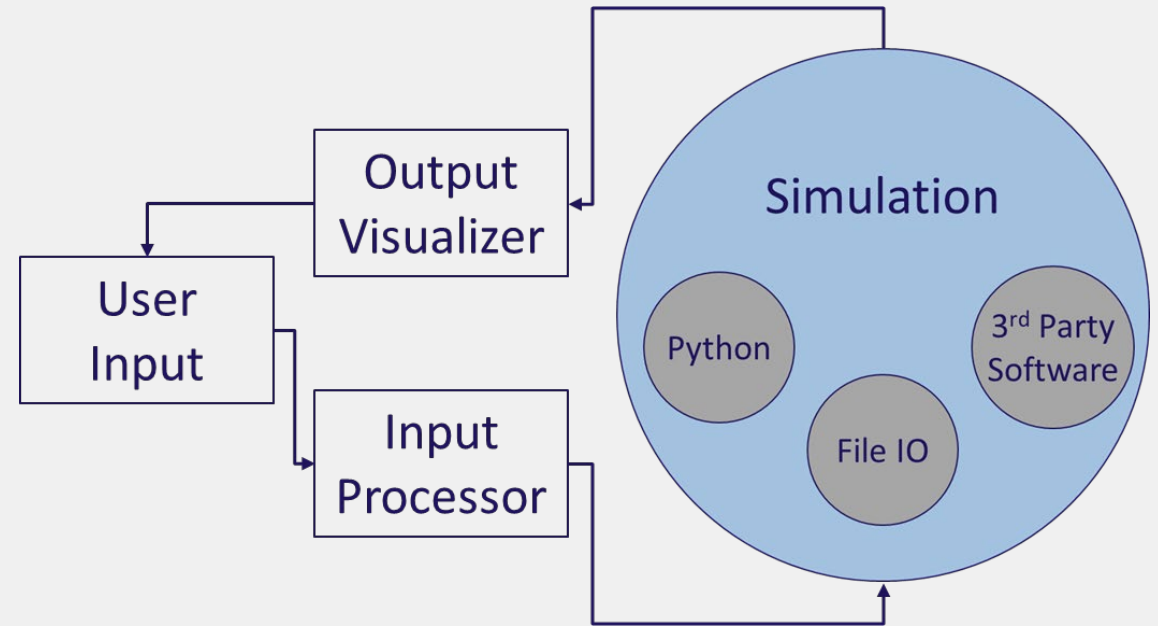
- Commercial DTs are typically standalone – only 1 person can interact with DT at once
- However, complex engineering systems are collaborative, multi-disciplinary projects
- Python Flask allows for deployment to various accessibility options





# Modular Layout

- Python Flask
- Separate user input and calculations for easier implementation
- Each aspect can be written by separate experts
- New simulations need
  1. Functionalized calculation
  2. Modified HTML/CSS/JS for inputs/outputs





# DTOP-Cristallo

- The demonstration operational platform : DTOP-Cristallo
- System specific
- Browser-based user interface
- Python-based calculations
- 6 total tools
  - 3 general categories

## Digital Twin Operational Platform (DTOP) - Cristallo



Welcome to DTOP - Cristallo!



This Digital Twin Operational Platform (DTOP) is Flask-based with the user interface being provided via HTML and CSS/Javascript. The demonstration system is a three-storey structure as shown in the graphic below.



The left-hand menu has links to a set of tools that can be used to interact with the digital twin. Documentation can also be found in the left-hand menu via either a downloadable PDF file or an interactive HTML.



This version of DTOP-Cristallo is designed to be used within the standalone framework and is primarily aimed at demonstrating how this operational platform framework applies to an engineering system in a modular and open-source manor. In the spirit of demonstrating the concept, data is either simulated or in some cases pre-recorded experimental data is used.



[GitHub](#)

### Research themes

- Design under uncertainty
- Structural vibration control
- Uncertainty propagation
- Finite element analysis
- Nonlinear control-based continuation
- Experimental cross validation



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# Three-Storey Structure

- BENCHTOP scaled 3-storey building
- Aluminium construction with reinforced joints
- Simple prototype for demonstration purposes







# Self-Contained Tools

- Simulations programmed purely in python
- Fundamentally separated into frontend/backend operations
- User input simulation parameters (variety of object types)
- Output displays results via browser

### Simulate controller

Control strategy:

- Passive --> Tuned Mass Damper
- Active --> Direct Velocity Feedback
- Active --> Direct Velocity Feedback + Electronic Compensator
- Active --> Linear-Quadratic Gaussian regulator (server/developer version only)

Location of control action:

- Floor 1
- Floor 2
- Floor 3

Design Tuned Mass Damper:

Base mass  $m_b = 0.5$  [kg]  
Moving mass  $m_p = 1$  [kg]  
Suspension stiffness  $k_p = 1670$  [N/m] --> Natural frequency = 6.50 [Hz]  
Internal damping  $c_p = 5$  [Ns/m] --> Damping ratio = 6.12 [%]

Design transducer parameters:

Force factor  $Bl = 10$  [N/A]  
Electrical impedance  $Z_e = 8$  [ $\Omega$ ]

Tune feedback gain:

Control gain  $h = 5$  [-]

Electronic compensator settings:

Estimated natural frequency TMD  $\hat{\omega}_p = 6$  [Hz]  
Estimated damping ratio TMD  $\hat{\xi}_p = 4.0$  [%]  
Compensated natural frequency  $\omega_c = 6$  [Hz]  
Compensated damping ratio  $\xi_c = 4.0$  [%]

Tune Linear-Quadratic Regulator weights (server/developer version only):

LQR state weight  $q = 200$  [-]  
LQR input weight  $r = 0.1$  [-]

Set Kalman Filter noise covariances (server/developer version only):

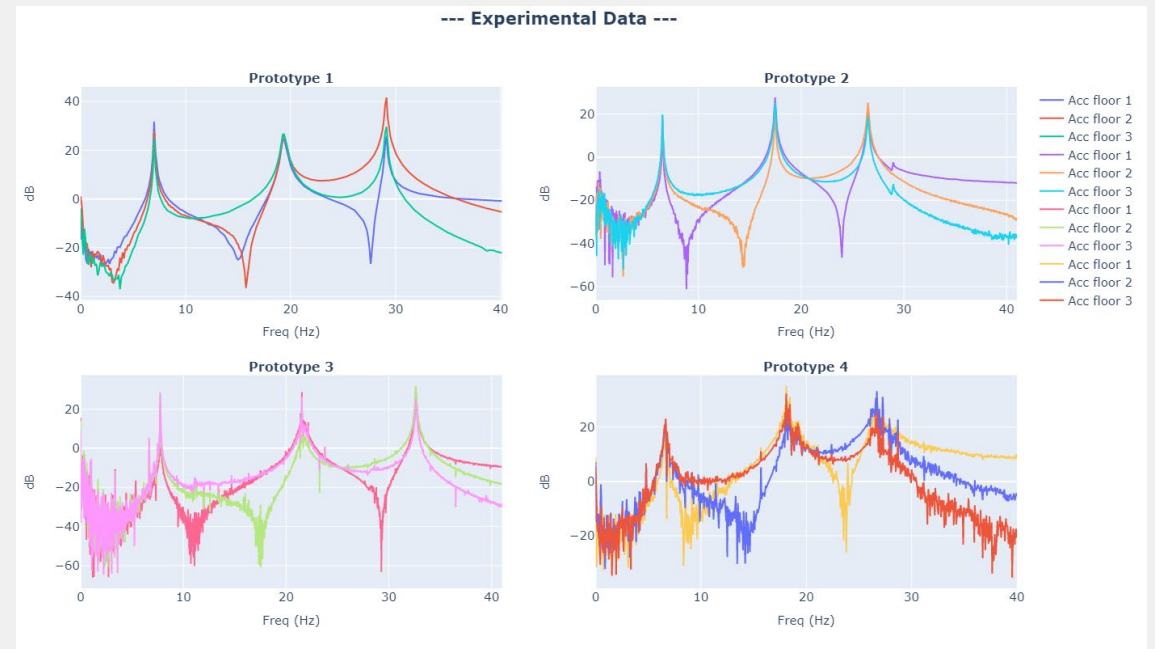
KF process noise covariance  $Q_n = 1.0$  [-]  
KF measurement noise covariance  $R_n = 1e-12$  [-]

Simulate



# File IO

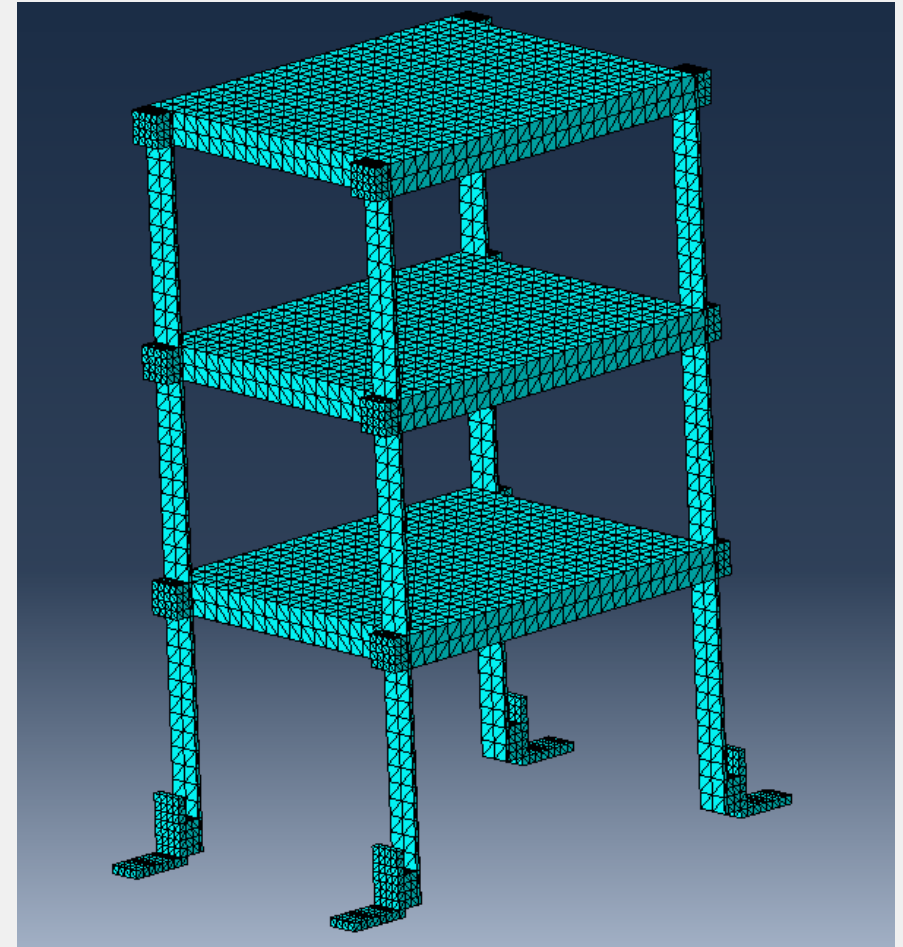
- Python interacts with local files
- Location can be hard-coded or user supplied
- Pre-recorded data
- Low RAM simulation utilization





# 3<sup>rd</sup> Party Simulation Tools

- Most engineering designs use multiple licensed software
- High degree of trust in those software
- Easier to sell if using trusted software
- ABAQUS shown as example
  - Python script generated from user input
  - ABAQUS called via command prompt





# GIT Repository

- Publicly available GIT repository
  - All 6 simulations available with open-source code
  - Instructions to deploy in Standalone, with easy modification to deploy in LAN
  - Spread possibilities for collaborations with engineering and computer science communities
- <https://github.com/Digital-Twin-Operational-Platform/Cristallo>



# Remarks

- Our framework puts forth an open-source and easy to implement Digital Twin Operational Platform
- Our DTOP connects the user with the DT, PT, and computational resources
- Our DTOP gives accessibility options for both local and global deployment
- DTOP-Cristallo gives a demonstration of the interface layer and is freely available for download/use via GIT
- The whole purpose is for collaborations, so let me know your thoughts



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# Thanks for your Attention

<https://github.com/Digital-Twin-Operational-Platform/Cristallo>