CONTRIBUTION OF DONUT (DEVELOPMENT AND IMPROVEMENT OF NUMERICAL METHODS AND TOOLS FOR MODELLING COUPLED PROCESSES) TO DIGITAL TWINS

16/02/2022 • F. CLARET (f.claret@brgm.fr)

This project has received funding from the European Union's Horizon 2020 research and innovation programme 2014-2018 under grant agreement N°847593

CONTEXT

Wright and Davidson
Adv. Model. and Simul. in Eng. Sci. (2020) 7:13
https://doi.org/10.1186/s40323-020-00147-4

Advanced Modeling and Simulation in Engineering Sciences

RESEARCH ARTICLE **Open Access**

How to tell the difference between a model and a digital twin

Louise Wright* and Stuart Davidson

*Correspondence:
louise.wright@npl.co.uk
National Physical Laboratory, Hampton Road, Teddington, UK

Abstract

"When I use a word, it means whatever I want it to mean": Humpty Dumpty in Alice's Adventures Through The Looking Glass, Lewis Carroll. "Digital twin" is currently a term applied in a wide variety of ways. Some differences are variations from sector to sector, but definitions within a sector can also vary significantly. Within engineering, claims are made regarding the benefits of using digital twinning for design, optimisation, process control, virtual testing, predictive maintenance, and lifetime estimation. In many of its usages, the distinction between a model and a digital twin is not made clear. The danger of this variety and vagueness is that a poor or inconsistent definition and explanation of a digital twin may lead people to reject it as just hype, so that once the hype and the inevitable backlash are over the final level of interest and use (the "plateau of productivity") may fall well below the maximum potential of the technology. The basic components of a digital twin (essentially a model and some data) are generally comparatively mature and well-understood. Many of the aspects of using data in models are similarly well-understood, from long experience in model validation and verification and from development of boundary, initial and loading conditions from measured values. However, many interesting open questions exist, some connected with the

The Defense Acquisition University definition of digital twin, commonly used in defence, aerospace and related industries, (quoted in [1]) is:

> *"an integrated multiphysics, multiscale, probabilistic simulation of an as-built system, enabled by Digital Thread, that uses the best available models, sensor information, and input data to mirror and predict activities/performance over the life of its corresponding physical twin."*

and NAFEMS council member Rod Dreisbach recently defined it as:

> *"a physics-based dynamic computer representation of a physical object that exploits distributed information management and virtual-to-augmented reality technologies to monitor the object, and to share and update discrete data dynamically between the virtual and real products"*

in the April 2018 issue of Benchmark Magazine [2].

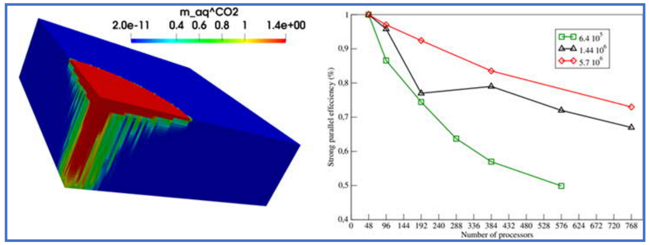
From these definitions it is clear that there are three important parts in the digital twin of an object:

- a model of the object,
- an evolving set of data relating to the object, and
- a means of dynamically updating or adjusting the model in accordance with the data.

CONTRIBUTION OF DONUT TO DIGITAL TWINS GALAXY (1/3)

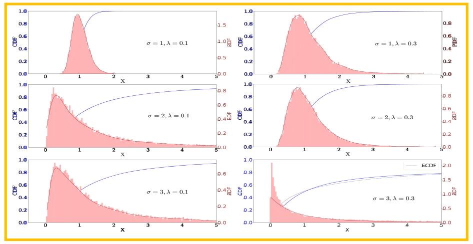
- A DT is developed by, as far as possible, reproducing its multi-physical twin's behavior => better understanding and modeling of coupled multi-physics phenomena is one of the main goal of DONUT.

- A DT needs the use of HPC



Task 2 Numerical methods for high performance computing of coupled processes (Leader C. Cances)

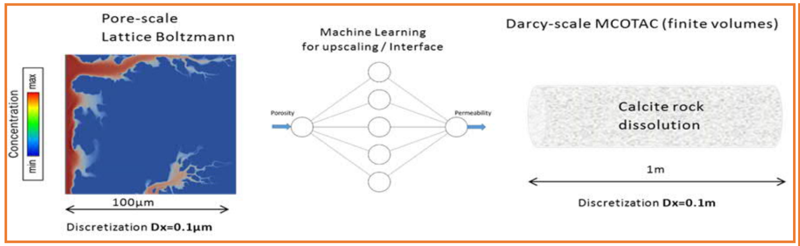
- A DT needs model calibration and uncertainty analysis



Task 5 Tools and methods to quantify/derive uncertainties induce by coupled processes (Leader A. Baksay)

CONTRIBUTION OF DONUT TO DIGITAL TWINS GALAXY (2/3)

- A DT needs to integrate multiscale representation



Task 4 Scale transition schemes for coupled processes (Leader O. Kolditz & N. Prasianakis)

- A DT needs model reduction (surrogate model) and the use of machine learning

Task 5 Benchmarks of methods and tools for coupled processes (Leader D. Lukin)

Machine Learning and Geochemistry → ACED & FUTURE WPs + PREDIS

THM model evaluation → HITEC

Multiphase multicomponent reactive transport → ACED & GAS WPs

MACHINE LEARNING AND GEOCHEMISTRY BENCHMARK: SO FAR > 10 MODELLING TEAMS

- CROSS-EURAD Collaborative effort
- Participants inside/outside EURAD continue to join
- Meetings every 1-2 months to discuss progress
- Joint Development of methodologies and codes. Modelling teams are working closely together.
- Open source software is heavily used. Progress may be followed at anytime at project place: https://service.projectplace.com/#project/1773878474/documents/1964331616

#CLAY00634

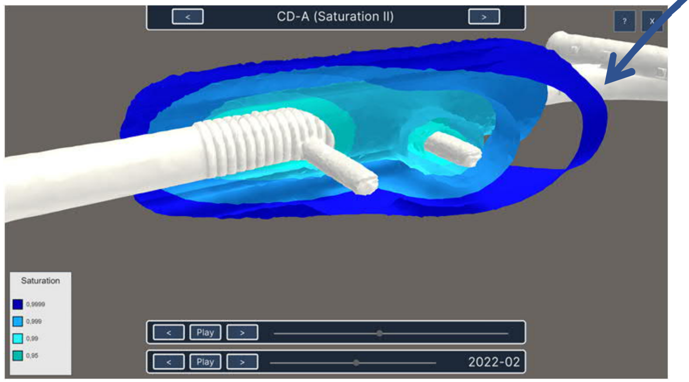
GEOCHEMISTRY AND MACHINE LEARNING BENCHMARK WITHIN EURAD

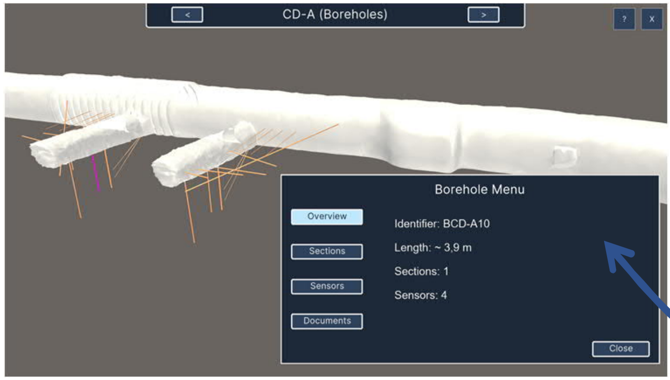
TOPIC 08: Fluid flow and radionuclide migration

N. Prasianakis [1], E. Laloy [2], D. Diederik [2], H. Meeussen [3], C.H. Tournassat [4], G.D. Miron [1], D.A. Kulik [1], M. Marques [1], S.V. Churakov [1, 5], P. Sochala [6], V. Montoya [7], J. Samper [8], O. Kolditz [7], F. Claret [6].
[1]Laboratory For Waste Management, Paul Scherrer Institut - Villigen (Switzerland), [2]Engineered And Geosystems Analysis, Belgian Nuclear Research Centre - Mol (Belgium), [3]Nuclear Research And Consultancy Group (nrg) - Petten (Netherlands), [4]Institut Des Sciences De La Terre D'orléans, Université D'orléans—cnrs/insu—brgm - Orléans (France), [5]Institute for Geological Sciences, Bern University - Bern (Switzerland), [6]Brgm - Orléans (France), [7]Department Of Environmental Informatics, Helmholtz Centre For Environmental Research, Ufz - Leipzig (Germany), [8]Universidade Da Coruña, Centro De Investigaciones Científicas, Enresa, Universidade Da Coruña - A Coruna (Spain)

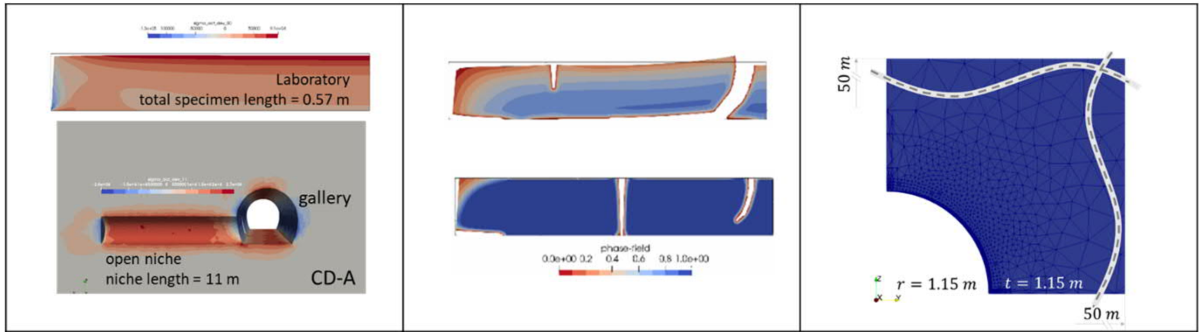
EMBEDDING MULTI-PHYSICS TO VIRTUAL REALITY

- A DT needs to embed complex process models into real context (overarching DONUT Tasks and link to other WPs GAS and MODATS)





- Multiscale modelling using the phase-field approach
- Using Virtual Reality methods (CD-A experiment in Mont Terri)



Drying-induced shrinkage (horizontal stress)	Drying-induced shrinkage/cracking	
	Laboratory (crack phase-field)	Simplified in-situ model (ongoing)

- Linking models to data bases (borehole information system and sensor data base) -> link to EURAD MODATS
- In close collaboration with Mont Terri CD-A Team

CHALLENGES TO OVERCOME, AND NEEDS FOR THE FUTURE

- Successful deployment of digital twins will require trust in the model, trust in the data, and trust in algorithms used to update the model based on the data. Once these elements are in place, we can have confidence in the decisions made using the technology (Wright and Davidson Adv. Model. and Simul. in Eng. Sci. (2020) 7:13) => DONUT is contributing (for model and algorithms) but it is a long term R&D effort.
- Make our code interoperable/interoperability/ open source => comprehensive pooling platform/ simulation platform/collaboration platform
- Embedding multi-physics to virtual reality
- Structure a ROAD MAP on DT to fill the gap and share a common vision

THANK YOU FOR LISTENING

16/02/2022