Overview of the BioDT Project and Pollinator pDT

Volker Grimm

Tomas Martinovic (IT4I, Czech Republic)
Tuomas Rossi (CSC, Finland)
Ondrej Salamon (IT4I, Czech Republic)
Kata Sara-aho (CSC, Finland)
Jürgen Groeneveld (UFZ, Germany)

What is a Digital Twin?

- A Digital Twin is a model
- But, models are simplified representations
- Why call a model a “twin”?
- Obviously, to emphasize the high level of realism (similarity of real entity and model)

What is a Digital Twin?

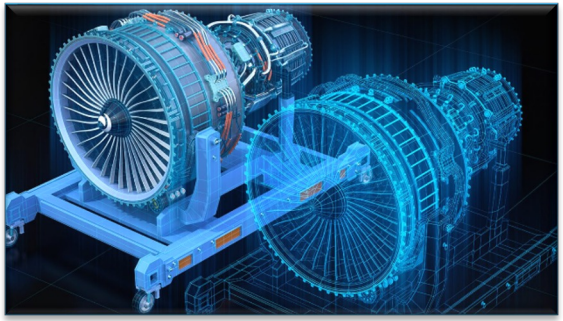
“The digital twin concept consists of three distinct parts:

- **the physical object or process and its physical environment,**
- **the digital representation of the object or process,**
- **and the communication channel between the physical and virtual representations.” (Wikipedia)**

The model (digital representation) is regularly updated with sensory data – to recalibrate and/or to account for the model’s uncertainties.

Where and why are DTs used?

- Space crafts (NASA)
- Manufacturing (e.g., assembly lines)
- Mechanical engineering (e.g., turbines)
- Construction (e.g., large buildings)
- Healthcare
- Retail (e.g., department stores)
- Logistics (supply chaines)
- Aerospace



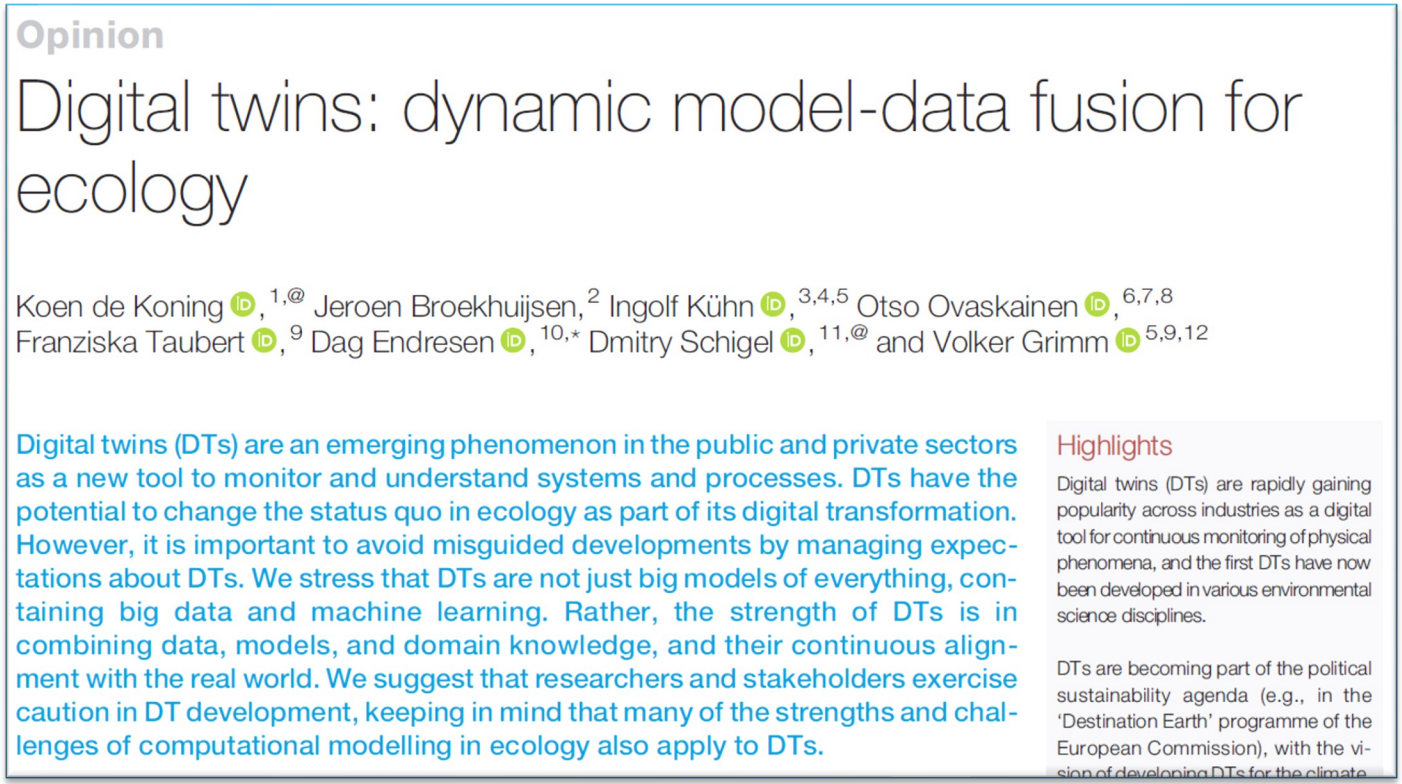
https://www.konicaminolta.eu/

https://www.esri.com/en-us/digital-twin/overview

Are Digital Twins of nature possible?

DTs of engineered systems	DTs of ecological systems
Engineered by us	„Engineered“ by nature
Full understanding of behavior of components	Limited or missing understanding
DT often developed BEFORE the physical counterpart	??
Sensors part of the DTs design, therefore comprehensive, near real-time data available	Sensors and data sparse. Data are limited, highly uncertain, and often incompatible

DTs of biodiversity: beware of wrong expectations!



Opinion

Digital twins: dynamic model-data fusion for ecology

Koen de Koning [1,@] Jeroen Broekhuijsen,[2] Ingolf Kühn [3,4,5] Otso Ovaskainen [6,7,8] Franziska Taubert [9] Dag Endresen [10,*] Dmitry Schigel [11,@] and Volker Grimm [5,9,12]

Digital twins (DTs) are an emerging phenomenon in the public and private sectors as a new tool to monitor and understand systems and processes. DTs have the potential to change the status quo in ecology as part of its digital transformation. However, it is important to avoid misguided developments by managing expectations about DTs. We stress that DTs are not just big models of everything, containing big data and machine learning. Rather, the strength of DTs is in combining data, models, and domain knowledge, and their continuous alignment with the real world. We suggest that researchers and stakeholders exercise caution in DT development, keeping in mind that many of the strengths and challenges of computational modelling in ecology also apply to DTs.

Highlights

Digital twins (DTs) are rapidly gaining popularity across industries as a digital tool for continuous monitoring of physical phenomena, and the first DTs have now been developed in various environmental science disciplines.

DTs are becoming part of the political sustainability agenda (e.g., in the 'Destination Earth' programme of the European Commission), with the vi-

Trends in Ecology & Evolution.2023, 38: 916-926.

The benefits of “digital twinning”

While fully-fledged DTs of “biodiversity” might be impossible,

- **professionally developing infrastructure and workflows for regularly updating, recalibrating, and improving models with observations,**
- **with clear applications in mind,**
- **is timely and much needed – and the reason for the EU initiative on digital twins (and Destination Earth)**

EU project BioDT

EU project BioDT

A digital twin is a virtual representation of real-world entities and processes, synchronized at a specified **frequency** and **fidelity***

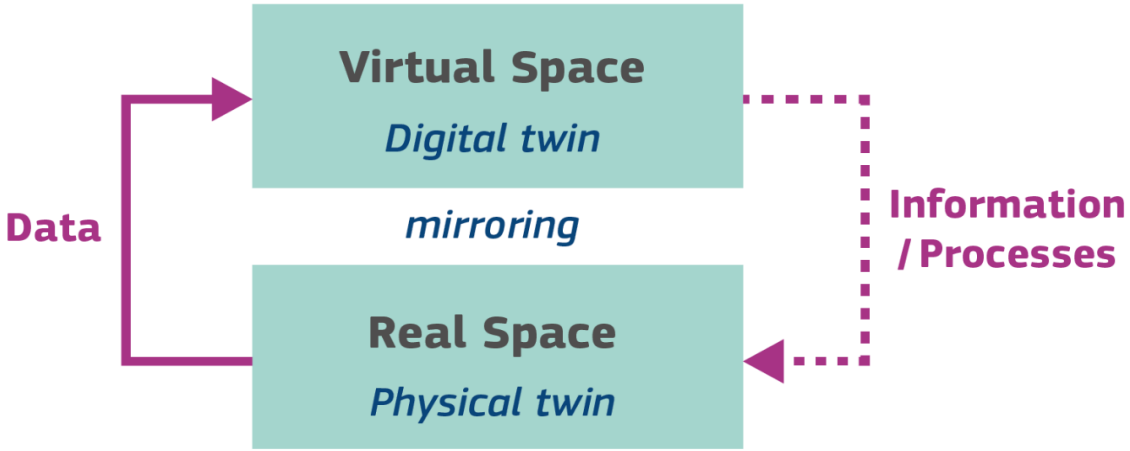


Image: digital-strategy.ec.europa.eu

**Here, fidelity refers to the level of precision captured by the DT in comparison with its physical counterpart.*

Use Cases split into four groups

Species response to environmental change

- Biodiversity dynamics
- Ecosystem services

Genetically detected biodiversity

- Crop wild relatives and genetic resources for food security
- DNA detected biodiversity, poorly known habitats

Dynamics and threats from and for species of policy concern

- Invasive species
- Endangered species

Dynamics and threats from and for species of policy concern

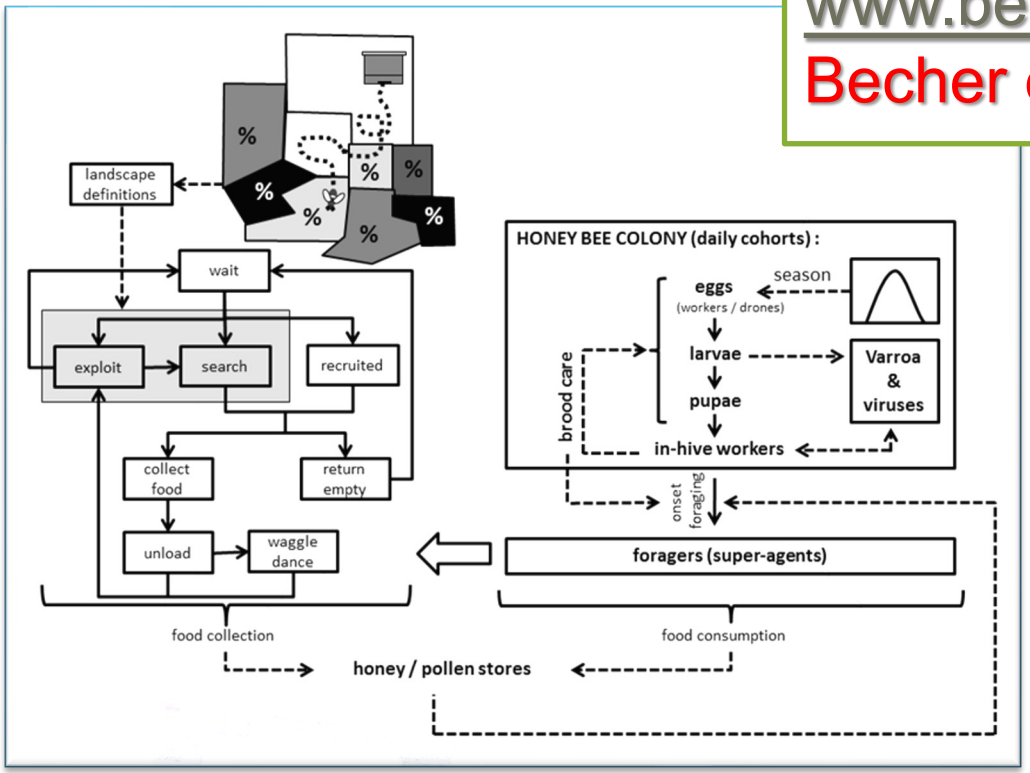
- Disease outbreaks
- Pollinators

https://www.biodt.eu/

Example: Honey bee colony model BEEHAVE

www.beehave-model.net

Becher et al. 2014



- Driven be first principles (energy, proteins – collection and consumption)
- 1 colony in 5x5 km² landscape
- Designed to explore response to multiple stressors
- Freely available
- Open software platform
- Fully documented
- Has been used since in >25 publications

Límitations of BEEHAVE → pDT Pollinator

- Spatial extent too small for providing decision support for policies for regions or nations – computing power needed
- Compilation of map of floral resources is cumbersome – workflows needed
- Validation at regional or national level – monitoring data needed
- User interface too complex – Web-based GUI needed

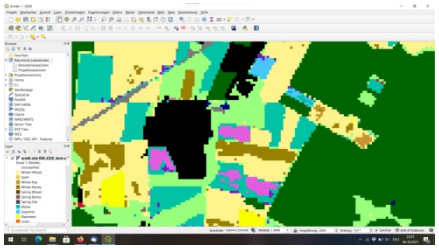
prototype Digital Twin: pDT Pollinator

Data

Weather – daily
Hive weights – daily
Land use (crops) – yearly, up to 2019

Management:
Beekeeping: Specific intervals

Land use scenarios: Cropping system and rotation, flower strips, re-establishment of semi-natural field margins and hedgerows, pesticide use



Model

BEEHAVE

Colony demography:
Daily

Foraging:
Minutes (implicit)

Output/results:
Daily; forage risk maps: static

Users

- **Beekeepers:** daily (disease and harvest management)
- **Regulators**: risk assessment of pesticides
- **Policy developers**: design cost- and biodiversity-effective EU-level subsidy schemes
- **Farmers**: Optimize cropping system to support biodiversity with minimal costs
- **General public**: High interest in the well-being of a charismatic species, that is an important pollinator

So, how far did we get in just two years?

- A highly competent and motivated team of experts with different, complementary expertise emerged
- Jürgen will speak next about the achievement of this team
- All this would not have been possible with the EU DT initiative (and funding)

Summary

- Digital Twin is a concept from engineering etc.
- Central idea: large scale application in mind, regular update of model with sensory data
- DTs of ecological systems are different – but the emerging workflows will move predictive modelling to the next level
- BioDT provides prototypes – proof of concept

Groeneveld V, Martinovic T, Rossi T, Salamon O, Sara-aho K, Grimm V. Prototype biodiversity digital twin: honey bees in agricultural landscapes. *Research Ideas and Outcomes* – to appear soon.