Digital Twins of Ecosystems

Einar Broch Johnsen[1,2]
S. Lizeth Tapia Tarifa[2]
Eduard Kamburjan[2]
Rudolf Schlatte[2]
Laura Ann Slaughter[1]

University of Oslo
[1]dScience Center for Computational and Data Science
[2]SIRIUS SFI for Scalable Data Access

Motivation: Ecosystems and Automatized Ecological Systems

Motivation: Ecosystems and Automatized Ecological Systems

- How to collect, analyze and handle data of ecosystems?
- How to connect with models?
- How to coordinate decisions?

Motivation: Ecosystems and Automatized Ecological Systems

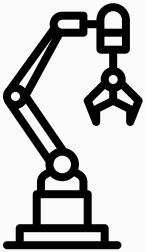
- How to collect, analyze and handle data of ecosystems?
- How to connect with models?
- How to coordinate decisions?

Motivation: Ecosystems and Automatized Ecological Systems

- How to collect, analyze and handle data of ecosystems?
- How to connect with models?
- How to coordinate decisions?

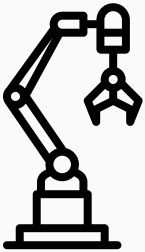
- How to collect, analyze and handle data of automatized ecological systems?
- How to automatically decide on actions?
- How to use models to explore decisions using real-time data?

PT

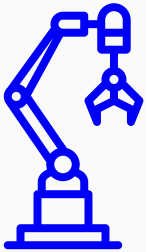


What is a Digital Twin?

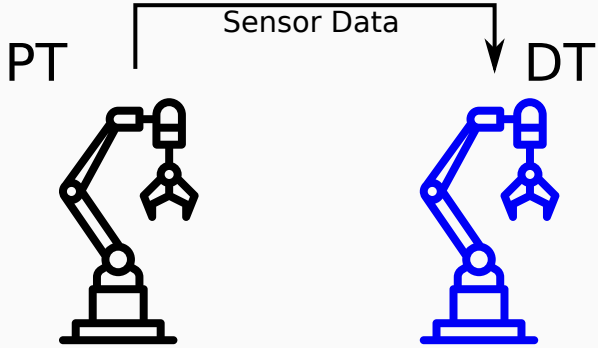
PT



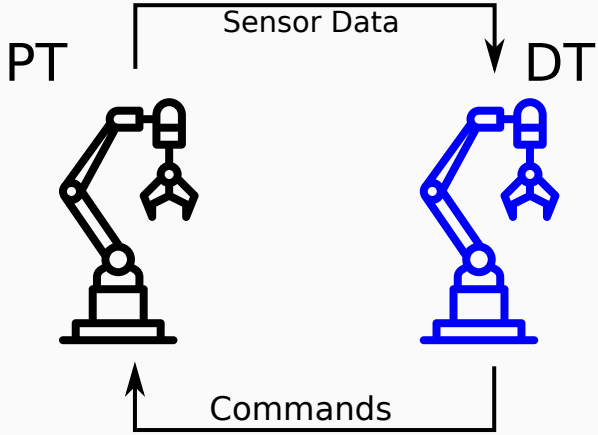
DT



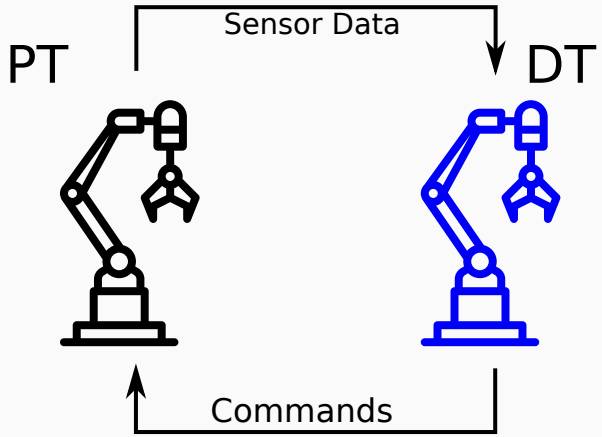
What is a Digital Twin?



What is a Digital Twin?

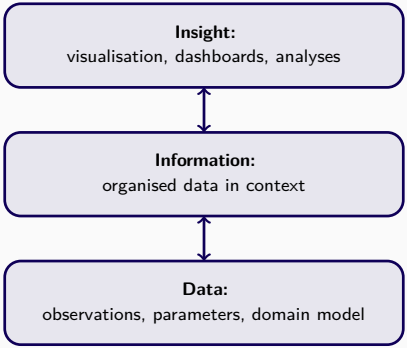


What is a Digital Twin?

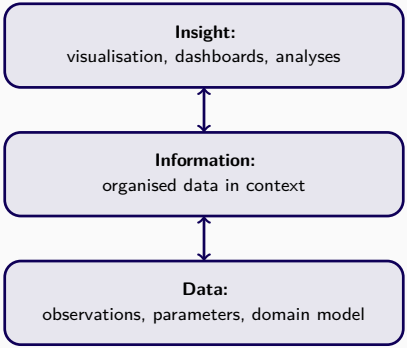


- A DT is a live replicate of a physical system, connected in near real-time.
- PT may be a *(partially) natural* system!

Digital Twins: Enabled Analyses

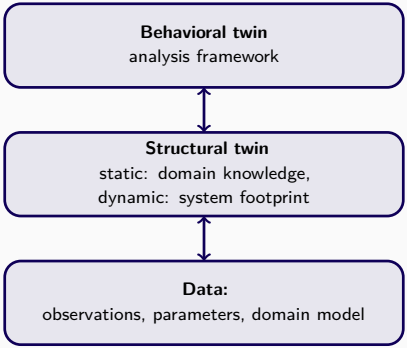


Digital Twins: Enabled Analyses



- **Descriptive:** Insight into the past ("what happened" scenarios)
- **Predictive:** Understanding the future ("what may happen" scenarios)
- **Prescriptive:** Advise on possible outcomes ("what if" scenarios)
- **Reactive:** Automated decision making

Digital Twins: Enabled Analyses



- **Descriptive:** Insight into the past ("what happened" scenarios)
- **Predictive:** Understanding the future ("what may happen" scenarios)
- **Prescriptive:** Advise on possible outcomes ("what if" scenarios)
- **Reactive:** Automated decision making

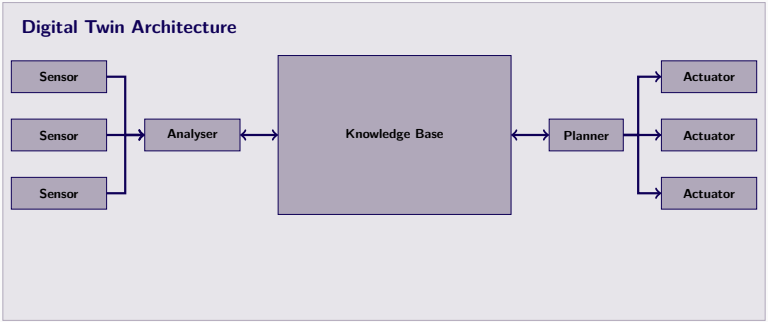
Digital Twins for Ecosystems: Commonalities

UNIVERSITY OF OSLO

From Conceptual Layers to Software Architecture

- **Data layer:** Event monitoring framework
- **Information layer:** static domain knowledge, asset model, dynamic footprint(s) from monitoring the twinned system
- **Insight layer:** UI, decision making, model-based predictions

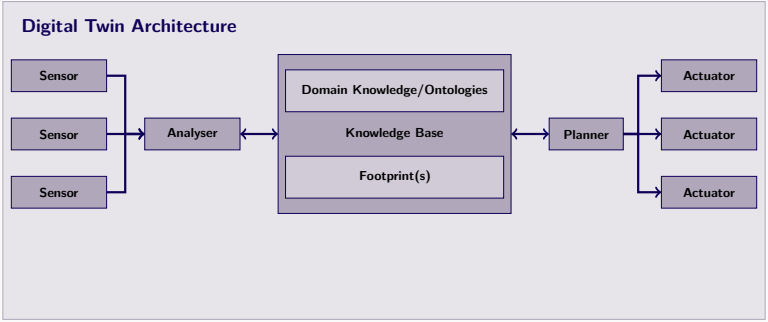
Digital Twins for Ecosystems: Commonalities



From Conceptual Layers to Software Architecture

- **Data layer:** Event monitoring framework
- **Information layer:** static domain knowledge, asset model, dynamic footprint(s) from monitoring the twinned system
- **Insight layer:** UI, decision making, model-based predictions

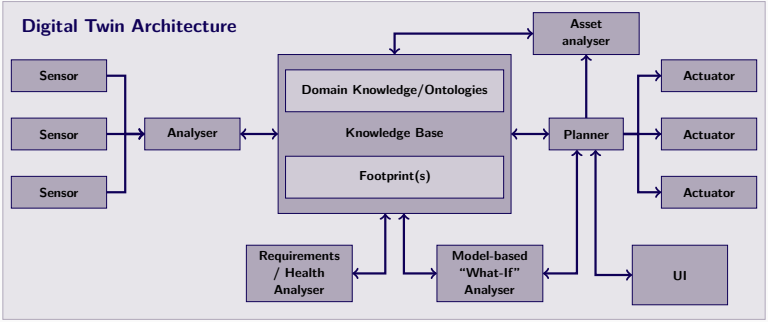
Digital Twins for Ecosystems: Commonalities



From Conceptual Layers to Software Architecture

- **Data layer:** Event monitoring framework
- **Information layer:** static domain knowledge, asset model, dynamic footprint(s) from monitoring the twinned system
- **Insight layer:** UI, decision making, model-based predictions

Digital Twins for Ecosystems: Commonalities



From Conceptual Layers to Software Architecture

- **Data layer:** Event monitoring framework
- **Information layer:** static domain knowledge, asset model, dynamic footprint(s) from monitoring the twinned system
- **Insight layer:** UI, decision making, model-based predictions

From Twinned Plant to Twinned Greenhouse

1. **Information Level:** greenhouse asset model, plant knowledge
2. **Sensors:** humidity, light, temperature,...
   Actuators: water pumps, lamps, ...
3. **Insight level:** control system to optimise plant health & growth

Plant Life Cycle & Health Analysis

UNIVERSITY OF OSLO

Life Cycle of the Asset

- Design stage of greenhouse
- Maintenance, extensions, ...
- Decommissioning

Plant Health & Life Cycle Analyses

- Use image analysis to "understand" the plant
- Can we determine the stage of the plant in the plant life cycle?
- Measure the healthiness of the plant with NDVI

Plant Life Cycle & Health Analysis

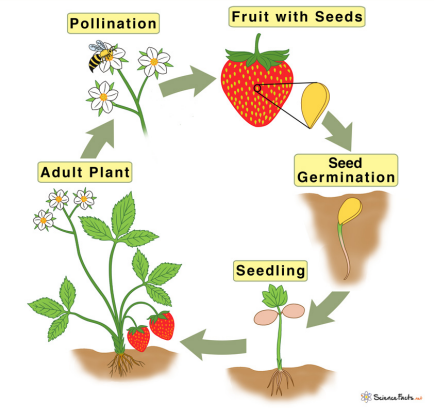
UNIVERSITY OF OSLO

Life Cycle of the Asset

- Design stage of greenhouse
- Maintenance, extensions, ...
- Decommissioning

Plant Health & Life Cycle Analyses

- Use image analysis to "understand" the plant
- Can we determine the stage of the plant in the plant life cycle?
- Measure the healthiness of the plant with NDVI



Plant Life Cycle & Health Analysis

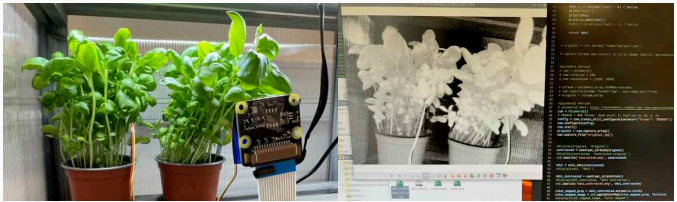
UNIVERSITY OF OSLO

Life Cycle of the Asset

- Design stage of greenhouse
- Maintenance, extensions, ...
- Decommissioning

Plant Health & Life Cycle Analyses

- Use image analysis to "understand" the plant
- Can we determine the stage of the plant in the plant life cycle?
- Measure the healthiness of the plant with NDVI



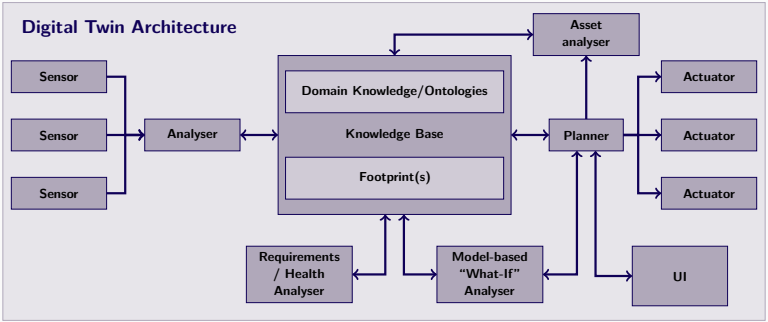
Digital Twins for Ecosystems: Commonalities

UNIVERSITY OF OSLO

From Conceptual Layers to Software Architecture

- **Data layer:** Event monitoring framework
- **Information layer:** static domain knowledge, asset model, dynamic footprint(s) from monitoring the twinned system
- **Insight layer:** UI, decision making, model-based predictions

Digital Twins for Ecosystems: Commonalities



From Conceptual Layers to Software Architecture

- **Data layer:** Event monitoring framework
- **Information layer:** static domain knowledge, asset model, dynamic footprint(s) from monitoring the twinned system
- **Insight layer:** UI, decision making, model-based predictions

Climate Barometer for the Oslo Fjord

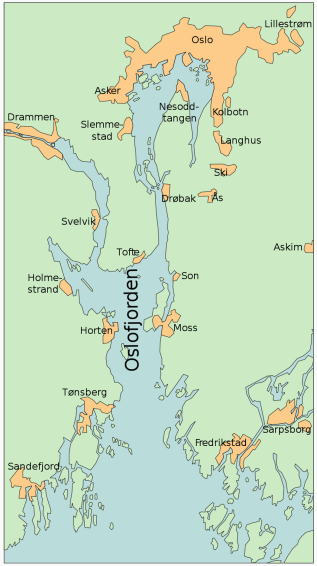
UNIVERSITY OF OSLO

Healthy Oslo Fjord

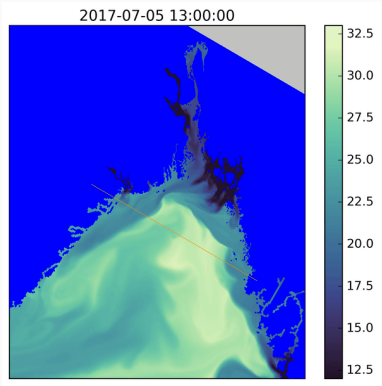
Data collection project to instrument the fjord with sensors, by combined public and industrial consortium

Instruments on the lander

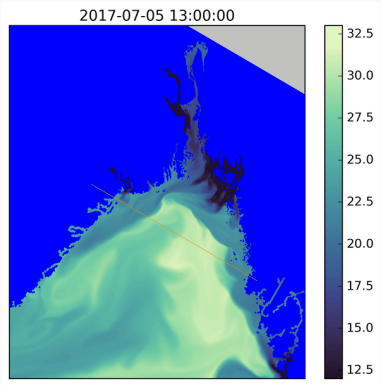
- EK80 WBT echosounder (Kongsberg Maritime)
- Hydrophone
- Camera
- Light unit
- CTD (salinity, pressure, turbidity, temperature)



Twinning Effects of Climate Change on Physical Processes

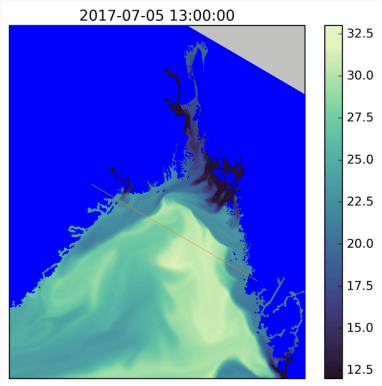


Twinning Effects of Climate Change on Physical Processes



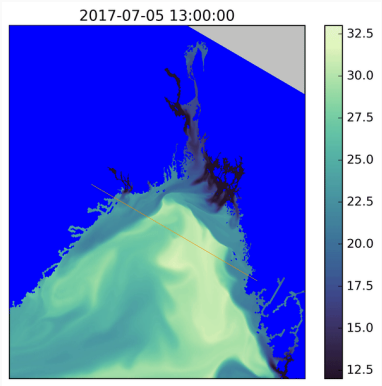
What is the effect of extreme weather on fjord circulation?

Twinning Effects of Climate Change on Physical Processes



What is the effect of extreme weather on fjord circulation?

Twinning Effects of Climate Change on Physical Processes



What is the effect of extreme weather on fjord circulation?

Twinning Physical Processes

- Data from custom sensors
- Use data to compose (low-res) circulation models with (high-res) hydro-dynamical models

UNIVERSITY OF OSLO

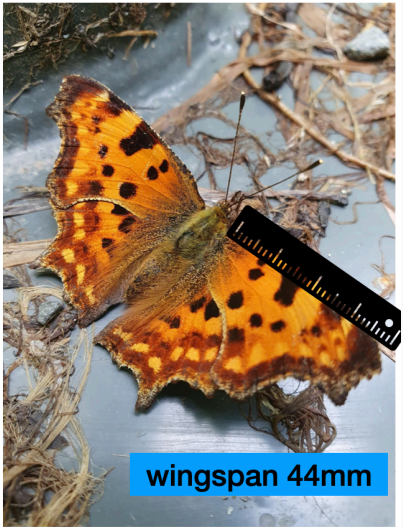
DTs for Autonomous Underwater Robots

1. **Information level:**
   Sensor data & domain knowledge
2. **Insight level:**
   On-the-fly mission planning
3. **Safety + reliability** between information and insight levels

REMARO
RELIABLE AI FOR MARINE ROBOTICS

MSCA

Further Projects: Robotics and Biodiversity



Opphav Tiril Myhre Pedersen
Lisens CC BY 4.0

TraitBank modeling for Artsdatabanken

1. Representations of traits and modeling trait knowledge
2. Ontology integrating data coming from habitat codes, red list data, ...
3. Created a trait-entry system maintainable by domain experts
4. On-going: populating useful interaction data for digital twins
5. Automatically assessing quality of incoming observations from citizens

ARTSDATABANKEN

Conclusion

UNIVERSITY OF OSLO

Our Mission

Methodology, design, maintenance, architectures and tools for **Digital Twins for ecological systems**.

Engineering Digital Twins in Life Sciences

- Common challenges, technologies and architectures between different digital twins
- Projects and demonstrators across several sciences: biodiversity, robotics, oceanology, ...

We are looking for collaborators and use cases in smart agriculture.

contacts: einarj@uio.no
eduard@uio.no
l.a.slaughter@dscience.uio.no