# DEVELOPING A PHYSICAL AND DIGITAL TWIN: AN EXAMPLE PROCESS MODEL

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## **OVERVIEW**

- An example process model of developing a physical and digital twin
- The end product: Incubator and its Digital Twin.



- Development process and the process model.
  - Early Modelling Stage
  - Prototyping and assumption checking
  - Plant and controller modeling
  - Real-time co-simulation
  - Digital Twin component development





#### INCUBATOR

Plant







#### INCUBATOR

Controller



### **DIGITAL TWIN**



Temperature Sensor

#### Visualization Temperature Information

#### **Controller Information**



#### **DIGITAL TWIN**





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#### **DIGITAL TWIN**

**Anomaly Detection**  $\left[ \widehat{B}_{k} \right]$ State Estimation Visualization  $\left[\widehat{T}_{k}\right]$ Plant Incubator Temperature 555 — avg\_T Room:  $R_k = 19^{\circ}C$  $\widehat{T}_k$ ----- heater\_on avg\_temp(4pModel) Communica Styrofoam Id Onened  $B_k = 80^{\circ}\text{C}$ tion Server ---- room T\_heater(4pMode Ħ — T\_heater(Kalman)  $T_k = 25^{\circ} C$ **Anomaly Detection** Room Temperature Controller :1.4  $H_{k} = 1$ 









DEPARTMENT OF ELECTRICAL AND COMPUTER

ENGINEERING

- 0DModeling:
  - Sketched the algebraic equations
  - Guess parameters
- CheckEnoughPower:
  - 400 J, from 25 °C to 35 °C
  - A power supply of 100W could provide the energy in about 4s.



#### Prototyping and Assumption Checking



ENGINEERING

- Assumption Checking:
  - To check how fast the obtained power supply could warm up the air inside the box
  - How uniform the temperature inside the box was
  - How fast temperatures could be read
    from the temperature sensors
- Optimization







- It is now used as "baseline" integration test, to try out new DT components, and ensure that existing ones are working correctly
- Setup Timeseries Frameworks
  - Data gathering with InfluxDB, and RabbitMQ
  - validated with the creation of a basic DT component: a KF.
- Controller Implementation and Deployment
  - A plant emulator was created to mimic sensors and respond to actuation signals.
  - Multiple failures modes for the controller can be identified



#### **Digital Twin Component Development**



ENGINEERING

- Thanks to the **real-time co-simulation** infrastructure developed earlier and thanks to the **virtualization technology** provided by Docker, we enabled continuous integration of DT services.
- This also greatly enhanced safety.
- Remote collaboration is made possible



#### SUMMARY

- Demonstration the end product of the incubator system and its DT development.
- presented the development process model of the incubator and its DT, including the development of models, controller, co-simulation, and DT component development from its beginning stage





