Alessandra Somma

Digital Twin Space (DTS): integration of Digital Twin and Data Spaces

Tutor: Prof. Alessandra De Benedictis

Cycle: XXXVII Year: Second

My background

- MSc degree: Computer Engineering
- Research group/laboratory: SECLAB
- PhD start date: November 1st 2021
- Scholarship type: UNINA

Summary of study activities

- **Ad hoc PhD courses / schools**
  - "IoT Data Analysis", Dr. Raffaele Della Corte, January 2023.
  - "Semantic Artifacts and Multimedia Knowledge Graphs for bio-data integration ", Dr. Cristiano Russo, September-October 2023.

- **Conferences / events attended**
  - Training campus on "FIWARE" technologies, University of Naples Parthenope, June 5th – 9th 2023.
  - First plenary "DYNABIC" meeting in Barcelona held by BEWARE, June 18th-20th 2023.
  - *The 2023 IEEE International Conference on Digital Twin* held in the IEEE Smart World Congress, August 28th – 31st 2023, University of Portsmouth where I presented my work "A Cyber Digital Twin Framework to Support Cyber-Physical Systems Security".

Research field of interest

My research field concerns Software Architecture (SA) aspects of **Digital Twin** (DT), namely a virtual replica of a physical asset/process used for optimization, monitoring, prediction purposes.

still so many, domain-related definitions (currently ~ 45)
- great interests of the communities defining the term
- no common understanding of DT concept

lack of architectural models for DT design and development
- only one framework standard (ISO-23247)
- majority of proposal are domain-related

- few solutions, not always accessible
- delay in the widespread DT implementation and adoption

DT architectural models' issue

According to the state-of-the-art analysis of the architecture proposals for DTs that I conducted [P1], the complexity of software-intensive systems is addressed by different *layered architectural models*:

three layers – physical; digital; connectivity

four layers – physical; digital; connectivity; application

five/six layers – some extensions of the previous one

DT architectural models' issue

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three layers – physical; digital; connectivity

The proposed architectural solutions:

- confuse Digital Twins with mere **static models → no closed-loop connection between digital and physical worlds**
- are mainly **domain-dependent → limitations to the applicability**

five/six layers – some extensions of the previous one

Methodological approach

1. In-depth **analysis of state-of-the-art** DT definitions, requirements, framework proposals, applications and security issues;

2. Design of a **domain-independent software architecture** for DT implementation;

3. **Validation** of the whole proposal by example.

Methodological iterative approach

1. In-depth **analysis of state-of-the-art** DT definitions, requirements, framework proposals, applications and security issues;

2. Design of a **domain-independent software architecture** for DT implementation;

3. **Validation** of the whole proposal by examples.

the concept of Digital Twin is subject to an *increasing volume of literature*

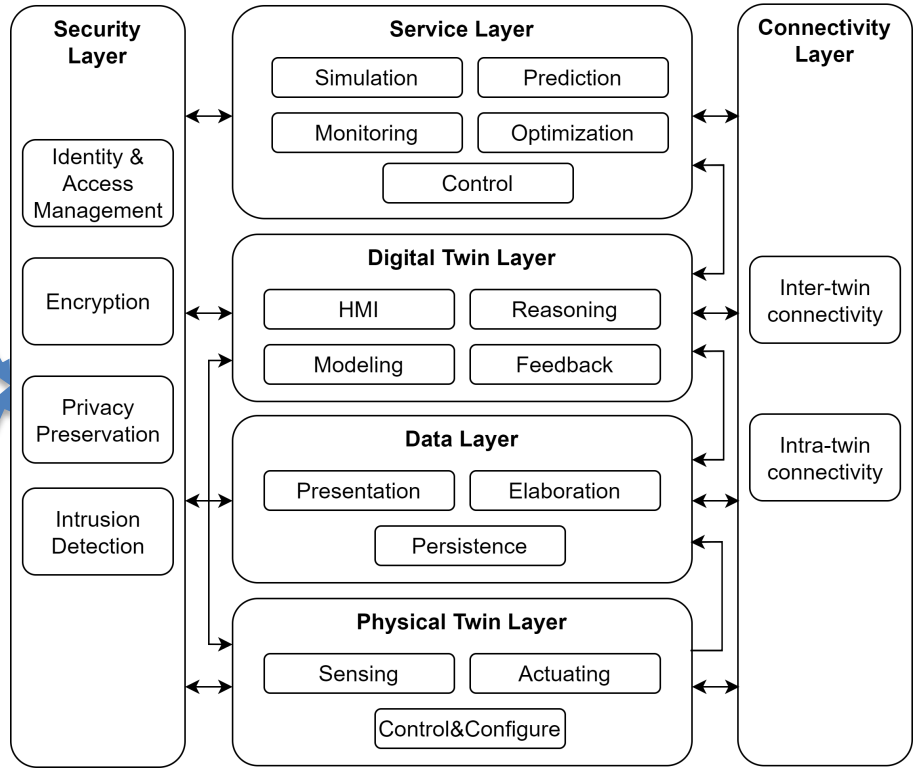
First high-level DT architectural model

Digital Twin **definitions**

"a **live digital coupling** of the **state** of a physical asset or process to a **virtual representation** with a **functional output**"

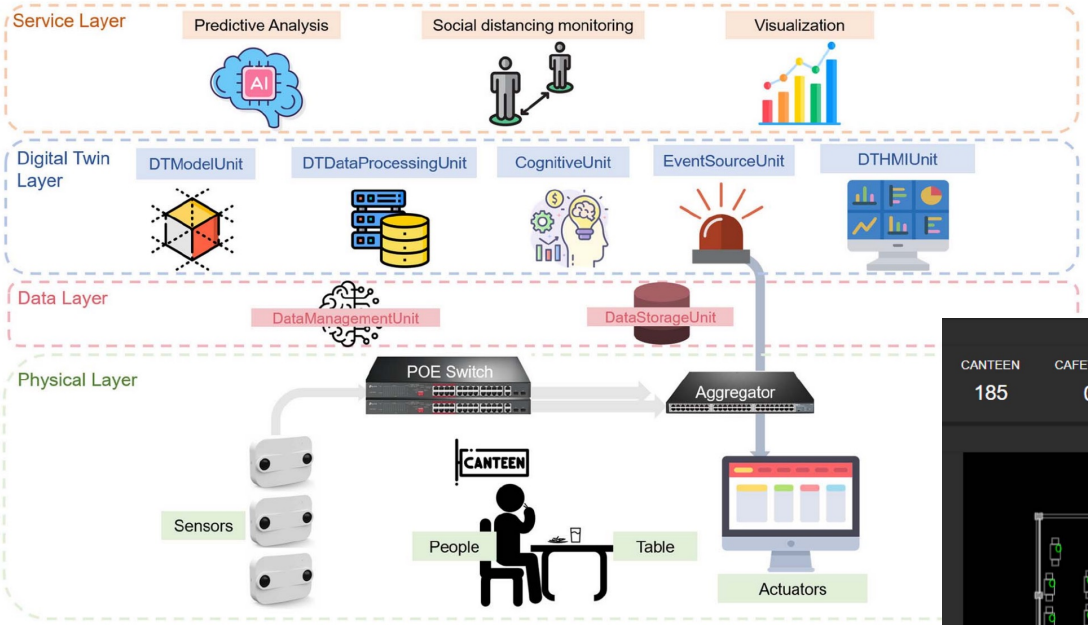
Digital Twin **requirements**

1. Virtual representation
2. State twinning
3. Liveness
4. Digital coupling
5. Functional output



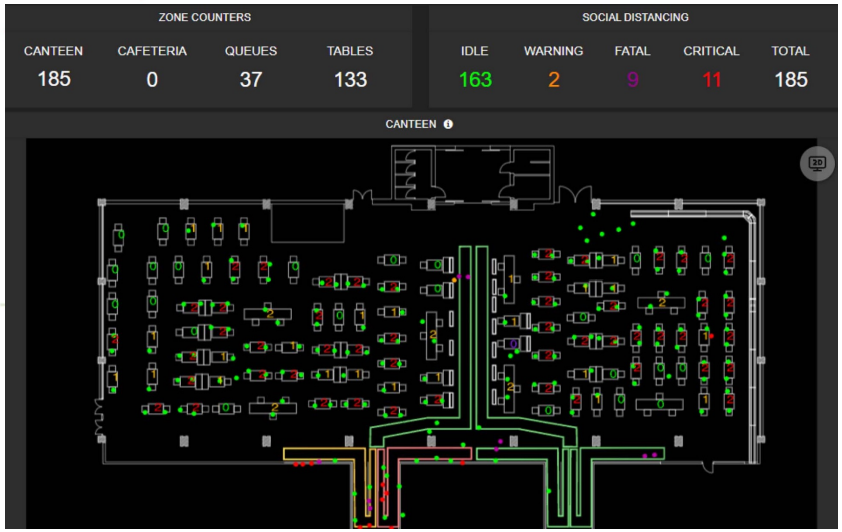
First high-level DT architectural model validation by example (1)

CanTwin: application of the proposed architectural model to *a real-life industrial case study* powered by *Hitachi Rail*.



Case study architecture.

Case study HMI.

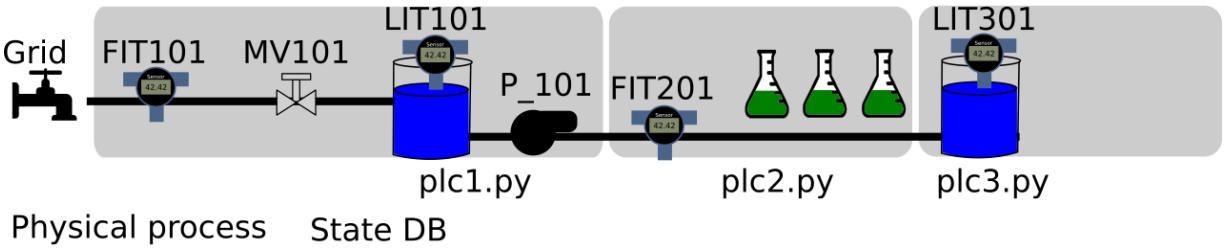


First high-level DT architectural model validation by example (2) – period abroad

Cyber Digital Twin: application of the proposed architectural model for a specific *DT service* → enhancement of CPSs cybersecurity.

Six months period abroad at **Montimage EURL** (Paris) in **DYNABIC European project:**

1. state-of-the-art analysis to understand what is a Cyber Digital Twin and what are its use-cases;
2. classification of CDT usage according to security objectives;
3. proved applicability of the proposal through a PoC leveraging on **MiniCPS**, security-oriented simulator.



Industrial filling plant simulated through MiniCPS

Collaborations

Deliverable D2.1 "DYNABIC Framework Use cases, Requirements and Architecture" in European Union's Horizon Europe research and innovation program under grant agreement No. 101070455 (DYNABIC).

Deliverables of MUR-PNRR High-Performance Computing, Big Data e Quantum Computing Research Centre (CN_00000013) – Spoke 9 (WP2 and WP8)

DT architectural model: what about data?

1. **Data Security**
   - investigation of DLTs usage to secure data used by DT when both in transit or at rest and ensure data trustworthiness.
     - SLR on the adoption of DLTs in DTs systems;
     - Extension of DT architectural model + validation with *MiniCPS* and *Eclipse Ditto*.

2. **Data Space**
   - umbrella term for data sharing approaches
   - enable the access to and privacy-compliant data usage
   - starting to integrate *International Data Space* (IDS) reference architecture into DT architectural model

DT architectural model:
future work

METHODOLOGICAL	TECHNOLOGICAL	EXPERIMENTAL
Re-apply the iterative methodology to ***refine*** the first proposed model.	Develop a ***comprehensive platform*** for DT implementation.	Application and evaluation of the proposal on PNRR case studies.
Digital Twin Space	**FIWARE 4 Digital Twin**	**Urban Digital Twins**

Products

[J1]	De Benedictis, A., Flammini, F., Mazzocca, N., ***Somma, A.***, Vitale, F., "A Digital Twin Architecture for Anomaly Detection in the Industrial Internet of Things", ***IEEE Transactions on Industrial Informatics***, published.
[J2]	De Donato, L., Dirnfeld, R., ***Somma, A.,*** De Benedictis, A., Flammini, F., Marrone, S., Saman Azari, M., Vittorini, V., "Towards AI-Assisted Digital Twins for Smart Railways: Preliminary Guideline and Reference Architecture", ***Journal of Reliable Intelligent Environments****,* published.
[J3]	De Donato, L., Dirnfeld, R., ***Somma, A.,*** Flammini, F., Marrone, S., Saman Azari, M., Vittorini, V., "Integrating AI and DTs: Challenges and Opportunities in Railway Maintenance Application and Beyond", ***Journal of Simulation: Transactions of the Society for Modeling and Simulation International****,* accepted.
[J4]	***Somma, A.***, De Benedictis, A., Esposito, C., Mazzocca, N. "The convergence of Digital Twins and Distributed Ledger Technologies: A systematic literature review and an architectural proposal", ***Journal of Computer Network Applications***, under 1st stage of review.
[J5]	***Somma, A***., De Benedictis, A., Urciuolo, F., Mazzocca, N., Netti, P., "Digital Twins applied to bioengineering: tissue-on-chips", to be submitted.
[C1]	***Somma, A.***, Casola, V., Cavalli, A. R., De Benedictis, A., Mallouli, W., Valdés, V. E., "A Cyber Digital Twin Framework to Support Cyber-Physical Systems Security", ***IEEE 2023 Smart World Congress****,* published.
[C2]	***Somma, A.,*** De Benedictis A., Longo, A., Martella, A., Martella, C., "Digital Twin Space: integration of Digital Twin and Data Space concepts", ***2023 IEEE International Conference on Big Data****,* to be submitted.

Thank you for your attention!

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