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## ► To cite this version:

Miriam Zawadi Muchika, Pauline Folz, Fano Ramparany, Flavien Balbo, Shenle Pan. Combining Multi-Agent System and Knowledge Graph to Address the Resolution of Decentralized Problems following Digital Twins approach in Open Cyber-Physical System. IMT Seminar “ Data Analytics & Artificial Intelligence ”, Nov 2023, Nantes, France. emse-04291927

**HAL Id: emse-04291927**

**<https://hal-emse.ccsd.cnrs.fr/emse-04291927>**

Submitted on 17 Nov 2023

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# Combining Multi-Agent System and Knowledge Graph to Address the Resolution of Decentralized Problems following Digital Twins approach in Open Cyber-Physical System



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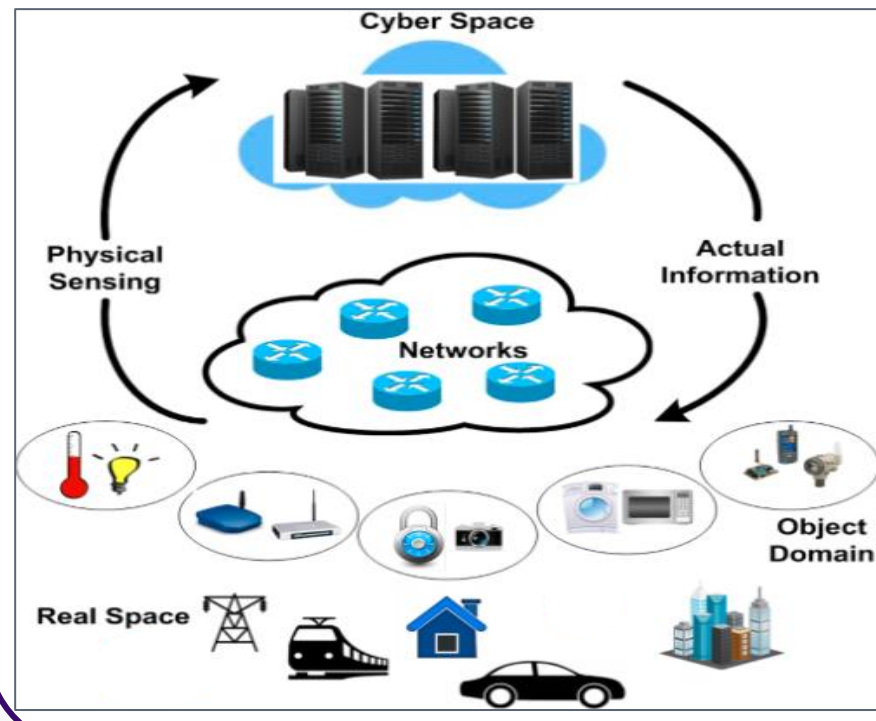
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## I. Context

**Cyber-Physical System (CPS):** system in which computing devices work together to control and command physical entities in a feedback loop.

Figure 1. Cyber-Physical System [1]



Use case – **Urban logistics** (Last miles deliveries)

Open CPS allows:

- Optimizing delivery route
- Ensuring ponctual delivery schedule
- Handling unexpected events on-the-fly
- **Decentralising decision-making**
- Involving multiple stakeholders

## II. Research Problem

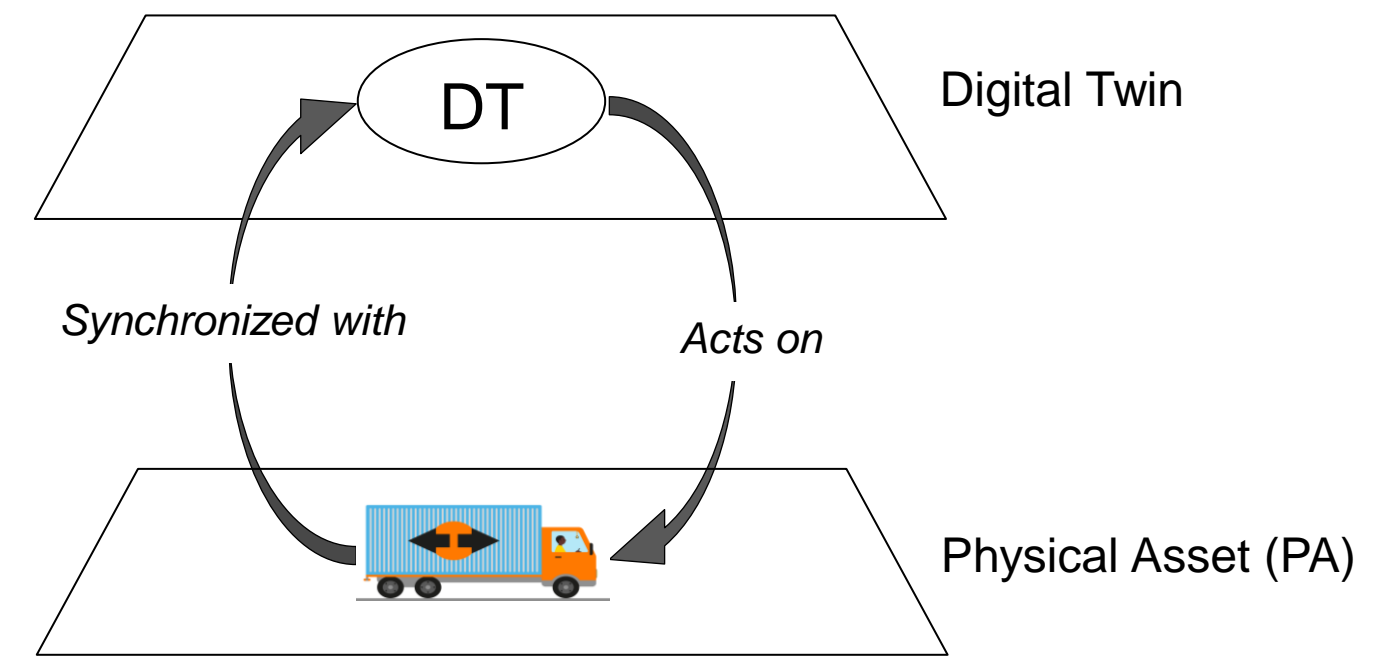
**How to address resolution of decentralized problems in open Cyber-Physical System?**

Resolving decentralized problems involves multiple independent entities that collaborate to achieve a common goal or address a common issue without central control.

## III. State of the art

**Multi-Agent System (MAS)** simulates the physical assets (PA) and makes decisions (eg. in Healthcare4.0, Smart City, Smart Grids), but physical assets cannot be directly modified by agents.

**Digital Twin (DT)** connects the physical and digital worlds [2,3]



In [2,3] agents are responsible for achieving the application's goals by using DTs to access and control the physical world.

However, [2,3] fails to consider the autonomy of the physical world and decision are taken at applications layer.

**How can DTs coordinate to make autonomous decisions, monitor, control, and act upon their physical counterparts?**

## IV. Proposed Solution

### Hypothesis

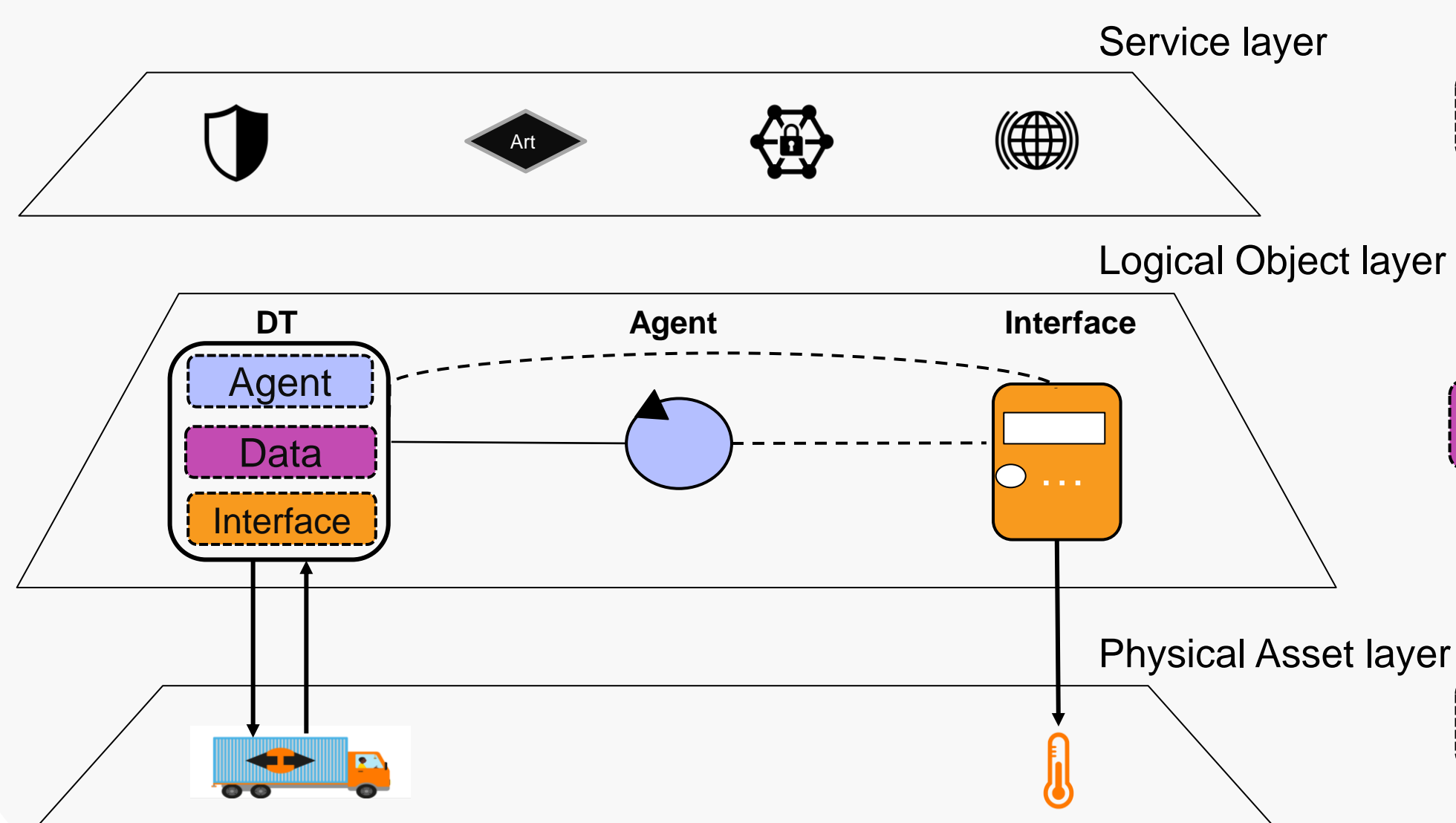
DT is:

- atomic ;
- autonomous ;
- collaborating with other DTs in the system.

### Requirements:

- Distributed autonomous decision-making in the Logical Object layer by DTs and agents
- DT takes actions to change physical assets
- Effective communication and coordination among DTs and agents in the Logical Object layer
- Semantic modelling of the physical world

### Proposed Architecture



**Agent** → Autonomous entity: communication (coordination, negotiation, argumentation), autonomous decision (operational- tactical-strategic planification, simulation, analytics, prediction, control)

**Data** → System knowledge with real-time updates: knowledge graph (current state of the PA - representations, PA model, historization), behavior model

**Interface** → Interface between the digital twin and its physical counterpart (used to change the state of the physical asset): synchronization, monitoring, operations

## References

- [1] [https://www.researchgate.net/figure/Examples-of-cyber-physical-systems\\_fig1\\_346986587](https://www.researchgate.net/figure/Examples-of-cyber-physical-systems_fig1_346986587)
- [2] About Digital Twins, agents, and multiagent systems: a cross-fertilisation journey by Stefano Mariani, Marco Picone, Alessandro Ricci (2022)
- [3] Web of digital twins. *ACM Transactions on Internet Technology*, Ricci, A., Croatti, A., Mariani, S., Montagna, S., & Picone, M. (2022). 22(4), 1-30.

## V. Conclusion & Perspectives

The proposed architecture enables the digital twins to operate autonomously within the Logical Object layer and modify the state of the corresponding physical assets, thus promoting real-time adaptation and optimization.

### Perspectives

- Integration of behavior models in the architecture
- Manage decision conflicts between the digital and physical world