Cyber Physical System and Digital Twin

A brief introduction

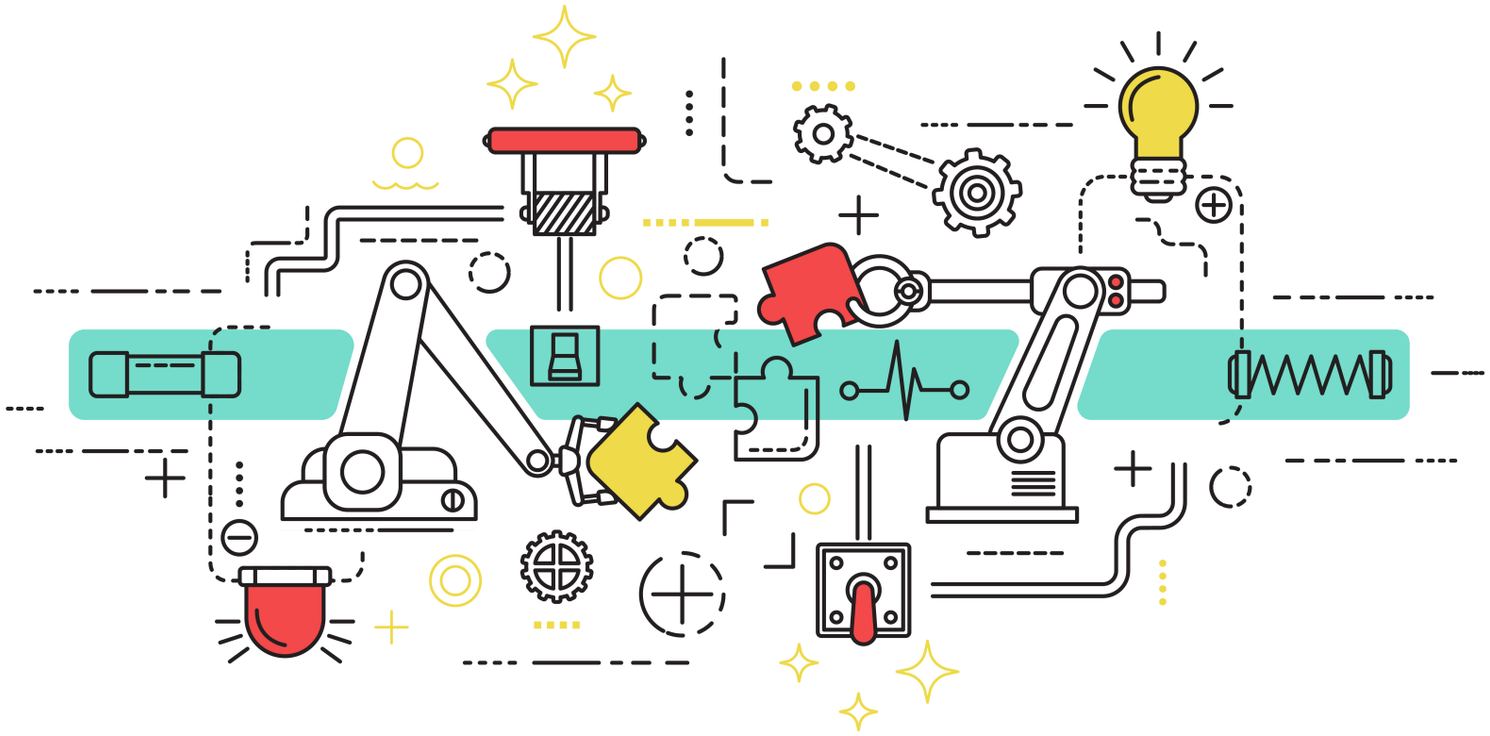
MSc. Tran Quang Khai. September 2021.

Information in this presentation is extracted from “Chapter 12 - Digital Twin, Cyber–Physical System, and Internet of Things” in “Digital Twin Driven Smart Manufacturing, 2019”, Pages 243-256.

What are Cyber Physical Systems?

“Cyber physical system (CPS) embeds computing, communication, and control capabilities into physical devices [...] to monitor, control, and coordinate the corresponding physical activities”

J. Shi, J. Wan, H. Yan, H. Suo

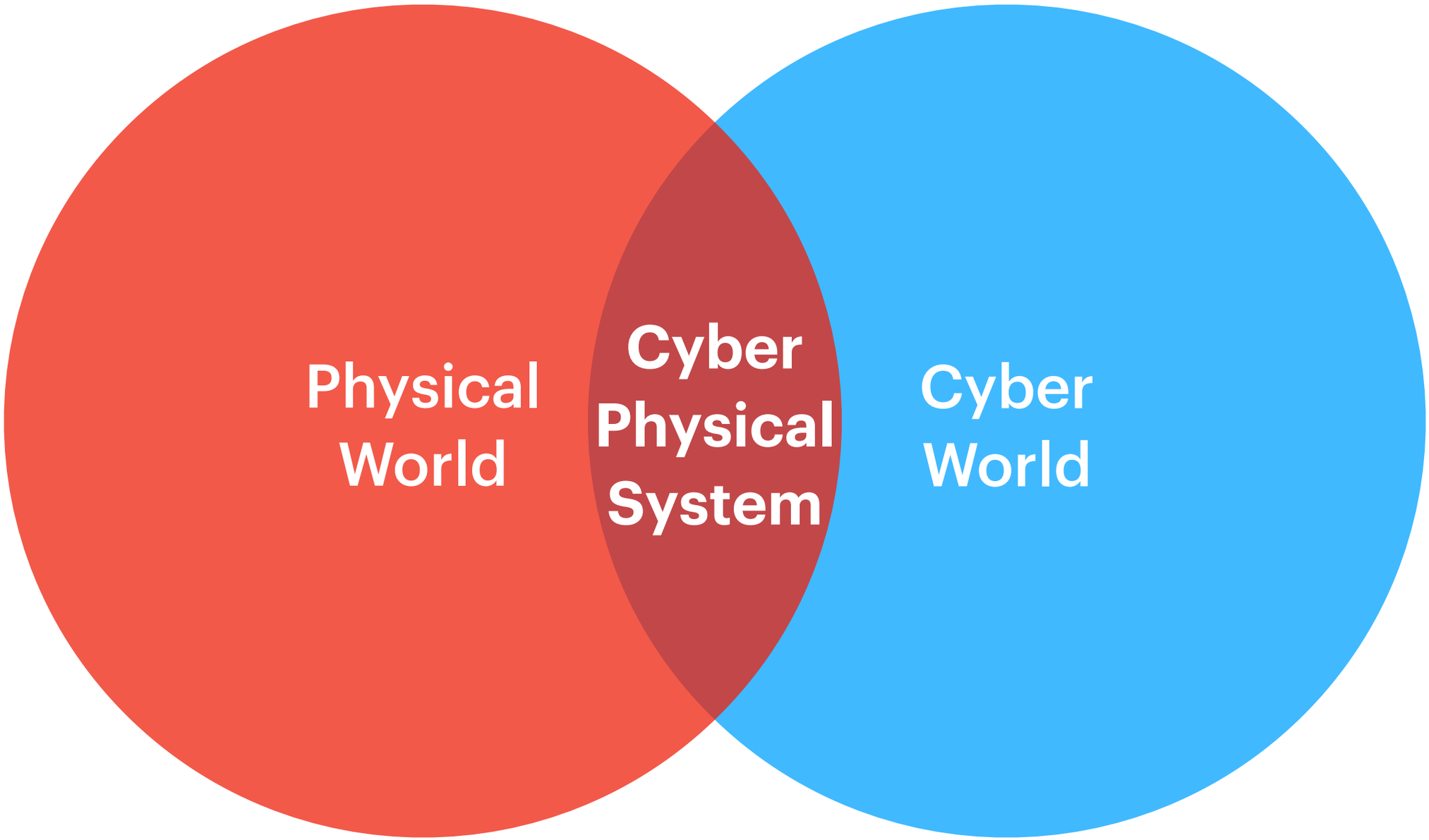


“In CPS, the physical world includes physical objects that need to be controlled, while cyber systems conduct data analysis and decision making”

V. Gunes, S. Peter, T. Givargis, F. Vahid

Mathematical Illustration

Where is the Cyber Physical System?



CPS is about the intersection, not the union

Interaction between the two worlds

- To realize the interaction, data from the physical objects can be collected using sensors in real time and transmitted to the cyber systems for processing and analysis, while real-time orders will be fed back to the actuators to regulate operations of the physical objects.
- CPS forms a closed loop between the physical world and cyber world, aiming at integrating the two words seamlessly.

Application of CPS in manufacturing

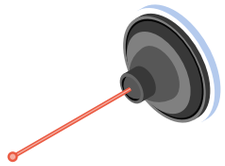
- Setty et al. proposed a unified framework to design and deploy a CPS-based manufacturing system composed of networked embedded controllers and mechatronic devices, which provides a smart automation solution for production.

Conceptual Design

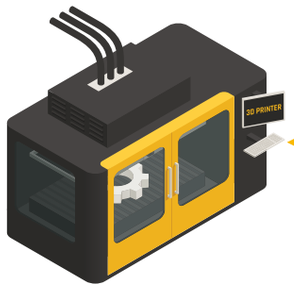
How do we describe a simple CPS?

Physical World

Robots



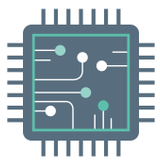
Sensors



CNC Machines

RFIDs

AGVs



Embedded systems

Data

Control Orders

Cyber World

Data Management

Real states

Knowledge

Fused data

Simulated data

Data

Services

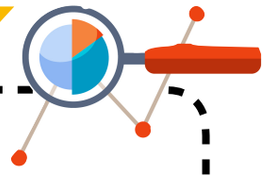
Diagnosis Service

Energy Service

Monitoring Service

Calibration Service

Data Analysis



Machine Learning

Principal Component Analysis

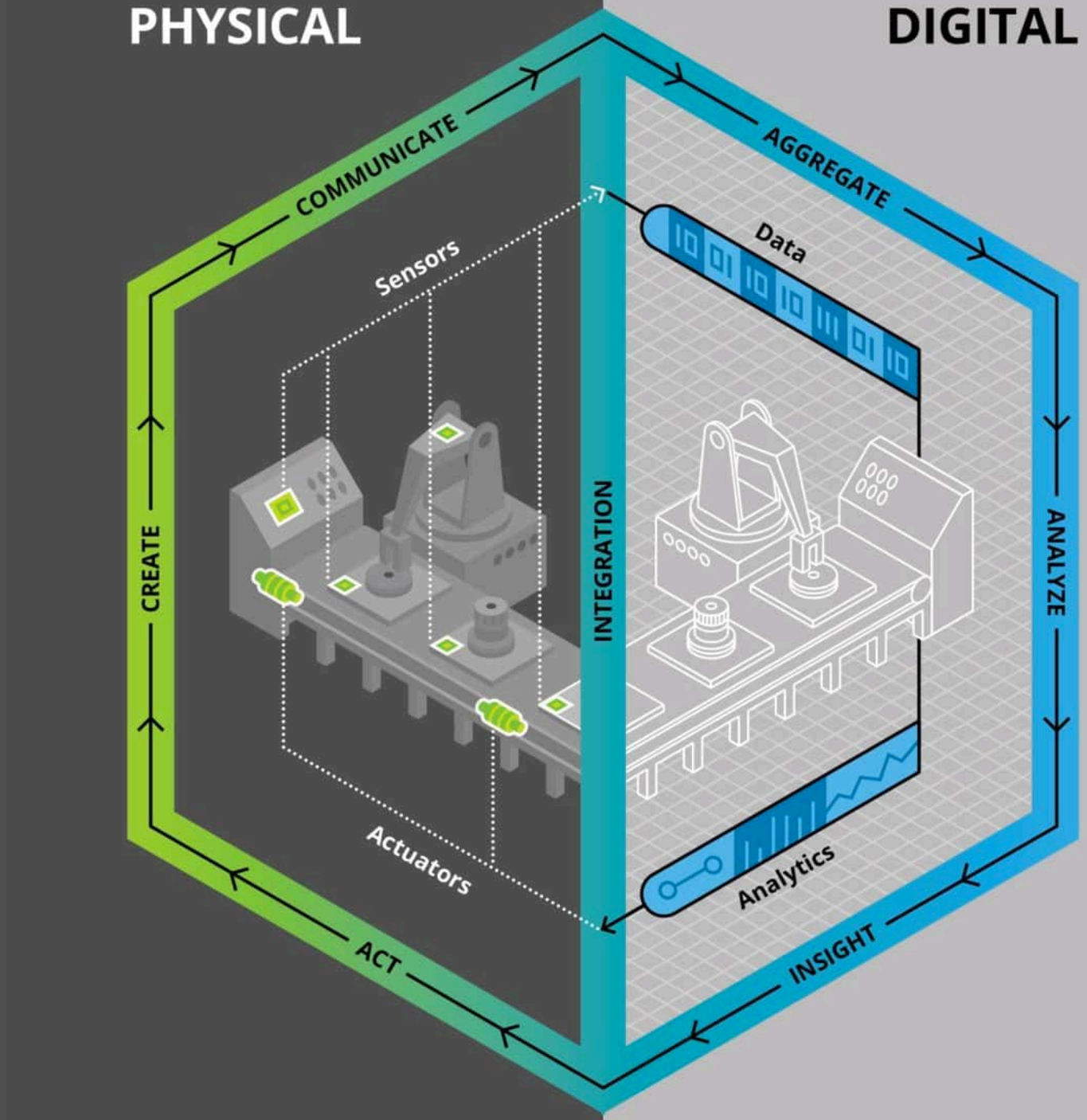
Statistics

Decision Making

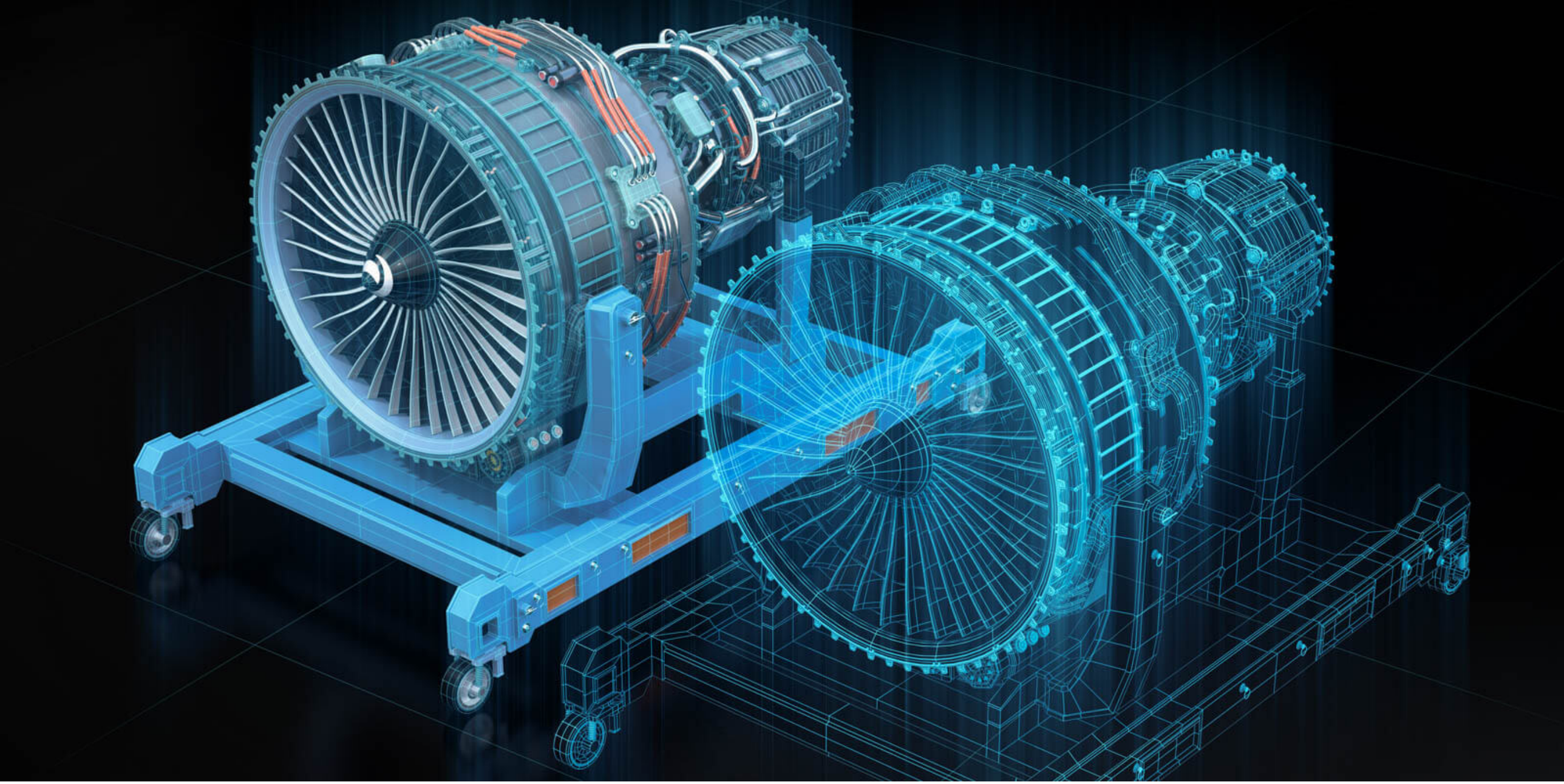
Process Control

Scheduling

Maintenance



Digital Twin



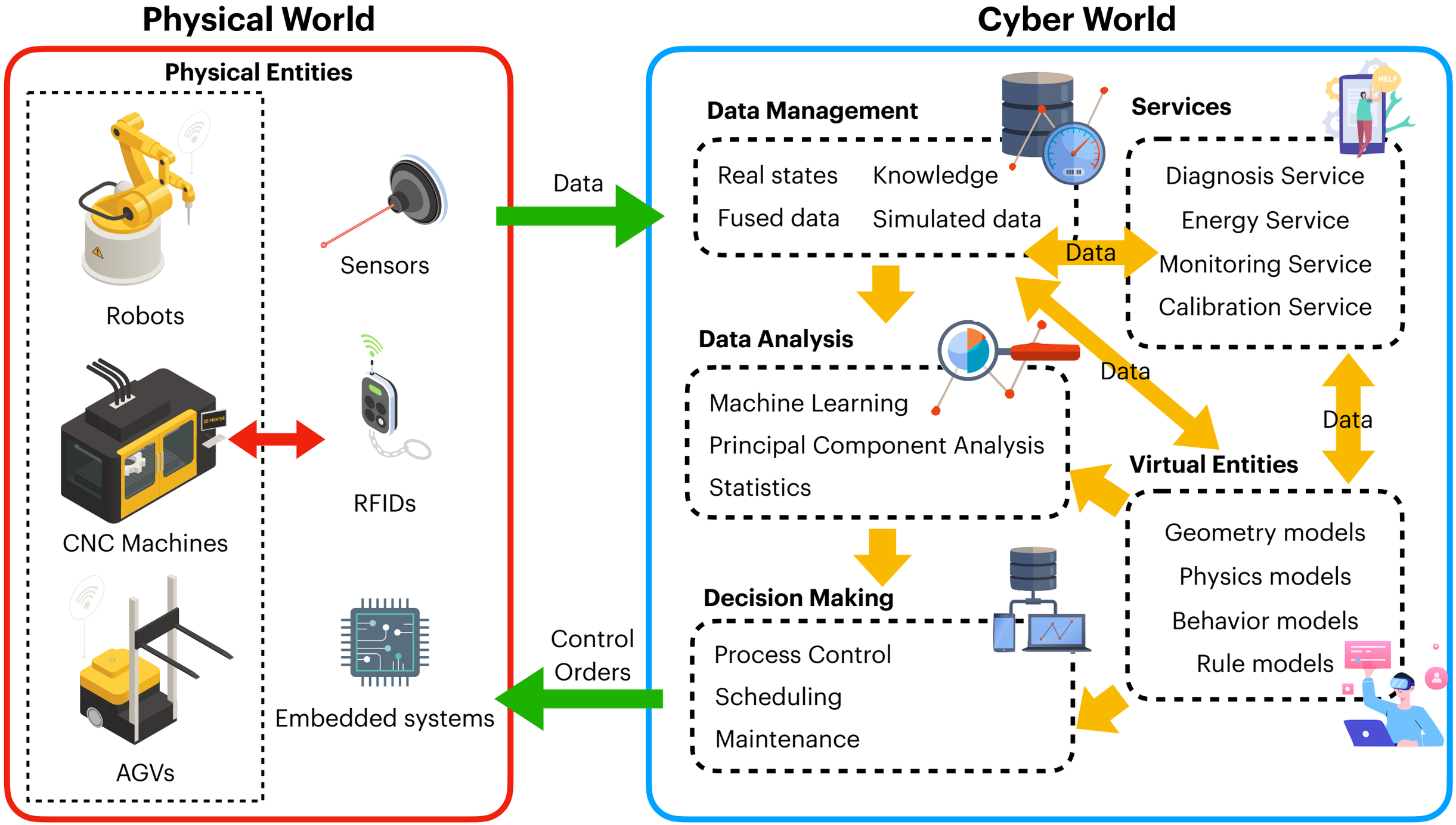
Digital twin (DT) is another concept that can support cyber physical integration. The DT creates high-fidelity virtual models for physical entities to simulate their states and behaviors and provide more insights.

It keeps virtual models behaving realistically and allows physical processes to be detected and predicted efficiently, which can implement the coupled optimization for both physical and virtual objects.

Let’s take a look!

Conceptual Design

DT-based CPS



Summary

Cyber Physical Systems and Digital Twin

- DT can be considered as a focused application of CPS.
- On one side, the DT inherits characteristics of CPS such as cyber physical mapping and closed-loop control to make the physical and cyber worlds interactive and integrated.
- On the other side, elements of DT can be combined with the CPS framework to support the high-fidelity simulation, data fusion, and service invocation, thus providing the CPS with more efficient data analysis and decision making.

Useful Resources

(Most of them are in English)

- Demonstration on CPS: https://www.youtube.com/watch?v=c5gu8xmmum4
- Demonstration on DT: https://www.youtube.com/watch?v=iVS-AuSjpOQ