Energy-aware Smart Planning for Flexible Assembly Line Systems (ESPLINE)

Applied Research Solutions

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The Company

- New start-up company founded in 2020 in Bucharest, Romania
- Develops complete data science solutions for (smart) industry and energy applications
- Provides research consulting and training services in these areas
- Promotes new technologies, in particular with regard to IT/OT convergence in automation

- More information: www.research-solutions.eu
- Sister company: www.astiautomation.com

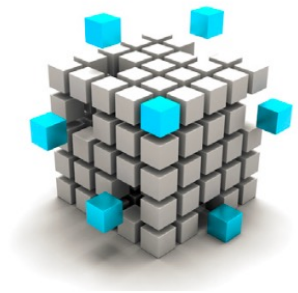
Outline

- **CONTEXT – FLEXIBLE ASSEMBLY LINE SYSTEM**
- **DEMO**
- **PLANNING APPLICATION / USE CASE**

Industry 4.0 Flexible Assembly Line

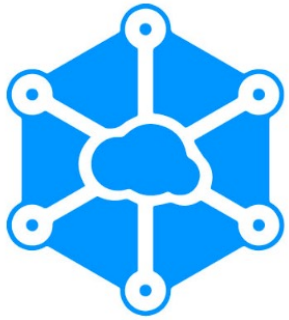
- Pilot system for training and research and development of smart manufacturing solutions
- Complete production of a 3D printed part with current, connected, automation technology
- Five stages: pallet station, base piece station, robot and assembly station, top piece station, storage station

Flexible Assembly Line – Core Concepts



- **Modularity**: adapts to changing requirements by replacing or expanding individual modules or sensors

- **Real-Time Capability**: ample on-board/edge computing resources enabling the system to collect, analyse and provide feedback on process data in real-time



- **Decentralization**: enabling the cyber- physical systems within the Future Digitalized Factory concept to make decisions without the aid of centralized guidance and commands

Flexible Assembly Line – Core Concepts

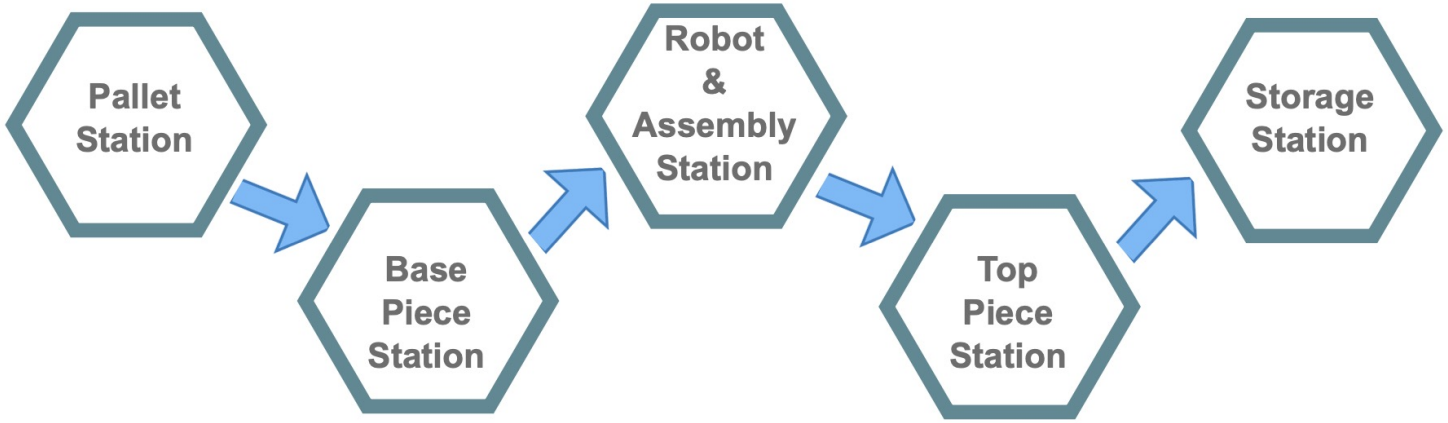
- **Virtualization**: virtual plant models and simulation models of the assembly Line can be linked to real sensor data in order to create a virtual copy

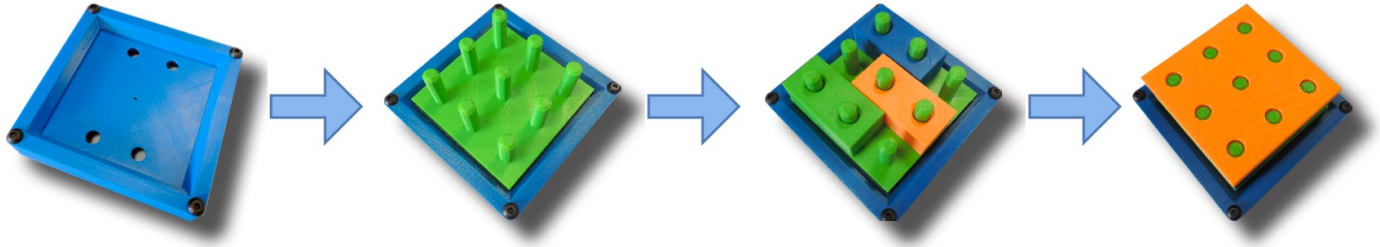
- **Interoperability**: the ability of assembly stations, warehouses and products (cyber-physical systems) to communicate and receive feedback from humans and Smart Factories Command Units via Internet of Things and Internet of Services

- **Service Orientation**: Internet of Services compatibility through linking operators, cyber-physical systems and Smart Factories interfaces

The Process

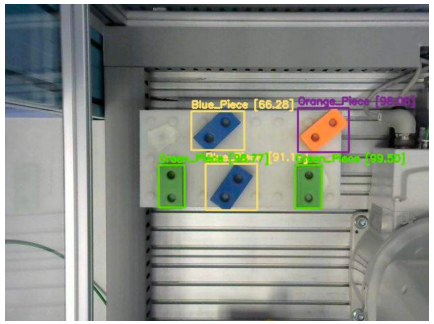
- Model manufacturing process that assembly 3D-printed workpieces

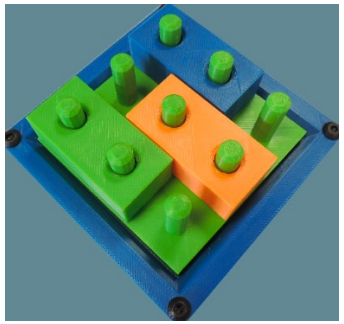


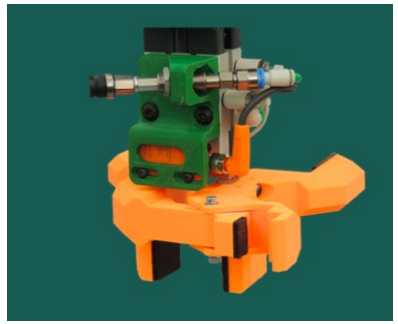


Robot Cell

- Interfacing the robot with PLCs and SFCs for conveyor belt control and synchronisation through standardised communication protocols
- Vision-based control of the robot using industry-grade camera (Cognex/IFM)
- Upper layer sequence commissioning



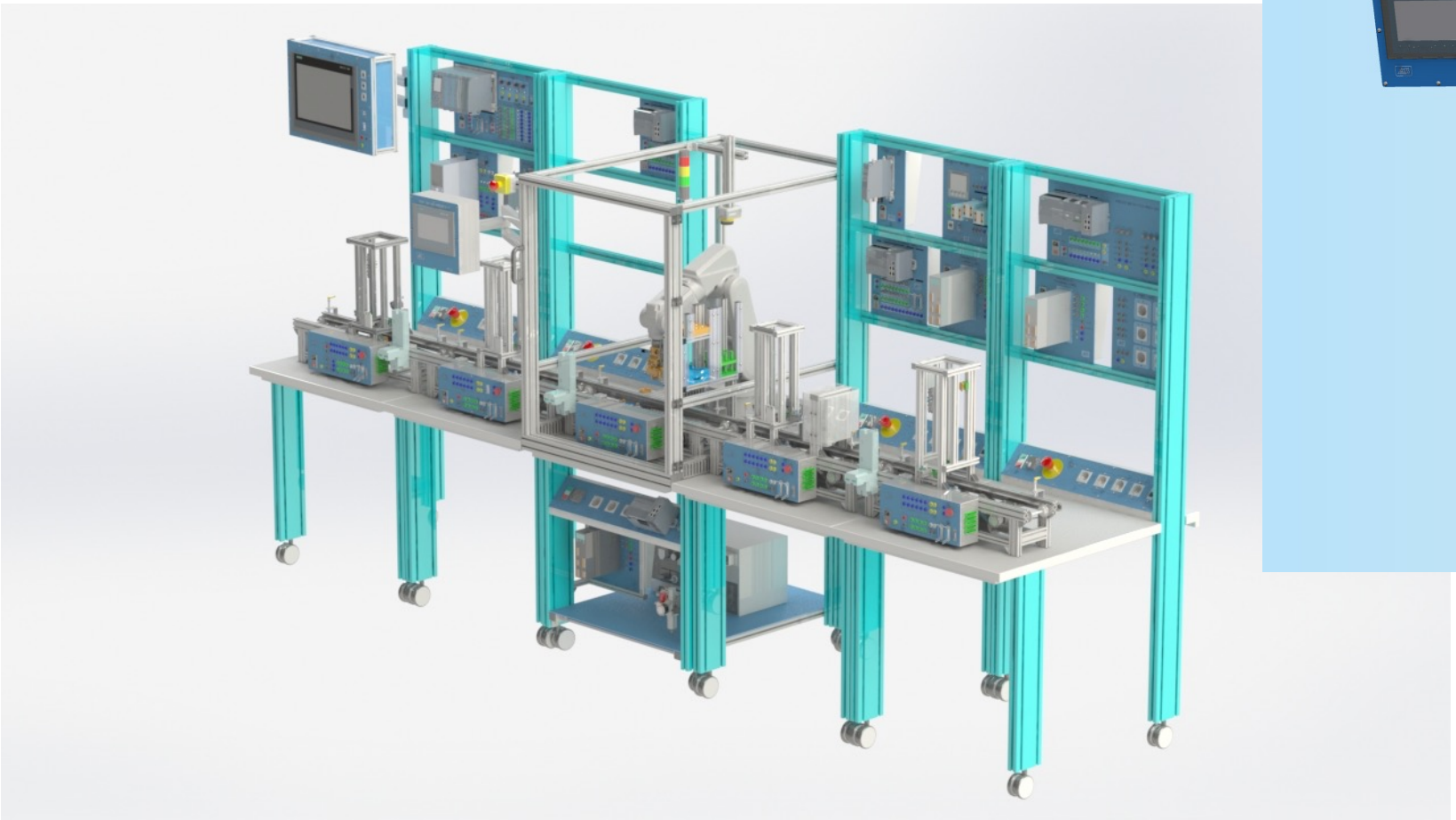


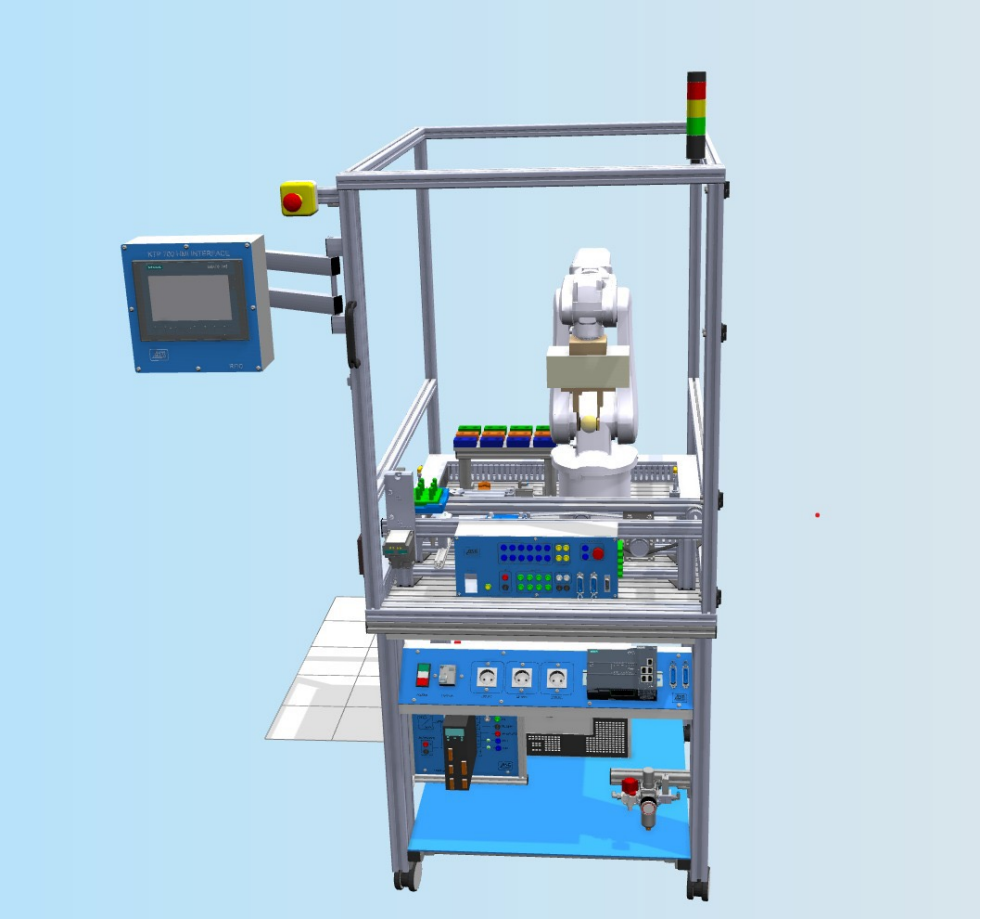


Applications

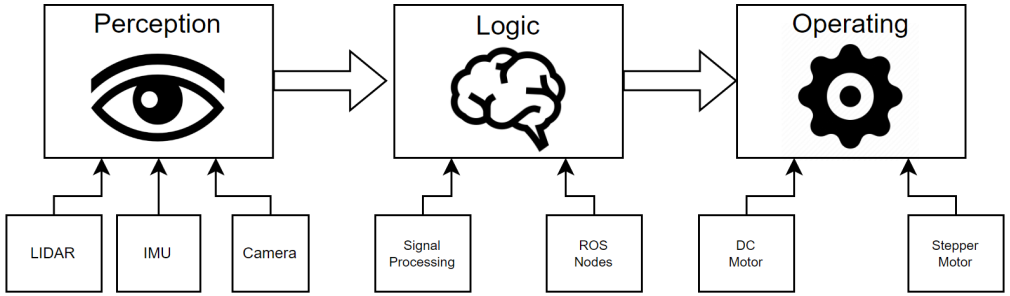
- PLC programming
  - Siemens S7-1200 and S7-1500 family IEC 61131-3 compliant PLC programming under the TIA Portal/Step 7 development environment
- Standards-based industrial communication
  - IO-LINK, CANopen, PROFIBUS, PROFINET, RFID, OPC-UA, MQTT
- Drive systems: AC and DC motors, synchronous and asynchronous motors, brushless motor
- Human Machine Interface: Siemens TP700/TP1500
- Robot programming and integration: ABB IRB120C
- Energy monitoring and management: SENTRON PAC3220 + SM1238

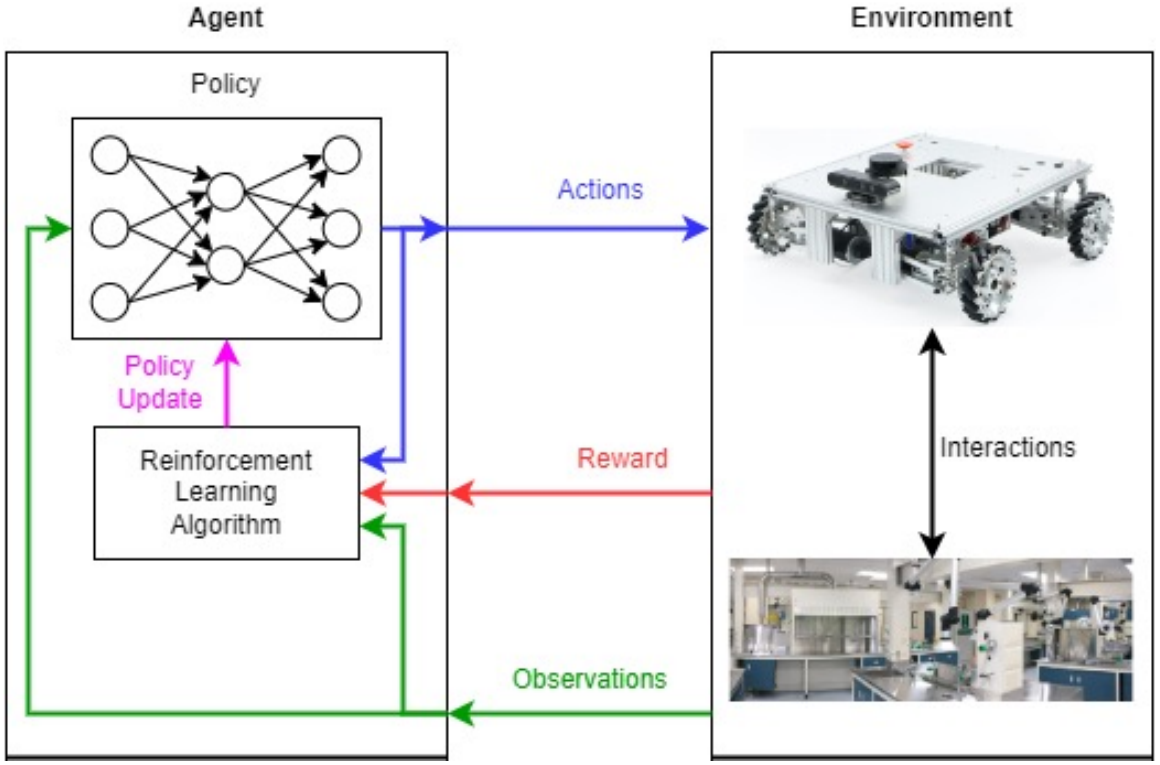
Digital Twin Model





[OPTION] Mobile Robotic Platform Support





[1] Pavel, M.D.; Rosioru, S.; Arghira, N.; Stamatescu, G. Control of Open Mobile Robotic Platform using Deep Reinforcement Learning. In Proceedings of the SOHOMA 2022, 12th International Workshop on Service Oriented, Holonic and Multi-Agent Manufacturing Systems for Industry of the Future, Bucharest, Romania, 22–23 September 2022; pp. 1–12.

2. DEMO

Ing. Mihai-Daniel Pavel

Similar to the live demo: https://www.youtube.com/watch?v=tSinSe3YHDg

3. USE CASE

Description and potential planning/optimisation tasks

Objectives

- Implement and test a planning and optimization layer on a flexible assembly line system in order to generate energy-aware control decisions and manufacturing operation subsequences
- Validation on an existing five-station flexible assembly line (including digital twin model) for standardized integration with the AIPland4EU APIs
- Support the AIPlan4EU objectives in the area of smart manufacturing for various industry verticals such as food processing, automotive and electronics

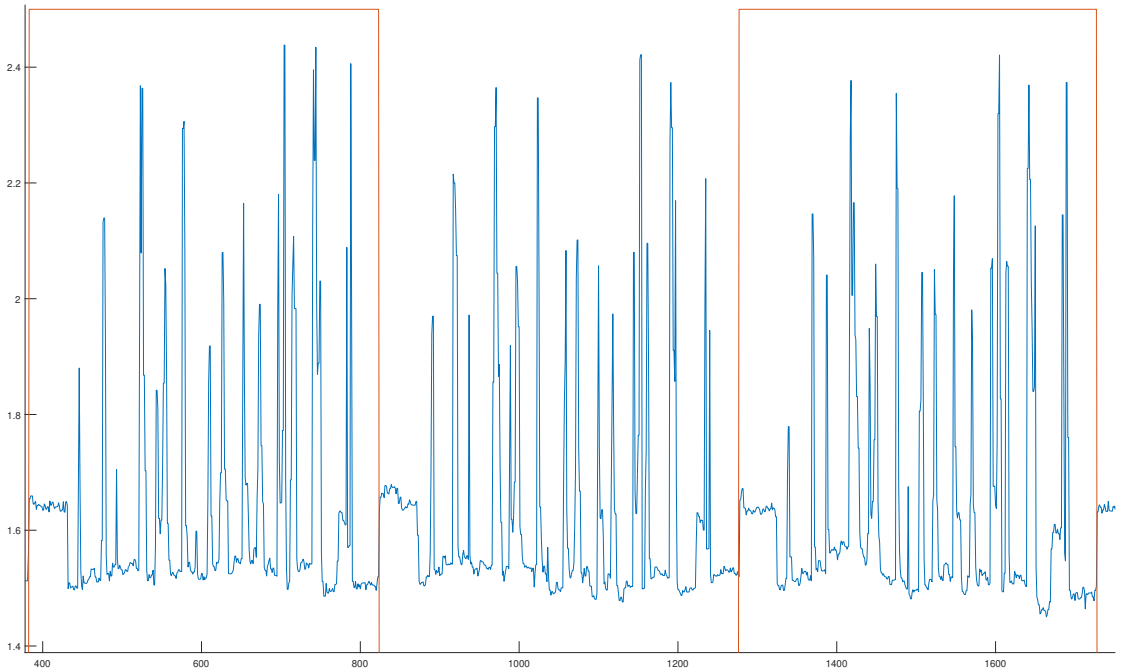
Planning Variables

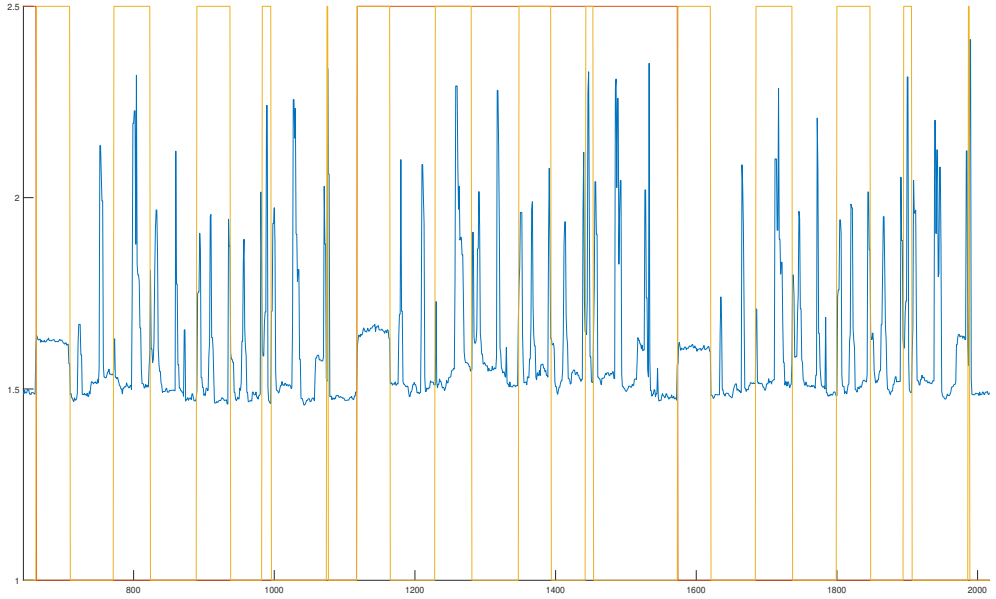
- The planning outcome can impact the following:
  - Conveyor belt speed and associated static frequency converter (SFC) parameters;
  - PLC program parameters;
  - Robot arm speed and pick-and-place strategy;
  - Spare parts supply and placement.

- Optimal sequence of products and timeslots for the manufacturing and correlate these with external factors such as time-of-day energy pricing or the availability of renewable energy

Data Availability

- Existing dataset of labelled energy traces corresponding to individual operations/operation subsequences





Digital Sensor Timestamps

- Used for synchronisation purposes

Sensor/Pallet	Station 1 - Central sensor	Station 2 – Output sensor	Station 2 – Input sensor …
Pallet 1	DTL#2021-05-21-16:03:02.364227079	DTL#2021-05-21-16:03:05.920744306	DTL#2021-05-21-16:03:07.231312
Pallet 2	DTL#2021-05-21-16:03:10.114215079	DTL#2021-05-21-16:03:13.671337653	DTL#2021-05-21-16:03:30.365849
Pallet 3	DTL#2021-05-21-16:03:33.236650666	DTL#2021-05-21-16:03:36.788910097	DTL#2021-05-21-16:04:14.468784
Pallet 4	DTL#2021-05-21-16:04:17.355895746	DTL#2021-05-21-16:04:20.891481573	DTL#2021-05-21-16:05:12.273724
Pallet 5	DTL#2021-05-21-16:05:15.172554693	DTL#2021-05-21-16:05:18.704034826	DTL#2021-05-21-16:05:58.672564

Constant vs. Contingent Data

- **Constant data** is considered all data that corresponds to the baseline mechanical and electrical characteristics of the flexible assembly line components such as the conveyors, drive systems, sensors, robot arm

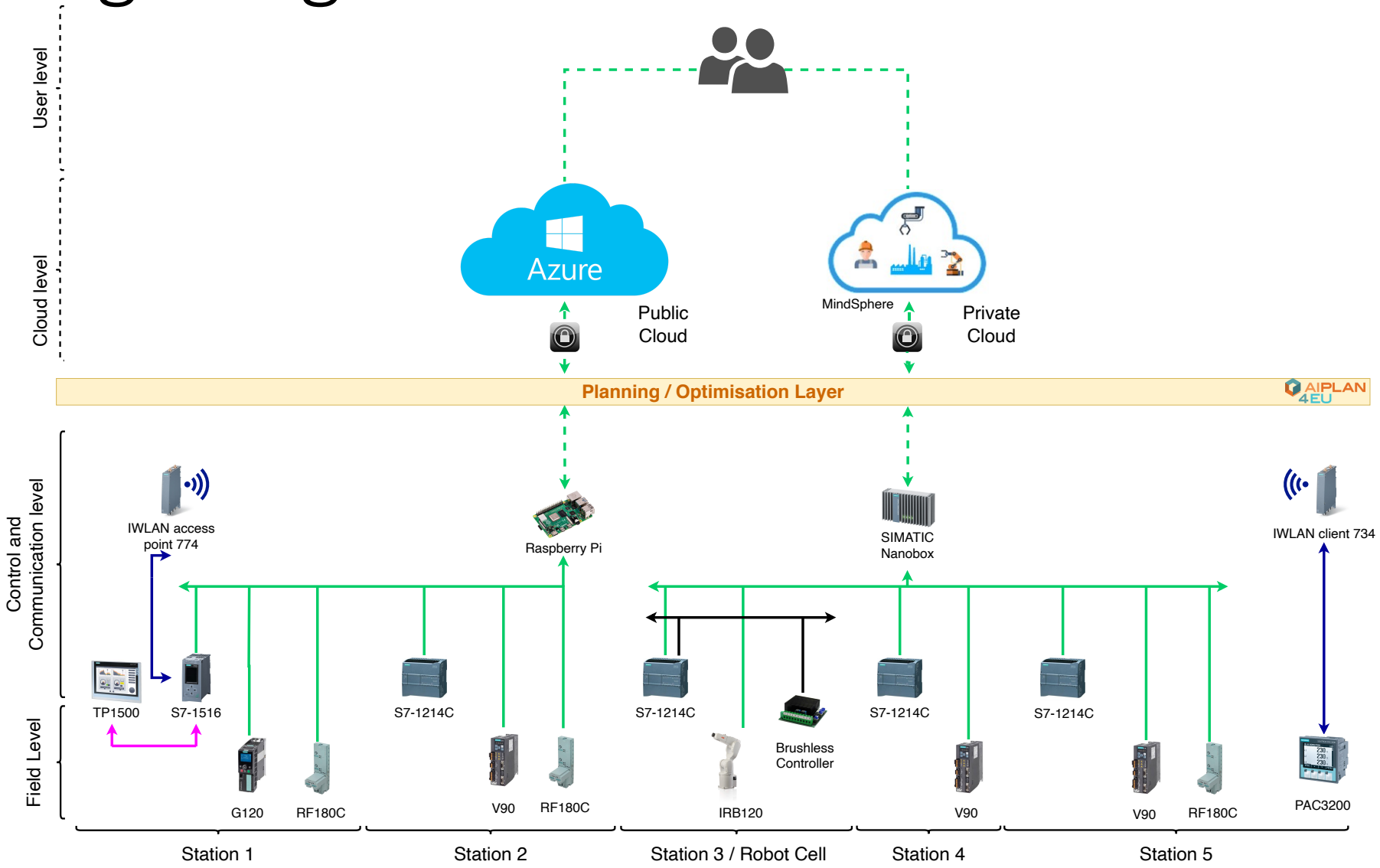
- **Contingent data** can be considered as stemming from wear and tear, maintenance requirements, mechanical tuning, and software programming decisions. This will be reflected in variations and emerging trends in the operational logs and energy measurement over multiple runs

Hierarchical Planning and Scheduling

- Define the planning optimisation problem (cost function) with energy-related constraints

1. Establish the optimal sequence of parts picking at the robot cell level considering energy
2. Determine the optimal sequence of products in a batch
3. Plan the mobile robot platform actions for improving overall flexible assembly line performance

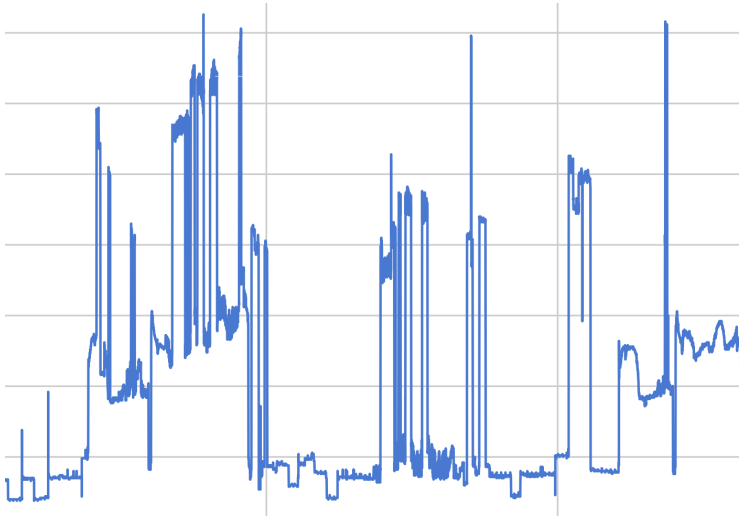
Planning Integration

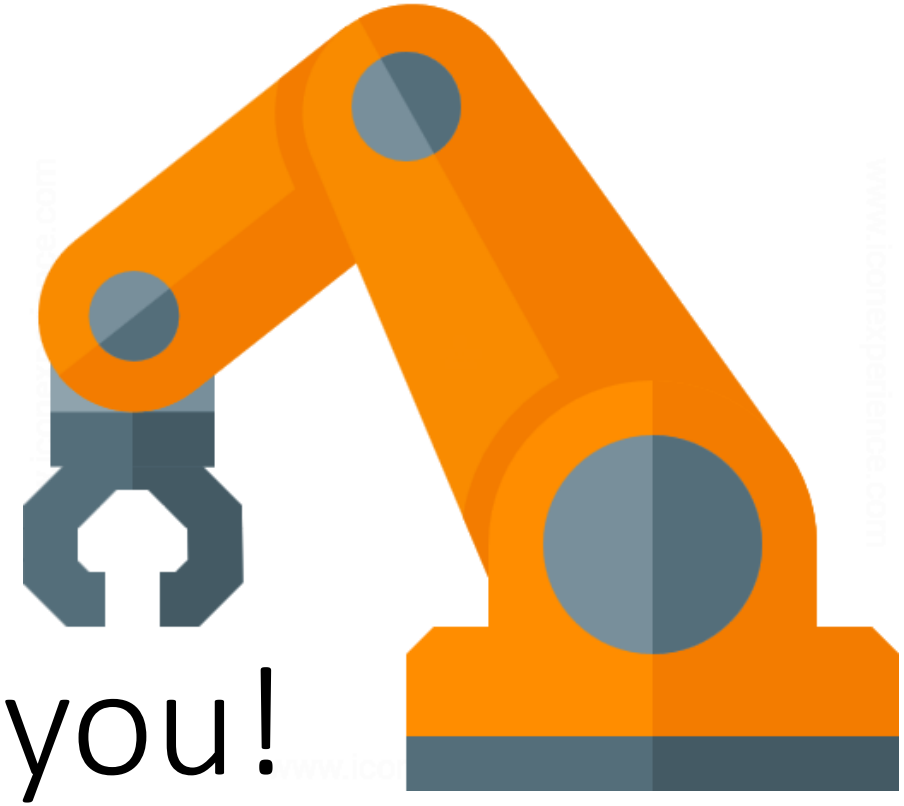


KPIs

- Product-level energy consumption (-15%)
- **Batch-level energy consumption / Overall manufacturing line energy**
- Costs savings from unplanned downtime avoidance

- Computational efficiency of the solution
  - On-line planning with regard to the sampling period of the local control loops
  - Off-line/Day ahead planning to maximize operational efficiency





Thank you!

Q&A