SUPSI Laboratory of Sustainable Production Systems (SPS-Lab)

Software-Defined Industrial Operations

Industrial operations are increasingly required to be flexible, data-enabled, interoperable and rapidly adaptable to changing production needs. This requires moving beyond isolated automation solutions towards integrated operational architectures where machines, control systems, data infrastructures, robotic systems, human operators and decision-support tools can be designed and orchestrated as part of a coherent industrial system.

SPS-Lab supports companies in the design and validation of software-defined industrial operations, combining expertise in industrial automation, cyber-physical systems, OT/IT integration, robotics, artificial intelligence and production system engineering. The objective is to help companies introduce advanced digital and automation capabilities in real industrial environments, while maintaining a strong connection with production processes, operational constraints and industrial scalability.

Research and technology transfer activities address both discrete manufacturing and process-oriented environments, including laboratory automation, pilot-scale production, modular manufacturing systems and flexible intralogistics. Specific attention is given to software-defined automation architectures, industrial data connectivity, process-aware digital infrastructures, neuro-symbolic techniques for real-time and non-real-time industrial operations, and motion/task planning for robotic and autonomous production systems.

Services

- Design and validation of software-defined automation and OT/IT architectures for modular and scalable industrial systems.
- Development of industrial data connectivity, monitoring and analytics solutions for production, laboratory and pilot environments.
- Application of neuro-symbolic AI methods for supervision, diagnostics, decision support, operational knowledge management and intelligent control support.
- Development of motion and task planning solutions for robotic cells, automated laboratories, intralogistics and reconfigurable production systems.
- Modelling, simulation and experimental validation of cyber-physical production systems and flexible industrial operations.

SUPSI Laboratory of Sustainable Production Systems (SPS-Lab)

Sustainable and circular manufacturing

Sustainability has become a key element for manufacturing competitiveness, combining strategic challenges and business opportunities. Despite an increasing interest on sustainability principles, their deployment in manufacturing contexts is often challenging and ineffective, especially when SMEs are concerned. Reasons for these are to be found in the complexity of the related topics and in the knowledge distance between sector-specific areas of expertise and sustainability. Also, existing sustainability-centered decision support tools and methodologies require such a high level of specialization and dedicated resources inhibiting their widespread use on a day-to-day basis, which would be essential for a systematic performance improvement of products and processes.

Research activities carried out in the SPS-Lab result in innovative methodologies and platforms aimed at making sustainability a commodity, accessible for all industrial entities and embedded in their every-day decision making processes. This is currently done supporting manufacturing companies and supply-chains in the sustainability-driven transformation process, from performance assessment against validated maturity models, through advisory services for the selection of fitting strategies, technologies and circular products, up to project deployment and monitoring of the results.

Services

- Sustainability maturity assessment of companies and supply chains
- Measurement of environmental, social, and circular performances of products and processes
- Development of customized sustainability and circularity management platforms combining data gathering, repository and analysis from heterogeneous sources to support and monitor the sustainable transition
- User-friendly decision support tools for every-day sustainability-enhancing decision making.
- Sustainability and circularity labelling

SUPSI Laboratory of Sustainable Production Systems (SPS Lab)

Human-Centred Smart Production

Human-Centred Smart Production places people at the core of industrial transformation. While automation, artificial intelligence, robotics, and digital technologies are becoming increasingly pervasive in manufacturing, their adoption can only generate sustainable value when technological innovation is effectively aligned with human capabilities, needs, and aspirations. Human-Centred Smart Production aims to create working environments where humans and advanced technologies collaborate synergistically, enhancing productivity, quality, flexibility, and resilience while simultaneously promoting worker well-being, safety, and skills development.

At the SPS-Lab, we develop and validate methods, technologies, and demonstrators that enable this vision. Our activities focus on understanding, modelling, and improving the interaction between operators and intelligent systems across a wide range of industrial contexts. Particular attention is devoted to collaborative robotics, adaptive human-machine interaction, AI-enabled decision support, and the integration of digital technologies that augment rather than replace human capabilities.

A key research and innovation area concerns the development of solutions that allow production systems to adapt to workers' characteristics, intentions, and conditions in real time. This includes AI-based approaches for monitoring human factors, intention recognition systems that support natural and intuitive collaboration, and Human Digital Twin technologies that create digital representations of workers to enable personalized assistance, simulation, and optimization. Our Human Digital Twin platform, Clawdite, serves as the foundation for the orchestration of advanced human-centred applications and intelligent production environments.

The Lab also supports companies in their digital transformation journey by developing assessment methodologies and maturity models for the adoption of collaborative robotics and artificial intelligence, with particular attention to the needs and constraints of small and medium-sized enterprises (SMEs). Through industrial demonstrators and collaborative projects, we help organizations explore, validate, and scale innovative solutions that combine technological excellence with human value creation.

Services

- Assessment of organizational and technological readiness for AI and collaborative robotics adoption.
- Development of roadmaps and maturity evaluations for Industry 5.0 and human-centred transformation.
- Design and validation of industry-ready smart solutions for human-robot collaboration.

- Development of AI-based solutions for worker monitoring and intention recognition.
- Human Digital Twin modelling and deployment through the Clawdite platform.

SUPSI Laboratory of Sustainable Production Systems (SPS Lab) - Infrastructure

Mini-Factory and OmniFactory model

The SUPSI Mini-Factory is a modular and flexible production environment used to demonstrate, test and validate advanced concepts for digitalized and automated industrial operations. Originally developed as a small-scale IIoT manufacturing facility, it provides a practical environment for research, training and technology transfer in modular automation, data-driven production, industrial interoperability and human-centred manufacturing.

The infrastructure is being extended towards the OmniFactory model: a more general experimental framework for software-defined industrial operations, where automation systems, robotic cells, mobile or flexible intralogistics, digital platforms, data services and intelligent decision-support functions can be integrated and validated together. The OmniFactory model aims to represent not only a production line, but a configurable industrial operations environment in which different technologies, vendors and operational scenarios can coexist.

Within this framework, the infrastructure supports research and demonstration activities on modular control architectures, IEC 61499-based automation, industrial data connectivity, neuro-symbolic reasoning for industrial operations, motion and task planning, human-machine collaboration, and the orchestration of machines, robots, operators and digital services. It is designed to provide companies with a realistic but controlled environment for testing new automation concepts, evaluating integration strategies and supporting the transition from isolated digital solutions to deployable industrial operations.

Worker Fatigue Monitoring System

The Fatigue Monitoring System (FaMS) is a reasoning engine that uses a machine learning model to estimate the exertion level of workers based on data gathered at different levels. It relies, in fact, on a static characterisation of the worker (e.g. age, weight, lifestyle habits, etc.) and on the real-time acquisition of physiological data from wearable devices (e.g. heart rate, electrodermal activity, skin temperature, etc.). These data are completed by contextual data representing the environmental conditions (e.g. room temperature, assigned job, etc.) to determine the current level of exertion as a proxy for worker fatigue level that becomes input for decision makers.

Clawdite

Clawdite is an extensible and flexible IIoT - industrial internet of things - based platform supporting the creation of customised data representations of production systems and their entities, including humans. Clawdite features a modular infrastructure with interchangeable components, which ease the digital twin instantiation and ramp-up.

AI readiness and collaborative robotics surveys

Two online surveys that allows companies, especially Small and Medium Enterprises, to assess autonomously their readiness towards the adoption of Artificial Intelligence and Collaborative Robotics. The surveys explore different pillars representing areas that companies need to develop for the adoption of AI and collaborative robotics At the same time, both surveys cover adoption barriers, economic and financial implications and the research vs. reality gap providing practical tips to rapidly achieve usability, standardization, and process efficiency usgin the analysed technologies.

IIoT platform

StarDust is an IIoT platform designed for the manufacturing industry, integrating advanced AI services to enhance and support manufacturing processes. By leveraging the connection to sensors and machine logic controls, StarDust collects, exchanges, and analyzes data from industrial operations, optimizing productivity and offering actionable analytics. Emphasizing the anonymization and security of information, StarDust integrates protocols such as multifactor authentication and end-to-end encryption, vital for the protection of sensitive manufacturing data. Additionally, the platform is engineered to align with the latest communication technologies, including Siemens S7 and OPCUA protocols, ensuring real-time data sharing and analysis. At the top of its architecture, Stardust features different AI-based services to transcend basic connectivity and data collection, offering anomaly detection for maintenance insights that can significantly reduce costs and minimize downtime in manufacturing processes.

Sustainability maturity model

This set of tools allow the collection of significant data from manufacturing companies to provide a reliable indication on the actual maturity status of a company in terms of sustainability performances, and a high-level indication on the hot spots to prioritize. Data can be compared with average industry profiles available for specific sectors.

GRETA platform

GRETA is a versatile, web- and microservices-based software application tailored for the manufacturing sector, focusing on assessing and enhancing the sustainability and circularity of products and processes. This comprehensive platform offers diagnostic and advisory tools to optimize manufacturing practices through data-driven decisions. Central to its functionality are robust assessments, including Life Cycle Assessment

(LCA), Life Cycle Costing (LCC), Social Life Cycle Assessment (SLCA), and upcoming Circular Economy (CE) evaluations, all equipped with advanced calculation and visualization capabilities. GRETA's adaptability allows for a wide range of evaluations covering products, processes, machines, and entire production lines. A standout feature is its ability to compare different product alternatives, aiding users in understanding the impacts of diverse manufacturing strategies. The platform integrates smoothly with real production environments using IoTs, middleware, and REST services. Additionally, GRETA supports OpenLCA model imports, standard BOM file integration, and comes equipped with comprehensive reporting functionalities. Enhanced security is ensured through authenticated REST APIs and data isolation, safeguarding sensitive information. Catering to sustainability experts and customers alike, GRETA provides tailored solutions to address the specific needs of each group in sustainable decision-making.